INDUSTRIAL DISCHARGES TO SURFACE WATER

1.0 INDUSTRIAL DISCHARGES TO SURFACE WATER

1.1 INTRODUCTION

The Industrial Discharges to Surface Water problem area addressed risks to the environment, and human health and welfare, from all point source discharges, including all NPDES (National Pollution Discharges Elimination System) permitted sources except discharges from publicly and privately owned municipal waste water facilities. Industrial sources vary in the types of pollutants they produce, and pollutants vary in their ecosystem, health and welfare impacts.

Data associated with permitting requirements allow for a direct quantification of the number and location of each regulated industrial waste discharger. However, unregulated, illegal releases of industrial contaminants are not considered in this assessment, and their importance is unknown.

In Region VIII there are 1437 industrial waste NPDES dischargers. Of these, 103 are classified as major facilities and 1,334 are classified as minor facilities.

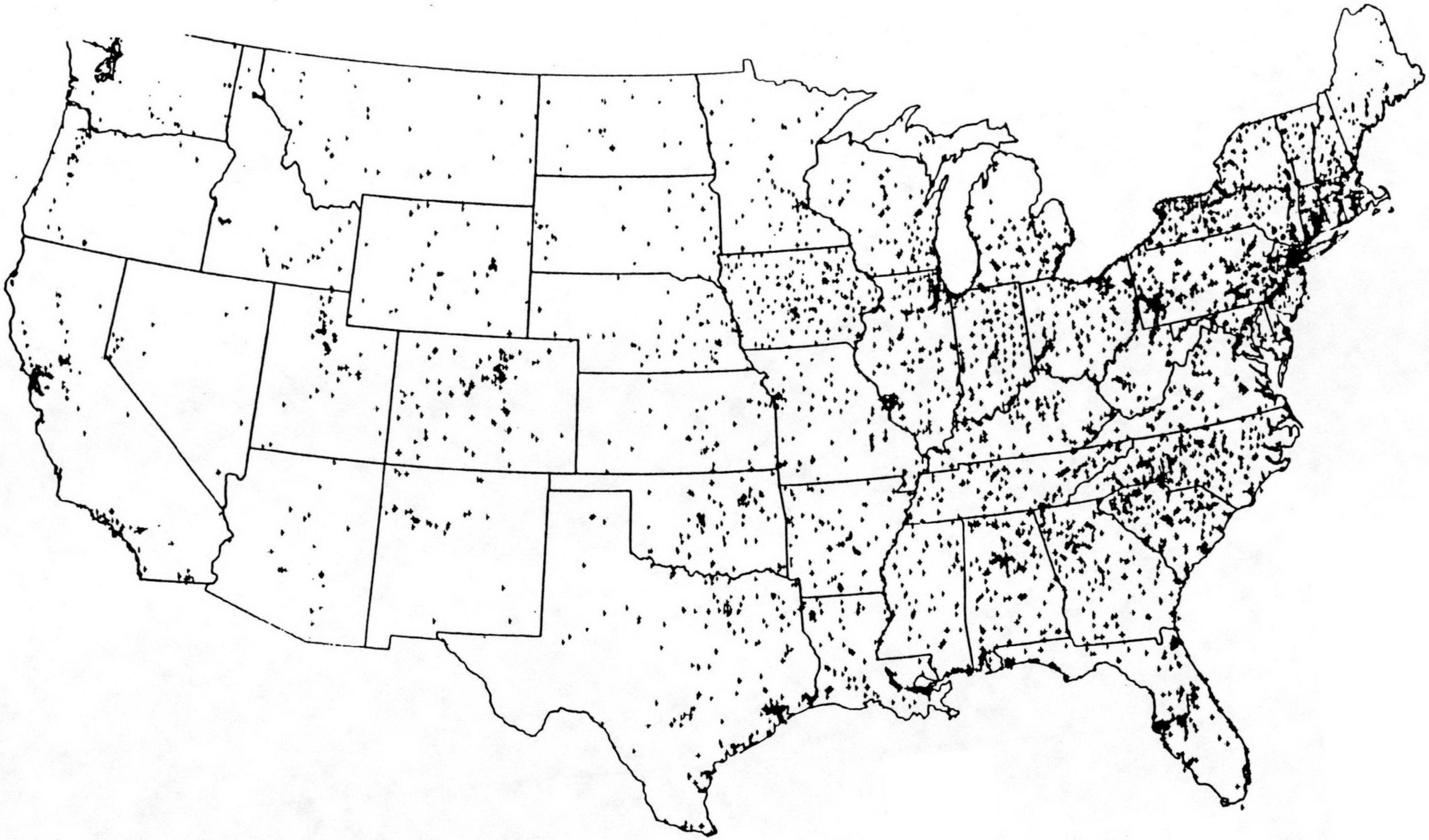
The distribution of major discharges including, municipal waste facilities, is shown in Figure 1.1. Industrial point sources in Region VIII are concentrated around populated and industrialized areas including the Front Range of Colorado, the Great Basin-Salt Lake area of Utah, and Casper, Wyoming.

Risks from industrial point sources result from the release of both conventional and hazardous materials into surface waters. The NPDES permit system limits the amount and concentrations of pollutants released. NPDES permits must contain effluent limits to satisfy the appropriate receiving water quality standards. If the standards have not addressed the appropriate pollutant(s) the permits may allow discharges at a level that will allow ecosystem, welfare and human health effects.

Human health risks are associated with direct and indirect contact with polluted receiving waters. Direct exposure to contaminated receiving waters occurs through drinking water and via dermal contact and recreation. Indirect exposure to pollutants, derived from receiving waters, may occur by ingestion of contaminated fish and waterfowl or by ingesting toxicants in other food chains.

The magnitude of ecological risk associated with industrial discharges depends upon pollutant type, concentration, and the amount of effluent versus the dilution by receiving waters. Receiving waters with large flows and low background pollutant concentrations are not as at risk from point source discharges as receiving waters with low flows and high background pollutant concentrations.

Figure 1.1
Geographic Distribution of 7,000 Major Point Source Dischargers



Welfare effects of industrial point source surface water contamination are associated with consumer surplus losses and replacement and mitigation costs due to lost uses of aquatic resources. Affected resource uses include: surface and groundwater drinking water supplies, irrigation waters for agriculture and livestock, and water recreation uses.
Other welfare effects of industrial point source pollution are not necessarily associated directly with aquatic resources. For example, nutrient enrichment and subsequent eutrophication may be associated with a drop in riparian real estate values and cost of illness measures associated with human health effects due to contaminated surface waters.

Risks are characterized by the number of NPDES permitted facilities, their size and industry type, and the number of permit violations in the Region. Ecosystem impacts are quantified as reported in State 319 and 305b reports as the number of miles of streams and acres of lakes impacted by the "industrial point sources category" or specific pollutants.

1.2 SOURCES

Risks are associated with those industrial waste sources in which permits allow pollutant releases that may cause impacts, because they are allowed by the receiving water quality standards.

The numbers of Region VIII major and minor NPDES industrial waste water sources for each SIC (Standard Industrial Code) class, are listed in Table 1-1.

The largest numbers of the 103 major permits in Region VIII are associated with various mining industries (32), electrical power generation (15), petroleum industries (14), and sugar beet processing (10). Other industries with more than one major facility in the Region are: meat packing plants (3), national security facilities (2), softwood veneer mills (2), and steel blast furnaces (2).

While there are over 100 different SIC classed facilities that require minor NPDES permits, only a hand full of industrial activities dominate the 1334 minor point sources in Region VIII. Crude petroleum industry facilities predominate with 669 permits. Next in number are bituminous coal operations and water supply facilities, with 105 each. Metal mining operations account for 95 minor permits, while fish hatchery minor permits number 48. The other industries with greater than 10 minor permits include: construction sand and gravel operations (25), electrical power facilities (23), "special trade companies" (18), beef cattle feedlots (17), crop preparation services (11), and steam & air conditioning plants (11).

NPDES industrial dischargers are not randomly distributed across the Region (Figure 1.1) and cumulative impacts may be associated with the density of facilities in a given drainage basin.

Table 1-1
Major and Minor NPDES Facilities
by SIC Code in Region VIII

Industry SIC Name	Major	Minor	TOTAL
TOTAL Region VIII	103	1334	1437
ELECTRICAL SERVICE	15	23	38
PETROLEUM REFININ	12	7	19
BEET SUGAR	10	1	11
URANIUM-RADIUM-V	9	9	18
BITUMINOUS COAL	8	105	113
GOLD ORES	8	63	71
COPPER ORES	4	1	5
FERROALLOY ORES	4	0	4
MEAT PACKING PLANT	3	4	7
LEAD AND ZINC ORE	3	3	6
SILVER ORES	2	4	6
NATIONAL SECURITY	2	1	3
SOFTWOOD VENEER	2	0	2
BLAST FURN/STEEL	2	0	2
CRUDE PETROLEUM	1	669	670
METAL ORES, NEC	1	14	15
RAILROADS, LINE	1	8	9
INDUSTRIAL INORG	1	3	4
MALT BEVERAGES	1	3	4
LAND, MIN, WILDL	1	3	4
FLUID MILK	1	3	4
CYCLIC CRUDES IN	1	2	3
PULP MILLS	1	1	2
GUIDED MISSILES	1	1	2
MECHANICAL RUBBER	1	1	2
REFUSE SYSTEMS	1	1	2
AIRPORTS	1	1	2
PRIMARY SMELTING	1	1	2
NONCLASSIFIABLE	1	0	1
PHOTOGRAPHIC EQU	1	0	1
MOTOR VEHICLE PA	1	0	1
PHOTOFINISHING LAB	1	0	1
TRANSFORMERS	1	0	1
WATER SUPPLY	0	105	105
FISH HATCHERIES	0	48	48
CONSTRUCTION SAN	0	25	25
SPECIAL TRADE CO	0	18	18
BEEF CATTLE FEED	0	17	17

Table 1-1 (cont.)
Major and Minor NPDES Facilities
by SIC Code in Region VIII

Industry SIC Name	Major	Minor	TOTAL
STEAM & AIR-COND	0	11	11
CROP PREP SERVICE	0	11	11
SANITARY SERVICE	0	9	9
CRUSHED AND BROKE	0	7	7
MUSEUMS AND ART	0	6	6
CHEESE, NATURAL	0	6	6
CHEMICALS & CHEM.	0	5	5
CEMENT, HYDRAULI.	0	5	5
ELEM.& SEC SCHOOL	0	5	5
OIL & FIELD	0	5	5
MISC NONMETAL MINE	0	4	4
INDUSTRIAL GASES	0	4	4
GEN. MEDICAL/SUR	0	4	4
INDUST. ORGANIC	0	3	3
HEAVY CONSTR.	0	3	3
NATURAL GAS LIQU	0	3	3
POTASH, SODA	0	3	3
HOTELS AND MOTEL	0	3	3
READY-MIXED CONCR	0	2	2
METAL MINING SERVIC	0	2	2
COMMERCIAL PHYSI	0	2	2
LOGGING CAMPS	0	2	2
CAR WASHES	0	2	2
NATURAL GAS TRAN	0	2	2
EATING PLACES	0	2	2
PROD OF PETROLIUM	0	2	2
BRIDGE, TUNNEL	0	2	2
PHOSPHATIC FERTI	0	2	2
GASOLINE SERVICE	0	2	2
ALKALIES AND CHL	0	2	2
H20,SEW,PIPE	0	2	2
SHEEP AND GOATS	0	2	2
COLLEGES, UNIV	0	2	2
PAVING MIXTURES	0	2	2
BOT&CAN SOFT DRINK	0	1	1
SPECIALTY CLEANING	0	1	1
INDUSTRIAL VALVE	0	1	1
FOOD CROPS GROWN	0	1	1
RELAYS AND INDUS	0	1	1
LIVESTOCK	0	1	1
MINERAL WOOL	0	1	1

Table 1-1 (cont.)
Major and Minor NPDES Facilities
by SIC Code in Region VIII

Industry SIC Name	Major	Minor	TOTAL
VEG.OIL MILLS	0	1	1
FARM MACHINERY	0	1	1
BUSINESS SERVICE	0	1	1
CIVIC, SOCIAL	0	1	1
PETROLEUM BULK ST	0	1	1
GRAY IRON FOUNDR	0	1	1
GYPSUM PRODUCTS	0	1	1
ELECT. COMPUTERS	0	1	1
EXPLOSIVES	0	1	1
ANIMAL AND MARINE	0	1	1
BRICK AND STRUCT.	0	1	1
FLUID POWER VALV	0	1	1
FROZEN FRTS, FRT	0	1	1
PIPELINES, NEC	0	1	1
SKILLED NURSING	0	1	1
MARINAS	0	1	1
DIMENSION STONE	0	1	1
CHEM & FERT. MINE	0	1	1
STRUCTURAL STEEL	0	1	1
COAL MINING SERV	0	1	1
CONDENSED AND EV	0	1	1
GRAIN AND FIELD	0	1	1
GROCERY STORES	0	1	1
PORCELAIN ELECTR	0	1	1
LOCAL AND SUBURBA	0	1	1
PETROL & PET PROD	0	1	1
PLATING AND POLISH	0	1	1
NONCOMMERCIAL RE	0	1	1
SPACE PROPULSION	0	1	1
AMUSEMENT AND REC	0	1	1
PLSTC MAT./SYN R	0	1	1
FARMS	0	1	1
HWY & STREET CONST	0	1	1
GLASS CONTAINERS	0	1	1
RAILROAD SWTCHING	0	1	1
CANNED FRUITS VEG.	0	1	1
HOGS	0	1	1
ELEC &OTHER SERV.	0	1	1
PHARMACEUTICAL P	0	1	1
IRISH POTATOES	0	1	1
SPORTING & RECRE	0	1	1

Table 1-1 (cont.)
Major and Minor NPDES Facilities
by SIC Code in Region VIII

Industry SIC Name	Major	Minor	TOTAL
PREP FEEDS	0	1	1
PSYCHIATIRC HOSP	0	1	1
GEN CONTRACT-RES	0	1	1
STEEL PIPE	0	1	1
MEDICAL LAB	0	1	1
POULTRY SLAUGHTER	0	1	1
STEEL FOUNDRIES	0	1	1
CLAY, CERAMIC	0	1	1
CONCRETE PROD EX	0	1	1
MANUFACTURED ICE	0	1	1
JUNIOR COLLEGES	0	1	1
AIR TRANSPORTATION	0	1	1

River systems at high risk, all other factors being equal, are those with the greatest number of dischargers facilities. For example, the Yellowstone and South Platte Rivers have many more major industrial waste sites than other rivers in the Region.

However, the types of pollutants released, the volume of effluent verses the receiving water volume, and background pollution burden are each important factors that prevent a credible assessment of risks based only on the data in Table 1-1. The amount of non-compliance may also be related to risk sources. The numbers of major and minor violations which occurred between April, 1989 and April, 1990, in each of the major drainages in Region VIII are listed in Table 1-2.

1.3 STRESSORS

Pollutant streams vary with different industrial effluents. Many industries are consistently associated with specific pollutants. For example, hard rock mining activities produce heavy metals, electrical power generation produces waste heat and thermal pollution, petroleum industries are associated with toxic organics, oil and grease, and food processing facilities produce biological oxygen demand. The pollutants associated with some industries are harder to characterize, however, making generalizations difficult (Manahan, 1975).

The types of pollutants associated with Region VIII industrial discharges include, but are not limited to the following:

POLLUTANT	MAJOR SOURCE
total suspended solids	mining, construction activities
biological oxygen demand (BOD)	sugar beet plants, meat packing plants, feedlots, and fish hatcheries
toxic organics	petroleum industries,
halogenated aliphatics phenols and cresols phthalate esters polycyclic aromatic hydrocarbons	

Table 1-2
Number of Major and Minor Industrial Discharge Facilities
by Drainage Basin in Region VIII

Drainage Basin	Major	Minor	Total
UNNAMED	1	13	15
COLORADO			
GREEN RIVER	7	83	136
LOW COLORADO	0	0	3
SAN JUAN	3	20	66
UP COLORADO	8	55	171
GREAT BASIN			
SALT LAKE	8	48	105
SEVIER R.	1	6	16
MISSOURI			
BIG SIOUX R.	2	12	76
CEN MR, NIOBRARA	2	185	327
SPRING R.	3	42	174
JAMES R.	0	7	103
KANSAS R.	0	0	8
LOW MR, NIOBRARA	1	9	38
MR, NIOBRARA	0	36	38
NORTH PLATTE	3	134	164
SOUTH PLATTE	22	87	257
UP MR, MILK R.	4	64	115
YELLOWSTONE	17	411 *	497
PACIFIC NORTH			
CLARK FORK	4	28	54
KOOTENAI R.	1	1	4
UPPER SNAKE R.	1	3	10
SM			
ARKANSAS	0	3	3
UP ARKANSAS	6	36	105
UM			
MINNESOTA R.	0	0	11
RED RIVER OF NOR	3	32	151
SOURIS R.	0	12	54
WG			
UPPER RIO GRANDE	3	8	32

* 332 CRUDE PETROLEUM

toxic inorganics	
heavy metals: arsenic, beryllium, cadmium, chromium, copper, lead, nickel, selenium, zinc mercury	hard rock and coal mining operations
ammonia	fish hatcheries
cyanides	gold extraction
chlorine	water treatment plants
sulfide	organic decomposition of sulfur compounds
pH	acid mine drainage
nutrients	fish hatcheries, plant and animal production facilities
nitrogen (ammonium, nitrate, nitrite) phosphorous	
oil and grease	petroleum industries
thermal	electrical power facilities, steam and air conditioning plants

1.4 ECOLOGICAL EFFECTS OF INDUSTRIAL WASTE DISCHARGE TO SURFACE WATERS

Effects of chronic high doses of individual pollutants on specific organisms are relatively well known. On the other hand, effects to the community or ecosystem due to combinations of pollutants at low doses are very uncertain.

Regardless of the kind of pollutant, a number of factors affect the severity of ecological impacts from industrial waste discharges. Effects are greatest where receiving waters provide the least dilution. Downstream cumulative effects are more likely where dischargers are clustered along a water way. (Permitted pollution loads at specific facilities may not consider the overall pollution burden of the receiving ecosystem.) Elevated temperatures associated with thermal pollution enhance the toxic effects of most inorganic and organic pollutants.

Ecological impacts of industrial effluents on surface waters include, but are not limited to, the following:

- aquatic toxicity;
- eutrophication of lakes and reservoirs;
- reduced species diversity; and
- reduced fisheries productivity.

Numerous organic and inorganic compounds and oxygen depletion have toxic effects on aquatic biota. Direct toxicity can lead to community level effects such as reductions in species diversity, and ecosystem effects such as reduced productivity.

Excessive concentrations of nutrients, nitrogen and phosphorous leads to eutrophication of surface waters. Eutrophication is associated with reduced species diversity, and altered ecosystem structure and function. Eutrophication is of greater concern in lakes, which have longer water residence times, than in streams.

Excessive noxious plant growth can lead to impaired recreational use and poor aesthetic appeal. Increased production and subsequent respiration can lead to oxygen deprivation in stratified lakes especially during ice cover, and may enhance the frequency of "winter kill" of fish populations.

Elevated levels of total suspended solids are associated with reduced light penetration and increased sedimentation rates, subsequently autochthonous productivity may decline and benthic habitats may be altered.

Numerous industrial effluents increase the biological oxygen demand (BOD) of the receiving waters leading to oxygen depletion and well known biotic effects. Species intolerant of low oxygen levels, such as salmonid fishes, stonefiles, and mayflies, become locally extinct and are replaced by tolerant forms such as blood worms, and midges.

Waste heat from power generation facilities increases temperatures of receiving waters with direct and indirect consequences. Some organisms have explicit temperature tolerances and once exceeded are no longer viable. Indirect effects of temperature occurs through controls on oxygen solubility and increased toxicities of many other pollutants at higher temperatures.

1.5 DATA QUANTIFYING ECOSYSTEM EFFECTS OF INDUSTRIAL WASTE DISCHARGE TO SURFACE WATERS

Potential ecosystem effects due to industrial waste discharge are related to the number of discharge sites and the total resource at risk. Their are over 83 thousand miles of streams and 6 million acres of lakes in Region VIII (Table 1-3). Impacts from industrial waste discharge may occur to these surface waters at each of the 103 major and 1334 minor NPDES facilities distributed across the Region.

If we assume that the loss of best use designation reported in the State 319 and 305b reports is related to ecosystem impacts then the number of miles of streams and acres of lakes impacted by the "industrial point sources category" or by specific pollutants is an indicator of their ecosystem effects.

The miles of streams and acres of lakes in the Region impacted by industrial point sources of water pollution are listed in Table 1-4. Fewer than 6,000 stream miles in Region VIII are impacted by point source surface water pollution and fewer than 2,000 miles are attributed to industrial point sources (Table 1-4). Streams with major impacts from industrial point sources total 432 miles, with most of these impacts due to oil industry activity in Wyoming (314 miles).

Over 200,000 lake acres are impacted by point sources in the Region, and less than half of this lake area is impaired by industrial point sources (97,183 acres). Impacts on lakes from industrial point sources were observed primarily in Utah (96,900 acres), and were classified as major impacts (Table 1-4). In contrast, Wyoming listed no lakes as impaired by industrial point sources.

Another indication of the extent of surface water pollution, some fraction of which is attributable to industrial point sources, can be derived from the State 305b and 319 reports, as the miles of streams and acres of lakes impacted by specific pollutants. However none of the pollutants listed are exclusively found in industrial point sources.

Table 1-5 lists the miles of streams and acres of lakes impacted by various pollutants in Region VIII. An unknown fraction of the impacts due to these specific pollutants are attributable to industrial point sources.

In Region VIII industrial point source impacts are much less extensive than nonpoint sources (see Problem 3) and are slightly less extensive than municipal point source impacts (Problem 2).

Table 1-3
Aquatic Resources at Risk

State	Miles of Stream	Acres of Lakes
Colorado	14,655	265,982
Montana	20,532	756,450
North Dakota	11,868	619,088
South Dakota	9,937	1,598,285
Utah	6,855	2,398,267
Wyoming	19,437	427,219
Region VIII	83,284	6,065,291

Table 1-4
Aquatic Resources Exhibiting Major and Minor Impacts
from Industrial Point Source Pollution

State	Miles of River			Acres of Lake		
	Major	Minor	Total	Major	Minor	Total
Colorado 1988						
Total Point Sources	320	1,139	1,459	262	7,172	7,434
Industrial	42	250	292	262	0	262
Montana 1990						
Total Point Sources	46	1,416	1,462	0	5,100	5,100
Industrial	0	339	339	0	0	0
North Dakota 1990						
Total Point Sources	37	804	840	0	2,701	2,701
Industrial	0	12	12	0	0	0
South Dakota 1988						
Total Point Sources	22	43	65	1,953	0	1,953
Industrial	11	0	11	0	0	0
Utah 1990						
Total Point Sources	130	1,018	1,148	194,484	42	194,526
Industrial	65	509	574	96,900	21	96,921
Wyoming 1988						
Total Point Sources	321	399	720	0	0	0
Industrial (Oil)	314	399	713	0	0	0
Industrial (Others)	7	0	7	0	0	0
Region VIII						
Total Point Sources	876	4,819	5,694	196,699	15,015	211,714
Industrial	432	1,509	1,941	97,162	21	97,183

Table 1-5
Miles of Stream and Acres of Lake Impaired by Pollutant

Miles of Stream Impaired

Pollutant	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Pesticides						275	275
Metals	1345	1141	1016	11	1908	7	5428
Ammonia				823			823
Chlorine				4			4
Other Inorganics				790			790
Nutrients	756	3178	7269	232	1747		13181
pH		163		656	758		1577
Siltation	2133	6769	4375	385		3303	16965
Organic Enrichment/DO		120	1184	204	2748		4256
Salinity/TDS/chlorides	1488	3032	1818		1333	891	8562
Thermal modification		1699		875		8	2582
Flow alterations		2746	414			401	3561
Other habitat alterations		1363		43		965	2371
Pathogens	53	510	2844	1185	1623	418	6633
Radiation		2					2
Oil and Grease		64					64
Taste and odor							
Suspended solids			2563	1707			4270
Noxious aquatic plants							
Filling and draining							

Acres of Lake Impaired

Pollutant	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Pesticides							0
Metals	3715	57598			32472		93785
Ammonia					131579		131579
Chlorine							0
Other Inorganics							0
Nutrients	22554	107664	581539	88046	134453	56950	991205
pH		5600					5600
Siltation	6278	350654	500930	67753	10905	89775	1026294
Organic Enrichment/DO		11411	574014	158	112547	54772	752902
Salinity/TDS/chlorides	590	27759	425981		11255	489	466074
Thermal modification		25226	46		2874		28146
Flow alterations		83522	56324	7868		12332	160046
Other habitat alterations		6848					6848
Pathogens	325	10743					11068
Radiation							0
Oil and Grease							0
Taste and odor				27			27
Suspended solids		44282	113911	952	108627		267772
Noxious aquatic plants		61018		86501	122932		270451
Filling and draining		353					353

Risks from these different sources of surface water pollution can not be quantified and compared based solely only on the miles or acres of streams impacted. While the extent of industrial point source water pollution is far less than nonpoint sources, industrial emissions occur in more populated areas where potential human interactions with pollutants are more likely. In contrast, many nonpoint sources of surface water pollution are associated with rural sparsely populated areas (ie. agricultural runoff or abandoned mines) where direct interactions with humans are less likely. The type of pollutant released from industrial point sources tends to be more toxic (metals, toxic organics) than the dominant form of nonpoint pollutant (sediments).

1.6 HUMAN HEALTH EFFECTS DUE TO INDUSTRIAL WASTE DISCHARGES

For the States in Region VIII, the 305b reports document no specific human health effects attributable directly to industrial point source water pollution. However, significant human health effects due to two primary pathways, body contrast and drinking water contamination, are considered unlikely.

1.7 WELFARE EFFECTS DUE TO INDUSTRIAL WASTE DISCHARGES

Many different types of welfare effects may be associated with the contamination of aquatic ecosystems by industrial wastes in Region VIII. Typically addressed damage categories include:

- Replacement or treatment of contaminated drinking water;
- Reduced suitability of surface water for agricultural uses;
- Declining riparian property values near eutrophied water bodies;
- Cost of illness due to ingesting contaminated waters;
- Loss of recreation opportunities; and,
- Loss of valued aquatic habitats

Existing data are not sufficient to allow, credible estimates of welfare damages due to or associated with Industrial Point Sources in Region VIII. Even if credible economic damage estimates were available for selected societal uses of surface waters damaged by industrial point sources, these measures are at best partial approximations.

1.8 ASSUMPTIONS

Quantification of the amount of industrial point source pollution described in this assessment relies on the quality of the 319 and 305b State reports. These data have serious reservations associated with their use in risk assessment. Using these data, we must assume:

1) Ecosystem effects are related to "impairment" from designated use categories.

   Since a state can designate a use as "industrial" or contaminated, then chronic pollution of such a designated use is not revealed as an impairment by definition. Quantitative information is hard to derive from the State reports, as the same stream reach can be listed as impaired by more than one activity and impaired from more than one use designation.

2) State listings of the amount of impairment represent a reasonable estimate of the actual amount of impairment.

   However, only a fraction of each state's surface waters are evaluated subjectively and even a smaller fraction is actually sampled and evaluated quantitatively.

These assumptions are important. While appearing to be quantitative data the impairment data reported in the 319 and 305b reports should be interpreted with caution.

1.9 UNCERTAINTY

Effects of individual point source pollutants are certain. The cumulative impacts of several pollutants are not well known. The extent of impacts are not well known, either. Water quality is not monitored in a statistically meaningful manner. Data presented here on the extent of water quality impacts from industrial point source pollution are also uncertain. The true extent of pollution impacts are unknown.

1.10 OMISSIONS

The detailed effects of specific pollutants on aquatic biota do not differ substantially between sources of specific pollutants, therefore specific effects of each pollutant are fully described in Problem 3, nonpoint source pollution.

1.11 RECOMMENDATIONS FOR IMPROVING RISK ASSESSMENT-REDUCING UNCERTAINTY

Statistically relevant water quality monitoring would allow for a more meaningful and less uncertain assessment of the extent of industrial point source pollution in Region VIII. Data on the amount of effluent, receiving water volume, and background concentrations for each discharge site would be most useful. Knowledge of the long term effects of multiple pollutants on stream and lake ecosystem structure and function would improve our ability to predict ecological risks. Whole effluent toxicity studies are a minimal first step toward evaluating complex interactive pollutant effects.

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2.0 MUNICIPAL WASTEWATER DISCHARGES TO SURFACE WATER

2.1 INTRODUCTION

The Municipal Wastewater Discharges to Surface Water problem area covers risks to ecosystems, and human health and welfare, from all publicly and privately owned NPDES (National Pollution Discharges Elimination System) permitted wastewater treatment facilities.

Point source pollution issues from municipal waste treatment discharges are similar to those of industrial point source discharges. However, municipal waste effluents have some unique properties. Municipal wastes combine wastes from numerous industries with domestic sewage wastes and, in some cases, storm sewer overflows.

Permitting requirements allow for direct quantification of the number and location of each municipal waste discharger. In Region VIII, there are 1298 municipal waste NPDES dischargers. Of these, 189 are classified as major facilities, and 1109 are classified as minor facilities.

The distribution of major dischargers including, industrial waste facilities, is shown in Figure 1-1. Point sources in Region VIII are aggregated around populated areas including; the Front Range of Colorado, the Great Basin-Salt Lake area of Utah, and Casper, Wyoming.

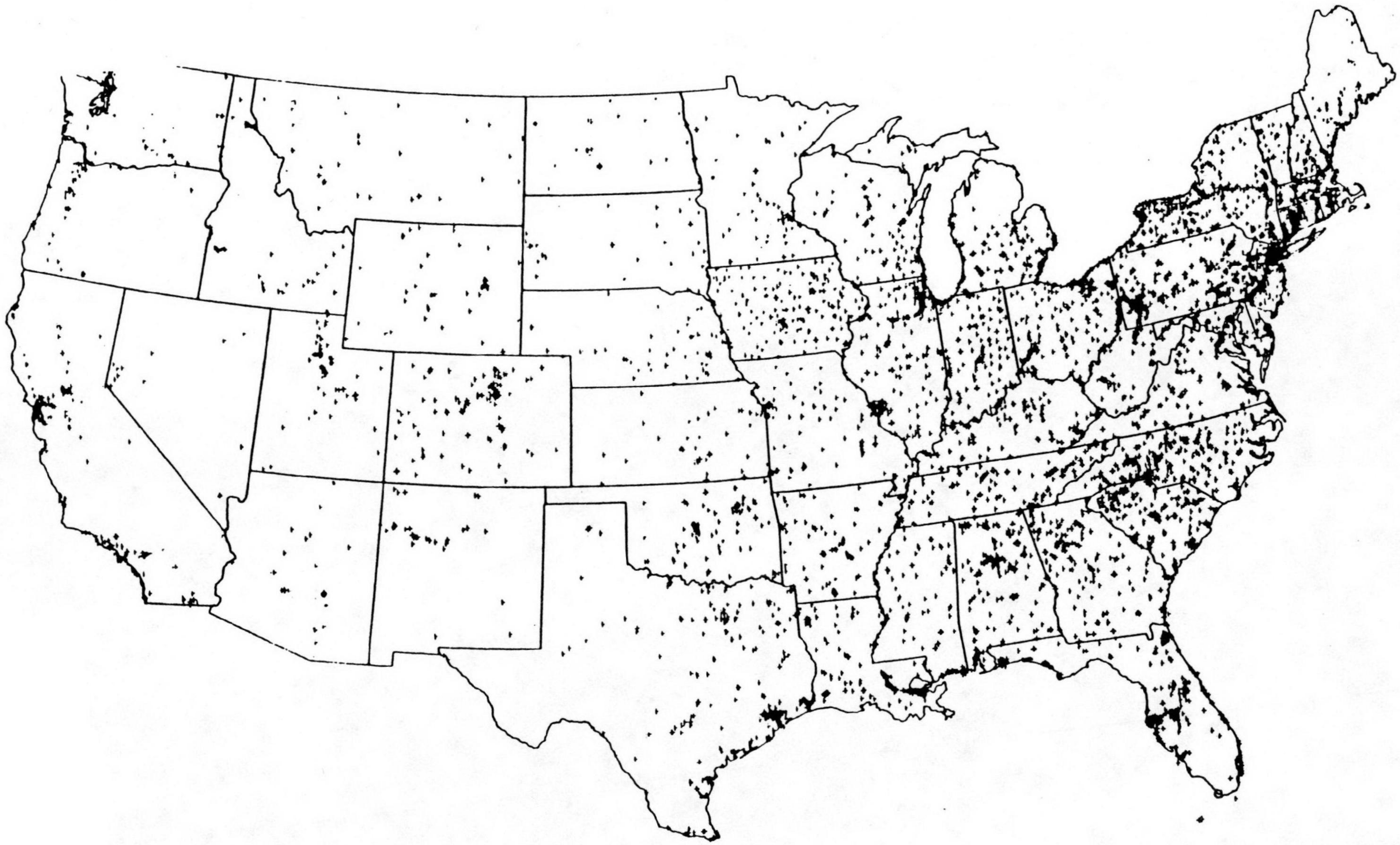
Impacts are quantified as reported in State 319 and 305b reports as the number of miles of streams and acres of lakes impacted by the "municipal point sources" category. Impacts associated with specific pollutants were quantified in Problem 1.

2.2 SOURCES

Risks are associated with each municipal waste water source, as permits allow pollutant releases that may cause impacts. Furthermore, permitted levels of pollutant release may be exceeded by any facility at any time. During high runoff events CSOs may contribute to municipal waste facilities and overwhelm facility capacities.

All municipal waste treatment facilities release suspended solids, nutrients, and BOD. The presence and importance of other pollutants depends on the amount and kind of discharges flowing through the facility, and the contribution and characteristics of combined sewer overflows. Each source varies in the types of pollutants they produce and pollutants vary in their environmental, health and welfare impacts.

Figure 2.1
Geographic Distribution of 7,000 Major Point Source Dischargers



There are 1,298 NPDES municipal waste generating facilities in Region VIII, of which 189 are classified as major and 1109 are classified as minor facilities. Waste generating facilities are not randomly distributed across the Region (Figure 2-1) and cumulative impacts may be associated with the density of facilities in a given drainage basin. The numbers of major and minor municipal waste facilities in each major drainage basin in the Region are listed in Table 2-1.

River systems at highest risk, all other factors being equal, are those with the greatest number of waste facilities. For example, the South Platte River has the greatest number of major municipal waste facilities. Since the Salt Lake basin is a closed drainage, the 23 major and 26 minor facilities should lead to significant cumulative effects. Other river systems with numerous major and minor municipal waste facilities include: the Upper Colorado and Arkansas Rivers, and the Niobrara River in the Central Missouri basin.

However, the types of pollutants released, the volume of effluent verses the receiving water volume, and background pollution burden are all important factors that prevent a credible assessment of risks based only data enumerating and locating municipal waste facilities.

2.3 STRESSORS

The types of pollutants associated with municipal discharges in Region VIII include:

total suspended solids

biological oxygen demand (BOD)

bacterial pathogens (fecal coliform)

- **ammonia**
- **chlorine and chlorination products**

nutrients

- **nitrogen**
- **phosphorous**

Table 2-1
Number of Major and Minor Municipal Discharge Facilities
by Drainage Basin in Region VIII

	Municipal Waste NPDES		
Drainage Basin	Major	Minor	Total
UNNAMED	0	1	15
COLORADO			
GREEN RIVER	7	39	136
LOW COLORADO	1	2	3
SAN JUAN	2	41	66
UP COLORADO	19	89	171
GREAT BASIN			
SALT LAKE	23	26	105
SEVIER R.	1	8	16
MISSOURI			
BIG SIOUX R.	5	57	76
CEN MR, NIOBRARA	14	126	327
SPRING R.	8	121	174
JAMES R.	5	91	103
KANSAS R.	0	8	8
LOW MR, NIOBRARA	3	25	38
MR, NIOBRARA	0	2	38
NORTH PLATTE	3	24	164
SOUTH PLATTE	36	112	257
UP MR, MILK R.	10	37	115
YELLOWSTONE	12	57	497
PACIFIC NORTH			
CLARK FORK	9	13	54
KOOTENAI R.	1	1	4
UPPER SNAKE R.	0	6	10
SM			
ARKANSAS	0	0	3
UP ARKANSAS	16	47	105
UM			
MINNESOTA R.	2	9	11
RED RIVER OF NOR	9	107	151
SOURIS R.	1	41	54
WG			
UPPER RIO GRANDE	2	19	32

2.4 ECOSYSTEM EFFECTS OF MUNICIPAL WASTE DISCHARGE TO SURFACE WATERS

Ecosystem effects of municipal waste discharges are, for the purposes of this analysis, similar to those associated with industrial wastes for the pollutants listed above.

2.5 DATA QUANTIFYING ECOSYSTEM EFFECTS OF MUNICIPAL WASTE DISCHARGE TO SURFACE WATERS

Potential ecosystem effects due to municipal waste discharges are related to the number of discharge sites and total resources at risk. As documented in Problem 1, there are over 83 thousand miles of streams and 6 million acres of lakes in Region VIII. Impacts from municipal waste discharge may occur to these surface waters at each of the 189 major and 1109 minor NPDES facilities distributed across the Region. The distribution of major NPDES sites is not random but is clustered in areas of industrial development (Figure 2-1) and varies between drainage basin (Table 2-1).

If we assume that the loss of best use designation reported in the State 319 and 305b reports is related to ecosystem impacts then the number of miles of streams and acres of lakes impacted by the "municipal point sources" category or by specific pollutants is a direct measure of their environmental effects.

The miles of streams and acres of lakes in the Region impacted by municipal point sources of water pollution are listed in Table 2-2 as compiled from the various State reports.

Fewer than 6,000 miles of streams in Region VIII are impacted by point source surface water pollution and over half, 3,310 miles, are attributed to municipal point sources (Table 2-2). Streams with major impacts from municipal point sources total 443 miles, with the majority of impacts occurring in the Colorado Front Range region (278 miles).

Over 200,000 acres of lakes are impacted by point sources of water pollution in the Region and more than half of this lake area is impaired by municipal point sources (114,531 acres). Impacts on lakes from municipal point sources were observed primarily in Utah (97,584 acres) and were classified as major impacts (Table 2-2).

Table 2-2
Aquatic Resources Exhibiting Major and Minor Impacts
from Municipal Point Source Pollution

State	Miles of River			Acres of Lake		
	Major	Minor	Total	Major	Minor	Total
Colorado 1988						
Total Point Sources	320	1,139	1,459	262	7,172	7,434
Municipal	278	889	1,167	0	7,172	7,172
Montana 1990						
Total Point Sources	46	1,416	1,462	0	5,100	5,100
Municipal	46	1,077	1,123	0	5,100	5,100
North Dakota 1990						
Total Point Sources	37	804	840	0	2,701	2,701
Municipal	37	792	829	0	2,701	2,701
South Dakota 1988						
Total Point Sources	22	43	65	1,953	0	1,953
Municipal	11	43	54	1,953	0	1,953
Utah 1990						
Total Point Sources	130	1,018	1,148	194,484	42	194,526
Municipal	65	509	574	97,584	21	97,605
Wyoming 1988						
Total Point Sources	321	399	720	0	0	0
Municipal	62	114	176	0	8,300	8,300
Region VIII						
Total Point Sources	876	4,819	5,694	196,699	15,015	211,714
Municipal	444	3,310	3,754	99,537	14,994	114,531

Another indication of the extent of surface water pollution, some fraction of which is attributable to municipal point sources, can be derived from the State 305b and 319 reports as the miles of streams and acres of lakes impacted by specific pollutants (See Problem 1). However none of the pollutants listed are exclusively found in municipal point sources, therefore, these data only serve as an index to the potential extent of surface water pollution from all sources.

In Region VIII municipal point source impacts are much less extensive than nonpoint sources (see Problem 3), and are larger than industrial point source impacts (Problem 1).

Risks from these different sources of surface water pollution can not be quantified and compared based solely only on the miles or acres of streams impacted. While the extent of municipal point source water pollution is far less than nonpoint sources, municipal emissions occur in more populated areas where potential human interactions with pollutants are more likely. In contrast, many nonpoint sources of surface water pollution are associated with rural, sparsely populated areas (ie., agricultural runoff or abandoned mines) where direct interactions with humans are less likely. The type of pollutant released from industrial point sources tends to be more toxic (metals, toxic organics) than the dominant form of nonpoint pollutant (sediments).

2.6 HUMAN HEALTH EFFECTS OF MUNICIPAL WASTE DISCHARGES

Available data do not allow credible quantitative estimates of human health effects associated with this problem area. Likely exposure pathways include direct contact and drinking water contamination. Neither are considered to pose significant health risks.

2.7 EFFECTS OF MUNICIPAL WASTE DISCHARGE TO SURFACE WATERS ON WELFARE

Categories of welfare damages associated with contamination of surface waters by municipal wastes are similar to those caused by industrial point sources. See Problem 1 for a listing of the kinds of welfare damages associated with point source water pollution. Lack of data prohibit a quantitative assessment of welfare damages associated with this problem area.

2.8 ASSUMPTIONS

This assessment of risks associated with municipal point sources of water pollution employs the same assumptions regarding the use of State 319 and 305b reports as did the industrial point source assessment (see Problem 1).

2.9 UNCERTAINTY

Effects of individual point source pollutants are certain. The cumulative impacts of several pollutants is not well known. The extent of impacts are not well known either. Water quality is not monitored in a statistically meaningful manner. The data presented here on the extent of water quality impacts from municipal point source pollution is uncertain. True extent of pollution impacts are unknown.

2.10 OMISSIONS

The detailed effects of specific pollutants on aquatic biota do not differ substantially between sources of specific pollutants, therefore specific effects of each pollutant are fully described in Problem 3, nonpoint source pollution.

2.11 RECOMMENDATIONS FOR IMPROVING RISK ASSESSMENT-REDUCING UNCERTAINTY

Statistically relevant water quality monitoring would allow for a more meaningful and less uncertain assessment of the extent of point source pollution in Region VIII. Data on the amount of effluent, receiving water volume, and background concentrations for each discharge site would be most useful. Knowledge of the long term effects of multiple pollutants on stream and lake ecosystem structure and function would improve our ability to predict ecological risks. Whole effluent toxicity studies are a minimal first step toward evaluating complex interactive pollutant effects.

2.12 REFERENCES

Environmental Protection Agency. 1987. Comparative Ecological Risk. A Report of the Ecological Risk Workgroup. U.S. EPA, Office of Policy Analysis, Office of Policy, Planning and Evaluation. Washington, D.C. 20460.

3.0 NONPOINT SOURCE DISCHARGES TO WATER

3.1 INTRODUCTION

Nonpoint source water pollution is defined as pollution not discharged through discrete conveyances. Nonpoint pollution originates from large diffuse sources or more confined and localized areas. The delivery mechanism is the primary parameter; nonpoint pollutants are carried by some agent such as runoff, groundwater, or wind. Alternatively, these contaminants enter waters due to proximity e.g. landslides from unstable slopes, or direct animal access. Some sources of nonpoint pollution are not fully discussed in Section 3.0; these have been identified as specific threats to be addressed separately in this risk assessment. These nonpoint sources include mining waste sites, leaching from storage tanks, RCRA hazardous waste and superfund sites, municipal and industrial solid waste sites, accidental chemical releases, pesticides, and acid deposition.

The environmental risks from both point and nonpoint pollution are similar. Both types of pollution are positively correlated with population growth and development pressure. The prime population growth/development areas in Region VIII will experience the most serious effects in terms of impacted waters.

This risk assessment uses literature to define and characterize the qualitative effects associated with each nonpoint source activity (e.g. agriculture, resource extraction, etc.) and each pollutant (e.g. sedimentation, metals, etc.) or stressor (e.g. canal leakage, dredging). The individual State 319 and 305b reports from 1988 and 1989 are then used to quantify the contribution of the nonpoint source activity and pollutant type to non-attainment of designated beneficial uses in the Region.

3.2 DATA ON NONPOINT SOURCE EFFECTS

Impacts of nonpoint source water pollution vary depending upon the activity responsible for the pollutant discharge and the quality and quantity of the receiving water. Specific sources of nonpoint pollutants in Region VIII include agriculture, livestock grazing, resource extraction (mining), silviculture, construction, (urban development), urban runoff, hydromodifications (dam construction and operation, surface water withdrawal, flood control activities, and irrigation projects). Miles of streams and acres of lakes impaired by various nonpoint sources are listed in Table 3-1.

Stream impairment due to agricultural activities is 5-10 times more significant than the next most important nonpoint source of pollution in Region VIII, followed by hydromodification, resource extraction, construction, silviculture, urban runoff, and land disposal (Table 3-1). "Other" activities include impairment, highway maintenance, in-place contaminants, recreational activities, and atmospheric deposition.

Table 3-1
Miles of Stream and Acres of Lake Impaired by Source Category - Region VIII

Miles of Stream Impaired

Source Category	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources				817	574	624	2015
Nonpoint Sources							0
Agriculture	4709	11276	17874	4664	5868	7176	51566
Silviculture	43	748		112	161	495	1559
Construction	7	204		26	285	1965	2487
Urban Runoff	129	131	38	262	400	315	1275
Resource Extract/explore/dev.	1359	1605	255	62	293	731	4305
Land Disposal		301		26	115	76	518
Hydromodification	221	3116	4362		216	1572	9488
Other	118	732	4616	1224	1600	2686	10975
Source Unknown		10		18		114	142

Acres of Lake Impaired

Source Category	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources		3500		1897	221443	20509	247349
Nonpoint Sources				443			443
Agriculture	19816	395435	2011717	103386	272831	206950	3010135
Silviculture		41475		1004			42479
Construction		13625			10695	76442	100762
Urban Runoff	9451			16	10011	1434	20912
Resource Extract/explore/dev.	1955	4200	60	83		40720	47018
Land Disposal	325	42345	130	22003			64803
Hydromodification	1760	37930	57910	9577	119171	49536	275884
Other		78402	571768	2028	26921	104232	783350
Source Unknown				454		1991	2445

Lake impairment from agricultural nonpoint sources is more than 10 times as important as that from any other source. Potential pollutants include bacteria, nutrients (nitrogen and phosphorus), sedimentation and siltation, pesticides and herbicides, salts, dissolved oxygen and biological oxygen demand, temperature, and metal contamination.

The miles of streams and acres of lakes impaired by various pollutants are listed in Table 3-2.

Specific pollutants associated with nonpoint source pollution activities contribute to stream and lake impairment. Stream impairment from siltation and nutrients (nitrogen and phosphorus) is common. Following siltation and nutrients, the most important pollutants are salinity, bacteria, and metals (Table 3-2).

Siltation and nutrients are the mosts common contributors to lake impairment, followed by: organic enrichment, salinity, and noxious aquatic plants.

Data from the State reports breaking down miles of streams and acres of lakes impaired by nonpoint source categories (and subcategories) are shown for the Region (Table 3-3) and each State (Table 3-4). Impacts are ranked as slight, moderate, or high, and quantified by use category in each State in Table 3-5. Table 3-6 shows miles of streams and acres of lakes impacted in specific water use categories by each nonpoint source activity for the Region; this information is further broken down by each State in Table 3-7.

The water use categories include aquatic fish and wildlife, warm water fishery, cold water fishery, public water supply, agriculture and irrigation, livestock watering, industrial, and recreation.

The State 309 and 305b reports are compiled such that more than one source category or pollutant can impact the same stream or lake and affect multiple uses. Thus, the data presented do not reflect the actual miles of streams or acres of lakes impacted by a single activity.

The following description of the effects of different categories of activities contributing to nonpoint source water pollution based on The State of the Environment Report (State of Washington, 1989), unless otherwise cited.

Table 3-2
Miles of Stream and Acres of Lake Impaired by Pollutant - Region VIII

Miles of Stream Impaired

Pollutant	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Pesticides						275	275
Metals	1345	1141	1016	11	1908	7	5428
Ammonia				823			823
Chlorine				4			4
Other Inorganics				790			790
Nutrients	756	3178	7269	232	1747		13181
pH		163		656	758		1577
Siltation	2133	6769	4375	385		3303	16965
Organic Enrichment/DO		120	1184	204	2748		4256
Salinity/TDS/chlorides	1488	3032	1818		1333	891	8562
Thermal modification		1699		875		8	2582
Flow alterations		2746	414			401	3561
Other habitat alterations		1363		43		965	2371
Pathogens	53	510	2844	1185	1623	418	6633
Radiation		2					2
Oil and Grease		64					64
Taste and odor							
Suspended solids			2563	1707			4270
Noxious aquatic plants							
Filling and draining							

Acres of Lake Impaired

Pollutant	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Pesticides							0
Metals	3715	57598			32472		93785
Ammonia					131579		131579
Chlorine							0
Other Inorganics							0
Nutrients	22554	107664	581539	88046	134453	56950	991205
pH		5600					5600
Siltation	6278	350654	500930	67753	10905	89775	1026294
Organic Enrichment/DO		11411	574014	158	112547	54772	752902
Salinity/TDS/chlorides	590	27759	425981		11255	489	466074
Thermal modification		25226	46		2874		28146
Flow alterations		83522	56324	7868		12332	160046
Other habitat alterations		6848					6848
Pathogens	325	10743					11068
Radiation							0
Oil and Grease							0
Taste and odor				27			27
Suspended solids		44282	113911	952	108627		267772
Noxious aquatic plants		61018		86501	122932		270451
Filling and draining		353					353

Table 3-3
Impact by Source Subcategory - Region VIII

Miles of Stream

Source Category Subcategory	Slight	Moderate	High
Point Sources	0	0	0
Industrial	196	328	330
Municipal	17	825	297
Nonpoint Sources	0	0	0
Agriculture	7	1047	675
Non-irrigated crop prod.	2071	8987	3199
Irrigated crop prod.	2361	6637	2357
Pasture land	1513	6627	1397
Range land	2606	6119	3071
Feedlots	677	3768	393
Aquaculture	0	0	0
Animal holding areas	792	1516	352
Streambank erosion	563	2271	900
Silviculture	12	522	59
Harvesting, restoration	163	366	150
Forest management	52	93	23
Road construct/maint.	25	201	183
Construction	0	55	0
Highway/road/bridge	1329	1923	1128
Land development	132	140	87
Urban Runoff	0	82	56
Storm sewers	10	226	21
Surface runoff	328	516	202
Resource Extract/explore/dev.	61	484	65
Surface mining	383	316	60
Subsurface mining	573	834	469
Placer mining	16	176	57
Dredge mining	0	84	48
Petroleum activities	470	371	484
Mill tailings	134	147	224
Mine tailings	6	20	37
Land Disposal	0	2	0
Wastewater	0	120	0
On-site wastewater treat.	81	276	73
Hydromodification	23	71	115
Channelization	495	1431	1580
Dredging	0	0	0
Dam construction	254	75	259
Flow regulation	122	1505	269
Bridge construction	0	0	0
Removal of riparian veg.	30	296	41
Streambank modification	1002	4380	2191
Other	0	50	0
Atmospheric deposition	0	27	0
Highway maintenance	18	108	48
In-place contaminants	0	427	18
Natural	2836	7054	2936
Recreational activities	0	0	0
Source Unknown	0	30	132

Table 3-3 (cont.)
Impact by Source Subcategory - Region VIII

Acres of Lake

Source Category Subcategory	Slight	moderate	High
Point Sources	0	27	0
Industrial	0	0	0
Municipal	20509	20509	20970
Nonpoint Sources	0	0	443
Agriculture	327468	30854	82639
Non-irrigated crop prod.	113713	592213	96568
Irrigated crop prod.	84568	479478	83995
Pasture land	113972	510751	20324
Range land	93424	106830	65922
Feedlots	112771	491793	28817
Aquaculture	0	0	0
Animal holding areas	919	71938	63346
Streambank erosion	0	1955	615
Silviculture	34775	31236	162
Harvesting, restoration	3350	0	0
Forest management	0	0	0
Road construct/maint.	3350	410	0
Construction	13625	0	0
Highway/road/bridge	73205	80072	44399
Land development	25	25	0
Urban Runoff	0	0	0
Storm sewers	0	0	0
Surface runoff	3594	6065	2676
Resource Extract/explore/dev.	0	0	83
Surface mining	9480	9480	0
Subsurface mining	0	4055	0
Placer mining	0	2100	0
Dredge mining	0	0	0
Petroleum activities	31300	31300	13300
Mill tailings	0	0	0
Mine tailings	0	0	0
Land Disposal	7555	32830	0
Wastewater	0	0	0
On-site wastewater treat.	4870	9322	13881
Hydromodification	34580	34580	0
Channelization	0	897	897
Dredging	0	0	0
Dam construction	0	0	0
Flow regulation	31005	38773	25729
Bridge construction	0	80	0
Removal of riparian veg.	325	56919	56507
Streambank modification	12169	15116	15810
Other	0	55	55
Atmospheric deposition	1580	60	0
Highway maintenance	0	25	915
In-place contaminants	113095	566030	73021
Natural	143208	149780	67520
Recreational activities	0	30	58
Source Unknown	0	41	2404

Table 3-4
Impact by Source Subcategory by State - Region VIII

Miles of Stream Impaired

Source Category / Subcategory	Colorado			Montana			North Dakota		
	Slight	Moderate	High	Slight	Moderate	High	Slight	Moderate	High
Point Sources									
Industrial									
Municipal									
Nonpoint Sources									
Agriculture	7				888	102			
Non-irrigated crop prod.		176			1830	135	1542	5512	2395
Irrigated crop prod.	464	685	370	179	3576	508		124	15
Pasture land				67	2029	215	615	2633	222
Range land	563	572	460				699	3160	642
Feedlots							677	3078	387
Aquaculture									
Animal holding areas					236	22	699	570	255
Streambank erosion	486	700	384	55	1454	241			
Silviculture				12	522	59			
Harvesting, restoration					100	20			
Forest management									
Road construct/maint.		43			72	20			
Construction					29				
Highway/road/bridge		7			175				
Land development									
Urban Runoff					45	45			
Storm sewers					38	5			
Surface runoff	36	93			38	5		38	38
Resource Extract/explore/dev.					361	3			
Surface mining	72				22				
Subsurface mining	553	461	306	6	358	163			
Placer mining	4	18		12	158	47			
Dredge mining					81	35			
Petroleum activities					64		255		255
Mill tailings	15			119	147	224			
Mine tailings			10	6	20	28			
Land Disposal					2				
Wastewater					120				
On-site wastewater treat.				5	174	59			
Hydromodification					48	45			
Channelization		1		119	207	119	291	933	1100
Dredging									
Dam construction					75		229		234
Flow regulation		17			1126	58		109	
Bridge construction									
Removal of riparian veg.					54			199	
Streambank modification	50		153		1382	56	615	2342	1554
Other					50				
Atmospheric deposition								27	
Highway maintenance					32				
In-place contaminants								427	
Natural		118			638	12	927	3525	656
Recreational activities									
Source Unknown					10				

Table 3-4 (cont.)
Impact by Source Subcategory by State - Region VIII

Miles of Stream Impaired

Source Category / Subcategory	South Dakota			Wyoming		
	Slight	Moderate	High	Slight	Moderate	High
Point Sources						
Industrial		11	11	196	317	319
Municipal		686	178	17	139	119
Nonpoint Sources						
Agriculture		49	463		110	110
Non-irrigated crop prod.		941	462	529	529	207
Irrigated crop prod.		157	47	1718	2097	1418
Pasture land		685		831	1281	960
Range land		312	455	1344	2075	1514
Feedlots		690	6			
Aquaculture						
Animal holding areas		555		94	156	75
Streambank erosion				22	118	275
Silviculture						
Harvesting, restoration				163	266	130
Forest management				52	93	23
Road construct/maint.			112	25	86	51
Construction		26				
Highway/road/bridge				1329	1741	1128
Land development				132	140	87
Urban Runoff		37	11			
Storm sewers		178	6	10	10	10
Surface runoff		47	47	292	300	112
Resource Extract/explore/dev.		62	62	61	61	
Surface mining				311	294	60
Subsurface mining				15	15	
Placer mining						10
Dredge mining					3	13
Petroleum activities				215	307	229
Mill tailings						
Mine tailings						
Land Disposal						
Wastewater						
On-site wastewater treat.		26		76	76	14
Hydromodification				23	23	70
Channelization				85	290	361
Dredging						
Dam construction				25		25
Flow regulation				122	253	211
Bridge construction						
Removal of riparian veg.				30	43	41
Streambank modification				337	655	428
Other						
Atmospheric deposition						
Highway maintenance		37	11	18	39	37
In-place contaminants			18			
Natural		389	831	1909	2385	1437
Recreational activities						
Source Unknown			18		20	114

Table 3-4 (cont.)
Impact by Source Subcategory by State - Region VIII

Acres of Lake Impaired

Source Category Subcategory	Colorado			Montana			North Dakota		
	Slight	Moderate	High	Slight	Moderate	High	Slight	Moderate	High
Point Sources									
Industrial									
Municipal									
Nonpoint Sources									
Agriculture				327468	30246				
Non-irrigated crop prod.					11450	9750	113713	580763	86818
Irrigated crop prod.	2160	7430	6716		7640	7650		368231	
Pasture land					7640	1423	112563	495567	12801
Range land		325	615				495	4360	1985
Feedlots							112771	491558	10557
Aquaculture									
Animal holding areas							919	71238	61046
Streambank erosion		1955	615						
Silviculture				34775	30800				
Harvesting, restoration				3350					
Forest management									
Road construct/maint.				3350					
Construction				13625					
Highway/road/bridge					3655				
Land development									
Urban Runoff									
Storm sewers									
Surface runoff	2160	4631	2660						
Resource Extract/explore/dev.									
Surface mining							60	60	
Subsurface mining		1955			2100				
Placer mining					2100				
Dredge mining									
Petroleum activities									
Mill tailings									
Mine tailings									
Land Disposal		325		7555	32505				
Wastewater									
On-site wastewater treat.				4870	920	150		130	
Hydromodification				34580	34580				
Channelization								197	197
Dredging									
Dam construction									
Flow regulation			1760					324	324
Bridge construction								80	
Removal of riparian veg.							325	56919	56507
Streambank modification				3350				197	391
Other								55	55
Atmospheric deposition				1520			60	60	
Highway maintenance									
In-place contaminants							113095	566030	73021
Natural				48375	40274		495	5575	3284
Recreational activities									
Source Unknown									

Table 3-4 (cont.)
Impact by Source Subcategory by State - Region VIII

Acres of Lake Impaired

Source Category Subcategory	South Dakota Slight	South Dakota Moderate	South Dakota High	Wyoming Slight	Wyoming Moderate	Wyoming High
Point Sources		27				
Industrial						
Municipal			1870	20509	20509	19100
Nonpoint Sources			443			
Agriculture		608	82639			
Non-irrigated crop prod.						
Irrigated crop prod.				82408	96177	69629
Pasture land		35		1409	7509	6100
Range land		35	99	92929	102110	63223
Feedlots		235	18260			
Aquaculture						
Animal holding areas			1600		700	700
Streambank erosion						
Silviculture		436	162			
Harvesting, restoration						
Forest management						
Road construct/maint.		410				
Construction						
Highway/road/bridge				73205	76417	44399
Land development				25	25	
Urban Runoff						
Storm sewers						
Surface runoff			16	1434	1434	
Resource Extract/explore/dev.			83			
Surface mining				9420	9420	
Subsurface mining						
Placer mining						
Dredge mining						
Petroleum activities				31300	31300	13300
Mill tailings						
Mine tailings						
Land Disposal						
Wastewater						
On-site wastewater treat.		8272	13731			
Hydromodification						
Channelization					700	700
Dredging						
Dam construction						
Flow regulation		7868	1209	31005	30581	22436
Bridge construction						
Removal of riparian veg.						
Streambank modification			500	8819	14919	14919
Other						
Atmospheric deposition						
Highway maintenance		25	915			
In-place contaminants						
Natural		412	724	94338	103519	63512
Recreational activities		30	58			
Source Unknown		41	413			1991

Table 3-5
Source Subcategory by State - Region VIII

Miles of Stream Impaired

Source Category Subcategory	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources							0
Industrial				11		462	473
Municipal				806		162	968
Nonpoint Sources							0
Agriculture	7	945		506		110	1568
Non-irrigated crop prod	176	1965	7036	1305		529	11011
Irrigated crop prod.	1480	4104	124	157		2321	8185
Pasture land		2264	2633	685		1572	7153
Range land	1517		3797	767		2214	8294
Feedlots			3078	690			3768
Aquaculture							0
Animal holding areas		249	1206	555		156	2165
Streambank erosion	1530	1750				275	3554
Silviculture		536					536
Harvesting, restoration		120				291	411
Forest management						97	97
Road construct/maint.	43	92				107	242
Construction		29		26			55
Highway/road/bridge	7	175				1825	2007
Land development						140	140
Urban Runoff		45		37			82
Storm sewers		43		178		10	231
Surface runoff	129	43	38	47		305	562
Resource Extract/explore/dev.		364		62		61	487
Surface mining	72	22				314	408
Subsurface mining	1242	486				15	1743
Placer mining	21	205				10	236
Dredge mining		81				13	94
Petroleum activities		64	255			318	637
Mill tailings	15	336					351
Mine tailings	10	48					57
Land Disposal		2					2
Wastewater		120					120
On-site wastewater treat.		179		26		76	281
Hydromodification		48				70	118
Channelization	1	326	1162			388	1877
Dredging							0
Dam construction		75	234			25	334
Flow regulation	17	1184	109			323	1633
Bridge construction							0
Removal of riparian veg.		54	199			43	296
Streambank modificatio	203	1429	2659			723	5014
Other		50					50
Atmospheric deposition			27				27
Highway maintenance		32		37		39	108
In-place contaminants			427	18			445
Natural	118	650	4161	1169		2647	8745
Recreational activities							0
Source Unknown		10		18		114	142

Table 3-5 (cont.)
Source Subcategory by State - Region VIII

Acres of Lake Impaired

Pollutant	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources		3500		27			3527
Industrial					99470		99470
Municipal				1870	121973	20509	144352
Nonpoint Sources				443			443
Agriculture		349882		83122			433004
Non-irrigated crop prod.		21200	580763		115943		717906
Irrigated crop prod.	16306	15290	368231			96207	496034
Pasture land		9063	495567	35	4268	7509	516442
Range land	940		4360	134	122364	102534	230332
Feedlots			491558	18495	10927		520980
Aquaculture							0
Animal holding areas			71238	1600		700	73538
Streambank erosion	2570				19329		21899
Silviculture		34775		594			35369
Harvesting, restoration		3350					3350
Forest management							0
Road construct/maint.		3350		410			3760
Construction		13625			10695		24320
Highway/road/bridge						76417	76417
Land development						25	25
Urban Runoff					10011		10011
Storm sewers							0
Surface runoff	9451			16		1434	10901
Resource Extract/explore/dev.				83			83
Surface mining			60			9420	9480
Subsurface mining	1955	2100					4055
Placer mining		2100					2100
Dredge mining							0
Petroleum activities						31300	31300
Mill tailings							0
Mine tailings							0
Land Disposal	325	36405					36730
Wastewater							0
On-site wastewater treat.		5940	130	22003			28073
Hydromodification		34580			119171		153751
Channelization			197			700	897
Dredging							0
Dam construction							0
Flow regulation	1760		324	9077		33917	45078
Bridge construction			80				80
Removal of riparian veg.			56919				56919
Streambank modification		3350	391	500		14919	19160
Other			55		480		535
Atmospheric deposition		1520	60				1580
Highway maintenance				940			940
In-place contaminants			566078				566078
Natural		76882	5575	1005	14373	104232	202067
Recreational activities				83	12068		12151
Source Unknown				454		1991	2445

Table 3-6

Miles of Stream and Acres of Lake Impaired by Source Subcategory by Use Category - Region VIII

Miles of Stream

Source Category Subcategory	Aquatic Fish & Wildlife	Warm Water Fishery	Cold Water Fishery	Public Water Supply	Agriculture & Irrigation	Livestock Watering	Idus-trial	Rec-reation	TOTAL
Point Sources	0	0	0	0	0	0	0	0	0
Industrial	11	110	239	194	196	109	0	41	473
Municipal	628	795	67	244	862	806	0	902	968
Nonpoint Sources	0	0	0	0	0	0	0	0	0
Agriculture	506	709	950	334	574	567	0	678	1568
Non-irrigated crop prod.	4450	5564	1050	3386	3857	2262	231	6460	11011
Irrigated crop prod.	438	3247	4662	3179	3439	1539	0	3861	8185
Pasture land	2201	3095	2549	1806	1782	1737	0	2378	7153
Range land	2218	2534	2597	1241	3064	767	209	4779	8294
Feedlots	1809	1929	0	207	931	690	209	2296	3768
Aquaculture	0	0	0	0	0	0	0	0	0
Animal holding areas	624	810	306	604	789	563	0	1763	2165
Streambank erosion	0	1853	1655	2244	2517	1037	0	1886	3554
Silviculture	0	0	536	45	0	0	0	79	536
Harvesting, restoration	0	0	411	0	0	0	0	0	411
Forest management	0	0	67	0	0	0	0	30	97
Road construct/maint.	112	112	242	28	155	112	0	155	242
Construction	26	26	29	0	36	36	0	36	55
Highway/road/bridge	157	629	1349	209	408	0	0	76	2007
Land development	0	40	104	0	0	0	0	0	140
Urban Runoff	37	26	56	45	37	37	0	82	82
Storm sewers	178	178	43	0	178	178	0	188	231
Surface runoff	85	177	300	96	126	47	0	223	562
Resource Extract/explore/d	62	51	436	13	68	68	0	68	487
Surface mining	0	317	91	82	365	2	0	74	408
Subsurface mining	0	49	1636	1177	1216	156	0	1616	1743
Placer mining	0	0	236	22	21	3	0	68	236
Dredge mining	0	0	94	47	35	35	0	47	94
Petroleum activities	77	280	305	319	319	64	0	319	637
Mill tailings	0	0	351	188	88	73	0	300	351
Mine tailings	0	0	57	27	7	0	0	32	57
Land Disposal	0	0	2	0	0	0	0	2	2
Wastewater	0	0	120	0	0	0	0	0	120
On-site wastewater treat.	26	26	193	72	26	26	0	156	281
Hydromodification	0	0	118	68	0	0	0	45	118
Channelization	816	643	715	406	343	78	0	1052	1877
Dredging	0	0	0	0	0	0	0	0	0
Dam construction	234	234	100	0	0	0	0	75	334
Flow regulation	109	683	955	574	152	57	0	871	1633
Bridge construction	0	0	0	0	0	0	0	0	0
Removal of riparian veg.	199	0	97	199	0	0	0	0	296
Streambank modification	1892	2338	1717	1500	567	23	0	2208	5014
Other	0	0	50	0	0	0	0	0	50
Atmospheric deposition	27	0	0	0	0	0	0	0	27
Highway maintenance	37	26	82	0	37	37	0	37	108
In-place contaminants	217	18	0	322	18	18	0	123	445
Natural	2767	3000	2335	1355	2740	1260	231	4575	8745
Recreational activities	0	0	0	0	0	0	0	0	0
Source Unknown	18	18	95	0	42	28	0	23	142

Table 3-6 (cont.)
Miles of Stream and Acres of Lake Impaired by Source Subcategory by Use Category - Region VIII

Acres of Lake

Source Category Subcategory	Aquatic Fish & Wildlife	Warm Water Fishery	Cold Water Fishery	Public Water Supply	Agriculture & Irrigation	Livestock Watering	Idus-trial	Rec-reation	TOTAL
Point Sources	27	0	3500	27	0	27	0	3527	3527
Industrial	98990	98000	1470	990	99470	99470	0	98480	99470
Municipal	110860	120775	23577	13973	121973	123843	0	111948	144352
Nonpoint Sources	443	443	0	350	0	443	0	443	443
Agriculture	83122	336303	56721	295605	25639	83122	0	380554	433004
Non-irrigated crop prod.	99098	156324	16262	32973	131453	131453	0	692695	717906
Irrigated crop prod.	0	34083	17613	10400	24186	7650	0	396327	496034
Pasture land	35	13728	94348	4268	5691	5726	0	508713	516442
Range land	99124	137977	14577	24209	123763	122498	0	115553	230332
Feedlots	18495	24007	103467	10927	23287	29422	0	520360	520980
Aquaculture	0	0	0	0	0	0	0	0	0
Animal holding areas	1600	16347	0	0	0	1600	0	63380	73538
Streambank erosion	10000	10965	10934	10804	21899	19329	0	21549	21899
Silviculture	594	0	35369	53	0	594	0	1644	35369
Harvesting, restoration	0	0	3350	0	0	0	0	0	3350
Forest management	0	0	0	0	0	0	0	0	0
Road construct/maint.	410	0	3760	32	0	410	0	410	3760
Construction	10000	10011	9509	5484	10695	10695	0	10695	24320
Highway/road/bridge	0	25797	66297	0	0	0	0	9505	76417
Land development	0	0	25	0	0	0	0	0	25
Urban Runoff	10000	10011	0	0	10011	10011	0	10011	10011
Storm sewers	0	0	0	0	0	0	0	0	0
Surface runoff	16	2327	8574	7691	7691	16	0	9467	10901
Resource Extract/explore/d	83	83	0	0	0	83	0	83	83
Surface mining	0	9480	0	0	0	0	0	0	9480
Subsurface mining	0	0	4055	1955	1955	0	0	4055	4055
Placer mining	0	0	2100	0	0	0	0	2100	2100
Dredge mining	0	0	0	0	0	0	0	0	0
Petroleum activities	0	13300	31300	0	0	0	0	0	31300
Mill tailings	0	0	0	0	0	0	0	0	0
Mine tailings	0	0	0	0	0	0	0	0	0
Land Disposal	0	0	36730	325	325	0	0	3980	36730
Wastewater	0	0	0	0	0	0	0	0	0
On-site wastewater treat.	22003	21729	6344	1503	1749	22003	0	23163	28073
Hydromodification	108000	119171	34580	11171	119171	119171	0	108266	15371
Channelization	0	897	0	0	0	0	0	0	897
Dredging	0	0	0	0	0	0	0	0	0
Dam construction	0	0	0	0	0	0	0	0	0
Flow regulation	9077	17612	26257	1209	0	9077	0	10837	45078
Bridge construction	0	80	0	0	0	0	0	0	80
Removal of riparian veg.	0	919	0	0	0	0	0	56919	56919
Streambank modification	500	6991	12169	0	0	500	0	694	19160
Other	0	55	480	0	480	480	0	2055	535
Atmospheric deposition	0	60	1520	0	0	0	0	0	1580
Highway maintenance	940	851	89	671	0	940	0	940	940
In-place contaminants	108	27597	24146	0	0	0	0	553203	566078
Natural	2103	29060	108114	62667	14832	15378	0	76311	202067
Recreational activities	83	11	12140	12057	12068	12151	0	12151	12151
Source Unknown	454	454	1962	41	0	454	0	483	2445

Table 3-7

Source Subcategory by Use Category by State: Aquatic Fish & Wildlife

Miles of Stream Impaired

Source Category Subcategory	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources							0
Industrial				11			11
Municipal				628			628
Nonpoint Sources							0
Agriculture				506			506
Non-irrigated crop prod.			3243	1127		80	4450
Irrigated crop prod.			124	157		157	438
Pasture land			1694	507			2201
Range land			1294	767		157	2218
Feedlots			1297	512			1809
Aquaculture							0
Animal holding areas			248	377			624
Streambank erosion							0
Silviculture							0
Harvesting, restoration							0
Forest management							0
Road construct/maint.				112			112
Construction				26			26
Highway/road/bridge						157	157
Land development							0
Urban Runoff				37			37
Storm sewers				178			178
Surface runoff			38	47			85
Resource Extract/explore/dev.				62			62
Surface mining							0
Subsurface mining							0
Placer mining							0
Dredge mining							0
Petroleum activities						77	77
Mill tailings							0
Mine tailings							0
Land Disposal							0
Wastewater							0
On-site wastewater treat.				26			26
Hydromodification							0
Channelization			816				816
Dredging							0
Dam construction			234				234
Flow regulation			109				109
Bridge construction							0
Removal of riparian veg.			199				199
Streambank modification			1892				1892
Other							0
Atmospheric deposition			27				27
Highway maintenance				37			37
In-place contaminants			199	18			217
Natural			1441	1169		157	2767
Recreational activities							0
Source Unknown				18			18

Table 3-7 (cont.)
Source Subcategory by Use Category by State: Warm Water Fisheries

Miles of Stream Impaired

Source Category Subcategory	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources							0
Industrial						110	110
Municipal				795			795
Nonpoint Sources							0
Agriculture		119		480		110	709
Non-irrigated crop prod.	176	1053	2719	1305		311	5564
Irrigated crop prod.	805	1728	109	157		449	3247
Pasture land		1019	1374	685		18	3095
Range land	650		836	767		281	2534
Feedlots			1239	690			1929
Aquaculture							0
Animal holding areas			255	555			810
Streambank erosion	676	1067				110	1853
Silviculture							0
Harvesting, restoration							0
Forest management							0
Road construct/maint.				112			112
Construction				26			26
Highway/road/bridge						629	629
Land development						40	40
Urban Runoff				26			26
Storm sewers				178			178
Surface runoff	50			47		80	177
Resource Extract/explore/dev.				51			51
Surface mining	6					311	317
Subsurface mining	47	2					49
Placer mining							0
Dredge mining							0
Petroleum activities			255			25	280
Mill tailings							0
Mine tailings							0
Land Disposal							0
Wastewater							0
On-site wastewater treat.				26			26
Hydromodification							0
Channelization			629			14	643
Dredging							0
Dam construction			234				234
Flow regulation		569	109			5	683
Bridge construction							0
Removal of riparian veg.							0
Streambank modification	144	494	1686			14	2338
Other							0
Atmospheric deposition							0
Highway maintenance				26			26
In-place contaminants				18			18
Natural	118		1073	1160		649	3000
Recreational activities							0
Source Unknown				18			18

Table 3-7 (cont.)
Source Subcategory by Use Category by State: Cold Water Fisheries

Miles of Stream

Source Category Subcategory	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources							0
Industrial				11		228	239
Municipal				11		56	67
Nonpoint Sources							0
Agriculture	7	807		26		110	950
Non-irrigated crop prod.		912				138	1050
Irrigated crop prod.	676	2376				1611	4662
Pasture land		1245				1305	2549
Range land	867					1730	2597
Feedlots							0
Aquaculture							0
Animal holding areas		249				57	306
Streambank erosion	854	683				118	1655
Silviculture		536					536
Harvesting, restoration		120				291	411
Forest management						67	67
Road construct/maint.	43	92				107	242
Construction		29					29
Highway/road/bridge	7	175				1167	1349
Land development		4				100	104
Urban Runoff		45		11			56
Storm sewers		43					43
Surface runoff	79	43				178	300
Resource Extract/explore/dev.		364		11		61	436
Surface mining	66	22				3	91
Subsurface mining	1137	484				15	1636
Placer mining	21	205				10	236
Dredge mining		81				13	94
Petroleum activities		64				241	305
Mill tailings	15	336					351
Mine tailings	10	48					57
Land Disposal		2					2
Wastewater		120					120
On-site wastewater treat.		179				14	193
Hydromodification		48				70	118
Channelization	1	326				388	715
Dredging							0
Dam construction		75				25	100
Flow regulation	17	615				323	955
Bridge construction							0
Removal of riparian veg.		54				43	97
Streambank modification	59	935				723	1717
Other		50					50
Atmospheric deposition							0
Highway maintenance		32		11		39	82
In-place contaminants							0
Natural		650		9		1676	2335
Recreational activities							0
Source Unknown						95	95

Table 3-7 (cont.)
Source Subcategory by Use Category by State: Public Water Supply

Miles of Stream

Source Category Subcategory	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources							0
Industrial						194	194
Municipal				178		66	244
Nonpoint Sources							0
Agriculture	7	217				110	334
Non-irrigated crop prod.	15	1616	1548	207			3386
Irrigated crop prod.	824	2227				128	3179
Pasture land		1346	115	207		138	1806
Range land	871		370				1241
Feedlots				207			207
Aquaculture							0
Animal holding areas		87	255	207		55	604
Streambank erosion	805	1172				267	2244
Silviculture		45					45
Harvesting, restoration							0
Forest management							0
Road construct/maint.	28						28
Construction							0
Highway/road/bridge	7	69				133	209
Land development							0
Urban Runoff		45					45
Storm sewers							0
Surface runoff	78					18	96
Resource Extract/explore/dev.		13					13
Surface mining	60	22					82
Subsurface mining	831	346					1177
Placer mining	18	4					22
Dredge mining		47					47
Petroleum activities		64	255				319
Mill tailings	15	173					188
Mine tailings	5	22					27
Land Disposal							0
Wastewater							0
On-site wastewater treat.		54				18	72
Hydromodification		45				23	68
Channelization		78	328				406
Dredging							0
Dam construction							0
Flow regulation	16	558					574
Bridge construction							0
Removal of riparian veg.			199				199
Streambank modification	104	678	718				1500
Other							0
Atmospheric deposition							0
Highway maintenance							0
In-place contaminants			322				322
Natural	118	243	793			201	1355
Recreational activities							0
Source Unknown							0

Table 3-7 (cont.)
Source Subcategory by Use Category by State: Irrigation and Agriculture

Miles of Stream

Source Category Subcategory	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources							0
Industrial				11		185	196
Municipal				806		56	862
Nonpoint Sources							0
Agriculture	7	61		506			574
Non-irrigated crop prod.	176	957	1197	1276		251	3857
Irrigated crop prod.	1390	1361		157		532	3439
Pasture land		1052		656		74	1782
Range land	1476		693	767		128	3064
Feedlots			269	661			931
Aquaculture							0
Animal holding areas		8	255	526			789
Streambank erosion	1480	1037					2517
Silviculture							0
Harvesting, restoration							0
Forest management							0
Road construct/maint.	43			112			155
Construction		10		26			36
Highway/road/bridge	7					401	408
Land development							0
Urban Runoff				37			37
Storm sewers				178			178
Surface runoff	79			47			126
Resource Extract/explore/dev.		6		62			68
Surface mining	72	2				291	365
Subsurface mining	1060	156					1216
Placer mining	18	3					21
Dredge mining		35					35
Petroleum activities		64	255				319
Mill tailings	15	73					88
Mine tailings	7						7
Land Disposal							0
Wastewater							0
On-site wastewater treat.				26			26
Hydromodification							0
Channelization	1	78	264				343
Dredging							0
Dam construction							0
Flow regulation	17	57				78	152
Bridge construction							0
Removal of riparian veg.							0
Streambank modification	203	23	264			77	567
Other							0
Atmospheric deposition							0
Highway maintenance				37			37
In-place contaminants				18			18
Natural	118		957	1169		497	2740
Recreational activities							0
Source Unknown		10		18		14	42

Table 3-7 (cont.)
Source Subcategory by Use Category by State: Livestock Watering

Miles of Stream

Source Category Subcategory	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources							0
Industrial				11		98	109
Municipal				806			806
Nonpoint Sources							0
Agriculture		61		506			567
Non-irrigated crop prod.		957		1305			2262
Irrigated crop prod.		1361		157		21	1539
Pasture land		1052		685			1737
Range land				767			767
Feedlots				690			690
Aquaculture							0
Animal holding areas		8		555			563
Streambank erosion		1037					1037
Silviculture							0
Harvesting, restoration							0
Forest management							0
Road construct/maint.				112			112
Construction		10		26			36
Highway/road/bridge							0
Land development							0
Urban Runoff				37			37
Storm sewers				178			178
Surface runoff				47			47
Resource Extract/explore/dev.		6		62			68
Surface mining		2					2
Subsurface mining		156					156
Placer mining		3					3
Dredge mining		35					35
Petroleum activities		64					64
Mill tailings		73					73
Mine tailings							0
Land Disposal							0
Wastewater							0
On-site wastewater treat.				26			26
Hydromodification							0
Channelization		78					78
Dredging							0
Dam construction							0
Flow regulation		57					57
Bridge construction							0
Removal of riparian veg.							0
Streambank modification		23					23
Other							0
Atmospheric deposition							0
Highway maintenance				37			37
In-place contaminants				18			18
Natural				1169		91	1260
Recreational activities							0
Source Unknown		10		18			28

Table 3-7 (cont.)
Source Subcategory by Use Category by State: Industrial

Miles of Stream

Source Category Subcategory	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources							0
Industrial							0
Municipal							0
Nonpoint Sources							0
Agriculture							0
Non-irrigated crop prod.			231				231
Irrigated crop prod.							0
Pasture land							0
Range land			209				209
Feedlots			209				209
Aquaculture							0
Animal holding areas							0
Streambank erosion							0
Silviculture							0
Harvesting, restoration							0
Forest management							0
Road construct/maint.							0
Construction							0
Highway/road/bridge							0
Land development							0
Urban Runoff							0
Storm sewers							0
Surface runoff							0
Resource Extract/explore/dev.							0
Surface mining							0
Subsurface mining							0
Placer mining							0
Dredge mining							0
Petroleum activities							0
Mill tailings							0
Mine tailings							0
Land Disposal							0
Wastewater							0
On-site wastewater treat.							0
Hydromodification							0
Channelization							0
Dredging							0
Dam construction							0
Flow regulation							0
Bridge construction							0
Removal of riparian veg.							0
Streambank modification							0
Other							0
Atmospheric deposition							0
Highway maintenance							0
In-place contaminants							0
Natural			231				231
Recreational activities							0
Source Unknown							0

Table 3-7 (cont.)
Source Subcategory by Use Category by State: Recreation

Miles of Stream

Source Category	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources							0
Industrial				11		30	41
Municipal				806		96	902
Nonpoint Sources							0
Agriculture	7	165		506			678
Non-irrigated crop prod	176	1007	3972	1305			6460
Irrigated crop prod.	1480	2000	124	157		100	3861
Pasture land		477	977	685		240	2378
Range land	1517		2438	767		57	4779
Feedlots			1605	690			2296
Aquaculture							0
Animal holding areas		174	959	555		76	1763
Streambank erosion	1530	356					1886
Silviculture		79					79
Harvesting, restoration							0
Forest management						30	30
Road construct/maint.	43			112			155
Construction		10		26			36
Highway/road/bridge	7	69					76
Land development							0
Urban Runoff		45		37			82
Storm sewers				178		10	188
Surface runoff	129			47		47	223
Resource Extract/explore/dev.		6		62			68
Surface mining	72	2					74
Subsurface mining	1242	375					1616
Placer mining	21	47					68
Dredge mining		47					47
Petroleum activities		64	255				319
Mill tailings	15	285					300
Mine tailings	10	23					32
Land Disposal		2					2
Wastewater							0
On-site wastewater treat.		54		26		76	156
Hydromodification		45					45
Channelization	1	219	832				1052
Dredging							0
Dam construction		75					75
Flow regulation	17	689	109			56	871
Bridge construction							0
Removal of riparian veg.							0
Streambank modificatio	203	651	1354				2208
Other							0
Atmospheric deposition							0
Highway maintenance				37			37
In-place contaminants			105	18			123
Natural	118	463	2782	1169		44	4575
Recreational activities							0
Source Unknown				18		5	23

Table 3-7 (cont.)
Source Subcategory by Use Category by State: Aquatic Fish & Wildlife

Acres of Lake Impaired

Source Category Subcategory	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources				27			27
Industrial					98990		98990
Municipal				1870	108990		110860
Nonpoint Sources				443			443
Agriculture				83122			83122
Non-irrigated crop prod.			108		98990		99098
Irrigated crop prod.							0
Pasture land				35			35
Range land				134	98990		99124
Feedlots				18495			18495
Aquaculture							0
Animal holding areas				1600			1600
Streambank erosion					10000		10000
Silviculture				594			594
Harvesting, restoration							0
Forest management							0
Road construct/maint.				410			410
Construction					10000		10000
Highway/road/bridge							0
Land development							0
Urban Runoff					10000		10000
Storm sewers							0
Surface runoff				16			16
Resource Extract/explore/dev.				83			83
Surface mining							0
Subsurface mining							0
Placer mining							0
Dredge mining							0
Petroleum activities							0
Mill tailings							0
Mine tailings							0
Land Disposal							0
Wastewater							0
On-site wastewater treat.				22003			22003
Hydromodification					108000		108000
Channelization							0
Dredging							0
Dam construction							0
Flow regulation				9077			9077
Bridge construction							0
Removal of riparian veg.							0
Streambank modification				500			500
Other							0
Atmospheric deposition							0
Highway maintenance				940			940
In-place contaminants			108				108
Natural			108	1005	990		2103
Recreational activities				83			83
Source Unknown				454			454

Table 3-7 (cont.)
Source Subcategory by Use Category by State: Warm Water Fisheries

Acres of Lake Impaired

Source Category Subcategory	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources							0
Industrial					98000		98000
Municipal				1870	118905		120775
Nonpoint Sources				443			443
Agriculture		253599		82704			336303
Non-irrigated crop prod.		11360	35443		109521		156324
Irrigated crop prod.	13983					20100	34083
Pasture land			7593	35		6100	13728
Range land	615		2610	134	109521	25097	137977
Feedlots			5397	18260	350		24007
Aquaculture							0
Animal holding areas			14047	1600		700	16347
Streambank erosion	615				10350		10965
Silviculture							0
Harvesting, restoration							0
Forest management							0
Road construct/maint.							0
Construction					10011		10011
Highway/road/bridge						25797	25797
Land development							0
Urban Runoff					10011		10011
Storm sewers							0
Surface runoff	2311			16			2327
Resource Extract/explore/dev.				83			83
Surface mining			60			9420	9480
Subsurface mining							0
Placer mining							0
Dredge mining							0
Petroleum activities						13300	13300
Mill tailings							0
Mine tailings							0
Land Disposal							0
Wastewater							0
On-site wastewater treat.			130	21599			21729
Hydromodification					119171		119171
Channelization			197			700	897
Dredging							0
Dam construction							0
Flow regulation			324	7868		9420	17612
Bridge construction			80				80
Removal of riparian veg.			919				919
Streambank modification			391	500		6100	6991
Other			55				55
Atmospheric deposition			60				60
Highway maintenance				851			851
In-place contaminants			27597				27597
Natural			2634	713	616	25097	29060
Recreational activities					11		11
Source Unknown				454			454

Table 3-7 (cont.)
Source Subcategory by Use Category by State: Cold Water Fisheries

Acres of Lake Impaired

Source Category Subcategory	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources		3500					3500
Industrial					1470		1470
Municipal					3068	20509	23577
Nonpoint Sources							0
Agriculture		56303		418			56721
Non-irrigated crop prod.		9840			6422		16262
Irrigated crop prod.	2323	15290					17613
Pasture land		903			4268	89177	94348
Range land	325				12843	1409	14577
Feedlots				235	10577	92655	103467
Aquaculture							0
Animal holding areas							0
Streambank erosion	1955				8979		10934
Silviculture		34775		594			35369
Harvesting, restoration		3350					3350
Forest management							0
Road construct/maint.		3350		410			3760
Construction		8825			684		9509
Highway/road/bridge						66297	66297
Land development						25	25
Urban Runoff							0
Storm sewers							0
Surface runoff	7140					1434	8574
Resource Extract/explore/dev.							0
Surface mining							0
Subsurface mining	1955	2100					4055
Placer mining		2100					2100
Dredge mining							0
Petroleum activities						31300	31300
Mill tailings							0
Mine tailings							0
Land Disposal	325	36405					36730
Wastewater							0
On-site wastewater treat.		5940		404			6344
Hydromodification		34580					34580
Channelization							0
Dredging							0
Dam construction							0
Flow regulation	1760					24497	26257
Bridge construction							0
Removal of riparian veg.							0
Streambank modification		3350				8819	12169
Other					480		480
Atmospheric deposition		1520					1520
Highway maintenance				89			89
In-place contaminants		24146					24146
Natural				293	13757	94064	108114
Recreational activities				83	12057		12140
Source Unknown						1962	1962

Table 3-7 (cont.)
Source Subcategory by Use Category by State: Public Water Supply

Acres of Lake Impaired

Source Category Subcategory	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources				27			27
Industrial					990		990
Municipal					13973		13973
Nonpoint Sources				350			350
Agriculture		293579		2026			295605
Non-irrigated crop prod.		15510			17463		32973
Irrigated crop prod.	2750	7650					10400
Pasture land					4268		4268
Range land	325				23884		24209
Feedlots					10927		10927
Aquaculture							0
Animal holding areas							0
Streambank erosion	1955				8849		10804
Silviculture				53			53
Harvesting, restoration							0
Forest management							0
Road construct/maint.				32			32
Construction		4800			684		5484
Highway/road/bridge							0
Land development							0
Urban Runoff							0
Storm sewers							0
Surface runoff	7691						7691
Resource Extract/explore/dev.							0
Surface mining							0
Subsurface mining	1955						1955
Placer mining							0
Dredge mining							0
Petroleum activities							0
Mill tailings							0
Mine tailings							0
Land Disposal	325						325
Wastewater							0
On-site wastewater treat.				1503			1503
Hydromodification					11171		11171
Channelization							0
Dredging							0
Dam construction							0
Flow regulation				1209			1209
Bridge construction							0
Removal of riparian veg.							0
Streambank modification							0
Other							0
Atmospheric deposition							0
Highway maintenance				671			671
In-place contaminants							0
Natural		47848		157	14373	289	62667
Recreational activities					12057		12057
Source Unknown				41			41

Table 3-7 (cont.)
Source Subcategory by Use Category by State: Irrigation and Agriculture

Acres of Lake Impaired

Source Category Subcategory	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources							0
Industrial					99470		99470
Municipal					121973		121973
Nonpoint Sources							0
Agriculture				25639			25639
Non-irrigated crop prod.		15510			115943		131453
Irrigated crop prod.	16306	7650				230	24186
Pasture land		1423			4268		5691
Range land	940				122364	459	123763
Feedlots				12360	10927		23287
Aquaculture							0
Animal holding areas							0
Streambank erosion	2570				19329		21899
Silviculture							0
Harvesting, restoration							0
Forest management							0
Road construct/maint.							0
Construction					10695		10695
Highway/road/bridge							0
Land development							0
Urban Runoff					10011		10011
Storm sewers							0
Surface runoff	7691						7691
Resource Extract/explore/dev.							0
Surface mining							0
Subsurface mining	1955						1955
Placer mining							0
Dredge mining							0
Petroleum activities							0
Mill tailings							0
Mine tailings							0
Land Disposal	325						325
Wastewater							0
On-site wastewater treat.				1749			1749
Hydromodification					119171		119171
Channelization							0
Dredging							0
Dam construction							0
Flow regulation							0
Bridge construction							0
Removal of riparian veg.							0
Streambank modification							0
Other					480		480
Atmospheric deposition							0
Highway maintenance							0
In-place contaminants							0
Natural					14373	459	14832
Recreational activities					12068		12068
Source Unknown							0

Table 3-7 (cont.)
Source Subcategory by Use Category by State: Livestock Watering

Acres of Lake Impaired

Source Category Subcategory	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources				27			27
Industrial					99470		99470
Municipal				1870	121973		123843
Nonpoint Sources				443			443
Agriculture				83122			83122
Non-irrigated crop prod.		15510			115943		131453
Irrigated crop prod.		7650					7650
Pasture land		1423		35	4268		5726
Range land				134	122364		122498
Feedlots				18495	10927		29422
Aquaculture							0
Animal holding areas				1600			1600
Streambank erosion					19329		19329
Silviculture				594			594
Harvesting, restoration							0
Forest management							0
Road construct/maint.				410			410
Construction					10695		10695
Highway/road/bridge							0
Land development							0
Urban Runoff					10011		10011
Storm sewers							0
Surface runoff				16			16
Resource Extract/explore/dev.				83			83
Surface mining							0
Subsurface mining							0
Placer mining							0
Dredge mining							0
Petroleum activities							0
Mill tailings							0
Mine tailings							0
Land Disposal							0
Wastewater							0
On-site wastewater treat.				22003			22003
Hydromodification					119171		119171
Channelization							0
Dredging							0
Dam construction							0
Flow regulation				9077			9077
Bridge construction							0
Removal of riparian veg.							0
Streambank modification				500			500
Other					480		480
Atmospheric deposition							0
Highway maintenance				940			940
In-place contaminants							0
Natural				1005	14373		15378
Recreational activities				83	12068		12151
Source Unknown				454			454

Table 3-7 (cont.)
Source Subcategory by Use Category by State: Industrial

Acres of Lake Impaired

Source Category Subcategory	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources							0
Industrial							0
Municipal							0
Nonpoint Sources							0
Agriculture							0
Non-irrigated crop prod.							0
Irrigated crop prod.							0
Pasture land							0
Range land							0
Feedlots							0
Aquaculture							0
Animal holding areas							0
Streambank erosion							0
Silviculture							0
Harvesting, restoration							0
Forest management							0
Road construct/maint.							0
Construction							0
Highway/road/bridge							0
Land development							0
Urban Runoff							0
Storm sewers							0
Surface runoff							0
Resource Extract/explore/dev.							0
Surface mining							0
Subsurface mining							0
Placer mining							0
Dredge mining							0
Petroleum activities							0
Mill tailings							0
Mine tailings							0
Land Disposal							0
Wastewater							0
On-site wastewater treat.							0
Hydromodification							0
Channelization							0
Dredging							0
Dam construction							0
Flow regulation							0
Bridge construction							0
Removal of riparian veg.							0
Streambank modification							0
Other							0
Atmospheric deposition							0
Highway maintenance							0
In-place contaminants							0
Natural							0
Recreational activities							0
Source Unknown							0

Table 3-7 (cont.)
Source Subcategory by Use Category by State: Recreation

Acres of Lake Impaired

Source Category	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources		3500		27			3527
Industrial					98480		98480
Municipal				1870	110078		111948
Nonpoint Sources				443			443
Agriculture		297432		83122			380554
Non-irrigated crop prod.		21050	567947		103698		692695
Irrigated crop prod.	16306	11790	368231				396327
Pasture land		9063	495347	35	4268		508713
Range land	940		4360	134	110119		115553
Feedlots			491288	18495	10577		520360
Aquaculture							0
Animal holding areas			61780	1600			63380
Streambank erosion	2570				18979		21549
Silviculture		1050		594			1644
Harvesting, restoration							0
Forest management							0
Road construct/maint.				410			410
Construction					10695		10695
Highway/road/bridge		9505					9505
Land development							0
Urban Runoff					10011		10011
Storm sewers							0
Surface runoff	9451			16			9467
Resource Extract/explore/dev.				83			83
Surface mining							0
Subsurface mining	1955	2100					4055
Placer mining		2100					2100
Dredge mining							0
Petroleum activities							0
Mill tailings							0
Mine tailings							0
Land Disposal	325	3655					3980
Wastewater							0
On-site wastewater treat.		1030	130	22003			23163
Hydromodification					108266		108266
Channelization							0
Dredging							0
Dam construction							0
Flow regulation	1760			9077			10837
Bridge construction							0
Removal of riparian veg.			56919				56919
Streambank modification			194	500			694
Other			55		480		535
Atmospheric deposition							0
Highway maintenance				940			940
In-place contaminants			553203				553203
Natural		56744	5529	1005	13033		76311
Recreational activities				83	12068		12151
Source Unknown				454		29	483

3.2.1 Effects of Agriculture and Grazing

Agricultural nonpoint discharges result from both crop and animal production. Pollution from agricultural activities is highly variable, depending on both environmental factors, such as precipitation and runoff, and land treatment practices such as row cropping and manure management. A variety of specific pollutants including fecal bacteria, nutrients, sediment, organic chemicals and pesticides, and salts are a consequence of the diverse agricultural practices in Region VIII.

3.2.2 Effects of Crop Production

Crop production (irrigated, non-irrigated, and specialty crops) disturbs the soil and removes vegetative cover. Poor tillage practices increase runoff and soil loss. Application of fertilizers, pesticides, and herbicides, concomitant with increased runoff introduces these pollutants to surface and groundwater. Major water quality concerns related to crop production are pesticides/herbicides, increased nutrients, sedimentation and turbidity.

In Region VIII about 20,000 miles of streams and 1.2 million acres of lakes are impacted by crop production (Table 3-5). The intensity of impact is ranked moderate to high for most impacted reaches (Table 3-3).

3.2.3 Effects of Animal Production

Intensive animal production activities affect pasture and range land, feedlots, animal holding areas and streambank erosion. These activities can cause increased stream pollution in the following ways: inadequate waste management systems in animal confinement areas, increased runoff and erosion due to overgrazing of pasture lands, improper application of manure to fields, and unlimited access of animals to streams where riparian vegetation and streambanks may be damaged. Major concerns related to animal production include bacteria (fecal coliform), sedimentation and turbidity, increased nutrient levels, salts, ammonia, and habitat destruction due to shoreline vegetation removal and erosion.

In Region VIII animal production and grazing lands impact about 25,000 miles of streams and 1.4 million acres of lakes (Table 3-5). Impacts are ranked as moderate to low for most activities (Table 3-3).

3.2.4 Sources of Specific Pollutants

Agricultural practices result in a variety of endpoint effects due to specific pollutants. The sources of the specific pollutants associated with agricultural practices and grazing are described here.

1. Bacteria- Major sources are animal operations and manure in fields. Riparian areas are heavily used by grazing animals which add fecal bacteria to streams via runoff and direct input. Nearly 6,000 miles of streams and 60,000 acres of lakes in Region VIII are impacted by feedlots and animal holding areas (Table 3-5) at moderate levels of intensity (Table 3-3).

2. Sedimentation/Siltation: Sediments are derived from soil erosion due to agricultural and range land practices. We have estimated tons of soil loss by water borne erosion per acre of surface water per year for each State and the Region. We use data from the Soil Conservation Service National Resource Inventory of non-federal lands. By this estimate over 450,000,000 tons of soil are lost per year in the Region (Table 3-8). Figure 3-1 represents annual soil loss due to water erosion per acre of surface water per year in each state and for Region VIII. It is not surprising that siltation and sedimentation are major nonpoint source pollution problems in the Region. (Table 3-2).

3. Nutrients (nitrogen and phosphorus): Major sources of nutrients include runoff from fertilized fields, animal manure operations, and sedimentation. Tillage practices on crop lands may enhance runoff and transport of sediment born nutrients.

   Poor tillage practices and cropping on steep slopes generate large soil losses with subsequent sedimentation and siltation effects downstream. The removal of vegetative cover from agricultural lands enhances soil loss and sedimentation/siltation effects.

   Livestock move and forage throughout a watershed but are most attracted to riparian areas adjacent to streams and lakes, and use this part of the range more heavily. Although riparian areas comprise only 1 to 2% of the watershed area, up to 80% of forage is obtained there (Platts, 1985). Streambank erosion caused by agricultural activities in Region VIII impaired over 3,000 miles of streams and 20,000 acres of lakes (Table 3-5) at moderate levels of intensity (Table 3-3).

   Watersheds subject to intensive grazing suffer from increases in peak runoff and erosion as well as decreased infiltration because of soil disturbance and compaction. These changes decrease groundwater recharge and baseflow (groundwater discharge to streams during the dry season). The most serious effects occur in riparian areas where vegetation is overgrazed and trampled, moist soils (compared to uplands) are severely compacted, and stream channels are widened by trampling of stream banks, all leading to greatly increased erosion.

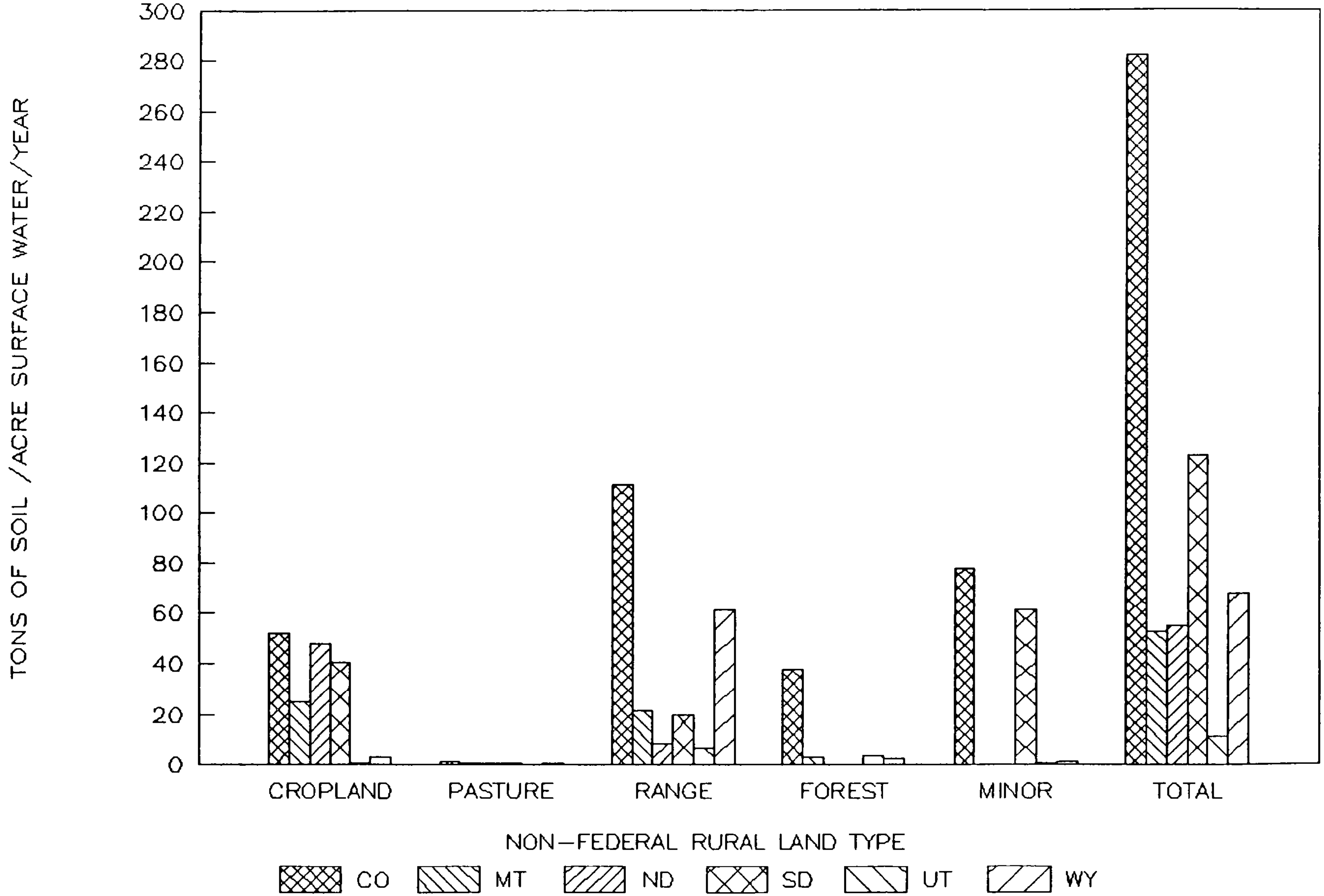
Table 3-8
Soil Erosion via Water
Non-Federal Rural Land (1,000 tons/yr)

State	Year	Cropland	Pasture	Range	Forest	Minor	TOTAL
Colorado	1982	24,387	502	53,112	16,469	36,416	131,742
	1987	24,128	633	51,540	17,540	35,954	131,025
	Change	259	(131)	1,573	(1,071)	462	717
Montana	1982	30,954	607	34,013	4,177	0	71,070
	1987	33,973	634	29,415	4,202	161	71,150
	Change	(3,019)	(27)	4,598	(25)	(161)	(81)
North Dakota	1982	51,375	510	9,879	132	265	61,584
	1987	53,321	603	8,940	129	138	61,520
	Change	(1,946)	(93)	939	3	127	65
South Dakota	1982	44,062	811	22,790	281	64,054	129,088
	1987	40,984	706	19,937	283	62,188	124,329
	Change	3,078	105	2,853	(2)	1,865	4,758
Utah	1982	1,835	49	20,316	13,223	1,392	37,274
	1987	2,002	56	15,312	8,303	1,027	27,158
	Change	(167)	(7)	5,004	4,920	365	10,116
Wyoming	1982	1,811	225	40,172	786	1,685	44,930
	1987	1,653	278	34,819	1,279	610	38,489
	Change	158	(53)	5,353	(493)	1,074	6,441
USA	1982	1,812,032	172,006	529,964	354,211	393,582	3,253,537
	1987	1,606,797	168,967	482,022	315,524	317,539	2,817,637
	Change	205,235	3,039	47,943	38,687	76,043	435,900
Region VIII	1982	154,424	2,704	180,283	35,068	103,811	475,688
	1987	156,061	2,910	159,963	31,735	100,078	453,672
	Change	(1,637)	(206)	20,320	3,333	3,733	22,016
Region VIII	1982	8.5	1.6	34.0	9.9	26.4	14.6
as % of US	1987	9.7	1.7	33.2	10.1	31.5	16.1

F[redacted]3.1

SOIL LOSS FROM SHEET AND RILL ERROSION

PER ACRE OF TOTAL SURFACE WATER AREA



Approximately 140 million acres of the Region's non-federal lands are grazing and pasture lands (NRI, 1987). Included in grazing lands are rangeland, native pasture, meadows, and forests with herbaceous understory. The number of domestic grazing animals can far exceed wildlife numbers and carrying capacity, leading to serious ecosystem damage.

4. Salts: Major sources are from irrigation return flows, and runoff from agricultural areas. Salinity results from the passage of irrigation water through the root zone with subsequent salt leaching. Evapotranspiration of crop plants and evaporation from irrigation canals and reservoirs also contribute to high salt concentrations downstream.

   Pesticides and Herbicides: Major sources include crop production (all types), pasture, and range lands.

   Dissolved oxygen (DO) and biochemical oxygen demand (BOD): major sources of BOD that can reduce DO levels are runoff from agricultural lands and direct inputs of manure. Grazing activities can deposit manure directly into streams or via runoff. Feedlots adjacent to streams are a particular hazard. High carbon and nutrient levels from this manure stimulate bacterial growth which in turn depletes DO.

   Temperature: The lack of streamside shading due to intensive grazing of riparian vegetation leads to increased water temperatures.

3.2.5 Effects of Best Management Practices

Nonpoint pollution from agricultural activities can be controlled and significantly reduced by use of best management practices (BMPs). Examples of BMPs include contour farming, nutrient and pesticide management systems, pasture management, runoff control, proper irrigation strategies, limiting animal access to streams, and revegetating unstable stream banks.

3.2.6 Effects of Hydromodifications

The physical modification of waterways, or hydromodifications, includes channelization, dredging, dam construction and operation, flow regulation, bridge construction, riparian activities, and streambank modifications. Nearly 11,000 miles of streams and over 275,000 acres of lakes are listed as impaired by hydromodifications in Region VIII (Table 3-1), most of which are moderately or severely impaired (Table 3-3).

State reports apparently vary in their accounting of hydromodification impacts. For example, Colorado has only 221 miles and South Dakota has no miles listed as impaired by hydromodifications, compared with over 3,000 miles listed for Montana and over 4,000 miles listed in North Dakota (Table 3-1). It is possible that these differences (low values for Colorado and South Dakota), reflect a lack of data, not a lack of impact.

3.2.7 Effects of Dam Construction and Operation

Dam construction and operation account for at least 2,000 miles of stream impairment and 45,000 acres of lake impairment in Region VIII (Table 3-5), with most impacts in the slight and moderate range (Table 3-3).

Dams are generally of two types: "reservoir" dams which backup water in order to create sufficient head drop at the generators, and "run-of-the-river " dams which backup very little water.

Hydrologic Effects
Flow volume in streams is regulated by controlled release from reservoirs and is diminished by seasonal diversions. Downstream from reservoirs water temperature is altered. The upper strata of water in reservoirs are warmed during summer, while water at greater depths stays colder. The water temperature downstream then depends on the level in the reservoir from which water is released.

Reservoirs are characterized by slow-moving water, which is associated with changes in water temperature, dissolved oxygen levels, turbidity, water chemistry, and aquatic habitat. In deep reservoirs, thermal and chemical stratification occurs. Downstream effects can be beneficial or adverse, depending on the downstream ecosystems and facility design. In general, creation of a reservoir transforms an ecosystem dependent on moving water into one dependent on still water. This results in substantial changes in the distribution, abundance, and diversity of organisms and on the carrying capacity of the habitat.

Creation of a reservoir may flood valuable natural or cultural resources. These include roads, utilities, buildings, sites of historic, cultural, archeological, or scientific interest; productive farm or forest land; terrestrial, riparian, and stream-dependent habitat; free flowing/whitewater streams, waterfalls, and associated recreation areas. Creation of a reservoir may attract new shoreline development, thus introducing a wide range of secondary environmental effects associated with such activities. New recreation opportunities can be created that displace existing recreational activities associated with free-flowing streams and natural environment; however, reservoir fluctuations may limit these later factors. The scenic value of the site is usually altered and sometimes impaired.

In deeper reservoir waters where photosynthesis (which releases oxygen) does not occur, microbial respiration depletes oxygen. Oxygen levels are not recharged through diffusion from the atmosphere, and oxygen levels stay low for much of the year. When surface waters cool and turn over, oxygen is restored to the reservoir depths.

Sediment moving downstream is blocked at many dams in the Region. Bedload is comprised of coarser materials that are too large to be suspended by turbulent action of the water and which, instead, roll along the streambed. This portion obviously will not pass over a spillway near the top of a dam. Finer sediment which is ordinarily suspended along free-flowing streams will settle out of the slower moving water in reservoirs. Sediment accumulates behind these dams, filling the reservoir and decreasing the water storage capacity. While most dams in the Region were designed to allow sediment passage by providing for water release at the base of the dams, sediment accumulation is an increasing problem.

Sediment trapping by dams will change the character of sediments downstream of the dam. Gravel supply from upstream areas may be reduced or cutoff. Downstream of the dam, reduced sediment loads result in increased water velocity. Consequently, streambeds and banks suffer erosion. Large amounts of material in the diversion structure pool accumulate in streams with high sediment bedloads. Sufficient material may be collected that water diversion is impaired, necessitating cleaning by dredging or sluicing. These activities may affect water quality and must be scheduled to minimize effects on fish and downstream water quality.

The operation of a reservoir hydroelectric project generally results in large fluctuations in reservoir level. Fluctuations may be daily, seasonal, or both. Alteration in the natural flow regime can be detrimental to downstream aquatic life forms and recreation. The channel downstream may be degraded over time by the reduction in bed load transport.

Construction of dams or diversion structures presents considerable potential for adverse environmental effects. Erosion and resultant sediment increases occur when clearing the stream bank, blasting underlying bedrock, or during construction within the steam channel. Clearing and revegetation for the project facilities, pipelines, transmission line right-of ways, and access roads can impact wildlife in the area. Riparian and upland terrestrial habitat is inundated by impounded waters and is permanently lost. Project operation can also adversely effect the streams natural resources. The drawn down zone formed along downstream banks by variations in water level is typically unattractive, biologically unproductive,and subject to erosion. Downstream water quality may be affected by the decay of flooded organic matter and the release of soil chemicals into the water.

Sediment captured behind dams will alter streambed substrate downstream. For instance, if the gravel is trapped behind the dam it must be replenished constantly to replace that moved downstream by bedload transport.

Insufficient instream flows through a bypass section will affect fish and wildlife habitat, water quality, recreation, scenic and aesthetic values, navigation, and other environmental values. Decreased instream flows reduce fish habitat and aquatic productivity. In some cases, barriers that were insignificant under natural flows can become impassible to migrating fish.

Table 3-9 summarizes the primary (hydrologic) and secondary ecological effects of dam construction and operation.

3.2.8 Effects of Surface Water Withdrawal

Surface water withdrawal involves the diversion of water from streams. No data on the extent of this considerable problem is available, as The State reports don't list this activity as a specific subcategory of stream impairment. The effects of diversion of surface water are widespread and well documented across the Region however. Once water is diverted, it is difficult to return it to the stream. The extent of impact of surface water diversion on instream resources is uncertain, however, some streams are unaffected by diversion, especially in headwaters areas and National Parks and Wilderness Areas.

The largest volumes of water withdrawal are taken for municipal, irrigation, and hydroelectric uses. Hydroelectric power generation in many cases diverts water for a relatively short distance and then returns water to the stream channel. Irrigation return flows may also recharge streams or aquifers. Small domestic water supply diversions which use surface water for inside uses or outside watering of lawns and gardens are widespread on streams and springs across the Region. Many streams have had relatively smaller percentages of flow diverted, but still suffer impacts of diversion. The cumulative effects of many small diversions can become significant.

Increased efficiency in water use, water conservation efforts, and unified uses of surface and groundwater supplies will reverse or mitigate future impacts. Artificial recharge of aquifers during high winter flows is a means of storing water which may also mitigate impacts of surface water diversion during seasonal low flows. Improvements to low summer flows could be made through better management practices in other areas: controlling the amount of watershed that is developed or covered with asphalt; minimizing cattle grazing around riparian areas to maintain riparian ecosystem integrity and improve stream flow; and looking at impacts of watershed deforestation and number attendant low flow exacerbation in silviculture and forest management.

Table 3-9
Summary of the Ecological Effects of Dam Construction and Operation

Source	Stressor	Ecological Effects
Dam Construction and Operation	stream flow volume fluctuations	blocking aquatic organisms
	stream temperature alterations sediment transport dissolved oxygen depletion	
	bed-load/sediment transport interruption	fish mortality
	vortexing and entraining of air at the penstock	fish mortality
	loss of spawning and sediment trapping behind dam	
	gravel deprivation downstream of dam	adandromous fish
	increased bank erosion	
	reservoir creation	reduced water velocity, low dissolved oxygen turbidity, thermal and chemical stratification, flooding of natural and cultural resources expansion of aquatic habitat, loss of upland and riparian habitat, creation of recreation opportunities, loss of anadromous fish spawning opportunities
	penstock, pipeline and canal leakage	slope destabilization and land slides decreasing stream productivity

From: The State of Environment Report, State of Washington, October, 1989.

Hydrologic Effects

Because of the minimal summer rainfall usually occurring in many areas of the Region, naturally occurring low flows are found in many rivers and streams during summer and fall. Diversions further reduce streamflow. Impacts are more significant on smaller streams as a relatively greater amount of streamflow is lost more quickly from the channel. During summer and fall low flow periods, groundwater recharge constitutes the base flow remaining in many small streams.

As flow decreases, water temperature and velocity are altered, leading to changes in water chemistry and physical properties, and dissolved oxygen availability. Reduced dilution of permitted waste and non-point pollutant discharges could also result from flow diversion.

Recharge depending on stream flow may be affected, such as wetlands or groundwaters. Seepage from irrigation canals and reservoirs and recharge of areas below irrigated areas have led to formation of new wetland and riparian habitats.

Ecological Effects

The biological effects of reduced flows occur both at the aquatic and terrestrial levels. Fish and fish habitat are affected through reductions in flow, cover, stream velocities and aquatic production of food species, increased temperatures, crowding, competition for food, and predation. These problems are particularly severe when stream flow is limited during the low flow season. Where populations have already been stressed, further diversion causes severe impact. Abundance of desirable species and overall species diversity are impacted as well.

Wildlife that depend on given levels of instream flow during certain life-stages are affected in several ways: decreased flow either eliminates habitat and food or increases competition for these elements. Increased predation might also result.

Adverse affects to wetlands and other riparian habitats are likely following diversion of stream flow. Decreased recharge to wetlands could lead to alterations in hydrology and effects on animal and plant species. In streams, dewatering the stream could lead to changes in shoreline vegetation.

Table 3-10 presents a summary of ecological risks associated with withdrawal of water from streams.

As seasonal low flows are limiting to fish production in many areas, further flow reduction can have an immediate impact on fish populations and productivity. Small and medium-sized streams are particularly sensitive to flow reduction because of channel size and flow distribution. The high productivity of small streams suffer disproportionately as a consequence of decreased flows.

Table 3-10
Summary of the Ecological Effects of Surface Water Withdrawal

Source	Stressor	Ecological Effects
Surface Water Withdrawal	decreased flow	reduction in fish habitat
	velocity alterations	reduction in fish food species
	water chemistry changes	fish crowding increased predation, competition for food, reduction of instream species diversity
	changes in availability of dissolved oxygen	elimination of wildlife habitat, increased competition for food in wildlife population, increased predation
	changes in biochemical oxygen demand	
	reduced ability to dilute permitted waste and non-point pollution	
	reduced wetland and groundwater recharge capacity	

From: The State of the Environment Report, State of Washington, October, 1989.

The ecological effects of diversion may be reversed to some extent by augmenting low flows, particularly in ares where storage and redistribution of high flows are possible. This would allow the reconstruction of fish habitat. Some irreversible losses have occurred already through loss of genetic stocks and endemic species. Nonetheless, restoration of flows could lead to reestablishment of some species or increases in aquatic and terrestrial ecosystems biodiversity.

3.2.9 Effects of Flood Management and Construction Activities

Flood management activities include stream channel alterations (e.g. dikes and levees), dredging and filling, and bridging. Numerous other construction/human activities take place in and around streams and lakes. Examples are docks, launch ramps, logging, bulkheads, outfall structures, and conduit crossings. In Region VIII, approximately 1,900 miles of streams and 150,000 acres of lakes have been impacted (Table 3-5); most affected water falls in the moderate to high range (Table 3-3).

Hydrologic Effects

Stream channel alterations, in general, result in straightened, shorter channels with higher bank gradients. This destroys existing pools and riffles. Flood control projects, in particular, restrict channels to maintain a self-cleaning status, but eliminate the potential for the streams to reestablish a satisfactory pool-riffle ratio with concomitant habitat loss.

Constraining a stream within dikes or levees often leads to aggradation (raising of the grade) of the stream bed during floods. The result is less water storage capacity in the channel which, in turn, leads to overbank flooding during smaller volume floods than before levee construction.

The hydrologic effects of dredging and filling are nearly identical. Both reduce the shallow water area and increase the proportion of deep water area. Removal or addition of streambed materials causes continuous and excessive bedload movement, shifting of substrate, and turbidity for long periods following the activity.

Bridges built with too little free space above the water can catch and accumulate flood debris such as logs, stumps, and tree limbs which impede the flow, back up flood waters, and cause more overbank flow. Improper bridge construction or culvert installation may cause long term excessive erosion and heavy siltation.

Poorly designed bridges and culverts increase stream velocity; channel scouring, turbidity and bank erosion. Undersized culverts cause upstream flooding during high flows. Bridges may also increase flow velocities by restricting the channel at higher flows.
Ecological Effects

Streambed mining, dredging, and filling reduce and degrade spawning and rearing habitat. Mortality of fish eggs and insect larvae is generally high where shifting gravel conditions occur. The loss of suitable gravel from bars creates crowded spawning conditions in remaining areas. Large numbers of fry and fingerlings are invariably trapped and die in the pits and pockets left by gravel excavations of riverbanks when rivers recede during low-flow periods. Channel straightening destroys existing pool and riffle ratios essential to feeding, spawning and rearing.

Channel diversions almost always adversely affect spawning or rearing habitat. Aquatic habitat is completely destroyed downstream in the abandoned channel section. The new channel cannot duplicate lost habitat for many years. A change in species composition and/or reduced population sizes almost invariably occur. Stream reaches downstream of the new channel suffer siltation, bank erosion, or channel scouring.

Riprap for bank protection eliminates streamside vegetation, thereby reducing insect populations that serve as food for fish. Loss of shade plants increases water temperatures, which is injurious to resident fish. Vegetation loss also affects wildlife using the riparian zone for migration, feeding, and rearing. Riprap projects eliminate aquatic vegetation used as a food source by animals such as beaver, muskrat, shorebirds, and waterfowl, and which provide habitat for a variety of reptiles, amphibians, and invertebrates.

Bank protection measures, dredging, and instream gravel moving decrease or eliminate shallow water areas. Habitat is lost for small fish that feed in shallows. Fish dependent on shallow water for escape are then subject to higher predation. Changes occur in species composition and abundance of fish, benthic organisms, and vegetation. In turn, this affects wildlife, such as waterfowl and mammals which use shallow areas for feeding. Construction of bank protection devices, dredging and instream mining downstream increase turbidity, siltation, and sedimentation that destroy spawning habitat and food supplies for many aquatic organisms. Heavy sedimentation downstream ruins gravel substrate for egg-hatching and initial fish development. In addition, dredging and gravel mining directly destroy habitat and food sources. Severe siltation abrades fish gills, causing stress and respiration problems, and clogs digestive tracts. Higher fish mortality and susceptibility to disease result. Contaminated sediments disturbed or re-suspended by dredging may be harmful to aquatic life.

Culverts may increase flow velocity so much that the stream reach becomes impassable by fish. Improper culvert placement may create a waterfall at the outlet, which is too high for fish to jump over. Culverts which are too long can also block fish passage. When placed in spawning habitat, culverts eliminate a portion of the habitat. Effects due to poor culvert installation continue until installation is corrected, but then may last for several additional years. Slotted weirs within culverts will stabilize stream velocities.

Increased stream velocity due to poor culvert or bridge design causes gravel scouring which eliminates spawning habitat. As gravel is scoured from the streambed, spawning habitat is eliminated. If velocity becomes excessive, fish migration can be reduced or eliminated. Bridge approaches and abutments often extend into or to the water's edge. Many animals use the shore areas as "transportation" corridors. This use is blocked by bridges and may be eliminated by a number of closely spaced bridges. Effects on aquatic habitat may last for several years after bridge construction. Spawning beds and fry and fingerling habitat can be restored with appropriate mitigating measures. Streamside vegetation can be reestablished to some degree.

Table 3-11 presents a summary of the ecological effects of construction and flood control activities.

3.2.10 Effects of Irrigation Activities

The irrigation activities considered here are distribution works (canals) and on-farm practices (sprinkler, trickle, and furrow irrigation). Some fraction of the impairment attributed to irrigated crop production stems from these activities (see Table 3-5). In Region VIII, some 8,000 miles of streams and 500,000 acres of lake have been impaired (Table 3-5); most of this impact falls in the moderate classification (Table 3-3).

Hydrologic Effects

Canal leakage recharges groundwater and augments water tables in formerly unsaturated soils or rising water tables in unconfined aquifers. In some areas, this artificial recharge has created a long-standing supply of groundwater.

In places the resulting water table rises to ground surface, creating wetlands in low-lying areas and supplementing seasonal streamflow in natural drainage paths. An unknown portion of the wetlands in the Region have been created in this fashion. Sometimes this flooding affects developed areas not associated with farms.

Some excess water must be applied in order to prevent "salt" buildup in the soils. Ordinarily the excess water infiltrates the soil and percolates to the water table. At times the soil infiltration capacity is exceeded and the excess water runs off the field surface; this is most likely to occur on land under furrow irrigation. Whether the excess irrigation water becomes groundwater recharge or surface runoff, most of the water (some is evaporated) eventually returns to these sources and may contain undesirable levels of fertilizer nutrients, pesticides, herbicides, salts and sediment.

Table 3-11
Summary of the Ecological Effects of Construction and Flood Control in Lakes, Riparian Areas, and Floodplains

Source	Stressor	Ecological Effects
Stream Channel Alterations (e.g., dikes, levees)	decreased length and higher stream gradient	degradation of spawning and rearing habitat
	decreased pool/riffle ratio	fish egg and insect larvae mortality
	rising stream bed during floods, causing overbank flooding	fish crowding, fish fry and fingerling mortality
Dredging and filling	induced continuous excessive bed-load movement, reduction of shallow water area increased proportion of deep water habitat, induced shifting of substrate	elimination of stream side vegetation causing thermal change, loss of wildlife, increased predation
	increased turbidity	abrading of fish gills, sedimentation of spawning gravels
Bridging/Culverts	debris trapping causing flooding	
	excessive erosion and heavy siltation	alteration in number and diversity of species in the water and benthos, resuspension of contaminated sediments
	increased stream velocity scouring of gravel	loss of fish spawning area, interference with fish passage

From: The State of the Environment Report, State of Washington, October, 1989.

Ecological Effects

Irrigation development is a major contributor in reducing the quality of stream habitat in the Region. This is due to unscreened diversions and relatively lower flows during the dry season. The availability of irrigation water has reduced the size of dryland habitat previously uncultivated. Return flow from irrigated fields results when water in excess of plant requirements is applied. Return flow can create new fish and wildlife habitat through the formation of new wetlands and streams. The ecological risks associated with irrigation distribution works and on-farm practices are summarized in Table 3-12.

The instream and out of stream effects are totally reversible only if irrigation is discontinued. The use of proper on-farm water management techniques as recommended by the Soil Conservation Service, however, can eliminate most return flow from the surface of an irrigated field. Return flow could be substantially reduced but not entirely eliminated because of the need for leaching of salts. Some soils with extremely high percolation rates should not be irrigated. Through best management practices such as irrigation scheduling and proper application methods, farmers can reduce the undesirable ecological effects of irrigation activities.

3.2.11 Effects of Resource Extraction

Resource extraction activities, especially activities related to processing or storing tailings and wastestreams, can have a major effect on surface and groundwater quality. This problem is a prominent concern in Region VIII and is discussed in a separate problem area, Problem 20, Mining Wastes. Many of the problems associated with mining are due to inactive or abandoned sites.

In Region VIII, approximately 4,500 miles of streams have been impaired by resource extraction activities, with Montana (1,600 miles) and Colorado (1,400 miles) impacted most severely (Table 3-1). The bulk of the impact on streams has been moderate (Table 3-3). The primary pollutants associated with resource extraction activities vary with the type of mining operation and the associated geology. For example, coal mines and other mines extracting sulfide ores are associated with acid mine drainage. Acid mine drainage results from the oxidation of sulfide minerals to iron sulfate, and subsequent hydrolysis to sulfuric acid. Low pH acid mine drainage puts numerous metals including copper, zinc and lead into solution, resulting in heavy metal contamination of surface or groundwater. Stream ecosystems with metal contaminated sediments derived from mining activities may never fully recover with out expensive remediation which can also cause extensive physical disturbances. The efficacy of stream restoration of stream restoration in Region VIII is currently the focus of active research and debate. Many resource extraction practices produce silt and sediment as water flows over disturbed surfaces.

Table 3-12
Summary of the Ecological Effects of Irrigation Distribution Works and On-Farm Irrigation Practices

Source	Stressor	Ecological Effects
Canal Leakage	groundwater recharge	reduction of dryland habitat
	creation of perched water tables, rising water tables, increased groundwater supply	creation of fish and wildlife
	wetlands creation flooding of land, increased seasonal streamflow,	reduction of fish runs in the lower Columbia system and low summer flows due to diversion to canals
Return Flow (i.e., application of water excess to plant requirements)	water table recharge, surface water runoff	unintended transport of ag. chemicals

From: The State of the Environment Report, State of Washington, October, 1989.

Water passing through mine workings especially low pH acid mine drainage, roads, and spoil banks leaches minerals. Minerals may include heavy metals, calcium, or magnesium depending on local geology. Under some conditions, radiological contamination occurs adjacent to uranium mines. Phosphate mines yield high levels of phosphorous as well as fluorine and fluoride.

Stream impairment due to resource extraction is less than one tenth that of agricultural impacts and about half as extensive as hydromodification and "other" impacts (Table 3-1), however, the environmental consequences of non-attainment due to mining activities may not be the same as non-attainment stemming from other activities.

Over 47,000 acres of lakes are impaired by resource extraction activities in Region VIII (Table 3-1), with Wyoming lakes being most affected (over 40,000 acres; Table 3-5) and the balance primarily due to effects in Montana (4,200) and Colorado (2,000; Table 3-5). Most of the lake area affected is classified as moderately impaired (Table 3-3).

The miles or acres of aquatic ecosystem impairment due to specific resource extraction activities by use category are summarized for Region VIII and by State in Tables 3-6 and 3-7.

As suggested in these tallies, mining activities most often impair cold water fisheries, recreation and public water supplies. Impairment occurs primarily due to subsurface mining, followed by petroleum activities, generic unspecified mining activities, surface mining, mill tailings, placer mining, dredge mining, and mine tailings.

3.2.14 Effects of Silviculture

Typical logging and forest management practices have been linked to nonpoint pollution of surface water. Road construction, maintenance and abandonment; site preparation (clearcut and partial cut practices); removal of riparian vegetation; herbicide and pesticide spraying; and debris management contribute to nonpoint pollution. Silviculture in Region VIII impacts over 1,200 miles of streams and 42,000 acres of lakes (Table 3-5) at moderate levels of intensity (Table 3-3). Effects may be cumulative and can occur offsite or downstream from the forest practice. Cumulative effects, which are suspected in large logged watersheds, are poorly understood, but are a major concern. Effects of nutrients leached from forest lands after cutting and turbidity (solids) may have short-term impacts; whereas modifications of habitat, temperature, hydrologic regime, and large organic debris may take years to correct. Extensive streambed siltation with consequent impacts to the fisheries, especially in lower gradient waterways, may never recover without remedial action. Removal of riparian strips along water ways and the removal of natural organic debris dams can dramatically affect the structure and function of stream ecosystems for decades.

Altered sedimentation of streams is perhaps the largest single factor affecting water quality practices. Increased sediment loads can alter spawning habitat and actually cause physical damage to fish. Major sources include road construction, stream channel alterations, slope destabilization, removal of organic debris dams and riparian vegetation, increased runoff due to alteration of precipitation inputs, changes in precipitation interception and evaporation, and soil compaction. Road construction activities tend to have greater of impact than the other silvicultural activities (Table 3-3).

Logging and slash burning lead to increases in nutrient (especially nitrogen and phosphorous) releases from the watershed. Major sources include nutrient overapplication and subsequent loss down stream, soil loss and erosion, direct aerial application of fertilizers, and fire suppression chemicals. Sensitive nutrient poor waters may be enriched, leading to potentially significant changes in ecosystem structure and function.

3.2.13 Effects of Construction

Nonpoint discharges resulting from construction include highway/road/bridge construction and maintenance, land development, vegetation removal, and aquatic construction activities (dredging, channelization, and riparian modification). A variety of nonpoint concerns including hydrocarbons, metals, contaminated particles, sedimentation and erosion, organic chemicals, debris, nutrients, and habitat alteration result from the diverse construction practices in Region VIII.

Construction activities in Region VIII impact about 2,000 miles of streams and 100,000 acres of lakes (Table 3-5) at moderate levels of intensity (Table 3-3). Sediment loads and turbidity are created at both the site of origin and of disposal (if aquatic) with consequent ecological effects on aquatic biota.

Dredging and channelization displace subaquatic sediments, which are moved to new locations in the aquatic environment or removed to a fill area. These activities impact about 1,900 miles of streams and 900 acres of lakes in the Region (Table 3-5) at moderate and high impact levels (Table 3-3). Runoff from roads and equipment used in construction introduces metals, hydrocarbons, and other toxic substances to aquatic environments. Runoff from fertilized roadside areas adds nutrients (primarily nitrogen and phosphorous) to surface and groundwater. Pesticides and herbicides which have been used to treat roadside areas also runoff and accumulate in surface and groundwater.

3.2.14 Effects of Urban Construction

In Region VIII, some 3,000 miles of stream (Table 3-5) have been impacted, by urban construction (Table 3-3), and approximately 21,000 acres of lakes (Table 3-5) have been impacted; again, most of this acreage falls in the moderate rating (Table 3-3).

Hydrologic Effects

Increased peak flows along stream channels causes erosion and channel shifting. Stormwater detention attempts to correct for the increased runoff and higher peaks flows caused by development. Poor design may actually increase bedload movement and channel erosion. This problem has only recently been recognized (Moglen and McCuen, 1988).

Ecological Effects

Home building along streams leads to removal of streambank vegetation which acts to stabilize soils, serve as habitat cover for fish and filters runoff of fertilizers and soil. Consequently, soils may erode and aquatic habitat and water quality are degraded. Mass movements of clay and silt cause compaction of spawning gravel and suffocation of embedded eggs. Field and stream bank erosion cause similar problems. Table 3-13 summarizes the effects of homebuilding as a nonpoint pollution source.

Table 3-13
Summary of the Ecological Effects of Detention Ponds and Homebuilding Along Streams

Source	Stressor	Ecological Effects
Storm water detention	increased peak stream flows	loss of riparian vegetation
Ponds and home-building along streams	stream channel erosion	increased bedload movement and loss of wildlife habitat
		loss of cover for fish
		loss of filtration for fertilizers and oil
		siltation of spawning gravel
		suffocation of fish eggs

Source: The State of the Environment Report, State of Washington, October, 1989.

3.2.15 Effects of Urban Development

Urban development involves human activities and land uses that occur after rural land is converted to urban, suburban, and industrial communities. Increased population densities lead to higher densities of buildings and roads that make much of the area impervious or impermeable to water infiltration. These impervious surfaces produce fundamental changes in local hydrology and ecosystems. In Region VIII, almost 2,500 miles of stream have been impaired by construction (Table 3-1); impacts of slight, moderate, and high ratings are fairly uniformly distributed (Table 3-3). Over 100,000 acres of lakes have been affected (Table 3-1); most of this area has been designated as slightly or moderately impacted.

Hydrologic Effects

The hydrologic cycle is affected by man's activities more dramatically in urban areas than in any other part of the land. Dunne and Leopold (1978) state: "There are four interrelated but separable effects of land use changes on the hydrology of an area: changes in peak flow characteristics, changes in total runoff, changes in quality of water, and changes in hydrologic amenities. The hydrologic amenities are what might be called the appearance or the impression which the river, its channel and its valleys, leaves with the observer. Of all land use changes affecting the hydrology of an area, urbanization is by far the most forceful."

Hydrologic changes due to urban development may also occur in drainage patterns, erosion and sediment movement, water demands, and shifts in the water balance between evaporation, infiltration, recharge, and runoff.

Hydrologic problems develop in urban areas for a variety of reasons. The concentration of population and industry is accompanied by rising water needs that soon exceed the natural supply in the area. The increase in impervious surfaces reduces the infiltration of rain water, reduces groundwater recharge, and greatly increases the volume and peak rates of stormflow runoff (Canning, 1988). Increased volumes and peak flow rates of urban stormwater runoff lead to enlargement of stream channels by scouring during the high flow periods (Canning, 1988). Channel scouring destabilizes stream banks and eventually undermines and removes protective vegetation that may not easily be re-established. Extensive groundwater use and reduced recharge depletes ground-water storage, reducing the base flows of streams and aggravate water quality problems as dilution is reduced. Wastewater volumes grow, placing chemical burdens on rivers, lakes, and marine waters. Increasing amounts and types of wastes, with a decrease in the space or number of suitable places for disposal, complicates water quality protection.

Ecological Effects

The ecological effects of hydrologic changes due to urban development occur primarily in the riparian and aquatic ecosystems. Increased storm water runoff carries higher sediment loads off the land and erodes the stream's channel. Thus, riparian and aquatic habitat is degraded or destroyed by erosion and siltation.

Lowered baseflows resulting from decreased groundwater recharge have the same effect as direct surface water withdrawal. Aquatic habitat is decreased by lowered flows, spawning may be disrupted, and migrating fish may not be able to pass up or down stream.

The percentage of the total land area in the Region that is developed is about 1.4% or half the National average (see Problem 22). Large urban populations are highly dependent on outlying areas for water, because the water available in the urban area is never sufficient and often is made unusable by urban pollution. Table 3-14 summarizes the ecological effects of urban development.

3.2.16 <u>Effects of Runoff</u>

Runoff occurs when the precipitation rate exceeds the soil infiltration rate. Infiltration rates are slowest when soils are very tight, saturated with water, frozen, or covered with impervious surfaces. Water has the ability to dissolve pollutants and physically carry contaminated particles and sediments into the environment. Therefore, runoff quality is partially a function of adjacent land uses. Highway runoff can be contaminated with solids, metals, and many organic compounds. Both water and sediments can be affected. Failed septic systems can also contribute significantly to this problem.

In Region VIII urban runoff impacted less than 1,000 miles of streams and about 20,000 acres of lakes (Table 3-5) at moderate levels of intensity Table (3-3).

Table 3-14
Summary of the Ecological Effects of Urban Development

Source	Stressor	Ecological Effects
Urban Development (e.g., impervious surface and population growth)	changes in peak flows	degradation of riparian habitat
	changes in total runoff	
	changes in water quality	increased waste loads in surface and groundwater
	degradation of hydrologic amenities	
	alteration of drainage patterns	reduced baseflows in streams due to impaired infiltration
	erosion and sediment movement	
	increased water demand	fish spawning disruptions
	alteration in the balance between evaporation, runoff infiltration and recharge	

From: The State of the Environment Report, State of Washington, October, 1989.

3.2.17 Effects of Atmospheric Deposition

Atmospheric deposition has had little influence on water quality of Region VIII to date (see Problem 15). North Dakota lists 27 miles of moderately impacted streams and 60 acres of moderate and 60 acres of slightly impaired lakes due to atmospheric deposition (Tables 3-2 and 3-4). Montana lists one lake, 1,520 acres, as being slightly impacted by atmospheric deposition (Tables 3-2 and 3-4).

3.3 NONPOINT SOURCE POLLUTANT EFFECTS

3.3.1 Effects of Sedimentation/Siltation

Effects due to sediments in streams and lakes stem from both siltation and suspension. Together, these two processes have impacted approximately 20,000 miles of streams and 1.3 million acres of surface waters in Region VIII (Table 3-2). Impacts on lakes tend to be low and stem primarily from reduced sunlight due to the suspended sediment in the water column. Nutrient addition is a secondary effect. Impacts on streams and rivers are high, typically the benthos is smothered and the habitat is changed.

Many of the problems associated with other ecological stressors are linked to sedimentation. Sediments rich in organic material can alter the benthic community by changing levels of dissolved oxygen (Wilber 1971). Agricultural soils rich in nutrients can cause eutrophication. This problem is considered as nutrient effect. Sediments rich in toxic organic or inorganic chemicals also can have adverse effects on aquatic ecosystems.

Species-Level Effects
Sedimentation adversely affects respiration in fish, feeding areas for aquatic organisms, alters availability of invertebrate food for fish, limits growth of aquatic plants, increases surface water temperature, and decreases oxygen supply.

Direct smothering is the main effect of sediments on benthic aquatic invertebrates. Two studies have documented a decrease in benthic invertebrate populations by 60% and 71% because of smothering in areas of sediment deposition (EPA, 1986).

The main effect of sediments on fish is reduced reproduction with consequent effects on population size and species diversity. High egg mortalities occur when solids block gravel spawning beds, presumably because silt attached to the eggs prevents sufficient gaseous exchange between the embryo and the water. Moreover, some species of salmonids will not spawn in such areas (EPA, 1986). In lakes, sediments deposited in shallow areas can cover spawning areas or subject developing eggs to greater thermal stress, by effectively reducing water depth.

Ecosystem-Level Effects

The effects of excess sediment levels on aquatic ecosystems are well documented (Klein, et al., 1962, Wilber, 1971, NAS, 1972, EPA, 1986). Aquatic communities have adapted to the natural composition and depth of sediments in the water bodies they inhabit. In flowing water bodies, the nature of the benthic community depends to a large part on the size, nature, and stability of the bed medium and the speed of the current over the bed (Klein, et al., 1962). In rapid stretches with coarse-grained beds, benthic organisms are characterized by adaptations that prevent them from being swept away by the current. Such adaptations include mechanisms for attaching to or grasping stones (e.g. insect larvae), flattened bodies, and behavioral mechanisms for seeking shelter from the full force of the current between the stones. In sluggish stretches, the fine-grained silt and mud forming the bed favors organisms that burrow or feed in sediments (e.g. worms, certain insect larvae, mussels, snails, and flat worms). Hence, altering the natural composition and depth of sediment in streams (and lakes) can completely alter the benthic community.

The most severe ecosystem-level effect of sediments is the permanent alteration of one type of habitat to another. If sufficient sediments are added, a lake, pond, or slow-moving stream can be converted into a wetland. Intermediate steps in this process could include significant changes in the structure and function of aquatic communities.

Certain types of anthropogenic sediments can effectively eliminate benthic invertebrate communities by making the stream or lake bed unstable and hence unsuitable as a medium for attachment.

Fine sediments added to fast-moving streams can alter the species composition of the benthic community from species associated with coarse-grained gravel or rock beds to those associated with fine-grained silt or mud beds.

Threshold Criteria

According to readily available documents and materials, there are no regulations or criteria that establish acceptable levels (depth) or rates of sedimentation in rivers, streams, or lakes. In water bodies naturally devoid of fine-grained sediments (e.g., fast-moving streams, oligotrophic lakes), the threshold for adverse effects on aquatic organisms is likely to be very low.

Klein, et al. (1962) have suggested that any discharge of sediments that caused a change in the physical nature of the stream bed would be expected to change the nature of the stream-bed community. Ellis (referenced in Wilber, 1971) has suggested that the bottom of a natural body of water should not have an accumulation of silt more than 1/4 of an inch (0.635 cm).

In water bodies naturally containing fine-grained sediments (e.g., slow moving streams or eutrophic lakes), the threshold for adverse effects on aquatic organisms is likely to be high. Adverse effects would be expected only when the sedimentation rate is high enough so that benthic organisms cannot relocate upward before being smothered as the bed fills with sediment.

Exposure-Response Relationships

There are few data in the literature relating sedimentation rates to aquatic ecosystem effects. In most aquatic ecosystems, however, the exposure range between threshold and maximum effect on invertebrates and fish reproduction is likely to be very small. Once the stream or lake bed is covered with sediments deep enough to smother eggs or benthos, the addition of more sediment will not have much additional effect. The rate at which sediments change one ecosystem into another (e.g., a pond into a wetland) is likely to be directly related to the sedimentation rate.

The panel of scientists convened by the Cornell Ecosystems Research Center (EPA, 1987) was unable to estimate the reversibility of the effects of sedimentation (solid matter) on aquatic ecosystems. Case studies suggest that biotic effects in swift-flowing streams can be reversed within 1-10 years as the current flushes out the sediment deposits (Klein, et al. 1962). Biotic effects on water bodies with beds that naturally contain fine-grained sediments also are likely to be rapidly reversible. Extreme effects (e.g., silting up of a pond) are essentially irreversible, except by excavation.

Adverse effects from sediments are likely to be most severe in streams and lakes that naturally have coarse-grained or rocky beds. Such beds are typically found in swift-flowing, cold water streams and higher-elevation, oligotrophic lakes. Effects of sediments on fish populations are likely to be most severe when sediments are deposited on spawning areas, particularly those associated with coarse-grained stream beds and the shallower portions of lakes. Adverse effects are probable when nutrients or toxic organic chemicals are carried by sediments.

Siltation Effects

The effects of suspended solids on aquatic organisms and ecosystems are well known (e.g. NAS, 1972, EPA, 1986). Increasing siltation decreases light transmission through water which decreases primary productivity and obscures sources of food, habitat, hiding places, and nesting sites.

Species-Level Effects.

Inert suspended solids affect aquatic invertebrates by clogging of gills, and obstructing filter feeding mechanisms which, result in depressed food intake and excretion. Fish suffer through reduced growth rates, reduced resistance to disease, prevention of successful development of eggs and larvae, modified natural movements and migration (particularly among highly visual species), and death (at very high levels of suspended solids).

Ecosystem-Level Effects.

The most important effect of inert suspended solids on ecosystems is the reduction of primary productivity of the aquatic ecosystem as photosynthetic activity by aquatic plants is decreased. In sufficiently deep receiving waters (e.g., lakes), increased turbidity/suspended solids can alter the thermal stratification patterns and thus change the oxygen distribution, and the composition of the biological communities.

Threshold Criteria

The National Academy of Sciences (NAS, 1972) has suggested a threshold criterion of 25 mg/l TSS for the protection of aquatic life. EPA has suggested a threshold criterion for the protection of aquatic life of no more than a 10% reduction in the depth of the normal photosynthetic compensation point. Because the photosynthetic compensation point generally is not determined routinely at most water quality monitoring stations (e.g., those reporting to STORET), data for this measure probably are not readily available.

Exposure-Response Relationships

The National Academy of Sciences (1972) suggested that protection of normal structure and function of aquatic communities is related to the maximum concentrations of suspended solids (measured in TSS) in the following manner:

High level of protection	25 mg/l
Moderate protection	80 mg/l
Low level of protection	400 mg/l
Very low level of protection	more than 400 mg/l

Although outright fish population mortality is generally not observed until TSS concentrations exceed 20,000 mg/l, lowered reproduction in some species is likely to be found at much lower concentrations (e.g., effects in largemouth bass (Micropterus), trout (Salmonides), and bluegills (Lepomis) have been observed when TSS concentrations were 25-100mg/l (NAS, 1972).

The panel of scientists convened by the Cornell Ecosystems Research Center (EPA, 1987) designated the reversibility of the effects of suspended solids in aquatic ecosystems as 1-10 years.

3.3.2 Effects of Nutrients (Nitrogen and Phosphorus)

Nutrients, including ammonia, are listed as impairing 14,000 miles of streams and over 1 million acres of lakes in Region VIII (Table 3-2). Necessary at low concentrations by all organisms, nutrients can cause algal blooms when present at higher levels and promote unwanted plant growth. In lakes, ecosystem impacts can range from medium to high, depending on the native nutrient status. Reversibility times range from 1 to 100 years to correct depending on water residence times. Streams and rivers, on the other hand, have low-to-medium ecological impacts from nutrient loading. One to 10 years are generally sufficient for reversibility.

3.3.3 Effects of Salts

Salinity is an pollutant in Region VIII. Over 8,500 miles of streams and over 460,000 acres of lakes are impacted by salinity (Table 3-2). Impact levels can be high for rivers and lakes. Inorganic salts are leached from the soil, and usually enter surface waters through irrigation return flows. Once soils are contaminated, the duration of the condition ranges from 1 to 100 years. The ecological effects of increased ionic strength are not well defined. The major impact is associated with water reuse. High dissolved inorganic solids preclude irrigation use and makes water undesirable for potable uses.

The salinity tolerance of aquatic animals varies considerably depending upon the range of salinity normally encountered by the species. In general, the upper limit of what is considered "fresh water" is 500 mg/liter (the 1958 "Venice System" value reported in Reid and Wood (1976), Macan (1963), and Pennak (1953). The degree of salt loading required to produce significant changes in species composition is extremely site-specific and difficult predict.

Most salts do not accumulate in sediments. As a consequence, recovery of surface water can begin soon after the source of salt contamination is eliminated. Nonetheless, the time required for full recovery (in the absence of other stressors) would depend upon the extent and degree of the contamination. Furthermore, impacted stream reaches that are flushed by adjacent, uncontaminated sections recover more rapidly than isolated stream reaches.

3.3.4 Effects of Bacteria (Pathogens)

In Region VIII pathogens are reported to impair over 6,500 miles of streams and 11,000 acres of lakes (Table 3-2). The level of impact for all waterbody types is considered to be moderate and has a relatively short term effect (one year) if corrected. However, if high loadings occur (i.e. sludge beds), longer term impacts may be seen (1 to 10 years).

3.3.5 Effects of Metals

Various metals and metal species produce different types of toxic effects. Data available to evaluate the potential effects of various levels of sediment metal contamination on rooted plants, benthic invertebrates, and fish are limited. There are few data available to relate fish tissue residue levels of metals to possible adverse effects on the fish. Both active and inactive mines, urban runoff, and irrigation return flows (selenium) are sources of metals to surface and groundwaters in Region VIII. Metals are listed as impairing over 5,000 miles of streams and 94,000 acres of lakes in Region VIII (Table 3-2). Lower pH has been reported to increase the toxicity of some metals (e.g., chromium VI), there are few data relating toxicity to pH for most metals. There also are few data concerning community and ecosystem effects of metals; and such effects are likely to be very site-specific.

Species-Level-Effects

Effects of metal contamination on fish species include neurotoxicity, impaired reproduction, reduced growth, damage to gill surfaces and impaired respiration, mortality, and other effects such as cancers and degenerative diseases.

Ecosystem-Level Effects

The most important effects of aquatic metal contaminants are reduced primary and secondary productivity, loss of top carnivores, changes in community composition, and modification of nutrient cycling.

Effects of heavy metals in the environment depend on their concentrations and chemical form(s). The chemical form(s) of metals are determined by complex suites of both abiotic and biotic factors including pH, salinity, alkalinity, the presence of other metals and ligands, dissolved oxygen, and the presence or absence of specific types of bacteria. Toxic compounds like metals that are persistent and bioaccumulate can have serious adverse effects on species at high trophic levels (e.g., trout) despite low environmental concentrations.

Water quality standards for metals vary by State. Standards are defined as either an absolute limit to the concentration of the chemical in any body of water or relative to a specific body of water.

Table 3-14 lists the EPA acute and chronic Ambient Water Quality Criteria (AWQC) for metals. These toxicity values indicate that iron, nickel, and zinc are unlikely to cause problems except at high surface water concentrations. On the other hand, mercury, cadmium, lead, and beryllium can produce adverse effects at low environmental concentrations. Chromium VI and copper are also highly toxic, although they do not often reach toxic concentrations in surface water.

Representative bioconcentration factors for aquatic invertebrates or fish are also listed in Table 3-14. Chronic AWQC are designed to protect against bioaccumulation to levels that would be toxic to fish. Mercury, lead, and cadmium have a high potential for bioaccumulation to toxic levels in aquatic food chains.

The expert panel convened by the Cornell Ecosystems Research Center (EPA 1987) in the National Comparative Risk Project estimated that decades or centuries would be required for surface water bodies to recover from metal contamination. Metal contaminated sediments will continue to contaminate biota, particularly benthic invertebrates and bottom feeding fish. Animals exposed to heavy metals and that have developed significant body burdens will remain contaminated for years or for life.

Because the natural "flushing" of some metals from sediments is a very slow process, metal-contaminated sediments can produce adverse effects on aquatic life for decades or centuries after the sources of contamination are eliminated. Recovery time for lakes and ponds is longer than that for flowing surface waters (e.g., rivers and streams) because the "flushing" process is slower (i.e., longer residence time).

The exposure of biota to multiple metals and consequent metals bioaccumulation are two means by which metals can produce more severe effects than what might be expected from laboratory toxicity tests alone. Other conditions that would alter the toxicity of metals to aquatic life include methylation and pH. Certain bacteria are capable of transforming inorganic metal compounds to methylated organic compounds, which are often more toxic and are bioconcentrated by biota to a greater degree than are their inorganic precursors. Bacterial methylation occurs with mercury, selenium, lead, tin, and arsenic. Low pH levels release sediment-bound metals and increase their concentrations in the water column (EPA 1979). Thus, the presence of metals in acid mine drainage increases the exposure of aquatic organisms to metals in the water column.

WATER QUALITY CRITERIA TABLE

Specific Considerations

Arsenic. The acute and chronic toxicity of arsenic depends upon its valence state (Table 3-14). The chemistry of arsenic in water is particularly complex and the form present in solution depends upon pH, organic content, suspended solids, and sediment concentrations (EPA 1984a).

Beryllium. Beryllium has low aqueous solubility and can be found in high concentrations adsorbed to particulate matter in turbid waters. Water hardness has a substantial effect on the acute toxicity of beryllium (EPA 1980a).

Cadmium. The impact of cadmium on aquatic organisms depends upon its chemical form. In well-oxygenated fresh waters low in organic carbon, free divalent cadmium will be the predominant form while in turbid waters, dissolved organic material can bind a substantial portion of the total cadmium. As water hardness decreases, the toxicity of cadmium increases (EPA 1984b).

Chromium. Chromium exists in two oxidation states in aqueous systems, chromium III and chromium VI. The hexavalent form of chromium is quite soluble and is not absorbed to any significant degree by clays or hydrous metal oxides. Hexavalent chromium is a moderately strong oxidizing agent and reacts with reducing materials to form trivalent chromium. Trivalent III chromium reacts with aqueous hydroxide ions to form the insoluble chromium hydroxide. Hexavalent chromium is substantially more toxic than the trivalent form. Water hardness affects the toxicity of chromium III. Insufficient data were available to relate the toxicity of chromium VI to water hardness, but the toxicity of chromium VI appears to increase with decreasing pH (EPA 1984c).

Copper. The cupric ion, responsible for most of copper's toxic effects, is highly reactive, forms moderate to strong complexes, and precipitates with many inorganic and organic constituents of natural waters. Thus, in eutrophic waters, copper complexing predominates, and most organic and inorganic copper complexes and precipitates appear to be much less toxic than free cupric ion.

Iron. Iron is an essential trace element required by both plants and animals. High iron loading in alkaline conditions can produce precipitates that coat the natural bottom of a surface water body, smothering existing benthic flora and fauna and making the substrate unsuitable for recolonization by the species originally present (EPA 1984d).

Lead. Lead toxicity to aquatic organisms increases as water hardness decreases (EPA 1986a).

Manganese. Manganese does not occur naturally as an uncomplexed metal but is found in various salts and minerals, frequently in association with iron compounds. Permanganates have been reported to kill fish at concentrations of 2.2 to 4.1 mg/liter, but permanganates are not persistent; they rapidly oxidize organic materials and are thereby reduced and rendered less toxic (EPA 1986a).

Mercury. Mercury (II) can be methylated by both aerobic and anaerobic bacteria. Methylmercury is more toxic than mercury (EPA 1984e).

Selenium. Selenium occurs naturally in surface water from the weathering of parent rock material and exists in several forms. The inorganic selenites (+4) and selenates (+6) are soluble. Because the ratios between the concentrations of selenium in water that are acutely and chronically toxic to aquatic species are small (EPA 1980), surface water bodies with high background levels of selenium would be particularly at risk if additional selenium loading occurred (EPA 1980b).

Tin. Tin is not usually considered to pose a major problem as a heavy metal contaminant. However, under reducing conditions, tin can be methylated, and alkyl tin compounds are central nervous system toxins (WHO 1980).

Zinc. Zinc is an essential micronutrient, and organisms have evolved mechanisms for accumulation of zinc from water and excretion of zinc, at least within limits of ambient zinc concentrations. As water hardness decreases, zinc toxicity increases. Most zinc introduced into aquatic environments is partitioned into sediments by sorption onto hydrous iron and manganese oxides, clay minerals, and organic materials. As sediments change from a reduced to an oxidized state, more zinc is mobilized and released in a soluble form (EPA 1987).

It is important to note that while much is known about the toxic effects of individual metals on certain aquatic species, community and ecosystem level effects may occur at lower concentrations than those specified in the standards. Furthermore, synergistic interactions may affect the toxicity levels of various metals.

3.3.6 Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD)

Organic enrichment of surface waters causes a depletion of dissolved oxygen, DO, by increased biochemical oxygen demand, BOD. Oxygen is depleted by respiration of aerobic decomposers as they metabolize the added organic material. Impacts are high on lakes, rivers, and streams and are due primarily to sedimentation and organic and nutrient loading.

In Region VIII over 4,000 miles of streams and 753,000 acres of lakes are listed as impaired by organic enrichment (Table 3-2).

Effects of DO on freshwater aquatic life have been studied for much of this century. Ecological impacts of changes in DO associated with municipal wastes have been documented well enough to be included in many textbooks. Models exist to relate source loads of BOD to changes in DO in receiving waters, in some cases with extremely high accuracy.

Species-Level Effects

Significant effects of decreased oxygen cause acute mortality of adults (asphyxiation), increased susceptibility to disease, reduced growth and activity, and lowered reproduction (usually due to mortality of eggs or early life stages).

Ecosystem-Level Effects

At its extreme, elimination of DO from receiving waters will cause the extermination of all forms of life that require oxygen for respiration. Under conditions of severe reduction of DO, there is a replacement of the normal complement of aquatic fauna and flora with characteristic "pollution species" (e.g., certain types of bacteria, algae, fungi, and protozoans, sludge worms (Tubificidae), and blood worms (Chironomid larvae). Fish usually are eliminated completely, either due to mortality, or migration from the area.

Threshold Criteria

Criteria for DO are derived from estimates of reproductive impairment based primarily upon growth data and information on temperature, disease, and pollutant stresses. National criteria for ambient DO for the protection of freshwater aquatic life (EPA, 1986) are presented in Table 3-15.

Average DO concentrations selected are values 0.5 mg/l above values causing slight reproductive impairment and represent values between those that cause no reproductive impairment and those that cause slight reproductive impairment. Each criterion thus may be viewed as an estimate of the threshold concentration below which detrimental effects are not expected.

Criteria for coldwater fish are intended to apply to waters containing a population of one or more species in the family Salmonidae or to waters containing other coldwater or coolwater fish with sensitivities close to salmonids. Criteria for warmwater fish are intended to protect early life stages of sensitive warmwater fish (e.g. channel catfish) and to protect other life stages of sensitive fish (e.g. largemouth bass). Criteria for early life stages are intended to apply only where and when these stages occur.

Many states have more stringent DO standards for cooler waters, waters that contain either salmonids, nonsalmonid coolwater fish, or the sensitive centrarchid, the smallmouth bass. Criteria do not represent assured no observed effect levels. Criteria do represent DO concentrations believed to protect the more sensitive populations of organisms against potentially damaging impairment.

Table 3-15
Water Quality Criteria for Ambient Dissolved Oxygen Concentration[1]

	Coldwater Criteria		Warmwater Criteria	
	Early Life Stage[2,3]	Other Life Stages	Early Life Stages[3]	Other Life Stages
30 Day Mean	NA[4]	6.5	NA	5.5
7 Day Mean	9.5 (6.5)	NA	6.0	NA
7 Day Mean Minimus	NA	5.0	NA	4.0
1 Day Minimus[5,6]	8.0 (5.0)	4.0	5.0	3.0

1 From EPA (1986).

2 These are water column concentrations recommended to achieve the required intergravel dissolved oxygen concentrations shown in parentheses. The 3 mg/L differential is discussed in the criteria document. For species that have early life stages exposed directly to the water column, the figures in parentheses apply.

3 Includes all embryonic and larval stages and all juvenile forms to 30-days following hatching.

4 NA (not applicable).

5 For highly manipulatable discharges, further restrictions apply (see page 37).

6 All minima should be considered as instantaneous concentrations to be achieved at all times.

DO concentrations in the criteria are intended to be protective at typically high seasonal environmental temperatures for the appropriate taxonomic and life stage classification categories. In receiving waters with marked daily cycles of DO (e.g., those with dense populations of algae), several daily measurements may be required to characterize the cycles.

Exposure-Response Relationships
The effects of various DO concentrations on early life stages of fish, adult fish, and their invertebrate food are presented in Table 3-16 (EPA, 1986).

Numerous studies have documented the return of some natural fauna within months of removing BOD loads, and a nearly-full complement of fauna within a year (Hynes 1974). Recolonization depends partially on the mobility of the absent species. For example, mollusks usually will require more time to return than fish. These data are consistent with the designation of reversibility as 1-10 years by the panel of scientists convened by the Cornell Ecosystems Research Center (EPA 1987).

3.3.7 Effects of Temperature, Thermal Pollution

Temperature effects are most common (and best studied) in the vicinity of power plants and industrial facilities, although effects due to deforestation, stream channelization, and impoundment of flowing water must be considered.

The effects of temperature on aquatic organisms have been reviewed comprehensively (e.g., Fry, 1967, FWPCA 1967), and annual literature reviews are published by the Water Pollution Control Federation. Knowledge of the temperature tolerances of site specific aquatic organisms is probably essential to evaluate the impacts of this stressor on specific aquatic organisms in specific habitats. Over 2,500 miles of streams and 28,000 acres of lakes are listed as impaired in Region VIII (Table 3-2).

The extent of damage to aquatic biota depends greatly on the rate of temperature change, the duration of exposure, the magnitude of "natural" daily temperature cycles, and where the ambient temperature lies in relation to the tolerance range of a given species.

Species-Level Effects
Important effects of thermal change on aquatic biota include increased metabolic rates, increased respiration rates, altered behavior (e.g., feeding, migration), altered growth, and decreased reproduction. Rapid changes in temperature are most stressful to organisms: temperature acclimation requires several days, and ambient temperature and exposure time are critical factors. Effects occurring during the spawning season probably have the greatest influence on fish populations.

Table 3-16
Dissolved Oxygen Concentrations (mg/l) Versus Level of Effect[1]

1. Salmonid Waters

a. Embryo and Larval Stages

No Production Impairment	=	11 * (8)
Slight Production Impairment	=	9 * (6)
Moderate Production Impairment	=	8 * (5)
Severe Production Impairment	=	7 * (4)
Limit to Avoid Acute Mortality	=	6 * (3)

(* Note: These are water column concentrations recommended to achieve the required intergravel dissolved oxygen concentrations shown in parentheses. The 3 mg/L difference is discussed in the criteria document.)

b. Other Life Stages

No Production Impairment	=	8
Light Production Impairment	=	6
Moderate Production Impairment	=	5
Severe Production Impairment	=	4
Limit to Avoid Acute Mortality	=	3

2. Nonsalmonid Waters

a. Early Life Stages

No Production Impairment	=	6.5
Slight Production Impairment	=	5.5
Moderate Production Impairment	=	5
Severe Production Impairment	=	4.5
Limit to Avoid Acute Mortality	=	4

b. Other Life Stages

No Production Impairment	=	6
Slight Production Impairment	=	5
Moderate Production Impairment	=	4
Severe Production Impairment	=	3.5
Limit to Avoid Acute Mortality	=	3

3. Invertebrates

No Production Impairment	=	8
Some Production Impairment	=	5
Acute Mortality Limit	=	4

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1 From EPA (1986).

Ecosystem-Level Effects

Thermal pollution has a variety of effects on aquatic ecosystems, including altered phytoplankton communities:

> Between 20°C - 25°C diatoms predominate, between 30°C - 35°C green algae predominate, and above 35°C blue-green algae predominate, with altered benthic invertebrate communities, and changes from a coldwater to a warmwater fishery.

Threshold Criteria

EPA's Ambient Water Quality Criteria are helpful in developing a risk assessment for the effects of increased temperature on fish populations. These criteria are described in some detail here to assist in understanding the suggested hazard function.

EPA (1986) recommends upper limiting temperatures for a surface water body. These are based on the important sensitive (fish) species and are designed to meet the following requirements:

> Maximum sustained temperatures that are consistent with maintaining desirable levels of productivity.
>
> Maximum levels of metabolic acclimation to warm temperatures that will permit return to ambient winter temperatures should artificial sources of heat cease.
>
> Time-dependent temperature limitations for survival of brief exposures to temperature extremes.
>
> Restricted temperature ranges for various states of reproduction, including (for fish) gametogenesis, spawning migration, release of gametes, development of the embryo, commencement of independent feeding and other activities by juveniles, and temperatures required for metamorphosis, emergence, or other activities of lower forms.
>
> Thermal limits for diverse species compositions of aquatic communities, particularly where reduction in diversity creates nuisance growths of certain organisms, or where important food sources (food chains) are altered.
>
> Thermal requirements of downstream aquatic life where upstream diminution of a coldwater resource will adversely affect downstream temperature requirements.

Exposure-Response Relationships

Adequate data on thermal tolerances are available for only a small percentage of aquatic species, mainly fish; there is a serious paucity of data on the effects of thermal alteration on communities of aquatic algae and invertebrates. Owing to the numerous factors that affect temperature tolerances, the necessity for using data on site-specific aquatic organisms, and the variability among bodies of surface water, it is not possible to derive a general exposure-response relationship for this stressor, which should be obtained locally.

There is an interaction between toxic materials and temperature: organisms subjected to stress from toxic materials generally are less tolerant of temperature extremes, and the toxicity of toxic materials to fish generally increases with increased temperature.

Potential for Reversibility of Effect

The panel of scientists convened by the Cornell Ecosystems Research Center (EPA 1987) designated reversibility as ranging from years to decades, but stressed the highly localized nature of these effects.

3.3.7 Effects of Pesticides and Herbicides

The problem of pesticide and herbicide nonpoint source pollution is more wide spread than indicated in Table 3-2 due to a lack of monitoring for these pollutants. Only Wyoming lists pesticides as a pollutant stressor and only 275 miles of streams and no lake acres are listed as impaired. Pesticides and herbicides are considered in a separate problem area.

The effects of pesticides and herbicides include decreased photosynthesis; lowered resistance and increased susceptibility to other environmental stresses; lower reproductive success; lowered respiration, growth, and development in aquatic species; reduced food supply; habitat destruction; mortality of non-target organisms (including fish); and increased cancer risks in fish and related organisms. Some indirect effects include threats to nearshore aquatic dwelling animals (i.e. birds, muskrats), and creation of human health hazards from consumption of contaminated fish and/or water. Impact levels for lakes, rivers and streams are high and thus represent a concern as a potential threat to humans. Intensity and duration of the ecological effects are functions of toxicity, persistence, fate-transport, partitioning, and bioaccumulation of the chemical at hand. Reversibility can range from less than 1 to 1000 years, depending on the above criteria for the chemical.

3.4 LIMITATIONS

3.4.1 Assumptions

The quantification of nonpoint source pollution attributed to each activity and stressor described in this assessment relies on the quality of the 319 and 305b State reports. These data have serious limitations associated with their use in a risk assessment. To use these data as an indication of the extent of ecosystem damage we must assume:

1) Ecosystem effects are related to "impairment" from designated use categories.

   Because a State can designate a use as "industrial" or contaminated, then chronic pollution by such a designated use does not show up as an impairment, even though the ecosystem is impaired. Quantitative information is hard to derive from the State reports as the same stream reach can be listed as impaired by more than one activity; furthermore, impairment may result from more than one use designation.

2) State listings of the amount of impairment represent an accurate estimate of the actual amount of impairment.

   Only a fraction of each State's surface water is evaluated subjectively and even a smaller fraction is actually sampled and evaluated quantitatively.

These assumptions are critical and necessitate the use of extreme caution when interpreting the apparently quantitative data in the 319 and 305b reports.

3.4.2 Uncertainty

Effects of individual nonpoint source pollutants are known with a fair degree of certainty. The cumulative impacts of several pollutants is not well understood. The extent of multiple impacts are not well documented either. Water quality is not monitored in a statistically meaningful manner. The data presented here on the extent of water quality impacts from nonpoint source pollution are highly uncertain. True extent of pollution impacts are unknown.

3.4.3 Recommendations for Improving Risk Assessment-Reducing Uncertainty

The use of statistically acceptable sampling in water quality monitoring would allow for more meaningful and less uncertain assessment of the extent of nonpoint source pollution in Region VIII.

3.4.4 Omissions

Several potentially important nonpoint sources of water pollution are not considered here in detail. Sources addressed in detail elsewhere include: mining waste sites, leaching from storage tanks, RCRA hazardous waste and superfund sites, municipal and industrial solid waste sites, accidental chemical releases, pesticides, and acid deposition. Also variation in reporting, e.g. hydromodification.

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4.0 PHYSICAL DEGRADATION OF WETLANDS AND AQUATIC HABITATS

4.1 INTRODUCTION

The physical degradation of Wetlands and Aquatic Habitats problem area covers the risks to the environment and human welfare resulting from the destruction and damage of wetlands. Wetland damage results from: channelization, dam construction, irrigation systems, urban development, agricultural drainage, and dredge and fill activities. Human health effects associated with this problem area were not estimated.

4.2 DATA AND ANALYSIS

This analysis focuses on the ecological and welfare effects associated with the destruction and damage of wetlands, and damages from alterations in the quantity and flow patterns of surface water bodies. These alterations include channelization, dams, construction, irrigation systems, urban development, and dredge and fill activities (Cummins, 1990). However, sufficient quantitative data to confidently document Region VIII's wetland resource base or trends in that base do not currently exist (Elliot, 1990; Reetz, 1990; Fowler, 1990; and Helbig, 1990).

The U.S. Fish and Wildlife Service is conducting a nationwide inventory of wetlands, the National Wetlands Inventory, that will expand on a partial survey conducted in the 1950s. This survey, when completed, will provide statistically valid representations of wetlands in Region VIII. Currently, acreage statistics are available for approximately 18 1:100,000 map units in Region VIII. These are included as Appendix A of this Report. Unfortunately, these data are not currently sufficient to estimate wetland area in the Region.

In lieu of adequate data, wetland area was estimated using best professional judgement and the State 305b Reports. Wetland area estimates for North and South Dakota are based on estimates provided by the U.S. Fish and Wildlife Service (Elliot, 1990), while estimates for Wyoming, Montana, and Utah were based on the State 305b Reports. These estimates are summarized in Table 4-1.

There is considerable uncertainty surrounding the wetland estimates contained in the State 305b reports, as there is little or no methodological discussion of their derivation. Indeed, the South Dakota (1988) 305b report mistakenly attributes its wetland estimate to National Wetland Inventory Survey data when it was based on personal opinion, see USDI (1984). In addition, there is no clarification regarding the inclusion or exclusion of reservoirs, deep water lakes and rivers as wetland acreage.

Table 4-1
Estimated Wetland Acreage
Used in Risk Analysis

State	Total Square Miles	Total Acres	Known Wetland Acres	% of State Area as Wetland	Estimated Annual Loss	% Annual Wetland Loss	0.75 of Wetland Acres	1.25 of Wetland Acres
Colorado	104,091	66,618,240	1,132,510	1.70%		0	849,383	1,415,638
Wyoming	97,809	62,597,760	940,000	1.50%		0	705,000	1,175,000
Montana	147,046	94,109,440	2,000,000	2.13%		0	1,500,000	2,500,000
Utah	84,899	54,335,360	1,000,000	1.84%		0	750,000	1,250,000
North Dakota	70,702	45,249,280	2,250,000	4.97%	20000	0.89%	1,687,500	2,812,500
South Dakota	77,116	49,354,240	1,350,000	2.74%		0	1,012,500	1,687,500

Colorado wetland acreage estimated by assuming that 1.7% of the state's area is wetland. This assumption seemed consistent with the distribution of wetlands in other Region VIII States.

To estimate wetland acreage for the purpose of this report we assumed that "true values" could be 25% smaller or greater than estimates provided by Elliot or the State 305b reports, see Table 4-1. These values were used to specify a probability distribution used in a Monte Carlo Simulation to estimate wetland loss in Region VIII.

We were unable to find any referenced or published estimate of wetland area in Colorado. This was derived by evaluating the % of wetland area in the remaining Region VIII States relative to total area, see Table 4-1. As a starting point, we assumed that 0.17% of Colorado's area is in wetlands. This was considered a reasonable assumption by U.S. Fish and Wildlife personnel responsible for the regional implementation of the National Wetlands Inventory (Elliot, 1990).

Estimates of wetland loss were available only for North Dakota. These losses were estimated to be 20,000 acres per year, or 0.88% per year. To estimate annual wetland loss for the remainder of the States, we assumed that annual loss could be described using a probability distribution with a minimum annual loss of 0.2%, a mean of 0.4%, and a maximum of 0.8%. This assumption was discussed with Elliot (1990). The 0.8% upper bound annual loss estimate was considered too high for the remaining states by Elliot due to the high prairie pot hole drainage rates in North Dakota. On the other hand, 0.2% was considered to be a lower bound of wetland loss across the Region. By selecting a mean wetland loss of 0.4%, the distribution of loss values is skewed toward the lower bound estimate.

Wetland loss estimates were made using a Monte Carlo analysis, the results of which are summarized in Table 4-2. More detailed state results are presented individually in Tables 4-3 through 4-8 and Figures 4-1 through 4-6.

4.3 ASSUMPTIONS

These results assume that annual wetland loss can be, for the purposes of this Comparative Risk Project, estimated using probability distributions describing total wetland area and annual loss. North Dakota results are not included in these distributions, as U.S. Fish and Wildlife Service Data is considered more reliable than these probabilistic estimates.

4.4 WELFARE ANALYSIS

Economic damages to wetlands are interpreted and estimated according to the loss in the economic value of the "service flows" the wetlands provide to individuals. The economic concept is to reflect the loss on individual well-being arising from the change in the quality of the services derived from the wetland.

Table 4-2

Summary Estimates of Region VIII Wetland Loss

Statistics and Targets Across Output Range
(Values in Thousands)

Colorado
Mean = 5.28821
Std.Dev = 1.518042
5th Percentile = 2.905543
95th Percentile = 8.043561
Target Value:0
Prob. of Value >= Target: 100%

Wyoming
Mean = 4.388161
Std.Dev = 1.264604
5th Percentile = 2.478282
95th Percentile = 6.695415
Target Value:0
Prob. of Value >= Target: 100%

Montana
Mean = 9.332093
Std.Dev = 2.656258
5th Percentile = 5.407222
95th Percentile = 13.86604
Target Value:0
Prob. of Value >= Target: 100%

Utah
Mean = 4.66129
Std.Dev = 1.324608
5th Percentile = 2.639189
95th Percentile = 6.963386
Target Value:0
Prob. of Value >= Target: 100%

North Dakota
Mean = 10.52616
Std.Dev = 3.107991
5th Percentile = 5.856411
95th Percentile = 16.37276
Target Value:0
Prob. of Value >= Target: 100%

South Dakota
Mean = 6.311316
Std.Dev = 1.857227
5th Percentile = 3.646536
95th Percentile = 9.655909
Target Value:0
Prob. of Value >= Target: 100%

Table 4-3

Annual Wyoming Wetland Loss

==============================

Expected/Mean Result = 4388.161
Maximum Result = 8377.97
Minimum Result = 1915.505
Range of Possible Results = 6462.465
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 1264.604
Skewness = .4477854
Kurtosis = 2.835811
Variance = 1599223
ERRs Calculated = 0
Values Filtered = 0
Simulations Executed = 1
Iterations = 500

Percentile Probabilities:
(Chance of Result <= Shown Value)
(Actual Values)

==============================

<= 1915.505= 0%
<= 2478.282= 5%
<= 2849.568= 10%
<= 3075.434= 15%
<= 3260.837= 20%
<= 3441.545= 25%
<= 3602.39= 30%
<= 3744.21= 35%
<= 3922.307= 40%
<= 4059.402= 45%
<= 4244.906= 50%
<= 4477.783= 55%
<= 4666.84= 60%
<= 4863.317= 65%
<= 5014.778= 70%
<= 5165.25= 75%
<= 5396.25= 80%
<= 5782.673= 85%
<= 6019.231= 90%
<= 6695.414= 95%
<= 8377.97= 100%

Probabilities for Selected Values:

==============================

Probability of Result > 0 = 100%
>=900 = 100%
>=1800 = 100%
>=2700 = 92.2%
>=3600 = 70.4%
>=4500 = 45%
>=5400 = 20%
>=6300 = 8%
>=7200 = 2.2%
>=8100 = 4%
>=9000 = 0%
Probability of Result <= 0 = 0%

@Function For This Output Distribution:

====================================

4381.357

Table 4-4

Annual North Dakota Wetland Loss

==============================

Expected/Mean Result = 10526.16
Maximum Result = 20071.66
Minimum Result = 4048.671
Range of Possible Results = 16022.99
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 3107.991
Skewness = .4467889
Kurtosis = 2.764407
Variance = 9659609
ERRs Calculated = 0
Values Filtered = 0
Simulations Executed = 1
Iterations = 500

Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in Thousands)

==============================

<= 4.0487 = 0%
<= 5.8564 = 5%
<= 6.6056 = 10%
<= 7.335 = 15%
<= 7.6669 = 20%
<= 8.2148 = 25%
<= 8.7339 = 30%
<= 9.0739 = 35%
<= 9.3959 = 40%
<= 9.8185 = 45%
<= 10.177 = 50%
<= 10.516 = 55%
<= 11.0256= 60%
<= 11.3825= 65%
<= 11.8867= 70%
<= 12.518 = 75%
<= 13.1097= 80%
<= 14.03 = 85%
<= 14.8836= 90%
<= 16.3728= 95%
<= 20.0717= 100%

Probabilities for Selected Values:

==============================

Probability of Result > 0 = 100%
>=2.25 = 100%
>=4.5 = 99.2%
>=6.75 = 89.4%
>=9 = 66.2%
>=11.25 = 37.6%
>=13.5 = 18%
>=15.75 = 6.8%
>=18 = 1.4%
>=20 25 = 0%
Probability of Result <= 0 = 0%

@Function For This Output Distribution:

==================================

10517 6238771

Table 4-5

Annual South Dakota Wetland Loss

==============================

Expected/Mean Result = 6311.315
Maximum Result = 11704.71
Minimum Result = 2717 916
Range of Possible Results = 8986.791
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 1857.227
Skewness = .4623601
Kurtosis = 2.579345
Variance = 3449292
ERRs Calculated = 0
Values Filtered = 0
Simulations Executed = 1
Iterations = 500

Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in Thousands)

==============================

<= 2.7179 = 0%
<= 3.6465 = 5%
<= 4 0995 = 10%
<= 4.3941 = 15%
<= 4.5974 = 20%
<= 4.9304 = 25%
<= 5.1249 = 30%
<= 5.3094 = 35%
<= 5.5333 = 40%
<= 5.761 = 45%
<= 6.0244 = 50%
<= 6.2926 = 55%
<= 6.627 = 60%
<= 6.8611 = 65%
<= 7.2221 = 70%
<= 7.5854 = 75%
<= 7.8796 = 80%
<= 8.5099 = 85%
<= 9.0512 = 90%
<= 9.6559 = 95%
<= 11.7047= 100%

Probabilities for Selected Values:

==============================

Probability of Result > 0 = 100%
>=1 5 = 100%
>=3 = 98.8%
>=4.5 = 81.6%
>=6 = 50.8%
>=7.5 = 26.4%
>=9 = 10.4%
>=10.5 = 1.4%
>=12 = 0%
Probability of Result <= 0 = 0%

@Function For This Output Distribution:

====================================

6292.527

Table 4-6

Annual Utah Wetland Loss

==============================
Expected/Mean Result = 4661.29
Maximum Result = 8888.122
Minimum Result = 2040.549
Range of Possible Results = 6847 573
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 1324.608
Skewness = .4835615
Kurtosis = 2.95964
Variance = 1754587
ERRs Calculated = 0
Values Filtered = 0
Simulations Executed = 1
Iterations = 500

Percentile Probabilities:
(Chance of Result <= Shown Value)
(Actual Values)
==============================
<= 2040.549= 0%
<= 2639.189= 5%
<= 3063.935= 10%
<= 3305.827= 15%
<= 3538.015= 20%
<= 3702.281= 25%
<= 3858.052= 30%
<= 4038.76= 35%
<= 4202.583= 40%
<= 4343.961= 45%
<= 4476.375= 50%
<= 4684.093= 55%
<= 4878.99= 60%
<= 5047.575= 65%
<= 5270.259= 70%
<= 5586.215= 75%
<= 5820.872= 80%
<= 6056.857= 85%
<= 6357.566= 90%
<= 6963.385= 95%
<= 8888.122= 100%

Probabilities for Selected Values:
==============================
Probability of Result > 0 = 100%
>=900 = 100%
>=1800 = 100%
>=2700 = 94.6%
>=3600 = 79.2%
>=4500 = 49.4%
>=5400 = 27.8%
>=6300 = 10.2%
>=7200 = 4.2%
>=8100 = 1%
>=9000 = 0%
Probability of Result <= 0 = 0%

@Function For This Output Distribution:
====================================
4657.367

Table 4-7

Annual Colorado Wetland Loss

==============================

Expected/Mean Result = 5288.209
Maximum Result = 9552.693
Minimum Result = 2119.25
Range of Possible Results = 7433.443
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 1518.042
Skewness = .3564928
Kurtosis = 2.611675
Variance = 2304453
ERRs Calculated = 0
Values Filtered = 0
Simulations Executed = 1
Iterations = 500

Percentile Probabilities:
(Chance of Result <= Shown Value)
(Actual Values)

==============================

<= 2119.25= 0%
<= 2905.543= 5%
<= 3382.033= 10%
<= 3719.662= 15%
<= 3947.71= 20%
<= 4169.257= 25%
<= 4387 215= 30%
<= 4548 552= 35%
<= 4735.873= 40%
<= 4973.711= 45%
<= 5134.289= 50%
<= 5318.657= 55%
<= 5525.971= 60%
<= 5783.737= 65%
<= 6060.618= 70%
<= 6248.24= 75%
<= 6561 225= 80%
<= 6978 902= 85%
<= 7432.499= 90%
<= 8043 561= 95%
<= 9552.693= 100%

Probabilities for Selected Values:

==============================

Probability of Result > 0 = 100%
>=1000 = 100%
>=2000 = 100%
>=3000 = 94%
>=4000 = 79.4%
>=5000 = 54.4%
>=6000 = 31 2%
>=7000 = 15%
>=8000 = 5 6%
>=9000 = 1%
>=10000 = 0%
Probability of Result <= 0 = 0%

@Function For This Output Distribution

==============================

5281.0872856

Table 4-8

Annual Montana Wetland Loss

==============================
Expected/Mean Result = 9332.093
Maximum Result = 17564.13
Minimum Result = 3718.109
Range of Possible Results = 13846.02
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 2656.258
Skewness = 340035
Kurtosis = 2.503426
Variance = 7055708
ERRs Calculated = 0
Values Filtered = 0
Simulations Executed = 1
Iterations = 500

Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in Thousands)
==============================
<= 3.7181 = 0%
<= 5.4072 = 5%
<= 5.9509 = 10%
<= 6.3556 = 15%
<= 6.9235 = 20%
<= 7 3877 = 25%
<= 7.7507 = 30%
<= 8.1081 = 35%
<= 8 4368 = 40%
<= 8.7446 = 45%
<= 9.1503 = 50%
<= 9.366 = 55%
<= 9.6558 = 60%
<= 10 0893= 65%
<= 10 6908= 70%
<= 11.2483= 75%
<= 11.725 = 80%
<= 12.5305= 85%
<= 13.1398= 90%
<= 13.866 = 95%
<= 17.5641= 100%

Probabilities for Selected Values:
==============================
Probability of Result > 0 = 100%
>=2 = 100%
>=4 = 99.8%
>=6 = 89.6%
>=8 = 66.6%
>=10 = 36.2%
>=12 = 18.6%
>=14 = 4.4%
>=16 = 8%
>=18 = 0%
Probability of Result <= 0 = 0%

@Function For This Output Distribution:
======================================
9320.0470982

Figure 4-1
North Dakota

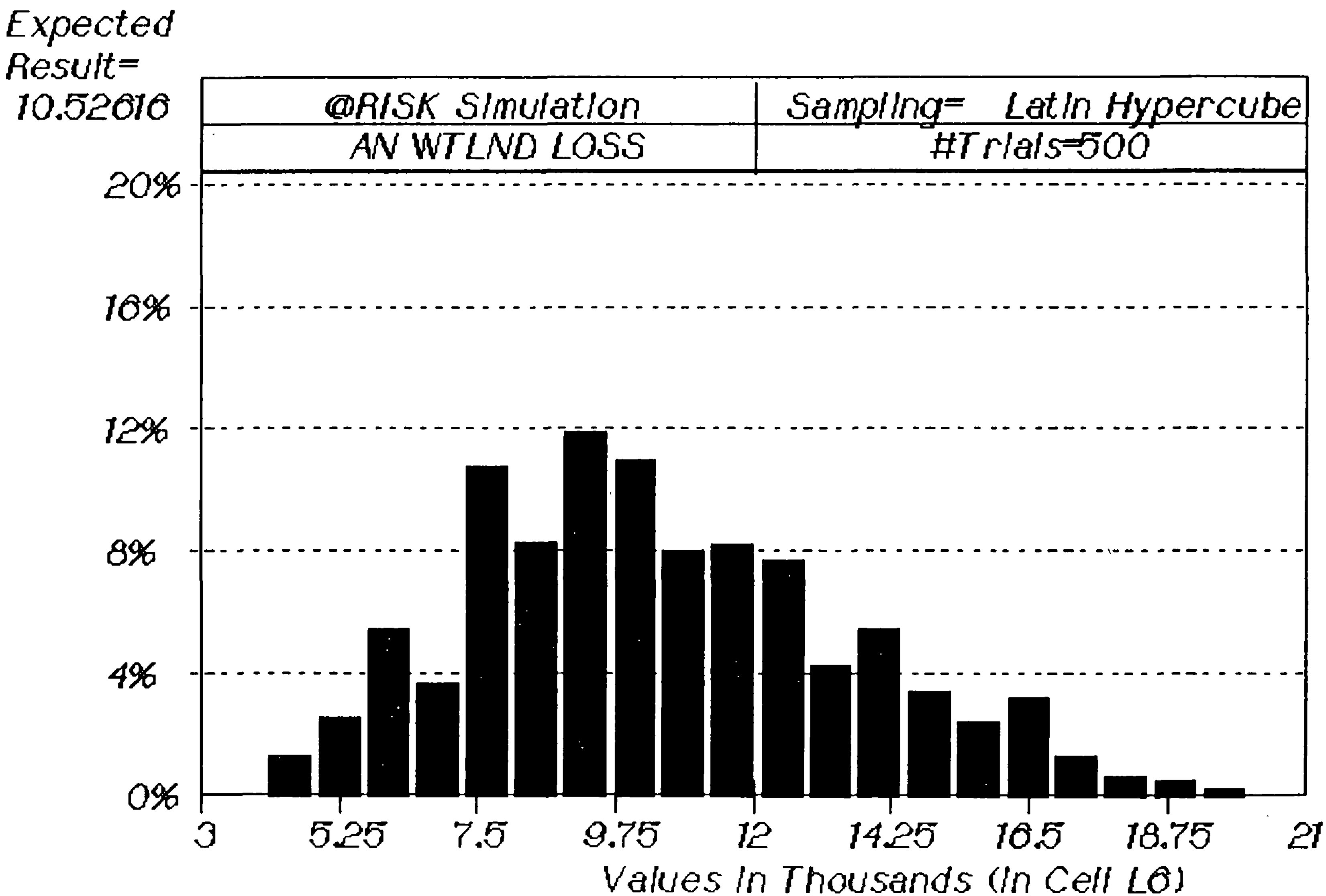


Figure 4-2
South Dakota

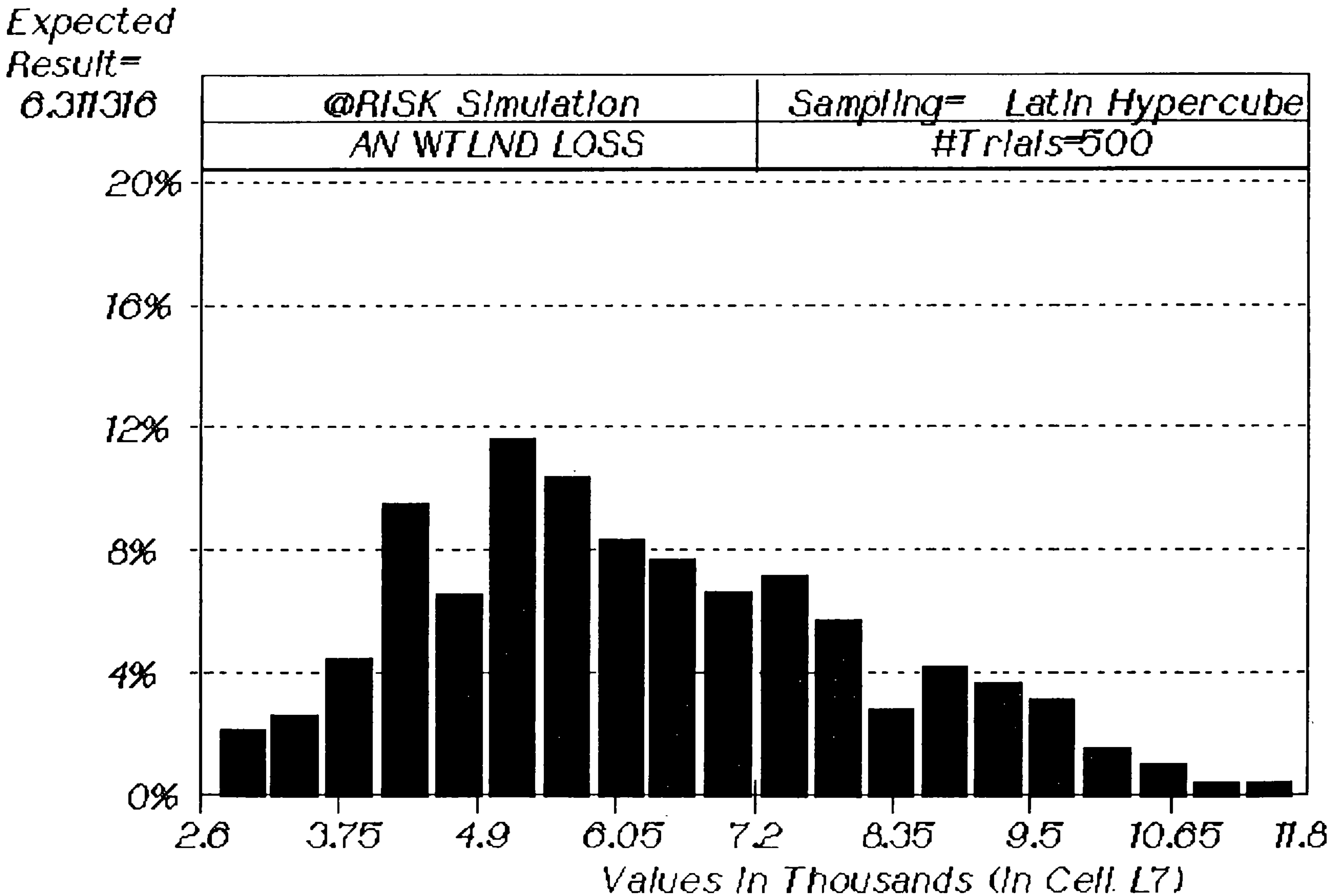


Figure 4-3
Colorado

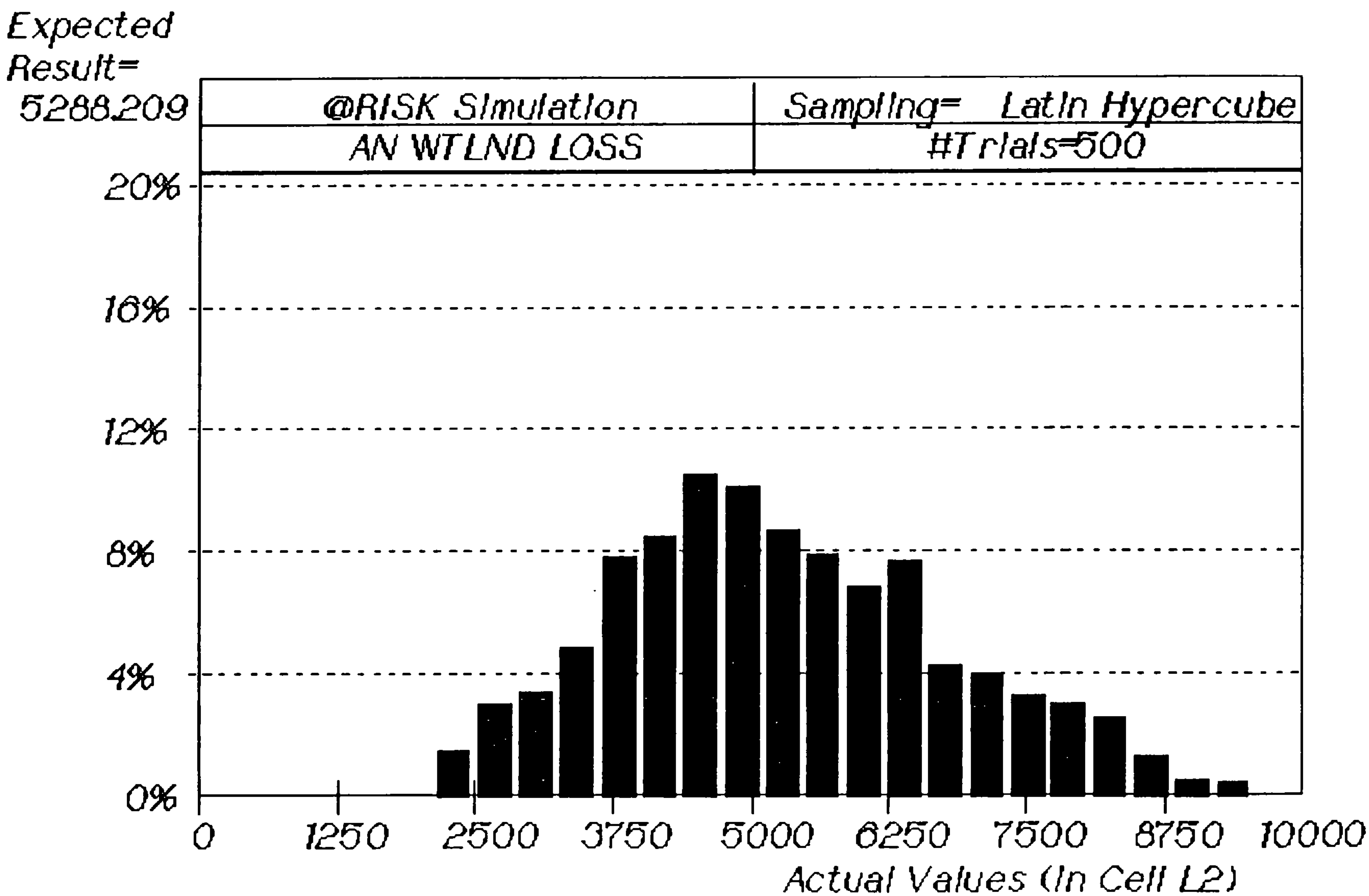


Figure 4-4
Utah

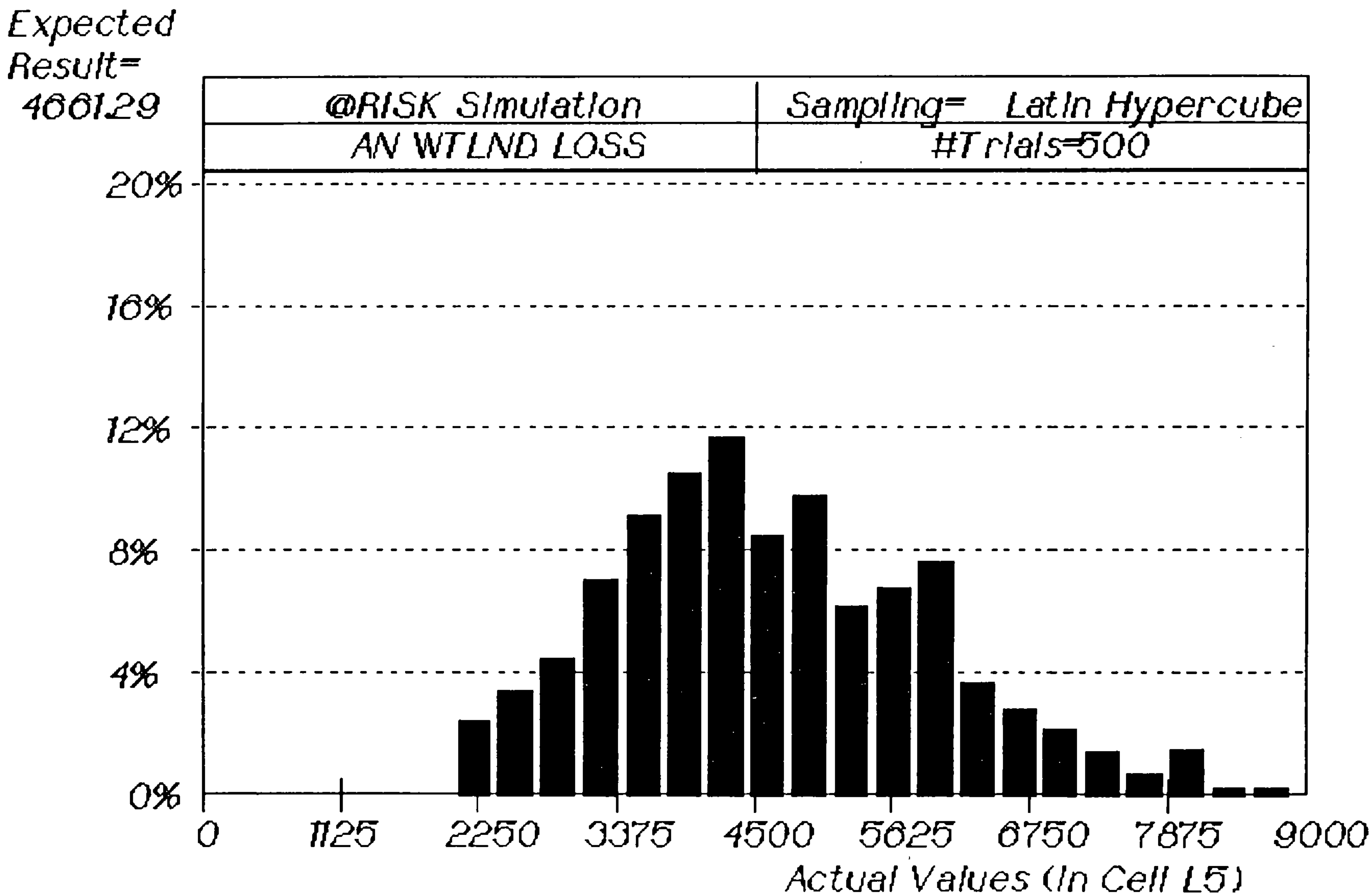


Figure 4-5
Montana

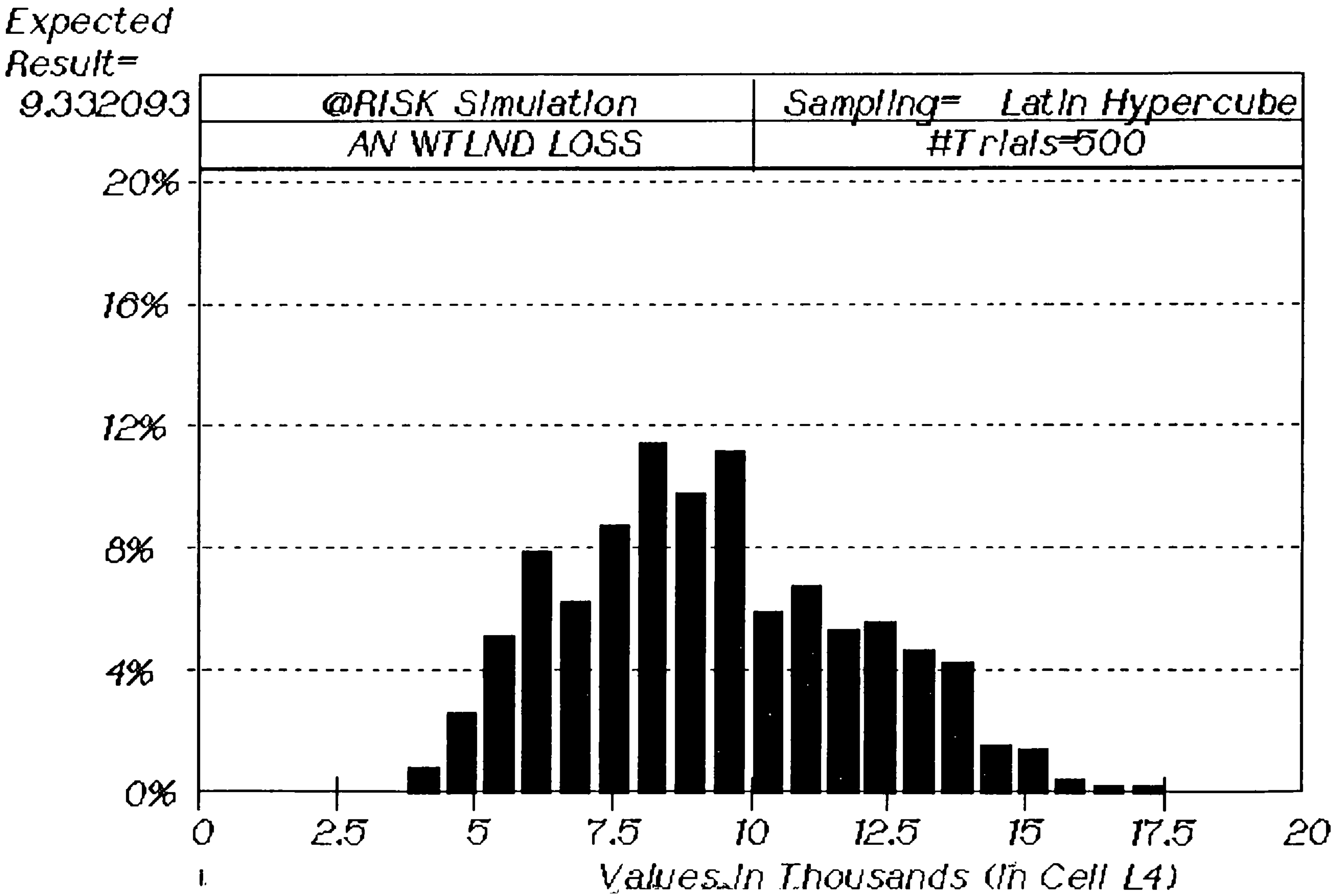
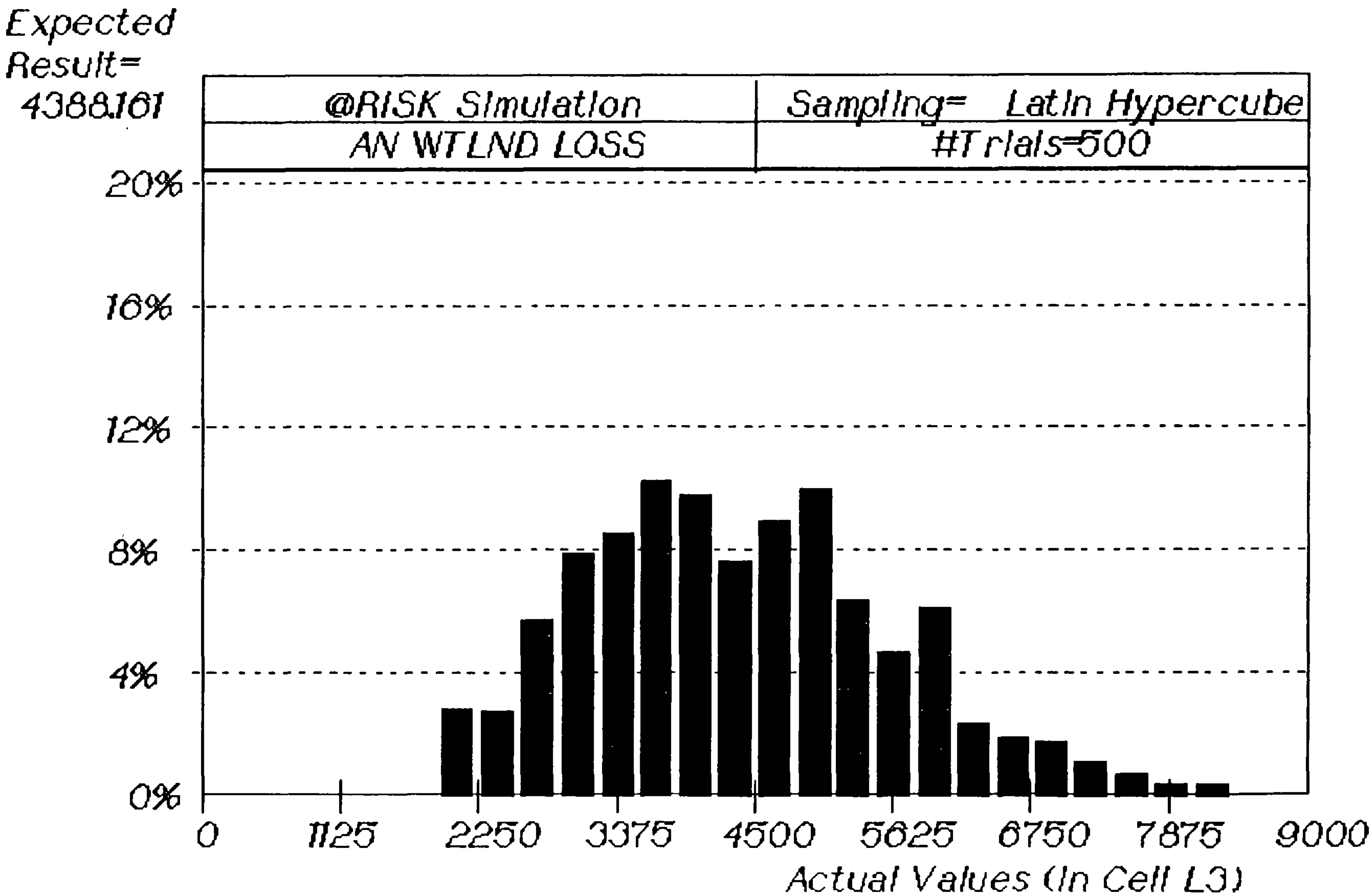


Figure 4-6
Wyoming



The economic concept of "service flows" encompasses the commodities, activities, or general sense of well-being that individuals derive from a wetland of given quality. For example, a clean and healthy wetland may provide water supply, regulation of floodwaters, recreational opportunity, and aesthetic pleasure, among other services. These are the services that the wetland provides to individuals -- services from which individuals derive value and well-being.

There is a growing body of literature concerning wetland services and the valuation of those services. Wetlands valuation studies have addressed the following wetland services:

- Water supply (groundwater recharge and discharge);
- Floodwater regulation;
- Timber harvest;
- Commercial harvest of fish and game;
- Visual, cultural, and educational opportunities;
- Recreational fishing and hunting;
- Erosion control;
- Water purification; and,
- Habitat provision.

This section addresses these wetland services, providing a brief review of the published literature that estimates economic values deriving from them.

4.4.1 Water Supply Services

Wetland areas may provide support for water supply systems as the wetland affects movement of water into and out of aquifer systems. However, there is considerable uncertainty regarding the capacity of individual wetlands to function in support of water supply systems, as the role that wetlands play in groundwater recharge is not clear. According to Carter, et al. (1978), there is currently very little data suggesting that wetlands perform significant groundwater recharge functions. Indeed, wetlands may function more as important groundwater discharge rather than recharge areas (Adamus, 1983; Novitzki, 1978; Larson, 1978). Carter, et al. (1978) argued that many wetlands perform a groundwater discharge function, and consequently are reliable predictors of potential water supply sources.

Gupta and Foster (1972) estimated the value of Massachusetts wetland for water supply. They compared the cost of providing additional community water from wells, which were assumed to be recharged by wetlands, with the next most costly substitute means of acquiring additional water. They reported that wetland groundwater recharge was responsible for a cost savings of $0.0713 (1972 $) per 1,000 gallons of water used.

Wharton (1970) estimated potential water supply damages associated with the destruction of wetland areas in the Alcovy River of the Georgia Piedmont to equal $228,014. Tilton, Kaldec, and Schwegler (1978) used damage estimates provided by Gupta and Foster (1978) to compute wetland water supply values in Michigan.

4.4.2 Floodwater Regulation

Because of soil and topographic features, wetlands adjacent to waterbodies may hyrologically function to retain high water flows. Landscape depressions have the capacity to store water, thus providing flood control. Many depressions contain wetlands, and when not filled to capacity perform flood control functions. There is widespread agreement that wetlands associated with streams and rivers provide flood storage, slow flood waters, reduce flood peaks, and increase the duration of water flow (Carter, et al. 1978; Verry and Boelter, 1978; Clark and Clark, 1979; Larson, 1981; Zinna and Copeland, 1982).

According to the U.S. Fish and Wildlife Service (1984), wetland characteristics most often associated with flood water control are:

- Size, the larger the wetland, the greater the capacity for flood storage and flood water velocity reduction;
- Location in the drainage basin;
- Substrate texture; and
- Vegetation lifeform.

While possible for isolated wetlands to perform significant flood control services, effective flood control more often results from the interrelationship of a series of wetlands within a particular watershed. For example, flood peaks in Wisconsin were reduced by 60 to 80% in watersheds with a 30% wetland or lake area, as compared to watersheds with no wetland or lake area (Verry and Boelter, 1978).

The U.S. Army Corps of Engineers (1971) estimated that property value damage due to projected wetland loss and consequent flooding in the Charles River Basin in Massachusetts would equal $647,000 annually. A projected loss of 40% of the wetlands in the Basin was to predicted to increase flood damage by at least $3,193,000 annually. The Corps revised the damage estimate to $2,022,000 annually in 1976. Thibodeau and Ostro (1981) use this estimate for 30% reduction in wetland valley storage to calculate the total annual storage value of Charles River wetlands at approximately $17 million per year for the 8,422 wetland acres. The Corps determined that the most cost effective mechanism of controlling flooding damage in the Basin was to protect existing wetlands.

4.4.3 Timber Harvest

Johnson (1979) estimated the stumpage value, the market price of standing trees, per acre for southern wetland forests to be $250. York, Dysart and Galan (1977) estimated stumpage values in the Santee Swamp in South Carolina to range from $22.00 per million board feet to $36.10 per million board feet. Barstow (1970) calculated the value of hardwoods in the Obion-Forked Deer Basin, Tennessee, to be $2,087,700 for 218,900 acres of wetland area.

4.4.4 Commercial Harvest of Fish and Game

Wetlands provide habitat for fish and game, which can be commercially harvested providing economically valued services to individuals.

Batie and Wilson (1978) valued Chesapeake Bay wetlands for oyster production on a county-by-county basis. Using a 10 percent discount rate, they estimated the marginal value of wetlands for oyster production to range from $11 to $1,414 per acre. Lynne, Conroy and Pochasta (1981) estimated the marginal contribution of wetlands to the blue crab industry in Florida to be approximately $3.00 per acre.

The contribution of Michigan's wetlands to the annual harvest of fur bearing animals was estimated by Raphael and Jaworski as being $3.78 per wetland acre annually.

4.4.5 Visual, Cultural and Educational Opportunities

Wetland areas can provide aesthetic and cultural services to individuals, such as historical, educational, aesthetic and research values.

Smardon (1978) noted that wetlands have a significant 'Visual-cultural' value, tied strongly to both recreation and outdoor classes in natural history. He argued that from an 'ecological aesthetic' perspective, wetlands have "high visual and education values relative to other portions of the environment." Smardon pointed out that small wetlands, those under 20 acres, share high values in visual quality and educational opportunities with larger wetlands. He also noted that urban settings serve to emphasize some wetland attributes.

Smardon's 'visual-cultural' value is further expanded in Smardon and Fabos (1983). Different components of this value are analyzed, such as contrast, diversity, size, and wetland edge. Estimated value of the 'visual-cultural' values of wetlands ranged from $700 per acre for low visual-cultural resource values alone, capitalized at 5.375%, to $64,000 per acre for high visual, cultural, water supply, and flood control values capitalized at 7%. Unfortunately, Smardon and Fabos did not separately estimate the component values of the upper bound estimate.

4.4.6 Recreational Hunting and Fishing
Wetlands provide a broad array of hunting and fishing experiences to individuals. Economists have focused more attention on the value of these service flows than other wetland services. However, the majority of the literature evaluating the value of these experiences focuses on the value of waterfowl hunting or fishing.

Numerous valuation studies have used recreation expenditures as value proxys. For example, Raphael and Jaworski (1979) estimated the economic value of wetland fishing and hunting based on average annual expenditures. The annual per acre value attributable to fishing was $286 and for hunting $31.23. Unfortunately, these values measure gross recreation expenditures rather than the appropriate value measure, which is the willingness to pay to hunt or fish at the wetland site.

Thibodeau and Ostro (1981) estimated recreation values for wetlands in the Charles River Basin by summing user expenditures, lost pay, and marginal willingness to pay per user. The present value of the wetlands for recreation purposes was estimated as $187.74 per acre per year or a $3,130 discounted present value.

Gupta (1972) valued wetlands as wildlife and fisheries habitat by using the purchase price of land. He estimated the public cost of producing wildlife benefits when based on the average purchase price as being approximately $70 per acre.

Finally, Farber and Constanza (1987) estimated the average willingness to pay for recreation in 650,000 acres of wetiand in Louisiana's coastal zone as being $111 per acre per year.

4.4.7 Shoreline Anchoring and Erosion Control
Vegetation significantly influences shoreline anchoring and erosion (Scoffin, 1970; Wayne, 1975; Allen, 1978; Carter, et al., 1978; Clark and Clark, 1979). Carter, et al., concluded that wetland vegetation plays three principal roles in erosion control:

- Substrate stabilization and binding;
- Dissipation of wave and current energy; and
- Sediment trapping.

Carter, et al. suggest that the role played by vegetation in erosion control is the same for coastal as it is for inland lakes and riverine habitats. However, there is not much data regarding the relative erosion control efficiencies of different types of wetland plant communities (Clark and Clark, 1979). Clark and Clark indicated that shoreline vegetation's effectiveness in erosion control is a function of:

- The particular plant species involved, eg., its flood tolerance and resistance to undermining;
- Vegetated shoreline band width;
- The efficiency of the vegetation band in trapping sediment;
- Bank or shore sediment composition;
- Bank or shore slope; and
- The elevation of the toe of the bank with respect to the mean elevation of high storm water.

On the other hand, Larson (1981) and Owens (1980) indicated that evidence of the role of vegetation in shoreline stabilization and erosion control is lacking. Larson indicated that experimental evidence suggesting wetland erosion control is insufficient. Owens selected a case study area in Chesapeake Bay and examined historical erosion rates in two areas. He concluded that wetlands erode at the same rate as fastlands when subjected to similar winds, tides, currents, or storms, and thus that the value of these wetland areas for services related to erosion control was zero.

4.4.9 Water Purification

There is substantial evidence that the presence of wetlands helps maintain ambient water quality and that, within limits of their assimilative capacity, wetland areas may serve as alternatives to conventional secondary and tertiary treatment plants or conventional acid mine drainage remediation technologies. Recent research suggests that urban wetlands may usefully reduce urban non-point source runoff pollution (Silverman, 1989) and bacteria and viral concentrations (Scheuerman, et al., 1989).

Water quality changes as it passes through wetlands. These changes are primarily the result of:

- Reduced velocity of flowing water as it enters and passes through wetlands;
- Decomposition of organic substances by micro-organisms;
- The metabolic activities of wetland flora and fauna; and
- Sediment trapping and binding of particles.

Wastewater Treatment
Recently, there has been considerable interest in utilizing natural and/and or manmade wetlands for the treatment of wastewater. Studies related to this function/service have covered a variety of wetland types, for example, cypress domes, brackish marshes, freshwater tidal marshes, freshwater inland marshes, and bogs, as well as a broad geographic range (Kuenzler, 1989; Grant and Patrick, 1970; Banus, et al., 1975; DeJong, 1976; Ewel and Odum, 1978; Fetter, et al., 1978; Craig, et al., 1980; and Thibodeau and Ostro, 1981). Several reviews of the role of natural and artificial wetlands in wastewater treatment have recently appeared, see Hammer (1989), Whigham (1982) and Sloey, et al. (1978).

Despite the many examples of successful wastewater treatment by wetlands, the exact nature of the processes that contribute to water quality improvement are not well understood. Of particular concern for natural and not artificial wetlands is the impact on the biota from the introduction of waste materials into a wetland over an extended period of time.

Several studies have made estimates of the cost of replacing wastewater treatment functions and have used the costs as a basis for ascribing values to wetlands.

Tilton (1978) assessed the value of freshwater marshes in nutrient assimilation and water quality improvement, and found an annual return of $20,300 to $34,600. Gosselink, Odum and Pope (1974) estimated water purification values based on the cost of building a wastewater treatment facility for treating the waste capable of being assimilated by a hypothetical one acre wetland. Water treatment values were estimated to be $2,500 per year.

Acid Mine Drainage and Heavy Metal Pollutant Treatment
Numerous studies have been conducted addressing the fate of acid mine drainage and heavy metals in wetlands, for a survey of selected research see Hammer (1989). These studies have generally revealed that heavy metals and other toxic substances are either partially or totally assimilated by wetlands. The processes are complex, and the variability in the physical and biological characteristics of wetlands adds to the complexity. The long range capability of natural or artificial wetlands to perform these assimilative services remains largely unknown.

Wetland construction has been used extensively to treat acid drainage emanating from coal mines and coal-fired steam plants (Brodie, et al., 1989). The economic benefits of wetland construction versus prewetland acid mine drainage treatment expenditures varies significantly and is a function of numerous site specific attributes. However, Brodie, et al. reported that the TVA spent approximately $500,000 on chemical treatment, land reclamation, and engineering attempts to mitigate acid mine discharge associated with Impoundment 3 of its coal mine near Flat Rock, Alabama, even though noncomplying discharges were a chronic occurrence. During the period 1984-1986, annual treatment costs associated with Impoundment 3 averaged $28,500. In 1986, TVA constructed a wetland at the cost of $41,200, with annual operating and maintenance costs of less than $3,700. Brodie, et al. report that the TVA experience demonstrates that artificial wetlands can be an environmentally effective and cost-effective alternative to the conventional treatment of coal mine acid drainage.

Drainage from abandoned gold/silver mines in the Rocky Mountains with characteristic high metals concentrations and low pH discharges has continued to pose significant non-point source pollution. Due to the predicted high costs associated with conventional chemical treatment systems for these waters, the use of constructed wetlands as an alternative remediation technology has been investigated at the Clear Creek/Central City Superfund site (Morea, et al., 1989). Preliminary results indicate that wetland-based passive treatment provides a viable and cost effective alternative to traditional treatment technology. More detailed cost measures are currently not available.

4.4.10 Habitat Provision

Wetlands provide habitat for a wide variety of flora and fauna. Some animals are entirely dependent on wetlands for food, protection from weather, and/or predators, resting areas, reproductive materials or sites, molting grounds, and other life requisites. Other animal species utilize wetlands for only part of their life functions. Some species spend their entire life within a particular wetland; other species are resident only during a particular period in their life cycle or during the year or travel from wetland to wetland. Some animals use wetland habitat throughout their lives, but reside primarily in deepwater or upland habitats. Wetlands also provide necessary habitat for many rate and endangered plant and animal species. More than half the areas identified as critical habitat under provisions of the Endangered Species Act involve wetland areas (Zinn and Copeland, 1982).

Factors important in determining the value of wetlands as animal habitat include:

- The structure and species diversity of the wetland vegetation;
- Surrounding land uses;
- Spatial patterns within and between wetlands;
- Vertical and horizontal zonation;
- Size; and
- Water chemistry.

The importance of wetland habitats for nongame birds has been documented for riparian habitats and for saltmarsh and estuarine habitats. There are few studies addressing inland freshwater wetlands as habitat for nongame birds. The principal gamebird species relying on wetlands for habitat are waterfowl. Wetland attributes affecting bird habitat include:

- Availability of cover;
- Freedom from disturbance;
- Availability of food;
- Availability of specialized habitat requirements; and
- Interspersion.

As noted in Fowler and Peters (1988), the prairie pothole wetlands located in North and South Dakota are part of the most valuable inland marsh system providing waterfowl production in North America. Prairie pothole wetlands originally covered 7 million acres in North and South Dakota. Only approximately 3 million remain (Tiner, 1984 cited in Fowler and Peters, 1988).

Prairie pothole wetland losses are principally caused by conversion for agriculture, water resource development for irrigation and flood control, stream channelization, and highway construction (Fowler and Peters, 1988).

4.4.11 Estimated Welfare Damages Associated with Region VIII Wetland Loss

The uncertainty associated with valuing wetland loss is considerable. However, for the purposes of this study annual wetland losses were estimated based on a range of values taken from the existing literature. We assume that per acre annual damages may range from $360 to $2,000 dollars.

To estimate annual welfare damages we assumed that these damages could be represented with a triangular probability distribution with a mean value of $1,000. Welfare damages are summarized in Table 4-9, and range from a lower bound of approximately $7.13 million to an upper bound of $14.7 billion. The estimated expected value of damages is approximately $4.50 billion.

Table 4-9
Estimated Annual Welfare Damages
Associated with Wetland Losses [1]

Upper Bound Damages

State	Minimum	Mean	Maximum
Colorado	$4,110,000	$10,600,000	$18,500,000
Wyoming	$3,610,000	$9,300,000	$16,200,000
Montana	$7,560,000	$19,500,000	$34,000,000
Utah	$3,830,000	$9,870,000	$17,200,000
North Dakota	$8,640,000	$22,300,000	$38,800,000
South Dakota	$5,040,000	$12,900,000	$22,600,000
TOTAL	$32,800,000	$84,500,000	$147,000,000

Mean (Expected Value) Damages

State	Minimum	Mean	Maximum
Colorado	$2,280,000	$5,870,000	$10,200,000
Wyoming	$1,890,000	$4,870,000	$8,490,000
Montana	$4,020,000	$10,400,000	$18,100,000
Utah	$2,010,000	$5,170,000	$9,020,000
North Dakota	$4,530,000	$11,700,000	$20,400,000
South Dakota	$2,720,000	$7,010,000	$12,200,000
TOTAL	$17,400,000	$45,000,000	$78,400,000

Lower Bound Damages

State	Minimum	Mean	Maximum
Colorado	$912,000	$2,350,000	$4,100,000
Wyoming	$825,000	$2,130,000	$3,710,000
Montana	$1,600,000	$4,130,000	$7,200,000
Utah	$8,780,000	$2,260,000	$3,950,000
North Dakota	$1,740,000	$4,490,000	$7,840,000
South Dakota	$1,170,000	$3,020,000	$5,260,000
TOTAL	$7,130,000	$18,400,000	$32,000,000

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5.0 GROUNDWATER CONTAMINATION

5.1 INTRODUCTION

The Groundwater Contamination Problem Area analyses risks to the Region's groundwater resources and provides an estimate of the relative contribution of the major contaminant sources to human health, ecological, and welfare damages. The major sources of contamination include waste disposal facilities (landfills, septic systems, land spreading), mining, direct discharge to groundwater, (injection wells), storage facilities, spills and agricultural chemical application. Risk is evaluated from two perspectives, residual and potential impacts.

Since the Region VIII States' economies rely on numerous industrial and agricultural activities, there is a wide variety contamination sources found in the Region. Region VIII has approximately 3% of the U.S. population, of which 42% relies on groundwater for potable water supplies (see Table 5-1). These data indicate that South Dakota has the greatest percentage of its population dependent on groundwater and Colorado the least.

Although groundwater resources are, in general, of high quality numerous contamination incidents and the number of potential contamination sources pose a chronic risk for groundwater degradation and impacts. To illustrate the magnitude of the numbers of potential and known contaminant sources a compilation of these sources is presented in Table 5-2.

In addition, there is extensive land application of various pesticides and nitrate based fertilizers in Region VIII. However, it has not been possible to quantify the quantity of agricultural chemicals applied in Region VIII. The types of contaminants associated with these sources include volatile organics, pesticides, heavy metals, inorganic salts and nutrients.

Groundwater contaminant sources affect every populated area in Region VIII. For most contaminants sources, there appears to be a strong correlation between population density and the number of sources in a given area. The notable exceptions are agricultural chemicals, which are applied in rural areas and Superfund NPL sites which are just as likely to be found in rural areas as urban and suburban areas. However, simply because a contaminant source or potential source exists does not mean that exposure is occuring. Acontaminant source must exist, the source must affect the groundwater, the contaminant(s) must move with the groundwater media, the groundwater must serve as a drinking water source, a water supply well must be subject to the contamination, and individuals must be consuming or otherwise contacting the contaminated water for health effects to occur.

This distribution of contaminant sources exposes the majority of the 3,211,760 people dependant on groundwater to potential degradation of their drinking water supplies.

Table 5-1
Region VIII Groundwater Characaterization

State	Total SW and GW withdrawals per day (Mgal)	Total SW and GW withdrawals per year (Mgal)	% of Pop. served by ground water	Population	Population served by ground water	Ground Water with-drawals per day (Mgal)	Ground Water with-drawals per year (Mgal)
Colorado	16,000	5,840,000	15%	3,231,000	484,650	2,800	1,022,000
Montana	11,000	4,015,000	54%	826,000	446,040	200	73,000
North Dakota	1,000	365,000	62%	685,000	424,700	110	40,150
South Dakota	690	251,850	77%	708,000	545,160	330	120,450
Utah	4,300	1,569,500	63%	1,645,000	1,036,350	770	281,050
Wyoming	5,300	1,934,500	54%	509,000	274,860	540	197,100
Total	38,290	13,975,850	42%	7,604,000	3,211,760	4,750	1,733,750

Table 5-2
Groundwater Contaminant Sources

Source	Number in Region VIII
CERCLA NPL	46
CERCLIS Total Sites	1,037
RCRA TSD	124
Generators	4,923
Transporters	655
Total Tanks	71,656

Data for most potential contamination sources are presented in other problem areas. See, for example, active and inactive hazardous waste sites, storage tanks, and drinking water.

5.2 HUMAN HEALTH EFFECTS

Groundwater is a source of drinking water for 42% of the residents of Region VIII. We assume that contaminated groundwater can affect human health only when it impacts drinking water supplies. However, it should be noted that contaminated groundwater can also pose risk of human exposure via the consumption of farm crops that have been irrigated by the contaminated groundwater and absorbed or adsorbed the contaminants. In general, residual carcinogenic risks due to contaminated groundwater are minor for the population at large, excepting lung cancers due to radon. There are three factors responsible for this low incidence of excess cancers due to drinking water. They are:

- A small percent of public water supplies and an unknown percent of the private water supplies are currently contaminated with carcinogens above the MCL level.
- Usually, it takes less than three years to install treatment systems or replace wells for public water supplies, therefore the time of exposure is less than lifetime.
- Individuals and communities use alternative water sources and other means of mitigation.

It should be noted, however, that it is not possible to segregate cancers related to drinking water from any other exposure route. It is possible to estimate the number of excess cancers possibly resulting from an assumed or actual exposure and dose, but this is simply an estimate.

However, there are subpopulations, namely small community water systems and residential wells where the risks are greater due to longer exposure times and the potential for higher concentrations of contaminants. This is due primarily the lack of resources to replace contaminated water supplies, use of shallow wells and in the case of residential wells, the lack of periodic monitoring which leads to longer term exposures to contamination. These subpopulations may be significant as Table 5-3 demonstrates. It should be noted that Table 5-3 relates the overall population of potential risk , but for a variety of factors, only a portion of this ppopulation would actually be at risk.

A more detailed discussion of the cancer and non-cancer risks can be found in the aggregated Drinking Water Program area. Both the cancer and non-cancer residual risks are not considered large due to the stringent standards and regulatory infrastructure. The potential health risks are much greater provided no action was taken to mitigate and prevent groundwater contamination.

Table 5-3
Population at Risk (Groundwater) in Region VIII

State	<500	501-3300	3301-1000	>10001
Colorado	138,854	162,165	170,864	115,210
Montana	170,027	75,592	26,651	55,500
North Dakota	65,557	107,592	49,758	26,361
South Dakota	73,169	131,577	64,836	101,395
Utah	89,838	147,450	125,338	244,903
Wyoming	61,691	56,733	56,595	408,490
Indian Lands	14,867	15,763	8,200	0
Total Region VIII	614,003	696,872	502,242	951,859
Grand Total	2,764,976			

5.3 ECOLOGICAL IMPACTS

Groundwater can impact ecological systems via the discharge of contaminated groundwater to surface water bodies and wetland areas. Groundwater may have a significant impact in localized areas but is not likely the major contributor of nonpoint source contamination region-wide.

Table 5-4 summarizes potential ecosystem damages that may be associated with contaminated groundwater discharges to surface water near Region VIII NPL sites. This Table was developed using the expert judgment of EPA staff. The column labelled "TOX" represents the potential toxicity of groundwater effluents associated with the site. The column "ECO" represents a subjective appraisal of the potential magnitude of the ecological risks at the site.

Remedial actions can also impact habitat. For sites with nearby wetlands, pump and treat groundwater remediation efforts can lower water tables and adversely impact the Vegetation in wetlands. In areas where this is a concern, the extraction well network and pumping schedule should be designed to minimize impacts on wetlands.

5.4 WELFARE DAMAGES

Welfare damages associated with groundwater pollution may be estimated by summing damages associated with Storage Tanks, Active and Inactive Hazardous Waste Sites, and Aggregated Drinking Water. In addition to these damages, however, the Region faces significant welfare damages due to the loss of option value associated with contaminated groundwater in the future. In addition to use limitations imposed by the lack of groundwater quality, groundwater quantity issues may also limit future economic well-being in the Region. Unfortunately, the current lack of data estimating groundwater quality severely constrains the estimation of welfare risks at this time.

5.5 RECOMMENDATIONS FOR IMPROVING THE ANALYSES

Assessment of risks associated with groundwater pollution in Region VIII is severely limited by the lack of data. When this data becomes available, more credible analyses can be performed.

Table 5-4
Severity of Risk of Ecosystem Damage due to Groundwater at NPL Sites

Site Name	Location	State	TOX	ECO
Air Force Plant PJKS	Waterton	CO	M	L
Broderick Wood Products	Adams Co.	CO	L	L
California Gulch	Leadville	CO	H	H
Central City/Clear Creek	Central City	CO	H	M
Chemical Sales Co.	Commerce City	CO	M	L
Denver Radium	Denver	CO	L	L
Eagle Mine	Minturn/Redcliff	CO	H	M
Lincoln Park	Canon City	CO		
Lowry Landfill	Arapahoe Co.	CO	M	L
Marshall Landfill	Boulder Co.	CO	M	M
Rocky Flats	Golden	CO	H	M
Rocky Mountain Arsenal	Adams Co.	CO	H	L
Sand Creek Industrial	Commerce City	CO	M	L
Smuggler Mountain	Pitkin Co.	CO	L	L
Union Carbide/Uravan Mill	Uravan	CO	M	L
Woodbury Chemical	Commerce City	CO	L	L
Anaconda Smelter	Anaconda	MT	M	H
East Helena Site	East Helena	MT	M	M
Idahoe Pole Co.	Bozeman	MT	L	M
Libby Ground Water	Libby	MT	L	M
Milltown Reservoir	Milltown	MT	M	M
Montana Pole	Butte	MT	L	L
Mount Industries	Columbus	MT	L	M
Silver Bow Cr/Butte Area	Silver Bow	MT	M	M
Arsenic Trioxide	Lidgerwood	ND	L	M
Minot Landfill	Minot	ND	M	M
Ellenworth Air Force Base	Rapid City	SD	M	L
Whitewood Creek Tailings	Whitewood	SD	H	M
Williams Pipe Line Disposal	Sioux Falls	SD	H	H
Rill Air Force Base	Ogden	UT	M	L
Midvale Slag	Midvale	UT	L	M
Monticello Mill Tailings	Monticello	UT	L	L
Monticello Properties	Monticello	UT	L	L
Ogden Defense Depot	Ogden	UT	M	L
Portland Cement Co.	Salt Lake City	UT	M	M
Richardson Flat Tailings	Summit Co.	UT	L	M
Rose Park Sludge Pit	Salt Lake City	UT	M	L
Sharon Steel Corp.	Midvale	UT	M	M
Tooele Army Depot	Tooele	UT	M	L
Utah P&L/American Barrel	Salt Lake City	UT		
Wasatch Chemical Co.	Salt Lake City	UT	M	M
Mystery Bridge/Highway 20	Evansville	WY	H	M
Union Pacific/Baxter	Laramie	WY	M	M
USAF, F.E. Warren AFB	Cheyenne	WY	H	M

6.0 AGGREGATED PUBLIC AND PRIVATE DRINKING WATER SUPPLIES

6.1 INTRODUCTION

This risk assessment describes numerous factors influencing health risks associated with drinking water in Region VIII. In addition, quantitative estimates of waterborne disease based on National data are presented. Due to the paucity of data, quantitative welfare risk estimates were prepared only for cancer cases associated with radon exposures.

While the risk of drinking water-related disease outbreaks may be regarded as unlikely in most large public water systems of the Region, this threat remains in the smaller, less technically competent communities and in the population of private users. Rural and private water supply systems continue to present a significant risk for several reasons.

- Many small water supplies are not regulated under an enforceable well construction code. As a result, systems are constructed that fail to provide even minimal water supply protection (U.S. EPA Region V, 1990). Substandard well construction allows contaminated surface water to enter the well; improper well abandonment allows unfiltered surface water to enter the aquifer; septic tanks, drainage fields and dry wells, and other disposal facilities are commonly sited within the zone of influence of the water supply wells; small production wells are commonly found to tap the upper portion of shallow aquifers where nitrate and other surface contaminants have not yet attenuated; makeshift repairs, using inadequate materials and procedures often result in pressure loss and the infiltration of contaminants, allowing holding tanks to flow back into distribution lines and threaten consumers when water pressures are restored. These are just a few examples of threats presented by unenforceable well construction regulations.

- The majority of small water supplies/suppliers are without benefit of a competent, certified water supply operator (U.S. EPA Region V, 1990). All drinking water facilities are subject to mechanical and construction failure. Larger water utilities maintain a constant vigilance of all components, and are prepared to handle common maintenance requirements. Smaller utilities, having at least minimal safeguards such as proper well construction in place may lack the incentive to provide such surveillance, and most of the smallest systems lack financial capability. In these systems, problems representing even serious health risks are usually discovered only through regulatory procedures considered inadequate by most water supply experts.

- As stated above, problems associated with public drinking water supplies are identified through compliance monitoring programs being enforced by the State agencies. Hundreds of violations occur each month, and the most significant of the violations (i.e. those considered to present a more immediate health risk) rarely remain unaddressed. The fact that States are addressing noncompliance should not suggest that those violations considered to be relatively insignificant should be ignored. Intermittent monitoring violations may present a small risk of contamination being undetected within a single water system, but the sheer number of violations occurring in unrelated systems is cause for concern. The vast majority of these violations are for failure to monitor the water supply. Essentially all of this non-compliance is due to ignorance of SDWA regulations. The issue of non-compliance by small water systems is often side-stepped by stating that such facilities serve only a minor portion of the population. This statement is, for the most part, true but most non-community drinking water supplies serve transient populations (travelers), which may potentially affect a significant portion of an area's population. Other non-compliance water supplies serve schools and other facilities that may provide most of the drinking water a person potentially consumes during a 24-hour period.

The above discussions identify the most significant risks to public health by drinking water. Additional risks can arise from inadequate response to these situations. Perhaps the most visible threat is the increasingly common use of home water treatment devices. Many consumers are aware of the findings of environmental groups, and the lack of timely and effective State response to recognized situations serves to fuel public concern. Home water treatment devices and bottled water are industries growing at rates unprecedented in the past, far exceeding the development of appropriate health regulations. This situation now threatens the basic support of public water supplies. Home treatment devices in particular have an undeniable place in public health protection, but they are not without risk. In almost every case, the risk presented by reliance upon a home treatment unit exceeds that of a public water supply violation. Lack of consumer education encourages inappropriate use of these devices, often leading to a false sense of security.

Currently, the U.S. EPA has promulgated regulations for 30 drinking water contaminants that are expected to have adverse impacts on human health, and secondary regulations for contaminants that affect drinking water aesthetics. In addition, EPA has established monitoring requirements for other contaminants. Under the Safe Drinking Water Act Amendments of 1986, Congress stipulated that EPA set monitoring and MCL requirements for 83 additional contaminants by June 1989. Since it is not possible to assess quantitatively risks for all drinking water contaminants or even a subset of those that are regulated, a number of representative drinking water contaminants were selected for characterization in this report: microbiological contaminants, inorganic chemicals, volatile organic chemicals (VOC), pesticides, disinfection by-products, radionuclides and corrosion byproducts.

6.2 POLLUTANT CHARACTERIZATION

6.2.1 Total Coliform/Microbiological Contaminants

There are many historical records with reported cases of disease transmission from microbial agents in drinking water supplies. Pathogenic and nonpathogenic bacteria, viruses, protozoa and cysts can all be transmitted via ingestion of contaminated drinking water. Cases of waterborne disease in Region VIII have involved such diverse contaminants as Giardia lamblia, Campylobacter, and a multitude of pathogenic coliforms and viruses. Since there are literally hundreds of possible microbial agents, agent-specific monitoring of water supplies is not practiced. Instead, the indicator organisms of the coliform bacteria group are used to evaluate bacteriological quality of water. Turbidity is also an important parameter since it acts to shield bacteria during the disinfection process, thus making disinfection less effective. Available data indicate that there may be no direct relationship between turbidity levels and coliform in drinking water and the incidence of waterborne disease. Turbidity is an important indicator of the effectiveness of surface water treatment and therefore, is currently regulated for surface water supplies only. Thus, its significance throughout the Region is unknown. Table 6-1 indicates that coliform is the most widely reported contaminant causing either Type 1 or Type 2 violations as reported for Region VIII in FRDS. Besides total coliform violations data, additional data is needed to relate disease incidence to drinking water. This additional data would consist of the following:

- Disease incidence reports by state
- Surveys of water systems that experienced a contamination problem
- Special studies or investigations conducted by State, local or Federal health agencies that involved data collected from drinking water supplies

6.2.2 Nitrate as Nitrogen

Nitrate present in drinking water in excess of 45 mg/L (10 mg/L as nitrogen) is associated with the incidence of methemoglobinemia, which can cause "blue baby" syndrome. This problem is mainly confined to infants less than 6 months of age and primarily to agricultural areas. Nitrate violations are reported by EPA staff to cause approximately 0.9% of the Type 1 and 2 violations reported in FRDS, see Table 6-1.

Table 6-1
Listed Region VIII Contaminants Responsible for Type 1 and 2 Violations

Contaminant	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Arsenic	1	0.1	1	0.1
Coliform	994	90.2	995	90.3
Combined Radium	4	0.4	999	90.7
Fluoride	40	3.6	1039	94.3
Nitrate	10	0.9	1049	95.2
TThm	20	1.8	1069	97.0
Turbidity	33	3.0	1102	100.0

6.2.3 Lead

Lead was regulated as a primary drinking water contaminant at .05 mg/L in 1976. Since that time, additional toxicological data have indicated that lead concentrations in drinking water far below the MCL are capable of producing adverse health effects, particularly in younger children, infants and fetuses. Lead causes damage to the nervous system, the blood-forming processes (hemopoietic), the gastrointestinal system and the kidney. More recent studies show that lead also causes cognitive damage, retards growth and can raise blood pressure in adult males, even at low exposure levels. Health effects range from relatively subtle biochemical change at low doses (it has been learned that blood lead levels in children such as 15 µg/Dl are capable of producing measurable neurological changes) to severe retardation or death at higher levels. Lead is also regarded as a B2 carcinogen from the weight of evidence.

Currently, the MCL for lead is being revised downward to reflect our greater knowledge of its adverse effects and widespread occurrence in water supply distribution systems. In Region VIII, there were very few violations of the lead MCL reported in the FRDs database.

6.2.4 Trihalomethanes

Trihalomethanes (THM) are volatile organic compounds that are formed when chlorine used in the disinfection process comes in contact with organic humic and fulvic acids. While four different by-products are formed (chloroform, bromoform, dichlorobromomethane, and dibromochloromethane), chloroform is the species found in the highest concentration. The THMs are regulated collectively as total THMs. The interim MCL is set at 0.1 mg/L and applies for the total concentration of any combination of THMs present. The population exposed to THMs would be those surface water systems serving populations of 10,000 or more customers (as per the regulations these systems are required to chlorinate) and any other surface supplies that chlorinate.

The Office of Drinking Water is preparing a mandatory disinfection treatment rule for groundwater. The anticipated proposal date is January 1991, with promulgation approximately one year later. ODW is also preparing a rule that will limit levels of disinfectants and disinfection by-products in finished drinking water. The anticipated proposal date for this rule is September 1991. Promulgation is planned for 1992. Chemicals that have been confirmed as subject to this rule include total trihalomethanes, haloacetic acids, chlorine dioxide, chlorite, chlorate, chlorine and chloramine. Several other chemicals may potentially be added to this rule as well.

Total trihalomethanes were reported to cause approximately 1.8% of all reported Region VIII Type 1 and 2 violations.

6.2.5 Radionuclides

Radium 226-and Radium-228 were regulated under An interim primary standard which combined MCL of 5 Pci/l under the SDWA in 1976. This MCL used gross alpha as a screen (15 Pci/l) for these regulated alpha emitters. Since that time, the Office of Drinking Water has been developing new regulations and is expected to publish a Notice of Proposed Rulemaking in January 1991. This Notice is expected to propose MCLGs, MCLs, Best Available Technologies (BAT) for setting MCLs and as conditions for receiving variances and exemptions and monitoring requirements for radon-222, radium-226, radium-228, gross alpha, natural uranium, and beta particle and photon emitters. All radionuclides that will be considered are classified as Group A, known human carcinogens; thus, the MCLGs will be proposed as zero. The Agency is considering proposing a separate MCL for each radium isotope which centers around 5 Pci/L.

Data on the average occurrence of radium in public water supplies in Region VIII is not available from FRDS database since measured concentrations for compliance monitoring are not reported. However, EPA's Office of Radiation Programs conducted a nationwide survey in 1980-81 of 2,500 public groundwater supplies in 27 States representing 45% of the drinking water nationally consumed. The population weighted average value for radium-226 in all community drinking water supplies is estimated to range between 0.3 and 0.8 Pci/l, while that for radium-228 is estimated to be in the range of 0.4-1.0 Pci/l. These results are described in Federal Register, Vol.51, No. 189, Sept. 30, 1986. FRDs indicates that for one year (1989), the average violation level was 8.6 Pci/l. Approximately 0.4% of reported Type 1 and 2 violations in Region VIII are due to combined radium.

6.2.6 Radon

Radon is another concern of the State public water supply programs. It has been estimated that between 5,000 and 20,000 lung cancers occur annually in the U.S. because of radon levels in indoor air. About 1-7% of these cases result from the release of radon from drinking water sources related activities such as showering, bathing, flushing toilets, cooking and washing clothes and dishes (Lammering, 1990). In an average lifetime of 70 years, it is estimated that between 2,000 and 40,000 lung cancer deaths will occur as the result of radon levels in public water supplies (primarily groundwater) in the U.S. The average radon concentration in water supplies varies between States.

Currently, there is no good database on radon levels specific to Region VIII. Wyoming is the only state that has survey data. The NIRs survey will provide additional data on radon occurrence. The present combined national data available show the population weighted average concentration for radon in public drinking water supplies from groundwater is about 420 Pci/l.

6.2.7 Trichloroethylene

Trichloroethylene was regulated as a primary regulated drinking water contaminant at .005 mg/L in July 1987. It is classified as a Class B2 probable human carcinogen based on the weight of toxicological evidence. Acute oral exposures (15-25 ml) to TCE in humans have resulted in vomiting, abdominal pain and transient unconsciousness, while longer-term occupational exposures suggest liver damage. The major source of TCE released to the environment is from its use as a metal degreasers. Since TCE is not spent during its use, the majority of all TCE produced is released to the environment. TCE released to the air is degraded within a few days. TCE released to surface waters migrates to the atmosphere within a few days or weeks where it is also degraded. However, TCE that is released to the land migrates readily to the groundwater where it remains for months to years. TCE does not easily degrade in groundwater, but under certain conditions may degrade to dichloroethylene and vinyl chloride. TCE is a common contaminant in ground and surface water, with higher levels found in groundwater. National surveys of drinking water supplies have shown that 3% of all public water systems using groundwater contain TCE at levels of 0.5 μg/L or higher. Approximately 0.4% have levels greater than 100 μg/L.

6.2.8 Tetrachloroethylene

Tetrachloroethylene (PCE) is another chemical that falls under the classification of VOCs. Originally slated for promulgation at the same time as TCE in July 1987, it was withdrawn from the group due to newly available bioassay data. This data created a controversy surrounding its weight of evidence classification as a E2 or C carcinogen. Currently, PCE is classified as a E2 carcinogen is scheduled for promulgation of an MCL and MCLG in June 1990. The MCL and MCLG will be .005 mg/L and zero, respectively. PCE also has many industrial uses and, like TCE, is not spent during its use, but is released directly back into the atmosphere. During its disposal, it is usually discharged directly to land and surface water. PCE released to air degrades within days or weeks. PCE released to water degrades slowly. It is very mobile in soil and easily travels to the groundwater where it remains for months or years. Under certain conditions, PCE is degraded to TCE and then to dichloroethylene and vinyl chloride. National surveys of drinking water supplies have shown that 3% of all public water systems using groundwater contain PCE at levels of 0.5 ug/L or higher. About 0.7% have PCE levels above 5 μg/L.

6.2.9 Trichloroethane

Trichloroethane (TCA) was regulated as a primary drinking water contaminant at 0.2 mg/L in July 1987. It has been placed in the category of class D carcinogens, which have not been evaluated as to their human carcinogenic potential due to insufficient data. The major source of TCA released to the environment is from its use as a metal degreaser. As with the other two previously discussed VOCs, TCA is not consumed during metal degreasing; thus, all of it is released to the environment. TCA released to the air degrades slowly with an estimated half life of 1 to 8 days. TCA released to surface waters migrates to the atmosphere in a few days or weeks. TCA which is released to land does not sorb onto soil and travels quickly to groundwater. It slowly hydrolyses in groundwater with an estimated half-life exceeding 6 months. As with TCE, TCA does not bioaccumulate in animals or food chains. TCA is a good representative chemical because it occurs widely in the environment. It is a common contaminant in groundwater and surface water, with higher levels measured in groundwater. National drinking water surveys have found that 3% of all public water systems using groundwater contain TCA at levels of 0.5 μg/L or higher.

6.2.10 Alachlor

Alachlor is currently scheduled for promulgation in June 1990. The proposed MCL is 0.002 mg/L and the MCLG is zero. Alachlor has been classified as a B2 carcinogen due to the weight-of-evidence of human carcinogenic properties. Alachlor had one of the largest production volumes of any pesticide. It is applied to the soil either before or just after the crop has emerged and is rapidly metabolized by crops after application. It is widely used for corn and soybean crops. In the soil, alachlor is degraded by bacteria under both anaerobic and aerobic conditions. Alachlor is not photodegradable and does not hydrolyze under environmental conditions. Alachlor is moderately mobile in sandy and silty soil and has been shown to migrate to groundwater. On a national basis, alachlor has been reassured in both surface and groundwaters. Federal and State surveys of surface water have reported alachlor to occur at levels of 1 ppb.

6.2.11 Atrazine

Atrazine is currently scheduled for promulgation in June 1990. The proposed MCL and MCLG is 0.003 mg/L. Atrazine has been classified as a C (possible human carcinogen) due to the lack of evidence of its human carcinogenic potential and incomplete evidence of its animal carcinogenic potential. The STORET 1988 national database indicates that atrazine has been found in 4,123 of 10,942 surface water samples and in 343 of 3,208 groundwater samples. These samples were collected at 1,659 surface water locations and 2,510 groundwater locations. The 85th percentile of all non-zero samples was 2.3 μg/L in surface water and 1.9 ug/L in groundwater. This information serves to provide a general idea of its occurrence. Atrazine is moderately to highly mobile in soils ranging in texture from clay to gravelly sand. Studies show that under aquatic field conditions, atrazine is relatively stable under environmental Ph conditions, but does dissipate due to leaching and to dilution from irrigation water, with residues persisting for three years in soil on the sides and bottoms of irrigation ditches. Atrazine degrades in soil by photolysis and microbial processes.

6.2.12 Sources, Contaminants, Exposure Pathways and Effects

All public and private drinking water supplies should be regarded as potential sources of contaminants, as stated by the problem definition. However, under the Safe Drinking Water Act, the State and Federal governments are not mandated to regulate private drinking water supplies, thus information regarding the quality of private drinking water supplies is not readily available.

There are three possible routes of exposure from drinking water as a source of contaminants. These include ingestion, inhalation and dermal contact. The major route of exposure from most drinking water contaminants is through ingestion, however defending on the physical properties of the contaminant, i.e., volatility, Kow, etc., inhalation of VOCs such as trichloroethylene can occur as the compound is released into the air from use of hot water such as showering, bathing, or washing dishes. Some studies have shown that absorption of chemicals via inhalation of indoor air can be equal to that of ingestion.

As with the VOCs, similar concerns exist for the inhalation of radon in drinking water. Radon is released from drinking water under the same conditions as VOCs.

6.3 HUMAN HEALTH RISK ASSESSMENT

6.3.1 Toxicity Assessment

This section presents both cancer and noncancer toxicity information on the representative chemicals described in the previous section. For carcinogens, this determines the relationship between the dose and the probability of developing cancer. This relationship predicts the level of risk associated with a certain exposure. Data presented in Table 6-2 includes the U.S. EPA weight-of-evidence, the oral and inhalation cancer potency factors (slope factors), the unit risk factors for ingestion (ug/L) and inhalation (ug/m3) for a 10 - 6 excess lifetime cancer risk.

Table 6-2
CARCINOGENIC PARAMETERS OF DRINKING WATER CONTAMINANTS

Unit Factor Contaminant	Carcin- ogen Class	Oral CPF (slope- factor) (mg/kg/d)-1	Inhal. CPF (slope- factor) (mg/kg/d)-1	Oral Unit Risk Factor (ug/L)	Inhal. Risk (ug/m^3)
Coliform	NA	NA	NA	NA	NA
Nitrate	NA	NA	NA	NA	ND
Lead	B2	1.4 E-4	ND	0.88	ND
TTHMs*	B2	6.1 E-3	8.1 E-2	1.7 E-7	2.3 E-5
TCE	B2	1.1 E-2	1.7 E-2	3.1 E-7	1.7 E-6
PCE	B2	5.1 E-2	3.3 E-3	1.4 E-6	9.5 E-7
1,1,1-TCA	D	NA	NA	NA	NA
Toluene	D	NA	NA	NA	NA
Atrazine	C	ND	ND	ND	ND
Alachlor	B2	ND	ND	ND	ND
Radium 226-228	A	3.6 E-5	ND	1.0 E-9	ND
Radon 222	A	ND	1.8 E-6	ND	ND

* TTHMs - (Total Trihalomethanes) is expressed as chloroform.

TCE - Trichloroethylene
PCE - Tetrachloroethylene
TCA - Trichloroethane
NA - Not Applicable
ND - Not Determined

For noncarcinogens, this step determines the relationship between dose of a contaminant and the probability of developing an adverse health effect. Unlike the dose-response relationship for carcinogens, these relationships are thought to involve a threshold below which an adverse health effect will not likely occur. The toxicity information for noncarcinogens is listed in Table 6-3 and includes the Maximum Contaminant Levels (MCLs) for drinking water, the oral and inhalation chemical reference doses (RfD) for chronic exposures, the one and ten-day Health Advisories (exposure doses considered by the Agency to be acceptable for acute exposures), and toxicological effects and endpoints.

Of the contaminants examined, the carcinogens include two Class A (human carcinogen) contaminants, i.e., combined radium 226-228 and radon 222. Several probable human carcinogens (Class B) are also included such as, tetrachloroethylene, trichloroethylene, alachlor, and total trihalomethanes (evaluated using chloroform). Since IRIS is not regularly updated, the oral and inhalation cancer potency factors (CPF) and unit risk factors were obtained from the OERR/ORD Health Effects Assessment Summary Tables (HEAST) of fourth quarter, FY 1989. Other values were obtained from the U.S. EPA Region 3 Reference Concentration Worksheet, Version 4.1. One Class C (possible human carcinogen) chemical, atrazine was also evaluated, although no risk factors have been determined yet. Thus, atrazine will only be assessed in terms of noncarcinogenic risks. Other selected contaminants, which have not yet been evaluated with respect to evidence of human carcinogenicity (Class C D), include l,l,l-trichloroethane and toluene. These will also be assessed for noncarcinogenic risk .

The toxicity assessment for all selected contaminants (see Table 6-3) summarizes toxicity values which were also obtained from the HEAST tables and verified through the Office of Drinking Water (ODW) materials. All other toxicology information in the table was obtained from the ODW Health Advisory documents for the respective chemicals. Only the chronic oral and inhalation RfDs have been listed in Table 6-3. The Health Advisory values reflect acute exposure limits in drinking water.

6.4 EXPOSURE ASSESSMENT

Defensible quantitative health risks associated with this problem area could not be prepared with the available data. However, we have attempted to dimension the risk to State and Indian populations by defining the number of individuals that rely on different categories of drinking water supply.

Table 6-4 summarizes the source of water supply by State and Indian Lands across Region VIII. These data suggest considerable variety in drinking water sources across the Region. Colorado and Utah, on the one hand, rely to a far greater extent than the remaining States or Indian Lands on surface water systems. Residents of Indian Lands rely more heavily on groundwater supply than any other State or ownership group.

Table 6-3
TOXICOLOGICAL PARAMETERS OF DRINKING WATER CONTAMINANTS

Contaminant	Chronic Oral Reference Dose (mg/kg/day)	Chronic Inhalation Reference Dose (mg/kg/day)	Chronic Maximum Contaminant Level (mg/L)	Acute Health Advisory Level 1 and 10-day (mg/L)	Toxicological Endpoints Acute/ Chronic
Coliform Bact	NA	NA	Varies *	NA	GI irritation
Inorganic Lead	1.4 E-4	4.3 E-4	.005 mg/L source TT at tap	NA	neurological: subtle biochemical changes, impaired mental perf, circul. syst. kidney fct.
Nitrate (as N)	1.0	ND	10.0	10.	methemoglobinemia in infants less than 6 months / death
TTHMs as chloroform	.01	ND	0.1	NA	hepatotoxicity/cancer
Trichloroethylene	.007	NA	.005	NA	abdominal pain, unconsciousness, hepatotoxicity / cancer
Tetrachloroethylene	.01	ND	.005[a]	2.0	hepatotoxicity, nephrotoxicity, CNS effects/cancer
1,1,1 - TCA	.09	1.0	0.2	100/40	CNS effects / hepatotoxicity, pulmonary congestion (inhn) edema
Toluene	0.3	1.5	2.0[a]	20/3	CNS toxicity / peripheral nervous syst. eff./ nepatoxicity, renal toxicity
Atrazine	.005	ND	.003[a]	0.1	kidney, liver, lung congestion/ poss. reprod. develop. and mutogenic effect
Alachlor	.01	ND	.002[a]	0.1	hepatotoxicity, ocular eff/ cancer, possible devel. effects
Radium 226/228	NA	NA	5 pci/1	NA	bone and mastoid cancers
Radon	NA	NA	ND	NA	lung cancer

ND - Not Determined   TT - Treatment Technology   NA - Not Applicable   a - Proposed

* MCL varies based on anal method, sample volume and number of samples collected per month. Also, two types of MCLs. monthly average and single sample MCL, based on coliform density After 12/31/90, no more than 5% of samples may be positive For systems collecting less than 40 samples per month no more than 1 may be positive

Table 6-4
Potential Population at Risk
due to Drinking Water in Region VIII

State	Total State Population	Population Served By: Surface Water Systems		Ground Water Systems		Private Wells	
Colorado	3,476,000	2,876,733	82.8%	599,738	17.3%		
Montana	703,000	350,996	49.9%	327,770	46.6%	24,234	3.4%
North Dakota	551,000	274,444	49.8%	250,928	45.5%	25,628	4.7%
South Dakota	650,000	247,955	38.1%	370,977	57.1%	31,068	4.8%
Utah	3,143,000	2,535,203	80.7%	607,619	19.3%		
Wyoming	866,000	282,732	32.6%	583,509	67.4%		
Indian Lands	52,000	13,431	25.8%	38,830	74.7%		
Total Region VIII	9,441,000	6,581,494		2,779,371		80,930	

Numbers do not add up due to reporting inaccuracies in the FRDS data base, rounding off, rough State specific estimates of private well use.

Populations and percentages are estimated.

Water system categories are inclusive of purchased water.

All systems included in this table are only the active and current systems.

Table 6-5 lists the population by State and Indian Lands being served by four separate categories of groundwater supply systems. As mentioned previously, individuals served by the smallest water suppliers and private systems are generally regarded as being at greater risk. These data suggest that Montana and Colorado have the largest absolute populations at risk due to contaminated groundwater drinking supplies. On the other hand, Montana and residents of Indian Lands have the highest relative risks, with approximately 52 and 38% of their populations served by groundwater in the <500 category.

Table 6-6 lists data similar to Table 6-5, but for surface water systems. These data indicate that Colorado has the greatest number of people served by systems <500 people, followed by Montana. On the other hand, Colorado has over 2.5 million residents served by the largest category of water supplier, thus enjoying increased drinking water protection.

In lieu of a specific Region VIII estimate of health effects due to contaminated drinking water, we have relied on a statistic reported in "Waterborne Diseases in the United States" (CRC, 1986). 29,185 cases of waterborne illness were reported between 1981 and 1983. This suggests an annual incidence of approximately 14,593 cases for both public and private supplies. Scaling to Region VIII by the ratio of populations, implies roughly 490 cases of illness annually associated with aggregated drinking water pollution.

Using a previously cited range of annual national cancer cases due to radon exposures (5,000 to 20,000) and an estimate that between 1 and 7% of these cancers are due to exposures associated with drinking water, estimated annual lung cancer cases in Region VIII can be estimated to range between approximately 2 and 46.

6.5 WELFARE DAMAGES

Welfare damages associated with contaminated drinking water supplies may be due to a number of factors, including: cost of illness and lost wages; the cost of replacing contaminated water supplies; the opportunity costs associated with lost uses of contaminated ground and surface water supplies; and costs associated with home purification devices.

To estimate health effects costs, the annual lung cancer cases estimated above were multiplied by the direct medical cost and foregone earnings per cancer case:

(Annual Cancer Cases)(Direct Costs and Forgone Earnings) = HC

where:

HC = health costs

Table 6-5
Population at Risk (Groundwater) in Region VIII

State	<500	501-3300	3301-1000	>10001
Colorado	138,854	162,165	170,864	115,210
Montana	170,027	75,592	26,651	55,500
North Dakota	65,557	107,592	49,758	26,361
South Dakota	73,169	131,577	64,836	101,395
Utah	89,838	147,450	125,338	244,903
Wyoming	61,691	56,733	56,595	408,490
Indian Lands	14,867	15,763	8,200	0
Total Region VIII	614,003	696,872	502,242	951,859
Grand Total	2,764,976			

Table 6-6
Population at Risk (Surface water) in Region VIII

State	<500	501-3300	3301-1000	>10001
Colorado	17,385	83,976	188,545	2,556,050
Montana	12,528	36,674	90,904	236,000
North Dakota	3,205	18,863	20,903	257,017
South Dakota	9,692	34,923	51,579	182,865
Utah	4,807	51,156	115,494	2,363,746
Wyoming	12,198	33,534	63,849	173,151
Indian Lands	1,185	12,246	0	0
Total Region VIII	61,000	271,372	531,274	5,768,829
Grand Total	6,632,475			

Estimated direct and indirect medical cancer costs are based on a range of cost per case estimates. The lower bound estimate, based on Hartunian, et al., is \$80,000, while the upper bound estimate developed by the American Cancer Society is \$137,000. These estimates provide differing values for foregone earnings and medical costs. Both estimates are weighted average costs associated with all types of cancers.

Lower bound estimate

HC=(2)(\$80,000)=\$160,000 (1988 \$)

Upper bound estimate

HC=(46)(\$137,000)=\$6,302,000 (1988 \$).

Quantified welfare damage estimates for other endpoints have not been prepared due to the lack of readily usable data describing the number of effects and Regional costs of replacement and remediation.

Given the number of annual private well replacements and public water supply hook ups associated with drinking water contamination, the cost of replacing contaminated drinking water supplies could be estimated. These costs may be estimated by assuming that the capital costs for are \$3,500 for replacing a private well by digging a new well and \$300,000 for replacing a public supply well by extending a hook up from another public supply. These costs do not include the annual operating costs for these private and public systems.

6.6 OMISSIONS

It was not possible to estimate quantitatively and credibly the number of health effects due to contaminated drinking water supplies in Region VIII without using national data and scaling it to the Region. In addition, welfare damages have not been estimated. These omissions may be particularly significant, as costs associated with meeting new EPA drinking water standards may be very high for a number of Region VIII States.

6.7 RECOMMENDATIONS FOR IMPROVING THE ANALYSES

There was little data available to characterize the exposure of Region VIII populations to contaminated drinking water. In addition, there is very little data estimating the quality of private drinking water supplies.

6.8 PRINCIPAL CONTACTS

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Sanders, Doris

6.9 BIBLIOGRAPHY

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7.0 STORAGE TANKS

7.1 INTRODUCTION

The Storage Tanks problem area covers risks to human health and welfare, and the environment posed by the following types of storage tank facilities:

- Underground storage tanks used for storing petroleum products or regulated substances.

- Ground level or on ground storage tanks used for storing petroleum products or regulated substances.

- Above ground storage tanks used for storing petroleum products or regulated substances.

The types of risks to human health and the environment from storage tanks that fall within this problem area are those resulting from the routine or continuous release of petroleum products or regulated substances to the soils, surface water, groundwater, and air. Typically, these releases occur in the form of undetected leaks. This analysis considers only the distribution of, and risks due to, under ground storage tanks (USTs). Quantified welfare risks are estimated based on the number of tanks requiring corrective action and cost estimates associated with those actions.

Stored substances falling within this area are petroleum products and regulated substances, including gasoline, diesel fuel, motor oils, heating oils, solvents, lubricants, and inorganic acids and bases. These substances can contaminate soils, water, and air with such toxic substances as benzene, toluene, xylene, ethylbenzene, chlorinated solvents, petroleum hydrocarbons, and heavy metals.

This problem area does not include risks arising from the following types of facilities or releases:

- Storage tanks used to store hazardous wastes. These facilities fall within the Active Hazardous Waste Facility problem area.

- Acute accidents or releases from storage tanks, including tank collapses or explosions. These releases are covered under the Accidental Chemical Release problem area. It should be noted that it has not been possible to precisely define the boundary conditions separating "acute" and "routine" releases in this report. By not considering acute releases, this report may underestimate risks due to USTs in Region VIII.

There are an estimated 71,656 USTs in Region VIII (see Table 1). Of these, approximately 39% are between 110 and 1,999 gallons in volume, with 38% and 23% ranging between 2,000 and 9,999 and 10,000 and 29,999 gallons, respectively. Approximately 91% of the USTs in Region VIII are used for petroleum storage. Fourty-seven percent of the tanks in the Region are between 0 and 10 years of age; however, approximately 21% are over 20 years old or have undetermined ages, see Appendix 1 for additional data regarding the types and distribution of USTs in the Region. However, the estimated universe of releases is approximated at 10-30% of the total registered tanks. Discussion and analysis of this problem area focuses on petroleum products due to the large percentage of lists used for petroleum storage in the Region.

Petroleum products can include a wide variety of commercial products including crude oil, gasoline, fuel oils, and lubricants. There are a number of compounds associated with petroleum, primarily saturated and unsaturated hydrocarbons. In addition, it is common practice to enhance the performance of petroleum products by adding various compounds. Some of the additives may be acutely or chronically toxic. Benzene, toluene, ethylbenzene, and xylene are the compounds that are known to have potentially serious adverse health and environmental effects. A number of studies have been conducted on the human health effects of these constituents, but there is relatively little data on their ecological impact.

7.2 HUMAN HEALTH RISK ASSESSMENT

7.2.1 Toxicity Assessment

Epidemiological literature suggests a relationship between exposure to gasoline, or its constituents, principally benzene, and cancer incidence. To date, only benzene has been causally linked to human cancer. NESCAUM's 1989 study evaluating the health effects due to gasoline exposure offers the following summary of findings from the literature:

- Gasoline is presumed to be carcinogenic to human beings. This finding is based largely on the fact that benzene, a volatile component of gasoline, is an established human carcinogen. Any exposure to gasoline entails benzene exposure. In addition, limited animal data indicates that toluene and xylene, which are also gasoline components, are carcinogenic in rodents. Finally, evidence from epidemiological studies on gasoline suggests that exposure may itself be carcinogenic to humans, irrespective of benzene's carcinogenicity.

- The epidemiological evidence regarding benzene carcinogenicity is widely accepted. The evidence regarding the human carcinogenicity of the gasoline mixture, however, is subject to significant uncertainties. These uncertainties stem from the limited ability of epidemiological studies to identify carcinogens (particularly weak carcinogens), the complexity of the chemical exposures associated with the petroleum industry, and the lack of any clearly defined target organ that gasoline may affect. Moreover, the fact that many epidemiological investigations have been conducted, each one analyzing several types of cancer, raises the concern that apparently significant associations may actually have been random statistical fluctuations. Nonetheless, a more qualitative analysis of the study findings suggests that clearer positive associations could be established upon more rigorous analyses.

Non-cancer health effects have been attributed to the ingestion, inhalation, or dermal exposure to gasoline or its constituents. The most sensitive endpoint for gasoline is kidney toxicity, which has been shown to result from human equivalent exposure in the 2 to 4 mg/kg/day range. The most sensitive endpoints for principal constituents of concern include hematoxicity associated with benzene exposure in the range of 0.1 to 1 mg/kg/day and neurobehavioral, hematological, and immunological effects associated with toluene exposure in the range of 0.5 to 1.5 mg/kg/day. Reproductive and fetotoxic effects have been associated with exposure to xylene at an equivalent dose level of 17 mg/kg/day.

7.2.2 Exposure Assessment

Primary exposure pathways of concern are via contaminated groundwater and soil. Human exposures may occur through ingesting contaminated water, inhaling vapors, and dermal exposure from contaminated water while showering, washing clothes or dishes, or through inhaling vapors penetrating basement or foundation walls. In unusual cases, vapor concentrations may reach levels conducive to fire or explosion. Vapor inhalation may also occur outdoors in areas adjacent to a leaking tank, but this is generally viewed as a less significant exposure pathway.

In addition to the public health hazard posed by the problems outlined above, there is an occupational health and safety hazard resulting from the exposure of environmental remediation workers involved in the removal of leaking underground storage tanks. Failure to render tanks properly inert and improper handling during the removal process may result in explosion. These health risks are not considered in this analysis, as occupational risks are not considered in other problem areas.

The population potentially at risk in Region VIII is defined as those dependent upon groundwater as a primary source of drinking water supplied without benefit of routine monitoring and treatment for volatile organic compounds (VOCs). Such measures would otherwise prevent ingestion of petroleum-contaminated water. Estimated population supplied by groundwater-based public water systems serving populations of 3,300 or less, presented below for the six states in Region VIII and indian lands (see Table 7-2).

This definition of the population at risk may underestimate the population at risk in Region VIII. For example, mountain properties located within large municipal or county jurisdictions are not all hooked up to public water supplies. Boulder County, Colorado (population 200,000) for example, has a number of mountain properties that use private wells and septic systems.

Primary water supply systems serving 3,300 customers or less are not yet required to test for volatile organics. Effective January 1, 1991, all systems serving 25 people or more will be required to sample each water supply source, initially on a quarterly basis, to determine the presence and extent of VOC contamination. Assuming the regulations are observed by smaller systems and are effectively enforced by the Agency, this requirement will substantially reduce the estimated population at risk of ingesting contaminated groundwater.

Note that the population potentially at risk constitutes approximately 14% of total Regional population and ranges from a low of 8% in Utah to a high of 35% in Montana. Note that approximately 60% of the Region's Indian population may be at risk, while approximately 75% of the population residing on Indian Lands utilizes groundwater systems. The assumption that tribal communities larger than 3,300 monitor for VOCs may underestimate health risks. The magnitude of this underestimate is unknown.

7.2.3 Human Health Risk Characterization

Both cancer and non-cancer risks associated with ingesting contaminated groundwater and inhalating vapors from contaminated water have been estimated in NESCAUM's 1989 study of health effects resulting from gasoline exposure. Estimates were based on an analysis of case studies involving leaking underground petroleum storage tanks in New England. Since comparable case study analyses were not available for the states in Region VIII, the NESCAUM exposure scenarios were used to derive estimated annual cancer deaths and non-cancer hazard indices for the population at risk in Region VIII. These data and estimates are presented in Table 7-3 (annual cancer deaths) and Table 7-4 (non-cancer hazard indices).

It is important to emphasize that these estimates are conservative. They are based on many simplifying assumptions necessary to fill primary data gaps or inadequacies. Resulting estimates probably overstate "true" risk levels.

There is considerable uncertainty regarding the comparative human health effects of exposure via ingestion of contaminated drinking water versus inhalation of vapors and dermal exposure from contaminated water while showering, bathing, washing hands, dishes, or clothes. Comparative exposure levels simulated from modeling efforts reported in the literature range from 90+ percent to parity for ingestion versus inhalation. Dermal exposure has been estimated at relatively insignificant levels by comparison to either ingestion or inhalation.

We have confined our attention to cancer and non-cancer risks associated with daily ingestion of two liters of drinking water contaminated by low levels of petroleum or its by-products. Higher exposure levels are assumed to trigger a taste or odor response that effectively limits subsequent exposure. It is further assumed that few, if any, would be subjected to a lifetime of exposure. Available evidence points to much shorter exposure periods. The subchronic level of seven years provides a suitably conservative assumption for purposes of this analysis.

Calculation of non-cancer risk has also been derived with reference to the ingestion of contaminated drinking water. The non-cancer hazard index is computed by dividing estimated exposure levels by the corresponding oral reference doses. Note from the estimates outlined below that ingestion-induced exposure levels for gasoline exceed the oral reference dose for non-cancer effects. Benzene exposure levels are well below the corresponding reference dose for benzene. Toluene and xylene exposure levels are orders of magnitude below their respective reference doses and do not appear to present serious health concerns.

7.3 ECOLOGICAL RISK ASSESSMENT

7.3.1 Toxicity Assessment

Depending on extent of release and proximity to sensitive receptors, UST releases may result in potentially significant adverse ecological effects. The extent of ecosystem damage depends on numerous of factors, including: nature of released material, type of habitat, ecosystem stability, and affected species.

7.3.2 Exposure Assessment

Locations of USTs in Region VIII were not identified in this analysis; therefore, this section contains no site-specific data. However, there is generally a correlation between urban population clusters and UST locations. This is true because the majority of USTs are used by gasoline retailers. In addition, most USTs are located in areas that are not in their original natural state; the areas have been disturbed as a result of urbanization. This does not, however, exclude the possibility that a leaking UST can have significant effects on the environment. Groundwater, surface water, soil, and air are the primary environmental concerns associated with leaking USTs. Contamination from leaking USTs can create environmental problems that can lead to an increase in plant and animal morbidity and mortality.

In a national survey conducted by versar, SCS, and Franklin Associates, 12,444 release incidents from USTs were identified between 1970 and 1984 (Versar, 1986). Of those 12,444 releases, 68% were releases to soil; 45% released to groundwater; 22% released to surface water; and 15% released to air. Gasoline was identified as the released material in 70% of the reported incidents.

Releases from USTs have the potential to adversely affect surface water. A number of factors influence the incidence of surface water contamination from leaking USTs, including: proximity of tank to body of water; materials leaking from tank; amount of released material; groundwater flow; and local soils and geology.

If conditions exist that allow the flow of released material to surface water, the negative ecological impacts can be extensive. Historically, leaks from USTs have not had an overwhelming impact on surface water due to the fact that soil and ground between the leak and the surface water body acts as an attenuator.

Leaking USTs can also affect ecosystems via soil contamination and by releasing to groundwater, which can ultimately contaminate aquifiers and surface water. Soil contamination may adversely affect terrestrial organisms at the lowest level of the food chain. This may expose higher-order organisms to adverse health consequences due to ingestion of contaminated food sources. Groundwater contamination may result in adverse health effects upon plant and animal life at the surface. Ingestion of contaminated water where it emerges in springs or wetland areas represents one exposure pathway. Groundwater may, consequently, contaminate surface waters, presenting immersion or ingestion hazards for a wide range of terrestrial and aquatic organisms.

7.3.3 Ecological Risk Characterization

Severity

Ecological damage resulting from underground storage tank releases generally can be considered low in severity relative to other problem areas. However, there is considerable uncertainty associated with this conclusion.

It is difficult to determine the time frame in which the affected ecosystems will recover from contamination due to leaking underground storage tanks. Oil and gas spills to surface water will evaporate quickly (depending on the extent of the release). If sediments are contaminated, the period of recovery will be extended accordingly. Water temperature and turbidity will also affect the rate of recovery. Groundwater contamination is more complex, and it is difficult to determine the rate of recovery. Contaminated groundwater may affect the overall water supply, which in turn may affect both plant and animal life.

7.4 WELFARE RISK ASSESSMENT

Welfare risks associated with this problem area potentially include:

- cost of illness and lost wages associated with cancer and non-cancer illness;
- loss of groundwater option value, where option value can be thought of as an economic measure of the value of future uses that would be foregone due to contamination;
- costs associated with replacing or testing drinking water contaminated by releases to ground and surface water;
- property value damages associated with explosions or accidents due to leaking USTs;
- aesthetic harms and damages associated with drinking water contamination, as well as the costs associated with private individuals purchasing home drinking water filtration devices; and
- costs associated with clean-up of leaking USTs.

Quantitative welfare damages are based only on an estimate of the annual cost associated with UST clean-up in Region VIII. These costs were estimated by assuming that a mean clean-up cost is $150,000 (Geise, 1990). This damage estimate was multiplied by the number of reported clean-up actions reported by the states in the 1989 Activities Report. A total of 383 enforcement actions to clean-up were reported in 1989. Thus, damages associated with LUST enforcement actions could be approximately $57,450,000 annually in Region VIII.

7.9 BIBLIOGRAPHY

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Table 7-1
Distribution of Known Underground Storage
Tanks in Region VIII by Numbers, Volume, and Age.

State	Total Tanks	Volume of USTs in Gallons					Age of USTs in Years					Pétroleum Tanks
		110-1999	2000-9999	10000-29999	30000-49999	50000+	0-5	6-10	11-15	16-20	>20 or Unknown	
Colorado	20,901	5,851	9,013	5,805	150	82	6,543	4,439	4,180	3,184	3,470	19,043
Montana	18,138	11,120	4,710	2,817	36	85	3,064	4,689	3,827	2,802	4,023	16,936
North Dakota	6,707	2,591	2,330	1,711	23	52	1,538	1,478	943	892	1,971	6,075
South Dakota	6,794	2,800	2,667	1,308	14	5	1,411	1,578	1,199	989	1,737	6,232
Utah	11,112	2,795	4,723	3,506	50	38	2,886	2,495	2,038	1,548	2,090	10,032
Wyoming	8,004	2,757	3,683	1,531	17	16	1,843	1,894	1,416	1,107	1,936	7,229
TOTAL	71,656	27,914	27,126	16,678	290	278	17,285	16,573	13,603	10,522	15,227	65,547

Percent of Total Tanks

Colorado	27.99%	43.12%	27.77%	0.72%	0.39%	31.30%	21.24%	20.00%	15.23%	16.60%	91.11%
Montana	61.31%	25.97%	15.53%	0.20%	0.47%	16.89%	25.85%	21.10%	15.45%	22.18%	93.37%
North Dakota	38.63%	34.74%	25.51%	0.34%	0.78%	22.93%	22.04%	14.06%	13.30%	29.39%	90.58%
South Dakota	41.21%	39.26%	19.25%	0.21%	0.07%	20.77%	23.23%	17.65%	14.56%	25.57%	91.73%
Utah	25.15%	42.50%	31.55%	0.45%	0.34%	25.97%	22.45%	18.34%	13.93%	18.81%	90.28%
Wyoming	34.45%	46.01%	19.13%	0.21%	0.20%	23.03%	23.66%	17.69%	13.83%	24.19%	90.32%
TOTAL	38.96%	37.86%	23.28%	0.40%	0.39%	24.12%	23.13%	18.98%	14.68%	21.25%	91.47%

From: State Surveys of Underground Storage Tanks, Spring 1989. See appendix 1 for a complete data set.

Table 7-2
Population Served by Groundwater Systems
of Less than 3300 People. [1]

State	Population	Ground Water <500	Ground Water Between 501-3300	Total Population at Risk	Percent of Population at Risk
Colorado	3,476,000	138,854	162,165	301,019	8.66%
Montana	703,000	170,027	75,592	245,619	34.94%
North Dakota	551,000	65,557	107,592	173,149	31.42%
South Dakota	650,000	73,169	131,577	204,746	31.50%
Utah	3,143,000	89,838	147,450	237,288	7.55%
Wyoming	866,000	61,691	56,733	118,424	13.67%
Indian	52,000	14,867	15,763	30,630	58.90%
TOTAL	9,441,000	614,003	696,872	1,310,875	13.88%

[1] Data provided by Bob Benson of Region VIII, U.S. EPA, Denver, CO.

Table 7-3
Cancer Risk Assessment

State	Population	Ground Water <500 [1]	Ground Water 501-3300 [2]	Total Population at Risk	Percent of Population at Risk	Population Exposed	Estimated Cancer Deaths	Estimated Annual Cancer Deaths
Colorado	3,476,000	138,854	162,165	301,019	8.66%	19,867	1.19	0.02
Montana	703,000	170,027	75,592	245,619	34.94%	16,211	0.97	0.01
North Dakota	551,000	65,557	107,592	173,149	31.42%	11,428	0.69	0.01
South Dakota	650,000	73,169	131,577	204,746	31.50%	13,513	0.81	0.01
Utah	3,143,000	89,838	147,450	237,288	7.55%	15,661	0.94	0.01
Wyoming	866,000	61,691	56,733	118,424	13.67%	7,816	0.47	0.01
Indian Lands	52,000	14,867	15,763	30,630	58.90%	2,022	0.12	0.00
TOTAL	9,441,000	614,003	696,872	1,310,875	13.88%	86,518	5.19	0.07

[1] Population served by groundwater systems serving populations < 500.
[2] Population served by groundwater systems serving populations between 501 and 3300.

Table 4
Non-Cancer Risk Assessment

	Exposure (mg/kg/day)	Reference Dose (mg/kg/day)	Hazard Index (Exposure/RFD)
Gasoline	1.7 x 10-1	0.1	1.70
Benzene	1.4 x 10-2	0.1	0.14
Toluene	8.1 x 10-3	0.5	0.02
Xylene	8.6 x 10-3	1.2	0.01

APPENDIX 1

SURVEY OF UNDERGROUND STORAGE TANKS - SPRING, 1989

Report for the State of COLORADO, Prepared on October 5, 1989

	Volume of UST in Gallons					
1 Material of Construction	110-1,999	2,000-9,999	10,000-29,999	30,000-49,999	50,000+	Totals
Steel	5,026	7,979	4,433	133	63	17,634
FRP	310	579	1,173	10	4	2,076
Concrete	83	27	26	3	10	149
Unknown	415	424	154	4	5	1,002
Other	17	4	19	0	0	40
Totals	5,851	9,013	5,805	150	82	20,901
2 Contents in UST						
Petroleum	5,259	8,310	5,331	87	56	19,043
Hazardous Mat'l.	20	46	69	2	2	139
Empty	248	286	121	6	4	665
Unknown	19	22	31	0	0	72
Other	254	308	253	52	20	887
Totals	5,800	8,972	5,805	147	82	20,806

Avg. Data Entry Completed: 100.0 Percent
Survey Conducted 06/14/89

Records processed:	
Facility:	8,530
Tank:	23,080
Unreadable Records:	
Facility:	12
Tank:	0
Tanks with:	
Non-numeric Age Data:	0
Missing Age Data:	976
Tanks with:	
Non-numeric Capacity Data:	0
Missing Capacity Data:	434
Unknown Capacity Data:	163
Capacities Less than 110 Gallons:	1,312

SURVEY OF UNDERGROUND STORAGE TANKS - SPRING, 1989

Report for the State of COLORADO, Prepared on October 5, 1989

	Age of UST in Years					
aterial of nstruction	0-5	6-10	11-15	16-20	>20 or Unknown	Totals
Steel	4,590	3,888	3,761	3,005	3,101	18,345
FRP	1,490	323	237	19	24	2,093
Concrete	67	30	15	27	28	167
Unknown	370	195	162	133	309	1,169
Other	26	3	5	0	8	42
Totals	6,543	4,439	4,180	3,184	3,470	21,816
2 Contents in UST						
Petroleum	5,977	4,053	3,811	2,838	3,011	19,690
Hazardous Mat'l.	27	33	54	25	12	151
Empty	199	102	97	171	209	778
Unknown	37	5	30	15	32	119
Other	299	213	161	97	191	961
Totals	6,539	4,406	4,153	3,146	3,455	21,699
3 Corrosion Protect						
odic Protection	1,911	431	336	287	289	3,254
erior Lining	457	165	68	99	165	954
FRP	469	129	92	19	14	723
None	2,396	2,682	2,630	1,990	1,706	11,404
Unknown	1,264	1,035	1,057	795	1,307	5,458
Other	63	9	4	5	4	85
Totals	6,560	4,451	4,187	3,195	3,485	21,878
4 Piping						
Bare Steel	709	579	528	466	755	3,037
Galvanized Steel	2,599	2,422	2,316	1,728	1,452	10,517
FRP	1,893	416	386	257	191	3,143
Cathodic Protection	590	181	120	163	138	1,192
Unknown	928	727	779	597	886	3,917
Other	248	195	127	78	153	801
Totals	6,967	4,520	4,256	3,289	3,575	22,607
5 Ownership						
ate/Corporate	4,741	3,217	2,960	2,341	2,203	15,462
l/State Gov't	951	582	482	310	477	2,802
ral Government	171	136	110	106	373	896
Indian Trust Lands	24	6	15	3	0	48
Uncertain	37	12	18	24	19	110
Totals	5,924	3,953	3,585	2,784	3,072	19,318

SURVEY OF UNDERGROUND STORAGE TANKS - SPRING, 1989

Report for the State of MONTANA, Prepared on October 5, 1989

	Volume of UST in Gallons					
1 Material of Construction	110-1,999	2,000-9,999	10,000-29,999	30,000-49,999	50,000+	Totals
Steel	10,290	4,398	1,868	30	40	16,626
FRP	31	43	53	0	0	127
Concrete	37	11	6	1	3	58
Unknown	558	129	40	0	0	727
Other	204	129	220	5	42	600
Totals	11,120	4,710	2,187	36	85	18,138
2 Contents in UST						
Petroleum	10,292	4,490	2,069	34	51	16,936
Hazardous Mat'l.	29	15	12	0	5	61
Empty	210	68	28	0	3	309
Unknown	48	4	2	0	2	56
Other	519	115	95	2	25	756
als	11,098	4,692	2,206	36	86	18,118

Avg. Data Entry Completed: 100.0 Percent
Survey Conducted 06/08/89

Records processed:
- Facility: 9,441
- Tank: 18,587

Unreadable Records:
- Facility: 0
- Tank: 0

Tanks with:
- Non-numeric Age Data: 16
- Missing Age Data: 12

Tanks with:
- Non-numeric Capacity Data: 2
- Missing Capacity Data: 12
- Unknown Capacity Data: 151
- Capacities Less than 110 Gallons: 129

SURVEY OF UNDERGROUND STORAGE TANKS - SPRING, 1989

Report for the State of MONTANA, Prepared on October 5, 1989

	Age of UST in Years					
1 Material of onstruction	0-5	6-10	11-15	16-20	>20 or Unknown	Totals
Steel	2,816	4,414	3,563	2,613	3,412	16,818
FRP	65	34	19	6	4	128
Concrete	22	17	5	5	12	61
Unknown	41	125	156	109	349	780
Other	120	99	84	69	246	618
Totals	3,064	4,689	3,827	2,802	4,023	18,405
2 Contents in UST						
Petroleum	2,930	4,502	3,646	2,606	3,445	17,129
Hazardous Mat'l.	14	13	6	9	23	65
Empty	32	40	41	32	186	331
Unknown	2	2	2	2	59	67
Other	86	119	129	152	307	793
Totals	3,064	4,676	3,824	2,801	4,020	18,385
3 Corrosion Protect						
nodic Protection	568	199	87	189	183	1,226
erior Lining	90	93	76	61	45	365
FRP	76	56	27	11	13	183
None	1,933	3,482	2,669	1,783	2,068	11,935
Unknown	278	763	884	679	1,448	4,052
Other	118	109	90	82	266	665
Totals	3,063	4,702	3,833	2,805	4,023	18,426
4 Piping						
Bare Steel	371	650	512	395	672	2,600
Galvanized Steel	2,021	2,989	2,385	1,638	1,701	10,734
FRP	142	26	31	29	7	235
Cathodic Protection	193	118	55	50	117	533
Unknown	232	513	548	408	999	2,700
Other	254	445	326	309	613	1,947
Totals	3,213	4,741	3,857	2,829	4,109	18,749
5 Ownership						
Private/Corporate	2,694	4,220	3,439	2,375	3,208	15,936
al/State Gov't	305	315	284	238	304	1,446
eral Government	73	147	91	176	447	934
ian Trust Lands	1	10	5	2	8	26
Uncertain	19	16	35	29	82	181
Totals	3,092	4,708	3,854	2,820	4,049	18,523

SURVEY OF UNDERGROUND STORAGE TANKS - SPRING, 1989

Report for the State of NORTH DAKOTA, Prepared on October 5, 1989

	Volume of UST in Gallons					
1 Material of Construction	110-1,999	2,000-9,999	10,000-29,999	30,000-49,999	50,000+	Totals
Steel	2,398	2,175	1,633	20	46	6,272
FRP	73	86	52	0	0	211
Concrete	12	7	2	1	5	27
Unknown	103	60	23	2	1	189
Other	5	2	1	0	0	8
Totals	2,591	2,330	1,711	23	52	6,707
2 Contents in UST						
Petroleum	2,322	2,140	1,586	19	8	6,075
Hazardous Mat'l.	14	12	12	0	1	39
Empty	123	63	24	0	1	211
Unknown	8	5	4	0	0	17
Other	122	108	81	4	42	357
Totals	2,589	2,328	1,707	23	52	6,699

Avg. Data Entry Completed: 100.0 Percent
Survey Conducted 06/19/89

Records processed:	
Facility:	2,794
Tank:	6,833
Unreadable Records:	
Facility:	0
Tank:	0
Tanks with:	
Non-numeric Age Data:	0
Missing Age Data:	6
Tanks with:	
Non-numeric Capacity Data:	0
Missing Capacity Data:	7
Unknown Capacity Data:	78
Capacities Less than 110 Gallons:	37

SURVEY OF UNDERGROUND STORAGE TANKS - SPRING, 1989

Report for the State of NORTH DAKOTA, Prepared on October 5, 1989

	Age of UST in Years					
Material of :onstruction	0-5	6-10	11-15	16-20	>20 or Unknown	Totals
Steel	1,408	1,366	884	845	1,850	6,353
FRP	109	67	27	5	3	211
Concrete	8	11	4	0	6	29
Unknown	6	32	28	42	111	219
Other	7	2	0	0	1	10
Totals	1,538	1,478	943	892	1,971	6,822
2 Contents in UST						
Petroleum	1,436	1,375	872	809	1,663	6,155
Hazardous Mat'l.	21	14	2	0	3	40
Empty	16	25	25	47	117	230
Unknown	0	1	3	1	20	25
Other	63	63	41	35	162	364
Totals	1,536	1,478	943	892	1,965	6,814
3 Corrosion Protect						
1odic Protection	568	132	68	68	501	1,337
erior Lining	64	38	19	14	39	174
FRP	55	37	20	12	10	134
None	771	1,085	629	522	852	3,859
Unknown	78	186	207	276	570	1,317
Other	2	0	0	0	0	2
Totals	1,538	1,478	943	892	1,972	6,823
4 Piping						
Bare Steel	276	285	194	189	576	1,520
Galvanized Steel	977	924	578	491	883	3,853
FRP	69	19	1	3	2	94
Cathodic Protection	220	48	42	21	422	753
Unknown	83	192	130	180	439	1,024
Other	100	52	32	29	68	281
Totals	1,725	1,520	977	913	2,390	7,525
5 Ownership						
vate/Corporate	1,335	1,291	794	769	1,266	5,455
1/State Gov't	131	140	104	77	117	569
ral Government	60	48	43	44	580	775
Indian Trust Lands	0	0	0	0	0	0
Uncertain	7	0	0	2	9	18
Totals	1,533	1,479	941	892	1,972	6,817

SURVEY OF UNDERGROUND STORAGE TANKS - SPRING, 1989

Report for the State of SOUTH DAKOTA, Prepared on October 5, 1989

	Volume of UST in Gallons					
1 Material of Construction	110-1,999	2,000-9,999	10,000-29,999	30,000-49,999	50,000+	Totals
Steel	2,686	2,532	1,261	14	5	6,498
FRP	22	55	19	0	0	96
Concrete	5	0	1	0	0	6
Unknown	81	79	26	0	0	186
Other	6	1	1	0	0	8
Totals	2,800	2,667	1,308	14	5	6,794
2 Contents in UST						
Petroleum	2,567	2,483	1,169	12	1	6,232
Hazardous Mat'l.	5	7	20	0	0	32
Empty	126	85	16	0	0	227
Unknown	6	3	0	0	0	9
Other	98	71	92	2	4	267
Totals	2,802	2,649	1,297	14	5	6,767

Avg. Data Entry Completed: 10.0 Percent
Survey Conducted 07/10/89

Records processed:	
Facility:	2,887
Tank:	7,455
Unreadable Records:	
Facility:	0
Tank:	0
Tanks with:	
Non-numeric Age Data:	0
Missing Age Data:	496
Tanks with:	
Non-numeric Capacity Data:	0
Missing Capacity Data:	537
Unknown Capacity Data:	53
Capacities Less than 110 Gallons:	17

SURVEY OF UNDERGROUND STORAGE TANKS - SPRING, 1989

Report for the State of SOUTH DAKOTA, Prepared on October 5, 1989

	Age of UST in Years					
Material of onstruction	0-5	6-10	11-15	16-20	>20 or Unknown	Totals
Steel	1,346	1,524	1,158	943	1,609	6,580
FRP	53	25	15	2	2	97
Concrete	2	2	0	1	1	6
Unknown	6	25	25	43	123	222
Other	4	2	1	0	2	9
Totals	1,411	1,578	1,199	989	1,737	6,914
2 Contents in UST						
Petroleum	1,334	1,489	1,092	920	1,465	6,300
Hazardous Mat'l.	2	8	16	3	4	33
Empty	20	20	34	41	140	255
Unknown	0	5	0	0	17	22
Other	40	48	53	25	103	269
Totals	1,396	1,570	1,195	989	1,729	6,879
3 Corrosion Protect						
odic Protection	439	51	35	17	237	779
erior Lining	36	22	19	15	15	107
FRP	44	23	12	9	5	93
None	775	1,153	818	607	790	4,143
Unknown	107	330	318	340	685	1,780
Other	12	0	0	0	6	18
Totals	1,413	1,579	1,202	988	1,738	6,920
4 Piping						
Bare Steel	169	225	202	189	335	1,120
Galvanized Steel	884	1,104	749	569	676	3,982
FRP	104	7	4	1	6	122
Cathodic Protection	209	18	16	13	214	470
Unknown	93	194	189	194	429	1,099
Other	80	36	48	29	59	252
Totals	1,539	1,584	1,208	995	1,719	7,045
5 Ownership						
Private/Corporate	858	988	780	606	855	4,087
l/State Gov't	230	248	168	148	256	1,050
eral Government	50	14	25	25	273	387
Indian Trust Lands	3	3	1	3	16	26
Uncertain	0	3	1	5	20	29
Totals	1,141	1,256	975	787	1,420	5,579

SURVEY OF UNDERGROUND STORAGE TANKS - SPRING, 1989

Report for the State of UTAH, Prepared on October 5, 1989

	Volume of UST in Gallons					
1 Material of Construction	110-1,999	2,000-9,999	10,000-29,999	30,000-49,999	50,000+	Totals
Steel	2,488	4,286	3,018	47	16	9,855
FRP	104	209	384	0	0	697
Concrete	21	22	18	3	18	82
Unknown	174	203	74	0	0	451
Other	8	3	12	0	4	27
Totals	2,795	4,723	3,506	50	38	11,112
2 Contents in UST						
Petroleum	2,433	4,280	3,264	37	18	10,032
Hazardous Mat'l.	9	28	33	3	13	86
Empty	103	113	68	1	2	287
Unknown	9	11	2	1	0	23
Other	238	275	139	8	5	665
tals	2,792	4,707	3,506	50	38	11,093

Avg. Data Entry Completed: 100.0 Percent
Survey Conducted 06/20/89

Records processed:	
Facility:	3,964
Tank:	11,494
Unreadable Records:	
Facility:	7
Tank:	0
Tanks with:	
Non-numeric Age Data:	0
Missing Age Data:	401
Tanks with:	
Non-numeric Capacity Data:	0
Missing Capacity Data:	168
Unknown Capacity Data:	107
Capacities Less than 110 Gallons:	70

SURVEY OF UNDERGROUND STORAGE TANKS - SPRING, 1989

Report for the State of UTAH, Prepared on October 5, 1989

	Age of UST in Years					
1 Material of Construction	0-5	6-10	11-15	16-20	>20 or Unknown	Totals
Steel	2,286	2,233	1,909	1,435	1,917	9,780
FRP	516	133	35	16	12	712
Concrete	22	23	10	6	20	81
Unknown	37	102	84	91	139	453
Other	25	4	0	0	2	31
Totals	2,886	2,495	2,038	1,548	2,090	11,057
2 Contents in UST						
Petroleum	2,629	2,239	1,887	1,396	1,796	9,947
Hazardous Mat'l.	18	25	3	2	38	86
Empty	57	39	44	50	101	291
Unknown	4	5	7	0	5	21
Other	170	183	90	99	150	692
Totals	2,878	2,491	2,031	1,547	2,090	11,037
3 Corrosion Protect						
hodic Protection	1,185	366	342	150	135	2,178
erior Lining	218	119	37	19	32	425
FRP	142	38	16	3	5	204
None	1,065	1,416	1,165	934	1,013	5,593
Unknown	261	557	483	445	912	2,658
Other	18	3	0	1	0	22
Totals	2,889	2,499	2,043	1,552	2,097	11,080
4 Piping						
Bare Steel	265	222	323	152	466	1,428
Galvanized Steel	1,167	1,458	1,204	870	908	5,607
FRP	990	208	110	68	34	1,410
Cathodic Protection	168	53	57	51	67	396
Unknown	255	460	334	386	546	1,981
Other	163	124	58	46	124	515
Totals	3,008	2,525	2,086	1,573	2,145	11,337
5 Ownership						
Private/Corporate	2,321	1,944	1,494	1,143	1,376	8,278
al/State Gov't	283	257	222	181	380	1,323
eral Government	81	76	153	52	193	555
Indian Trust Lands	0	4	0	0	0	4
Uncertain	9	20	8	11	13	61
Totals	2,694	2,301	1,877	1,387	1,962	10,221

SURVEY OF UNDERGROUND STORAGE TANKS - SPRING, 1989

Report for the State of WYOMING, Prepared on October 5, 1989

	Volume of UST in Gallons					
1 Material of Construction	110-1,999	2,000-9,999	10,000-29,999	30,000-49,999	50,000+	Totals
Steel	2,436	3,352	1,405	13	15	7,221
FRP	73	138	87	3	0	301
Concrete	48	15	1	1	1	66
Unknown	181	163	37	0	0	381
Other	19	15	1	0	0	35
Totals	2,757	3,683	1,531	17	16	8,004
2 Contents in UST						
Petroleum	2,446	3,361	1,396	13	13	7,229
Hazardous Mat'l.	24	12	6	2	1	45
Empty	127	177	40	1	0	345
Unknown	10	16	5	0	0	31
Other	149	117	84	1	2	353
als	2,756	3,683	1,531	17	16	8,003

Avg. Data Entry Completed: 100.0 Percent
Survey Conducted 06/15/89

Records processed:
- Facility: 3,320
- Tank: 8,197

Unreadable Records:
- Facility: 0
- Tank: 0

Tanks with:
- Non-numeric Age Data: 0
- Missing Age Data: 1

Tanks with:
- Non-numeric Capacity Data: 0
- Missing Capacity Data: 1
- Unknown Capacity Data: 148
- Capacities Less than 110 Gallons: 44

SURVEY OF UNDERGROUND STORAGE TANKS - SPRING, 1989

Report for the State of WYOMING, Prepared on October 5, 1989

	Age of UST in Years					
	0-5	6-10	11-15	16-20	>20 or Unknown	Total
1 Material of Construction						
Steel	1,570	1,740	1,337	1,030	1,650	7,32
FRP	222	64	18	1	4	30
Concrete	18	12	6	4	28	6
Unknown	24	74	54	71	234	45
Other	9	4	1	1	20	3
Totals	1,843	1,894	1,416	1,107	1,936	8,19
2 Contents in UST						
Petroleum	1,648	1,727	1,316	997	1,665	7,35
Hazardous Mat'l.	26	12	0	7	3	48
Empty	54	61	48	73	128	364
Unknown	1	1	4	1	49	56
Other	114	93	47	29	90	373
Totals	1,843	1,894	1,415	1,107	1,935	8,194
3 Corrosion Protect						
thodic Protection	514	158	82	54	111	919
terior Lining	137	49	12	16	74	288
FRP	104	34	12	3	6	159
None	954	1,270	1,011	686	935	4,856
Unknown	113	378	297	346	807	1,941
Other	21	5	2	2	3	33
Totals	1,843	1,894	1,416	1,107	1,936	8,196
4 Piping						
Bare Steel	252	305	221	173	307	1,258
Galvanized Steel	1,060	1,060	906	605	817	4,448
FRP	207	74	21	23	6	331
Cathodic Protection	202	64	33	32	45	376
Unknown	119	309	220	238	685	1,571
Other	153	120	42	52	103	470
Totals	1,993	1,932	1,443	1,123	1,963	8,454
5 Ownership						
Private/Corporate	1,450	1,655	1,233	936	1,466	6,740
al/State Gov't	356	201	145	130	172	1,004
eral Government	33	34	22	30	270	389
dian Trust Lands	0	0	0	0	0	0
Uncertain	4	4	14	10	24	56
Totals	1,843	1,894	1,414	1,106	1,932	8,189

8.0 ACTIVE HAZARDOUS WASTE FACILITIES

8.1 INTRODUCTION

The Active Hazardous Waste Facilities problem area addresses risks to human health, welfare, and ecosystems posed by facilities that generate, store, treat, and dispose of hazardous wastes. Additionally, this area covers risks associated with the transportation of hazardous waste. Specific facilities and activities covered in this problem area include:

- Hazardous waste generating sites, including industrial plants and other facilities producing and accumulating hazardous wastes that meet the definition of a "Generator" under 40 CFR 260;
- Hazardous waste storage facilities storing wastes in tanks and containers;
- Hazardous waste treatment facilities that treat wastes through physical, chemical, or biological means;
- Hazardous waste incinerators;
- Boilers and industrial furnaces using hazardous waste as fuel;
- Hazardous waste surface impoundments;
- Hazardous waste land treatment facilities;
- Hazardous waste landfills and waste piles;
- Inactive solid waste management units at active; hazardous waste facilities;
- Hazardous waste recycling units which are exempted under current regulation, such as solvent recycling columns; and,
- Hazardous waste transportation.

The types of risks to human health, welfare, and ecosystems resulting from active hazardous waste facilities falling within this problem area include those resulting from accidental or nonaccidental releases of hazardous wastes and waste constituents to air, soils, surface water, and groundwater. Welfare risks are associated with the economic damages caused by these problems and also by the public's perception of risk associated with these sites.

Substances within this problem area include the approximately 450 hazardous wastes listed by EPA in 40 CFR 261, which include various solvents, process wastes, and discarded commercial chemical products, and wastes failing any of the waste characteristic tests defined in 40 CFR 261. Waste characteristics resulting in designation as a characteristic hazardous waste include:

- Ignitability
- Corrosivity
- Reactivity
- EP Toxicity

8.2 POPULATION OF HAZARDOUS WASTE FACILITIES IN EPA REGION VIII

The environmental risks associated with hazardous waste disposal have long been recognized in Region VIII. A 1985 Region VIII report ranked "hazardous waste control as the Region's most difficult environmental problem and number one priority not only because of its potential effects on human health and the high level of public concern it generates, but also because of the overwhelming time, costs and complexity involved in investigation, litigation, and cleanup of waste sites." (EPA, 1985).

Aggregate data reported in 1985 indicate that a total of 21,740 regulated large hazardous waste generators reported generation of 271.0 million tons of hazardous waste nationwide (U.S. EPA, 1989a). Of this total, Table 8-1 shows that Region VIII contained only 1.7% of total large hazardous waste generators, and produced only 0.5% of the total hazardous waste in the nation. Only Region I reported producing less hazardous waste by large hazardous waste generators in 1985. The relationship of hazardous waste generation in Region VIII to other Regions is graphically represented in Figure 8-1, while Figure 8-2 represents hazardous waste generation by state.

The population of active hazardous waste facilities in Region VIII includes several broad categories of facilities, such as generators, interim status or permitted hazardous waste management facilities, and other management facilities that may be exempt from interim status and permitting requirements, such as blenders and burners of hazardous waste fuels.

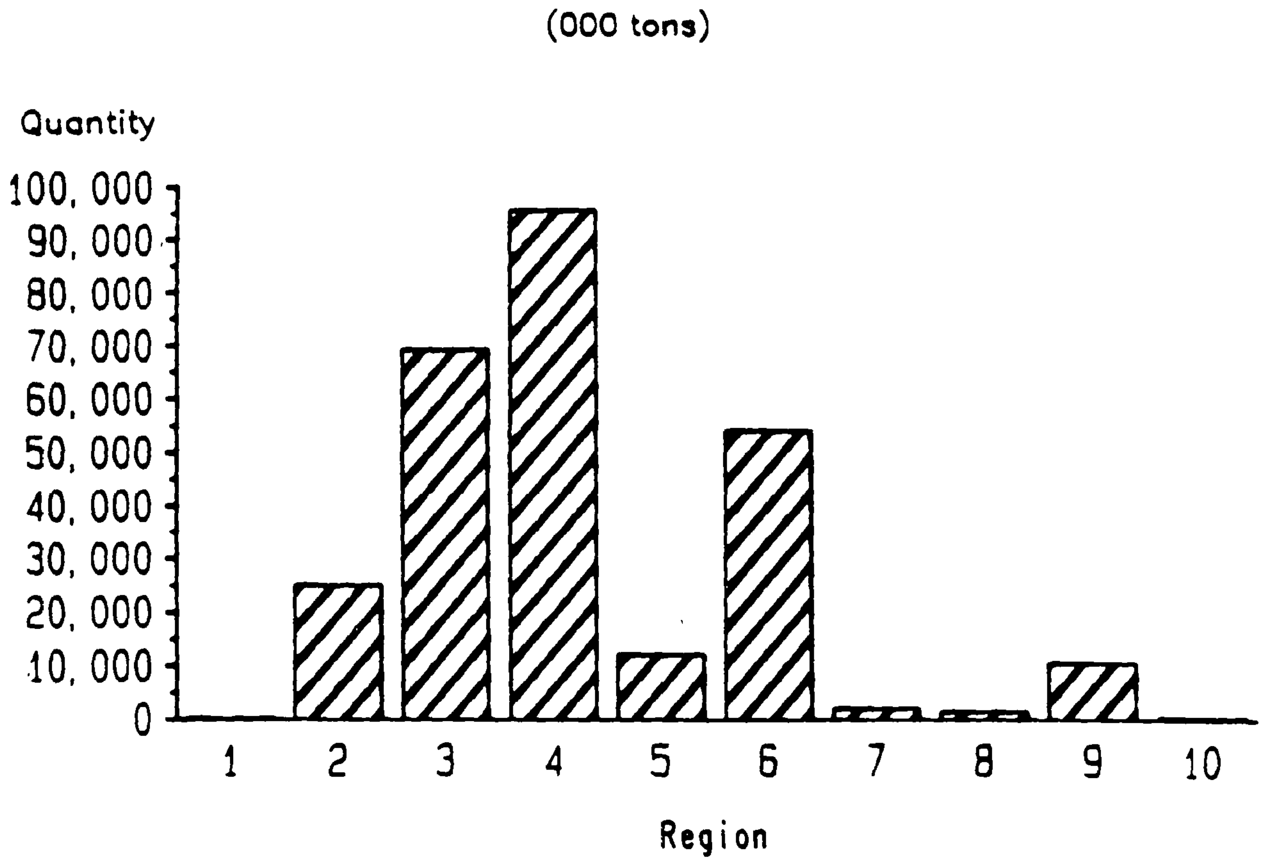
There are 1,391 (Minkoff and Valdez, 1990) large quantity generators of hazardous waste in Region VIII (see Table 8-2). Some of these generators treat or dispose of wastes on site, and are also classified as treatment, storage, and disposal facilities (TSDs). However, the majority of these generators temporarily store wastes in tanks and containers before shipping wastes off-site for treatment or disposal. About 44 large quantity generators have been identified as having violated groundwater protection standards in Region VIII (see Appendix 1).

Table 1
Percent Large Hazardous Waste Generators and Hazardous Waste Quantity Generated by EPA Region, 1985

Region	Hazardous waste generators Percent	Hazardous waste quantity Percent
1	9.6	0.1
2	10.3	9.3
3	15.8	25.5
4	10.3	35.2
5	13.4	4.5
6	14.0	20.0
7	2.4	0.8
8	1.7	0.5
9	19.3	3.9
10	3.3	0.2
TOTAL U.S.	100.0 *	100.0 *

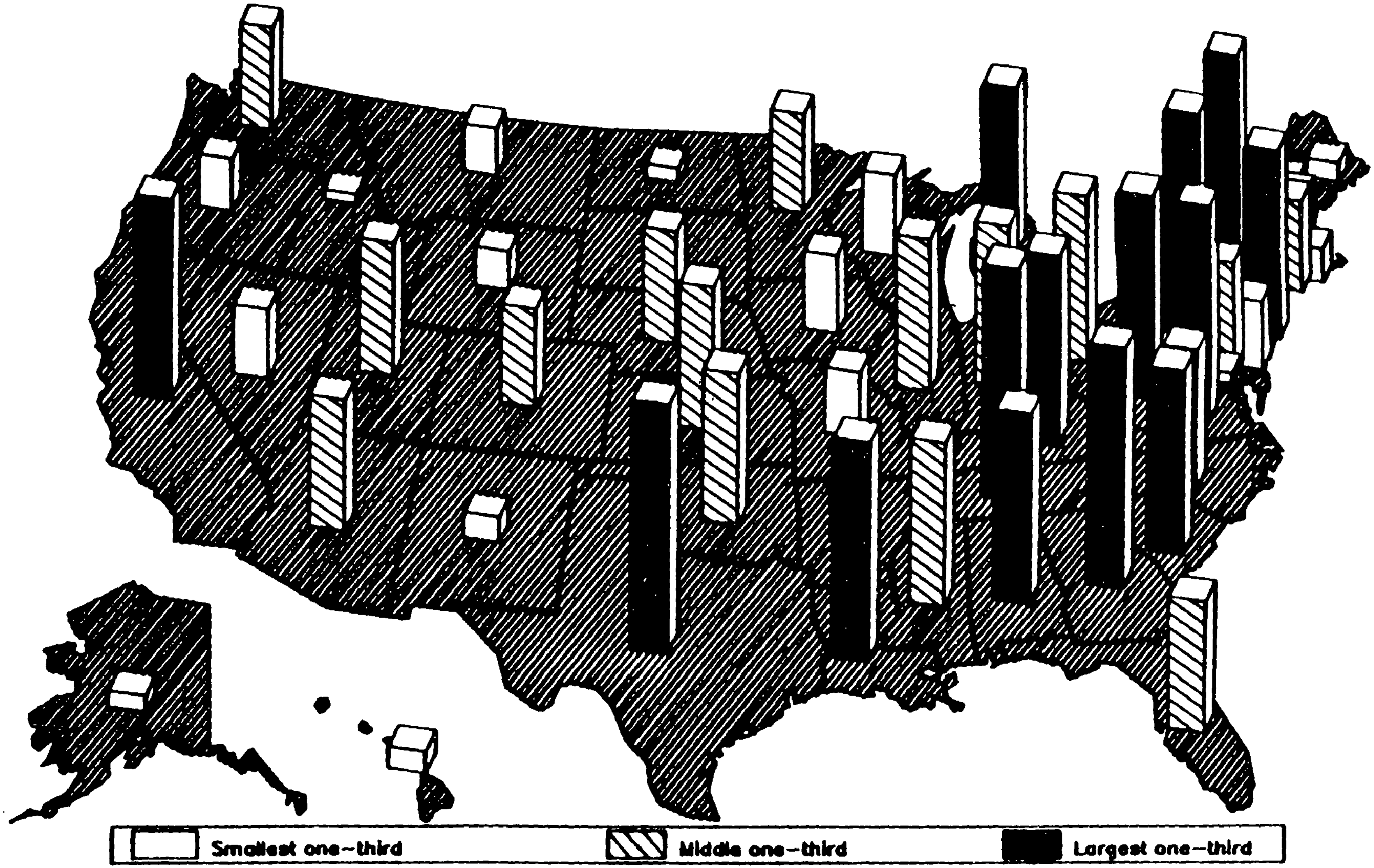
From: U.S. EPA 1989a, prepared by DPRA from the 1985 Biennial Report SAS Data Library. (Sections I and III data. DL88350)

FIGURE 1. AMOUNT OF HAZARDOUS WASTE GENERATED BY EPA REGION, 1985



Source: Prepared by DPRA from the 1985 Biennial Report SAS Data Library. (Sections I and III data. DL88350)

FIGURE 2. HAZARDOUS WASTE GENERATED IN THE U.S. BY STATE, 1985



Source: Prepared by DPRA from the 1985 Biennial Report SAS Data Library. (Sections I and III data. DL88350)

TABLE 2
EPA REGION VIII

07/27/90

Prepared by:
Jon Minkoff and Stella Valdez
RCRA Implementation Branch

HAZARDOUS WASTE NOTIFICATION FIGURES

					TSD Types				Withdrawals					Valid
State	LQG	SQG	Trans	TSD	Stor	Disp	Incin	B/B	NHW	XMT	RCY	CLS	TOT	Notifiers
CO	450	2049	242	53 ~~52~~	30 ~~29~~	22	1/(2)	65	581	59	78	276	994	3007
MT	92	257	73	11	2	9	0	40	41	20	14	67	142	437
ND	69	317	57	8	5	2	1	41	92	7	32	20	151	502
SD	171	212	59	2	2	0	0	18	152	7	41	13	213	425
UT	542	479	140	33	15	16	2/(1)	43	96	84	5	88	273	1153
WY	67	218	84	17	6	11	0	19	209	54	26	62	351	412
Total	1391	3532	655	~~123~~ 124	~~59~~ 60	60	4/(3)	226	1171	231	196	526	2124	5936

NOTE: LQG = large quantity generators (> 1000 kg/mo), SQG = small quantity generators (100-1000 kg/mo), Trans = transporters, TSD = treatment, storage and disposal facilities, TSD Types: Stor = storage &/or treatment only, Disp = disposal and any other processes, Incin = incineration without disposal (#s in parentheses show incineration with disposal), B/B = burner/blenders (used oil or hazardous waste fuel), Withdrawals = notifiers which have withdrawn from the system for the reason indicated: NHW = no hazardous waste (261.3), XMT = exempted from regulation (e.g., mining wastes; 261.4), RCY = recycling exempt (e.g., onsite; 266), CLS = closed business (most are not 264/5 closures), TOT = total withdrawals, Valid Notifiers = waste handlers still fully "in the system" (including SQGs). The number of Valid Notifiers is not equal to sum of generators, transporters, TSDs and burner/blenders because many handlers are engaged in more than one type of activity.

In addition to large quantity generators, there are approximately 3,532 small quantity generators (SQGs) in Region VIII (Minkoff and Valdez, 1990). These SQGs also generally store wastes on-site prior to shipment off-site for treatment or disposal.

There are approximately 1221 interim status or permitted hazardous waste treatment, storage, or disposal facilities in Region VIII (Minkoff and Valdez). These units include surface impoundments, waste piles, landfills, incinerators, land treatment units, storage and treatment tanks, and container storage units. Additionally, there are two facilities which burn hazardous waste fuel, which are exempt from interim status and permitting at this time (Minkoff and Valdez, 1990). The estimated distribution of RCRA Subtitle C Facilities in Region VIII is shown in Table 8-2.

Facilities that have had regulated active hazardous waste units are subject to the corrective action requirements for solid waste management units that are releasing or threaten to release hazardous constituents to the environment. Approximately 56 hazardous waste facilities are estimated to have required or require corrective action for one or more solid waste management units. The distribution of these facilities and current regulatory status is shown in Table 8-3.

8.3 HUMAN HEALTH RISK ASSESSMENT

8.3.1 Toxicity Assessment

Active hazardous waste management facilities manage a wide variety of wastes containing hazardous constituents. The broad categories of wastes and hazardous constituents reported by facilities in Region VIII include:

- Chlorinated and non-chlorinated solvents, including 1,1,1 trichloromethane, trichloroethylene, tetrachloroethylene, methyl ethyl ketone, toluene, xylene, etc.
- General mixtures, including some state-only regulated waste.
- Process wastes and sludges from petroleum refining, chemicals manufacturing, and wood treating containing heavy metals and toxic organics.
- Characteristic wastes that are ignitable, reactive, corrosive, or toxic.

Principal hazardous waste streams are characterized graphically for each state in Figures 8-3 through 8-9. Large quantity waste stream generation is further represented in Tables 8-4 through 8-9. These data indicate that general waste streams characteristics vary significantly across Region VIII states.

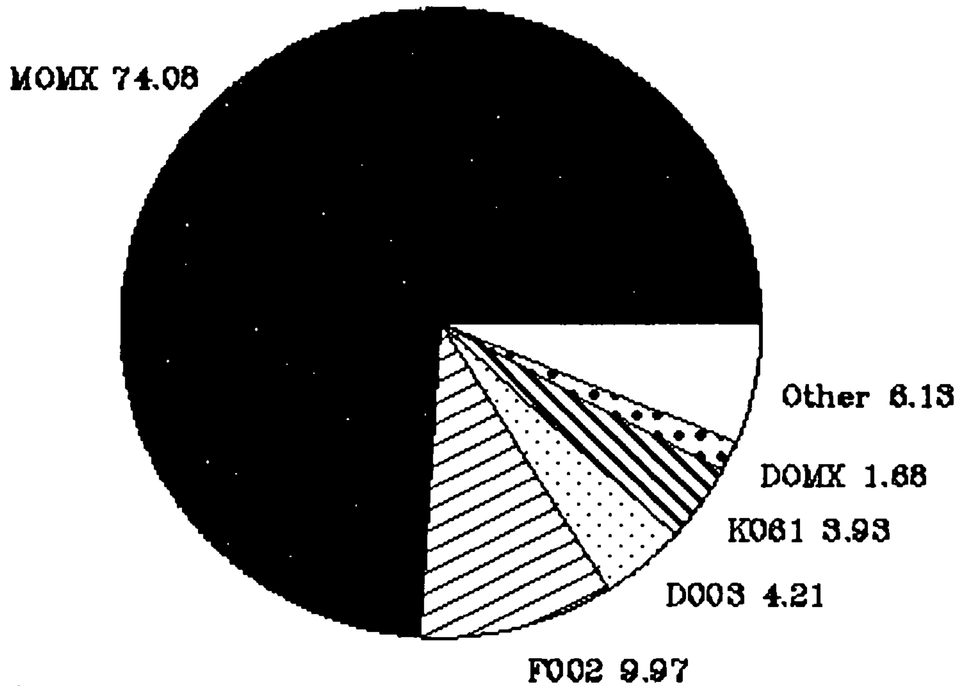
TABLE 3

U.S. ENVIRONMENTAL PROTECTION AGENCY
CORRECTIVE ACTION REPORT 6
NUMBER OF FACILITIES WITH RFA'S AND RFI'S
PART1

STATE	NO. OF RFA COMPLETED	NO. OF RFI IMPOSED	NO. OF WP APPROVED	NO. OF RFI COMPLETED	NO. OF RFI WORKPLAN NOD ISSUED
CO	25	18	11	5	0
MT	4	2	0	0	0
ND	3				
SD	1				
UT	12	4	0	0	0
WY	11	8	1	0	0
TOTAL	56	32	12	5	0

FIGURE 3

Waste Stream Generation
Colorado



MOMX: mixtures, general

F002: spent halogenated solvents

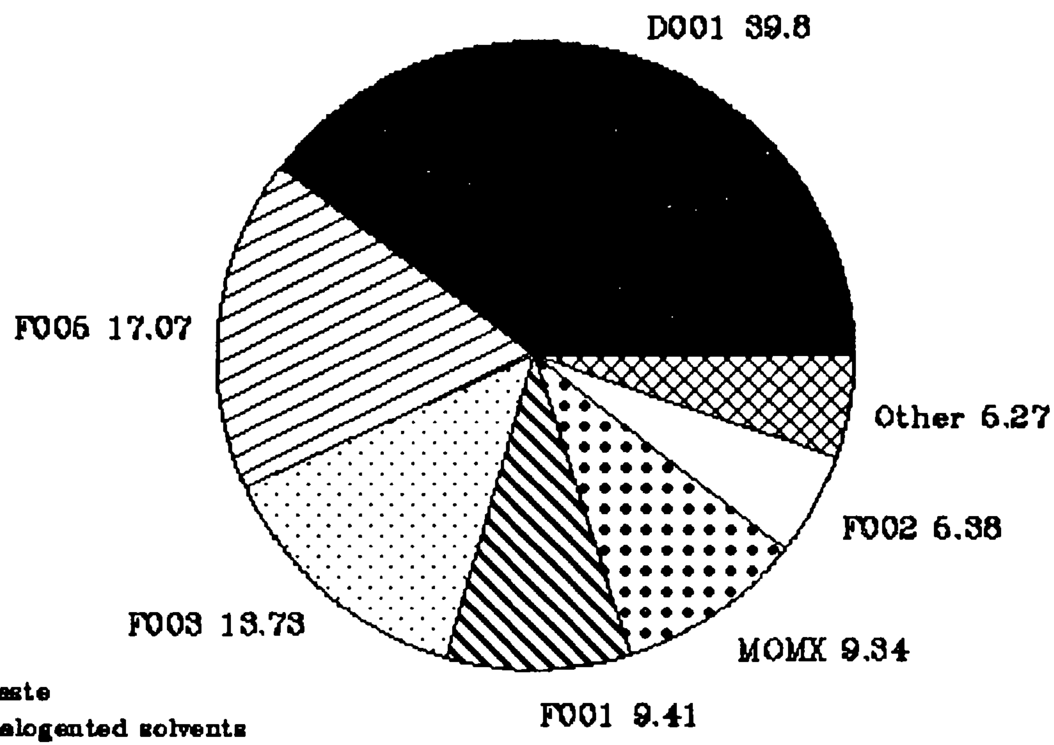
D003: reactive waste

K061: emission control dust/sludge from steelmaking

DOMX: mixtures, characteristic

FIGURE 4

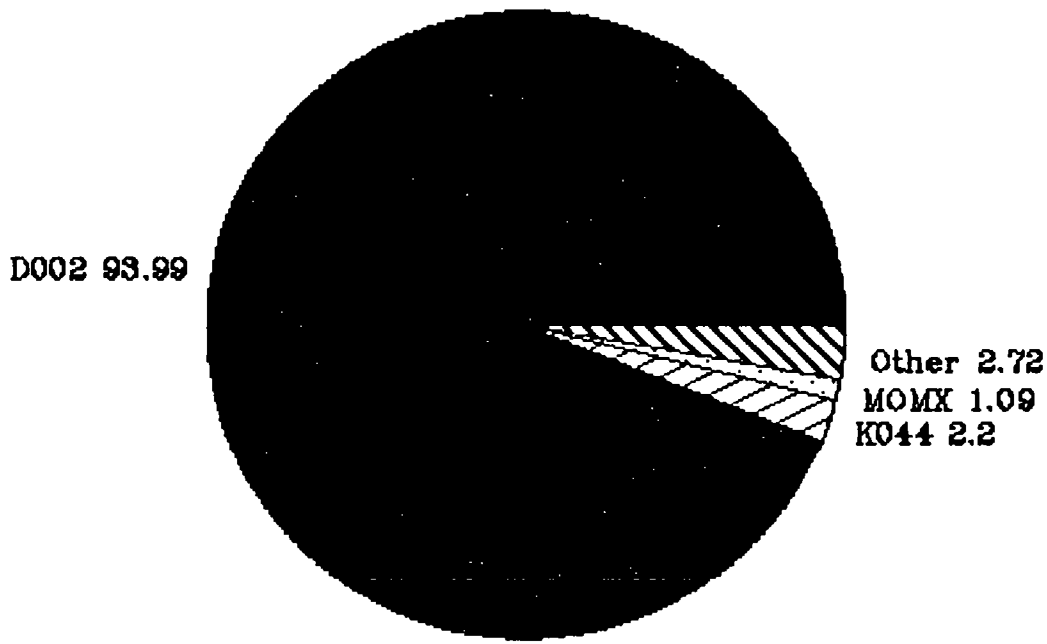
Waste Stream Generation
South Dakota



D001: ignitable waste
F005: spent nonhalogented solvents
F003: spent nonhalogented solvents
F001: spent halogenated solvents
MOMX: mixtures, general
F002: spent halogenated solvents

FIGURE 5

Waste Stream Generation
Utah



D002: corrosive waste

K044: wastewater sludge from production of zinc pigments

MOMX: mixtures, general

FIGURE 6

Waste Stream Generation
Wyoming

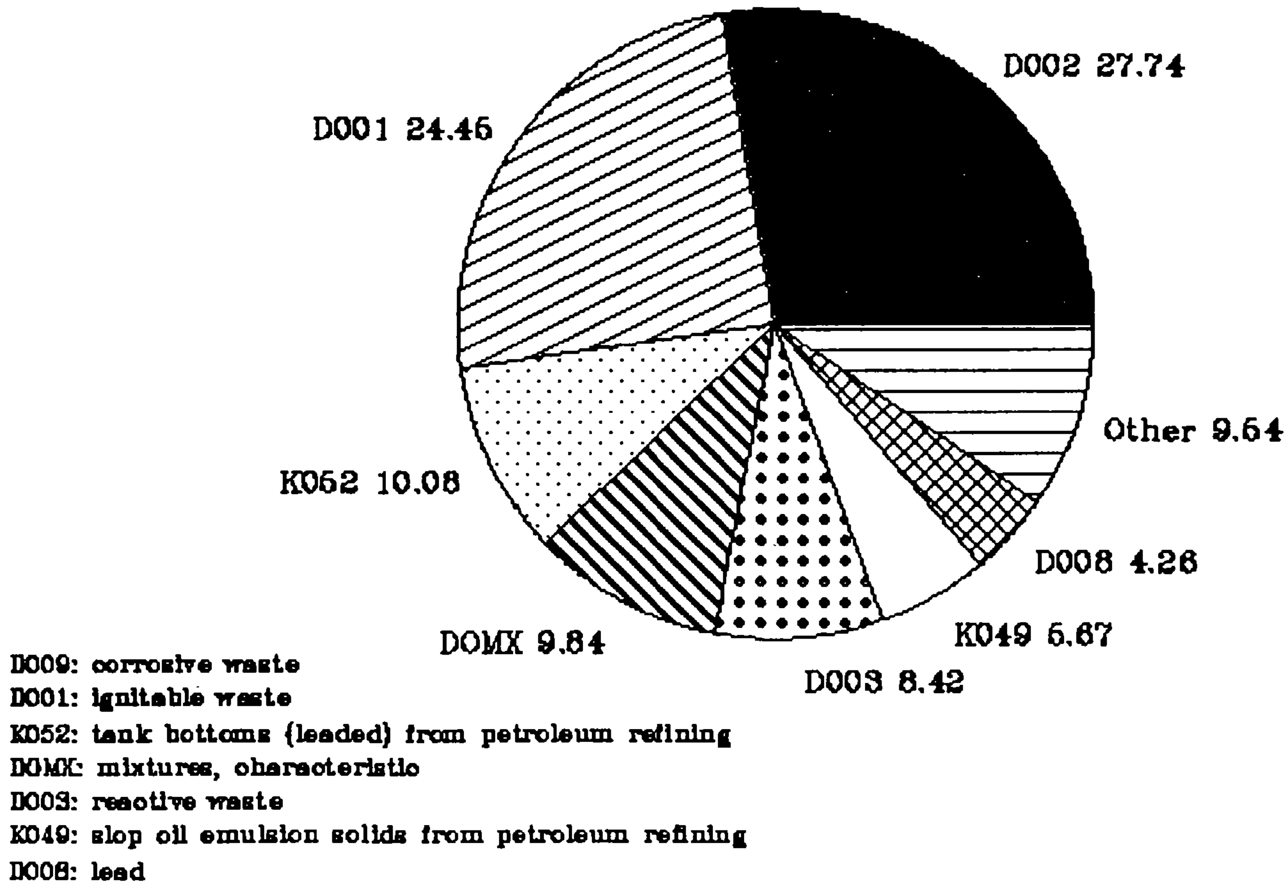
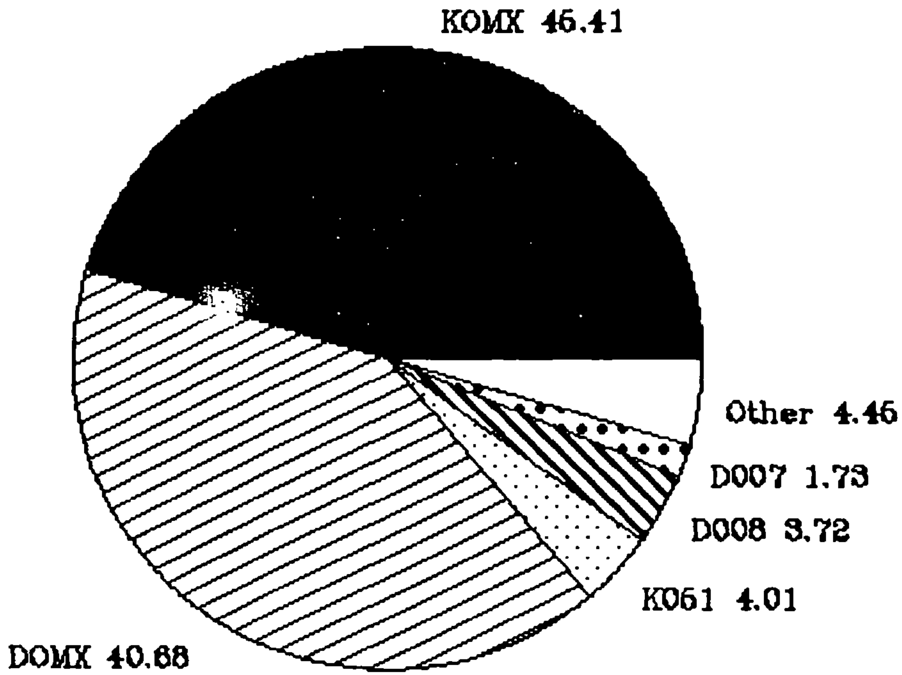


FIGURE 7

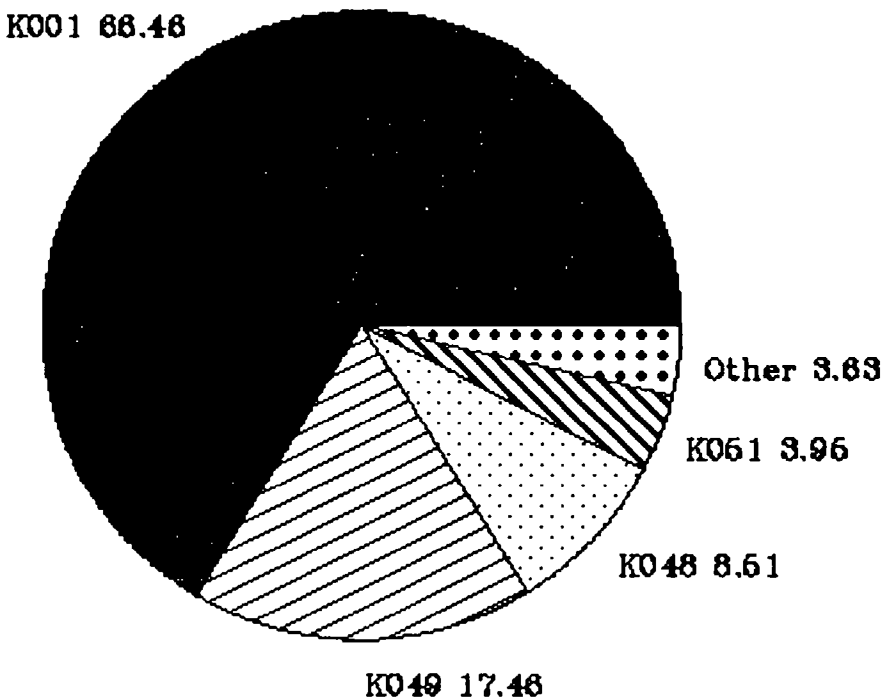
Waste Stream Generation
North Dakota



KOMX: mixtures, listed industrial
DOMX: mixtures, characteristic
K051: API separator sludge from petroleum refining
D008: lead
D007: chromium

FIGURE 8

Waste Stream Generation
Montana



K001: sludge from wastewater treatment from wood preserving
K049: slop oil emulsion solids from petroleum refining
K048: DAF float from petroleum refining
K051: API separator sludge from petroleum refining

TABLE 4
Waste Stream Generation State Ranking - Colorado

National Rank	Waste Code	Quantity Generated in State (tons)	State Waste Code Rank	% of State Total
27	K051	NONE	N/A	N/A
47	K031	NONE	N/A	N/A
36	K047	NONE	N/A	N/A
22	K048	NONE	N/A	N/A
14	K104	NONE	N/A	N/A
41	U188	NONE	N/A	N/A
15	K013	NONE	N/A	N/A
42	K071	NONE	N/A	N/A
16	K011	NONE	N/A	N/A
43	D010	NONE	N/A	N/A
17	K087	NONE	N/A	N/A
46	K002	NONE	N/A	N/A
18	P020	NONE	N/A	N/A
39	K022	NONE	N/A	N/A
37	F024	NONE	N/A	N/A
31	K049	NONE	N/A	N/A
20	K016	NONE	N/A	N/A
23	F007	NONE	N/A	N/A
44	K060	NONE	N/A	N/A
50	K018	NONE	N/A	N/A
49	K083	NONE	N/A	N/A
2	M0MX	218,522	1	74.08
19	F002	29,436	2	9.97
7	D003	12,444	3	4.21
11	K061	11,594	4	3.93
3	D0MX	4,971	5	1.68
9	K062	4,069	6	1.37
8	D001	3,036	7	1.02
4	D007	1,958	8	0.66
12	F0MX	1,915	9	0.64
1	D002	1,668	10	0.56
5	K0MX	1,175	11	0.39
38	D004	925	13	0.31
10	F006	527	14	0.17
25	F005	352	15	0.11
13	D008	301	17	0.10
26	F001	257	18	0.08
6	F003	111	20	0.03
24	U0MX	26	21	0.00
30	K001	24	22	0.00
48	K052	15	24	0.00
28	F019	12	25	0.00
40	K044	8	27	0.00
35	D009	5	32	0.00
29	D005	3	35	0.00
34	F009	3	36	0.00
45	U220	3	40	0.00
32	D000	2	41	0.00
33	D006	2	42	0.00
21	U036	2	48	0.00

TABLE 5
Waste Stream Generation State Ranking - South Dakota

National Rank	Waste Code	Quantity Generated in State (tons)	State Waste Code Rank	% of State Total
23	F007	NONE	N/A	N/A
24	U0MX	NONE	N/A	N/A
50	K018	NONE	N/A	N/A
3	D0MX	NONE	N/A	N/A
43	D010	NONE	N/A	N/A
49	K083	NONE	N/A	N/A
44	K060	NONE	N/A	N/A
46	K002	NONE	N/A	N/A
9	K062	NONE	N/A	N/A
42	K071	NONE	N/A	N/A
27	K051	NONE	N/A	N/A
11	K061	NONE	N/A	N/A
28	F019	NONE	N/A	N/A
48	K052	NONE	N/A	N/A
29	D005	NONE	N/A	N/A
15	K013	NONE	N/A	N/A
30	K001	NONE	N/A	N/A
17	K087	NONE	N/A	N/A
31	K049	NONE	N/A	N/A
47	K031	NONE	N/A	N/A
32	D000	NONE	N/A	N/A
21	U036	NONE	N/A	N/A
33	D006	NONE	N/A	N/A
45	U220	NONE	N/A	N/A
34	F009	NONE	N/A	N/A
7	D003	NONE	N/A	N/A
35	D009	NONE	N/A	N/A
12	F0MX	NONE	N/A	N/A
36	K047	NONE	N/A	N/A
16	K011	NONE	N/A	N/A
37	F024	NONE	N/A	N/A
20	K016	NONE	N/A	N/A
38	D004	NONE	N/A	N/A
5	K0MX	NONE	N/A	N/A
39	K022	NONE	N/A	N/A
14	K104	NONE	N/A	N/A
40	K044	NONE	N/A	N/A
22	K048	NONE	N/A	N/A
18	P020	NONE	N/A	N/A
10	F006	NONE	N/A	N/A
41	U188	NONE	N/A	N/A
8	D001	359	1	39.80
25	F005	154	2	17.07
6	F003	124	3	13.73
26	F001	85	4	9.41
2	M0MX	84	5	9.34
19	F002	49	6	5.38
1	D002	22	7	2.41
4	D007	19	8	2.09
13	D008	6	9	0.70

TABLE 6

Waste Stream Generation State Ranking - Utah

National Rank	Waste Code	Quantity Generated in State (tons)	State Waste Code Rank	% of State Total
15	K013	NONE	N/A	N/A
46	K002	NONE	N/A	N/A
44	K060	NONE	N/A	N/A
20	K016	NONE	N/A	N/A
18	P020	NONE	N/A	N/A
50	K018	NONE	N/A	N/A
49	K083	NONE	N/A	N/A
43	D010	NONE	N/A	N/A
37	F024	NONE	N/A	N/A
14	K104	NONE	N/A	N/A
47	K031	NONE	N/A	N/A
42	K071	NONE	N/A	N/A
36	K047	NONE	N/A	N/A
32	D000	NONE	N/A	N/A
39	K022	NONE	N/A	N/A
16	K011	NONE	N/A	N/A
1	D002	1,066,704	1	93.99
40	K044	25,079	2	2.20
2	M0MX	12,450	3	1.09
31	K049	7,823	4	0.68
27	K051	6,964	5	0.61
3	D0MX	2,626	6	0.23
5	K0MX	2,453	7	0.21
9	K062	2,128	8	0.18
8	D001	1,938	9	0.17
7	D003	1,703	10	0.15
17	K087	1,186	11	0.10
26	F001	831	12	0.07
12	F0MX	648	13	0.05
10	F006	449	14	0.03
19	F002	310	15	0.02
11	K061	272	16	0.02
25	F005	205	17	0.01
6	F003	204	18	0.01
48	K052	148	19	0.01
38	D004	126	20	0.01
13	D008	124	21	0.01
24	U0MX	100	22	0.00
4	D007	76	23	0.00
22	K048	73	24	0.00
28	F019	54	25	0.00
30	K001	40	26	0.00
23	F007	4	32	0.00
33	D006	3	35	0.00
21	U036	1	39	0.00
34	F009	1	41	0.00
35	D009	<1	46	0.00
45	U220	<1	50	0.00
29	D005	<1	53	0.00
41	U188	<1	60	0.00

TABLE 7

Waste Stream Generation State Ranking - Wyoming

National Rank	Waste Code	Quantity Generated in State (tons)	State Waste Code Rank	% of State Total
26	F001	NONE	N/A	N/A
19	F002	NONE	N/A	N/A
20	K016	NONE	N/A	N/A
50	K018	NONE	N/A	N/A
21	U036	NONE	N/A	N/A
47	K031	NONE	N/A	N/A
22	K048	NONE	N/A	N/A
46	K002	NONE	N/A	N/A
23	F007	NONE	N/A	N/A
9	K062	NONE	N/A	N/A
41	U188	NONE	N/A	N/A
11	K061	NONE	N/A	N/A
25	F005	NONE	N/A	N/A
44	K060	NONE	N/A	N/A
40	K044	NONE	N/A	N/A
15	K013	NONE	N/A	N/A
39	K022	NONE	N/A	N/A
42	K071	NONE	N/A	N/A
28	F019	NONE	N/A	N/A
36	K047	NONE	N/A	N/A
29	D005	NONE	N/A	N/A
6	F003	NONE	N/A	N/A
30	K001	NONE	N/A	N/A
10	F006	NONE	N/A	N/A
37	F024	NONE	N/A	N/A
14	K104	NONE	N/A	N/A
32	D000	NONE	N/A	N/A
18	P020	NONE	N/A	N/A
33	D006	NONE	N/A	N/A
45	U220	NONE	N/A	N/A
34	F009	NONE	N/A	N/A
16	K011	NONE	N/A	N/A
12	F0MX	NONE	N/A	N/A
49	K083	NONE	N/A	N/A
35	D009	NONE	N/A	N/A
1	D002	4,375	1	27.74
8	D001	3,856	2	24.45
48	K052	1,590	3	10.08
3	D0MX	1,552	4	9.84
7	D003	1,329	5	8.42
31	K049	895	6	5.67
13	D008	672	7	4.26
27	K051	537	8	3.40
5	K0MX	527	9	3.34
4	D007	194	10	1.23
43	D010	165	11	1.04
2	M0MX	37	12	0.23
24	U0MX	26	13	0.16
17	K087	6	15	0.03
38	D004	3	16	0.01

TABLE 8

Waste Stream Generation State Ranking - North Dakota

National Rank	Waste Code	Quantity Generated in State (tons)	State Waste Code Rank	% of State Total
22	K048	NONE	N/A	N/A
23	F007	NONE	N/A	N/A
50	K018	NONE	N/A	N/A
24	U0MX	NONE	N/A	N/A
21	U036	NONE	N/A	N/A
43	D010	NONE	N/A	N/A
49	K083	NONE	N/A	N/A
40	K044	NONE	N/A	N/A
42	K071	NONE	N/A	N/A
9	K062	NONE	N/A	N/A
10	F006	NONE	N/A	N/A
11	K061	NONE	N/A	N/A
47	K031	NONE	N/A	N/A
39	K022	NONE	N/A	N/A
46	K002	NONE	N/A	N/A
15	K013	NONE	N/A	N/A
38	D004	NONE	N/A	N/A
17	K087	NONE	N/A	N/A
28	F019	NONE	N/A	N/A
41	U188	NONE	N/A	N/A
45	U220	NONE	N/A	N/A
37	F024	NONE	N/A	N/A
30	K001	NONE	N/A	N/A
36	K047	NONE	N/A	N/A
31	K049	NONE	N/A	N/A
14	K104	NONE	N/A	N/A
32	D000	NONE	N/A	N/A
18	P020	NONE	N/A	N/A
33	D006	NONE	N/A	N/A
7	D003	NONE	N/A	N/A
34	F009	NONE	N/A	N/A
16	K011	NONE	N/A	N/A
12	F0MX	NONE	N/A	N/A
20	K016	NONE	N/A	N/A
44	K060	NONE	N/A	N/A
5	K0MX	1,449	1	45.41
3	D0MX	1,298	2	40.68
27	K051	128	3	4.01
13	D008	119	4	3.72
4	D007	55	5	1.73
8	D001	48	6	1.50
19	F002	41	7	1.29
26	F001	16	8	0.49
2	M0MX	14	9	0.43
48	K052	11	10	0.33
1	D002	5	11	0.15
25	F005	2	13	0.05
29	D005	1	14	0.04
6	F003	<1	15	0.00
35	D009	<1	17	0.00

TABLE 9

Waste Stream Generation State Ranking - Montana

National Rank	Waste Code	Quantity Generated in State (tons)	State Waste Code Rank	% of State Total
21	U036	NONE	N/A	N/A
18	P020	NONE	N/A	N/A
19	F002	NONE	N/A	N/A
3	D0MX	NONE	N/A	N/A
20	K016	NONE	N/A	N/A
5	K0MX	NONE	N/A	N/A
41	U188	NONE	N/A	N/A
40	K044	NONE	N/A	N/A
2	M0MX	NONE	N/A	N/A
9	K062	NONE	N/A	N/A
23	F007	NONE	N/A	N/A
11	K061	NONE	N/A	N/A
24	U0MX	NONE	N/A	N/A
38	D004	NONE	N/A	N/A
46	K002	NONE	N/A	N/A
15	K013	NONE	N/A	N/A
37	F024	NONE	N/A	N/A
17	K087	NONE	N/A	N/A
36	K047	NONE	N/A	N/A
50	K018	NONE	N/A	N/A
28	F019	NONE	N/A	N/A
39	K022	NONE	N/A	N/A
29	D005	NONE	N/A	N/A
12	F0MX	NONE	N/A	N/A
14	K104	NONE	N/A	N/A
44	K060	NONE	N/A	N/A
16	K011	NONE	N/A	N/A
49	K083	NONE	N/A	N/A
34	F009	NONE	N/A	N/A
47	K031	NONE	N/A	N/A
42	K071	NONE	N/A	N/A
30	K001	16,730	1	66.46
31	K049	4,396	2	17.46
22	K048	2,141	3	8.50
27	K051	996	4	3.95
48	K052	238	6	0.94
1	D002	209	7	0.83
8	D001	95	8	0.37
33	D006	25	9	0.09
13	D008	18	11	0.07
26	F001	14	12	0.05
6	F003	6	13	0.02
4	D007	4	14	0.01
43	D010	3	15	0.01
25	F005	1	18	0.00
45	U220	1	20	0.00
7	D003	1	21	0.00
32	D000	1	23	0.00
10	F006	1	24	0.00
35	D009	<1	28	0.00

For example, mixed general wastes constitute approximately 74% of the total hazardous wastes generated in Colorado, only approximately 9% in South Dakota and are insignificant in the remaining states. Table 8-10 shows that all Region VIII states except Wyoming are net exporters of Hazardous Waste. Regionwide, approximately 13,607 tons of hazardous waste were imported in 1985, while approximately 35,795 tons were exported.

8.3.2 Exposure Assessment

Potential routes of human exposure to releases of hazardous constituents from hazardous waste sites include exposure through groundwater contamination, surface water contamination, air emissions, and direct contact with hazardous wastes.

In general, exposure through ingestion of drinking water has been identified as the most important route of exposure to hazardous constituents from operating hazardous waste facilities and corrective action sites.

Surface water is not considered to be a significant route of concern for human exposures to contaminants from active hazardous waste sites because water systems which obtain supplies from surface waters are generally public systems. These systems are monitored and treated under provisions of the Safe Drinking Water Act, and potential exposures through complying public systems would be expected to be very low due to the combined factors of dilution in surface water, contaminant reduction through treatment (aeration, flocculation, filtration), and prevention of contaminant exceedences of maximum contaminant levels through monitoring. In particular, new Maximum Contaminant Levels (MCLs) and Maximum Contaminant Levels Goals (MCLGs) will be going into effect shortly for many of the volatile organic hydrocarbons (VOCs) found to contaminant groundwater at hazardous waste facilities; additional MCLs and MCLGs are under development for an expanded list of organic contaminants. Assuming that these standards will be enforced, it is not plausible to project that long term (e.g., 30 years) exposures to contaminants from active hazardous waste sites will occur through surface supplied public water systems.

It is not possible to quantify adequately estimates of human health risks associated with RCRA facilities in the Region. However, it appears that both the cancer and non-cancer risks associated with these facilities are quite small. For example, in a recent risk analysis using very conservative assumptions designed to provide upper bound risk estimates, A.T. Kearney estimated that exposure to hazardous waste from groundwater contamination in Region V was responsible only for 4.1 additional cancer cases. Given that Region V currently reports over 16,600 large quantity generators and a population of approximately 43 million people, if similar calculations were performed for Region VIII, the estimated number of annual cancer cases would be likely to be insignificant.

Table 8-10
Region VIII Hazardous Waste Imports and Exports -- 1985 by Ton

State	Imports	Exports
Colorado	1,214	21,590
Montana	0	389
North Dakota	2	3,178
South Dakota	180	861
Utah		10,883
Wyoming	1,330	515
TOTAL	13,607	35,795

From U.S. EPA 1989.

8.4 ECOLOGICAL RISK

EPA has recently completed a study of available information on ecological risks associated with RCRA Subtitle C facilities (U.S. EPA, 1989b), including both operating hazardous waste management units and inactive units requiring corrective action. The results of this study generally indicate that:

- Due to the focus of the RCRA program on risks to human health, relatively little information is available on ecological risk associated with facilities.

- 52 sites with ecological damages were identified in the study; documentary evidence was available for only 16 of these sites. Because ecological information has not been collected systematically, and is available for so.

- 52 sites with ecological damages were identified in the study; documentary evidence was available for only 16 of these sites. Because ecological information has not been collected systematically, and is available for so few sites, the information available is probably not representative of the nature and extent of ecological risks.

- In the professional judgement of EPA Regional staffs, many Subtitle C facilities probably pose ecological threats, but there is little factual information available to support this judgement.

8.4.1 Toxicity Assessment

RCRA Subtitle C facilities manage a wide variety of wastes which may be toxic to flora and fauna. Observed ecological damages from RCRA facilities include fish kills, diseased benthic (sediment) habitats, chronic or behavioral effects on aquatic and terrestrial plant and animal species, oyster mortality, reduced flora and fauna species diversity, and reduced productivity in wetland habitats (U.S. EPA, 1989b). These damages are associated with releases of toxic heavy metals, organochlorine and other pesticide wastes, and other toxic organics constituents.

From the national study of ecological threats, the primary routes through which ecological damages occur are through migration of contaminated groundwater and/or surface runoff to surface waters or wetlands. In 75 percent of the identified cases, groundwater discharge to surface waters was the route of concern; in 42 percent of the cases, overland flow to surface waters was the route of concern (U.S. EPA, 1989b).

The principal ecological damages of concern identified at Subtitle C facilities are toxic effects on aquatic and wetland organisms, resulting in mortality, reduced species diversity, and reduced productivity. In 83 percent of cases, damages to surface water environments were or primary concern; in 50 percent of the cases, damages to wetlands were of concern (U.S. EPA, 1989b). Only one case identified toxic effects of terrestrial wildlife.

8.4.2 Exposure Assessment

The primary types of waste management units contributing to ecological risks identified in the national study (U.S. EPA, 1989) were operating land disposal units (landfills, impoundments, and waste piles) and inactive units requiring corrective action.

Operating land disposal units are designed, constructed, operated, and monitored to prevent unauthorized (e.g., without a NPDES permit) releases of contaminants to surface waters or groundwaters. Thus, it is unlikely that a large percentage of these operating units would pose a threat to surface water or wetlands with continued inspection and enforcement under the RCRA program.

Units requiring corrective action, however, typically do not meet current operating criteria and frequently have had confirmed releases to the environment. However, information on the extent of damages at sites, and environmental concentrations of contaminants in surface waters, benthic deposits, or organisms, are very scant.

8.5 WELFARE DAMAGES

Known or suspected welfare damages associated with RCRA facilities include:

- the costs associated with replacing or testing drinking water contaminated by releases to surface or groundwater;
- the potential loss of groundwater option value, where groundwater option can be thought of as an economic measure of the value of future uses that would be foregone due to contamination;
- the depreciation of properties in the vicinity of a RCRA facility, including the potential reduced suitability for the development of alternative future uses;
- aesthetic harms and damages such as odors; and
- health care costs and foregone earnings due to illnesses caused by exposure to toxins originating at RCRA facilities.

It has not been possible to develop credible welfare damage estimates associated with this problem area due to numerous uncertainties and data gaps associated with this problem area. Principal uncertainties include:

- The lack of data regarding ground and surface water remediation costs. While some data is available for a number of Corrective Action facilities, it is not possible to credibly extrapolate this data to the universe of RCRA facilities in the Region.
- The lack of data regarding the extent and severity of groundwater contamination due to RCRA facilities in the Region, as well as the absence of any current estimates of groundwater option value. Given the importance of groundwater resources in Region VIII, groundwater option value could be a very significant source of welfare damages in Region VIII.

- The absence of studies evaluating property value effects associated with RCRA facilities in Region VIII, the difficulty of interpreting the current literature regarding these effects (as measured at municipal waste and CERCLA sites), and the inability to readily relate existing site data to commercial and residential property.

- The absence of quantified health effects estimates associated with RCRA facilities.

8.10 BIBLIOGRAPHY

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U.S. EPA. 1989b. The Nature and Extent of Ecological Risks at Superfund Sites and RCRA Facilities. Office of Policy Planning and Evaluation, Washington, D.C.

APPENDIX 1

EPA REGION VIII
INSPECTION - ENFORCEMENT REPORT

07/26/90

FACILITY NAME / CITY	FACILITY ID		INITIAL EVAL DATE / SUBSEQ DATE	TYPE EVAL	INSP	CLAS	GW	CP	FR	PB	CS	MA	OT	LB	CLAS	ENF	AREA OF VIOL	ACTION DATE	COMPLIANCE SCHED	COMPLIANCE ACTUAL	PENALTIES ASSESS	PENALTIES COLLECT
AERO PROPELLER INC / BROOMFIELD	COD078349727	9	020686 12																			
			01 020686	GW S	WA	1	R						X		1	05	GW 01	041988	111589			
			01 011790	CS S	WA	1	S	S					S		1	05	GW 01	041988	011589			
BOULDER SCIENTIFIC COMPANY / MEAD	COD000694869	GTF*	050688 10																			
			01 050688	EI S	JK	1	X	X					X		1	04	OT 01	071189	081189	091189		
			** (C2322) VIOLATION OF INTERIM STATUS;STORAGE VIOLATIONS;																			
BRODERICK INVESTMENTS CO / DENVER	COD000110254	G F* M	122084 01																			
			01 091785	CS E	MD	1	X		X						1	11	GW 01	022886	062886	052886		
															1	08	GW 02	052886	052887	052886		
															1	17	GW 03	052886	052887	052886		
															1	19	GW 04	052886	052887	070186	100000	100000
			** (C2322) PENDING																			
COLORADO STATE UNIVERSITY / FORT COLLINS	COT090011529	GTF* M	021185 05																			
			01 022784	GW E		1	X								1	04	GW 01	062984	073184	011085	17000	
															1	05	GW 02	011085	021085	031486	0	0
			** (C2322) 8/3/83-NO GWM WELLS																			
			011588 21																			
			01 011588	GW S	WA	1	X	O							1	03	GW 01	032188	042188	061989		
CONOCO INC / COMMERCE CITY	COD0606271[illegible]	GTF* M	122784 02																			
			01 122784	EI S		1	X						X		1	04	GW 01	052985	092685	091786		
															1	05	GW 02	091786	111786	050587	38250	38250
			030889 17																			
			01 030889	OT S		1	R								1	16	GW 01	030889				
			** (C2322) ORDER ADDRESS CORRECTIVE ACTION FOR RELEASE;																			
DENVER-ARAPAHOE CHEM WASTE PROCESS FAC / AURORA	COD000695007	G F* M	052082 11																			
			01 052082	EI E	EF	1	X						X		1	04	GW 01	012183	022183	032184	48650	
															1	05	GW 02	032184	041084	041084		990
															1	11	GW 03	011585	021585	102986	40000	
															1	18	GW 04	010885	040885	011585		
															1	19	GW 05	102986	102986	021787		49516
			** (C2322) COMPANY HAS COMPLIED WITH ORDER; STILL LITIGATING PENALTY;\																			
			021986 21																			
			01 021986	GW S	JK	1	X					O	O		1	05	GW 01	103086	123086	112086	0	0
EAGLE PICHER INDUSTRIES INCORPORATED / COLORADO SPRINGS	COD048126726	G F* M	092884 02																			
			01 092884	GW S		1	B				C		X		1	04	GW 01	080585	090585	122986	36000	

FACILITY NAME / CITY	FACILITY ID	INITIAL EVAL DATE / SUBSEQ DATE	TYPE EVAL	INSP	CLAS	GW	CP	FR	PB	CS	MA	OT	LB	CLAS	ENF	AREA OF VIOL	ACTION DATE	COMPLIANCE SCHED	COMPLIANCE ACTUAL	PENALTIES ASSESS	PENALTIES COLLECT
														1	05	GW 02	122986	012987	030587	5000	5000
														1	16	GW 03	122986	122987	050688	0	0
														1	04	CS 01	~~120287~~	010288		38050	
														1	16	GW 04	050688	101188			
		** (C2322) 4/25/85-PRE-WELL INSTALLATION — CORRECTIVE ACTION																			
		120887 22																			
		01 120887	GW S	WA	2	X	O							2	03	GW 01	031688	041688			
		** (C2322) SAMPLING TECHNIQUE USED IS INADQEQUATE;																			
HEWLETT-PACKARD COLORADO SPRINGS DIV																					
COLORADO SPRINGS	COD041099086 G F*	M 030389 13																			
		01 030389	EI S	FD	1	X								1	16	GW 01	010290	060191			
KOPPERS (BEAZER EAST INC)																					
DENVER	COD007077175 GTF*	M 092982 02																			
		01 092982	EI E		1	X						0		1	04	GW 01	092884	102884	061786	33600	
														1	05	GW 02	091988	111988		15000	
														1	16	GW 03	091988	111988			
		** (C2322) 9/29/82-GWM ISSUES, NO FREEBOARD, PROTECTIVE COVERING, SPILL, CONTINGENCY PLAN																			
		102786 08																			
		01 102786	GW S	WA	1	X						X		1	05	GW 01	042088	123088			
		042589 29																			
		01 042589	GW S	NR	1	X								1	04	GW 01	052289				
MARTIN MARIETTA AEROSPACE																					
LITTLETON	COD001704790 GTF*	M 120384 04																			
		01 120384	GW S		1	X								1	05	GW 02	022785	032785	032785		
														1	04	GW 03	022185	030285	030285		
		** (C2322) 12/3/84-PENDING REPORT FROM TES CONTRACTOR ON COMPREHENSIVE MONITORING																			
		022685 11																			
		08 022685	EI S	NJ	1	X					X	X		1	05	GW 01	050786	123086	123086	1000000	520000
														1	04	OT 01	020690	022892			
		110785 13																			
		01 110785	EI E	MF	1	R						0		1	16	GW 01	020786	090786			
NCR MICROELECTRON																					
COLORADO SPRINGS	COD059113142 G	070885 01																			
		01 070885	GW S	WA	1	X						X		1	05	GW 01	061388	083088	101588		
ROCKY FLATS PLANT - US DOE																					
GOLDEN	CO7890010526 G F*	M 081385 05																			
		01 081385	EI S	NJ	1	R					0	X		1	05	GW 01	073186	112886	112886	0	0
														1	16	GW 02	073186	073188			
		081385 07																			
		03 090985	EI S	MP	1	R					0	0		1	16	GW 01	073186	073187		0	0
														1	17	GW 02	073186	073187		0	0

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                                         INITIAL          I  C  A     F EVAL     C
                                         EVAL DATE        N  L                   L E  AREA               COMPLIANCE        PENALTIES
FACILITY NAME                              SUBSEQ  TYPE   S  A  G C F P C M O L A N   OF    ACTION
  CITY              FACILITY ID             DATE   EVAL   P  S  W P R B S A T B S F  VIOL    DATE      SCHED   ACTUAL    ASSESS   COLLECT
                                           ** (C2322) LOIS VISIT FOR GW WELLS AND OBSERVE SAMPLING;

                                           040687  10
                                         01  040687  GW S FD  1  X                 1 03  GW 01 071988  103189  060789
                                           ** (C2322) THIS WAS A 6 DAYS INSPECTION DONE ON 4/1-6-7-8-13-14/87

                                           042288  16
                                         01  042288  RR S PC  1  X             X   1 03  GW 01 071988  103189  060789

                                           011189  24
                                         01  011189  EI S JK  1  H             X   1 04  GW 01 060789  091589  071489
                                                                                   1 05  GW 02 071489  091489
                                                                                   1 22  LB 01 091989  091990
                                                                                   1 03  OT 02 080989  120989
                                           ** (C2322) THIS ORDER COVER INSPECTION FROM 1987 TO PRESENT 9/89;

                                           063089  26
                                         01  063089  GW S PC  1  X                 1 05  GW 01 110389  013090

ROCKY MOUNTAIN ARSENAL
  COMMERCE CITY     CO5210020769 G F*   M  062686  17
                                         01  062686  GW S WA  1  X                 1 18  GW 01 090386  110386  111486
                                                                                   1 11  GW 02 111486  111487

                                           050189  24
                                         01  050189  GW S JE  1  B X     O O X     1 04  GW 01 052389  120189

SYNTEX CHEMICALS INC
  BOULDER           COD076470525 GTF*   M  032988  10
                                         01  032988  RR S FD  1  R             X   1 04  GW 01 061388  022889  092888
                                                                                   1 05  GW 02 092888  022889

SYNTEX LYONS GROUNDWATER CLEANUP PROJECT
  LYONS             COD981551286 G         091087  01
                                         01  091087  EI S TM  1  R             X   1 05  GW 01 120987  123199  021188
                                                                                   1 05  OT 01 081288  013089  021188

TRANSPORTATION TEST CENTER
  PUEBLO            CO6670990039 G         091086  01
                                         01  091086  EI S JJK 1  X           O X   1 05  GW 01 121187  021188  010588

WESTERN SLOPE REFINING (GARY)
  FRUITA            COD067315390 G F*   M  112982  03
                                         01  112982  EI E     1  X             O   1 04  GW 01 042784  062784  022487    94100
                                                                                   1 05  GW 02 022487  032487  081787    18840
                                                                                   1
                                           ** (C2322) 11/29/82-GWM ISSUES, HW ANALYSIS, FREEBOARD, INADEQUATE CONTINGENCY PLAN
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FACILITY NAME / CITY	FACILITY ID	INITIAL EVAL DATE / SUBSEQ DATE	TYPE EVAL	INSP	CLAS	GW	CP	FR	PB	CS	MA	OT	LB	CLAS	ENF	AREA OF VIOL	ACTION DATE	COMPLIANCE SCHED	COMPLIANCE ACTUAL	PENALTIES ASSESS	PENALTIES COLLECT
CONOCO BILLINGS REFINERY																					
BILLINGS	MTD006229405 G F*	M 100583 01																			
		01 100583	EI	S JA	2	X								2	03	GW 01	031484		072186		
		** (C2322) GWM CLASS 3 VIOLATIONS - WL ISSUED 3/14/84																			
		** (C2363) NEW WELLS INSTALLED																			
EXXON BILLINGS REFINERY																					
BILLINGS	MTD010380574 G F*	M 051585 03																			
		01 051585	GW	S RT	2	X								2	10	GW 01	100885	111185	040786		
FARMERS UNION CENTRAL EXCHANGE (CENEX)																					
LAUREL	MTD006238083 GTF*	M 051986 10																			
		01 051986	EI	S PL	2	X								2	03	GW 01	060686		090386		
MONTANA REFINING CO																					
BLACK EAGLE	MTD000475194 G F*	M 091285 07																			
		01 091285	GW	S RT	2	X								2	03	GW 01	041486		060986		
														2	10	GW 02	060986		111286		
														2	10	GW 03	111286	121586	121086		
TRANSBAS INC																					
BILLINGS	MTD079711198 *	M 032483 40																			
		01 032483	EI	S BJ	1	X						X		1	11	GW 01	013184		021788		
														1	18	OT 01	042883		021788		
		01 050383	CS	S BJ	1	X								1	04	GW 01	071483		021788		
														1	11	GW 02	032284	042284	040484	10000	5000
														1	04	GW 03	083183		021788		
		050187 37																			
		01 050187	EI	S BJ	1	X								1	18	GW 01	052087		112487		
														1	11	GW 02	112487		021788	32000	5000

FACILITY NAME / CITY	FACILITY ID		INITIAL EVAL DATE / SUBSEQ DATE	TYPE EVAL	INSP	CLAS	GW	CP	FR	PB	CS	MA	OT	LB	CLAS	ENF	AREA OF VIOL	ACTION DATE	COMPLIANCE SCHED	COMPLIANCE ACTUAL	PENALTIES ASSESS	PENALTIES COLLECT
DAKOTA GASIFICATION CO																						
BEULAH	NDD000690594 GTF*	M	102985 03																			
		01	102985	GW S		2	X					0	0		2	03	GW 01	120685	010586	123085		
FLYING J INC (WESTLAND REFINERY)																						
WILLISTON	NDT390010049 G F*	M	082085 05																			
		01	082085	GW S		2	X								2	03	GW 01	091085	101085	102285		

** (C2322) 8-20-85 MONITORING WELL CONSTRUCTION APPEARED TO BE INADEQUATE FOR COMPLIANCE OF

FACILITY NAME / CITY	FACILITY ID		INITIAL EVAL DATE / SUBSEQ DATE	TYPE EVAL	INSP	CLAS	GW	CP	FR	PB	CS	MA	OT	LB	CLAS	ENF	AREA OF VIOL	ACTION DATE	COMPLIANCE SCHED	COMPLIANCE ACTUAL	PENALTIES ASSESS	PENALTIES COLLECT
			110488 22																			
		01	110488	GW E SZ		1	H	X					X		1	18	OT 01	080789		090789		
															1	19	OT 02	090789			200000	

** (C2322) AWAITING VALID'D LAB ANALYSIS RESULTS. STATE ADVISED OF VIOL'TNS 3-31-89.

INSPECTION - ENFORCEMENT REPORT

FACILITY NAME / CITY	FACILITY ID	INITIAL EVAL DATE / SUBSEQ DATE	TYPE EVAL	INSP	CLAS	AREA OF EVAL: GW	CP	FR	PB	CS	MA	OT	LB	CLAS	EN F	AREA OF VIOL	ACTION DATE	COMPLIANCE: SCHED	ACTUAL	PENALTIES: ASSESS	COLLECT
AMOCO OIL COMPANY SALT LAKE REFINERY																					
SALT LAKE CITY	UTD000826362 GTF*	M 060988 18																			
		01 060988	EI S	WH	1	X					O	O		1	05	GW 01	060689				
			S		2	X					O	X									
														2	03	OT 01	081988	091688	091688		
** (C2322) GW -- CEI																					
		062089 21																			
		01 062089	GW S	JTW	1	S					O	X		1	03	OT 01	101089	110389			
														1	04	OT 02	101089	110389			
BIG WEST OIL / FLYING J																					
NORTH SALT LAKE	UTD045267127 G *	M 011085 03																			
		02 030685	GW S		1	X					O	X		1	03	GW 01	040285	053085	103085		
														1	04	GW 02	040285	053085	103085		
		060989 17																			
		C: 060989	GW S	MG	1	Z		S			O	X		1	03	OT 01	082289	092289	042590		
														1	04	OT 02	082289	092289	042590		
														1	05	OT 03	042590	052490	052490	8000	8000
** (C2322) STIPULATION AND CONSENT ORDER SIGNED 04-25-90.																					
BROWNING MANUFACTURING COMPANY																					
MORGAN	UTD041310558 G	050285 01																			
		01 050285	EI S		1	X						X		1	03	GW 01	080285	090685	070588		
														1	04	GW 02	080285	090685	070588		
														1	05	GW 03	070588	042489	042489	10000	5000
** (C2322) 10-18-85 REFERRAL TO AGENCY FOR PENALTY ASSESSMENT;																					
** (C2342) STIPULATION AND CONSENT ORDER SIGNED 07-05-88.																					
		060487 04																			
		01 060487	GW S		2	Z					O	X		2	03	OT 01	072987	082887	082887		
** (C2322) VIOL IS CONTINUING, FIRST DOCUMENTED 5-2-85;WL ADDRESSES VIOL FOUND 6-4-87;																					
		032588 05																			
		01 032588	GW S	RP	2	S					O	X		2	03	OT 01	051688	062788	052688		
** (C2322) DATE OF VIOLATION DISCOVERY, 880511. GWM VIOLATION ARE CONTINUING, WILL BE																					
** (C2363) ADDRESSED THROUGH CLOSURE.																					
GENEVA STEEL (BMT) (FORMERLY USX)																					
PROVO	UTD009086133 G F*	M 032189 13																			
		01 032189	GW S	JP	2	Z					O	X		2	03	OT 01	052589	062089	061989		
HERCULES INC BACCHUS WORKS																					
WEST VALLEY CITY	UTD001705029 GTF*	M 060686 10																			
		01 060686	RR S	ST	1	X	X	X						1	03	GW 01	060686	070686	060686		
														1	05	GW 02	081688	081688	081689	315000	190000
** (C2322) STIPULATION AND CONSENT ORDER SIGNED 08-16-88.																					
PENNZOIL COMPANY (FORMERLY SEAGULL)																					
ROOSEVELT	UTD073093874 GTF*	M 032085 14																			

INSPECTION - ENFORCEMENT REPORT

FACILITY NAME / CITY	FACILITY ID	INITIAL EVAL DATE / SUBSEQ DATE	TYPE EVAL	INSP	CLAS	GW	CP	FR	PB	CS	MA	OT	LB	CLAS	ENF	AREA OF VIOL	ACTION DATE	COMPLIANCE SCHED	COMPLIANCE ACTUAL	PENALTIES ASSESS	PENALTIES COLLECT
		01 032085	GW S		1	X						0		1	05	GW 01	122386	030287	081889		
** (C2322) EXTENSION OF COMPLIANCE DATE FROM 1-30-87 TO 3-2-87;																					
RIVERSIDE INDUSTRIES INC																					
OGDEN	UTD094667995 G F*	M 020684 19																			
		01 020684	EI S	SA	1	X								1	03	GW 01	021584	051584	071885		
														1	05	GW 02	021584	051584	071885	10000	10000
														1	19	GW 03	071885	081886	081187		
		093087 22																			
		01 093087	GW S	AM	1	Z	Z					Z		1	02	GW 01	102687	120187			
SYRO STEEL COMPANY																					
CENTERVILLE	UTD041075896 G F*	M 012885 01																			
		01 012885	GW S		1	X								1	03	GW 01	022585	032985	120185		
														1	04	GW 02	022585	032985	032685		
** (C2322) ORDER CONTAINS SEVERAL DIFFERENT COMPLIANCE DATES																					
		092387 18																			
		01 092387	EI S	DV	1	B					0	0	0	1	03	GW 01	062388		122888		
														1	16	GW 02	122888				
** (C2322) NO SCH'D COMPL DATE. GWM VIOL'S TO BE ADDRESSED BY EPA'S 3008(H) ORDER.																					
** (C2363) STATE HAS CO PENDING TO RESOLVE ALL PAST VIOL., NOT PART OF 3008(H) ORDER																					
THIOKOL CORPORATION																					
BRIGHAM CITY	UTD009081357 GTF*	M 012885 02																			
		01 012985	GW S		1	X					0	X		1	03	GW 01	031985	050185	110885		
														1	04	GW 02	031985	050185	110885	100000	0
** (C2322) 1/29/85-COMBINATION EVALUATION/GWM INSPECTION																					
TOOELE ARMY DEPOT (NORTH)																					
TOOELE	UT3213820894 GTF*	M 111583 01																			
		01 111583	GW S		1	X								1	03	GW 01	120283	121083	121083		
		011085 04																			
		01 011085	GW S		1	X								1	03	GW 01	020485	020485	020485		
** (C2322) 2/4/85-UNDER REVIEW BY ATTORNEY GENERAL'S OFFICE																					
		052185 07																			
		01 052185	GW S		1	R					0	X		1	05	GW 01	090385	100385	011386		
														1	11	GW 02	011386	031386	030486	47000	47000
														1	16	GW 03	011386	011388			
** (C2322) OVERSIGHT VISIT BY J SILVERNALE																					
		092688 16																			
		01 092688	EI E	MP	1	X	X				X	X	X	1	04	LB 01	032990	050190			
** (C2322) COMPLAINT COVERED LAND BAN... OTHER VIOLATIONS TO BE ADDRESED BY STATE.																					
** (C2363) R3008-90-06																					
USPCI GRASSY MOUNTAIN FACILITY																					
CLIVE	UTD991301748 GTF*	M 011085 18																			
		01 011085	EI X		1	X								1	04	GW 01	091685	110885	101885		

INSPECTION - ENFORCEMENT REPORT

FACILITY NAME / CITY	FACILITY ID		INITIAL EVAL DATE / SUBSEQ DATE	TYPE EVAL	INSP	CLAS	GW	CP	FR	PB	CS	MA	OT	LB	CLAS	ENF	AREA OF VIOL	ACTION DATE	COMPLIANCE SCHED	COMPLIANCE ACTUAL	PENALTIES ASSESS	PENALTIES COLLECT
															1	05	GW 02	101885	110885	101885	0	0
			01 011085	GW S		1	X								1	03	GW 01	020585	030185	101885		
															1	05	GW 02	020585	030185	101885	20000	20000
			040488 54																			
			01 040488	GW S	RP	1	X					O	X		1	03	GW 01	071888	082988	020389		
			** (C2322) NOT. OF VIOLATION.																			
			041789 58																			
			01 041789	GW S	RP	1	Z			X		O	X	X	1	03	PB 01	082989	092989	061990		
															1	04	PB 02	082989	092989	061990		
															1	05	PB 03	061990	091790		180000	180000
			** (C2322) STIPULATION AND CONSENT ORDER SIGNED 6-19-90.																			
UTAH TEST & TRAINING RANGE (HILL AFB) WENDOVE	UT0570090001	F* M	101284 01																			
			01 101284	GW S		1	X					O	O		1	03	GW 01	011585	040185	040285		
															1	05	GW 02	011585	040185	040285	0	0
															1	04	GW 03	011585	040185	040285	0	0
			** (C2322) 10/12/84-COMBINATION EVALUATION/GWM INSPECTION																			
			052385 03																			
			01 052385	GW S		1	X						X		1	03	GW 01	071085	080785	072485		
															1	04	GW 02	071085	080785	072485	0	0
			** (C2322) 5-23-85-OVERSIGHT VISIT BY J. SILERNALE																			
WESTERN ZIRCONIUM INC OGDEN	UTD092024934	G F M	011085 02																			
			01 011085	GW S		1	X								1	03	GW 01	051085	061085	101585	0	0
			** (C2322) 10-15-85 ACTION WAS ISSUANCE OF CP FACILITY HAS CLEAN CLOSED 10-15-85;																			
			** (C2363) STATE ISSUED CLOSURE PLAN.																			

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                                             INITIAL            I  C  AREA OF EVAL        C
                                            EVAL DATE           N  L                      L E   AREA                   COMPLIANCE          PENALTIES
FACILITY NAME                                 SUBSEQ   TYPE     S  A  G C F P C M O L A N   OF     ACTION
  CITY              FACILITY ID                DATE    EVAL     P  S  W P R B S A T B S F   VIOL    DATE       SCHED   ACTUAL      ASSESS    COLLECT

FMC CORP PHOSPHORUS CHEMICAL DIVISION
  KEMMERER          WYD069811404 G F*   M  032289  13
                                         01  032289  EI S TL  2  X          O X O 2 03  OT 01 022190             022190
                                           ** (C2322) CEI (WDEQ LEAD) LDR (WDEQ LEAD)

FRONTIER OIL CHEYENNE REF (HUSKY/RMT)
  CHEYENNE          WYD051843613 G F*   M  122986  13
                                         01  122986  OT E DC  1  R                1 16  GW 01 093088
                                           ** (C2322) SAMPLING CONDUCTED BY FRONTIER IN DEC OF 1986.

JIMS WATER SERVICE INC
  GILLETTE          WYD990829673   F*   M  070881  04
                                         01  070881  GW E DS  1  X    X           1 04  GW 01 102681   112681  020382       12000      5400
                                                                                  1 05  GW 02 020382   020383                   0         C

LITTLE AMERICA REFINING COMPANY
  EVANSVILLE        WYD048743009 GTF*   M  042186  11
                                         01  04228€  GW E DS  1  X                1 04  GW 01 092386   112386  011287       12000
                                                        E     2  X
                                                                                  2 02  GW 01 111786   122086  011287

                                            041088  17
                                         01  041088  EI E DJS 1  R           X    1 08  GW 01 041988   060688  120188
                                         02  120188  CD E TEA 1  R           O    1 16  GW 01 120188   120190
                                         03  061589  CD E TEA 1  X        X  S    1 04  GW 01 061589
                                           ** (C2322) SEC 7003 ORDER ISSUED 4/19/88 DIRECT CIVIL REFERRAL TO DOJ ON 3/31/89.

SINCLAIR OIL CORPORATION
  SINCLAIR          WYD079959185 G F*   M  07098⁵  09
                                         01  070985  EI E     2  X         O O    2 03  GW 01 082885   092885  092885

                                            120285  11
                                         01  120285  GW E JH  1  X         O O    1 04  GW 01 050286   060286  020787        6500
                                                                                  1 05  GW 02 020987   032387  042487        2000      2000
                                           ** (C2322) NO WL SENT, FACILITY RESPONDED VIA CORRESPONDENCE TO PERSONNEL TRAINING

                                            041487  14
                                         01  042487  EI E HAG 2  X           O    2 02  GW 01 012588   022588  021188
                                           ** (C2322) VISUAL SITE INSPECTION;

TEXACO INC
  CASPER            WYD088677943 GTF*   M  060188  12
                                         01  060188  SI E FF  1  R                1 15  GW 01 092988   092991  041289
                                                                                  1 16  GW 02 041289   041292
                                           ** (C2322) THIS ORDER REPLACES INITIAL 3008(H) ISSUED 9/29/88

                                            060288  15
                                         01  060288  OM S MB  2  X                2 03  GW 01 102088   013089  012089

UNION PACIFIC RAILROAD
  LARAMIE           WYD061112470 GTF*   M  042181  01
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EPA REGION VIII
INSPECTION - ENFORCEMENT REPORT

FACILITY NAME / CITY	FACILITY ID	INITIAL EVAL DATE / SUBSEQ DATE	TYPE EVAL	INSP	CLAS	GW	CP	FR	PB	CS	MA	OT	LB	CLAS	ENF	AREA OF VIOL	ACTION DATE	COMPLIANCE SCHED	COMPLIANCE ACTUAL	PENALTIES ASSESS	PENALTIES COLLECT
		01 042181	EI E		1	X	X					O		1	04	CP 01	111083	111083	111083		
														1	05	CP 02	111083	043084	043084		
														1	05	CP 03	071784	113084	113084		

** (C2322) 4/21/81-GWM ISSUES, CLOSURE PLANS, INSPECTION OF SITES, RECORDS

FACILITY NAME / CITY	FACILITY ID	INITIAL EVAL DATE / SUBSEQ DATE	TYPE EVAL	INSP	CLAS	GW	CP	FR	PB	CS	MA	OT	LB	CLAS	ENF	AREA OF VIOL	ACTION DATE	COMPLIANCE SCHED	COMPLIANCE ACTUAL	PENALTIES ASSESS	PENALTIES COLLECT
WYOMING REFINING CO NEWCASTLE REFINERY / NEWCASTLE	WYD043705102 G	M 081881 01																			
		01 081881	EI E	RL	1	X				X		X		1	04	GW 01	010383	020383	020888	60850	
														1	18	AA 01	020888	020889	060188		
														1	19	GW 02	060188	100190		25000	25000
														1	11	GW 03	092686	122686	060188		

** (C2322) RESOLVED BY 6/1/88 CONSENT AGREEMENT

FACILITY NAME / CITY	FACILITY ID	INITIAL EVAL DATE / SUBSEQ DATE	TYPE EVAL	INSP	CLAS	GW	CP	FR	PB	CS	MA	OT	LB	CLAS	ENF	AREA OF VIOL	ACTION DATE	COMPLIANCE SCHED	COMPLIANCE ACTUAL	PENALTIES ASSESS	PENALTIES COLLECT
YELLOWSTONE CODY REF (HUSKY/RMT/BIGWEST) / CODY	WYD006230189 G F*	M 040683 01																			
		02 041284	EI E		1	X	X					X		1	04	GW 01	092884	102884	101084	15380	
														1	05	GW 02	101084	092486	021086	15380	8815

** (C2322) 4/6/83-CLOSURE, GWM, OPERATING W/O A PERMIT, STORAGE OVER 90 DAYS.

FACILITY NAME CITY	FACILITY ID	INITIAL EVAL DATE SUBSEQ DATE	TYPE EVAL	INSP	CLAS	AREA OF EVAL GW	CP	FR	PB	CS	MA	OT	LB	CLAS	ENF	AREA OF VIOL	ACTION DATE	COMPLIANCE SCHED	COMPLIANCE ACTUAL	PENALTIES ASSESS	PENALTIES COLLECT

9.0 ABANDONED HAZARDOUS WASTE SITES

9.1 INTRODUCTION

The Abandoned Hazardous Waste Site problem area covers risks posed to human health and welfare, and ecosystems by abandoned waste treatment, storage, disposal, or recycling facilities, illegal dumpsites, and other abandoned waste sites. Specific categories of sites covered within this problem area include:

- Superfund National Priority List (NPL) sites, including Federal facilities on the NPL.
- State Superfund sites (sites being remedied under state equivalents to the Superfund program).
- Other sites reported to EPA and listed on the CERCLIS site list, including Federal Facility sites, sites which have been scored using the Hazard Ranking System, and sites remaining to be scored.
- Other unmanaged hazardous waste sites which are no longer in operation.

This problem area includes a variety of different types of abandoned sites, including hazardous waste facilities, municipal and industrial waste facilities, mining sites, recycling facilities, illegal dumps, and contaminated sediment sites.

The types of risks covered within this problem area include risks to ecosystems and human health arising from:

- Exposure to contaminants through migration via air, surface water, and groundwater, and through food chain exposures
- Direct contact with wastes or contaminants

Welfare damages associated with Abandoned Hazardous Waste Sites may be due to remediation costs; direct health care costs and foregone earnings associated with adverse health effects; residential willingness to pay for clean up of hazardous waste sites; damage to residential property values near the sites; replacement or treatment costs of contaminated drinking water; loss of groundwater option value; loss of development potential and option values associated with contaminated lands; aesthetic/visual damages; and habitat loss and reduced recreational opportunities.

Region VIII Superfund staff have rightly pointed towards the numerous limitations of this assessment. It should be noted that Region VIII Comparative Risk Project and RCG/Hagler, Bailly, Inc. staff are well aware of the limitations associated with this analysis. However, a more refined analysis would require significantly more resources or Superfund staff effort than were available to support this very limited effort.

9.2 CHARACTERISTICS OF REGION VIII ABANDONED HAZARDOUS WASTE SITES

There are currently 46 sites in Region VIII on the National Priorities List (NPL) - 34 final and 12 proposed. In all, there are over 1,037 sites that have been or are to be reviewed for possible addition to the NPL. About 653 of these sites have been analyzed to some degree and no further remedial action is planned. The remainder have had or will have some sort of additional site characterization work done on them. Table 9-1 summarizes Region VIII site inventory data.

Data describing the location of all sites listed in the CERCLIS database exist, and further descriptive analysis of the distribution of Abandoned Hazardous Waste Sites would be straightforward. However, this analysis has not been conducted in this report as it wouldn't support the development of credible risk estimates given current time and resource constraints.

9.3 HUMAN HEALTH RISK ASSESSMENT

Health risks estimated in this report are based on the Human Health Risk Assessment performed during the Colorado Environment 2000 Project. Health risk data were explicitly evaluated for four Abandoned Hazardous Waste Sites in the Colorado 2000 Project: the Marshall Landfill, Sand Creek, Broderick Wood Products, and the Denver Radium Sites. Best estimate and worst case individual risk estimates were obtained for Marshall Landfill, Sand Creek, and Broderick Wood Products from public health evaluations in Remedial Investigation/Feasibility Studies for these sites. Best estimate and worst case individual risks for Denver Radium were estimated in a recent comparative risk analysis of metro-Denver Superfund sites prepared for the Denver Environmental Strategies Project.

To provide conservative estimates of the range of cancer risks, the report presented a range of individual lifetime cancer risks bounded by the highest worst case and highest best estimate of the risks at the above sites. Consequently, health risk estimates for the population surrounding these Denver sites are probably overestimated. Table 9-2 presents the best and worst case estimates of individual lifetime cancer risks for each pathway of concern at the four sites.

Population exposure estimates were developed for people residents near CERCLA sites in South Adams County based on the number of individuals served by the South Adams County water supply. Estimates developed by the report assume that water supply contamination in South Adams County is similar to contamination at the Sand Creek Site.

Table 9-1
Site Inventory and Progress Toward SARA Targets
As of April 30, 1990

	Region 8
Number of Sites	1,037
Percent of Total Sites	3.18
Number of Proposed NPL Sites	12
Number of Final NPL Sites	34
Non-Federal Sites	
Number of Non-Federal Sites	978
Percent of Total Non-Federal Sites	3.13
Number of PA Sites	888
Number of Non-PA Sites	90
Number of NFRAP PA Sites	653
NFRAP Percent of Non-Federal PA Sites	73.54
Number of SI Sites	289
Number of NFRAP SI Sites	172
NFRAP Percent of Non-Federal SI Sites	59.52
Federal Sites	
Number of Federal Sites	59
Percent of Total Federal Sites	4.51
Number of PA/SI Sites	57
Number of Non-PA/SI Sites	2
Number of NFRAP PA/SI Sites	27
NFRAP Percent of PA/SI Federal Sites	47.37

Table 9-2

Individual Lifetime Cancer Risks for Colorado Inactive Hazardous Waste Sites
(Best/Worst Case Estimates)

Site	Contaminants	Groundwater Ingestion	Air Inhalation	Soil Ingestion/Contact	Groundwater Inhalation	Surface Water Ingestion
Marshall Landfill	heavy metals, VOCs	8E-03/3E-01* (arsenic)	5E-07/1E-05 (1,1-dichloroethene)	low		
Sand Creek	VOCs, semi-volatile organics, heavy metals, pesticides, herbicides	2E-03/9E-03	2E-05/5E-04 (industrial workers) 2E-05/1E-4 (off-site receptors)	3E-07/6E-04* (children) 1E-06/2E-03* (industrial workers)	3E-04/9E-04	
Broderick Wood Products	PAHs, penta, and dioxin			2E-03/9E-02* (PAH, arsenic)		
Woodbury Chemical	VOCs, pesticides	possible exposure	possible exposure	possible exposure		possible exposure
Denver Radium	radiological contamination, heavy metals, organics		1E-02/1E-01	possible exposure		
Lowry Landfill	VOCs	exposure unlikely	possible exposure	possible exposure		possible exposure
Rocky Flats	organic, inorganic, radionuclide contamination	possible exposure	possible exposure	possible exposure		possible exposure
Rocky Mountain Arsenal	toxic and hazardous material, unexploded ordinance	possible exposure	possible exposure	possible exposure		possible exposure
Martin Marrietta	oils, heavy metals solvents	possible exposure	exposure unlikely			
Chemical Sales Corp.	NA	NA				

These risks estimates may be based on an outdated cancer potency factor for arsenic. Estimates based on revised information for arsenic are expected to be lower by approximately one order of magnitude.

The report developed two separate estimates of the exposed population for the South Adams County Sites. The first estimate was for current users of the South Adams County water system who switched from private wells to the public water supply because of private well contamination. The report estimated this population to be 3,000 residents, and assumed that this population was exposed to cancer risks similar to the Sand Creek Site.

A second exposed population estimate was developed for individuals consuming contaminated drinking water from the South Adams County water supply. The report estimated that approximately 27,000 individuals were exposed to TCE concentrations of 26 ppb.

For sites without individual and population cancer risk estimates, the report assumed that the upper bound population risks would be no higher than the highest population risks estimated for eight Superfund sites nationally. Lifetime cancer risks associated with these sites ranged from 5e-2 to 7 per site. The study assumed that there are seven lifetime cases per site for upperbound risk estimate purposes and three and a half cases for best estimate risks.

For the purposes of this study, we assumed lifetime cancer risks to range between 5e-2 and 7 cases each for the 46 NPL Sites in the Region. Estimated cancer cases are summarized for the sites estimated by the report and for the remaining NPL sites in the Region in Table 9-3.

Non-cancer endpoints were not estimated. However, exposure to pollutants originating at Abandoned Hazardous Waste Sites increases risks of systemic disease in an unknown population throughout the Region. Abandoned mining and milling sites pose potentially significant systemic health risks.

9.4 ECOLOGICAL RISK ASSESSMENT

Ecological effects at Abandoned Hazardous Waste sites can be severe. Death, depressed reproduction, and decreased genetic diversity in plant and animal life can result from toxicant release at hazardous waste sites. Most of these sites are contaminated with chemicals that are persistent and bioaccumulative (e.g., PAHs, PCBs, lead, cadmium) and have contaminants present that are acutely toxic to aquatic organisms when present in sufficient concentrations. At lower concentrations, these toxicants can present serious long-term threats to the environment. (Summary of Ecological Risks, Assessment Methods, and Risk Management Decisions in Superfund and RCRA, June 1989).

Table 9-3
Range of Estimated Annual Cancer Cases
Associated with Region VIII NPL Sites

Lower Bound

(5e-2)(46)/70 = .003 annual cancer cases

Upper Bound

(7)(46)/70 = 4.6 annual cancer cases

In this study of ecological risks from Region VIII Superfund sites, limited quantitative information was available. This paucity of information is partially due to reliance on the current Hazard Ranking System (HRS) for placement of sites on the NPL. The inclusion of ecological factors in the current HRS is limited; ecological hazard is scored simply in terms of the distance from a site to the nearest "sensitive environment." Under the current HRS scoring algorithm, NPL listing is impossible for sites where ecological risks are the sole concern. Obviously, sites that score just below the NPL listing threshold based on human health concerns can be pushed past the threshold based on ecological concerns, but ecological risk is not the driving factor. Because superfund remedial action is less likely to occur at a site if it is not listed on the NPL, this is a crucial decision point in the Superfund program, and one in which ecological risk is not an important consideration. The proposed revision to the HRS (53 Req. 51962, December 23, 1988) would expand the consideration of ecological concerns, but at this time it is uncertain to what extent the revisions will affect site placement on the NPL.

Due to data limitations it has not been possible to estimate the ecologic risks posed by Abandoned Hazardous Waste Sites in Region 8. However, EPA's Unfinished Business report ranked Superfund sites as presenting low ecological risks (five on a scale of one to six). This ranking was based on the conclusion that releases from Superfund sites tend to be localized. EPA also concluded that the overall intensity of the impacts is medium, although potentially high on a local level. The Unfinished Business report results do not reflect the widespread ecological risks in Region 8 associated with mining wastes. These risks are further discussed in Chapter 20.

Ecological damages associated with Abandoned Hazardous Waste sites in Region VIII are only beginning to be understood. This is due in part to the complexity of ecological processes, the absence of baseline biological data, and the magnitude of the affected areas. For additional discussion, see Problem Area 20.

9.5 WELFARE RISK ASSESSMENT

Quantitative welfare risk estimates are developed for the following potential damage categories: remediation costs; medical costs and foregone income associated with annual cancer cases; and residential property value decrement.

9.5.1 Remediation Costs

For Abandoned Hazardous Waste sites in the Region that have Records of Decision, remediation costs are summarized in Table 9-4. With the exception of annual operation and maintenance costs, cost data listed in Table 9-4 are not annualized. In addition, due to the

Table 9.4
Record of Decision for Region VIII
Fiscal Year 1982 through 1988

Site Name	State	Threat/Problem	Present Worth/ Capital Costs [1]	O&M Costs [2]
Anaconda Smelter Smelter Facility/ 160- Acre Mill Creek Community	MT	Air contaminated with metals including arsenic, cadmium, and lead	$300,000 pw	
Broderick Wood Products Wood Preserving Facility	CO	Soil, sludge, oil, and wastewater contaminated with VOCs including benzene, organics including PAHs, PCPs and dioxins, and metals including arsenic and lead	$2,264,000 pw $3,603,200	
California Gulch Mining District	CO	SW, sediments, and GW contaminated with metals including cadmium, copper, lead and zinc	$11,982,770 c	$460,307 a
Central City/Clear Creek	CO	Possible contamination of sediments, and downstream SW and GW with organics	$1,663,000 c	$511,000 a
Central City/Clear Creek Mining District	CO	Soil and SW contaminated with metals	$1,049,600 pw	$20,992 a
Denver Radium I 12th & Quivas	CO	Soil contaminated with radium and its decay products	$3,702,800 pw	$290,000 pw
Denver Radium II 11th and Umatilla	CO	Soil and debris contaminated with radium and its decay products	$4,230,300 pw	$194,700 pw
Denver Radium III 1,000 W. Louisiana	CO	Soil and debris contaminated with radium and its decay products	$2,172,800 c	$305,800 pw
Denver Radium/Card Property	CO	Soil, sediment, and debris contaminated with radium and its decay products	$1,148,000 pw	$89,500 pw
Denver Radium/Open Space Property	CO	Soil contaminated with radium and its decay products	$955,400 pw	
Denver Radium/ROBCO	CO	Soil and buildings contaminated with radiu	$1,912,400 c	$6,000 a
Denver Radium Site Streets	CO	Ashpalt contaminated with radium	$30,000 c	variable
Libby Ground Water	MT	Soil and GW contamiated with organics including creosote, and inorganics	PRP responsibility	
Marshall Landfill	CO	GW and SW contaminated with VOCs including TCE & PCE, organics, and metals	$1,819,000 c	$152,000 a

Table 9.4 (cont.)
Record of Decision for Region VIII
Fiscal Year 1982 through 1988

Site Name	State	Threat/Problem	Present Worth/ Capital Costs [1]	O&M Costs [2]
Milltown	MT	GW and soil contaminated with metals including arsenic	$262,714 c	$4,238 a
Milltown	MT	GW and soil contaminated with metals including arsenic	not specified	
North Dakota Arsenic Trioxide	ND	GW contaminated with metals including arsenic	$2,212,600 c	$57,400 a
Rocky Mountain Arsenal	CO	GW contaminated with VOCs including TCE, and inorganics	$8,869,000 c $10,100,000 with	$372,000 a air stripping
Smuggler Mountain	CO	GW and soil contaminated with metals including cadmium and lead	$1,816,550 c	$30,900 a
Union Pacific Railroad	WY	GW and soil contaminated with organics including PCBs and creosote, and inorganics	$7,000,000 c	$57,000 a
Woodbury Chemical	CO	GW, soil and sediments contaminated with pesticides, metals, and organics	$2,450,000 c	$21,000 a

1 pw = present worth, c = capital cost
2 pw = present worth, a = annual cost, and numbers are years annual cost applies

Table 9-4 (cont.)
Record of Decision for Region VIII
Fiscal Year 1989

Site Name	State	Threat/Problem	Present Worth/ Capital Costs [1]	O&M Costs [2]
Burlington Northern Somers Plant	MT	Soil, sediment, and GW contaminated with organics including PAHs and phenols, and metals including zinc.	$11,000,000 pw	$661,000 yrs 1-2 $811,000 yrs 3-10 $72,000 yrs 11-30
Libby Ground Water Contamination Well Field	MT	Soil, sediment, and GW contaminated with VOCs including benzene; other organics including dioxin, PAHs, and PCPs; metals including arsenic; and oil	$5,777,000 pw	$670,200 year 2 $521,200 yrs 3-5 $232,200 yrs 6-8 $80,000 yrs 9-30
Monticello Vicinity Properties Uranium Millsite	UT	Soil, construction materials, and debris contaminated with thorium 230, radium 226, and radon222 contained in the vanadium and uranium mill tailings	$5,915,000 avg Corresponds to $65,000 per property multiplied by 91 properties	
Sand Creek Industrial Former Pesticide Manufacturing Operation	CO	Soil, onsite buildings, and tanks contaminated with VOCs including TCE and PCE; and other organics including pesticides	$5,349,600 pw	not specified
Woodbury Chemical	CO	Soil contaminated with VOCs including PCE and TCE; other organics including pesticides; and metals including arsenic	$6,962,600 pw	$31,400 a

1 pw = present worth, c = capital cost
2 pw = present worth, a = annual cost, and numbers are years annual cost applies

numerous site factors that determine remedial action costs at Abandoned Hazardous Waste sites, it is not possible to extrapolate remediation costs from these sites to the remaining NPL sites in the Region or, even more broadly, to other CERCLIS sites.

9.5.2 Medical Costs and Foregone Earnings

To estimate health effects costs, the annual cancer cases estimated in the previous section were multiplied by the direct medical cost and foregone earnings per cancer case:

(Annual Cancer Cases)(Direct Costs and Forgone Earnings) = HC

where:

HC = health costs

Estimated direct and indirect medical cancer costs are based on a range of cost per case estimates. The lower bound estimate, based on Hartunian, et al., is $80,000, while the upper bound estimate developed by the American Cancer Society is $137,000. These estimates provide differing values for foregone earnings and medical costs. Both estimates are weighted average costs associated with all types of cancers.

Lower bound estimate

HC = (.032($80,000)=$2,560 (1988 $)

Upper bound estimate

HC = (4.6)($137,000)=$630,000 (1988 $).

9.5.3 Residential Property Value Decrement

Results of a growing body of empirical research suggest that values of residential properties increase as the distance of those properties increases from active hazardous waste facilities and other solid waste disposal sites. These studies use econometric analyses to estimate the difference in value or residences near a site and comparable homes further from the site.

Results from these studies indicate that:

> Homeowners in the Boston area are willing to pay from $300 to $500 per mile for a location more distant from a hazardous waste landfill (Smith and Desvouges, 1986).

The mean willingness to pay of homeowners in the Boston area for an increase of 0.8 miles in distance from a superfund site was $69 in the average housing market (Michaels et al., 1987).

McClelland, et al. (1989) determined that, on average, housing prices were $4,793 lower for residents concerned about the proximity of a superfund site than they would have been if residents were not concerned about the site.

To estimate a range in potential damage to property values from these studies, a lower bound estimate of $69 and an upper bound estimate of $500 per exposed home was assumed.

It was not possible to obtain estimates of the number of residences sufficiently near to Region VIII sites to suffer property value damages. To provide a very rough estimate of potential damages, we assumed a range of between 10 and 100 homes to be sufficiently close to sites to suffer property value damages. This results between 460 and 4,600 homes near the 46 NPL sites. Resulting property value damages range from $31,740 to $2,300,000.

9.6 ASSUMPTIONS

The analysis of cancer incidence relies on national data and a highly uncertain extrapolation. These estimates only address potential cancer cases deriving from Region VIII NPL sites and only very imperfectly address the range of carcinogens present at numerous Region VIII sites. We assume that the reliance on national estimates and limiting the scope of the analysis to NPL sites results in a downward biasing of the annual cancer estimates.

We assumed that no credible analysis of non-cancer health effects was possible in the context of this analysis. We are unable to determine the magnitude of error introduced by this assumption.

Quantitative estimates of the ecological risks due to Abandoned Hazardous Waste sites were not prepared. While these risks were considered to be small in the National Comparative Risk Project, ecosystem risks due to mining sites cause significant, yet unquantified damage to ecosystems in Region VIII. See Chapter 20 for an additional discussion of these damages.

The analysis of property values relies on numerous simplifying assumptions that were previously discussed. The most significant being the range of values associated with property value decrement and the housing distribution surrounding sites.

The analysis also assumes that economic damages associated with cancer cases can be adequately described without taking into account the pain and suffering caused by these cancers. This assumption leads to an underestimate of the actual economic damages. We also assume that the costs associated with non-cancer effects are adequately represented as zero, which probably understates damages to some extent. The magnitude of the bias introduced by these assumptions is unknown.

9.7 OMISSIONS

The analysis doesn't consider damages due to lost property redevelopment potential and public tax revenue. These are important sources of damage, but could not be estimated in this analysis.

9.8 RECOMMENDATIONS FOR IMPROVING THE ANALYSES

The analysis of health effects could potentially be improved by developing a statistically based sample of Region VIII NPL sites where health risks have been estimated. If properly stratified, the sample may allow for a broader characterization of health risks than contained in this report.

The development of a readily usable GIS capability to support risk analysis would be very useful in relating Abandoned Hazardous Waste sites to a variety of potentially important receptors, including: population, housing characteristics, property value characteristics, and potentially sensitive ecosystems.

9.9 PRINCIPAL CONTACTS

Paula Cifka
Charles Moar

9.10 BIBLIOGRAPHY

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10.0 MUNICIPAL SOLID WASTE SITES

10.1 INTRODUCTION

The Municipal Solid Waste sites problem area covers risks to human health and welfare, and (MSWS) posed by open or closed land disposal facilities (including landfills and open dumps) used to dispose of municipal refuse. Regulated under Subtitle D of the Resource Conservation and Recovery Act (RCRA), these facilities are not subject to the hazardous waste restrictions under Subtitle C of RCRA. Solid Wastes regulated under RCRA Subtitle D are defined in 40 CFR Part 257 as:

> ...any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant or air pollution control facility and other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities, but does not include solid or dissolved materials in irrigation return flows or industrial discharges which are point sources subject to permits under Section 402 of the Federal Water Pollution Control Act, as amended (86 Stat. 880), source, special nuclear, or by product material as defined by the Atomic Energy Act of 1954, as amended.

The following types of Subtitle D wastes have been identified (U.S. EPA, 1988):

- Municipal solid waste;
- Household hazardous waste;
- Municipal sludge;
- Municipal waste combustion ash;
- Infectious waste;
- Industrial nonhazardous waste;
- Very-small-quantity generator hazardous waste;
- Construction and demolition waste;
- Agricultural waste;
- Oil and gas waste;

- Utility waste; and,
- Mining waste.

This problem area considers risks associated with all of the above waste types with the exception of industrial nonhazardous waste, which is treated in problem area 11.

Table 10-1 lists the estimated contents of a typical Municipal Solid Waste Landfill. Considered in more detail, waste streams relevant to this problem area are:

Municipal solid waste (MSW) is a mixture of household, institutional, commercial, and municipal solid waste. The composition of MSW varies, by generally more than half (by weight) is paper products and yard waste. In 1986, approximately 158 million tons of MSW were generated in the United States. Table 10-2 describes Subtitle D Waste categories and U.S waste quantities, as described in U.S. EPA (1988). Table 10-3 shows the current estimated composition of MSW in the U.S.

Household hazardous waste (HHW) is waste generated by households that meets the technical definition of hazardous waste, but is exempted from Subtitle C regulations. "Typical" HHW includes automotive products, home maintenance products, household cleaners, lawn and garden products, and miscellaneous wastes, eg., batteries, pool chemicals, and nail polish remover.

Municipal sludge (MS) includes both drinking water and wastewater treatment sludges. Drinking water treatment processes produce sludge that consists of a variety of organic and inorganic materials. The concentration of these materials is a function of the treatment process chosen and the raw water quality used. Municipal sewage treatment is accomplished principally through biological processes. These result in primarily organic sludges.

Municipal waste combustion ash is produced in MSW fuel combustion. Approximately 6% of all MSW generated is incinerated at energy recovery facilities, producing fly ash and bottom ash wastes.

Infectious wastes are defined by the EPA Guided for Infectious Waste Management as wastes capable of producing an infectious disease. The U.S. EPA (1988) has estimated that between 8 to 13 pounds of infectious wastes are generated by each hospital bed, daily. These wastes include: isolation wastes, cultures and stocks of infectious agents, human blood, pathological wastes, contaminated sharps (needles), and contaminated animal parts.

Tires. The U.S. EPA (1988) estimated that over 70% of the discarded tires (approximately 168 million/year) are discarded in landfills or junkyards.

Table 10-1
Wastes Disposed of in a Typical
Municipal Solid Waste Landfill

Waste Types	Waste Composition Percentage (mean value) (a)
Household Waste	72.00%
Commercial Waste	17.00%
Construction/Demolition Waste	6.00%
Industrial Process Waste	2.73%
Other Waste	1.18%
Sewage Sludge	0.50%
Other Incinerator Ash	0.22%
Asbestos-Containing Waste	0.16%
Municipal Incinerator Ash	0.08%
VSQG Hazardous Waste	0.08%
Infectious Waste	0.05%

SOURCE: U.S. EPA (1988)
(a) Percentages are rounded and do not add to 100 percent.

Table 10-2
Wastes Disposed of in a Typical
Municipal Solid Waste Landfill

Waste Category	Estimated Annual Generation Rate (million tons)
Industrial Nonhazardous Waste	7,600 (a,b)
Oil and Gas Waste (c)	
- drilling waste	129 - 871 (d,e)
- produced waters	1,966 - 2,738 (e,f)
Mining Waste (c)	>1,400 (g)
Municipal Solid Waste	158 (b)
- household hazardous waste	0.002 - 0.56 (b)
Municipal Waste Combustion Ash	3.2 - 8.1 (h)
Utility Waste (c)	
- ash	69 (i)
- flue gas desulfurization waste	16 (i)
Construction and Demolition Waste	31.5 (j)
Municipal Sludge	
- wastewater treatment	6.9 (b)
- water treatment	3.5 (b)
Very-Small-Quantity (b) Generator Hazardous Waste (<100 kg/mo)	0.2 (e)
Waste Tires	240 million tires (g)
Infectious Waste	2.1 (e,l)
Agricultural Waste	Unknown
Approximate Total	>11,387

SOURCE: U.S. EPA (1988)

(a) Not including industrial waste that is recycled or disposed of off site.
(b) These estimates are derived from 1986 data.
(c) Waste category is the subject of a separate report to Congress.
(d) Converted to tons from barrels: 42 gals = 1 barrel, ~17 lbs/gal.
(e) These estimates are derived from 1985 data.
(f) Converted to tons from barrels: 42 gals = 1 barrel, ~8 lbs/gal.
(g) These estimates are derived from 1983 data.
(h) This estimate is derived from 1988 data.
(i) These estimates are derived from 1984 data.
(j) This estimate is derived from 1970 data.
(k) Small quantity generators (100-1,000 kg/mo waste) have been regulated under RCRA, Subtitle C, since October 1986. Before then, approximately 830,000 tons of small-quantity generator hazardous wastes were disposed of in Subtitle D facilities every year.
(l) Includes only infectious hospital waste.

Table 10-3
Average Annual U.S. Waste Stream Quantity and Composition

	Amount (millions of) tons	Percent of Waste Stream (%)
Paper & Paperboard	64.7	41.0
Glass	12.9	8.2
Metals	13.7	8.7
Plastics	10.3	6.5
Rubber & Leather	4.0	2.5
Textiles	2.8	1.8
Wood	5.8	3.7
Food Waste	12.5	7.9
Yard Waste	28.3	17.9
Other	2.7	1.7
TOTAL	**157.7**	**99.9**

Source: National Solid Waste Management Association, 1989, in "Interim Report of the Governor's Task Force on Integrated Solid Waste Management," 1990.

Very Small-Quantity-Generator Waste is waste that meets the definition of 40 CFR Part 261, and is generated at rates less than 100 kg/month. SQGs are estimated to generate approximately 1 million tons of hazardous waste annually in the U.S., and VSQGs produce about 20% of this waste. Table 10-4 summarizes national estimates of the number of VSQGs and waste quantities for the U.S.

Construction and demolition waste includes mixed lumber, roofing and sheeting scraps, broken concrete, asphalt, brick, stone, plaster, wallboard, glass, piping, and other building materials. Estimated quantities of demolition and construction waste range from 0.12 to 3.52 pounds per capita per day nationally (U.S. EPA, 1988).

Agricultural Wastes include animal wastes from feedlots and farms, crop production wastes, irrigation wastes, and collected field run-off.

Oil and Gas Waste is characterized by high concentrations of chloride, total dissolved solids, barium, sodium, and calcium.

Utility Wastes. Approximately 90% of the wastes generated during the combustion of fossil fuels are associated with coal-fired electric power plants. In 1984, coal-fired power plants generated 69 million tons of ash and 16 million tons of flue gas desulfurization wastes in the U.S. (U.S. EPA, 1988).

Mining Waste includes wastes from crushing, screening washing, flotation, smelting, and refining mined materials. High concentrations of heavy metals, sodium, and potassium may be associated with these waste streams.

MSWS threaten human health and ecosystems through air emissions of volatile toxic chemicals and methane gas, subsurface methane migration resulting in potentially explosive conditions in structures, and ground and surface water contamination by landfill leachate containing organic and inorganic toxic contaminants and/or pathogenic substances. Contamination may occur through subsurface migration, runoff, evaporation or wind erosion.

10.2 POPULATION AND DISTRIBUTION OF MUNICIPAL SOLID WASTE SITES

There are approximately 780 operating municipal solid waste landfills in Region VIII. The population of open municipal solid waste landfills distributed by state is shown in Table 10-5. We were unable to determine the spatial distribution of municipal waste sites in Region VIII. However, Figure 10-1 shows the current distribution of sites in Colorado.

In addition to these operating landfills, there are an undetermined number of closed municipal landfills in EPA Region VIII.

Table 10.4
Number of Small-Quantity Generators and Waste Quantity
Generated by Waste Stream

Waste Stream*	VSQGs: Generators of <100kg of Hazardous Waste/Month (Subtitle D Waste) Number of Generators	Waste Quantity (ton/yr)
Arsenic wastes	21	8
Cuanide wastes	587	19
Dry cleaning filtration residues	13,168	5,674
Empty pesticide containers	9,809	1,424
Heavy metal dust	48	11
Heavy metal solutions	15	7
Heavy metal waste materials	121	34
Ignitiable paint waste	12,788	2,028
Ignitable wastes	8,951	1,001
Ink sludges containing chromium or lead	1,093	99
Mercury wastes	19	1
Other reactive wastes	1,133	97
Paint wastes containing heavy metals	381	13
Pesticide solutions	3,207	1,153
Photographic wastes	21,287	4,856
Solutions of sludges containing silver	4,482	1,033
Solvent still botoms	2,114	126
Spent plating wastes	3,960	543
Spent solvents	77,629	21,420
Strong acids or alkalies	13,739	2,170
Used lead-acid batteries	119,747	71,495
Waste formaldehyde	11,930	3,805
Waste inks containing flammable solvents or heavy metals	3,642	290
Waste pesticides	2,852	441
Wastes containing ammonia	1,154	106
Wastewater containing wood	88	29
Wastewater sludges containing heavy metals	894	207
Total	314,679	118,090
Total**	314,859	118,090

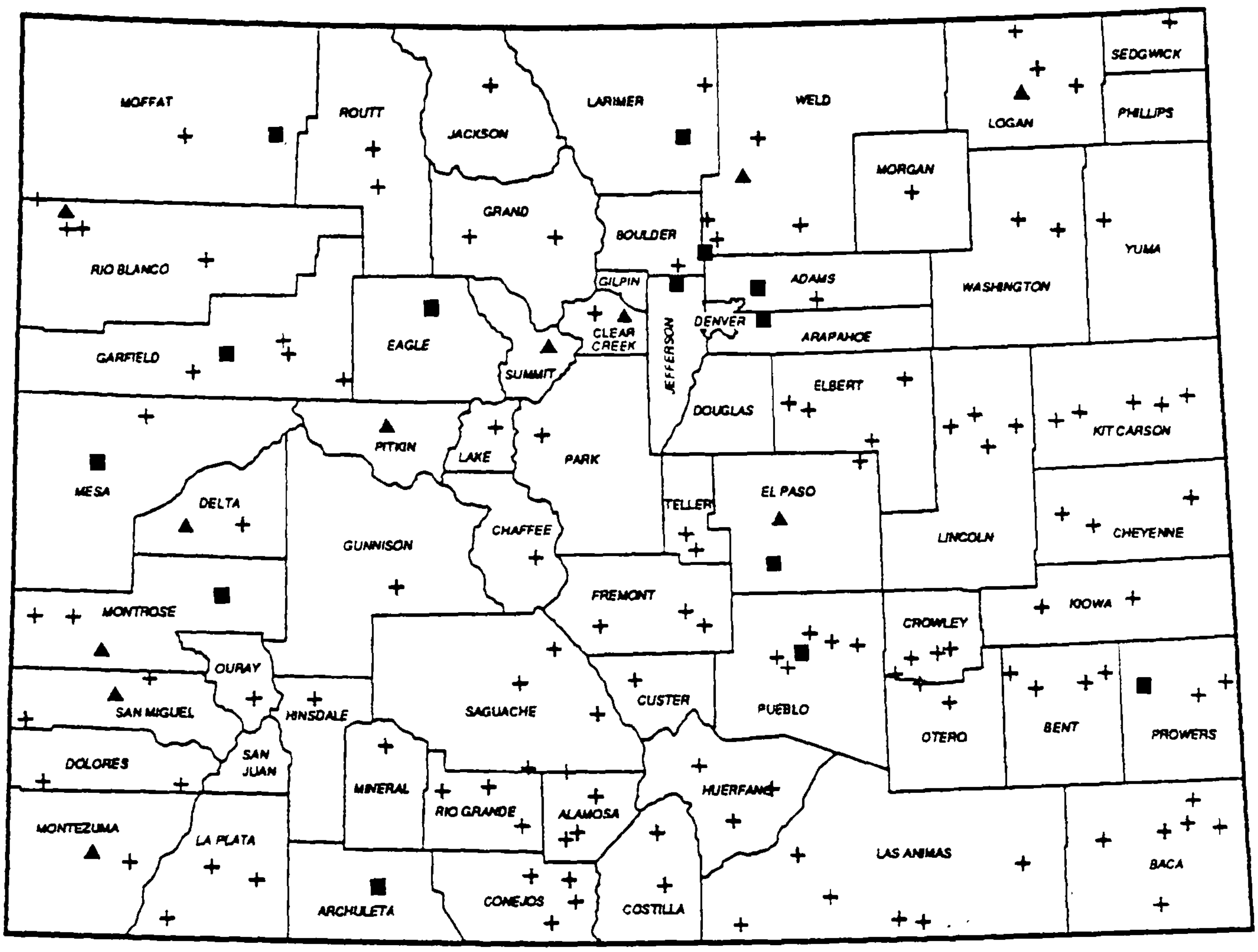
* Some SQGs generate more than one waste stream
** Total number of generators differed from published EPA source when added independently.
Source: (U.S. EPA, 1988)

Table 10-5
Distribution of Operating Region VIII Landfills, by State

State	Open	Closed
Montana	120	unknown
North Dakota	65	130
South Dakota	150	unknown
Utah	220	unknown
Wyoming	80	20
Colorado	148	—
	783	150

Sources: U.S. EPA, 1990; Wilbur, 1990; Wetzel, 1990; Dahl, 1990; Burns, 1990; and Link, 1990.

Figure 10-1
Municipal Solid Waste Landfills in Colorado



Municipal Solid Waste Landfills in Colorado
RCRA Subtitle D Compliance Status* - November 1989

+ Not In Compliance
▲ Potentially in Compliance
■ In Compliance

* EPA Region VIII preliminary assessment of probable compliance with anticipated RCRA Subtitle D revisions based on data from CDH.

10.3 HUMAN HEALTH RISK ASSESSMENT

10.3.1 Toxicity Assessment

Documented contaminants from municipal landfills include a set of approximately 200 constituents, including:

- Conventional pollutants, such as biochemical oxygen demand (BOD), chemical oxygen demand (COD), iron, chloride, and ammonia.

- Heavy metals, such as arsenic, antimony, cadmium, and chromium.

- Organic chemicals, including vinyl chloride, tetrachloroethylene, dichloromethane, carbon tetrachloride, and phenol.

In the regulatory impact analysis for proposed criteria for classification of municipal solid waste landfills, OSW evaluated risks to human health and the environment posed by selected hazardous constituents found in municipal landfill leachates. These constituents were selected to represent the maximum likely risks to be posed by municipal landfill leachates based on their prevalence in samples of leachate taken from multiple facilities, average concentrations found in leachate, toxicity, mobility, and persistence (TBS, 1987).

The constituents selected for risk modeling in the RIA were vinyl chloride, arsenic, iron, tetrachloroethane, dichloromethane, carbon tetrachloride, antimony, and phenol. Five of the contaminants are carcinogens. The non-cancer effects of these contaminants are neurotoxicity, cardiovascular changes, and kidney and liver damage. Information on the carcinogenicity and toxicity of these compounds is presented in Tables 10-6 and 10-7 (U.S. EPA, 1989).

10.3.2 Exposure Assessment

Table 10-8 lists violations of state media protection standards at MSWS in 1984. These data suggest that four principal exposure routes that should be considered in evaluating health risks associated with MSWS. Previous assessments of health risks associated with MSWS have focused on groundwater and methane migration based on available data.

Existing exposure data were insufficient to support a credible estimate of human exposure to toxicants associated with MSWS in Region VIII.

Two principal routes of exposure or risk should be considered in an analysis of health risks due to MSWS: exposure due to migration of contaminants from municipal solid waste landfills through groundwater, and risks arising through subsurface methane gas migration. These routes are based on data availability and previous risk assessments, which indicate that these are the principal routes through which risks to human health may occur.

Table 10-6
Carcinogenic Effects of MSW Leachate Constituents

Constituent	Carcin- ogen	Route	Level of Confidence	Slope Factor Oral (mg/kg/d)-1	Slope Factor Inhaled (mg/kg/d)-1	Tumor Site Oral	Tumor Site Inhaled
Tetrachloroethane	Yes	Oral, Inh	C	5.8E-05	2.0E-01	Liver	Liver
Carbon Tetrachloride	Yes	Oral, Inh	B2	1.5E-05	1.3E-01	Liver	Liver
Vinyl Chloride	Yes	Oral, Inh	A	4.2E-05	2.3E+00	Liver	Lung
Arsenic	Yes	Oral, Inh	A	NA	4.3E-03	Skin	Resp.Tract

Source: "Health Effects Assessment Summary Tables - Fourth Quarter, FY 19889",
U.S. EPA, OSWER, October 1989.

Table 10-7
Subchronic and Chronic Effects
of MSW Leachate Constituents

Constituent	Route	RFD Oral (mg/kg/d)	RFD Inhaled (mg/kg/d)	Effect of Concern Oral	Effect of Concern Inhaled	Uncertainty Factor
Carbon Tetrachloride						
Subchronic	Oral	7E-03	NA	Liver Lesions	NA	100
Chronic	Oral	7E-04	NA	Liver Lesions	NA	1000
Antimony						
Subchronic	Oral	4E-04	NA	Blood Chemis.	NA	1000
Chronic	Oral	4E-04	NA	Blood Chemis.	NA	1000
Arsenic						
Subchronic	Oral	1E-03	NA	Keratosis	NA	1
Chronic	Oral	1E-03	NA	Keratosis	NA	1
Phenol						
Subchronic	Oral	6E-01	NA	Reduced Fetal Body Weight	NA	100
Chronic	Oral	6E-01	NA	Reduced Fetal Body Weight	NA	100

Source: "Health Effects Assessment Summary Tables - Fourth Quarter, FY 1989", U.S. EPA, OSWER, October 1989.

Table 10-8
Violations of State Media Protection Standards at
Municipal Solid Waste Landfills in 1984 (a)

Medium of Concern	Number of Facilities with at Least One Violation	Facilities with Monitoring	Percent
Ground Water	586	2,331	25%
Surface Water	660	1,100	12%
Air	845	358	4%
Methane (subsurface gas)	180	427	5%

SOURCE: U.S. EPA (1988)
(a) Includes 9,284 municipal solid waste landfills identified by
the 1984 State census.

10.3.3 Human Health Risk Characterization

Cancer Risks

Quantitative cancer risks were not estimated in this analysis due to significant uncertainties regarding the distribution of open and closed MSWS, as well as difficulties inherent in estimating exposed populations.

Risk estimates presented in the RIA represent average individual lifetime cancer risks due to exposure to leachate contaminated groundwater. The analysis calculates these averages based on a 300 year modeling period, in order to provide time for risks to be manifested (e.g., for cap failure, leachate release, and contaminant migration) under a variety of different design and location scenarios.

The RIA apportions facilities by risk range. For MP IV facilities (facilities located in areas of high net precipitation and shortground water travel times), the distribution of facility risks is as follows (TBS, 1987):

- Approximately 10 percent of facilities have risks greater than 1 x lOE-5 (high)
- 17 percent have risks in the range of 1 x lOE-5 to 1 x lOE-6 (medium)
- 9 percent have risks in the range of 1 x lOE-6 to 1 x lOE-8 (low)
- 10 percent have risk lower than 1 x lOE-8 (very low)
- 54 percent had zero risk because no wells were in the vicinity of the facility

Closed municipal solid waste landfills probably pose a similar or greater threat of environmental contamination and resulting risks than operating landfills due to changes in landfill design, and operation of these landfills prior to the implementation of RCRA Subtitle C standards for hazardous waste management.

Cancer risks that may arise due to air exposures to emissions from municipal incinerators were not estimated due to a lack of information.

Non-Cancer Risks

Non-cancer health effects were initially evaluated in developing the regulatory impact analysis for criteria for municipal solid waste landfills. Modeled exposures were found to be substantially lower than the Reference Doses (Rfds) for the constituents due to the low concentrations of the constituents in leachate. Since non-cancer health effects demonstrate threshold doses below which no health effects are observed (No Observed Adverse Effect Levels, or NOAELs), and Rfds are based on these levels, no cases of non-cancer health damages were projected in the RIA.

Risks From Explosions

There is a risk of explosion due to methane gas migration from municipal waste landfills to nearby structures. Methane may collect in confined spaces within structures at levels exceeding the Lower Explosive Limit (LEL) and result in an explosion if provided a source of ignition. There are documented cases of such explosions.

In general, horizontal methane migration in the subsurface environment is limited because methane vents through the ground surface. Typically, only structures located in proximity to a landfill, or on a filled area, are at risk. However, were venting is prevented by pavement, locally saturated surface soils, or frozen surface soils, or where sewers or underground utilities provide a highly permeable pathway, methane may migrate substantial distances (up to approximately 1000 yards). Region VIII states typically will have frozen ground conditions for a substantial portion of the year.

10.4 ECOLOGICAL ASSESSMENT

The major routes of contaminant releases from MSWS are surface runoff of leachate (e.g., discharged from surface seeps in above-ground landfills) and leachate discharge to groundwater. In either case, MSWS ecological damages associated with these facilities would occur in surface waters or wetlands through surface runoff or discharge of contaminated groundwater from hydraulically connected surficial aquifers.

There is very limited documentation available on environmental damages resulting from MSWS. One documented damage case study identified damages to wetlands and nearby lakes from a 300 acre landfill leaching into these waters. Note that a 300 acre municipal waste landfill is a relatively large landfill (top 10 percent in size). Projected ecological damages from these releases included toxic effects on freshwater and estuarine fish and macroinvertebrates (U.S. EPA, 1989).

10.4.1 Toxicity Assessment

MSWS release a large variety of contaminants to surface or groundwaters. Constituents released include were reviewed in oxygen demand, chemical oxygen demand, chlorides, ammonia, aluminum, arsenic, barium, vinyl chloride, heavy metals, pesticides, and volatile organics. 80D and COD effect aquatic environments by depleting oxygen, which may affect fish and other aquatic organisms. Other of these constituents, including ammonia and aluminum, are toxic to marine organisms.

The effects any release of leachate on surface waters will largely depend on the ultimate concentration of the contaminants in the receiving body of water. In general, the volume of leachate flowing from an average landfill is low, but the relative concentrations of constituents are high compared to other sources of surface water contamination.

10.5 WELFARE RISK ASSESSMENT

Potential welfare damages associated with Region VIII MSWS include:

- Property damage resulting from methane gas explosions;
- Costs associated with replacing or treating drinking water supplies contaminated by MSWS;
- Loss of groundwater option value, where option value is an economic measure of the value of future use that would be foregone as a result of contamination;
- Aesthetic damages and nuisances such as odors, birds, and noise;
- Loss of fish and wildlife habitat, and the potential loss of recreational opportunity;
- Health care costs and foregone earnings associated with illnesses; and,
- Property value depreciation in the immediate vicinity of MSWS, in some cases this may be related to the reduced suitability of sites for post closure uses.

It was not possible to develop credible quantitative welfare damage estimates for the above categories due to missing data. If these data were available, welfare risks could be calculated with some measure of confidence.

10.6 REFERENCES

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10.0 MUNICIPAL SOLID WASTE SITES

10.1 INTRODUCTION

The Municipal Solid Waste sites problem area covers risks to human health and welfare, and (MSWS) posed by open or closed land disposal facilities (including landfills and open dumps) used to dispose of municipal refuse. Regulated under Subtitle D of the Resource Conservation and Recovery Act (RCRA), these facilities are not subject to the hazardous waste restrictions under Subtitle C of RCRA. Solid Wastes regulated under RCRA Subtitle D are defined in 40 CFR Part 257 as:

> ...any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant or air pollution control facility and other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities, but does not include solid or dissolved materials in irrigation return flows or industrial discharges which are point sources subject to permits under Section 402 of the Federal Water Pollution Control Act, as amended (86 Stat. 880), source, special nuclear, or by product material as defined by the Atomic Energy Act of 1954, as amended.

The following types of Subtitle D wastes have been identified (U.S. EPA, 1988):

- Municipal solid waste;
- Household hazardous waste;
- Municipal sludge;
- Municipal waste combustion ash;
- Infectious waste;
- Industrial nonhazardous waste;
- Very-small-quantity generator hazardous waste;
- Construction and demolition waste;
- Agricultural waste;
- Oil and gas waste;

11.0 INDUSTRIAL SOLID WASTE SITES

11.1 INTRODUCTION

In analyzing the comparative risks of this problem area, the most important issue is the scarcity or absence of data. Readily available data on the population of industrial solid waste facilities are limited, and, when available, are often aggregated at the national level. While states are in a better position to generate data on specific facilities, this information is not easily accessible.

There are virtually no data with which to assess the risks that industrial solid waste facilities pose to people or the environment. Although the toxic constituents in various types of industrial wastes are known and can be evaluated, the data needed to translate known potential health effects of these toxic constituents into risks posed to populations or ecological systems are currently unavailable. Basic data needs include the concentrations of toxic constituents in the solid wastes managed at industrial facilities, estimates of the potential for uncontrolled releases of contaminants from these facilities, and information on the potentially exposed populations residing near these facilities.

Until data on the characteristics of existing industrial solid waste facilities are available and the potential risks from the major types of facilities are assessed or modeled, rigorous, defensible assessments of risk cannot be made. Currently, any risk assessments must largely depend on assumptions or professional judgement, subject to substantial uncertainty. Data that can fill current gaps and meet some of these needs are scheduled to be collected in the relatively near future (Geise, 1990).

11.2 PROBLEM AREA DEFINITION AND DESCRIPTION

The Industrial Solid Waste Sites category includes any open industrial solid waste land disposal facility not subject to regulation under Subtitle C of RCRA. Specific types of facilities included in this category are:

- Commercial and on-site industrial waste landfills.
- Mining waste disposal sites, other than those coal mine waste sites regulated under the Surface Mine Reclamation Act. Mine waste is characterized as a high volume, low hazard waste. As such, it is distinct from the majority of industrial solid waste and will be addressed separately in the discussion below.
- Construction and demolition debris sites.

Types of waste management units at these facilities include landfills, surface impoundments, land application units, and waste piles.

These facilities threaten human health and the environment through air emissions of toxic materials, subsurface methane migration, and ground and surface water contamination by landfill leachate containing organic and inorganic toxic contaminants and/or pathogenic substances. Contamination may occur through subsurface migration, surface runoff, evaporation or wind erosion.

Substances disposed of at these facilities include a wide variety of industrial waste materials, including:

- process and waste treatment sludges;
- office wastes;
- discarded equipment;
- stripping and cleaning residues;
- food processing wastes; and,
- incinerator ash.

These wastes may include some toxic contaminants, including solvents and heavy metals, at concentrations below those which trigger regulation under Subtitle C of RCRA (for example, below the organic toxicity characteristic concentration limits). On-site and off-site facilities typically differ greatly in terms of the variety of wastes disposed and volume of waste.

This category excludes:

- Oil and gas waste sites, such as brine pits;
- High and low-level radioactive waste disposal sites;
- Closed industrial waste sites at operating RCRA Subtitle C facilities, which are covered under the Active Hazardous Waste Facilities problem area; and
- Other closed industrial waste sites, which are covered under the abandoned hazardous waste site problem area.

It is important to note that Subtitle D specifically excludes certain waste from its definition of industrial solid waste. In proposed rules for solid waste disposal facility criteria (40 CFR Parts 257 and 258, August 30, 1988), the Agency excluded mining waste and oil and gas waste from the definition of industrial solid waste. EPA, however, has revised its approach to mine waste and currently expects to include this waste within the scope of Subtitle D.

11.3 POPULATION OF INDUSTRIAL SOLID WASTE FACILITIES IN REGION VIII

Because of the absence of comprehensive inventories of facilities, the population of active industrial Subtitle D facilities in Region V must be estimated.

Estimates of the population of industrial Subtitle D facilities were developed using national level data collected for EPA in the mid-1980s. Two studies were used for the estimate: "Subtitle D Study Phase 1 Report" (subsequently referred to as the Phase 1 Report) and "Screening Survey of Industrial Subtitle D Establishments" (subsequently referred to as the Screening Survey). The major advantage of the studies is their comprehensiveness in addressing the range of facility types regulated by Subtitle D.

Estimates of Region VIII facilities developed using these studies are presented in Table 11-1. Table 11-1 first presents each study's estimate of the national total of industrial solid waste facilities by type of facility. As shown, the Phase 1 Report did not include waste piles and the Screening Survey did not include demolition landfills. For those type of facilities where direct comparisons can be made, the Phase 1 Report consistently indicates higher numbers. That report is based on a 1984 survey. The Screening Survey was conducted in 1985.

The method used to estimate Region VIII's share of the nation's industrial solid waste facilities was to determine the Region's share of industrial activity, as reported in <u>County Business Patterns</u>, and apportion facilities accordingly. To measure industrial activity we relied on estimates of the number of industrial establishments in the Region. Region VIII's share of all U.S. industrial establishments is also shown in Table 11-1. Using this regional "predictor", estimates of Region VIII industrial solid waste facilities were computed.

11.4 CHARACTERISTICS OF INDUSTRIAL SOLID WASTE FACILITIES

The Screening Survey discussed the degree to which the population of facilities is concentrated in a few industries. For the four types of facilities addressed by the Screening Survey -- landfills, surface impoundments, land application units, and waste piles, the majority of facilities is operated by a few industry segments. For example, almost half of all identified landfills are operated by the stone, clay and glass industry and 75 percent are

Table 11-1
Estimated Industrial Solid Waste Facilities in Region VIII

	Landfills	Demolition Landfills	Surface Impoundments	Land Application Units	Waste Piles
Estimates from <u>National Surveys</u>					
Total U.S. facilities estimated by Phase I report	3,511	2,591	16,232	5,590	NA
by screening survey	2,757	NA	15,253	4,308	5,335
Region VIII share of U.S. industrial establishments	2.8%	2.8%	2.8%	2.8%	2.8%
Region VIII facilities estimated by Phase I report: low	98	72	454	156	
high					
by screening survey: low					
high:	77		427	121	149

operated by that industry and the food products, paper, iron and steel, and electric power generation industries. The most concentrated case is the 73 percent of land application units operated by the food products industry.

This data also show similar patterns of concentration for the quantity of waste managed by industry in the four types of facilities. It should be noted that the industry segments that operate the majority of facilities typically do not also manage the majority of the waste generated by all industry. For example, the electric utility industry manages 62 percent of the industrial wastes that go to industrial landfills, but only operates 6 percent of the total number of industrial landfills. Conversely, the stone, clay, and glass industry operates 46 percent of all industry landfills, but only manages 9 percent of all solid waste disposed of in industrial landfills.

This data clearly demonstrate that industrial solid waste management is dominated by a relatively small number of industries. Whether the issue is the population of facilities or the quantity of wastes managed, the bulk of activity for a given type of facility can be found in five or six industries.

A mail survey conducted in 1984 provided data on the size of and volume of wastes managed by industrial and demolition landfills (Westat, 1986). That survey estimated that 71 percent of industrial landfills are less than 10 acres in area and that 98 percent are smaller than 100 acres. Similarly, 61 percent of demolition landfills are smaller than 10 acres in area and 97 percent are smaller than 100 acres.

Statistics on the quantity of waste accepted by these facilities showed similar patterns. Of industrial landfills, 79 percent accepted less than 30 tons of waste daily and 97 accepted less than 500 tons per day. Seventy-five percent of demolition landfills accepted less than 30 tons of waste per day, while 97 percent accepted less than 500 tons per day.

Other descriptive data on industrial facilities are not currently available. For example, data on characteristics relevant to the risks these facilities pose are absent, including the extent to which facilities are lined, the presence of monitoring systems, the frequency of releases from facilities, populations in close proximity, drinking water wells within close proximity. As noted at the end of this section, data collection relevant to some of these issues will begin shortly.

11.5 VOLUME OF WASTE MANAGED IN REGION VIII

Data on the volume of industrial solid waste managed in Region VIII are particularly limited. The Screening Survey provided national estimates of wastes managed by type of facility. Region VIII's share of these national estimates can be estimated with the procedure previously employed to estimate the Region's share of industrial facilities. That procedure uses the Region's share of industrial activity measured by establishments to estimate the Region's share of industrial solid waste.

Table 11-2 presents the results of this estimate for the types of facilities addressed by the Screening Survey. The obvious finding from this estimate is that surface impoundments are used to manage the predominate share of industrial solid wastes in Region VIII.

11.6 HUMAN HEALTH RISK ASSESSMENT

No information on waste characterization at industrial non-hazardous solid waste facilities was available. No detailed estimate of the quantities of wastes at these facilities was available, nor were data available for the types of waste managed at facilities. The following assessment is then largely based on assumptions about industrial solid waste and industrial Subtitle D facilities in Region VIII.

Industrial non-hazardous waste facilities in Region VIII are assumed to produce the following waste streams: sulfites, cellulosic residues, acetones, methanol, gypsum, stone, asbestos, silicates of limes, toluene, lead, mercury, arsenic, benzene, xylene, phenol, carbon dichloride, carbon disulfide, hydrogen cyanide, chrome, and heavy metals. Most of the inorganics will be present as metal oxides and hydroxides, but may be soluble under acidic conditions. In general, toxic constituents will be present at relatively low concentrations, below EP Toxic levels and, in the future, below the Organic Toxicity Characteristic limits.

Demolition debris waste disposal facilities handle mainly construction wastes: broken bricks, plaster, insulation material, wooden material, stone aggregate, reinforcing bars, glass, plastics, roofing, sheeting, scrap, broken concrete, asphalt, stone, piping and other building materials.

Mining waste facilities handle waste resulting from mining, smelting and refining operations. Wastes resulting from crushing, screening, washing and floatation are also mining wastes. Heavy metals, sodium, potassium, sulfates, and cyanides may be present in such waste.

In the absence of availability of information on the waste characteristics handled at individual waste disposal facilities, and any construction details and monitoring data at these facilities, credible estimates of human health risk cannot be provided. Previous studies have focused on professional judgment driven by assumptions to derive a the quantitative evaluation of the risks posed by these facilities. These reports have tried to model releases and exposures to hypothetical maximally exposed individuals (MEI), while making assumptions about the chemicals to which the MEI will be exposed, the concentration and duration of exposure, and the location of the MEI. Assumptions about exposure levels to various segments of population, and the number of people exposed were also made in previous evaluations.

This human health risk assessment addresses the general category of chemicals that individuals may be exposed to and the effects of such exposures by bounding the problem. The method used to derive an upper bound risk estimate involves:

Table 11-2
Estimated Industrial Landfill Facilities in Region VIII

	Industrial Landfills	Demolition Landfills	Total Landfills
U.S. Total Landfills	3,396	2,355	15,578
% of Total U.S.	21.80%	15.12%	
Region VIII Landfills			1,471
Region VIII Landfills based on Total U.S. %	321	222	

Source: U.S. EPA, "Subtitle D Study Phase I Report."

- Assuming that toxic constituents are present in industrial wastes at all facilities in the Region at levels just below the Subtitle C toxicity characteristic levels.

- Assuming that all facilities are located in areas where private wells are used as a water source, with an average potentially exposed population of 500 people per facility.

- Assuming a dilution/attenuation factor of 100 between the point of leachate discharge from the waste site to the receptor.

11.6.1 Toxicity Assessment

The severity and adverse effects of exposure to a chemical depend on the properties of the chemical exposure, the concentration and duration of exposure. In the absence of this data, the exposure effects are evaluated based on the general class of chemicals and their adverse effects.

Industrial Subtitle D facilities do not pose consistent risks. Demolition debris waste management units should not pose substantial risks because of the inert nature of the material in such facilities. Industrial waste and mining waste facilities will pose a larger exposure risk.

Exposures may occur from heavy metals such as lead, chrome, mercury, and cadmium from industrial landfills and from organics such as toluene, xylene, carbon tetrachloride, TCE and benzene. These toxic chemicals may be present in the industrial landfills due to the nature of operations in the major industries represented in Region VIII. So long as the concentrations of these chemicals do not exceed EPA criteria for hazardous waste, these toxic chemicals may be present in non-hazardous industrial waste. Most of the metals in industrial waste sludge are in the form of hydroxides or oxides, and as such are stable, but can easily be soluble under acidic conditions.

11.6.2 Exposure Assessment

Exposure from chemicals originating in individual waste facilities will primarily take place through drinking water. The chemicals may be mobilized into groundwater and also discharged into surface waters. Leachate generated in landfills, surface impoundments and land application units handling industrial waste is expected to be typically high in heavy metals such as lead, chromium, cadmium and mercury, but lower than that expected in leachate from hazardous waste facilities.

No data were available on actual concentrations of constituents in leachates from industrial facilities or at potential exposure points. Additionally, no data were available to directly estimate the potentially exposed population. Consequently, credible risk estimates were not possible.

11.7 ECOLOGICAL RISK ASSESSMENT

Discharges to the environment from industrial solid waste facilities may result in adverse effects to the ecological environment. The nature and severity of these impacts will depend on the size of the waste handling facility and the volume, characteristics, and duration of the discharges of chemicals from the facility. The component of the ecosystem affected adversely will depend upon the media into which the chemicals are released. Aquatic life will be impacted by releases to surface waters, whereas plants and avian species will be affected by releases to air and water.

Both acute and chronic effects may be observed. Ecological impacts such as fish kills, impairment of health and reproductive capabilities, and bioaccumulation in the food chain may result from discharges to the environment. These impacts may be reversible or non-reversible and severity of their effects will depend on the resiliency of the ecological system impacted and the presence of any fragile or endangered species in that system.

Ecological impacts can be evaluated only if information on the type and population of the exposed species, its stability, chemicals they are exposed to and duration of exposures is available. Such data relevant to industrial solid waste facilities were not available. As a result, no attempt was made to quantitatively evaluate risk assessment for ecological exposures.

It is assumed that larger ecological impacts will result from surface impoundments handling mining waste because of their size relative to other industrial solid waste facilities. Discharges to surface water and air may take place from industrial waste handling facilities resulting in adverse ecological impacts. At this point in time, such impacts cannot be quantitatively evaluated.

11.8 WELFARE RISK ASSESSMENT

Potential welfare damages associated with Region VIII industrial waste facilities include:

- Costs associated with replacing or treating drinking water supplies;

- Loss of groundwater option value, where option value is an economic measure of the value of future use that would be foregone as a result of contamination;

- Health care costs and foregone earnings associated with illnesses; and,

- Property value depreciation in the immediate vicinity of industrial waste sites, in some cases this may be related to the reduced suitability of sites for post closure uses.

It was not possible to develop credible quantitative welfare damage estimates for the above categories due to missing data. If these data were available, welfare risks could be calculated with some measure of confidence.

11.9 UNCERTAINTY

The reliability of this assessment is low due to the lack of data and the extensive reliance on professional judgement and assumptions in developing risk estimates. Assumptions encompass all compartments of the risk assessment: the chemicals considered, concentrations of exposure, the duration of exposure, and the size of population exposed. Although the analysis attempted to keep the chemicals modeled and their concentrations representative of the waste being considered, and to provide a reasonable estimate of the upper bound risk, it must be highlighted that a different set of assumptions could lead to completely different risk estimates.

There are substantial data gaps that prevent a careful assessment of the risks posed by industrial Subtitle D facilities. The areas where better data are needed include:

- The population of facilities by type of facility

- Characteristics of facilities related to risks posed to the human population and ecological systems

- Waste characteristics by type of facility and by industry

- Potential for releases by type of facility

- Risk assessment models for major types of facilities

State regulatory agencies are an obvious source of data on the population of facilities. Acquiring data from states, however, relies on-site work which was not within the scope of this effort.

EPA's final rule for municipal landfill criteria will also include a notice that industrial facilities covered by Subtitle D meet notification requirements. Those requirements include basic information on the facility and limited data on the potential for exposure of populations or ecological systems to wastes managed by these facilities. The final rule is scheduled for September 1990 and industry is expected to have 18 months to meet the notification requirement.

This summer, EPA's mine waste work group will initiate several studies to better assess risks from these wastes. The studies will include a national survey of sites, an environmental analysis at a variety of type of facilities, and a sampling effort. Results are expected in 12 to 18 months.

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12.0 ACCIDENTAL CHEMICAL RELEASE TO THE ENVIRONMENT

12.1 INTRODUCTION

The Accidental Chemical Release to the Environment problem area covers risks to human health and welfare, and ecosystems posed by accidental or episodic (non-recurring) chemical releases from:

- Manufacturing facilities, including refineries, chemical plants, metal manufacturing and finishing plants, and other similar operations.
- Product storage facilities, including tank farms and warehouses.
- Product and waste transportation equipment, including pipelines, barges, railroads, and trucks.

The threats posed by these releases are of several types:

- Risks of injury and death due to fires and explosions associated with chemicals.
- Risks of illness and death due to exposure to released chemicals, which may be acutely toxic, carcinogenic, teratogenic, or mutagenic. Exposures may occur through direct contact, air emissions, and surface and groundwater contamination.
- Ecosystem damage caused by air, surface water, ground water, and soil contamination, particularly damage to surface water and wetlands.

Virtually any chemical product or waste may be accidentally released during production, storage, and transportation. 40 CFR 302 lists over 800 hazardous substances for which EPA has designated reportable quantities, requiring that accidental releases of the chemical over the reportable quantity be reported to EPA. A wide variety of acids, bases, solvents, organic chemicals, pesticides, and heavy metal compounds are listed hazardous substances. Additionally, spills of crude oil and petroleum products to water must be reported. Releases of petroleum products, including crude oil, are required to be reported only if they enter a waterway and produce a sheen on top water.

This category excludes:

- Routine releases of chemicals to air or surface water which are permitted or regulated under the Clean Air Act or Clean Water Act, such as releases from process or tank vents.

- Routine releases of contaminants to surface waters, soils, or ground water from abandoned waste sites, active hazardous waste facilities, and storage tanks.

- It should be noted that some, but not all permitted releases are excluded from reporting. Abandoned waste sites and active hazardous waste facilities can have accidental releases of hazardous substances that are reportable. However, releases from these facilities are covered under separate problem areas.

Data on the number of accidental releases occurring in Region VIII were made available through the Emergency Response Notification System (ERNS) data base. The data base is maintained by the United States Department of Transportation (USDOT) and is made up of release reports received by USDOT, USEPA, and the United States Coast Guard. Whenever a release of a reportable quantity of a hazardous substance occurs it must be reported to USDOT, USEPA, or the US Coast Guard. These agencies, in turn, file a report with USDOT so that the incident may be recorded in the ERNS data base. The data base is meant to be a comprehensive listing of all the accidental releases to the environment that occur in the United States. However, many references cite tendencies for the data base to under report the number of releases of reportable quantities that occur.

12.2 POPULATION OF ACCIDENTAL CHEMICAL RELEASES

The Emergency Response Section in Region VIII believes that the ERNS data base contains between 25% and 45% of the accidental releases that occur in Region VIII. See Table 12-1 for a summary of reported spills for years 1987, 1988, 1989, and 1990 to the present. For that reason, the number of releases reported by the ERNS data base for Region VIII was taken as only 35% (the average of 25% and 45%) of the total releases that had occurred.

Using this assumption, approximately 1,351 releases of reportable quantities of oil and hazardous substances occurred in Region VIII in 1989.

Table 12-2 presents a breakdown of the percentages of releases by type of material. The data indicate that oil was the most frequently released material. Approximately 50% of the releases reported to ERNS from 1987 through 1989 were characterized as oil releases. Note that no data on type of release were available for Colorado.

When the data on releases were analyzed by state, Colorado accounted for 49% of all releases in Region VIII during 1987-1989.

12.3 HUMAN HEALTH RISK ASSESSMENT

12.3.1 Toxicity Assessment

Oil and petroleum products (fuel oil, diesel oil, gasoline) produce a wide variety of health effects due to the different makeup of each product. The toxicity of these hydrocarbons is generally considered indirectly proportional to their viscosity, with those materials having high viscosity considered to be less toxic. Gasoline can produce significant central nervous system toxicity with a potential aspiration hazard. Fuel oil and diesel oil are generally nontoxic in normal, ingested doses. However, ingestion may lead to lipoid pneumonia if aspiration occurs. The release of fuel oil, diesel oil, or gasoline is considered a more serious threat to ecosystems than to human populations.

While it has not been possible to identify principal chemicals/toxicants released in Region VIII, additional toxics released may include:

PCBs

The U.S. EPA has classified PCBs as probable human carcinogens based on evidence that PCBs cause cancer in animals. PCBs produce non-cancerous health effects as well. The health effects produced vary according to the duration of exposure and the exposure pathway (ref). Inhalation of air contaminated with PCBs can lead to skin irritation in humans if the PCB concentration exceeds 0.05 mg in a cubic meter of air and the exposure lasts longer than two weeks. For air exposures of less than two weeks, no quantitative data are available that support the identification of human health effects. Likewise, no quantitative data are available to support the identification of non-cancerous health effects due to ingestion of PCBs. However, doses have been identified below which only a minimal risk of non-cancerous effects can be assumed. Direct contact with PCBs can produce non-cancerous health effects in humans for exposures lasting more than two weeks. These include skin irritation and liver effects. No quantitative data are available to aid in the identification of human health effects due to direct contact with PCBs when exposures last two weeks or less.

Lead

Although it is suspected that lead is a potential human carcinogen, U.S. EPA's Carcinogen Assessment Group has recommended that a numerical estimate not be used in assessing the risks associated with lead. The group felt that too many uncertainties were involved with quantifying this risk. They added that the current state of knowledge in lead pharmacokinetics indicated that an estimate derived by standard procedures would not adequately describe the risks to exposed populations. However, under Section 109 of the Clean Air Act, USEPA has set a primary national ambient air quality standard for lead of 1.5 micrograms per cubic meter. This is a health-based quantity. In addition, a maximum contaminant level (MCL) of lead in drinking water has been set at 0.05 milligrams per liter. Currently, this value has interim status. USEPA OSWER has released a directive stating that soil concentrations for lead must not exceed 500 to 1000 ppm.

12.3.2 <u>Exposure Assessment</u>

Acute (short-term) exposures associated with releases are probably inhalation of airborne contaminants resulting from a release and direct (dermal) contact with released material. A secondary exposure pathway would be ingestion of contaminated material after dermal contact.

The Emergency Response Section also is concerned with the chronic (long-term) effects of spills and releases. Potentially important pathways for chronic exposures include ingestion, direct contact, and inhalation of groundwater and surface waters contaminated by spilled and released materials. Inhalation of air is also viewed as an important pathway when dealing with releases of heavy metals such as lead. It has not been possible to estimate human exposures associated with accidental exposures in this assessment.

12.4 ECOLOGICAL RISK ASSESSMENT

12.4.1 <u>Toxicity Assessment</u>

Oil

Research on the effects of oil on wildlife and resources has identified certain characteristics common in freshwater spills. The impacts on ecosystems of interest are summarized below.

Algae: Phytoplankton are largely unaffected by spilled oil except to certain components of oil. Filamentous and benthic algae suffer some impacts but also exhibit resistance and appear to recover quickly. Blue-green algae may actually increase after a spill.

Macrophyte vegetation: Submerged species and the submerged portions of emergent species are generally not affected. However, emergent species and those at the water's edge are affected and may die because of surface oiling.

Invertebrates: Impacts in real spills appear to be minimal or short-lived. The group most affected have been insects that dwell on the air/water interface.

Fish: Larvae and fry have generally suffered more impact than adults. Some adult fish have exhibited tainting of flesh.

Birds: Exposure to toxic effects occurs through ingestion, and absorption. Effects may be transferred to eggs and chicks. Oiling of feathers has also produced problems with heat regulation and buoyancy. The Peregrine Falcon inhabits the Region and is a Federal endangered species. Therefore, bird protection and cleanup may be important considerations.

Mammals: The effects are similar to those for birds. Surface oiling will change the insulative properties of the fur. Mortality can result from ingestion.

PCBs

For aquatic life, PCB concentrations in water of less than 0.014 ug total PCBs/L (ppb) appear to afford a reasonable degree of protection. LC-50 values for fish listed as inhabiting the Region ranged from 54 ug/L for Aroclor 1242 and 1254 in Bluegills to a reported high of 540 ug/L for Aroclor 1016 in the same species and 560 ug/L in Channel Catfish.

Among small mammals listed among the species inhabiting the wetlands of the Region, the mink is one of the most susceptible PCB poisoning. A dietary level as low as 100 ug PCBs/kg fresh weight produced death and reproductive toxicity in mink. A tolerable daily limit has been estimated at less than 1.5 ug/kg body weight. Mink given a single oral dose of three different Aroclors (1221, 1242, 1254) produced LD-SOs of 0.88 (avg.), 3.0, and 4.0 g/kg body weight, respectively. Recent data indicate that certain hexachlorobiphenyls (such as 3,4,5,3',4',5' HCBP) are extremely toxic to mink. Concentrations as low as 0.1 mg/kg fresh weight diet produced an LD-SO in 3 months and completely inhibited reproduction in survivors. However, other HCBPs (2,4,5,2',4',5' HCBP and 2,3,6,2',3',6' HCBP) were not fatal under similar conditions and did not produce adverse reproductive effects. The signs of PCB poisoning in mink include anorexia, bloody stools, fatty liver, kidney degeneration, and hemorrhagic gastric ulcers.

For birds, total PCB levels in excess of 3,000 ug/kg fresh weight (diet) have been frequently associated with PCB poisoning. As a group, birds are more resistant to acutely toxic effects of PCBs than mammals. Oral exposures given to Mallards in single doses resulted in LD-SO greater than 2 g/kg body weight. Signs of PCB poisoning among birds include morbidity, tremors, beak pointed upwards, and muscular incoordination. At necropsy, the liver frequently contains hemorrhagic areas and the gastrointestinal tract is filled with blackish fluid.

Lead

Adverse effects on aquatic biota have been reported at waterborne concentrations as low as 1 to 5 ug/l for lead. The observed effects included reduced survival, impaired reproduction, reduced growth, and high bioconcentration. Terrestrial plants suffer adverse effects at total concentrations of several hundred mg of lead per kilogram of soil. Plants residing in low pH or low organic content soils readily accumulate lead. Inhibited plant growth, reduced photosynthesis, and reduced mitosis and water absorption are some of the reported effects.

Although the evidence supporting the claim that ingested lead shot is a major cause of mortality in waterfowl and other birds is overwhelming, the use of lead shot is being phased out. By 1991-1992 all uses of lead shot for hunting waterfowl must be eliminated nationwide. Other forms of inorganic lead have not been shown to produce subclinical signs of lead toxicosis in bird populations. However, it should be noted that lead poisoning has been reported in eagles, vultures, and falcons (i.e. birds of prey). Most cases result from the ingestion of lead shot in food items. The outward signs of lead poisoning in birds are loss of appetite, lethargy, weakness, tremors, drooped wings, and impaired locomotion, balance and depth perception. Reports show that death follows exposure to lead poisoning in 2 to 3 weeks (Friend, 1985).

Fish that are continuously exposed to toxic concentrations of waterborne lead exhibit signs of lead poisoning: spinal curvature, anemia, darkening of tissue, degeneration of the caudal fin, reduced ability to swim against the current, adverse respiratory effects, elevated lead concentrations in blood, bone, gill, liver, and kidney, muscular atrophy, paralysis, growth inhibition, renal pathology, retardation of sexual maturity, and death. Although lead is concentrated by biota from water, no convincing evidence exists to support a claim that it is transferred through food chains.

Although some domestic and laboratory animals have exhibited reduced survival at acute oral lead doses, data are missing for toxic and sublethal effects on mammalian wildlife. Based on laboratory studies researchers have concluded that organolead compounds appear more toxic than inorganic lead compounds, food chain biomagnification is negligible, and younger organisms are more susceptible to adverse effects from lead exposure (USDOI, 1988).

Dioxin

Laboratory studies on 2,3,7,8-TCDD have reported that exposures of aquatic organisms, birds, and mammals result in acute and delayed mortality, and carcinogenic, teratogenic, mutagenic, mistopathologic, immunotoxic, and reproductive effects. The effects vary greatly among exposed species. The summary of some laboratory studies on the effects of this material on wildlife is presented below.

Accumulation of 2,3,7,8-TCDD from the aquatic environment was noted for algae and macrophytes, and channel catfish. Effects in channel catfish included fin necrosis, erratic swimming, hemorrhaging from anus and lower jaw, BCF of 2181 and mortality.

Mallards have an acute oral LD-50 value of more than 108 ug/kg of body weight for 2,3,7,8-TCDD. Some of the signs of intoxication observed included excessive drinking, loss of appetite, hpoactivity, weakness, muscular incoordination, fluffed feathers, falling, tremors, convulsions, and immobility. Death occurred between 13 and 37 days after exposure. Remission was observed in survivors, however, by day 30 of posttreatment. Although there may be no scientific evidence of biomagnification of PCDDs in birds, it has been hypothesized that piscivorous birds have a greater potential to accumulate PCDDs than the fish that they eat (NRCC, 1981).

12.4.2 Exposure Assessment

Exposures of birds and mammals to the materials reviewed typically occur by direct contact and ingestion. Fish are exposed through ingestion as well.

12.4.3 Ecological Risk Characterization

The principal ecological effects of concern associated with accidental chemical releases are effects on aquatic ecosystems, including effects on birds and mammals which come in contact with water contamination physically or through ingestion of contaminated water organisms. Generally, spills occurring on land which do not immediately run off into surface waters can be contained and cleaned up before serious, irreversible ecological damage occurs.

The effects of acute spills on aquatic ecosystems depends upon the material spilled, its volume, and the volume and mixing characteristics of the water body into which the material is spilled. Frequent results of major spills of oil and hazardous substances include kills of fish, birds, and mammals.

In dynamic environments, such as streams, the local effects of spills are frequently transient and reversible. That is, while the spill may result in one-time kills of fish, birds, and mammals, the effects are dissipated relatively rapidly over time due to dilution of the spilled materials. However, for large spills which exceed the dilution capacity of the receiving water body, releases to dynamic environments can spread the effects of the spill rapidly over a large geographic area, greatly magnifying the ultimate impacts of the spill.

In static aquatic ecosystems, such as wetlands and lakes, the effects of a major spill can persist for a long period unless measures are taken to actively remove the toxic materials. While the effects may be contained in geographical extent, materials can persist in toxic levels until diluted or degraded.

The most frequently spilled material in Region VIII is oil, which accounts for 50% of all reported spills (approximately 3900 spills in 1989). In sufficient volume, oil spills can result in kills of fish, birds, and mammals through ingestion of toxic levels of oil and oil constituents, and through physical contact (e.g., oiling of fur and feathers). Most oil spills in Region VIII are relatively small.

12.5 RISK SUMMARY

The most important health effects associated with accidental releases are short-term (acute), non-cancer effects that affect very localized areas. In the vast majority of cases, the populations affected by releases is small. However, some releases have the potential to produce catastrophic effects especially when releases involve toxic chemicals in the vapor phase. Prevailing wind speed and direction are important variables when dealing with releases where air is the major transport medium.

The health effects associated with the chemicals identified as major concerns in Region VIII range from skin irritations to possible mortality. Some effects such are systemic in nature while others are local. Non-cancer effects or more likely to result from accidental releases than cancer effects. This is due to the short-term nature of release events. Although some residual is usually left behind after cleanup, those levels should be low enough as to not produce cancer effects from a single episode.

Other types of releases may actually produce the opposite effects. Releases from leaking drums or tanks that go undetected or unchecked can lead to soil contamination, surface water contamination, and even ground water contamination. Releases of this type lead to exposures through direct contact with and/or ingestion of contaminated water or soil. These effects can produce long-term effects and usually result in more extensive cleanup efforts when they are discovered.

Other paths such as dermal contact and ingestion generally play only minor roles. Typically, populations in the immediate vicinity of a release or who are located close by and downwind receive the highest exposures.

The risks associated with accidental releases must be discussed qualitatively. Data are not generally available from EPA sources that allow exposures resulting from accidental releases to be calculated. In some cases where exposure data are available, risks can be quantified, but in other cases the chemical of interest does not possess an EPA-verified reference dose. In cases where cleanup levels have been established with the help of quantitative risk assessment (as is the case for PCBs), residual risks may be minimized with respect to the current level of knowledge concerning a pollutant. More work must be performed in this area as important data are lacking for many chemicals of interest.

12.6 WELFARE RISKS

Credible estimates of welfare risks associated with accidental releases could not be developed given available data and project resource constraints. However, accidental releases in the Region are likely to be associated with welfare damages through the following pathways:

- health care costs and costs of illness measures;
- ecosystem damages;
- cost of response and cleanup; and,
- property damages.

12.7 PRINCIPAL CONTACTS

Scott Whitmore, U.S. EPA, Region VIII.

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Table 12-1
Reported Spills by State and Type in Region VIII

Number of Reported Spills

State	1987	1988	1989	Totals
Colorado	211	329	408	948
Montana	23	54	58	135
North Dakota	37	41	77	155
South Dakota	45	48	28	121
Utah	77	89	112	278
Wyoming	80	129	136	345
Total Region VIII	473	690	819	1982

Number of Oil Product Spills

State	1987	1988	1989	Totals
Montana	12	30	37	79
North Dakota	21	34	19	74
South Dakota	20	31	7	58
Utah	25	40	46	111
Wyoming	43	82	71	196
Total Region VIII	121	217	180	518

Number of Hazardous Substance Spills

State	1987	1988	1989	Totals
Montana	5	20	18	43
North Dakota	11	13	51	75
South Dakota	10	15	13	38
Utah	23	34	41	98
Wyoming	16	32	43	91
Total Region VIII	65	114	166	345

Number of Other Spills

State	1987	1988	1989	Totals
Montana	8	10	12	30
North Dakota	5	3	7	15
South Dakota	14	3	7	24
Utah	25	13	25	63
Wyoming	16	14	21	51
Total Region VIII	68	43	72	183

Table 12-2
Percent of Spills by Type in Region VIII

Percent of Spills as Oil Product Spills

State	1987	1988	1989
Montana	52.2%	55.6%	63.8%
North Dakota	56.8%	82.9%	24.7%
South Dakota	44.4%	64.6%	25.0%
Utah	32.5%	44.9%	41.1%
Wyoming	53.8%	63.6%	52.2%

Percent of Spills as Hazardous Substance Spills

State	1987	1988	1989
Montana	21.7%	37.0%	31.0%
North Dakota	29.7%	31.7%	66.2%
South Dakota	22.2%	31.3%	46.4%
Utah	29.9%	38.2%	36.6%
Wyoming	20.0%	24.8%	31.6%

Percent of Spills as Other Spills

State	1987	1988	1989
Montana	34.8%	18.5%	20.7%
North Dakota	13.5%	7.3%	9.1%
South Dakota	31.1%	6.3%	25.0%
Utah	32.5%	14.6%	22.3%
Wyoming	20.0%	10.9%	15.4%

DIETARY CANCER RISK FROM EXPOSURE TO PESTICIDES

EXECUTIVE SUMMARY

Cancer risk from dietary exposure to potentially oncogenic pesticides is estimated using the OPP Dietary Risk Evaluation System (DRES) and State and Federal pesticide residue data for 39,578 samples collected over the past 2 1/2 years. Anticipated residues (ARs) for 7 of 13 pesticides, selected by OPP and OPPE on the basis of cancer potency and use information, were estimated using residue data from the FDA pesticide monitoring data base and the Mississippi State University 'Foodcontam' data base. The estimated ARs, along with cancer potency factors, were entered into the DRES, which contains information on food consumption, for the 7 pesticides to estimate lifetime cancer risk. Table 1 shows upper bounds on estimated additional cancer deaths by pesticide. These estimates are upper bounds on cancer risk; the true risk may be as low as zero.

PROBLEM AREA DEFINITION

The Agency is required under the Federal Insecticide, Fungicide and Rodenticide Act to assess the potential health hazard these pesticides pose to the human population. EPA has registered pesticide products containing approximately 600 active ingredients. This assessment is to include an evaluation of data submitted by the pesticide industry to demonstrate the acute, subchronic, chronic, developmental and reproductive, and oncogenic effects resulting from exposure to pesticides. Human exposure to pesticides may occur from ingestion of groundwater contaminated by agricultural runoff and leaching, and from ingestion of vegetables and other agricultural products treated with pesticides, as well as consumption of meat, milk, poultry, and eggs, and where livestock have been treated directly or have consumed feed items with pesticide residues.

The oncogenic risk associated with dietary exposure to agricultural products will be evaluated by combining estimates of human cancer potency for selected pesticides, residue data from direct chemical analysis of food items, and food consumption patterns.

METHODOLOGY

Introduction

To generate estimates of human cancer risk from dietary exposure to pesticides, specific data on oncogenic potential, pesticide residue data, agricultural use information, and food consumption patterns are required. For this analysis, cancer potency factors estimated by the Office of Pesticide Programs were used as measures of oncogenic potential. The Biological and Economic Analysis Division of OPP provided agricultural use information in terms of major crop uses and percentages of crops treated. Pesticide residue data in raw agricultural commodities were obtained from two sources: the FDA domestic surveillance pesticide residue monitoring data base (FDA data) and the FDA-sponsored Mississippi State University Foodcontam data base (Foodcontam data). Food consumption data were available from the OPP computerized Dietary Risk Evaluation System.

It is important to indicate some of the limitations of these data. This analysis is designed to comparatively rank dietary cancer risks from exposure to pesticides with other health and environmental risks posed by other problem areas defined under the Regional Comparative Risk Project. We have not attempted to characterize the complete spectrum of health risk associated with exposure to pesticides. This analysis considers only cancer risk from 13 registered active ingredients via one major exposure scenario (i.e., food residues). Uncertainties in the estimation of the cancer potency factors, the accuracy of the residue data, omissions in the use data, and uncertainties in food consumption patterns over time may influence the estimates described here. Analyses for each EPA region are not being attempted since food consumption patterns at a regional level were assumed not to vary significantly from one another (e.g., a crop grown in one region may be shipped and consumed in another region).

Selection of Pesticides of Concern

This analysis is concerned with human cancer risk from pesticide exposure. For that reason, all pesticides for which OPP has calculated a cancer potency factor were considered eligible for inclusion in this analysis. Excluded from this initial list of 69 pesticides were pesticides with no food uses, those that have been canceled or had their registrations withdrawn, and those that have not been classified into an EPA cancer category. Table 2 lists the 13 selected pesticides along with their cancer potency values and the effect, where available, on which the cancer potency factor is based. The cancer potency for ETU is used as a surrogate for the EBDCs: maneb, mancozeb, metiram, and zineb. The selection decisions were reached by consensus of scientific opinion between OPP and OPPE.

Cancer potency values are calculated primarily from animal studies by extrapolating from high doses given to animals under experimental conditions to low doses indicative of human exposure using the linearized multistage model, which describes the relationship between dose and cancer risk.

Residue Information

Pesticide residue information was obtained from two sources, the FDA data base, and the MSU Foodcontam data base. The FDA data base consists of pesticide residue information generated by FDA laboratories during routine monitoring of agricultural commodities grown or imported into the U.S. The Foodcontam data base comprises pesticide residue monitoring data obtained by the State laboratories of California, Florida, Indiana, Michigan, New York, Oregon, Virginia, and Wisconsin.

Searches of these two computerized data bases were performed for all crops for which the 13 pesticides of concern are used. Searches of the FDA data base for residue information gathered over a 2 1/2 year period (1988 to May 1990) were conducted by FDA, and the search results were provided as hardcopy printouts. Searches of the Foodcontam data base for the fiscal years 1988 and 1989 plus the first two quarters of fiscal year 1990 were performed by Dynamac on the data provided by MSU in electronic format.

For the two data sets, average pesticide residues of the positive samples were calculated for each commodity by summing the values of the measured residues and dividing by the number of samples reported above the detection limit for that commodity. The number of negative samples (i.e., residues less than the detection limit) and the minimum and maximum residue values were also determined for each commodity. In addition, the number of additional negative samples reported as having been analyzed by multi-residue methods capable of detecting the presence of a pesticide of concern (had the pesticide been present above its limit of detection), but not reported as having been analyzed for that pesticide, was also derived from the data for each commodity.

Anticipated residues for the pesticides on each commodity of interest were calculated based on the analytical results obtained for all samples analyzed for that pesticide. The influence of processing of foods on the anticipated residues was not considered. For the non-detects, two possibilities exist: either the pesticide is not present in the sample at all, or it is present at a level below the limit of detection of the analytical method. Therefore, the actual residue level may be as low as 0 ppm or as great as the limit of detection. A sensitivity analysis was performed to determine the influence of the assumed level of residue present in the non-detect samples on the calculated anticipated residue. Two scenarios that define the magnitude of this influence were investigated, i.e., assuming that the residue on the non-detects was either 0 ppm or equal to the limit of detection.

Both data bases contained residue values for only 7 of the pesticides of concern. Hence, this analysis encompasses only those 7 chemicals. In addition, FDA reports that routine monitoring methods are not available for acifluorfen.

Food Consumption

Food consumption patterns were estimated using the DRES, which contains the USDA national food consumption survey data gathered during 1977/1978.

Estimates of Cancer Risk

The dietary cancer risk analyses were performed using the DRES and its inherent food consumption data, the pesticide residue data generated from the FDA and Foodcontam data bases, and the cancer potency factors estimated by OPP to calculate lifetime cancer risk from dietary exposure to the 13 pesticides included in this analysis. All estimates are considered to be upper bounds on cancer risk. The true risk may be as low as zero.

Pesticide use information, which was provided by OPP and included all crops on which the chemical is used, the number of pounds of active ingredient used per crop, and the percentage of crop treated with that pesticide, was used to identify the crops upon which the pesticides of concerned are applied. Not all of this information was available for all 13 pesticides. In general, for the FDA data base, only pesticide residue data on crops with one percent or greater use of the pesticide of concern were included in the risk analyses.

RESULTS

Tables 3 and 4 give summaries of the additional cancer deaths resulting from dietary exposure to the pesticides of concern.

SENSITIVITY AND UNCERTAINTIES ANALYSIS

Selection of Pesticides of Concern

More than 600 active ingredients are currently registered with OPP under FIFRA for use as pesticides. This analysis concentrates on only a small fraction of these chemicals and involves only dietary risk; it does not examine additional risks from exposure via other pathways, including drinking water contamination through ground water or agricultural runoff and household exposure to insecticides or herbicides. Hence, cancer estimates produced here represent a portion of the overall cancer risks from exposure to pesticides. However, it is believed that the 13 pesticides of concern may represent a substantial portion of the dietary risk of cancer.

Estimation of Anticipated Residues

A number of uncertainties regarding the representativeness and the utility of the residue data exist, particularly with respect to the Foodcontam data. These uncertainties include sampling rationale, sampling and sample handling, and the accuracy and comparability of the various analytical methods used by different laboratories, including the limits of detection for each method. Some of the more important uncertainties are discussed below.

A problem with both data sets is the often low number of samples analyzed for a given pesticide on a given commodity. This lowers the statistical significance and reliability of the anticipated residue assigned to that pesticide/commodity pair. In some cases, no data were available for commodities known to be treated by a pesticide of concern. No estimate of anticipated residue was made, and therefore, these commodities were not included in the analysis. Another difficulty encountered was the differing schemes used by EPA, FDA, and MSU to describe and code the commodities. This added uncertainty to the assignment of pesticide residue data to the proper commodity. The lack of information on the limits of detection was another shortcoming of both data sets. Nominal limits of detection had to be assigned for each pesticide of concern for which there were residue data to calculate the upper bound of the anticipated residues.

In addition to the uncertainties described above for both data sets, the Foodcontam data may not be representative of the entire U.S. food supply because only eight States currently participate in this voluntary program. In addition, samples obtained as a result of focused monitoring may be included within the Foodcontam data set. This could have the effect of biasing the results upward, since these samples are not chosen randomly but for the purpose of identifying whether a problem exists.

Food Consumption Patterns

The food consumption data from the DRES are provided by the USDA from a survey of population food consumption habits from the late 1970s. The USDA survey was designed to be representative of the U.S. population at the time it was conducted. Changes in such habits through the 1980s are not reflected in these data. Hence, in addition to the uncertainties in the origional survey, there is also uncertainty associated with using food consumption patterns from the 1970s that may no longer be appropriate today.

Cancer Potency

Cancer potency data used in this analysis are derived by OPP through the evaluation of animal bioassays. Several uncertainties are associated with this approach:

(1) the use of animal data to estimate human cancer risk; (2) the selection of one bioassay over another equally well-conducted study; (3) the selection of one oncogenic response within a study over another oncogenic response; and (4) the use of a mathematical model, usually the linearized multistage, to correctly predict cancer risk at low doses.

Estimation of Dietary Risk

All the uncertainties discussed above contribute to the overall uncertainty in the estimates presented in this analysis. While it is not possible to quantify each one and to determine its effect on the numbers presented here, it is important to be aware of the sources of potential bias in the estimates.

USE OF DATA

The purpose of this analysis is to provide a relative ranking of dietary cancer risk with other environmental concerns. It is not intended to be an extensive evaluation of this risk, but rather a qualitative assessment of potential risks. As such, it should not be used to definitively predict human cancer risk. The uncertainties discussed in the preceding sections of the report explain the limits of these estimates.

Table 1
Summary of Estimated Additional Lifetime Cancer Risk By Pesticide

Pesticide	Estimated Additional Lifetime Cancer Deaths per 1,000,000 population			
	FDA Data Base		Foodcontam Data Base	
	Low AR	High AR	Low AR	High AR
Benomyl	1	1	1	2
Captan	16	17	3	3
Chlorothalonil	1	4	7	24
EBDCs	38	84	11	77
Permethrin	< 1	6	1	7
Simazine	0	41	INS	INS
Trifluralin	0	1	< 1	< 1

INS = insufficient information

Table 2
Cancer Potency Factors and Selected Toxicity Information
for the 13 Pesticides of Concern

Pesticide	Cancer Potency Factor $(mg/kg/day)^{-1}$	Basis for Cancer Assessment
Benomyl	4.2E-3	NA
Captan	3.6E-3	NA
Chlorothalonil	1.1E-2	female rat renal tumors
EBDCs	1.4E-1	NA
Propioconazole (Tilt)	7.9E-2	mouse liver tumors
Acifluorfen (Tackle)	3.55E-2	NA
Alachlor	8.0E-2	nasal turbinate tumors
Atrazine	2.2E-1	female rat mammary tumors
Diclofop-methyl (Hoelon)	1.35	NA
Oxyfluorfen	1.28E-1	NA
Simazine	1.2E-1	female rat mammary tumors
Treflan (Trifluralin)	7.7E-3	male rat thyroid adenoma/carcinoma
Permethrin	1.8E-2	mouse lung and liver tumors

NA = not available at the time this report was prepared.

Table 3.
Estimated Lifetime Cancer Risk from Dietary Exposure to Pesticides by Commodity Group for Low and High Anticipated Residue Estimates Derived from the FDA Data Base
(additional cancer cases per 1,000,000 population)

Commodity	Benomyl		Captan		Chlorothalonil		EBDCs		Permethrin		Simazine		Trifluralin	
	P=79 N=341		P=531 N=5592		P=371 N=6836		P=89 N=1148		P=730 N=5789		P=1 N=2957		P=0 N=319	
	Low AR	High AR	Low AR	High AR	Low AR	High AR	Low AR	High AR	Low AR	High AR	Low AR	High AR	Low AR	High AR
Leafy Veg. exc. Brassica	--	--	--	--	0.1	0.2	5	6	0.03	0.04	-	--	--	--
Leafy Veg.` Brassica	--	--	--	--	0.0005	0.06	--	--	--	--	--	--	--	--
Legume Veg.	--	--	0.2	0.3	0	0.3	--	--	0	0 03	--	--	0	0.007
Bulb Veg.	--	--	--	--	0.06	0.2	0	2	--	--	--	--	--	--
Fruiting Veg. exc. cucurbits	--	--	--	--	0.4	2	7	26	0.05	3	--	--	--	--
Fruiting Veg. inc. cucurbits	0.02	0.05	--	--	0.01	0.2	0.4	2	--	--	--	--	--	--
Root/Tuber Vegetables	--	--	--	--	0	1	2	13	0	2	--	--	--	--
Citrus	0	0.5	--	--	--	--	--	--	--	--	0	25	--	-
Pome Fruits	0.4	0.5	0.07	0.3	--	--	24	32	--	--	0	9	--	--
Stone Fruits	0.2	0.3	0.1	0.2	--	--	--	--	--	--	--	--	--	--
Small Fruits and Berries	0.1	0.1	0.09	0.1	--	--	0	3	--	--	0	3	--	--
Cereal Grains	0	0.03	16	16	--	--	--	--	0.04	0.6	0	4	0	1
Unspecified	--	--	--	--	--	--	--	--	--	--	--	--	0	0.001
TOTAL	0.7200	1.4800	16.4600	16.9000	0.5705	3.9600	38.4000	84.0000	0.1200	5.6700	0.0000	41.0000	0.0000	1.0080

P = Number of positive samples
N = Total number of samples
-- = residue information for crops in this commodity group were not available

Table 4.
Estimated Lifetime Cancer Risk from Dietary Exposure to Pesticides by Commodity Group for Low and High Anticipated Residue Estimates Derived from the Foodcontam Data Base (additional cancer cases per 1,000,000 population)

Commodity	Benomyl		Captan		Chlorothalonil		EBDCs		Permethrin		Simazine		Trifluralin	
	P=122 N=838		P=342 N=2115		P=351 N=3951		P=16 N=1804		P=775 N=7734		P=3 N=36		P=4 N=74	
	Low AR	High AR	Low AR	High AR	Low AR	High AR	Low AR	High AR	Low AR	High AR	Low AR	High AR	Low AR	High AR
Leafy Veg. exc. Brassica	0	0.009	0.04	0.08	0.4	0.9	0	2	0.6	0.7	INS	INS	--	--
Leafy Veg. Brassica	0	0.02	0.006	0.007	0.2	0.7	6	8	0.05	0.3	INS	INS	--	--
Legume Veg.	0.002	0.05	0.06	0.1	0.4	2	--	--	--	--	INS	INS	--	--
Bulb Veg.	--	--	0.004	0.04	0.0002	0.005	0	2	--	--	INS	INS	--	--
Fruiting Veg. exc. cucurbits	--	--	--	--	3	9	0	21	0.2	3	INS	INS	--	--
Fruiting Veg. inc. cucurbits	--	--	0.0006	0.01	3	7	0	1	0.0008	0 08	INS	INS	--	--
Root/Tuber Vegetables	--	--	--	--	0.01	3	2	20	0	0	INS	INS	0.005	0.005
Citrus	0.3	0.8	--	--	--	--	--	--	--	--	INS	INS	--	--
Pome Fruits	0.8	0.9	0.1	0.4	--	--	2	12	0	2	INS	INS	--	--
Stone Fruits	0.3	0.3	0.6	0.7	0.04	0.7	0	3	0	0.4	INS	INS	--	--
Small Fruits and Berries	0.04	0.07	2	2	0.1	0.3	1	5	--	--	INS	INS	--	--
Cereal Grains	--	--	--	--	--	--	--	--	0	0.4	INS	INS	--	--
Unspecified	0	0.05	--	--	--	--	0	3	0.001	0.09	INS	INS	--	--
TOTAL	1.4420	2.1990	2.8106	3.3370	7.1502	23.6050	11.0000	77.0000	0.8518	6.9700	INS	INS	0.0050	0 0050

P = Number of positive samples
N = Total number of samples
INS = insufficient data to estimate risk
-- = residue information for crops in this commodity group were not available

EPA Comparative Risk Study

Summary of Non-Dietary Risks from Pesticide Use

Region 8

EXECUTIVE SUMMARY

Pesticides are defined as substances used to kill, inhibit, regulate, or repel species such as insects and mites, weeds, fungi, rodents, and other organisms deemed undesirable (or as defined by FIFRA, substances which "prevent, destroy, repel, or mitigate" pests). They occupy an unusual niche among the universe of chemicals that humans encounter as they are deliberately added to various environments to achieve the stated purpose (Murphy 1986). There is little debate regarding the numerous benefits achieved by pesticides in agricultural productivity, public health, and other areas. However, it is well-documented that many pesticides are not selective in their toxicity, and that direct exposures to pesticide handlers and to residues remaining in indoor and outdoor environments have produced numerous cases of injury and death, and that pesticides are suspected of producing delayed adverse effects, including cancer.

Situations in Region 8 that represent potential occupational and other non-dietary health risks due to pesticide exposures include:

- persons handling pesticides intended for use on agricultural crops;
- persons performing hand labor tasks on pesticide-treated crops;
- persons applying pesticides in and to structures, especially residences, and on lawns surrounding these structures; and
- persons, especially children, occupying such structures.

This report attempts to assess the health risks in these exposure situations for comparison to other environmental concerns. Health risk, a function of both exposure and toxicity, is assessed for several pesticides of concern, using exposure and toxicological potency estimates from the published literature and from U.S. EPA, and using preliminary estimates prepared for this report. This analysis will not attempt to identify and develop quantitative estimates of health risks associated with all major uses of pesticides in agricultural and structural pesticide-use situations because of the diversity of use patterns, toxicity ranges, and exposure scenarios presented by agricultural and structural pesticide uses in Region 8. This analysis also does not attempt to prioritize the selected active pesticide ingredients for further review or regulatory action. Therefore, the results of this analysis are not appropriate for purposes other than the regional comparative risk project.

Region 8 agricultural patterns and population demographics indicate that pesticide usage has the potential for exposing significant populations of pesticide handlers and residents, compared to agricultural fieldworkers. This analysis identified several use and exposure situations which may represent unacceptable health risks. These include carcinogenic and other delayed-onset adverse effects from exposure of applicators and mixer/loaders handling the insecticides and herbicides used on major field crops and rangelands, and concerns for acute and subchronic effects for children playing on insecticide-treated surfaces such as carpets and turf. Quantitative risk estimate ranges for many of the assessed populations exceed levels deemed acceptable in other environmental areas (i.e. Hazard Indices exceed 1, cancer estimates exceed one per ten thousand). Examples of risk estimates are given in the following summary table.

Worker Activity	Pesticide	Cancer Risk	Hazard Index
Field Worker	Captan	3 per 100,000 to 2 per 1,000	0.09 to 5.6
	Chlorothalonil	1 per 10,000 to 8 per 1,000	0.8 to 48.7
	Malathion	- -	0.6 to 36.5
Commercial Groundboom Applicator	Atrazine	4 per 10,000 to 7 per 100	0.4 to 62
	Trifluralin	2 per 100,000 to 2 per 1,000	0.3 to 41.3
	Methyl Parathion	- -	32 to 4,080
	2,4-D	4 per 10,000 to 6 per 1,000	- -
	Carbofuran	- -	1.6 to 204
Commercial Mixer/Loader	Atrazine	2 per 1,000 to 3 per 100	2 to 24
	2,4-D	2 per 10,000 to 2 per 1,000	- -
	Carbofuran	- -	8 to 78

The interpretation and uncertainties of this analysis are discussed in the risk assessment, uncertainty analysis, and technical appendix sections of this report. Perhaps the largest area of uncertainty to be considered in interpreting the following results is the poor data base for dermal absorption of most pesticides. In the general absence of such data, an assumption of 100% absorption was necessary. Reduced absorption rates could have a marked effect in reducing the risk estimates presented in this report. For some pesticides, however, such reductions might not be enough to lower the estimates to levels deemed acceptable, even in small populations.

DESCRIPTION OF PROBLEM

A. Agriculture

Concerns for exposure of agricultural workers to pesticides first began to be raised during the 1950's and 1960's as many of the environmentally persistent organochlorine insecticides, generally of low acute toxicity, began to be replaced with less persistent but often highly acutely toxic cholinesterase-inhibiting organophosphates and N-methyl carbamate insecticides, including parathion, mevinphos, phosalone, dialifor, methomyl, and others. Persons handling these pesticides and those entering treated areas to perform hand labor tasks were exposed to these pesticides at levels capable of producing illness or death.

Agricultural pesticide usage shows an upward trend, with approximately 1 billion pounds each of pesticides and wood preservatives applied nationally in 1987 (Young 1987). In particular, there is an increasing use of herbicides, primarily due to reduced tillage on major grain crops, and a decreasing use of insecticides. Currently, herbicide use is over twice as high as insecticide use. These herbicides, along with most fungicides and some insecticides, are classified as being only slightly or moderately acutely toxic. However, these products may be of concern with regard to a possible potential to produce delayed adverse effects with repeated low level exposure over time, including reproductive and developmental toxicity, organ system toxicity (e.g. hepatic, pulmonary, neurological, and renal toxins), and oncogenic (cancer-causing) effects (Sharp et al. 1986, Wilk 1986, Moses 1989, Blair et al. 1989).

Concerns for reentry exposures exist on a nationwide basis. Reporting of pesticide-implicated illness and injury is mandatory in California and therefore it has the most complete record of suspected and confirmed effects attributed to pesticide exposures (as reviewed in U.S. EPA 1984). California is often viewed as a "worst case"; however, such a view is probably inaccurate given the incomplete incident-reporting in most states and the more stringent California worker protection regulations. However, California may be unique among the states in the employment of highly hand labor-intensive agricultural practices, the wide-spread usage of acutely toxic organophosphorus insecticides, and the arid climate which permits the persistence of these insecticides and their transformation into even more toxic oxidation products.

In 1977 in California, physicians reported 1,518 cases of occupational illness or injury from pesticides, of which 12% were to field workers. Approximately one-fourth of the field worker cases were of a systemic nature, with the remainder being injuries to the skin, eyes, or both (U.S. EPA 1984). In comparison, reported occupational injuries from pesticide exposure in 1987 numbered 1,595 (580 definitely from pesticides, 391 probable, and the remainder possible or unlikely), with approximately one-half of a systemic nature. Total reports did not show a clear trend in frequency between 1982 and 1987, however.

Also, of total occupational reports filed in 1987, 28% involved exposure to residues in agricultural fields or on commodities (Maddy et al. 1990).

Krieger and Edmiston (n.d.) analyzed and ranked pesticides in California according to reported occurrences of systemic injury from 1982 through 1986, and noted that the highest incidence was associated with parathion use which accounted for 18% of total reports, almost twice that of the second ranked pesticide - mevinfos. Fifteen of the 20 highest ranked pesticides were cholinesterase-inhibiting insecticides, including methomyl, methamidophos, dimethoate, methidathion, and carbofuran.

An accurate accounting of occupational pesticide-related illness and injury on a national scale may not be possible. In a compilation prepared by Jerry Blondell of OPP/U.S. EPA, over 63,000 pesticide-related incidents were reported to poison control centers in 1988, two-thirds of which were from insecticides. The organophosphates dominated the pesticide classes in terms of producing fatalities. Wasserman and Wiles (1985) estimate upwards of 300,000 pesticide-related illness and injury incidents occur nationwide on an annual basis. Thus, although statistics on pesticide-related occupational illness and injury for Region 8 were not available for this report, it can be concluded from the above national statistics, and extensive use of agricultural pesticides as discussed below, that a significant concern exists in this Region.

Mitigating the risk of immediate illness and injury resulting from exposures to highly acutely toxic pesticides such as organophosphates, N-methyl carbamates, fumigants, and paraquat has received much of the focus in regulating occupational exposure to pesticides. However, reducing the risk of delayed-onset adverse health effects, such as cancer, reproductive and developmental effects, and organ system toxicity resulting from exposures to pesticides is receiving increased attention.

1. Agricultural Workers

These concerns are especially great for migrant agricultural workers who rely upon field activities to provide their living. Nationally, it is estimated that there are 800,000 migrant farmworkers and dependents, and 1,900,000 seasonal farmworkers and dependents (Wilk 1986). The potential exists for both acute and chronic exposures upon entry into treated areas to perform hand labor tasks, and these populations are perhaps among those at highest risk for additive or synergistic toxicity from exposures to combinations of pesticides and other applied chemicals ("inert ingredients", fertilizers). Potentially sensitive populations include pregnant and nursing women, and young children who commonly work in fields (illegally) or accompany a working parent. Children working or living in treated fields may be exposed to amounts of pesticides equivalent to those of adults, and thus incur higher exposures on the basis of body weight. Poor health care, inadequate housing, alcoholism, heat stress and other factors are possible toxicity-modifying factors to be considered in assessment of health risks from pesticide exposure in these workers. In many areas, language barriers and lack of education may hamper understanding of increasingly complex safety-related issues and requirements. A number of exposure sources exist for agricultural field workers including: dermal contact with and inhalation of foliar, soil, and dust residues; spray drift; as well as ingestion of treated food (Wilk 1986, Maddy et al. 1990).

These concerns have, over the past twenty years, led to the development of a number of state and federal programs for agricultural worker protection, including establishment of reentry intervals for acutely toxic pesticides and those suspected of teratogenic or carcinogenic potential. While these programs have undoubtedly contributed to reduced occupational pesticide exposure, the concerns have not been eliminated, as evidenced by continuing documentation of exposure and injury in states such as California which have comparatively advanced exposure and safety standards (Maddy et al. 1990).

2. Agricultural Pesticide Applicators

Persons who handle agricultural pesticides on either a continuous or intermittent basis are also at risk from adverse pesticide effects, both because such pesticide handlers have the potential to contact large quantities of more highly concentrated formulations of the materials, and because certain application methods have an inherently high exposure potential. Pesticide handlers perform such activities as:

* mixing the formulated products with diluent (water, oil, etc.);
* loading pesticides into the application equipment;
* operating application equipment;
* flagging for aerial applications; and
* cleaning mixing, loading, and application equipment.

Exposures may occur:

* during normal operations;
* from spills, splashes, drift, or fallout;
* from equipment leakage and failure;
* from failure to appropriately use personal protective equipment; and
* from failure to follow other precautionary directions on labels (Maddy et al. 1990).

Certain application methods present high exposure potential to the applicator, including:

* airblast and other high-pressure sprayers that generate mists and fogs (common in Region 2 fruit trees and vegetable crops);
* backpack or knapsack sprayers; and
* airborne dispersal of pesticides in enclosed areas such as greenhouses (Waldron 1985).

Application equipment and methods that present lower exposure potential to the applicator include:

* low pressure, coarse droplet dispersal as from boom sprayers;
* granular applications;
* equipment and methods that release the pesticide in close proximity to the target area, such as soil-incorporation or soil injection techniques; and
* equipment that separates the applicator from the application environment such as enclosed cockpits or enclosed cabs.

Mixing and loading have the potential to produce higher exposures than the application tasks (Mumma et al. 1985), because mixers and loaders may be handling concentrated forms of the pesticides. Soluble packaging and closed mixing/loading systems, when available, aid in mitigating these exposures. Improved training for pesticide handlers, better hygiene practices, and the appropriate use of personal protective equipment also can contribute to decreased exposure potential in handling operations (Cowell et al. 1989). However, ignorance, accidents, and equipment failure can negate such safety programs. Furthermore, current personal protective equipment technology may not be adequate to protect pesticide handlers using pesticides that are highly toxic by the dermal route, such as parathion and mevinphos.

No national statistics were available for reported occupational injury to applicators of agricultural pesticides alone. However, Maddy et al. (1990) reported that occupational injuries for pesticide applicators (401) approximately equalled those reported for agricultural field workers (372) in California in 1987, and were much higher than those reported for mixer/loaders and flaggers (132).

B. Residential Pesticide Use

Individuals of all ages, occupations, and economic status are exposed to pesticides in a wide variety of non-dietary, non-agricultural uses and settings. These may include household, garden, and lawn chemicals (applied commercially or by private individuals), termiticide and other structural treatments (i.e. wood preservatives), nurseries, golf courses, public buildings, rights of way, mosquito control and related public health programs, industrial and medical disinfectants, and fumigation/sterilization (medical instruments, buildings).

Residential exposure to pesticides has been associated with a significant proportion of reported pesticide intoxication incidents, many either involving children or indicating they are a major population of concern for these usages (as reviewed in Fenske et al. 1990). Although statistics on pesticide exposures in Region 8 residential settings were not available for this report, there is little basis to conclude that substantial differences exist among the Regions. In 1984, 1180 calls were made to the San Francisco Poison Control Center and Toxic Information Center regarding pesticides, nearly one-third of which involved the exposure of children to insecticides (Berteau et al. 1989). The results of the Non-Occupational Pesticide Study, NOPES (U.S. EPA 1990) indicated the detection throughout the year of a number of home and garden-use pesticides in indoor air of two urban areas of the United States. Elements of this study have also developed data suggesting that exposure in homes may also occur via contact with products during application and with contaminated house dust (Roberts and Camann 1989). Currie et al. (1990) studied office exposure after application of formulations of several insecticides and found substantial and persistent indoor air and surface residues.

Commercial lawn care has grown into a major business. It depends heavily upon the use of chemical pesticides, which is a cause for increasing concern due to a shortage of chronic toxicity information for many of the products applied. Over 10% of individual homeowners may utilize such a service. Also, homeowners apply lawn and garden pesticides themselves (GAO 1990).

A recent study has suggested that a statistically significant increase in the incidence of childhood leukemia is associated with parental use of pesticides around the home (Lowengart et al. 1987). Additionally, although the weight of evidence is inconclusive at present, there have been suggestions in farmers of a carcinogenic effect from long-term usage of the herbicide 2,4-D (used on residential lawns) (Blair et al. 1989). Thus, chronic exposure, as indicated in NOPES and other sources, to residential and other non-agricultural pesticides may present a concern for public health in addition to the acute exposure and toxicity issues that have predominated the regulation of these chemicals.

Children may be particularly prone to elevated exposures to pesticides due to characteristic behaviors including extensive crawling and contact with ground and floor, and a high level of hand to mouth activity. Combined with a higher body surface area/weight ratio than adults, closer proximity to treated surfaces such as carpets and turf, and the probability of increased unprotected skin area in contact with contaminated surfaces, the potential for exposures via dermal contact, ingestion, and inhalation may be significant in children (Roberts and Camann 1989, Berteau et al. 1989, Fenske et al. 1990). Recent data by Fenske et al. (1990) indicates that indoor exposure to pesticide vapors from carpet treatment, even in ventilated rooms, may pose a particular concern for children, due to a gradient of airborne residue that results in higher concentrations in the breathing zone of a child playing on the carpet. It has also been estimated that children may be at up to 12-fold greater risk from exposure to indoor and outdoor contaminants associated with soil and dust, relative to adults (Hawley 1986). A substantial proportion of lead intake in children is via direct contact with dusts and soil, with subsequent ingestion of lead residues via hand to mouth contact. Lead can accumulate around the outside foundation of older homes due to the weathering and flaking of lead-based paints, and these residues appear to contribute significantly to levels of lead detected in indoor house dust from tracking in with foot traffic (Roberts et al. in press). This situation is analogous to the previous practice of applying persistent termiticides such as chlordane and heptachlor around outside foundations that appears to have contributed to the recent detection of such chemicals in the indoor air of numerous homes sampled in NOPES (U.S. EPA 1990). Transfer of outdoor residues of pesticides from lawns to indoor carpets by foot traffic was demonstrated in a recent study (Nelson et al. 1988). Therefore, ingestion of pesticides adsorbed to dusts is an important factor to be considered in developing residential exposure assessments for pesticides.

Exposure of children to cholinesterase-inhibiting insecticides, which account for a large proportion of residential use insecticides, may result in adverse effects not immediately recognized as pesticide toxicity given the nature of many children's behavior patterns such as drooling and frequent urination, which resemble symptoms of the onset of anticholinesterase-induced toxicity (Berteau et al. 1989). EPA recently issued a cancellation order for phenyl mercuric acetate and other mercury-based biocides in paints due to an investigation of a case of child poisoning in the home linked to these ingredients (Federal Register, 6/29/90). When these factors are considered in the context of the incompletely developed detoxification enzyme systems and nervous systems of children, it is clear that this population must be given priority in determining acceptable levels of exposure and health risk from the use of residential pesticides.

EXPOSURE ASSESSMENT AND HEALTH RISK CHARACTERIZATION

The first step in deriving estimates of health risk from potentially hazardous materials is to determine through measurements, models, or a combination thereof, the levels of exposure an individual may receive as a single (acute), repeated intermediate (subchronic), or repeated long-term (chronic) event(s). In the case of pesticides, each of these exposure estimates may be pertinent, although chronic exposure is generally most important for potential carcinogens, while acute and subchronic exposures may apply to other forms of toxicity, including neurotoxicity and other forms of systemic toxicity (renal toxicity, dermal toxicity, reproductive effects, and so forth). Route of exposure is another important element in the exposure assessment, as many compounds exhibit different patterns of toxicity and potency depending on whether entry into the body occurs via dermal absorption, inhalation (of particles, aerosols, or vapors), or ingestion.

Exposure estimates are then integrated with quantitative measures of carcinogenic potency (Cancer Potency Factors, CPF), or compared with measures of acute toxicity (lethal dose, No Observed Adverse Effect Levels, NOAELs) or chronic toxicity (Reference Doses, RfDs), to quantitatively estimate health risk. Toxicity data for select pesticides, as well as for other environmental contaminants included for comparative purposes, are summarized in Table 1 in the technical appendix to this report, along with a summary of the assessment approach .

This assessment of non-dietary pesticide exposure and risk in Region 8 begins with a determination of the major applications and types of pesticides used. For agricultural areas, this will define the relative importance of reentry exposure vs. handler exposure, as well as the major active ingredients to be considered. Non-agricultural exposures to a large degree are determined by the level of urban/suburban vs. rural populations, as the former will present greater usages of residential and turf pesticides (for homes, golf courses, parks, and the like) compared to rural areas where the crop and livestock (i.e dips, fly control, disinfectants, spray drift/track-in) sources contribute to residential exposure.

Pesticide Use in Region 8

A. Agricultural Pesticide Use Profile

Agricultural practices in Region 8 differ among the states. Grazing of beef cattle and sheep is the most important agricultural activity in Wyoming and Montana. Cash crops in these two states are wheat, oats, barley, sugar beets, and hay, but only a small percentage of agricultural land is devoted to their production. Livestock production is also significant in North and South Dakota (beef cattle, sheep, hogs). Wheat, oats, rye, barley, soybeans and hay are important crops. Sunflower seed (ND, SD), potatoes (ND), and sugar beets (ND) are also grown. Timber is produced in Montana, South Dakota, and Wyoming. The high technology features of crop production in this region indicate that exposures for farm workers entering treated fields for cultivating and harvesting are minor compared to other areas of the U.S. (i.e. Regions 4 and 9). Thus, applicators and other pesticide handlers involved in treating the extensive grain and other field crops grown in this region provide the primary concern for exposure to agricuultural pesticides. Statistics on populations of farm workers and pesticide handlers in Region 8 were not available.

Major pesticides utilized in Region 8, based on several sources including RFF (1986), and contact with Dallas Miller of Region 8 of U.S. EPA, include major field crop herbicides such as 2,4-D on grain crops, pichloram on pastureland, and lesser amounts of trifluralin and other herbicides. Major use insecticides include methyl parathion on field crops, aldicarb granular (potatoes), carbofuran, azinphos-methyl, and disyston. Due to dry climate, fungicide use is minor.

B. Non-Agricultural Pesticide Use Profile

Region 8 provides a blend of urbanized and rural populations. Therefore, patterns of non-agricultural pesticides observed nationally apply roughly to Region 2. However, Region 8 has the fewest number of single unit housing structures (1.8 million), and therefore, the magnitude of the exposed population is expected to be less than other regions which extensively use pesticides in these settings, such as Regions 4 and 5.

Representative non-agricultural compounds include: house, turf, and garden products such as propoxur, chloropyrifos, diazinon, oftanol, carbaryl, bendiocarb, benomyl, chlorothalonil, 2,4-D, dicamba, atrazine, dacthal and several others (GAO 1990); termiticides and structural wood preservatives; chloropyrifos, heptachlor and chlordane (discontinued but residual), pentachlorophenol, and inorganics (arsenic, copper). Less extensive population exposure, while potentially high on an individual basis, may be found from usages in: nurseries; public buildings (insecticides, disinfectants); rights of way (herbicides); mosquito and other control programs; industrial, food processing, and medical disinfectants; and fumigation (grain, food products, medical instruments, buildings).

Estimates of Non-dietary Exposure and Risk from Pesticides in Region 8.

Potential routes of exposure to pesticides include:

* dermal absorption of pesticides from a variety of contaminated surfaces such as foliage, soil, dust, and other indoor or outdoor surfaces;
* inhalation of vapors, dusts, and aerosols; and
* ingestion via transfer from contaminated skin or objects.

Dietary exposure to pesticide residues in food is considered in a separate component part of the pesticide comparative risk analysis. In occupational and residential contexts, dermal absorption appears generally to present the greatest avenue of entry of pesticides into the body (Durham 1985). However, the other exposure routes may be very important for certain active ingredients and circumstances, and must be given consideration in the design and conduct of an exposure assessment.

Major usage chemicals in fruit/vegetable and field crop areas and urban applications were considered in assessing risks for farm workers, pesticide handlers, and urban populations. EPA-verified toxicity values (from IRIS and U.S. EPA 1990) were used to estimate chronic risks. However, given the lack of basic toxicological information on many major pesticides and the on-going process of verifying dose/response data, certain pesticides could not be carried through a quantitative risk assessment.

Also, it is possible but unlikely that a given worker will be exposed to one single active ingredient or pesticide class exclusively over a work career, as was assumed in the exposure assessments which follow. Since not all fungicides or herbicides, for example, are carcinogenic, nor are all insecticides highly potent chronic nerve toxins, and because EPA and state review is systematically identifying and reducing exposure to such materials, assuming exposure over a full work career to selected carcinogenic or otherwise chronic toxins may not be a highly probable event. Exposure estimates were not adjusted downward on this basis, however, because additive or synergistic (or antagonistic) effects are conceivable in these exposure settings. As noted elsewhere in this analysis, dermal exposures estimated in this analysis assume 100% skin absorption efficiency, due to the variability in this parameter among pesticides and the general lack of data. For poorly absorbed pesticides, risks presented in this analysis may be overestimated. Captan, for example, is absorbed to the extent of approximately 1.3% per hour through the skin. Thus, depending on hygiene practices, risks from captan exposure may be approximately 5 to 10% of those presented in this report. In addition to consideration of exposure potential, considerable professional judgement was used to select pesticides for this regional comparative risk summary in order to achieve a representative and balanced range of toxicological concern, without unduly exaggerating or understating risks. The risk estimates were developed under considerable time and resource constraints, for use in a relativistic risk ranking process, and therefore should not be used for any other purpose.

A. Migrant Agricultural Workers

Many of the major field crops in Region 8 are raised with a minimum of hand-labor work and are harvested mechanically. Thus, fieldworker exposure presents less concern than in certain other Reions (i.e. 4 and 9). Estimating a typical or representative exposure rate for a worker is not possible due to the great variety of production practices, work activities, crop characteristics and growth stage, weather and climate, application rates and residue decay rates, and personal experience and hygiene habits. These all can directly affect levels of surface residues and dermal exposure. Furthermore, estimating long term exposure rates for this worker population is extremely difficult, due to the seasonal nature of the work and migration patterns (Lunchick 1990). Numerous studies have sought to characterize worker reentry exposure by integrating estimates of dermal transfer rates from various crop surfaces with measurements of surface residue dissipation. When combined with appropriate toxicological estimates of no effect levels or virtually safe doses, intervals intended to protect workers reentering treated fields can be estimated (as reviewed in U.S. EPA 1984 and Knaak et al. 1989).

For the purpose of this comparative summary, pesticide exposures and risks to agricultural workers in Region 8 will be estimated in several contexts utilizing published data and estimates and encompassing a range of exposure scénarios: harvesting strawberries (a low crop), and harvesting fruit trees. Popendorf and Franklin (1987) present a range of harvester pesticide exposure rates of 0.5 to 30 mg/hr, with a median of 15. The upper value corresponds with the high end of the range observed for orange harvesters (from Popendorf, 1980; often considered a high exposure situation due to head and upper body exposure to the leaves). The lower value corresponds with rates presented in Zweig et al. (1985) for strawberries. Therefore, this range will be used to estimate representative harvesting exposure rates for Region 8 vegetable or fruit crops.

Daily Exposure

At these hourly rates, and assuming an eight hour work day and 70 kg body weight, daily exposure is estimated from 0.06 mg/kg to 3.43 mg/kg. As a rough estimate of acute exposure risks, these exposures are approximately 100 times less than median lethal oral doses for three widely used and relatively less acutely toxic fruit and vegetable insecticides: malathion, carbaryl, and phenthoate (reliable estimates of dermal toxicity were generally unavailable for this analysis). Federal or state reentry standards would presumably apply to more highly toxic acute agents, although there continue to be documented cases of worker injury from Toxicity Class I materials.

Lifetime Exposure

As noted previously, basic knowledge of the extent of a work year and career for seasonal and migrant agricultural workers is lacking (Lunchick 1990). For the purposes of this assessment, it will be assumed that workers are engaged in hand labor activities requiring extensive pesticide contact for 35 years, 26 weeks per year, 6 eight hour days per week. The estimated range of long term daily lifetime exposure rates, normalized over a 70 year lifetime, for a worker weighing 70 kg is 0.012 mg/kg/day to 0.73 mg/kg/day (mean 0.37). Exposures in actual situations will be to mixtures of residue types, with possibilities for additive, synergistic, and antagonistic effects.

Using the cancer potency factors from Table 1, and assuming all of long term exposure is to one active ingredient, the following estimates of excess lifetime cancer incidence can be made for chronic exposure (Note: cancer risk is the probability of incurring the disease in excess of background levels over a lifetime; risks are presented as fractions, for instance 3 cases per 100,000 exposed people, 3E-5, or 3 x 10-5; for further information, refer to the technical appendix to this report).

Cancer Risks:

Captan: 3E-5 to 2E-3 (3 per 100,000 to 2 per 1,000)

Chlorothalonil: E-4 to 8E-3 (1 per 10,000 to 8 per 1,000)

Non-Carcinogenic Hazard Indices:

For non-carcinogenic effects, the ratio of lifetime daily exposure rate to the Reference Dose (RfD, summarized in Table 1), or Hazard Indices (HI, Hazard Indices of 1 or greater indicate a threshold for potential chronic toxicity may have been exceeded) for two insecticides and the above fungicides are:

Captan: 0.09 to 5.6

Chlorothalonil: 0.8 to 48.7

Carbaryl: 0.1 to 7.3

Malathion: 0.6 to 36.5

Summary

Estimates of both worker cancer incidence and the possibility for other chronic effects for selected fungicides and insecticides approach or exceed levels generally considered unacceptable. Risk estimates in the mid- to lower end of the range may perhaps better reflect reasonable estimates because of factors such as reentry intervals, use of work gloves (albeit an uncommon practice at present), limitations on levels of skin absorption of residues, and the unlikely event that all of an individual's exposure is from a single carcinogenic or chronic agent. All of these will serve to reduce exposure and risk level. However, the magnitude of the upper end of the estimated risk range suggests a serious concern for workers harvesting tree crops treated with fungicides, insecticides, and miticides. Nevertheless, this assessment places perspective on the potential health impacts of agricultural worker exposure to pesticides, relative to other environmental health problems.

B. Agricultural Pesticide Applicators

U.S. EPA and other organizations that have extensively studied the issues have determined that applicator exposure to pesticides is primarily a function of work practices, application method and rate, formulation type, and other factors largely independent of the active ingredient being applied.(U.S. EPA 1987, Honeycutt 1989, and Reinert and Severn 1985). This has permitted development of a generic approach to estimating applicator and mixer/loader exposure, which may include the use of a computer data base of measured values capable of calculating exposures for a variety of specified settings (Honeycutt 1989).

This data base is being developed and validated. Therefore, for the purposes of this comparative summary, select handler exposure estimates representing a range including a reasonable upperbound value were taken from the literature. Several scenarios pertinent to Region 8 agricultural practices were defined: including acute and chronic exposure of mixer/loaders and groundboom applicators of an insecticide and herbicides commonly used for major Region 8 field crops.

Based on information from Curt Lunchick of OPP/U.S. EPA (Lunchick 1990), seasonal application patterns for a commercial applicator may consist of applying preemergent herbicide for 15 full working days per season, followed by a ten week period of insecticide/fungicide treatment (weekly for each customer), or 50 days per year. For chronic estimation, a 35 year career is assumed. Mixer/loaders utilizing closed system equipment provide separate support for 4 hours per day. Farmers applying pesticides on a small scale may do so 1 to 3 days per year, and perform their own mixing and loading, frequently with open systems.

Lunchick et al. (1989) reviewed a number of surrogate applicator dermal exposure studies for groundboom application of alachlor herbicide and reported exposures ranging from 0.15 to 72.0 mg/hr, normalized for a 1 pound active ingredient (a.i.)/acre application rate, with various levels of protection accounting for some of the variability (especially the use of open vs. closed cab tractors). This range agrees well with the total dermal exposure rates of 1.0 to 130 mg/hour (mean = 24.4) contained in the review by Reinert and Severn (1985) for groundboom applicators on row crops. This latter range will therefore be used for this assessment.

Reinert and Severn (1985) present a range of measured exposure rates for mixer/loader exposures of 39 to 3,000 (mean 510) mg/hour for wettable powder formulations, and 27 to 32,000 (mean 7,800) mg/hour for liquid formulations. Virtually all (>95%) exposure was to the hands. Protective gloves used appropriately would be expected to reduce mixer/loader exposure by at least 90%. Such a reduction would be in keeping with the range of 10 to 100 mg/hour (median 45) presented by Popendorf and Franklin (1987) for mixing and loading with open systems. The latter estimate will be used for this assessment, as it incorporates a reasonable assumption of protective equipment use for the lower end of the exposure range.

Therefore, assuming 525 eight hour work days per lifetime (15 days per year, 35 year career) for the groundboom applicator and mixer/loader while handling herbicides, plus an additional 1,750 days for these same workers while handling insecticides/fungicides (50 days per year for 35 years); plus additional assumptions of 70 kg body weight, 70 year (25,550 day) lifespans, and that airborne exposures are minimal relative to dermal exposures (Durham 1985), the following short term and long term exposure estimates can be made:

Commercial Groundboom Application:

Daily Exposure = 0.11 to 14.9 mg/kg/work day [2.8 mean]

[1.0 to 130 mg/hour (24.4 mean) * 8 hour/70 kg]

This exposure rate presents less concern for herbicides of low acute toxicity, such as atrazine and trifluralin than for materials in higher toxicity categories, with the upper daily exposure estimate approaching or exceeding observable effect levels or median lethal doses measured in animals for the latter. Protective equipment requirements would lessen, but not eliminate, concerns for such highly toxic materials such as paraquat and methyl parathion. For compounds which are extremely toxic dermally, such as mevinphos and ethyl parathion, available personal protective equipment may not provide adequate protection.

Lifetime Exposure = 0.002 to 0.31 mg/kg/day for herbicides;

= 0.008 to 1.02 mg/kg/day for insecticides/fungicides.

[0.11 to 14.9 mg/kg/work day (2.8 mean) * number work days/25,550 days lifetime]

Cancer risk estimates for exposure to herbicides include:

Atrazine: 4E-4 to 7E-2 (4 per 10,000 to 7 per 100)

2,4-D: 4E-5 to 6E-3 (4 per 100,000 to 6 per 1,000)

Trifluralin: 2E-5 to 2E-3 (2 per 100,000 to 2 per 1,000)

Non-Carcinogenic Hazard Indices:

Methyl parathion: 32 to 4,080

Carbofuran: 1.6 to 204

Atrazine: 0.4 to 62

Trifluralin: 0.3 to 41.3

Summary

To summarize, application of major use pesticides to field crops by groundboom methods appears to present significant health risks to applicators for both carcinogenic and non-carcinogenic long-term toxicity endpoints, with quantitative estimates exceeding by large margins those levels of cancer risk and other long term toxicity typically deemed acceptable by the Agency for general populations or individuals.

Commercial Mixing and Loading (open system):

Daily Exposure = 0.6 to 5.7 (2.57 median) mg/kg/work day

[10 to 100 (45 median) mg/hour * 4 hours/70 kg]

These levels of exposure raise concerns for highly toxic materials such as methyl parathion and similarly toxic compounds in cases where appropriate personal protective equipment is used improperly or not at all. Acute toxicity concerns appear to be low for the herbicides and less acutely toxic insecticides and fungicides.

Lifetime Exposure = 0.01 to 0.12 (0.05 median) mg/kg/day for herbicides;
0.04 to 0.39 for insecticides and fungicides.

[0.6 to 5.7 (2.57 median) mg/kg/work day * number of work days for herbicides (525) or insecticides and fungicides (i.e. 1750)/25,550 days lifetime]

Cancer Risks:

Atrazine: 2E-3 to 3E-2 (2 per 1,000 to 3 per 100)

Chlorothalonil: 4E-4 to 4E-3 (4 per 10,000 to 4 per 1,000)

Captan: 9E-5 to 9E-4 (9 per 100,000 to 9 per 10,000)

2,4-D: 2E-4 to 2E-3 (2 per 10,000 to 2 per 1,000)

Trifluralin: 8E-5 to 9E-4 (8 per 100,000 to 9 per 10,000)

Non-Carcinogenic Hazard Indices:

Atrazine: 2 to 24.0

Captan: 0.3 to 3.0

Carbaryl: 0.4 to 4.0

Carbofuran: 8 to 78

Malathion: 2 to 20

Summary

To summarize, commercial mixers and loaders of selected herbicides, insecticides, and fungicides may be at risk of carcinogenic and non-carcinogenic long-term effects elevated above generally accepted levels. Concerns for acute toxicity may also exist for unprotected workers handling highly toxic chemicals such as methyl parathion.

C. Non-Agricultural Pesticide Users

Indoor sources of pesticide exposure include foggers (such as "flea bombs"), spot or crack and crevice treatments, vapor strips for flying insects, moth repellents, residual termiticides, pesticides for pet use (flea collars, dips, shampoos), disinfectants, and indoor plant applications. Outdoor pesticides can also gain entry into the household via foot traffic and dust. The materials applied in the home are primarily insecticides, with usage dominated by a limited number of active ingredients including chlorpyrifos, propoxur, diazinon, malathion, DDVP, and pyrethroids, as well as persistent discontinued products (chlordane, heptachlor, DDT and its degradates).

Region 8 has the fewest number of single unit housing structures among the Regions (ca. 1.8 million), suggesting relatively low to moderate usage of pesticides applied in urban settings among EPA regions (RFF 1986). Major urban insecticides include chloropyrifos (a major termiticide replacement and a major-use indoor insecticide), malathion, methoxychlor, bendiocarb, carbaryl, and diazinon; herbicides include 2,4-D and esters, dicamba, dacthal; and chlorothalonil fungicide (U.S. EPA 1990, GAO 1990).

At present, there is little consensus on approaches to estimating exposure in urban settings. The Non-Dietary Exposure Branch of OPP/U.S. EPA is currently evaluating residential outdoor and indoor exposure assessment methodology, as are the California Department of Food and Agriculture, the Canadian Ministry of Health and Welfare, pesticide manufacturers, and other organizations. To assess exposure to pesticides in residential settings, the following scenarios are considered: indoor and outdoor acute and long-term exposure to children playing on pesticide-treated surfaces, and commercial lawn care pesticide application. Chronic residential indoor exposure as developed by NOPES (U.S. EPA 1990) is reviewed in a companion risk analysis on indoor air quality.

Acute and chronic indoor and outdoor exposure

Fenske et al. (1990) measured available residues of chlorpyrifos in an unoccupied apartment following broadcast application by a professional applicator of an aqueous formulation for flea control. All rooms were carpeted with thick pile carpet. In the two ventilated rooms, surface residues declined rapidly, relative to the unventilated room. Air residues in the breathing zone of a child, closer to the carpet surface were considerably higher than the adult zone and were stated to be above a National Academy of Science interim guideline for indoor air chlorpyrifos residues after application for termite treatment. An exposure and risk assessment was also conducted. Based on both a series of assumptions on dermal transfer and absorption into the body (dermal absorption data was available for chlorpyrifos) and the measured residues, total dermal and inhalation exposure was estimated as 0.075 mg/kg for the day of application and 0.038 mg/kg for the day after application.

Berteau et al. (1989) of the California Department of Health Services and of CDFA conducted a worst case analysis for a child's exposure to three commonly used indoor insecticides: propoxur, chloropyrifos, and dichlovos (DDVP). They obtained estimates of 2.2 to 50 mg/kg for acute daily exposure beginning immediately after carpet treatment. The latter value included a 100% dermal absorption factor because measured data for the active ingredient assessed, DDVP, were not available. For the purpose of this assessment, a range of 0.04 (for chlorpyrifos estimated by Fenske et al.) to 5.7 mg/kg (for propoxur estimated by Berteau et al.) will be used to estimate acute exposure to an indoor pesticide-treated room. For subchronic and chronic exposure, it is assumed that exposure occurs three times per year for five years (mean body weight 15 kg); 0.0003 to 0.05 mg/kg/day for five years or 0.000005 to 0.0007 mg/kg/day over a 70 year lifetime (adjusted for 70 kg adult weight).

Acute Risks:

Both Berteau et al. (1989) and Fenske et al. (1990) concluded that their estimates of childhood exposure exceeded criteria for acute toxicity concerns in children playing on recently treated surfaces, including no effect levels for cholinesterase inhibition by chlorpyrifos and propoxur. By inference, insecticide treated lawns may represent similar (possibly reduced due to less inhalation exposure) potential acute risks to playing children.

Indoor Cancer Risks:

Cancer risks for propoxur using propoxur exposure estimates from Berteau et al. (1989) and a cancer potency factor of 0.0079:

Propoxur: 6E-6 (6 per 1,000,000)

Indoor Non-carcinogenic Subchronic Hazard Indices (using chemical-specific exposure estimates):

Chlorpyrifos: 0.1

Propoxur: 12.5

The estimates of Fenske et al. (1990) and Berteau et al. (1989) may apply to outdoor "reentry" exposure as well, for children playing on treated lawns, with allowance for lower inhalation exposures. The estimate of Fenske et al. (1990) contains a contribution from inhalation of 31 to 42%, while the Berteau et al. (1989) estimates for inhalation are less than 1% of the total. This would correspondingly reduce the chlorpyrifos hazard index, but the estimates for propoxur would not materially change.

The significance of air residues reported in NOPES (U.S. EPA 1990), and the assessment of potential health risks presented in that report is discussed fully in a companion comparative risk summary for indoor air contaminants.

Turf applicator exposure

Commercial (professional) applicators of turf chemicals may be exposed to a variety of pesticides - predominantly herbicides. Home garden pesticides are also a source of exposure. This assessment will consider turf pesticides as the focus for assessing outdoor urban exposure. Commercially and privately applied residential turf pesticides include such ingredients as the chlorophenoxy herbicides (2,4-D and esters, dicamba), and several insecticides such as diazinon and malathion. Thus, a broad spectrum of active ingredients and potential concerns for toxicity may exist for the outdoor residential usage patterns.

The work season of commercial lawn care applicators may consist of 6 days per week for up to 8 weeks per type of pesticide applied (i.e. insecticide vs. herbicide) (Freeborg et al. 1985). Neither good data on turf applicator exposure rates nor acceptable surrogate data were available for this assessment, therefore a quantitative risk assessment was not developed for this scenario. However, long-term exposure in professional applicators and support personnel, combined with the suspected carcinogenicity of several high use active ingredients, present concerns for long-term health risks to this worker population.

ASSESSMENT LIMITATIONS - UNCERTAINTY ANALYSIS

This analysis of the potential health impacts of non-dietary exposures to pesticides is intended to be used only as part of a general comparison with the potential health impact of other areas of environmental concern. Quantitative exposure and risk estimates presented in this report are derived either from peer reviewed publications or government reports and data bases, utilizing standard methodology for characterizing risks in the presence of data uncertainty and variability. Thus, they are generally reasonable estimates incorporating conservative assumptions regarding human exposure and toxicological response, including extrapolation from animal toxicity data, exposure models, and possible synergistic and additive effects (recognizing that antagonistic effects are possible) from exposure to mixtures of chemicals or from additional exposure sources.

They do not include adjustments for variables such as:

* individual work and hygiene practices;
* personal protective equipment use;
* formulation type; or
* weather (outdoors) and ventilation (indoors).

Perhaps the most significant area of uncertainty in these assessments, other than frequent lack of basic toxicological information on major active ingredients currently in use, is one based on the rate of dermal absorption of each pesticide. Depending on a variety of factors, pesticides vary widely in the rate they are absorbed through the skin. Known dermal absorption rates through human forearm skin range from 75% for carbaryl to a 0.3% rate for paraquat, for example. Other factors being equal, these rates would reduce the assessed risks by perhaps as little as 25% to as much as 300-fold. Unfortunately, dermal absorption rates are not available for most pesticides, including many of those assessed herein. Also, while inhalation exposures generally appear to be a relatively minor component of non-dietary exposure (thus not considered in depth in this analysis), they may be significant under certain circumstances. Further, dermal toxicity data were not readily available, particularly for chronic toxicity, necessitating the use of oral toxicity data. While it can be generalized that absorption following ingestion is more efficient than by the dermal route, it is not a proven phenomenon for all organic chemicals, including pesticides. In the face of these uncertainties, the analysis assumed a dermal absorption rate of 100% for all pesticides.

Because of time constraints in developing this analysis, other areas of uncertainty were not fully addressed. First, the weight of evidence for carcinogenicity of selected pesticides identified as possible vs. probable human carcinogens was not fully addressed. Neither was the seriousness of certain non-carcinogenic forms of toxicity weighed (i.e. irreversible kidney toxicity or teratogenicity vs. reversible neurotoxicity). The regulatory and usage status of all assessed pesticides could not be verified. It is possible that some of the pesticides assessed are being phased down or withdrawn from use, or soon will undergo a detailed safety review. Finally, the potential for modification of toxicological response from exposure to mixtures of pesticides and other chemicals could not be addressed given the innumerable combinations possible. The latter provides the principal basis for the conservative estimation techniques utilized in this analysis.

This analysis should therefore not be used as a rigorous determination of risks from exposure to specific products and usages, nor as an indication of potential risks from the hundreds of active ingredients currently applied in agricultural and non-agricultural settings. As a result, the conclusions of this analysis are inappropriate for other than the stated purpose.

TECHNICAL APPENDIX

RISK ASSESSMENT DEFINITION AND SAMPLE CALCULATIONS

Risk assessment, or risk analysis, is a highly complex science. In essence, it is predictive toxicology, seeking to determine the level of potential health effects present in select populations exposed to a given chemical or other agent, based on observations in controlled animal tests or human experience in other areas of endeavor. As might be expected, it is an uncertain science in many respects, and this is reflected in regulatory applications of risk assessment, where the goal of protection of public health imposes a number of conservative assumptions for toxicity mechanisms, extrapolation, and exposure assessment techniques (often highly debated in the scientific community) for particular contaminants and situations.

For this analysis of risks from non-dietary pesticide exposures, these conservative techniques were applied so as to be consistent with assessments in other areas addressed in this project and to acknowledge the many areas of uncertainty present in this subject area. For further information on the approach taken in this report, the reader is referred to the risk and exposure assessment guidelines issued by U.S. EPA in 1986, and other risk assessment guidance such as that issued by the EPA Superfund and other program offices. The following is a brief explanation of the approach taken in developing this risk analysis.

Cancer risk, defined as the probability of incurring cancer from a particular agent over a lifetime in excess of expected or background rates, was estimated by first determining daily exposure rate over a 70 year lifetime for a 70 kg (body weight) individual, after having calculated total lifetime exposure in units of milligrams (mg). Thus, the lifetime daily exposure is described in terms of mg/kg body weight/day of lifetime. This exposure estimate is multiplied by a value termed the cancer potency factor (CPF, also $q1^*$, unit risk factor). The CPF, in units of 1/(mg/kg/day), is an estimated measure of a chemical's ability to induce cancer in humans as a function of exposure or dose. It is usually derived from a controlled study in laboratory animals where, because of economic, logistic, and statistical considerations, the low end of the dose/response region most relevant to human exposure cannot usually be accurately determined. Thus, a conservative assumption of non-threshold response is made, and a biostatistical carcinogenesis model such as the linearized, multistage model of Crump and associates is applied to the data. The CPF is the upper-bound estimate from the modeled low-dose slope estimate of response vs. dose. The following is a sample calculation performed for this report, for agricultural field worker exposure to a suspect carcinogen: the fungicide captan.

Exposure per work day = 0.06 to 3.43 mg/kg/workday

Exposure per day of lifetime = 0.06 to 3.43 mg/kg/workday X 5460 workdays/25,550 days per lifetime = 0.012 to 0.73 mg/kg/day

Cancer Risk = 0.012 to 0.73 mg/kg/day X 0.0023/mg*kg*day (CPF) =
3E-5 to 2E-3; or 3 per 100,000 to 2 per 1,000.

Lifetime risks from exposure to individual carcinogens are considered to be additive in nature, although this assumption was not addressed directly in this report due to data limitations.

For compounds suspected of producing non-carcinogenic effects (frequently including carcinogens), such as organ toxicity, reproductive/developmental, or other effects upon subchronic or long-term exposure, an assumption is made, based on extensive experience, that thresholds may exist below which a toxic response is not observable. To quantify non-carcinogenic risk, an estimate is made, again usually from animal test data, termed the Reference Dose, or RfD. The RfD has generally superseded the previous concept of the Acceptable Daily Intake (ADI). Both values are usually derived by examining available dose/response data (usually from animals) and determining a no observed adverse effect level (NOAEL) for the particular toxic effect of concern - generally the effect which occurs at the lowest exposure with the most serious outcome to health. An uncertainty factor (formerly margin of safety) is applied to the NOAEL to estimate a comparable protective exposure in humans. Typically, an uncertainty factor of 100 is applied to the NOAEL to derive the human RfD: 10-fold to extrapolate from animals to humans, and 10-fold to be protective of sensitive human populations. Other modifying factors may on occasion be applied.

The Hazard Index, the ratio of long-term daily intake to RfD, or HI, is a measure of potential chronic toxicity for non-carcinogenic effects. If the HI equals or exceeds 1, it is considered that a threshold for chronic toxicity may have been exceeded, suggesting concerns for adverse effects in the exposed population. The following calculation demonstrates how the Hazard Index was derived for captan in agricultural field workers. The RfD of captan is 0.13 mg/kg/day. The estimated lifetime daily exposure of agricultural workers to captan is 0.012 to 0.73 mg/kg/day from above. Therefore, the HI = 0.12 to 0.73 mg/kg/day / 0.13 mg/kg/day = 0.09 to 5.6. Thus, long-term exposures in the mid- to upper range of exposure would raise concerns for chronic, non-carcinogenic effects from captan.

For exposures to multiple chronic toxicants, the HI values may be summed, particularly if the agents act upon the same systems, in order to estimate additive toxicity.

Table 1. Compiled Reference Toxicity Values for Selected Pesticides

Pesticide/Use	Cancer Potency Factor	Reference Dose	Acute Toxicity (c)
Alachlor/Field Crop Herbicide	ND	0.01 (b)	930 mg/kg, oral LD50, rats
Atrazine/Field Crop and Turf Herbicide	0.22 (a)	0.005 (a)	1,750 mg/kg, oral LD50, rats
Captan/Fruit and Vegetable Fungicide	0.0023 (a)	0.13 (a)	9,000 mg/kg, oral LD50, rats
Carbaryl/Fruit and Vegetable Insecticide	ND	0.1 (b)	246 mg/kg, oral LD50, rat
Chloropyrifos/ Home and Field Crop Insecticide	ND	0.003 (b)	97 mg/kg, oral LD50, rat
Chlorothalonil/ Vegetable Fungicide	0.011 (a)	0.015 (a)	>10,000 mg/kg, oral LD50, rat
2,4-D and esters/ Herbicide	0.019 (a)	ND	375 mg/kg, oral LD50, rat
Carbofuran/ Field Crop Insecticide	ND	0.005 (b)	11 mg/kg, oral LD50, rat
Dicamba/Lawn Herbicide	ND	0.03 (b)	1,707 mg/kg, oral LD50, rat
Dicofol/Citrus Miticide	0.34 (a)	0.001 (a)	820 mg/kg, oral LD50,
Malathion/Home and Vegetable Insecticide	ND	0.02 (a)	1000 mg/kg, oral LD50, rat
Methyl Parathion/ Field Crop Insecticide	ND	0.00025 (b)	9 mg/kg, oral LD50, rat
Paraquat/Field Crop Herbicide	ND	ND	150 mg/kg, oral LD50, rat
Propoxur/Home and Lawn Insecticide	0.0079 (a)	0.004 (a)	95 mg/kg, oral LD50, rat
Trifluralin/ Field Crop Herbicide	0.0077 (a)	0.0075 (b)	5,000 mg/kg, oral LD50, mice
PCBs	7.7 (b)	0.0001 (b)	
Benzo(a)pyrene	11.5 (b)		
Vinyl Chloride	2.3 (b)		
Ethylene Dibromide	41.0 (b)		

a) U.S. EPA (1990), b) IRIS (1990), c) EXTOXNET (1989)

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SUMMARY REPORT

Ecological Effects of Pesticides
EPA Region VIII

Regional Comparative Risk Project
U.S. Environmental Protection Agency

August 1990

EXECUTIVE SUMMARY

This report is a summary of the potential ecological effects of pesticide use. The objective of this summary is to provide technical support information for Region VIII analysts and managers involved in EPA's Comparative Risk project. This summary is not a definitive characterization of ecological risks; rather a synthesis of information readily available within the time frame of this assignment.

This report includes pesticide use information, a description of receptor elements, as well as the ecological impact assessment of pesticides. Acute toxicity data for the major classes of pesticides evaluated is included. A series of appendices presenting detailed data and information used to derive this summary report are provided for documentation.

The following summarizes this risk analysis[a] outcome for Region VIII:

1. The intensity of ecological risk from pesticides is considered medium based on regional information; though it is important to note that it may be intense in localized areas.

2. The potential duration of pesticide effects is moderate, but it could be considered long term in localized areas.

3. Pesticides typically affect ecosystems and their components, thus their impact can be considered of low global importance.

4. The value of the ecological resources impacted is considered moderate due to the unique regional habitats present.

5. The extent of pesticide application in the Region is considered high (62 percent devoted to agriculture).

[a]Region IV definitions for the evaluative terminology were used.

INTRODUCTION

Pesticides are unique environmental contaminants in that they are deliberately added to the environment for the purpose of killing or injuring living organisms. Ideally, pesticides should be highly specific to target pests, and noninjurious to desirable nontarget species. However, most pesticides are not highly selective and can be injurious to many nontarget organisms. Based on their widespread use, pesticides pose a risk to nontarget native fish and wildlife species, habitats, communities, and ecosystems; both aquatic and terrestrial systems are affected by pesticides. This analysis reviews the ecological risk of pesticides for Region VIII (the Region). Receptors with higher susceptibility to pesticides were identified based on their exposure potential and sensitivity. This analysis should be applicable to a great number of pesticides used in this Region. The information included in this report emanates from numerous discussions with experts from conservation groups, state and federal agencies, and academia. Published and unpublished reports were used to support these assessments.

Organochlorine pesticides (otherwise known as chlorinated hydrocarbon pesticides) were the first synthetic organic chemicals to be extensively used for pest control. Currently, organophosphorus compounds represent the largest group of pesticides used. The insecticidal properties of carbamates were discovered in 1931 and developed in the late 1940s; since then, other compounds like substituted phenols, substituted ureas, and nitro compounds have been developed and are widely used.

Ecological resources are at risk from pesticide use in agriculture, forestry, aquatic plant control, maintenance of transportation corridors, and municipal and private pest management (e.g., mosquito control). Pesticides are introduced into the environment through numerous routes including air (aerial spray and offsite drift), water (direct application and runoff), and land (direct application to crops or other "resources"). Receptors can be exposed to pesticides through numerous pathways including dermal contact, ingestion of pesticide granules or contaminated matter, and inhalation of pesticides during spraying operations. The receptors evaluated included species, biotic communities, and ecosystems. Changes in ecosystem structure and function were quantified as data were available. Due to the complexity of ecosystem responses, the severity of pesticide risk is difficult to address. The toxicological database is dominated by dose-response type of studies concentrating mainly on standard species under standard laboratory conditions. The evaluation of pesticide effects under field conditions has only recently been incorporated into ecological risk assessments prepared as part of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) registration process. Thus, previous field ecological impact information is available mainly as incidental effects, poisonings, or die-offs reported to various agencies.

A group of "risk factors" reflecting the likelihood that a pesticide could reach receptors and affect the structure and function of the ecosystem were identified. This analysis was conducted for EPA's Comparative Risk project. Although acceptable scientific procedures were followed, the information presented herein is not appropriate for other uses. This analysis was prepared to provide environmental managers with information and "tools" to relatively rank different environmental problems by the residual risk they pose to the environment.

THE REGION

Region VIII includes 20 ecoregions (listed in Figure 1) adapted to numerous anthropomorphic uses creating a pattern of pesticide use which is very complex. The vegetation is mostly prairie and high-altitude woodland including sage brush, conifers, saltbush/greasewood, juniper/pinyon woodland, alpine meadows, grama/buffalo grass, wheat grass/needle grass, sandhills prairie, and bluestem prairie. The land use pattern is primarily subhumid and semiarid grassland with components of croplands, cropland with grazing land, desert shrubland, forest and woodland, and irrigated agriculture. (Appendix A includes a detailed description of the Region). Region VIII has several endangered or threatened species and encompasses many rare ecosystems. The U.S. Department of the Interior (DOI) lists 63 animal species in the Region as endangered species, including 33 mammals, 9 birds, 4 reptiles and amphibians, and 17 fish and invertebrates (50 CFR Part 17). These species represent a broad cross-section of all taxonomic and ecological groups.

PESTICIDE USE

Accurate pesticide use information is needed to evaluate the potential impact of this group of chemicals on the environment. More than 50,000 pesticide products are registered for thousands of agricultural purposes in the United States (1), and about 70 percent of new chemicals produced are used in agriculture. Insecticides, fungicides, and herbicides comprise

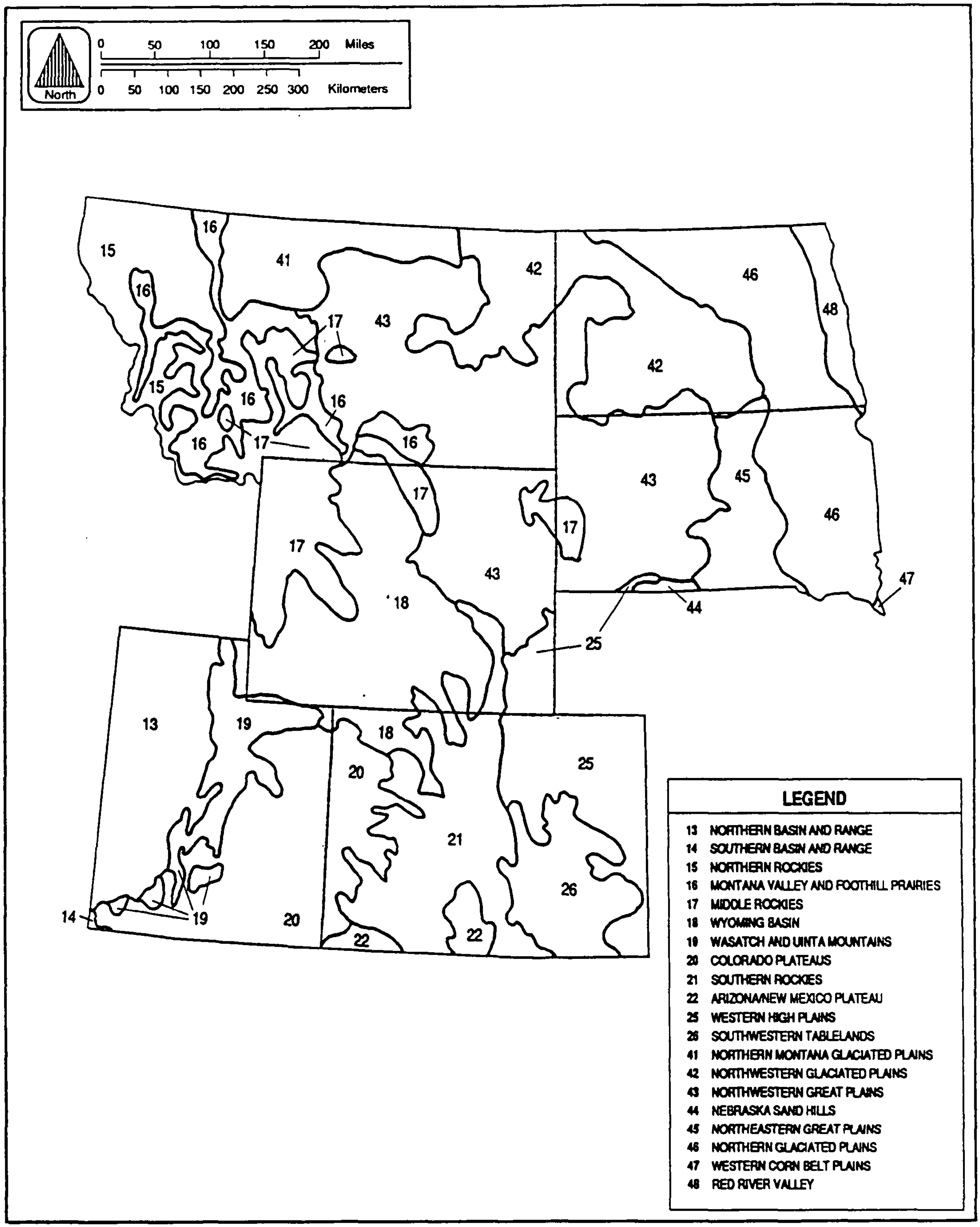

Figure 1 ECOREGIONS ENCOMPASSED BY EPA REGION VIII

SOURCES: Omernik, 1986; KBN Engineering and Applied Sciences, Inc., 1990.

EPA

about 90 percent of all pesticides used in agriculture (2). Herbicides are the most widely used agricultural pesticides in the United States. There are 121 chemicals registered as herbicides with hundreds of trademark products.

Due to the large number of pesticides used in the Region and the scarcity of pesticide use data, EPA (3) selected 41 active ingredients for national review based on their documented toxicity to avian, mammalian, and aquatic species. Pesticides potentially affecting groundwater were also included in this list (Table 1). Fifteen of the 40 pesticides selected are included in Gianessi and Puffer's (4) national use estimates of selected agricultural pesticides. It is important to note that Gianessi and Puffer's (4) estimates include 25 of approximately 200 commonly used active ingredients and was compiled using information from 1982 to 1985. Furthermore, pesticide use extrapolations should <u>not</u> be made from these 25 active ingredients to the remaining active ingredients not included in Gianessi and Puffer's (4) study. Acute toxicity data for the 41 selected pesticides are included in Appendix B. Agricultural lands comprise approximately 62 percent of the estimated 372 million acres in Region VIII. Pesticide use estimates for the Region were over 2.7 million pounds of organophosphates, 2.5 million pounds of carbamates, 2.0 million pounds of triazines, 3.8 million pounds of nitroanilines, 4.5 million pounds of acid amines, and 11.8 million pounds of phenoxy herbicides (2,4-D only) (Table 2).

In addition to agricultural applications, pesticides are used for mosquito control, aquatic plant control, forest management, human disease control, right-of-way, and golf course maintenance; these uses were not estimated by Gianessi and Puffer (4).

The 1982 Census of Agriculture (5), includes graphical displays of crops grown nationwide that can be used to identify major agricultural areas and ecosystems at risk from pesticides. Changes in land use should be reviewed to identify areas of advancing agriculture, as these areas may be receiving pesticides for the first time.

Table 1. Critical Stress Agents--Active Ingredients Selected for Review

Diazinon (B,F, GW)[a]	Azinphos ethyl/methyl (B, M)
Fenvalgrate (Esfenvalerate) (F)	Carbaryl (F, Honey Bees)[a]
Phorate (B, M)[a]	Coumaphos (F, B, M)
Cypermethrin (F)	Diflubenzuron (Dimilin)
Tralomethrin (F)	Endosulfan (F)
Befenthrin (F)	Fenthion (F)
Lamda-Cyhalothrin (F)	Terbufos (B, M)
Cyfluthrin (F)	Thiobencarb (B, M)[a]
Tefluthrin (F)	Chlorpyrifos (B, F)
Aldicarb (B, M, GW)	Carbofuran (B, M, GW)[a]
Demeton (B, M)	Disulfoton (B, GW)[a]
Ethoprop (B)[a]	Famphur (B, M)
Fenamiphos (B, M)	Fonofos (B, M)
Isophenphos (B, M)	Methomyl (B, M)
Oxamyl (B)	Permethrin (F)[b]
2,4-D (GW)[ab]	Atrazine (F, GW)[ab]
Cyanazine (GW)	Triflualin (GW, F)[ab]
Metolachlor (GW)[a]	Alachlor (GW)[ab]
Simazine (?)[b]	Malathion (B, F, GW, M)[a]
Parathion ethyl/methyl (B, F, GW, M)[a]	Dimethoate (B, M)
EPN (B, F, M)	

Note: B = indicates avian (bird) concerns.
F = indicates aquatic (fish) concerns.
GW = indicates groundwater impact concerns.
M = indicates mammalian concerns.

[a]Indicates use information available from Gianessi and Puffer (4).
[b]Indicates chemical is on Food Residue List.

Source: U.S. Environmental Protection Agency Office of Policy, Planning and Evaluation, 1990 (3).

Table 2. Pesticide Use Estimates[a] Available for Region VIII

Pesticide	Colorado	Montana	N. Dakota	S. Dakota	Utah	Wyoming	Region VIII Total
	Total Pounds of Active Ingredient Per Year						
Organophosphates							
Diazinon	4,240	574	8,291	NEA	2,230	NEA	15,335
Disulfoton	39,270	5,866	11,366	171	3,599	5,547	65,819
Ethoprop	27,771	2,267	NEA	NEA	1,970	NEA	32,008
Malathion	15,210	37,354	106,110	3,097	17,866	13,349	192,986
Parathion (ethyl)	214,736	311,019	333,791	124,562	17,138	13,590	1,014,836
Parathion (methyl)	2,061	60,105	7,007	7,232	2,534	NEA	78,939
Phorate	83,765	54,739	119,306	1,063,674	5,911	5,971	1,333,366
						Total Organophosphates	2,733,289
Carbamates							
Carbaryl	39,670	255,085	378,647	242,702	6,494	10,423	933,021
Thiobencarb	NEA	NEA	NEA	NEA	NEA	NEA	NEA
Carbofuran	247,897	420,425	333,066	620,247	5,821	10,348	1,637,804
						Total Carbamates	2,570,825
Triazines							
Atrazine	573,926	30,230	364,800	1,025,902	40,724	19,950	2,055,532
Nitroanilines							
Trifluralin	53,680	12,022	3,044,994	704,381	2,572	9,781	3,827,430
Acid Amides							
Alachlor	520,641	45,346	521,136	2,641,181	30,387	40,790	3,799,481
Metolachlor	265,238	18,993	101,256	321,225	19,098	3,628	729,438
						Total Acid Amines	4,528,919
Chlorinated Phenoxy Herbicides							
2, 4-D	1,557,927	4,097,466	3,120,325	885,355	919,137	1,316,549	11,896,754

Note: NEA = No estimate available
[a]Noncropland uses are not accounted.
Source: Gianessi and Puffer, 1989 (4) (Data for mid-1980s).

The indicator crops selected by EPA for review are corn, citrus, potatoes, apples, tomatoes, wheat, cotton, and soybeans (6). Maps of distribution of these crops are included in Appendix C. Crops of interest for the Region include wheat, corn, soybeans, and potatoes. Based on the number of acres harvested, wheat comprised the largest acreage, with its distribution mainly on the Red River Valley, Glaciated Plains, and Montana Valley and Foothill Prairies; corn is concentrated along the Northern Glaciated Plains. Soybeans and potatoes are mainly along the Red River Valley (5). Figure 1 shows the location of the ecoregions mentioned.

RECEPTOR ELEMENTS

Emphasis was placed on the identification of receptor elements (habitats and species) at risk due to the complexity of the pesticide use patterns. KBN Engineering and Applied Sciences, Inc. (KBN) has identified several sets of characteristics which make a habitat (ecological community) or species potentially vulnerable to damage from pesticides. These **risk factors** reflect the likelihood that a pesticide could reach a habitat and potentially affect the survival of significant populations directly through acute and/or chronic toxic effects or indirectly through damage to the habitat or food chain. All potential routes of exposure were assessed; they included water, land, and air.

The following are the risk factors for **habitats** identified:

1. Location of a habitat in low topographic situations (areas) or aquatic/wetland environments where pesticides could be brought in by surface water and groundwater;
2. Small patch size of a viable habitat surrounded by agricultural or forestry land that could be vulnerable to spray drift from adjacent fields or forests;
3. Ecological communities characterized by important and potentially sensitive populations or diverse assemblages of plants, invertebrates, amphibians, fish, and/or top carnivores;
4. Rare habitat types, presumed to support rare species;
5. Habitats and species that have not been previously exposed to toxic substances or other serious disturbances (most sensitive species are likely to have already dropped out of the biota of a disturbed system);

6. Agricultural regions where farmlands are expanding into native ecosystems not previously exposed to pesticides;
7. The leading edge of an agricultural or forestry epidemic that is being controlled by pesticides;
8. Systems with low regenerative capability;
9. Systems subject to natural and/or manmade stresses; and
10. Communities supporting threatened or endangered species.

A species can be considered potentially at risk if it has any of the following characteristics.

1. It represents a rare, threatened, or endangered species;
2. It represents a keystone species that plays a critical role in the ecosystem;
3. It is known to be susceptible to toxic effects of pesticides;
4. It is endangered and has a high exposure potential to pesticides, including wide ranging species with multiple exposure potential;
5. It has a critical life history stage or requirement (food or habitat) known to be sensitive to pesticides;
6. It is at the extension of its range or utilizing a marginal quality habitat exposed to pesticides.

ECOLOGICAL IMPACT ASSESSMENT

Habitats and Species at Risk

To identify habitats and species at risk, experts from U.S. Fish and Wildlife Service (USFWS), Heritage Programs, conservation organizations, and other appropriate agencies were contacted and interviewed regarding habitats and species with the risk factor characteristics outlined previously. The interviewers also inquired about known or suspected pesticide impacts on habitats or species. A number of types of habitats and species in Region VIII were identified potentially at risk from pesticides.

Two basic habitat risk concerns were identified as priority issues for Region VIII:

1. Multiple impacts on wetlands, which receive runoff from pesticide application areas. Drift from aerial sprays for grasshopper control is a serious problem in riparian and wetland habitats in eastern Dakotas. Impacts on migratory birds using pothole wetlands

are also of particular concern. Rare communities like fens and saline lakes are especially vulnerable to biodiversity degradation.

2. Damage to nontarget plants subjected to hayfield herbicide drift. Sprays for control of leafy spurge and Canada thistle have been observed to damage nearby cottonwood and boxelder woodlands, which are rare habitats in this region.

For a detailed presentation of ecological risk factors, see Appendix D.

Reported Effects

Fish and wildlife kills or die-offs from pesticides occur regularly in the Region. Data available were reviewed. Some of the studies reviewed referred to undocumented poisonings of fish and wildlife. Additional information can be obtained from the National Wildlife Health Center in Madison, Wisconsin. This Center maintains extensive records of suspected wildlife poisonings; due to time constraints these databases were not accessed for the Region. These wildlife poisonings and die-offs are the main documentation of pesticide field effects for most pesticides.

For Region VIII a complete record of fish and Wildlife kills or dieoffs from pesticides was not available for this review. However such episodes have been reported. The following is a description of three such episodes in Region VIII:

a. There are a number of incidences where birds of prey like eagles have eaten poisoned carcasses and have died as a result. For example along the Colorado river 10 eagles both bald and golden died from people lacing mule dear carcasses which were meant for coyotes.

b. In Pierre, North Dakota, ninety birds died, Canadian geese and Snow geese, from thimet poisoning. As a result four bald and three golden eagles died of secondary poisoning from eating the geese.

c. Within South Dakota there have been six or more documented cases where baits treated with carbofuran or a similar poison have killed eagles. The baits have been a dead calf that had been sprayed or injected with the chemical.*

It was the opinion of the scientists interviewed that both acute and subacute effects to nontarget fish and wildlife occur more often than realized.

Field pesticides studies are conducted by industry to evaluate the effects of particular pesticides on nontarget species. Nontarget species (mainly birds) are typically affected during these studies (7).

RISK ANALYSIS SYNTHESIS

Pesticide use is ubiquitous throughout the Region (Table 2). More than 50,000 pesticide products are registered currently for thousands of agricultural purposes and about 70 percent of new chemicals are used in agriculture. The issue of pesticide regional distribution is compounded by the fact that economics also plays a major role in pesticide use. A Florida study showed that there is a direct relationship between crop value and pesticide use per acre (8). Thus, in the assessment of risk, attention must be paid not only to the crops grown in largest areas but also to the pesticide use patterns locally (especially near sensitive habitats and species).

Most pesticides are not highly specific to the target organism and impact nontarget species, thus affecting ecosystem structure and function Region-wide. Pesticides enter the environment through all routes of exposure (air, land, and water) and receptors are exposed to them by all possible exposure pathways.

Wildlife poisoning and die-off incidents presented earlier document that pesticides impact nontarget organisms, even when applied according to label instructions. Unfortunately, documentation and identification of the exact cause and extent of the reported poisonings is often lacking. Animals that are affected by chronic exposure often leave the area of the poisoning and are not detected. Animals that are killed may rapidly decompose, making post mortem examinations and residue analysis difficult. In aquatic incidents, the animals are often carried away by currents and are subject to rapid decomposition as well. The above conditions lead to a significant probability of underreporting and, therefore, underestimate field pesticide effects.

Forty-one active ingredients were selected by EPA (3) for evaluation (Table 1); those with available use estimates by Gianessi and Puffer (4) are presented in Table 2. Pesticide estimates available should be cross-referenced with available use data or regional experts. Otherwise, critical active ingredients can be inadvertently omitted.

The following risk analysis is based on pesticides grouped by their chemical structure. Use estimates for selected pesticides is summarized in Table 2. Their acute toxicity profiles are included in Appendix B.

Organophosphates

Organophosphates represent one of the largest groups of pesticides used nationwide, but regional estimates indicate that organophosphate use is similar to other pesticides groups evaluated (with the exception of phenoxy herbicides) (Table 2). Several confirmed and suspected pesticide poisonings have been associated with this group of pesticides. The persistence of these pesticides is typically low to moderate (days to weeks) and the potential for bioaccumulation is low. However, the toxicity of these pesticides to insects, fish, and mammals is high due to their ability to inhibit the acetyl cholinesterase enzymes. For pesticides applied by aerial spraying, the risk of effects to nontarget organisms in adjacent habitats is high. For pesticides where broadcasting of granules is used, significant risk to nontarget species feeding in these areas exists unless the pesticides are quickly incorporated into the soil. Ethyl parathion has been identified more than any organophosphate as the cause of unintentional wildlife die-offs.

Carbamates

Carbamates are also anticholinesterases and are widely used for insect control. Carbamates have been identified as possibly responsible for several incidents of pesticide poisoning in Florida. Carbamates have relatively moderate persistence in the environment and typically have a low bioaccumulation potential. Most carbamates are considered highly acutely toxic to wildlife (bird and mammals) if ingested. Aldicarb is one of the most toxic pesticides in use today; unfortunately it was not included in Gianessi and Puffer's estimates (4). Aldicarb is applied as granules. Birds (e.g., herons, egrets, song birds, etc.) and other animals feeding in agricultural field can be considered at risk if the granules are not quickly and properly incorporated in the soil.

Pyrethroids

Eight pyrethroids were included in the national list (3). Use estimates are not available from Gianessi and Puffer (4) for this group of pesticides. The persistence and bioaccumulation potential of these pesticides is low. These compounds are typically toxic to fish and invertebrates. They are applied by aerial or ground spraying.

Chlorinated Phenoxy

The chlorinated phenoxy compound, 2,4-D, a systemic herbicide, has a moderate persistence and a low bioaccumulation potential. It has low to moderate toxicity to wildlife but is toxic to aquatic organisms. It is applied by aerial or ground spraying, broadcast granules, or injection (aquatic use). The environmental effect of 2,4-D on plant life is to change the dominant plant species in the area (ecosystem structure changes). The major risks appear to be habitat loss for species in or adjacent to areas sprayed due to drift. Changes in habitat caused by phenoxies have been shown to affect the following species: ducks in wetlands, pocket gophers in rangelands, and populations of deer, voles, elk, and chipmunks (9). Over 11.8 million pounds of 2,4-D are estimated to be used yearly in the Region.

Triazines

Triazines are moderately toxic to invertebrates, fish, and birds. They have low toxicity to mammals. Endangered aquatic species can be affected if the compounds are applied directly to aquatic system. Terrestrial endangered species may be affected if the pesticides are used in ditch banks and right-of-way. Simazine is registered for use as a herbicide and algicide on crops, noncrops, forest and aquatic sites. The primary action of all triazines is interference with photosynthesis. Simazine has a low bioaccumulation potential in fish. Its persistence in ponds is variable, the average half-life is 30 days, thus it is not persistent in aquatic systems.

Acid Amides

The acid amides are widely used herbicides. Most are used for selective control of seeding weeds either by preemergence application or preplant soil application. Alachlor is a preemergence herbicide relatively non-toxic to birds and mammals. The soil persistence in the environment is relatively short.

DISCUSSION

Two basic habitat risk concerns were identified as priority issues for Region VIII:

1. Multiple impacts on wetlands, which receive runoff from pesticide application areas. Drift from aerial sprays for grasshopper control is a serious problem in riparian and wetlands habitats in eastern Dakotas. Impacts on migratory birds using pothole wetlands are also of particular concern. Rare communities like fens and saline lakes are especially vulnerable to biodiversity degradation.

2. Damage to nontarget plants subjected to hayfield herbicide drift. Sprays for control of leafy spurge and Canada thistle have been observed to damage nearby cottonwood and boxelder woodlands, which are rare habitats in this region.

Appendix E includes summaries of analyses conducted by the Office of Pesticide Programs (7). These tables present listings of endangered species potentially at risk from pesticides used in croplands (Table E-1), forest lands (Table E-2), range and pasture land (Table E-3) and aquatic systems (Table E-4, mosquito larvicides). This information is presented by state for the Region. Sixty-three animal species are listed as endangered in Region VIII. Pesticides used on croplands were identified as potentially affecting two endangered fish and two endangered avian species. Forest products were identified as potentially affecting two endangered plants, and four fish species. Range and pastureland products were identified as potentially affecting numerous plants, five fish species, two reptiles, and one bird species. Mosquito larvicides were determined to potentially affect three bird, two fish, and one reptile species.

The following summarizes this risk analysis[a] outcome for Region VIII:

1. The intensity of ecological risk from pesticides is considered medium, based on regional information, though it is important to note that it may be intense in localized areas.

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[a]Region IV definitions for the evaluative terminology were used (11).

2. The potential duration of pesticide effects is moderate, but it could be considered long term in localized areas.
3. Pesticides typically affect ecosystems and their components, thus their impact can be considered of low global importance.
4. The value of the ecological resources impacted is considered moderate.
5. The extent of pesticide application in the Region is considered high (62 percent devoted to agriculture).

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(3) Worden, R.C. 1990. Personal Communication. U.S. Environmental Protection Agency, Office of Policy, Planning and Evaluation.

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(5) U.S. Department of the Census. 1982. The 1982 Census of Agriculture. Volume 2, Part I, Graphic Summary.

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(8) Nall, L.E., C. Phillippy, W. Tschinkel, S. Dwinell, and Ken Kuhl. 1987. Ranking of Possible Targets for Biological and Alternate Control Based on Pesticide Use. Pesticide Review Council, Florida Department of Agriculture and Consumer Services.

(9) Biggar, J.W. and J.N. Seiber, 1987. Fate of Pesticides in the Environment. Proceedings of a Technical Seminar. Agricultural Experiment Station. Division of Agriculture and Natural Resources. Publication Number 3320.

(10) Omernik, J.H. 1986. Ecoregions of the Conterminous United States. Corvallis Environmental Research Laboratory, U.S. Environmental Protection Agency.

(11) Berish, C. 1990.

APPENDIX A

ECOLOGICAL SETTING

REGIONAL SETTING

Region VIII extends from the Canadian border southward through the rocky Mountains and the western Great Plains to the borders of Arizona and New Mexico. Figure 1 shows the ecoregions, as defined by Omernik (10), covered by the five states comprising this Region. The Northern Rockies of northwestern Montana are high mountains with forests of cedar, hemlock, pine, spruce, and Douglas fir. These grade into the high Middle Rockies, which are characterized by spruce/fir forests and alpine meadows. There is some grazing in this ecoregion. The interdigitated Montana Valley and Foothill Prairies are more extensively grazed grasslands with some irrigated agriculture.

Croplands dominate the Northern Montana Glaciated Plains, Northwestern Glaciated Plains, Northern Glaciated Plains, and Red River Valley along the Canadian border, and the Northeastern Great Plains to the south. The grassy rangelands of the Northwestern Great Plains are the central heart of Region VIII. They grade southwestward into the desert shrubland of the Wyoming Basin, where there are areas with irrigated agriculture. To the southeast lie the high Southern Rockies, which are rangelands characterized by forests of spruce, fir, and pine with alpine meadows. To their west, in eastern Utah, the high mountains and plains of the colorado Plateaus have some irrigated agriculture in a juniper/pinyon woodland and desert shrub rangeland matrix.

Douglas fir, western spruce/fir/Douglas fir, and Arizona pine characterize the rangelands of the high Wasatch and Uinta mountains of central Utah. Further west are the plains and mountains of Northern Basin and Range, an area of sagebrush/greasewood desert rangeland. South of the Rockies, the edge of the Arizona/New Mexico Plateau extends into southern Colorado. This is a tableland range region with dry grasslands and sagebrush/saltbush/greasewood desert shrubland. Further east are the Southwestern Tablelands, where there is some cropland amidst expanses of grassland range. These tablelands grade northeastward into the Western High Plains, which have been largely converted to cropland, with some grazing land and irrigated agriculture.

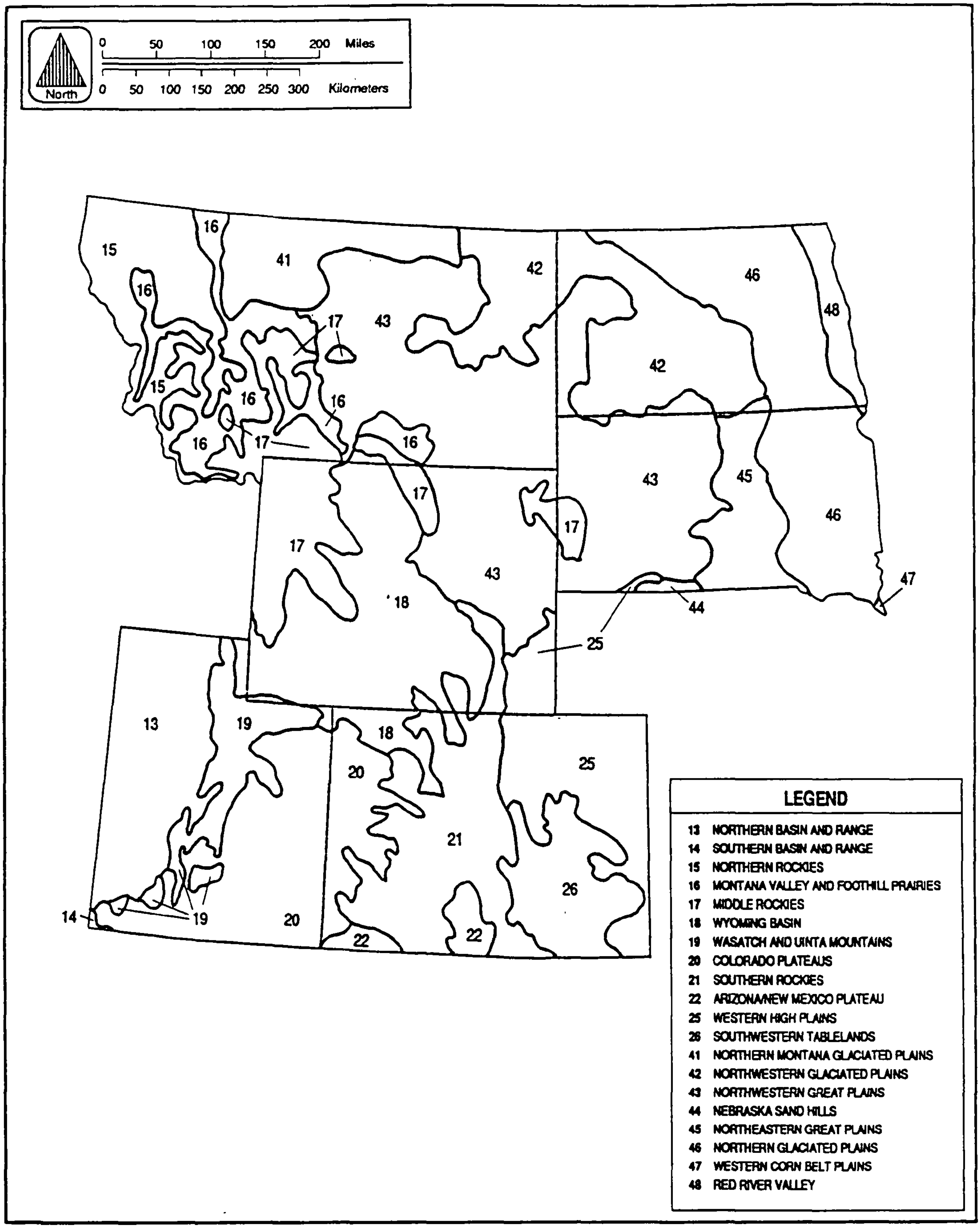


Figure 1 ECOREGIONS ENCOMPASSED BY EPA REGION VIII

SOURCES: Omernik, 1986; KBN Engineering and Applied Sciences, Inc., 1990.

EPA

APPENDIX B

ACUTE TOXICITY DATA OF SELECTED PESTICIDES

Table B-1. Representative Acute Toxicity Ranges for Selected Pesticides (Page 1 of 5)

Compound Name CAS Number	Oral LD50 (mg/kg) Mammals	Oral LD50 (mg/kg) Avians	Acute LC50 (µg/L) Fish	Acute LC50 (µg/L) Invertebrates	Acres of Application for Region VIII
Organophosphates					
Azinphos-methyl 86-50-0	4.4 to 80[a]	8.5 to 283[a]	0.36 to 4,810[a]	0.10 to 56[a]	275
Chlorpyrifos 2921-88-2	97 to 2,000[c]	8.4 to 1,590[a]	<1.0 to 280[a]	0.11 to 10[a]	393
Coumaphos 56-72-4	16 to 55[b]	3.5 to 32[a]	340 to 1,100[b]	0.07 to 0.10[a]	0
Demeton 8065-48-3	1.5 to 30[a]	2.38 to 22[a]	42 to 3,700[a]	14 to 78[a]	45
Diazinon 333-41-5	66 to 967[c]	2 to 110[a]	52 to 10,300[a]	0.2 to 522[a]	161
Dimethoate 60-51-5	28 to 500[b]	6.6 to 63.5[a]	6,000 to 8,600[c]	43 to 200[a]	485
Disulfoton 298-04-4	2 to <15[a]	3.2 to >32[a]	60 to 4,700[a]	3.9 to 52[a]	299
EPN 2104-64-5	9 to 200[a]	3.08 to 53.4[a]	100 to 110,000[b]	0.56 to 7.4[a]	10
Ethoprop 13194-48-4	61.5[c]	4.21 to 12.6[a]	1,000 to 2,000[b]	1.3 to 2.53[a]	139
Famphur 52-85-7	30 to 400[b]	1.8 to 9.87[a]			0

Table B-1. Representative Acute Toxicity Ranges for Selected Pesticides (Page 2 of 5)

Compound Name CAS Number	Oral LD50 (mg/kg)		Acute LC50 (µg/L)		Acres of Application for Region VIII
	Mammals	Avians	Fish	Invertebrates	
Fenamiphos 22224-92-6	8.1 to 100[a]	0.5 to 2.4[a]	72.1[a]	ND	0
Fenthion 55-38-9	150 to 300[c]	1.8 to 25.9[a]	550 to 3,404[b]	0.62 to 6,400[a]	0
Fonofos 944-22-9	8 to 17.5[a]	10 to 42[b]	6.8 to 110[a]	24[a]	694
Isophenphos 25311-71-1	28 to 127[b]	13 to 19[b]	1,000 to 4,000[b]		12
Malathion 121-75-5	480 to 4,060[c]	167 to 1,485[c]	4.1 to 12,900[a]	0.5 to >10,000[a]	704
Parathion 56-38-2	3 to 56[a]	0.125 to >24[a]	18 to 2,650[a]	0.04 to 600[a]	1,317
Phorate 298-02-2	1.6 to 4[a]	0.616 to 21[a]	1.0 to 340[a]	0.6 to 50[a]	605
Terbufos 13071-79-9	1.3 to 9.2[a]	15 to 26[b]	0.77 to 1,800[a]	0.2 to 1.4[a]	588
<u>Carbamates</u>					
Aldicarb 116-06-3	0.65 to 7[a]	1.78 to 5.34[a]	52 to 660[a]	ND	154
Bendicarb 22781-23-3	40 to 179[b]	21 to 33[b]			0

Table B-1. Representative Acute Toxicity Ranges for Selected Pesticides (Page 3 of 5)

Compound Name CAS Number	Oral LD50 (mg/kg) Mammals	 Avians	Acute LC50 (µg/L) Fish	 Invertebrates	Acres of Application for Region VIII
Carbaryl 63-25-2	200 to 850[c]	56 to 3,000[c]	250 to 39,000[b]	1.7 to 21,000[a]	538
Carbofuran 1563-66-2	2.5 to 34.5[a]	0.238 to 90[a]	88 to 2,859[a]	9.8 to 38.6[a]	1,174
Methomyl 16752-77-5	11 to >5,000[b]	10 to 42[b]	300 to 32,000[b]	7.6 to 1,050[a]	563
Oxamyl 23135-22-0	5.4 to 37[a]	2.6 to 9.4[a]	3,700 to 17,500[c]	170 to 5,600[b]	13
Triazines					
Atrazine 1912-24-9	1,750 to 5,100[d]	ND	4,500 to 42,000[c]	ND	NEA
Cyanazine 21725-46-2	334[c]	445 to >2,400[c]	9,000 to 21,300[c]	2,000[c]	NEA
Simazine 122-34-9	>5,000 to >15,380[e]	>4,640[e]	2,800 to 510,000[c]	1,000 to 130,000[b]	NEA
Nitroanilines					
Trifluralin 1582-09-8	>2,000 to >10,000[e]	>2,000[e]	8.4 to 2,200[a]	37 to 50,000[a]	NEA
Acid Amides					
Alachlor 15972-60-8	930 to >5,010[d]	ND	1,400 to 6,400[c]	2,500 to >320,000[c]	NEA

Table B-1. Representative Acute Toxicity Ranges for Selected Pesticides (Page 4 of 5)

Compound Name CAS Number	Oral LD50 (mg/kg)		Acute LC50 (µg/L)		Acres of Application for Region VIII
	Mammals	Avians	Fish	Invertebrates	
Metolachlor 51218-45-2	2,780[a]		2,000 to 10,000[c]	3,800 to 26,000[c]	NEA
Chlorinated Phenoxy Herbicides					
2,4-D	100 to 1,000[c]	340 to >2,025[c]	800 to 300,600[b]	740 to 64,290[b]	NEA
Pyrethroids					
Bifenthrin 82657-04-3					
Cyfluthrin 68359-37-5					
Lambda-Cyhalothrin 91465-08-6					
Cypermethrin 52315-07-8	247 to 309[c]	>4,640[a]	0.82 to 55[a]	0.26[a]	NEA
Fenvalerate 51630-58-1			0.32 to 76[a]	0.032 to 2.1[a]	NEA
Permethrin 52645-53-1			2.3 to 97[a]	0.17 to 1.26[a]	NEA
Tefluthrin 79538-32-2					
Tralomethrin 66841-25-6					

Table B-1. Representative Acute Toxicity Ranges for Selected Pesticides (Page 5 of 5)

Compound Name CAS Number	Oral LD50 (mg/kg) Mammals	Oral LD50 (mg/kg) Avians	Acute LC50 (µg/L) Fish	Acute LC50 (µg/L) Invertebrates	Acres of Application for Region VIII
Ureas					
Dimilin (Diflubeuzuron) 35367-38-5	>4,640 to >10,000[e]		>25,000 to 660,000[d]	2.1 to >100,000[a]	NEA
Organochlorines					
Endosulfan 115-29-7	30 to 110[b]	31.2 to 1,000[b]	0.09 to 11[a]	0.04 to 71.8[a]	NEA

Note: The classification of pesticides is based on the lower range of LC50 or LD50 values.

NEA = No estimate available.

[a]Very highly toxic.
[b]Highly toxic.
[c]Moderately toxic.
[d]Slightly toxic.
[e]Practically nontoxic.

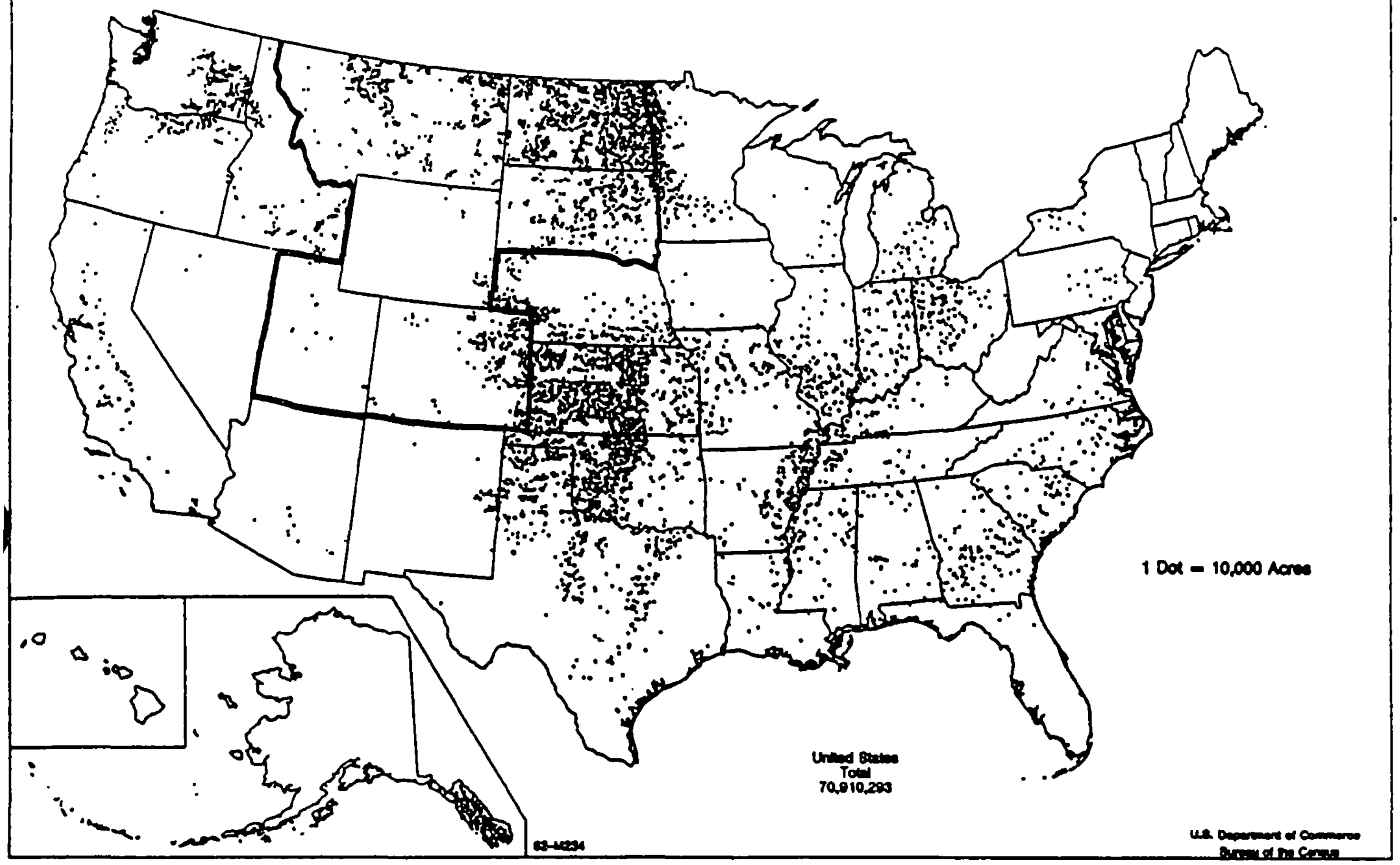
Sources: EPA Pesticide Fact Sheets.
Hudson et al., 1984.
Humburg et al., 1989.
Mayer and Ellersieck, 1986.
Smith, 1987.
Verschueren, 1983.

APPENDIX C

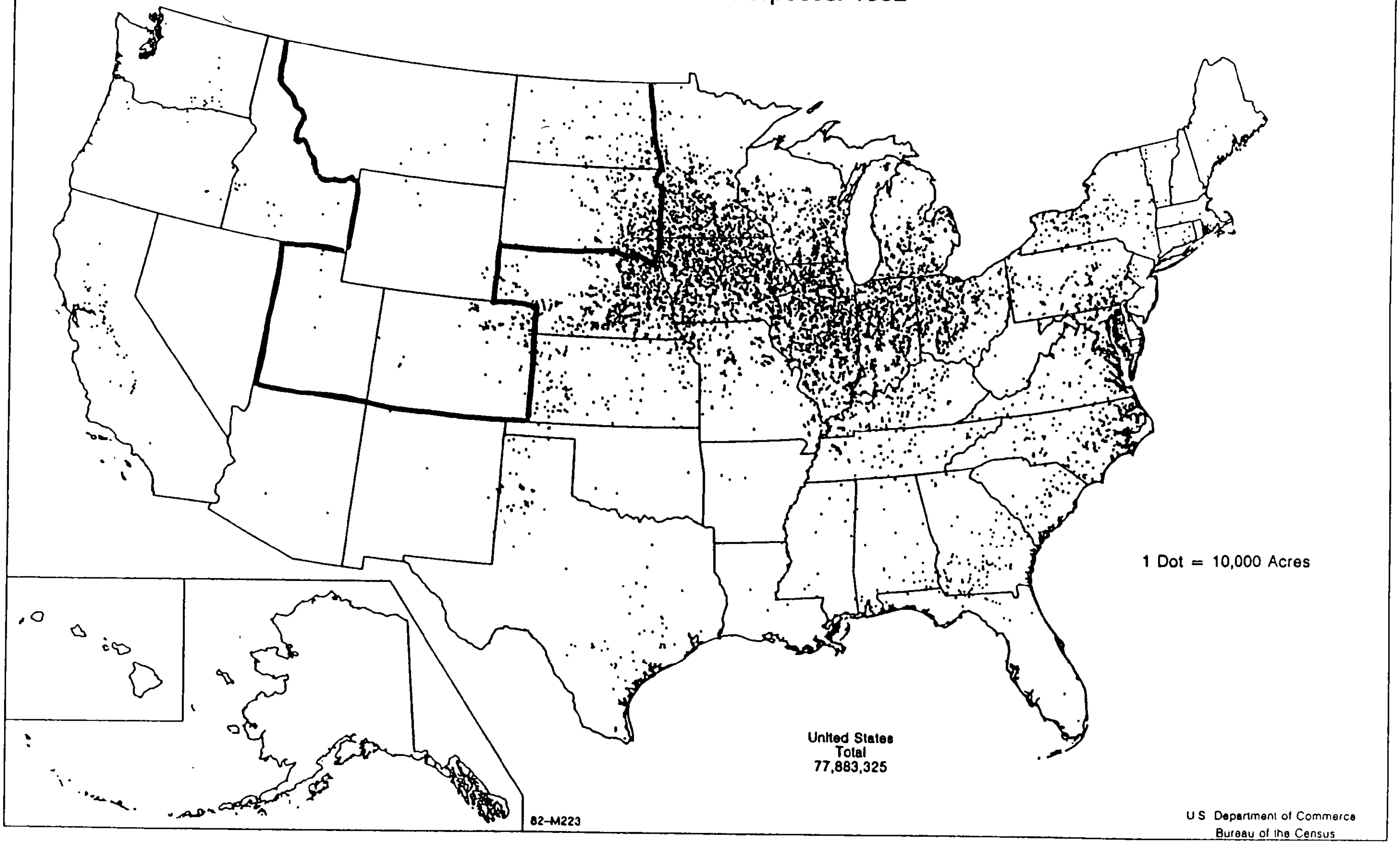
GRAPHIC DISPLAYS OF CROP DISTRIBUTION

COPIED FROM U.S. DEPARTMENT OF
THE CENSUS 1982 GRAPHIC SUMMARY (5)

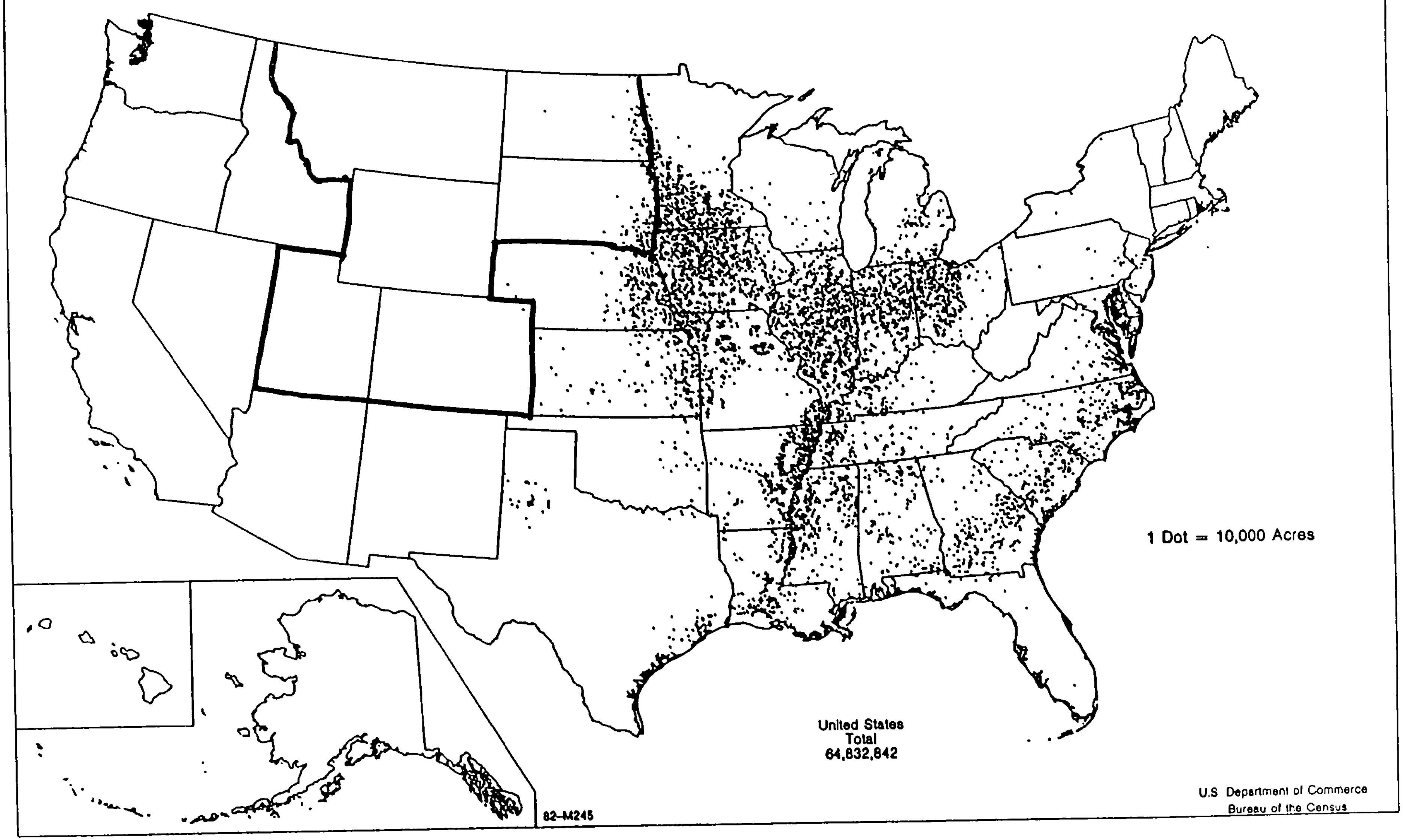
Wheat Harvested for Grain: 1982

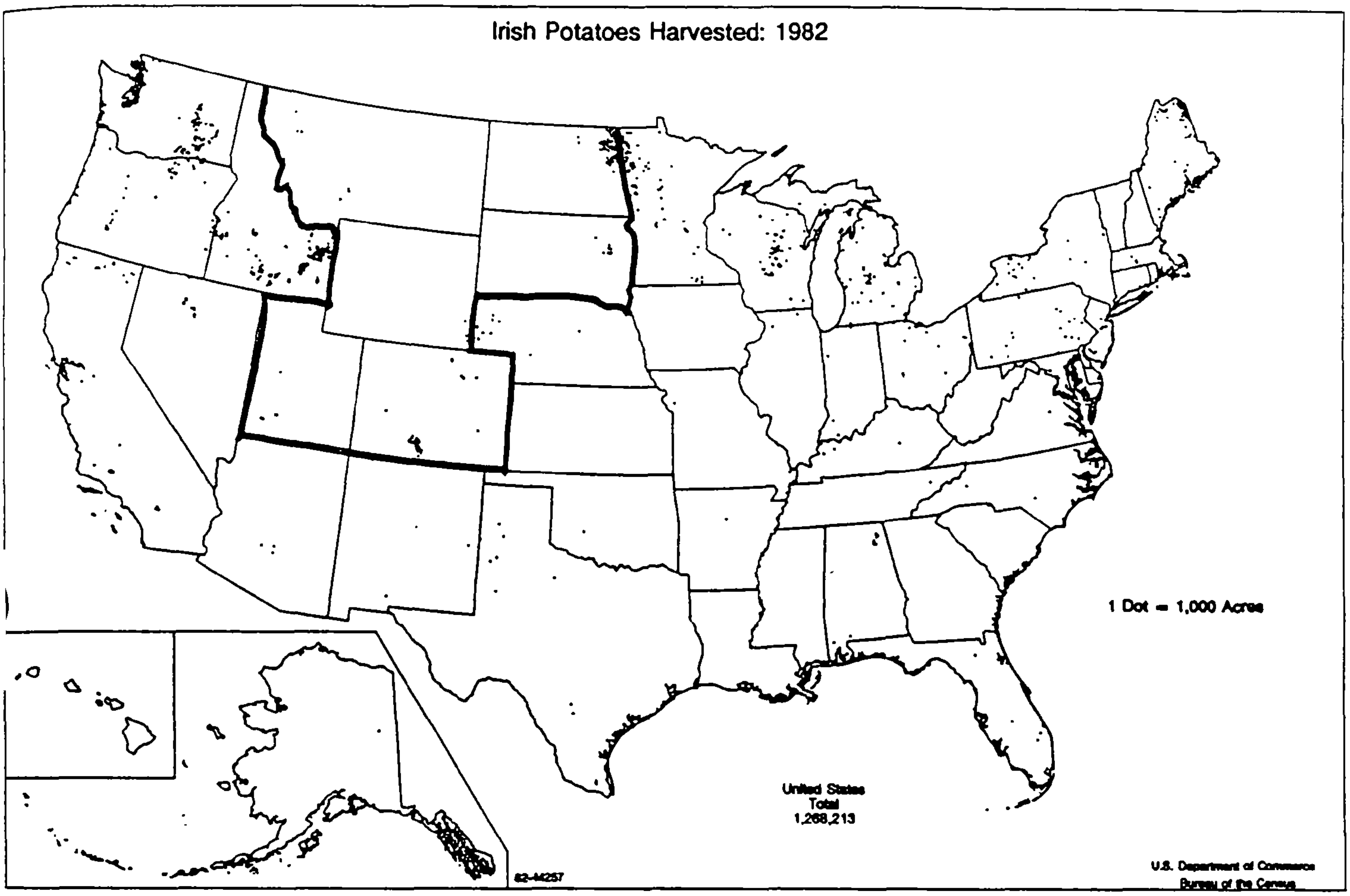


Corn Harvested for All Purposes: 1982

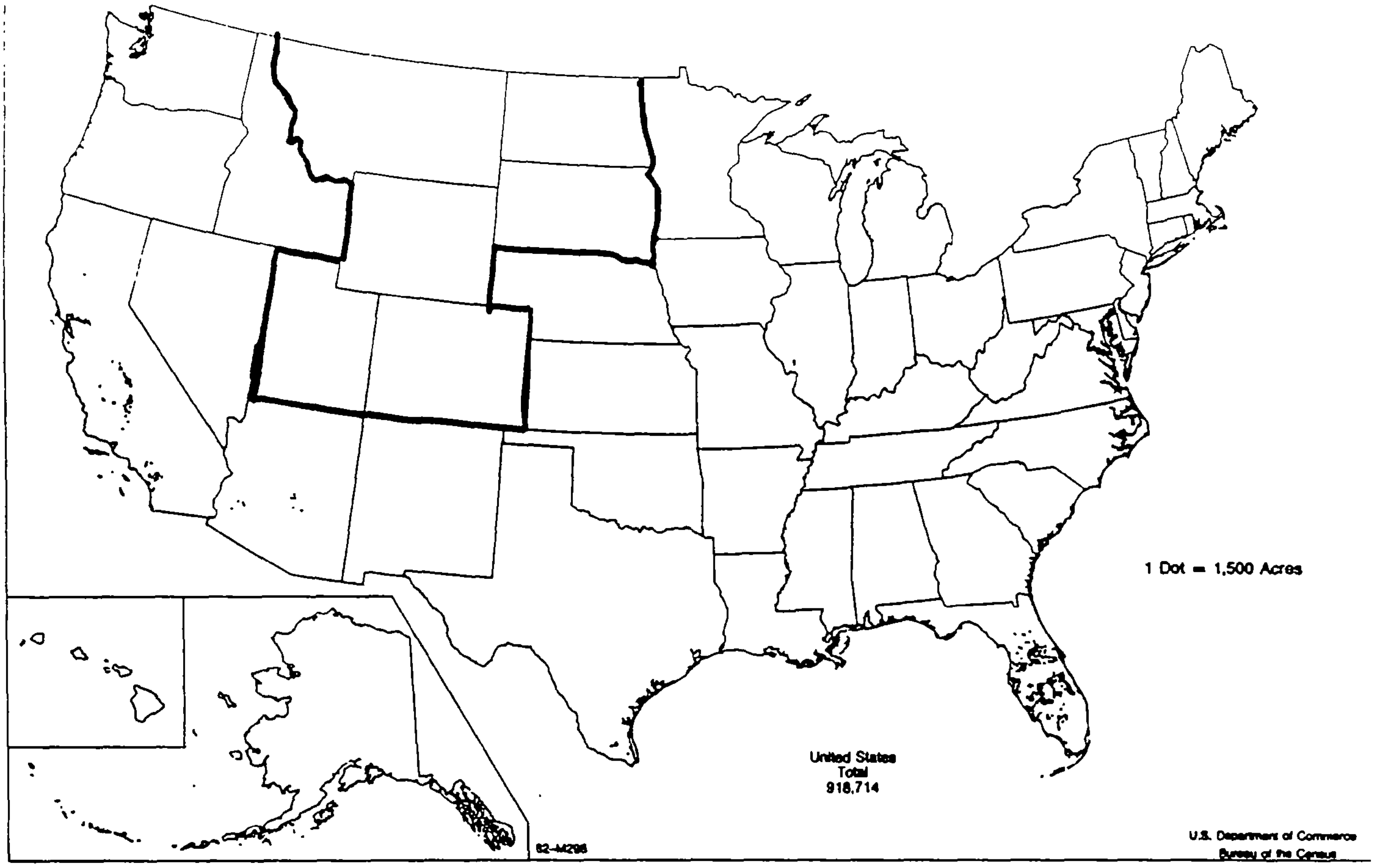


Soybeans Harvested for Beans: 1982

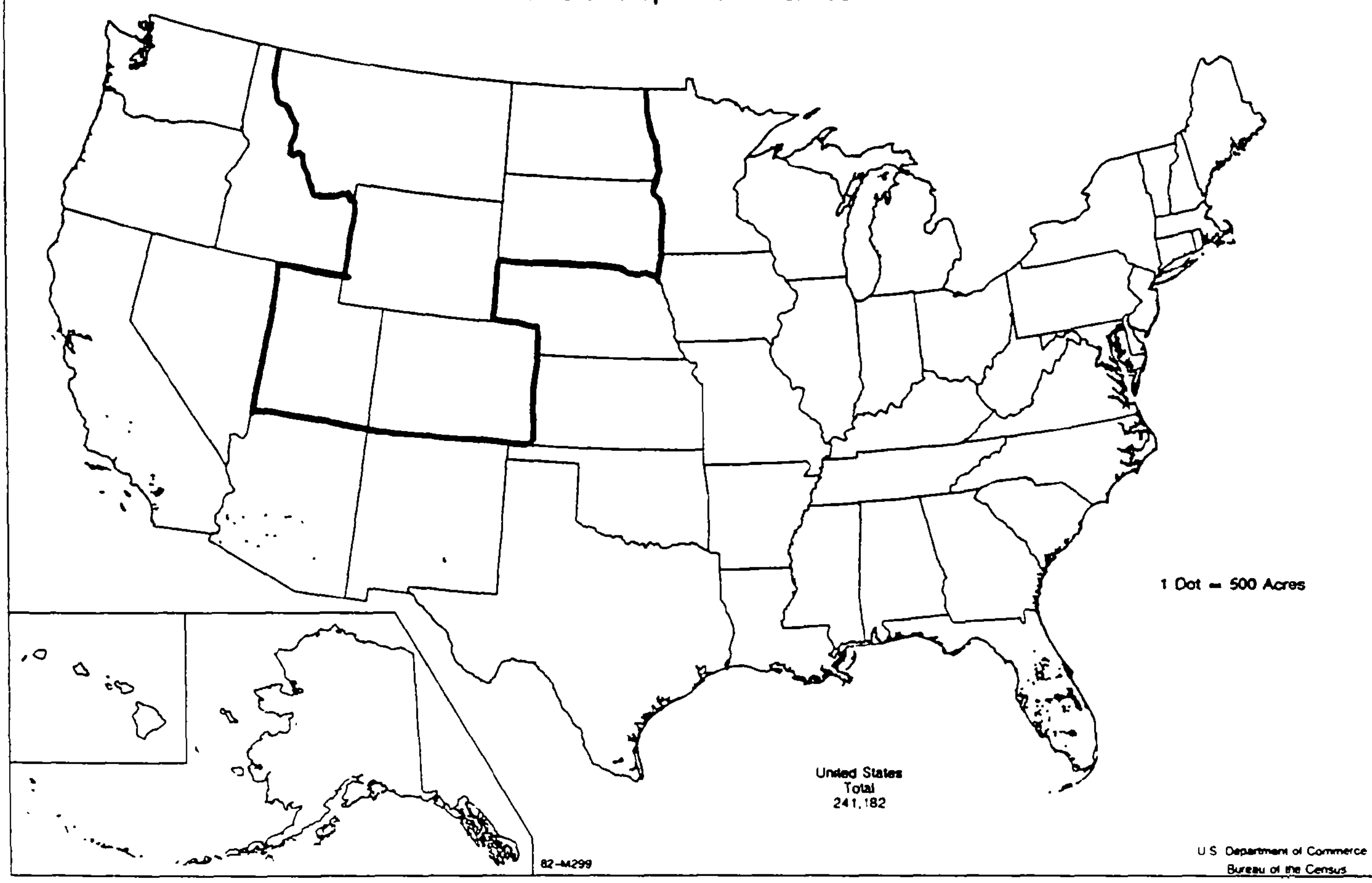


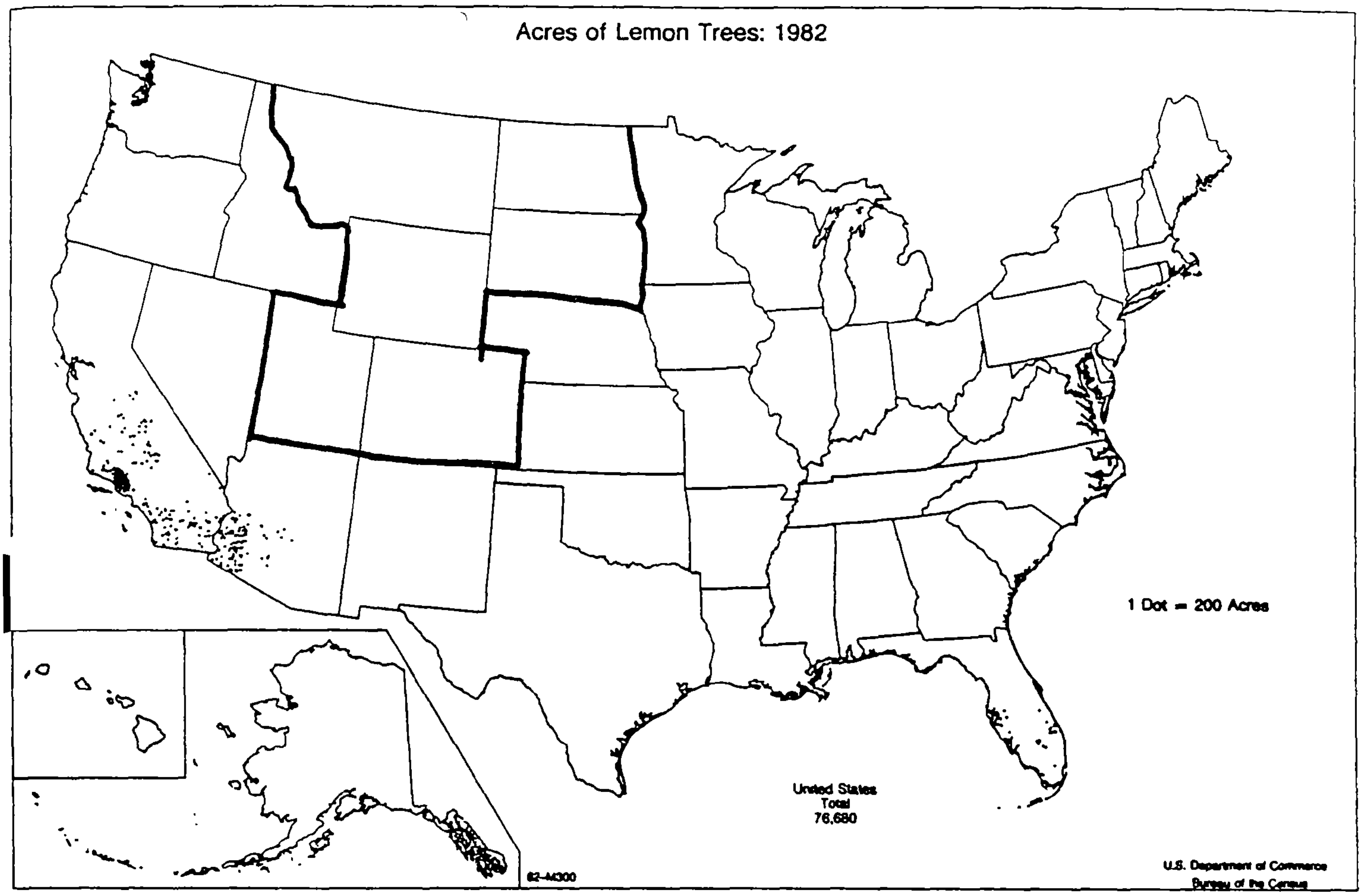

Irish Potatoes Harvested: 1982
1 Dot = 1,000 Acres
United States
Total
1,268,213
82-44257
U.S. Department of Commerce
Bureau of the Census

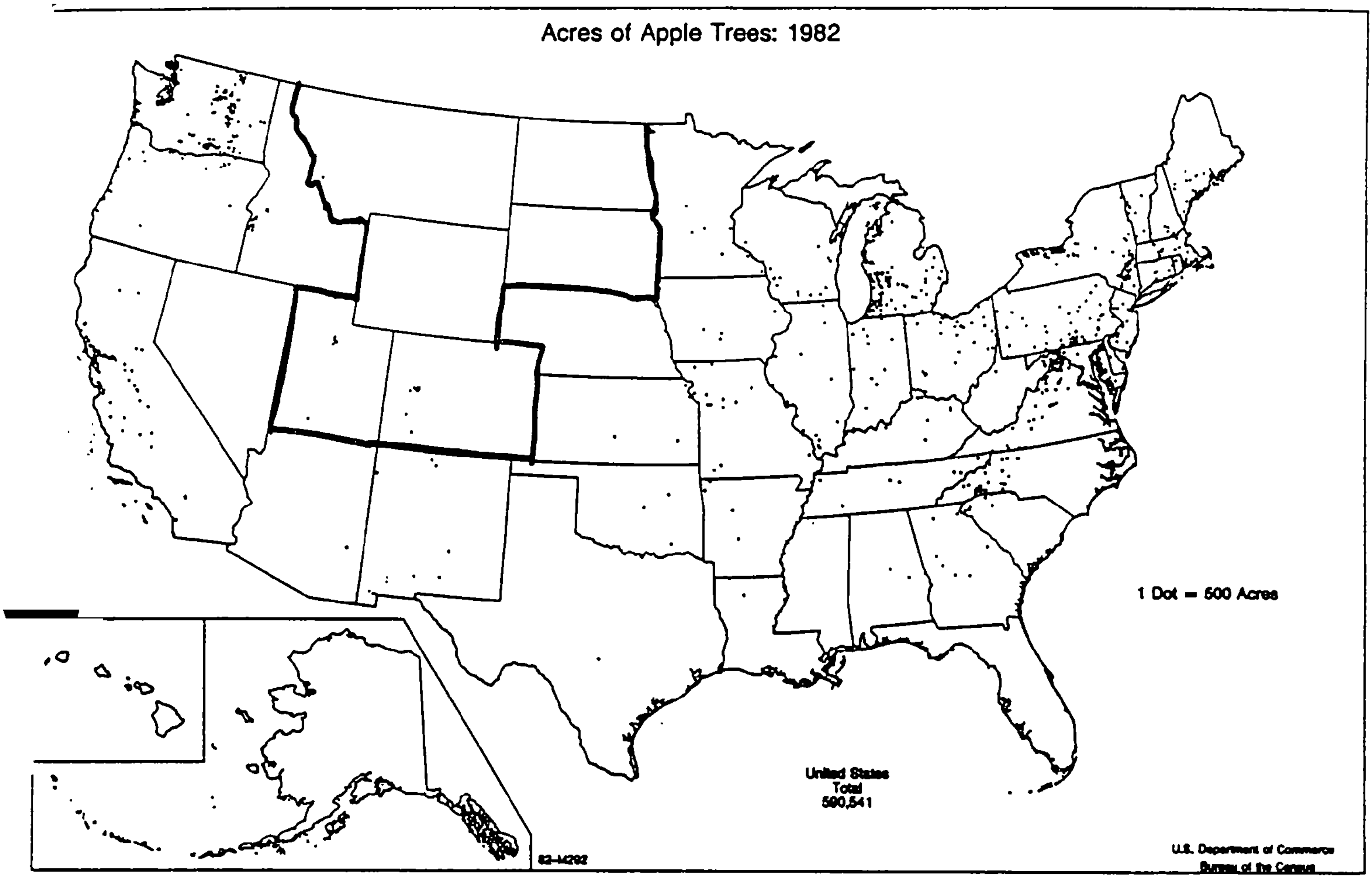
Acres of Orange Trees: 1982

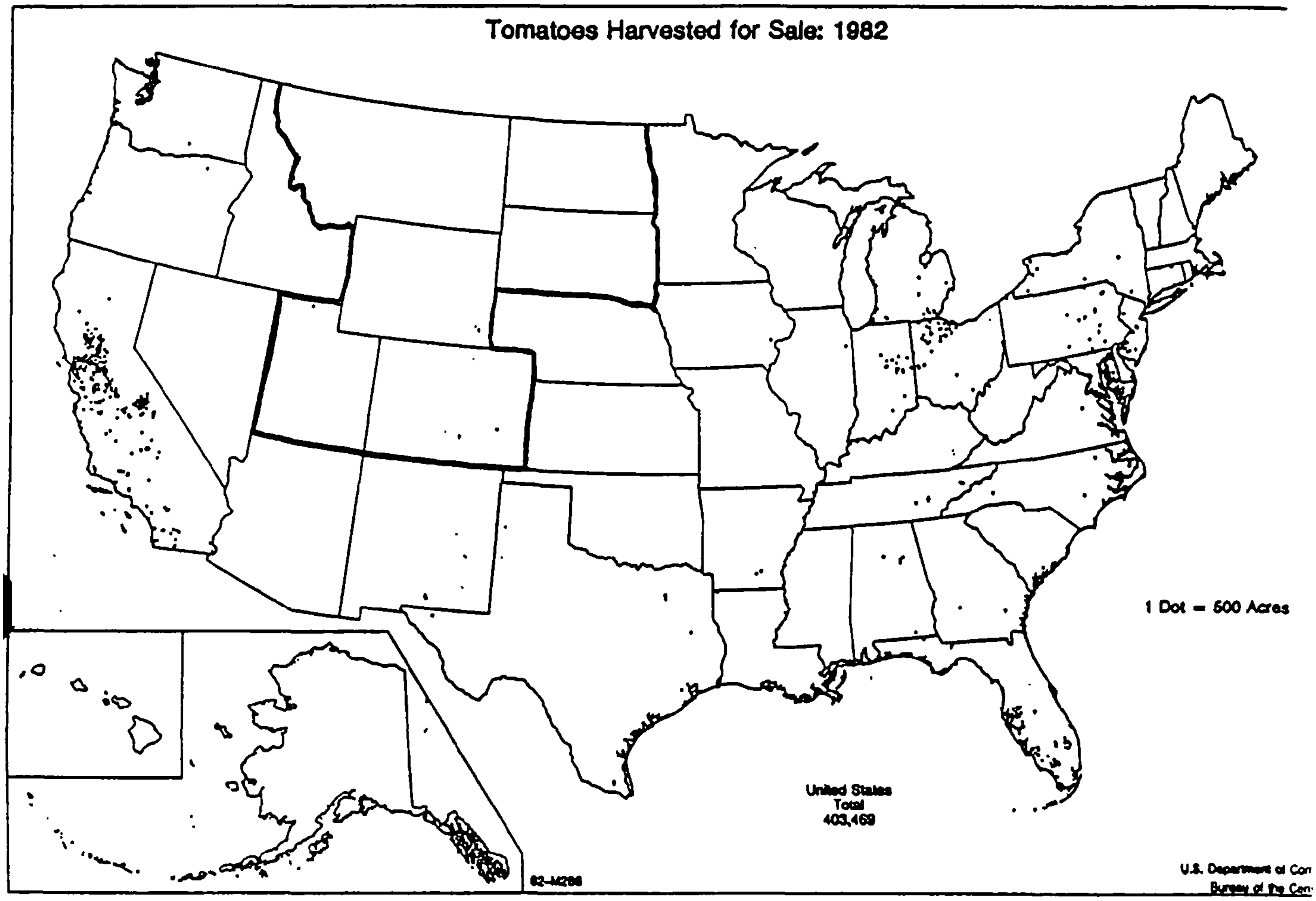


Acres of Grapefruit Trees: 1982

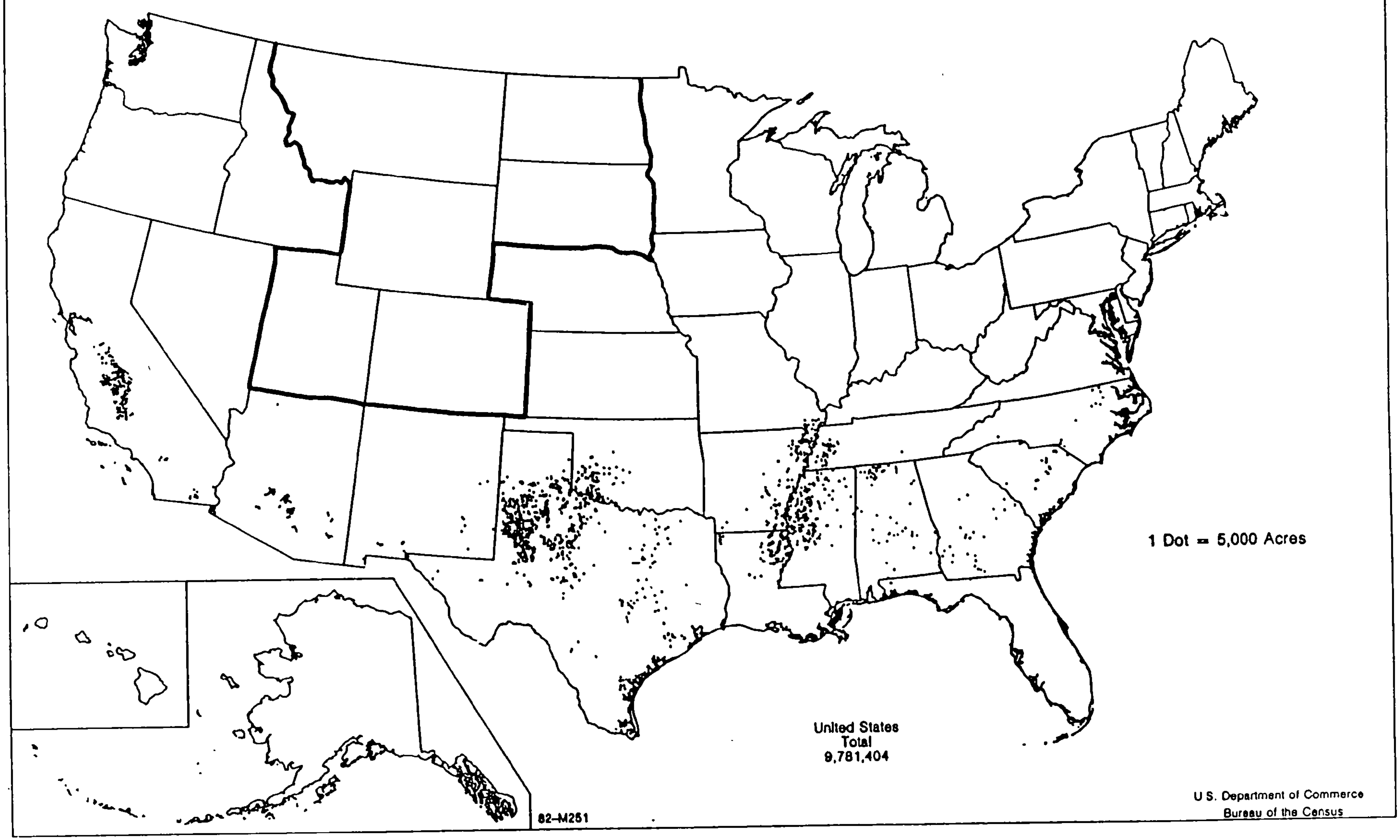



Acres of Lemon Trees: 1982
1 Dot = 200 Acres
United States
Total
76,680
82-A4300
U.S. Department of Commerce
Bureau of the Census


Acres of Apple Trees: 1982
1 Dot = 500 Acres
United States
Total
590,541
U.S. Department of Commerce
Bureau of the Census


Tomatoes Harvested for Sale: 1982
1 Dot = 500 Acres
United States
Total
403,469
82-M266
U.S. Department of Com
Bureau of the Cen

Cotton Harvested: 1982



APPENDIX D

ECOLOGICAL IMPACT ASSESSMENT

ECOLOGICAL IMPACT ASSESSMENT

OVERVIEW

To identify habitats at risk, experts from U.S. Fish and Wildlife Service (USFWS), Heritage Programs, conservation organizations, and other appropriate agencies were contacted and interviewed regarding habitats and species with the risk factor characteristics outlined previously. The interviewers also inquired about known or suspected pesticide impacts on habitats or species. The information below is a synthesis of the experts' comments and readily available literature; note that many of these were quick assessments, not scientifically based facts. Information from USFWS is identified by an asterisk (*). In Region VIII there are a number of types of habitats and species potentially at risk from pesticides.

HABITATS AT RISK

Synthesis of information from KBN's sources identified the habitats in the following listings as at risk from pesticides. The states/areas named are places where the problem was specifically mentioned; a thorough analysis might reveal that other parts of the Region may be equally or at higher risk. This technical support document records the diverse habitat/pesticide concerns elicited by the interviews. KBN's scientists integrated and evaluated this input to identify the priority issues discussed in the summary document.

The following listing presents examples of the kinds of habitats characterized by each risk factor. Many of these could be combined or listed under multiple risk factors. The grouping only illustrates the types of risk situations observed in Region VIII.

1. Habitats with low topographical location (e.g. aquatic systems and wetlands) subject to runoff potentially contaminated by pesticides such as:
    a. Riparian and wetland communities near agricultural land or highway buffer zones;
    b. Fens and saline lakes in North Dakota;
    c. Perennial and free-flowing rivers in North Dakota, which have sandbars important to rare shorebirds.
2. Habitats with small patch size surrounded by areas subject to aerial drift from pesticide spraying, including:
    a. Prairie potholes, where isolated wetlands important to waterfowl are surrounded by cropland.
3. Habitats not previously subjected to pesticide spraying (e.g., expanding agricultural areas, expanding pest control efforts), including:

a. Wetlands in the eastern Dakotas, where drift from aerial applications of grasshopper insecticide is a serious problem;

b. Cottonwood and boxelder woodlands in Wyoming, where spraying for leafy spurge and Canada thistle in hayfield areas has been observed to kill trees.

4. Habitats containing diverse and unique animal and plant communities, including:

INFORMATION NOT AVAILABLE

5. Rare habitats, including:

a. North Dakota's only sphagnum bog, which lies on the international boundary and is subject to herbicide spraying.

SPECIES AT RISK

1. Species with high (or suspected) sensitivity to pesticides, such as:

a. Prairie cordgrass (Spartina pectinata), occurring in the eastern half of Wyoming and Nebraska sedge (Carex nebrascensis), occurring throughout Wyoming, are suspected to be subject to herbicide spraying for leafy spurge and Canada thistle in hayfield areas.

b. Migratory birds including waterfowl, shore wading birds, and song birds utilizing wetlands that are subject to exposure to crop pesticide.

c. Piping plover (Charodius melodus) affected by crop pesticides,

d. Interior least tern (Sterna antillarium) affected by crop pesticide runoff,

e. Wyoming toad (Bufo hemiophrys baxteri) affected by runoff from rangeland, cropland pesticides, and mosquito larvicides,

f. Humpback chub (Gila cypha) affected by runoff of rangeland and forestry pesticides,

g. Kendall Warm Springs dace (Rhinichthys osculus thermalis) affected by runoff of forest and rangeland pesticides.

2. Endangered species with high exposure potential to pesticides, including wide ranging species with multiple exposure potential, such as:

a. Astragalus desereticus, which grows only alongside a highway in Utah County, Utah, and is at risk from highway herbicide spraying.

b. Peregrine falcon (Falco peregrinus) in Western Colorado and Eastern Utah is being affected by the spraying for momat crickets. Also the spraying of brush rangelands.

c. There are eight endangered fish in the region which include the squaw-fish, humback chub, boney tailed chub, pallid sturgeon. The pesticide runoff into rivers like the Colorado and the Mississippi are causing deaths.*

d. Golden eagle (Aquila chrysaetus) Grasshopper control programs involving spraying affect consumers directly, with some potential from secondary poisoning of ingesting poisoned consumers (i.e. golden eagle eating a sage grouse which had consumed poisoned grasshoppers). This spraying may affect upland game birds and tallgrass prairie remnants in extreme eastern North Dakota which are subject tó direct application of insecticide.

3. Endangered species with a critical life history stage or requirement (food or habitat) known to be sensitive to pesticides;

   INFORMATION NOT AVAILABLE

4. Keystone species/indicator species;

   INFORMATION NOT AVAILABLE

5. Species at the extension of their range or occurring in unsuitable habitats and exposed to pesticides or species with small or disjunt populations which are exposed to pesticides.

   INFORMATION NOT AVAILABLE

REPORTED EFFECTS

For Region VIII a complete record of fish and Wildlife kills or dieoffs from pesticides was not available for this review. However such episodes have been reported. The following is a description of three such episodes in Region VIII:

a. There are a number of incidences where birds of prey like eagles have eaten poisoned carcasses and have died as a result. For example along the Colorado river 10 eagles both bald and golden died from people lacing mule dear carcasses which were meant for coyotes.

b. In Pierre, North Dakota, ninety birds died, Canadian geese and Snow geese, from thimet poisoning. As a result four bald and three golden eagles died of secondary poisoning from eating the geese.

c. Within South Dakota there have been six or more documented cases where baits treated with carbofuran or a similar poison have killed eagles. The baits have been a dead calf that had been sprayed or injected with the chemical.*

It was the opinion of the scientists interviewed that both acute and subacute effects to nontarget fish and wildlife occur more regular than realized. In addition, field studies of pesticides conducted by industry to evaluate the effects of particular pesticides for pesticide registration are conducted to evaluate nontarget effects. Based on the understanding of these studies nontarget organism can be affected by the use of certain pesticides. For example, nontarget organisms are frequently affected by aldicarb.

Documentation and identification of the cause and extent of pesticide poisoning is often lacking. The actions related to the suspected poisoning are rarely observed or reported. Animals that are affected by chronic exposure often leave the area of the poisoning and are not detected. Animals that are killed may rapidly decompose, making post-mortem examination and residue analysis difficult. Animals may be carried away and consumed by other animals. In aquatic incidents, animals can be carried away by currents and subject to rapid decomposition.

DISCUSSION OF LIMITATIONS OF ASSESSMENT

The main limitation of the analysis was the scarcity of pesticide use data. Although estimates are available for some of the active ingredients used in the Region, pesticide use patterns and locations within counties is needed to assess the risk to habitats and species of concern. A somewhat "artificial" limitation of this assessment was the timeframe and level of effort scheduled. For example, episodic information was not able to be obtained within this project although it is important in understanding the nature of the ecological risks associated with pesticides use in Region VIII.

Mapping of pesticide use estimates and data, as well as crop locations, will be extremely useful. The location of habitats and species at high risk should then be added to maps. This exercise through a geographic information system can facilitate the evaluation of the extent of ecological risk from pesticide use.

APPENDIX E

PESTICIDE RISK TO ENDANGERED SPECIES

Table E-1. Region VIII--Suggested Endangered Species Restrictions for Crop[a] Use Products Containing One or More of the Following Active Ingredients (Page 1 of 2)

ACTIVE INGREDIENTS USED ON CROPLANDS				
ALDICARB AZINPHOS-METHYL DASANIT DIAZINON CHLORPYRIFOS EPN (NONGRANULAR) ENDOSULFAN (NON-GRANULAR) ENDRIN (NONGRANULAR)[b] ETHOPROP ETHYL PARATHION PHORATE TOXAPHENE (NONGRANULAR)	ATRAZINE BENSULIDE (BENTASAN) BIFENOX FLUCHLORALIN PENDIMETHALIN PROFLURALIN	BIPHENTHRIN (TALSTAR) BOLSTAR (SULPROFOS) BUFENCARB (BUX) CARBOPHENOTHION CYPERMETHRIN DEMETON DISYSTON EPN (GRANULAR) ENDOSULFAN (GRANULAR) ENDRIN (GRANULAR)[b] ETHION FENVALERATE (PYDRIN) FLUCYTHRINATE (PAYOFF) MALATHION METHIDATHION METHOXYCHLOR NALED PERMETHRIN PROFENOPHOS (CURACRON) TALSTAR TERBUFOS TOXAPHENE (GRANULAR)	CARBARYL DIMETHOATE IMIDAN (PHOSMET) METHOMYL PHOSPHAMIDON THIODICARB TRICHLORFON	CARBOFURAN CLOETHOCARB DICROTOPHOS ISOPHENPHOS METHYL PARATHION OXAMYL
ENDANGERED SPECIES POTENTIALLY AT RISK (BY STATE)				
MONTANA Piping plover NORTH DAKOTA Interior least tern Piping plover SOUTH DAKOTA Interior least tern Piping plover UTAH Woundfin June sucker	UTAH Woundfin June sucker	UTAH Woundfin June sucker	None listed	MONTANA Piping plover NORTH DAKOTA Interior least tern Piping plover SOUTH DAKOTA Interior least tern Piping plover

Table E-1. Region VIII--Suggested Endangered Species Restrictions for Crop[a] Use Products Containing One or More of the Following Active Ingredients (Page 2 of 2)

ACTIVE INGREDIENTS USED ON CROPLANDS

DEF 2,4-D (ISOOCTYL ESTER)	DICOFOL FENAMIPHOS (NEMACUR)	FONOFOS (DYFONATE)	PROPACHLOR TRIFLURALIN
ENDANGERED SPECIES POTENTIALLY AT RISK (BY STATE)			
None listed	MONTANA Piping plover NORTH DAKOTA Interior least tern Piping plover SOUTH DAKOTA Interior least tern Piping plover UTAH Woundfin June sucker	MONTANA Piping plover NORTH DAKOTA Interior least tern Piping plover SOUTH DAKOTA Interior least tern Piping plover UTAH Woundfin June sucker	UTAH Woundfin June sucker

Note: Underline indicates pesticide use estimates available from Gianessi and Puffer (4).
[a]Crop uses are corn, cotton, soybeans, sorghum and small grains (wheat, barley, oats and rye).
[b]Cotton use of endrin is allowed west of I-35 only.
Source: Turner, 1989 (7).

Table E-2. Region VII--Suggested Endangered Species Restrictions for Forest Products Containing One or More of the Following Active Ingredients

ACTIVE INGREDIENTS USED ON FOREST LANDS			
AMITROL AMMONIUM SULFAMATE ATRAZINE CACODYLIC ACID DALAPON DICHLOBENIL DIPHENAMID EPTC FOSAMINE AMMONIUM GLYPHOSATE HEXAZINONE MYLONE PARAQUAT PICLORAM SIMAZINE	2,4-DP	AZINPHOS-METHYL FENITROTHION AMINOCARB (MATACIL) METHYL PARATHION TRICHLORFON	CARBARYL DIFLUBENZURON

ENDANGERED SPECIES POTENTIALLY AT RISK (BY STATE)			
UTAH Last chance townsendia McGuire primrose	COLORADO Greenback cutthroat trout Bonytail chub Humpback chub Colorado squawfish UTAH Bonytail chub Humpback chub Colorado squawfish Last chance townsendia McGuire primrose	COLORADO Greenback cutthroat trout Bonytail chub Humpback chub Colorado squawfish UTAH Bonytail chub Humpback chub Colorado squawfish	COLORADO Greenback cutthroat trout Bonytail chub Humpback chub Colorado squawfish UTAH Bonytail chub Humpback chub Colorado squawfish

Note: Underline indicates pesticide use estimates available from Gianessi and Puffer (4).

Source: Turner, 1989 (7).

Table E-3. Region VII--Suggested Endangered Species Restrictions for Range and Pastureland Uses Containing One or More of the Following Active Ingredients

ACTIVE INGREDIENTS USED ON RANGE AND PASTURELAND		
Ammonium sulfamate Atrazine Chlopyralid 2,4-D 2,4-D (salts and esters) 2,4-DP Dalapon Dicamba Dimethylamine Dicamba Hexazinone MCPA, acid MCPA (salts and amines) Picloram Potassium Picloram Sodium Dicamba Tebuthiuron Triethylene Picloram	Carbaryl Malathion Naled	Diazinon Methyl Parathion Trichlorfon
ENDANGERED SPECIES POTENTIALLY AT RISK (BY STATE)		
COLORADO Clay-loving wild-buckwheat Knowlton cactus Mancos milkvetch Mesa Verde cactus North Park phacelia Spineless hedgehog cactus Uinta Basin hookless cactus UTAH Clay phacelia Dwarf bear-poppy Heliotrope milkvetch Jones cycladenia Last Chance townsendia Maguire daisy Maguire primrose Purple-spined hedgehog cactus Rydberg milk-vetch Toad-flax cress San Rafael cactus Siler pincushion cactus Spineless hedgehog cactus Spreading wild-buckwheat Uinta Basin hookless cactus Welsh's milkweed Wright's fishhook cactus	COLORADO Colorado squawfish Bonytail chub Humpback chub Greenback cutthroat trout UTAH Colorado squawfish Bonytail chub Humpback chub June sucker Woundfin WYOMING Kendall Warm Springs dace Wyoming toad	COLORADO Colorado squawfish Bonytail chub Humpback chub Greenback cutthroat trout MONTANA Piping plover NORTH DAKOTA Interior least tern Piping plover SOUTH DAKOTA Interior least tern Piping plover UTAH Colorado squawfish Bonytail chub Humpback chub Desert tortoise June sucker Woundfin WYOMING Kendall Warm Springs dace Wyoming toad Whooping crane

Note: Underline indicates pesticide use estimates available from Gianessi and Puffer (4).

Source: Turner, 1989 (7).

Table E-4. Region VIII--Suggested Endangered Species Restrictions for Mosquito Larvicides Containing One or More of the Following Active Ingredients

ACTIVE INGREDIENTS USED ON RANGE AND PASTURELAND	
FENTHION ETHYL PARATHION	METHYL PARATHION TEMEPHOS CHLORPYRIFOS DDVP
ENDANGERED SPECIES POTENTIALLY AT RISK (BY STATE)	
NORTH DAKOTA Interior least tern SOUTH DAKOTA Piping plover Interior least tern UTAH Woundfin June sucker WYOMING Kendall Warm Springs dace Whooping crane	NORTH DAKOTA Interior least tern SOUTH DAKOTA Piping plover Interior least tern UTAH Woundfin June sucker WYOMING Kendall Warm Springs dace Whooping crane

Note: Underline indicates pesticide use estimates available from Giannessi and Puffer (6).

Source: Turner, 1989 (7).

14.0 CRITERIA AIR POLLUTANTS

14.1 INTRODUCTION

Under the Clean Air Act, national ambient air quality standards have been established to protect public health and welfare for six major air pollutants. These pollutants, which are referred to as criteria air pollutants, include:

- ozone
- particulate matter
- carbon monoxide
- sulfur dioxide
- nitrogen dioxide
- lead

Major sources of these pollutants include motor vehicles, electric utilities, home heating, industrial and commercial processors, agricultural and forest burning, and mining activity.

This risk assessment estimates the current human health, welfare and ecologic effects associated with criteria air pollutants in EPA Region VIII. These estimates are intended for comparison to estimates similarly obtained for other environmental issues being considered in the Comparative Risk Project.

14.2 HUMAN HEALTH EFFECTS

There is a great deal of information available regarding the health effects associated with criteria air pollutants. The most comprehensive summaries are provided by the U.S. Environmental Protection Agency in the various criteria documents and staff reports listed in Section 14.3 of the bibliography. This analysis relies specifically on the syntheses of this literature from previous risk assessments conducted for several criteria air pollutants, which are listed in Section 14.2 of the bibliography.

This analysis is organized according to the six criteria air pollutants. Human health effects associated with each of these pollutants are different and, for the most part, separable. With the exception of lead, this plan of attack assumes that there are no significant health effects associated with exposures at ambient levels below the primary standards for each pollutant. However, health effects were estimated for particulate matter at thresholds below the current primary standard. Ambient air is only one pathway for lead exposure; therefore changes in airborne lead levels may be associated with significant health effects for individuals who are also exposed to lead from other sources.

It is important to note that although the federal primary standards for criteria air pollutants are set with the intention of protecting human health with some margin of safety, the scientific evidence is inconclusive in many cases regarding the level and even the existence of thresholds below which no health effects are observed. For several criteria air pollutants, particularly ozone and particulate matter, there is some evidence that health effects occur at levels below the current standards, although this conclusion is not necessarily widely accepted. For all criteria pollutants, the margin of safety provided by the standard is probably not large, especially for individuals in the most sensitive population groups. Many different types of health effects have been demonstrated or are suspected to occur as a result of exposures to various levels of the criteria pollutants. It is not feasible to cover all of these health effects for this risk assessment. The approach taken has been to select health effects categories that have been important in the standard setting process and are therefore expected to be the first effects to occur at levels just above the standards. We have also focused on health effects for which there is quantitative epidemiological information and that are representative of the most significant health effects expected (in terms of number of people affected or the seriousness of the effect on the individual). The results are, therefore, expected to give a good idea of the magnitude of the health problem associated with the criteria air pollutants, but should not be thought of as comprehensive.

Procedures used in this analysis start with estimates of the number of people exposed to ambient pollution levels that exceed the federal primary ambient air quality standards and the frequency with which these exposures occur. To this we add information about segments of the exposed population at risk of various health effects at ambient levels that occur in Region VIII, and, to the extent possible, suggest procedures for calculating incidence estimates for specific health effects. Data on monitored levels of criteria air pollutants and standard exceedances are compiled by state agencies responsible for air pollution control.

Types of health effects covered in this analysis are non-cancer and there are no significant (multi-year) time lags between exposure and effect. Calculations are summarized in the results tables are based both on yearly and average concentration data. In cases where estimates are based on average concentration data, we include estimates of the standard deviation. The estimated number of health effects cases are for a single year and would be expected to be the same in any other year with comparable pollution levels. Thus, if pollution levels were to remain the same for 70 years, the annual incidence estimates could be multiplied by 70.

14.2.1 <u>Ozone</u>

Ozone is a pollutant that forms in the atmosphere in the presence of hydrocarbons, nitrogen oxides, and sunlight. It is the primary component of what is known as photochemical smog. It is irritating to the human respiratory system, and there is some evidence that exposure to ozone is associated with higher rates of acute respiratory illness. Ozone is also believed to aggravate chronic respiratory diseases. Chronic exposure to elevated ozone levels may potentially contribute to the development of chronic respiratory diseases, although the evidence on this is not conclusive.

The federal primary standard for ozone is an hourly average of .12 ppm, not to be exceeded on average (over a three year period) more than once per year. It is set at this level to preventing acute respiratory irritation or other respiratory symptoms. Ozone monitoring data indicates that exceedances of the federal ozone standard occur in few locations in Region VIII, (see Table 14-1). This table shows the number of days exceeding both the Federal Primary Standard and 0.10 ppm during 1987 and 1988. These data suggest that known exceedances of the two thresholds are limited to the front range area of Colorado and the Salt Lake City/Provo area in Utah. Not unexpectedly, a large majority of the Region's population resides in these areas. Approximately one-third of the population is exposed above the Federal Primary Standard, while approximately two-thirds are exposed to ozone concentrations above 0.10 ppm.

Chestnut and Rowe (1988) and Chestnut et al. (1987a) used available epidemiological evidence to estimate two types of health effects associated with ozone: respiratory restricted activity days and asthma attacks. This was done for the metropolitan areas of Denver, Colorado, and San Jose, California. Respiratory restricted activity days are days on which the individual's normal activities are restricted due to respiratory illness. Most respiratory restricted activity days involve only minor activity restriction as opposed to a work loss day or a bed day. Calculating the number of cases for these health effects is somewhat more complex than for particulate matter due to the need to consider daily ozone levels. The results of the San Jose study can, however, be used to derive an estimate of the risk of experiencing these health effects for the individual in an area when elevated ozone levels occur on a given day. The results of the San Jose analysis indicate that the average daily risks on days when the highest hourly ozone reading is above 0.12 ppm are as follows:

$$\text{annual asthma attacks} = \sum_{j=1}^{J} 0.00029 * DAYS_j * 0.04 * POP_j \qquad (1)$$

$$\text{annual respiratory restricted activity days} = \sum_{j=1}^{J} 0.00092 * DAYS_j * 0.96 * POP_j \qquad (2)$$

where:

$DAYS_j$ = the number of days/year on which daily high ozone hour exceeds .12 ppm in location j

POP_j = total population in location j

Table 14-1

Health Effects due to Ozone in Region VIII

State County	Ozone Concentration Number of Exceedance Days >0.105 ppm 1987	>0.125 ppm	>0.105 ppm 1988	>0.125 ppm	>0.105 ppm 1989	>0.125 ppm	>0.105 ppm Average	>0.125 ppm	Population	Health Effects Asthma Attacks [1]	Restricted Activity Days [2]
Colorado											
Arapahoe Co	3	1	10	1	1		5	1	391,200	4	290
Boulder	8		4		2	1	5		81,239		
Denver	6	1	3				3		492,200		
Arvada	9	1	7	1	3		6	1	430,200	4	319
Utah											
Bountiful	4	1	9	2	13	2	9	2	32,900	1	61
Salt Lake Cit	2		10	2	5	2	6	1	674,201	13	1001
Provo			3		2	1	2		169699		
Roy	2				1		1		19700		
Total	Population >= 0.105								2,291,339		
	Population >= 0.125								1,528,501	22	1,672

1 Annual Asthma Attacks = 0.4*POPj*EXDAYj*0.00037 where: EXDAYj is the number of exceedance days and POPj is the exposed population at monitoring site j.

2 Annual Respiratory Restricted Activity Days = 0.96*POPj*EXDAYj*0.00116 where: EXDAYj is the number of exceedance days and POP is the exposed population at monitoring site j.

National statistics suggest that about 4% of the population currently has asthma. Equation 1 is therefore multiplied by 4% of the population living in the area where the daily high ozone reading equals or exceeds 0.12 ppm (or 0.10 ppm) and summed across all such days to obtain an estimate of the number of asthma attacks in a given time period. Equation 2 is multiplied by 96% of the population living in the area where the daily high ozone reading equals or exceeds 0.12 ppm (or 0.10 ppm) and summed across all such days to obtain an estimate of the number of respiratory restricted activity days in a given time period.

Table 14-1 summarizes results of the ozone health risk analysis, while additionally including cost of measures associated with these health end points. Derivation of these estimates will be discussed in Section ??. The number of annual asthma attacks and annual respiratory restricted activity days are estimated using county population data. This exposure assumption is very conservative, and assumes that every individual in the county where an evidence value was monitored is exposed to concentrations above the threshold value.

14.2.3 Particulate Matter

The current federal primary standard for particulate matter was set by EPA in 1987 for particles 10 microns in diameter or smaller (PM_{10}). An annual average of 50 $\mu g/m^3$ is not to be exceeded and a 24-hour average of 150 $\mu g/m^3$ is not to be exceeded more than once a year. The previous federal primary standard for particulate matter was based on total suspended particulates (TSP). This was an annual geometric mean not to exceed 75 $\mu g/m^3$, and a 24-hour level of 260 $\mu g/m^3$ not to be exceeded more than once a year.

Particulate matter is not really a single pollutant, but a composite of all the small particles suspended in the atmosphere. The chemical composition of these particles can vary at different times and at different locations. Studies that have found an association between health effects and ambient particulate matter levels do not provide sufficient information from which to infer whether some types of particles cause more problems than others. Smaller particles are believed to be more of a health hazard because they can be inhaled more deeply into the respiratory system, which was the rationale for changing the federal particulate matter standard from TSP to PM_{10}.

Sulfate particles are common types of small particles that form in the atmosphere when gaseous sulfur oxides are present. These types of fine particles are suspected of being especially harmful to human health and may be a significant factor in the observed association between ambient particulate matter and health effects. Health effects associated with sulfate particles are discussed in the acid deposition analysis of health effects. It is important to note, however, that there is some ambiguity regarding this division due to the difficulty of separating the effects of different types of particles in epidemiological studies.

Epidemiological studies that have covered fairly wide geographic areas in the U.S., have found an association between ambient particulate matter levels and restricted activity days. There is also some evidence that particulate matter is associated with a greater frequency of emergency room visits, with higher rates of chronic respiratory disease, and with adverse effects on lung function. Some of these latter health effects may actually underlie the observed association with restricted activity days. The biological pathways for these effects are not well understood, but it is believed that particulate matter affects human health via the respiratory system.

Restricted activity days are days on which an individual's normal activities are restricted to some extent due to illness. This includes confinement to bed and days missed from work as well as more minor activity restrictions. Based on results reported by Ostro (1983), we used the following procedure for estimating the number of restricted activity days currently associated with particulate matter expressed as TSP, in EPA Region VIII.

$$\text{Annual restricted activity days} = \sum_{j=1}^{J} .073 * (TSP_j - TSP_t) * POP_j \qquad (3)$$

where:

$TSPj$ = annual average TSP in $\mu g/m^3$ in location j
TSP_t = assumed TSP health threshold
$POPj$ = total population in location j

Tables 14-2 and 14-3 present results of alternative analysis used to estimate restricted activity days associated with particulate matter in Region VIII. Note that health effects estimated using Huse (?) different data and equations are significantly different. For the purpose of this analysis, they should be considered bounding estimates of health effects. We used the following equation to estimate restricted activity days associated with PM_{10}:

$$\text{Annual restricted activity days} = 0.046*(PM_{i0j} - 38)\ POP_j$$

where:

PM_{i0J} is measured particulate in $\mu g/m^3$ in Region i
POP_j is population in Region j

14.2.4 <u>Carbon Monoxide</u>

When carbon monoxide (CO) enters the respiratory system, it attaches to hemoglobin and forms carboxyhemoglobin (COHb), reducing the oxygen carrying capacity of the blood. CO's affinity for hemoglobin is much greater than that of oxygen and when present in significant amounts can result in a significant reduction in oxygen carried to the tissues of the body. Exposures to very high levels of CO for some period of time (such as in a closed garage with a running automobile) can result in death.

Table 14-2

Annual Health Effects due to
Particulate Matter (PM10) in Region VIII

State County or City	Population	Annual Average TSP in ug/m3 1987	1988	1989	Average	Standard Deviation	Annual Restricted Activity Days [1]
Colorado							
Alamosa	6,830			51	51	0.00	4,084
Archuleta Co.	5,200	60	52	44	52	6.53	3,349
Boulder	81,239	43	35	37	38	3.40	1,246
Denver	492,200	49	35	35	40	6.60	37,735
Montana							
Lincoln Co.	18,700	69	62	59	63	4.19	21,792
Sanders Co.	8,600	41	36	51	43	6.24	1,846
Utah							
Salt Lake Co.	720,000	37	44	42	41	2.94	99,360
Utah Co.	242,700	41	50	51	47	4.50	104,199
Wyoming							
Fremont Co.	33,900	50	35	31	39	8.18	1,040
Sheridan Co.	25,100	48	47	37	44	4.97	6,928
Total	1,634,469						281,578

1 Annual Restricted Activity Days = 0.046*(PM10j-38)*POPj where: PM10j is the 3 year average measured particulate concentration in ug/m3 and POPj is the exposed population in region j.

Table 14-3.
Annual Health Effects due to
Total Suspended Particulates (TSP) in Region VIII

State County	Population (1)	Annual Average TSP in ug/m3 1987	1988	1989	Average	Standard Deviation	Estimated Number of Resticted Activity Days (2)
Colorado							
Adams Co.	281,000	101	99	83	94	8.06	396,585
Alamosa	6,830	53	58	118	76	29.53	665
Englewood	30,021	86	73		80	6.50	9,862
Delta	21,225	103	110		107	3.50	48,807
Denver	492,200	104	102	104	103	0.86	1,013,243
Castle Rock	45,400	76	68	114	86	20.07	36,456
Montana							
Ronan Park	1,530	107	79	68	85	16.42	1,080
Polson	2,800	95	68	68	77	12.73	409
Rosebud	9,900	115	98	90	101	10.42	18,790
Total	890,906						1,525,896

1 1986 population estimates.

2 Annual Restricted Activity Days = 0.073*(TSPj-75)*POPj where TSPj is the 3 year averag annual arithmetic mean TSP in ug/m3 and POPj is population for region j.

Some population groups are believed to be at higher risk of ill effects for exposures to ambient CO levels that occur in many urban areas in the U.S. that exceed the federal primary CO standards. These include individuals with heart disease, with chronic respiratory disease, with chronic anemia, and fetuses. The normal healthy population is also at risk of some ill effects (primarily of a less serious nature) at ambient CO levels that occur in some areas.

In general, the available quantitative information regarding dose-response relationships between CO or COHb levels and adverse health effects is limited. The literature suggests COHb levels above which certain adverse health effects begin to occur in some population groups, but does not allow an estimation of the number of people expected to experience the adverse effects at different COHb levels. Estimating COHb levels that can be expected in the population at various ambient CO levels measured at stationary monitors has also proved very difficult. CO exposure models have been developed at EPA and used in the standard setting process, but specific quantitative results remain quite uncertain.

For this screening level risk assessment, we used the federal primary standard for CO and the pollution standard index levels for CO as thresholds with regard to ambient CO levels. Individuals living in areas where these levels are exceeded were presumed to be at some elevated risk of experiencing a CO related health effect on days when the CO standard is exceeded. The types of health effects likely to occur can be identified, but the magnitude of the risk for the exposed individual will remain unspecified. Thus, the outcome of this calculation is the number of people at elevated risk of each type of health effect and the number of days in the year that this elevated risk occurs, but the incidence of these health effects is unspecified.

The CO related health effect that has been demonstrated at the lowest CO¯b levels is reduced time to onset of angina pain for individuals with coronary heart disease, which involves about 10% of the population in the U.S. This is the health effect that the federal standard is set to prevent. Thus, when the standard is exceeded we can expect individuals with heart disease to be at elevated risk of having angina pain. As CO levels increase we can expect this risk to increase and also expect that other population groups will also be subject to elevated risk of some CO related health effects. For the general population, the first health effects observed at elevated COHb levels are reduced ability to concentrate on a complex task and reduced capacity for strenuous exercise.

The monitoring network for CO in each state in Region VIII can be used to identify the locations of CO levels that exceed the following levels. The health risks expected for the population in the area of the monitor are listed. We focus on the 8-hour standard since this is exceeded much more frequently than the l-hour standard.

CO 8-hour Average Exceeds	Pollution Standard Index	Health Risk
9 ppm (federal standard)	100	10% of population at moderate risk of increased angina pain
		90% of population at low risk of mild symptoms
15 ppm	200	10% of population at high risk of increased angina pain
		90% of population at moderate risk of mild symptoms

Table 14-4 summarizes the number of person days at risk due to elevated carbon monoxide concentrations based first on county and then on city populations.

14.2.5 Sulfur Dioxide

Probably the most significant health effects associated with sulfur dioxide are related to sulfate particles, which are a component of acid deposition. Sulfates are primarily secondary pollutants that form in the atmosphere in the presence of sulfur dioxide. The health effects associated with sulfate particles are discussed in the acidic deposition analysis. In this section we discuss the health effects associated with exposures to elevated gaseous sulfur dioxide only.

According to U.S. EPA's AIRS data, Region VIII is in attainment with the sulfur dioxide primary standards. We, therefore, do not estimate health effects due to gaseous sulfur dioxide concentrations.

14.2.6 Lead

Federal ambient air quality standards for lead are currently met throughout Region VIII, but people are exposed to lead through a variety of pathways from a variety of sources. Given this fact plus recent findings of health effects at lower blood lead levels, airborne lead may still be contributing to lead related health effects in Region VIII. The primary source of airborne lead is from automobiles. Lead in automobile emissions has been

Table 14-4
Health Effects due to Carbon Monoxide
in Region VIII

State / Area	Population	Number of Violations 8 hr. avg. > 9 ppm 1987	1988	1989	3 Year Average	Standard Deviation	Population at Risk of Increased Angina Pain [1]	Risk Severity	Population at Risk of Mild Symptoms [2]	Risk Severity	Number of Person Days at Risk Increased Angina Pain	Mild Symptoms
Colorado												
Adams Co.	281,000	5	1	0	2	2.16	28,100	moderate	252,900	low	56,200	505,800
Boulder	81,239	1	0	0	0	0.47	8,124	moderate	73,115	low	2,708	24,372
Denver Co.	492,200	15	6	3	8	5.17	49,220	moderate	442,980	low	393,760	3,543,840
8 hr. avg. > 15 ppm		2	1		1	0.50	49,220	high	442,980	moderate	49,220	442,980
Colorado Springs	276,872	1	2	1	1	0.47	27,687	moderate	249,185	low	36,916	332,246
Fort Collins	78,287	5	3	1	3	1.63	7,829	moderate	70,458	low	23,486	211,375
8 hr. avg. > 15 ppm		1			0	0.00	7,829	high	70,458	moderate	2,610	23,486
Greely	62,297	3	1	0	1	1.25	6,230	moderate	56,067	low	8,306	74,756
Montana												
Great Falls	66,256	3	1	0	1	1.25	6,626	moderate	59,630	low	8,834	79,507
Missoula	58,035	3	1	2	2	0.82	5,804	moderate	52,232	low	11,607	104,463
Utah												
Salt Lake City	674,201	2	0	0	1	0.94	67,420	moderate	606,781	low	44,947	404,521
Provo	169,699	10	3	6	6	2.87	16,970	moderate	152,729	low	107,476	967,284
8 hr. avg. > 15 ppm				2	1	0.00	16,970	high	152,781	moderate	11,313	101,854
Ogden	205,744	1	0	1	1	0.47	20,574	moderate	185,170	low	13,716	123,446
TOTAL	2,445,830						244,583	moderate	2,201,247	low	707,957	6,371,611
							74,019	high	666,219	moderate	63,143	568,320

1 At CO concentrations > 9ppm and < 15 ppm, 10% of the exposed population are at moderate risk of increased angina pain. At concentration > 15ppm the risk is high.

2 At CO concentrations > 9ppm and < 15 ppm, 10% of the exposed population are at low risk of mild symptoms. At concentration > 15ppm the risk is moderate.

reduced dramatically in the last 10 years and EPA regulations currently in place are expected to reduce lead in automobile emissions to near zero as older cars are retired. In the meantime, some lead is still being emitted.

Chestnut et al. (1987a,b) developed estimates of the health effects associated with current (1985 and 1986) lead emissions from automobiles in San Jose and in Denver, assuming that other sources of lead remain at current levels. The results of these analyses were used to derive per capita risks of health effects due to lead in gasoline in these two urban areas. There is no reason to expect per capita emissions of lead from automobiles to be significantly different in urban areas in Region VIII than in these two urban areas, so these per capita risk estimates can be used to estimate the approximate risks to the urban population in Region VIII from current levels of automobile lead emissions.

Significant health effects associated with lead in gasoline are not expected to occur in rural areas because automobile emissions are much less concentrated.

The analyses for Denver and San Jose covered eight types of health effects associated with lead. In this analysis, we have divided these into two categories, minor and serious, and have selected the highest individual risk for each population group to represent the magnitude of the risk in each category. The estimates will therefore be for the most common health effect expected, but will understate the total health effects to some extent. For all groups except children under 6 years old, the minor health category is dominated by peripheral nervous system effects, which essentially involve minor effects on motor nerve conduction. For children under 6, the minor category is elevated free erythrocyte protoporphyrin, which is an early indicator of elevated blood lead but is not directly associated with any serious health effects when it is the only symptom present. The serious health effects category is increased incidence of hypertension in adult males and central nervous system effects (including IQ decrements) in children under 6. The estimated incidence of serious health effects for adult women and children 6 to 17 was essentially inconsequential in the San Jose and Denver analyses.

	Population Group (approximate percent of urban population in parentheses)			
	Adult Males (35%)	Adult Females (35%)	Children 6-17 years (20%)	Children < 6 years (10%)
Per Capita Risk of Minor Health Effect	.0012 (p. neuro.)	.000043 (p. neuro.)	.00054 (p. neuro.)	.0091 (FEP)
Per Capita Risk of	.0051 (hypertension)	-----	------	.0024 (c. neuro.)

These per capita risk factors were multiplied by the urban population in Region VIII in each group to obtain incidence estimates in each health effect category. These results are summarized in Table 14-5.

14.2.7 Uncertainties and Omissions

All of the incidence estimates obtained using this analysis should be viewed as approximate, not exact point estimates. The uncertainty varies across the different pollutants and different health effects, but previous analyses that looked at potential ranges in these kinds of estimates found that in most cases the uncertainty was at least a factor of 2 and might be as high as a factor of 10.

As noted in the introduction, this analysis does not provide a comprehensive estimation of the health effects associated with the criteria pollutants. The health effects covered include, however, more than half of the categories of health effects for which quantitative information is available and cover the majority of the health effects cases that would be expected at the levels of these pollutants that occur in Region VIII. More important than the quantifiable effects that were excluded are the suspected effects that could not be quantified. Chronic exposures to elevated levels of particulate matter and ozone are suspected of contributing to the development of chronic respiratory diseases in some individuals, but this has not been demonstrated conclusively or in a way that lends itself to quantification of the risk. Due to the serious consequences of many chronic respiratory diseases this is a potentially significant omission.

Table 14-5
Health Effects due to Lead in Region VIII

State	Population [1]	% Urban Population [1]	Minor Health Effects [2]			
			Adult Males (35%) [p. neuro.]	Adult Females (35%) [p. neuro.]	Children 6-17 Yr. (20%) [p. neuro.]	Children < 6 yr. (10%) (FEP)
Colorado	3,231,000	80.6%	1094	39	281	2370
Montana	826,000	52.9%	184	7	47	398
North Dakota	685,000	48.8%	140	5	36	304
South Dakota	708,000	46.4%	138	5	35	299
Utah	1,645,000	84.4%	583	21	150	1263
Wyoming	509,000	62.7%	134	5	34	290
TOTAL Region VIII	7,604,000		2,273	81	584	4,924

State	Population	% Urban Population	Serious Health Effects	
			Adult Males [hypertension]	Children < 6 yr. [c.neuro]
Colorado	3,231,000	80.6%	4648	625
Montana	826,000	52.9%	780	105
North Dakota	685,000	48.8%	597	80
South Dakota	708,000	46.4%	586	79
Utah	1,645,000	84.4%	2478	333
Wyoming	509,000	62.7%	570	77
TOTAL Region VIII	7,604,000		9,659	1,299

1 From U.S. Department of Commerce 'Statistical Abstracts of the United States 1987'
2 Approximate percent of urban population in parentheses.

14.3 WELFARE DAMAGES

Welfare damages are estimated for human health endpoints, and damage to man-made materials. Human health damages are based on incidence estimates that have been discussed in the previous section, while damages to man-made materials are discussed below. Current air pollutant loads are not significantly high to be associated with either factory nor agricultural productivity losses.

14.3.1 Materials Damage

Four criteria air pollutants have been associated with materials damage: particulate matter, nitrogen dioxide, and ozone. Regional welfare damage estimates are based on the following approaches and are summarized in Table 14-6. Table 14-7 summarizes economic damage estimates to households due to particulate concentrations in Region VIII. Table ?? summarizes materials damage due to ozone, nitrogen oxides, and particulate matter effects to the manufacturing sector.

Particulate Matter

Particulate matter has been identified as causing soiling and discoloration effects on a wide variety of materials, including paint, structural metals, and other building materials. The primary effect is considered to be the soiling of surfaces. This soiling has welfare impacts through increased cleaning costs and by reducing the useful life of affected materials. Economic damages related to particulate matter soiling have been estimated for households and two manufacturing industries.

Methodology

1. Household Damages. Mathtech (1986) estimated annual household damages as \$0.906 (1988 \$)/μg change in the annual geometric mean total of particulates. They also used 10 $\mu g/m^3$ as an approximate background estimate for TSP. Using this approach, annual household soiling damages due to particulates are:

   AHSD = 0.906*HHj*(TSPj-10)
   where:

   Hhj = the number of households living in area j
   TSPj = the annual geometric mean TSP concentration in the area

Table 14-6
Annual Household Soiling Damage
due to Total Suspended Particulates (TSP) in Region VIII

State County or City	Population	Annual Average TSP in ug/m3 1987	1988	1989	Average	Standard Deviation	Household Soiling Damage [1] ($1988)
Colorado							
Adams Co.	281,000	86	88	74	83	6.18	$6,928,807
Alamosa	6,830	48	51	80	60	14.43	$115,107
Englewood	30,021	79	69		74	5.00	$651,962
Archuleta Co.	5,200	89			89	0.00	$139,395
Boulder	81,239	48	51	48	49	1.41	$1,075,093
Delta	21,225	94	97		96	1.50	$615,787
Denver	492,200	93	87	93	91	2.83	$13,528,311
Castle Rock	45,400	65	63	85	71	9.93	$939,729
Eagle Co.	15,900	89			89	0.00	$426,227
Colorado Springs	276,872	59	60	55	58	2.16	$4,509,592
Durango	12,000	38	37	30	35	3.56	$101,798
Canon City	13,000	53			53	0.00	$189,683
Glenwood Springs	4,700	62			62	0.00	$82,931
Jefferson Co.	430,200	60			60	0.00	$7,298,899
Lake Co.	5,900	41	41	39	40	0.94	$60,728
Limon	1,800	38	44	40	41	2.49	$18,731
Sterling	11,400	64	57	58	60	3.09	$192,126
Pitkin Co.	10,900	58	55	57	57	1.25	$172,604
Lamar	7,700	47			47	0.00	$96,674
Pueblo	109,444	38	42		40	2.00	$1,114,115
Steamboat Springs	5,100	80			80	0.00	$121,139
Telluride	1,500	89			89	0.00	$40,210
Platteville	1,662	62	66	57	62	3.68	$29,138
Montana							
Big Horn Co.	10,900	30	37	27	31	4.19	$78,905
Blaine Co.	7,000	44	42	34	40	4.32	$71,258
Cascade Co.	78,200	54	53	50	52	1.70	$1,123,327
Flathead Co.	58,600	86			86	0.00	$1,511,222
Bozeman	21,700	40			40	0.00	$220,901
Jefferson Co.	8,300	71	40	39	50	14.85	$112,656
Lake Co.	21,100	65	53	55	58	5.25	$341,283
Lewis & Clark Co.	47,000	56	57	48	54	4.03	$696,410
Lincoln Co.	18,700	83			83	0.00	$463,214
Missoula Co.	78,300	44	38	37	40	3.09	$788,220
Roosevelt Co.	11,100	49	38	38	42	5.19	$119,273

Table 14-6 (cont.)
Annual Household Soiling Damage
due to Total Suspended Particulates (TSP) in Region VIII

State County or City	Population	Annual Average TSP in ug/m3 1987	1988	1989	Average	Standard Deviation	Household Soiling Damage [1] ($1988)
Rosebud Co.	12,200	56	52	52	53	1.89	$179,390
Yellowstone Co.	116,400	60	52	46	53	5.73	$1,685,228
North Dakota							
Burleigh Co.	60,400	51	51		51	0.00	$840,307
Cass Co.	100,200	36	37		37	0.50	$901,012
Dunn Co.	4,500	18			18	0.00	$12,216
Grand Forks Co.	70,500	46			46	0.00	$861,209
Stark Co.	24,700	52			52	0.00	$352,017
Stutsman Co.	23,300	15			15	0.00	$39,531
Williams Co.	23,300	36			36	0.00	$205,564
South Dakota							
Brookings Co.	24,200	20			20	0.00	$82,117
Codington Co.	22,700	38			38	0.00	$215,676
Hughes Co.	15,200	46			46	0.00	$185,679
Minnehaha Co.	125,500	40	48		44	4.00	$1,447,903
Pennington Co.	82,000	49	66		58	8.50	$1,321,674
Yankton Co.	18,900	35			35	0.00	$160,331
Utah							
Davis Co.	184,800	43	52	53	49	4.50	$2,466,492
Emery Co.	11,300	46	47		47	0.50	$139,955
Moab	5,333	46	49	52	49	2.45	$70,575
Cedar City	19,200	47	46	44	46	1.25	$232,370
Salt Lake Co.	720,000	64	69	54	62	6.24	$12,785,798
Uintah Co.	22,300	33			33	0.00	$174,040
Utah Co.	242,700	54	84		69	15.00	$4,858,909
Weber Co.	160,200	45	56	43	48	5.72	$2,065,680
Wyoming							
Albany Co.	26,600	48	46	45	46	1.25	$327,947
Campbell Co.	32,800	30	28	30	29	0.94	$215,178
Fremont Co.	33,900	40	41	42	41	0.82	$356,598
Laramie Co.	75,200	29	27	27	28	0.94	$450,806
Natrona Co.	64,700	37	38	42	39	2.16	$636,677
Park Co.	24,200	46	45	31	41	6.85	$251,825
Sheridan Co.	25,100	46	41	33	40	5.35	$255,512

Table 14-6 (cont.)

Annual Household Soiling Damage
due to Total Suspended Particulates (TSP) in Region VIII

State County or City	Population	Annual Average TSP in ug/m3 1987	1988	1989	Average	Standard Deviation	Household Soiling Damage [1] ($1988)
Sweetwater Co.	43,300	37	33	35	35	1.63	$367,320
Teton Co.	11,600	49	39	46	45	4.19	$136,454
Uinta Co.	13,021	28	29	25	27	1.70	$76,585
Total	4,672,347						$78,334,029

1 Household Soiling Damage = 0.906*HHj*(TSPj-10)/2.67 where: TSPj is the annual geometric mean concentration in ug/m3 and HHj is the number of households in region j, and HHj = population/2.67 people per household.

Table 14-7
Welfare Effects of Materials Damage due to Ozone, Nitrogen Dioxide, and PM10 in Region VIII

State	Population 1986	Ozone Materials Damage (1)	Nitrogen Dioxide Materials Damage (2)	PM10 Manufacturing Sector Materials Damage (3)
Colorado	3,231,000	$3,033,195	$4,282,157	$49,958,501
Montana	826,000	$775,431	$1,094,727	$12,771,811
North Dakota	685,000	$643,064	$907,854	$10,591,635
South Dakota	708,000	$664,655	$938,337	$10,947,267
Utah	1,645,000	$1,544,291	$2,180,176	$25,435,387
Wyoming	509,000	$477,838	$674,595	$7,870,281
TOTAL	7,604,000	$7,138,475	$10,077,847	$117,574,882

1 Welfare effects of materials damage due to Ozone is estimated to be $0.94 per person in 1988 dollars.
2 Welfare effects of materials damage due to Nitrogen Dioxide is estimated to be $1.33 per person in 1988 dollars.
3 Welfare effects of materials damage due to PM10 is estimated to be $15.46 per person in 1988 dollars.

2. Manufacturing Sector Damages. Mathtech also estimated a model to calculate damages in the manufacturing sector. Estimates were made for two industries: fabricated structural metal products and metal working machinery. Mathtech estimated that national damages were approximately $3.3 million due to current levels of TSP. If we assume that these costs are largely passed on to consumers, this implies average per capita damages of $14. To estimate damages in Region VIII, we multiplied $14 by the Regional population.

Nitrogen Dioxide

The primary materials damage effect associated with nitrogen dioxide is dye fading. The EPA estimated that the national cost of dye fading due to nitrogen dioxide is $280 million/year, or $1.20 per capita. To estimate damages in Region VIII, we multiplied $1.20 by the Region's population. This estimate is very conservative and should be considered an upper bound.

Ozone

Elastomers are the most vulnerable material to ozone damage. The EPA estimated that annual damage to automobile and truck tires was about $200 million, or $.85/person. To calculate Region VIII damages, multiply this value by the Region's population. As with the NO_2 damage estimate, this estimate is very conservative.

14.3.2 Health Care Costs

Health care costs include direct medical costs and lost productivity due to inability to conduct normal work activities. The financial impact does not reflect the full social welfare impact because it does not reflect pain and discomfort of the individual, lost ability to conduct non-work activities such as recreation, and the inconvenience and concern of friends and families. Cost of illness measures do not include damages associated with mortality. We estimated average costs for three health endpoints described earlier in the Human Health Risk Assessment:

- Restricted Activity Day
- Asthma Attack
- Respiratory Restricted Activity Day

Restricted Activity Day

Restricted activity days are days on which an individual's normal activities are restricted due to illness. This includes confinement to bed and days missed from work as well as other minor restrictions in activity. Rowe et al. (1986) cite evidence that about one-third of all restricted activity days involve days missed from work. The average daily full-time wage in the U.S. is about $95. Rowe et al. suggest that the medical costs associated with the types of restricted activity days likely to be caused by air pollution might be expected to average about $5 per day. Thus, the average financial cost of a restricted activity day would be:

$.33 * \$95 + 5 = \text{approximately } \$35$

Asthma Attack

Rowe et al. (1986) estimate the direct medical costs associated with an average asthma attack as $10. Assuming that asthma attacks are equivalent to restricted activity days, one third of all asthma attacks will involve a lost day from work. The average cost of an asthma attack is:

$.33 * \$95 + 10 = \text{approximately } \$40$

Respiratory Restricted Activity Day

Direct medical costs associated with restricted respiratory activity days are likely to be minimal and can be reasonably assumed to be zero. Assuming that one-tenth of all respiratory restricted activity days involve a day missed from work, the average cost for a restricted respiratory activity day is $10.

2. Manufacturing Sector Damages. Mathtech also estimated a model to calculate damages in the manufacturing sector. Estimates were made for two industries: fabricated structural metal products and metal working machinery. Mathtech estimated that national damages were approximately $3.3 million due to current levels of TSP. If we assume that these costs are largely passed on to consumers, this implies average per capita damages of $14. To estimate damages in Region VIII, we multiplied $14 by the Regional population.

Nitrogen Dioxide

The primary materials damage effect associated with nitrogen dioxide is dye fading. The EPA estimated that the national cost of dye fading due to nitrogen dioxide is $280 million/year, or $1.20 per capita. To estimate damages in Region VIII, we multiplied $1.20 by the Region's population. This estimate is very conservative and should be considered an upper bound.

Ozone

Elastomers are the most vulnerable material to ozone damage. The EPA estimated that annual damage to automobile and truck tires was about $200 million, or $.85/person. To calculate Region VIII damages, multiply this value by the Region's population. As with the NO_2 damage estimate, this estimate is very conservative.

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Health care costs include direct medical costs and lost productivity due to inability to conduct normal work activities. The financial impact does not reflect the full social welfare impact because it does not reflect pain and discomfort of the individual, lost ability to conduct non-work activities such as recreation, and the inconvenience and concern of friends and families. Cost of illness measures do not include damages associated with mortality. We estimated average costs for three health endpoints described earlier in the Human Health Risk Assessment:

- Restricted Activity Day
- Asthma Attack
- Respiratory Restricted Activity Day

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Restricted Activity Day

Restricted activity days are days on which an individual's normal activities are restricted due to illness. This includes confinement to bed and days missed from work as well as other minor restrictions in activity. Rowe et al. (1986) cite evidence that about one-third of all restricted activity days involve days missed from work. The average daily full-time wage in the U.S. is about $95. Rowe et al. suggest that the medical costs associated with the types of restricted activity days likely to be caused by air pollution might be expected to average about $5 per day. Thus, the average financial cost of a restricted activity day would be:

$.33*\$95+5=$ approximately $35

Asthma Attack

Rowe et al. (1986) estimate the direct medical costs associated with an average asthma attack as $10. Assuming that asthma attacks are equivalent to restricted activity days, one third of all asthma attacks will involve a lost day from work. The average cost of an asthma attack is:

$.33*\$95+10=$ approximately $40

Respiratory Restricted Activity Day

Direct medical costs associated with restricted respiratory activity days are likely to be minimal and can be reasonably assumed to be zero. Assuming that one-tenth of all respiratory restricted activity days involve a day missed from work, the average cost for a restricted respiratory activity day is $10.

Table 14-8

Welfare Effects due to Ozone
in Region VIII

State County	Ozone Concentration Number of Exceedance Days >0.105 ppm 1987	>0.125 ppm	>0.105 ppm 1988	>0.125 ppm	>0.105 ppm 1989	>0.125 ppm	>0.105 ppm Average	>0.125 ppm	Population	Welfare Effects ($1986) Asthma Attacks [1]	Restricted Activity Days [2]
Colorado											
Arapahoe Co	3	1	10	1	1		5	1	391,200	$154	$2,904
Boulder	8		4		2	1	5		81,239		
Denver	6	1	3				3		492,200		
Arvada	9	1	7	1	3		6	1	430,200	$170	$3,194
Utah											
Bountiful	4	1	9	2	13	2	9	2	32,900	$32	$611
Salt Lake Cit	2		10	2	5	2	6	1	674,201	$532	$10,011
Provo			3		2	1	2		169699		
Roy	2				1		1		19700		
Total	Population >= 0.105								2,291,339		
	Population >= 0.125								1,528,501	$889	$16,719

1 Welfare effect is estimated to be $40 per Asthma Attack.

2 Welfare effect is estimated to be $10 per Restricted Activity Day.

Table 14-9
Annual Welfare Damage of Health Endpoints
due to Particulate Matter (PM10) in Region VIII

State County or City	Population	Annual Average TSP in ug/m3 1987	1988	1989	Average	Standard Deviation	Annual Restricted Activity Days [1]	Welfare Effect of Lost Days [2] ($1988)
Colorado								
Alamosa	6,830			51	51	0.00	4,084	$157,901
Archuleta Co.	5,200	60	52	44	52	6.53	3,349	$129,465
Boulder	81,239	43	35	37	38	3.40	1,246	$48,157
Denver	492,200	49	35	35	40	6.60	37,735	$1,458,848
Montana								
Lincoln Co.	18,700	69	62	59	63	4.19	21,792	$842,468
Sanders Co.	8,600	41	36	51	43	6.24	1,846	$71,372
Utah								
Salt Lake Co.	720,000	37	44	42	41	2.94	99,360	$3,841,258
Utah Co.	242,700	41	50	51	47	4.50	104,199	$4,028,341
Wyoming								
Fremont Co.	33,900	50	35	31	39	8.18	1,040	$40,191
Sheridan Co.	25,100	48	47	37	44	4.97	6,928	$267,821
Total	1,634,469						281,578	10,885,821

1 Annual Restricted Activity Days = 0.046*(PM10j-38)*POPj where: PM10j is the 3 year average measured particulate concentration in ug/m3 and POPj is the exposed population in region j.
2 Welfare effect is estimated to be $38.66 per Restricted Activity Day in 1988 dollars.

Table 14-10
Annual Welfare Damage of Health Endpoints
due to Total Suspended Particulates (TSP) in Region VIII

State County	Population (1)	Annual Average TSP in ug/m3 1987	1988	1989	Average	Standard Deviation	Estimated Number of Resticted Activity Days (2)	Welfare Damage for Resticted Activity Days (3) ($1988)
Colorado								
Adams Co.	281,000	101	99	83	94	8.06	396,585	$15,330,219
Alamosa	6,830	53	58	118	76	29.53	665	$25,698
Englewood	30,021	86	73		80	6.50	9,862	$381,218
Delta	21,225	103	110		107	3.50	48,807	$1,886,660
Denver	492,200	104	102	104	103	0.86	1,013,243	$39,167,516
Castle Rock	45,400	76	68	114	86	20.07	36,456	$1,409,236
Montana								
Ronan Park	1,530	107	79	68	85	16.42	1,080	$41,735
Polson	2,800	95	68	68	77	12.73	409	$15,802
Rosebud	9,900	115	98	90	101	10.42	18,790	$726,347
Total	890,906						1,525,896	$58,984,431

1 1986 population estimates.
2 Annual Restricted Activity Days = 0.073*(TSPj-75)*POPj where TSPj is the 3 year average annual arithmetic mean TSP in ug/m3 and POPj is population for region j.
3 Estimated welfare damage is $38.66 per Restricted Activity Day in 1988 dollars.

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15.0 ACID DEPOSITION AND VISIBILITY DEGRADATION

15.1 INTRODUCTION

Emissions from the combustion of fossil fuels include oxides of sulfur and nitrogen which transform in the atmosphere into sulfuric and nitric acids. Organic acids, natural and anthropogenic VOCs, and seasalts may also contribute to the acidity of precipitation. Wet and dry deposition of these acidic substances impact on sensitive terrestrial and aquatic ecosystems causing widespread damage where deposition levels are high and ecosystems and their components are sensitive. Emissions of SO_2, NO_x, VOCs (volatile organic compounds) and small particles also contribute to visibility degradation. The direct effects these criteria air pollutants on health, welfare and ecosystems are not considered in this problem but are dealt with separately in Problem 14. Health, ecosystem, and welfare effects of acid deposition and visibility degradation are the focus of this assessment.

Region VIII contains vast areas of terrestrial and aquatic ecosystems which are extremely sensitive to acidic deposition impacts, however, current emissions and deposition levels are low and chronic acidification effects have not been detected or are quite small (Landers, et al., 1987; Vertucci, In Press; Turk and Campbell, 1987). The extent of sensitive lake ecosystems in Region VIII (exclusive of the Dakotas) has been defined as part of the EPA Western Lake survey (Landers, et al., 1987). The sensitivity of regional soils is poorly known (Binkely, 1989), however, sensitive soils generally occur in the watersheds of poorly buffered lakes. Recent studies have quantified the extreme sensitivity of native western trout to low pH and elevated Al concentrations (Woodward, et al., 1989).

At current deposition levels effects may be limited to, short term episodic effects in very sensitive aquatic ecosystems, and subtle long-term changes in soil chemistry. Episodic acidification has been documented at current levels of deposition for a Rocky Mountain lake, however effects were slight and short term (approximately 3 days) (Vertucci, In Press). The structure and function of sensitive, poorly buffered, freshwater ecosystems in Region VIII can be significantly altered if deposition levels rise significantly. Model evidence suggests that even at current deposition levels, depletion of soil base saturation and a reduction in the watershed export of alkalinity is possible (Binkely, 1990). Effects on terrestrial biota are unlikely at this time, with the possible exception of sites very near large copper smelters, and damage at these sites is more likely to be associated with gaseous $S0_2$ effects.

15.2 DATA DESCRIBING POLLUTANT SOURCES: EMISSIONS

Emissions data used in this assessment include those complied since 1975 by month by state for VOCs, SO_2 and NO_x by Kohout et al. (1989) as part of DOE's Month and State Current Emission Trends (MSCET) program. Given the long range transport of air pollutants, and dominant meteorologic patterns, Region VIII's airshed is taken to be the Western U.S., states west of the Mississippi River and Minnesota. The predominant pollutant emitted from 1975-1985 was VOC. VOC emissions levels declined from a peak at 10.1 million metric tons in 1978 to a 1988 level of 7.4 million metric tons. NO_x emissions peaked at 6.1 million metric tons in 1978, fell to 7.8 in 1986 and have risen to 8.1 in 1988. The SO_2 emissions for the West region peaked at 6.6 million metric tons in 1979 declined to 5.3 million metric tons in 1987 and has risen to 5.8 million metric tons in 1988.

Figure 15-1 shows the total annual U.S. emissions and the declining national emissions trends for NO_x, SO_2 and VOC. The 13 year trends in SO_2, NO_x and VOC emissions for Region VIII states are depicted in Figures 15-2, 15-3 and 15-4, respectively.

The trends in emission flux of SO_2, plus NO_x for each State in Region VIII are shown in Figure 15-5. Montana has shown a dramatic decline in S and N emissions since 1975 associated with the 1980 closure of the Anaconda copper smelter. Utah also exhibited declining emissions until 1986. Emissions in South Dakota have been relatively constant and are the lowest in the Region. North Dakota has had the most consistent increase in emissions; since 1975 emissions have doubled. Emissions from Colorado and Wyoming have generally increased since 1975.

The percentage contribution of Region VIII States to total national emissions has remained constant for VOCs and increased slightly, in 1988, for SO_2, and increased markedly for NO_x, since 1975 (Figure 15-6). Regional emissions of NO_x and SO_2 have increased their fraction of national total emissions by over 2% since 1975. While national emissions have been declining, total Region VIII emissions have declined for VOC, increased for NO_x and generally decreased for SO_2 except for the precipitous increase in SO_2 observed in 1988 (Figure 15-7).

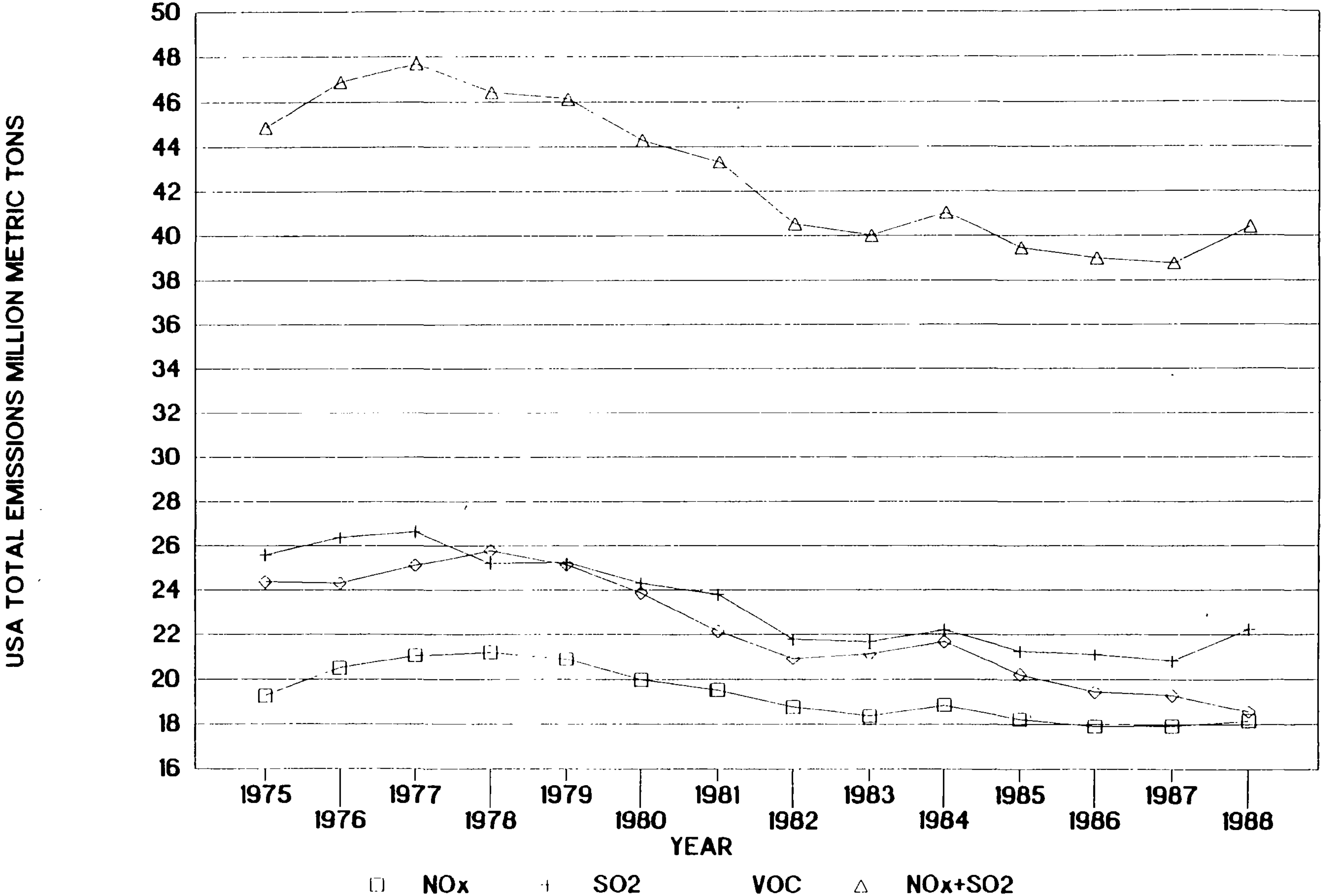
Ranked by order of importance, SO_2 emissions in the Western U.S. include: electric utilities, industrial processes, industrial fuel, transportation, commercial/residential energy use, and miscellaneous sources. NO_x emissions, also ranked by importance, are: transportation, electric utilities, sources of industrial fuel, industrial processes, commercial/residential energy use, and miscellaneous sources. (Kohout et al., 1989).

A projection of estimated total emissions trends for Region VIII States in the NAPAP Interim Assessment of 1987 included SO_2 increases of 42% and NO_x increases of 142% between 1980 and 2030. State projections in utility emissions from 1980-2010 suggest increases in SO_2 emissions for Colorado, Montana, North Dakota, South Dakota, and Utah of 104%, 178%, 177%, 208% and a decrease in SO_2 emissions for Wyoming (47%). NO_x

Figure 15.1

ANNUAL EMISSIONS OF SO2, NOx, VOC

FOR ALL UNITED STATES

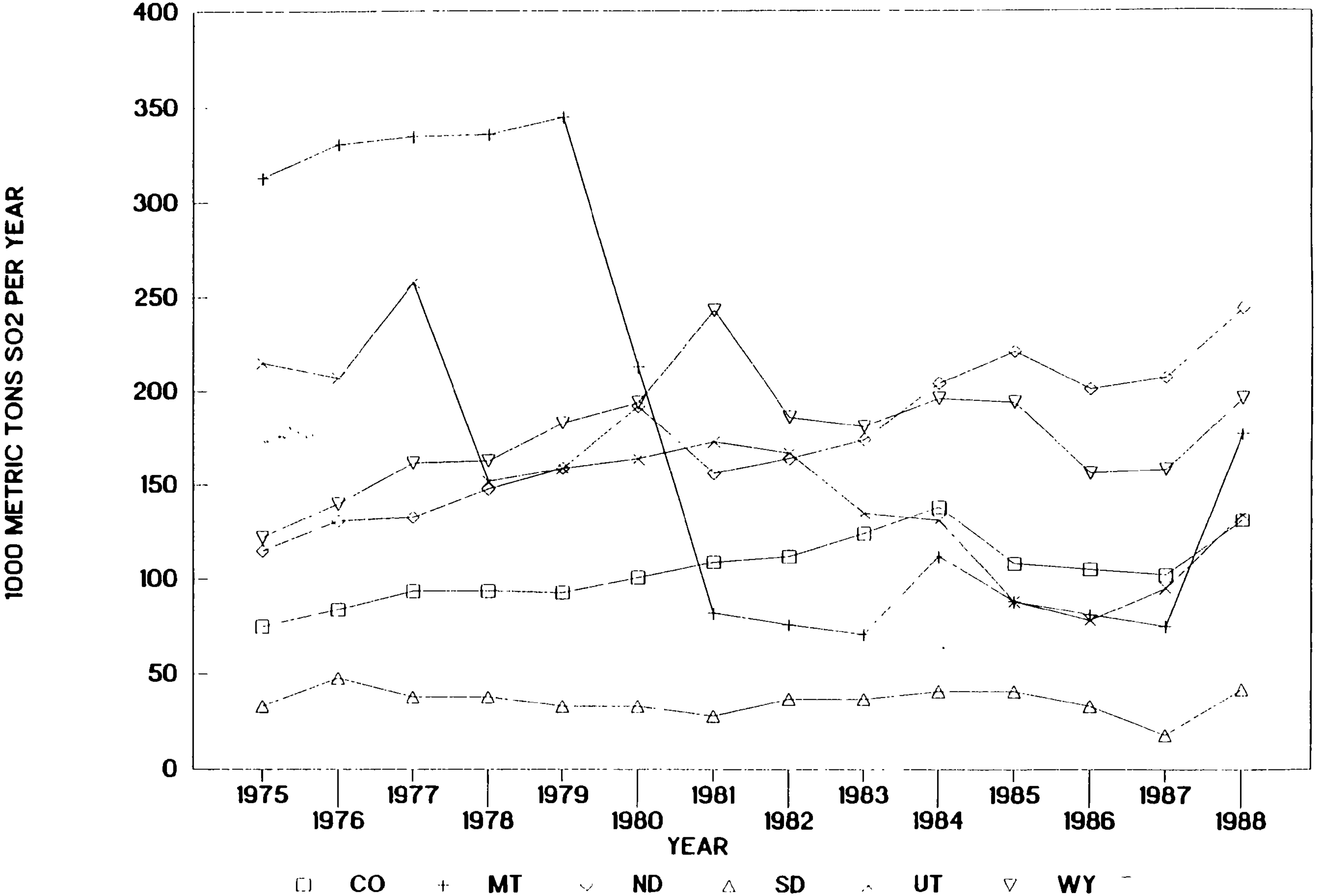


(Kohout et al., 1989)

Figure 15.2

ANNUAL EMISSIONS OF SO2

EPA REGION VIII STATES

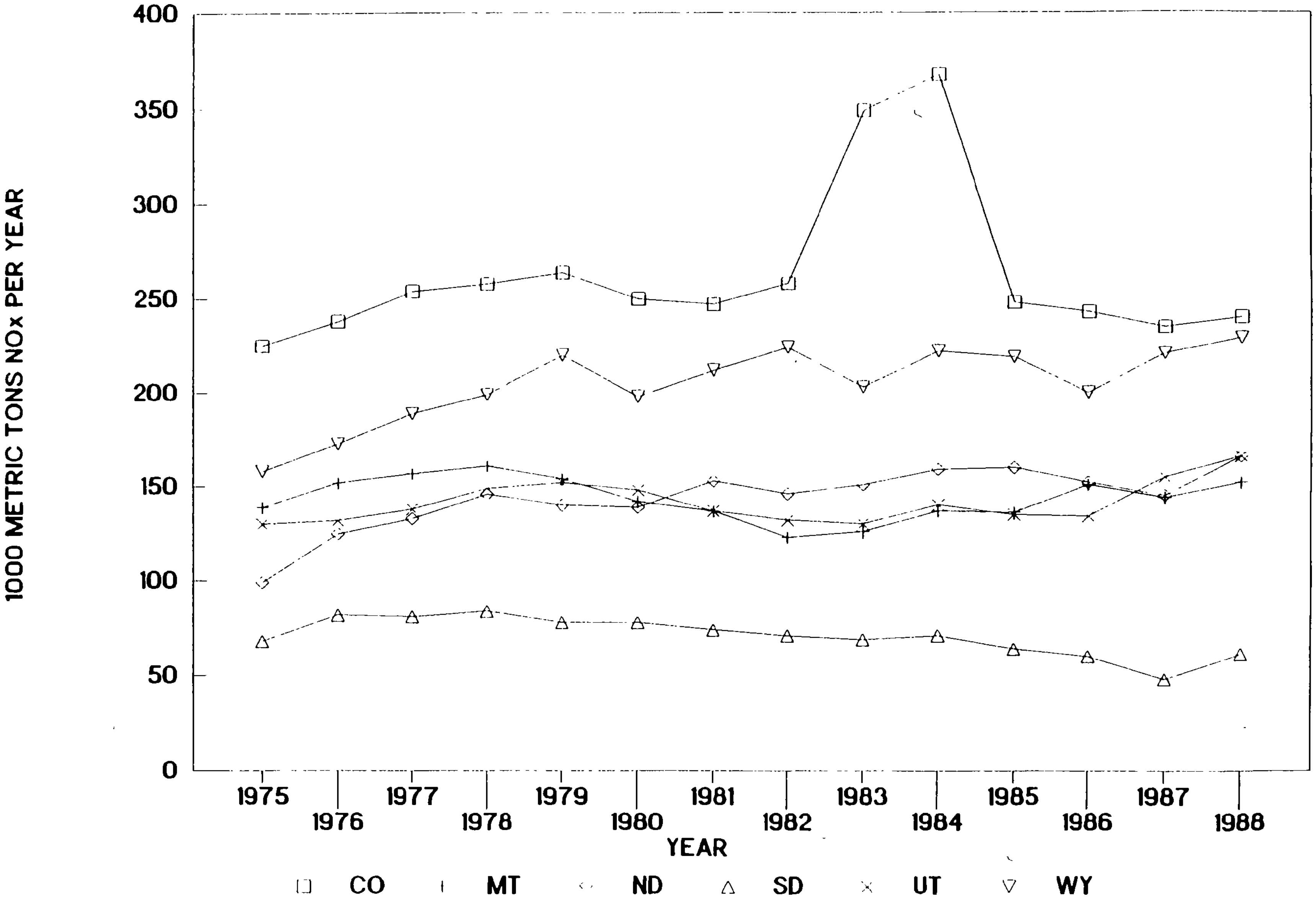


(Kohout et al., 1989)

Figure 15.3

ANNUAL EMISSIONS OF NOx

EPA REGION VIII STATES

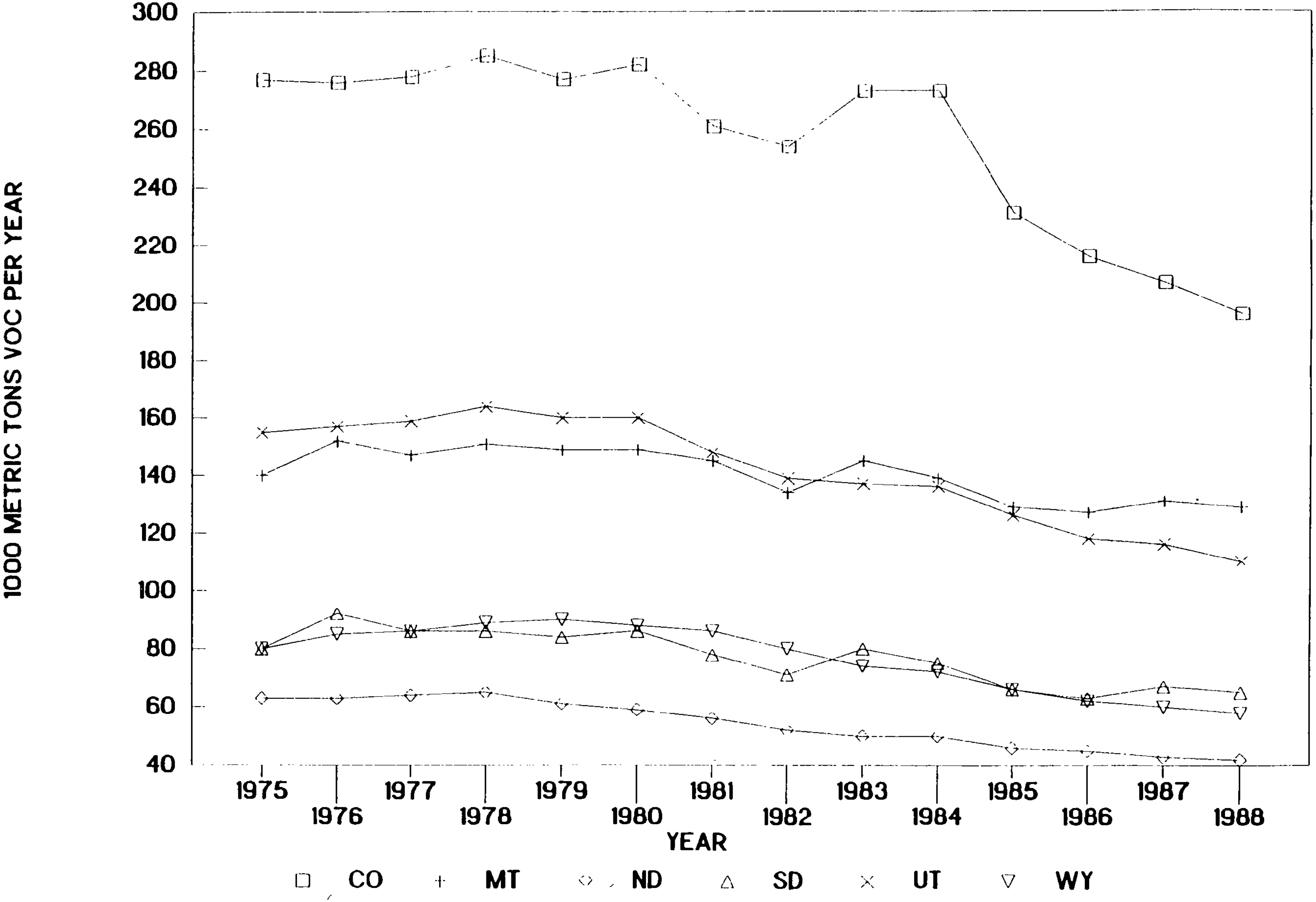


(Kohout et al., 1989)

Figure 15.4

ANNUAL EMISSIONS OF VOC

EPA REGION VIII STATES

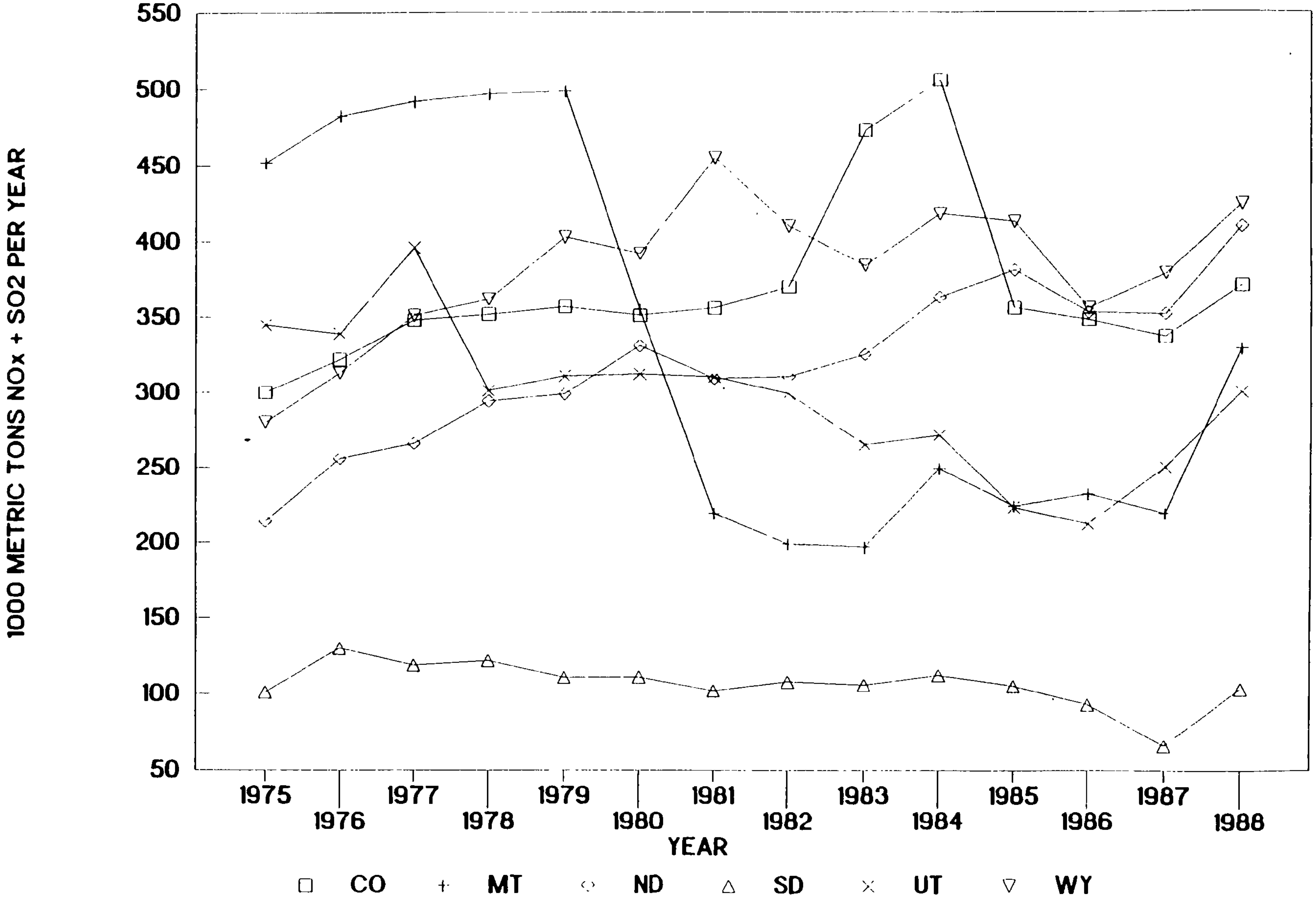


(Kohout et al., 1989)

Figure 15.5

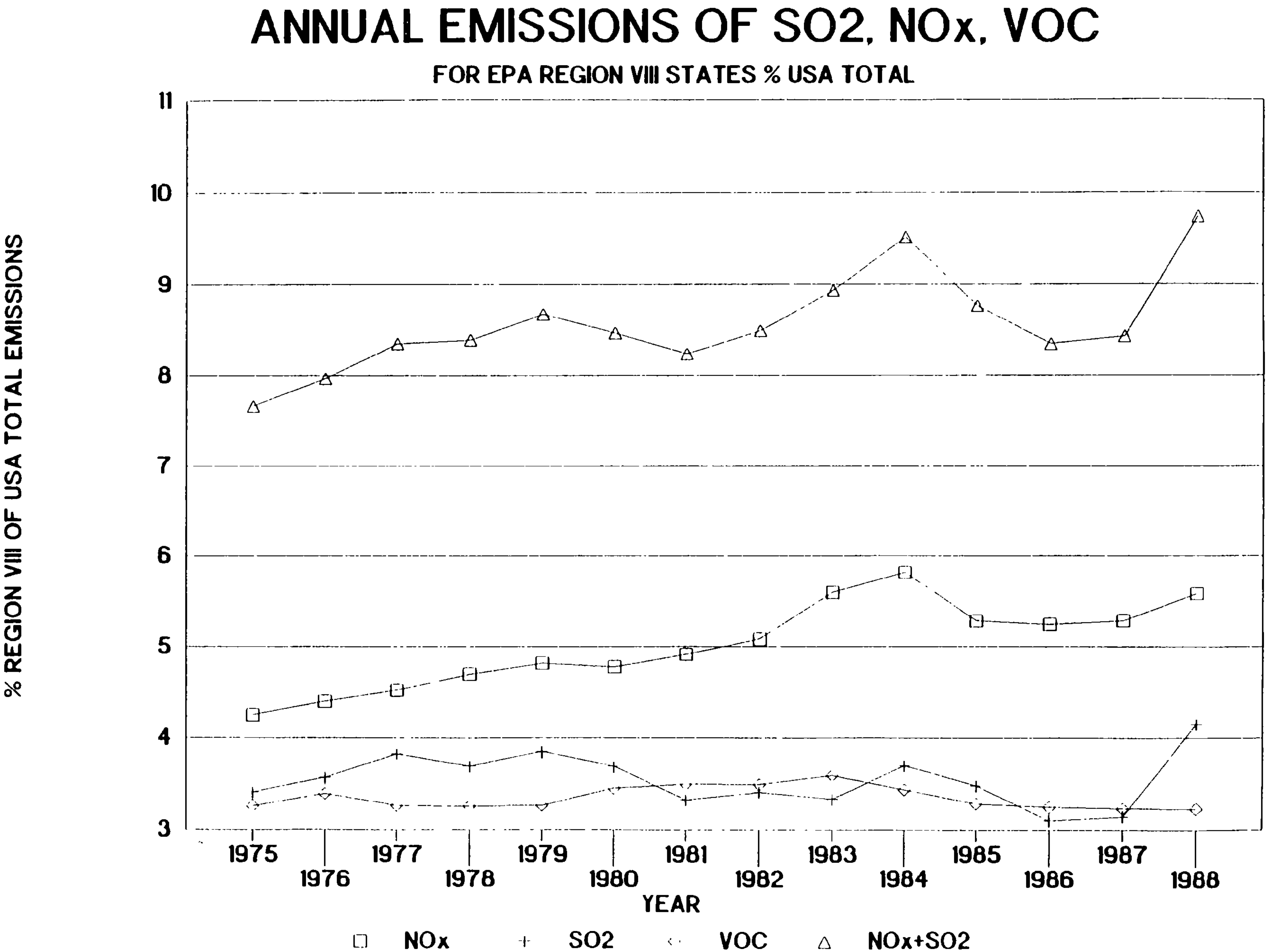
ANNUAL EMISSIONS OF SO2 + NOx

EPA REGION VIII STATES



(Kohout et al., 1989)

Figure 15.6

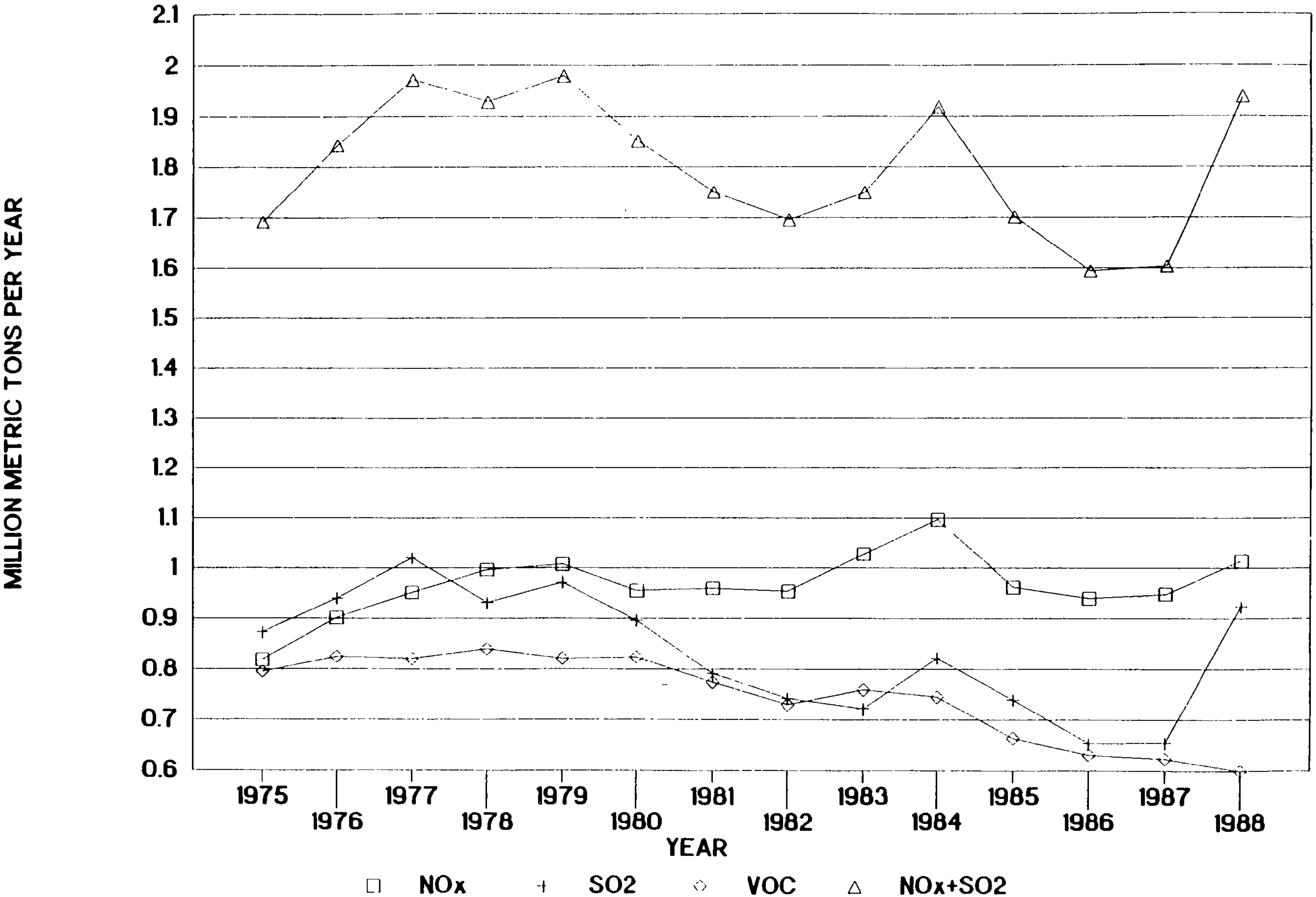


(Kohout et al., 1989)

Figure 15.7

ANNUAL EMISSIONS OF SO2, NOx, VOC

FOR ALL EPA REGION VIII STATES



(Kohout et al., 1989)

emissions are projected to increase by 80%, 280%, 234%, 230% and 64% for Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming, respectively. While these emissions projections are replete with uncertainty, the trend is clearly toward increases in emissions for the Region (NAPAP, 1987).

15.2.1 Data Describing Pollutant Stressors: Deposition of H+, Nitrate and Sulfate

Acid deposition data used in this assessment are from the NADP, NTN network of precipitation chemistry monitoring (NADP, 1989). There are 40 active NADP/NTN monitoring sites in Region VIII(Figure 15-8).

Current precipitation concentrations of H^+, SO4 and NO3 collected in Region VIII, (using the NADP Rocky Mountain National Park, Colorado station as an example), are about 10, 20 and 19 µeq/l respectively, or 1/6, 1/3 to 1/5, or 2/3 their respective concentrations found in the Eastern U.S. (Galloway, et al., 1984). The concentration of hydrogen ion is similar to "background" levels while the concentration of SO_4 is 2 to 5 times background and the concentration of NO_3 is 3 to 5 times levels at found in remote sites (Galloway et al., 1984).

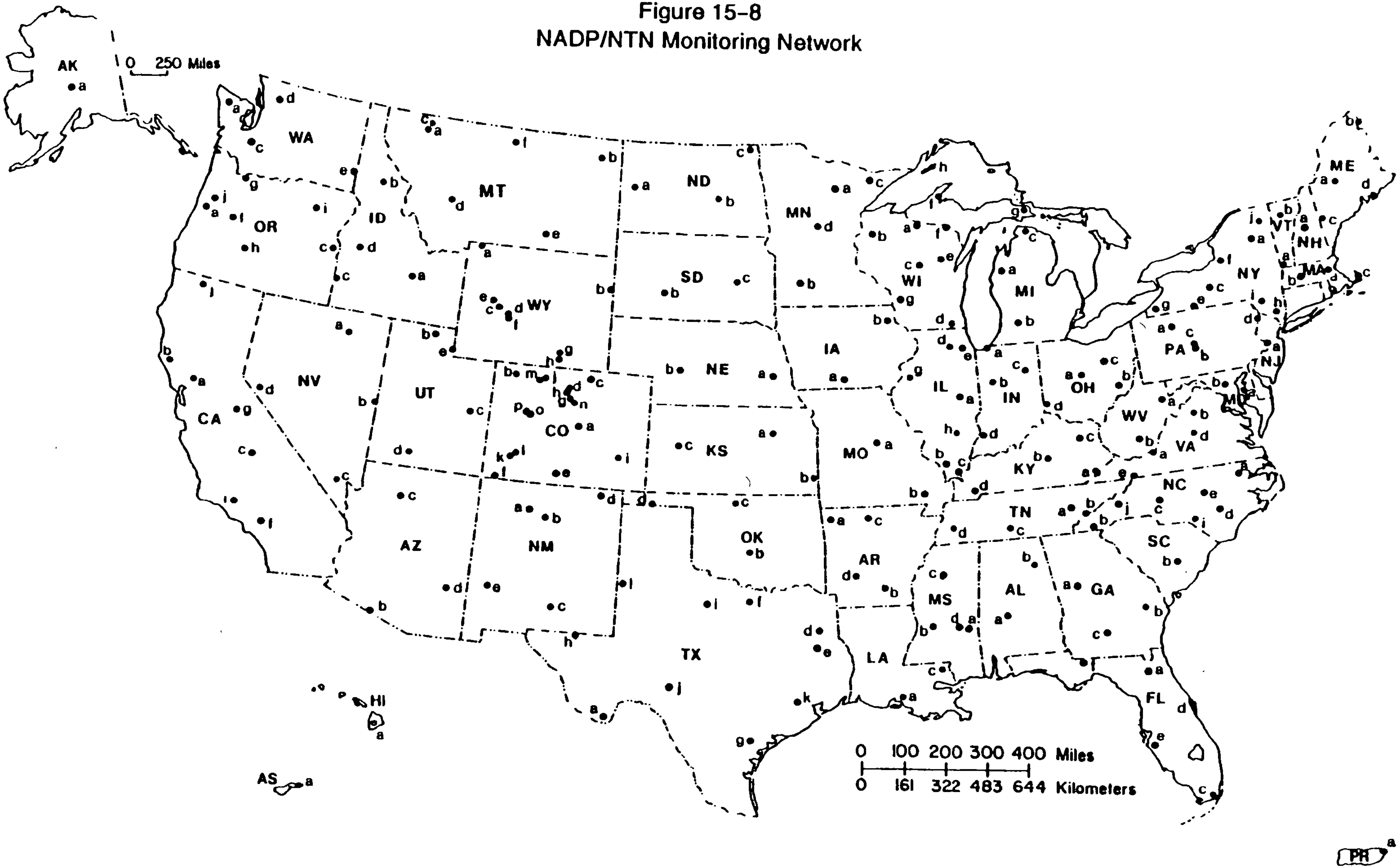
Current sulfur and nitrogen deposition levels in Region VIII have been estimated at 1.7 and 2.6 kg/ha/yr respectively (Fox, et al., 1989). Nitrogen deposition includes nitrate and ammonium and an added 30% for dry N deposition. In contrast, deposition of sulfur and nitrogen in the Eastern U.S. can be as high as 13 and 7 kg/ha/yr, respectively (Fox et al., 1989). Precipitation-weighted mean annual hydrogen ion concentration as pH is generally greater than 5.1 for the Region (NADP, 1989).

15.2.2 Uncertainty of Deposition Estimates

NADP wet deposition estimates underestimate total deposition since dry deposition is not measured. Deposition of strong anions varies between monitoring sites due primarily to variations in precipitation anion and, secondarily, through variations in precipitation concentrations. Actual deposition to sensitive ecosystems is not precisely known, as few estimates of dry deposition exist from the Region and monitoring stations are not typically located in the most sensitive terrain (remote mountain wilderness areas).

The dominant form of precipitation in the Region is snow. However, collection efficiencies of dry light snow falling during high wind conditions are very low. Thus, deposition estimates critical to assessing potential impacts on sensitive mountain ecosystems contain much uncertainty. One study provides some insight into these uncertainties. NADP wet deposition was compared with the bulk deposition to a snow-pack in the Snowy Range of the Medicine Bow Mountains in Wyoming (Vertucci and Fox (in prep). Precipitation volume collected by NADP and snow-pack water equivalent compared well at this site. The

Figure 15-8
NADP/NTN Monitoring Network



Locations of active sites in the NADP/NTN network as of 05 October, 1989

(NADP, 1989)

difference between bulk and wet-only deposition provided a crude estimate of dry deposition. NADP wet only deposition of SO_4 was similar to snow-pack deposition values (3.84 kg/ha versus 3.68($\pm$1.3)), while NO_3 wet deposition was lower than snow-pack bulk deposition values (2.56 kg/ha versus 4.00 ($\pm$0.80)), suggesting significant amounts of dry deposition of NO_3. Dry sulfur deposition may not be significant in the Region, as lake sulfate concentrations tend to reflect wet deposition concentrations, except for sites with geologic sources of sulfate (Landers et al., 1987; Turk, 1988). Due to the biological uptake of nitrate, a similar assessment of regional nitrogen dry deposition through comparison of precipitation concentrations and lake concentrations is not possible.

15.3 THE RELATIONSHIP BETWEEN EMISSIONS AND DEPOSITION

In order to discuss future risks of acidic deposition in Region VIII, data are needed on the relationship between emissions and deposition. Emissions projections can be linked to deposition, if the functional relationship between sources and deposition can be described. Evidence has been presented which suggests that emissions are linearly related to deposition in the West (Oppenheimer et al., 1985; Epstein and Oppenheimer, 1986). Changes in regional SO_2 emissions have been recently shown to correspond with changes in precipitation chemistry (SO_4 and pH) for the Eastern U.S. (Butler and Likens, In Press). The weight of evidence supports the assumption that increases in emissions will be followed by proportional increases in deposition amount in Region VIII.

15.4 DATA ON ECOSYSTEM SENSITIVITY TO POLLUTANT EXPOSURE

There are extensive data on the sensitivity of ecosystems to acidic deposition. Ecosystem sensitivity to acidic deposition has been found to be closely related to geologic, edaphic and hydrologic features (Turner et al., 1990).

Base-poor soils form over acidic slowly weatherable bedrock and have limited capacity to buffer incoming acidic deposition especially if soils are thin and hydrologic flow paths are short. Streams and lakes in such environments represent the most sensitive ecosystems to acidic deposition. Acidification effects on lakes have preceded detectable effects on terrestrial ecosystems, and can be measured through a variety of means (Schindler, 1988; Asbury et al., 1989; Sullivan et al., 1990; Vertucci, In Press)

The sensitivity of aquatic ecosystems can be quantified by assessment of the ecosystems' ability to neutralize incoming acids. The ability of a water sample to neutralize acids is quantified as the alkalinity or acid neutralizing capacity (ANC) of the sample. Lake alkalinity or ANC has been widely used as an index of lake sensitivity. In areas already influenced by acidic deposition the sum of the basic cations is used since acidification can reduce ANC. It should be noted that the sample ANC is only an index to the sensitivity of the ecosystem. The neutralization of incoming acids occurs in lake watersheds by mineral weathering and exchange reactions in soils and by within lake processes that consume acids. The relative importance and magnitude of these processes and their ability to sustain alkalinity production in the face of acidic deposition are what actually determines ecosystem "sensitivity". Once the processes controlling lake buffering capacity are overwhelmed by acid inputs, alkalinity decline and then pH depressions and subsequent aluminum dissolution occurs. Biological impacts follow chemical acidification.

Terrestrial ecosystems sensitive to the effects of acid deposition include those that are currently under stress from "normal" conditions such as short growing seasons, draughty periods and low nutrient availability. Such conditions characterize much of the landscape of the Rocky Mountain West. The sensitivity of regional soils is poorly known (Binkely, 1989), however, sensitive soils generally occur in the watersheds of poorly buffered lakes and streams. The sensitivity of terrestrial plants to direct effects from gaseous criteria pollutants will be discussed in Problem 14.

15.5 DATA ON ECOSYSTEM EFFECTS OF POLLUTANT EXPOSURE

The effects of acid deposition on terrestrial and aquatic ecosystems have been the focus of much attention. The end of the NAPAP (National Acid Precipitation Assessment Program) effort in 1990 will provide numerous detailed state-of-science/ technology assessments that can, when final drafts are completed, provide an extensive review of acid deposition effects. Only a brief summary of effects is presented here.

The effects of acid deposition on terrestrial ecosystems is neither as well known nor as well documented as aquatic ecosystem effects.

15.5.1 Terrestrial Effects

Documented terrestrial effects due to acid deposition as outlined by Binkely (1990) include:

- Direct acidity effects
- Leaching losses of nutrient cations
- Fertilization effect of sulfate and nitrate

Direct Acidity Effects

- Direct pH effects on tree roots, mycorrhizae and soil microbes

  The direct pH effects are likely to be small, as tree roots aren't very sensitive to pH. Impacts on mycorrhizae and microbes are not well known and are probably not critical.

- Soil solution alkalinity

  The soil solution can buffer additions of acids, to varying degrees depending on the soil type. Relatively small declines in soil pH caused by acid deposition can amplify into large reductions in the alkalinity of soil water which can lead to surface water acidification.

- Effects of lowering pH on aluminum in the soil solution

  Many plants and soil biota are very sensitive to concentrations of aluminum, and the concentrations of aluminum in soil solution depends strongly on soil pH. If soil pH declines by 1 unit, due to acidic deposition aluminum concentrations may increase by a factor of 1,000 unless some other factor intervenes (such as organic matter binding with the aluminum).

Leaching Losses of Nutrient Cations

The rate of leaching of nutrient cations such as calcium, magnesium and potassium may be increased by acidic deposition. For example, additions of HNO_3 (nitric acid) could result in the H^+ removing a K^+ from the soil exchange complex, and the K^+ could leach out of the soil associated with the NO_3-. The degree to which terrestrial ecosystem productivity in the West is limited by nutrient cations (rather than by nitrogen, phosphorous or sulfur) is not well known, but studies with lodgepole pine have shown that potassium deficiency may be common. Cation leaching could lead to reduced forest productivity.

Fertilization Effect of Nitrate and Sulfate

Two aspects of the fertilization effect are important:

- Neutralization of acidity and prevention of cation leaching

- Altered ecosystem productivity and species composition

Most ecosystems in the West are probably nitrogen limited, which means that any nitrate deposited in acidic deposition will be retained by the plants with two effects:

> First, the acidity of the nitric acid will be neutralized by the plants, because transforming nitrate into protein nitrogen requires consumption of H+ secondly there would be no opportunity to increase the leaching losses of cation nutrients.

Most western ecosystems probably aren't limited by the availability of sulfur, so the deposition of sulfuric acid may well lead to acidification and leaching of nutrient cations.

The effects of fertilization of ecosystems with low levels of nitrogen each year have not been well examined. Fertilization studies have tended to focus on large doses added only one or two times during a long forest rotation. Possible, but currently unexamined effects include:

- Increased tree leaf area
  - Increased tree growth
  - Decreased forest floor sunlight
    - Cooler temperatures
    - Reduced understory growth
      - Effects on forage wildlife

- Altered species composition
  - Overstory trees
  - Understory, shrubs and herbs
  - Change in diversity

- Altered food quality for grazers
  - Increased or decreased susceptibility to insect attack
  - Improved food quality leading to improve animal vigor and fecundity

There is an extensive literature on the effects acid deposition on aquatic biota and ecosystems (e.g. Haines, 1981; Schindler, 1988; Baker et al., In Review).

As noted previously, acidic deposition causes the acidification of sensitive surface waters resulting in reduced alkalinity, lower pH and elevated metal concentrations. Impacts have occurred on aquatic organisms at all trophic levels (decomposers, primary produces and primary and secondary consumers). Reductions in species abundance, production and growth have occurred and sensitive species have been lost. Fish mortality, reduced growth and reproductive failure have been documented. Ecosystem effects such as reductions in productivity and decomposition rate and nutrient concentrations have not been observed in ecosystem experiments (Schindler et al., 1985).

Direct biotic effects of acidification primarily occur due to the toxicity of hydrogen ion and elevated metal concentrations, chiefly aluminum metals toxicity may be mitigated by complexation with dissolved organic carbon (DOC). There is considerable variation in the sensitivity of aquatic biota to acidification (Eilers et al., 1984). The pH threshold determining ecosystem effects is difficult to specify, however, early effects have been noted up to pH 6.0. Indirect biotic responses have been documented which could not have been predicted from toxicological or mesocosm investigations (Schindler et al., 1985). The magnitude of biological impoverishment in impacted areas is largely unknown due to the absence of baseline biotic surveys. Schindler et al. (1989) modeled species loss for impacted regions of the U.S. and up to 70% of acid sensitive taxa such as leaches, molluscs, and insects may have been eliminated from some regions.

15.6 EXPOSURE-RESPONSE RELATIONSHIP DATA

The response of terrestrial ecosystems to acidic deposition is difficult to detect and quantify while the effects of surface water acidification can be detected and quantified in a number ways. Furthermore, aquatic ecosystems are consistently more sensitive to initial increases in acidic deposition than are terrestrial ecosystems. Therefore, this assessment will primarily focus on detection and quantification of aquatic ecosystem responses to chronic acidification. Episodic acidification will also be evaluated.

Several lines of evidence have been used by other investigators to show that lakes have been acidified through time. A majority of the evidence is indirect: loss of sport fish populations (Harvey and Lee, 1982; Baker and Harvey, 1985), changes in aquatic plant communities (Hendrey and Vertucci, 1980), sediment metal concentrations (Galloway and Likens, 1979; Baron et al., 1986; Charles and Norton, 1986), diatom species assemblages (Baron et al., 1986; Charles and Norton, 1986; Sullivan et al., 1990), and empirical geochemical models of the acidification process (Henriksen, 1979; Almer et al., 1978; Wright, 1983; Wright, 1988; Turk and Campbell, 1987; Schnoor, 1984).

Direct evidence of acidification is available as long-term data on surface water and precipitation chemistry and from "pairs" of data from historic and more recent lake chemistry surveys (Asbury et al., 1989; Lewis, 1982; Davis et al., 1978; Hendrey et al., 1980; Johnson, 1979a; Johnson, 1979b; Pfeiffer and Festa, 1980; Schofield, 1977; Schofield, 1982; Wright, 1977; Eilers et al., 1989). Screening procedures and target loading estimates have also been used to predict when effects may occur.

15.7 ENVIRONMENTAL RISK ALGORITHMS

No data are available to quantify the areal extent of risks on terrestrial ecosystems from acid deposition in Region VIII. There is no evidence of any current impacts on terrestrial ecosystems in the Region. This risk assessment will focus on aquatic ecosystems and will utilize the EPA lake survey and other results to document any extant effects and define ecosystem sensitivity and quantify the amount of aquatic resources at risk to acidic deposition. Qualitative risks are defined by evaluating the current extent of effects, regional sensitivity and estimates of the effects of projected emissions increases.

15.8 EVIDENCE OF CURRENT EFFECTS

15.8.1 Aquatic Effects

Each of the lines of evidence historically used to identify acidification of aquatic ecosystems, both direct and indirect, were evaluated for Region VIII.
There is little indirect evidence of lake acidification in the Region. There is no evidence that fish populations or aquatic plant communities have been impacted by acid deposition.

Some evidence suggests that lake sediment metal concentrations suggest these sources are not acid deposition related.

There is some controversy over the possible role of atmospheric deposition and the observed declines in amphibian populations in the Region. Hart and Hoffman (1989) suggest that episodic acidification of pond habitats has influenced the decline in tiger salamander populations in the Rocky Mountains of Colorado. The data published, however, do not support their suggestion, if a rigorous definition of episodic acidification is applied (Vertucci, In press). Furthermore, the wide-spread amphibian decline documented by Corn, et al. (1989) can not be explained by acid deposition effects.

Extensive surveys of lake water chemistry data have not provided evidence of significant chronic acidification effects in Region VIII. Landers, et al. (1987) use data from the EPA western lake survey and the empirical geochemical models developed by Henriksen, (1979) and Almer et al. (1978) to suggest there is no current effect of acid deposition in the Region. Turk and Campbell (1987) and Turk and Spar (In Press) have estimated an upper bound to the amount of lake acidification in the Region due to current deposition effects at 5 to 27 μeq/l. The use of these geochemical models to estimate acidification has numerous limitations and none have been verified with actual measures of acidification (Vertucci, In press). Modern survey data from the Region did not find any acidified lakes, defined as pH <5.5, or alkalinity < 0.0 μeq/l (Landers, et al., 1987).

There have been no clear direct measures of chronic lake acidification in the Region; either the data are lacking or effects are non existent. There are no long-term data on lake chemistry in Region VIII to evaluate subtle changes in alkalinity or pH associated with changes in deposition chemistry from pristine conditions. Historic and more recent lake survey data were compared by Lewis (1982) for lakes in the Front Range of Colorado and by Vertucci (In press) for lakes in the Wind River Range of Wyoming.

Lewis (1982) reported a loss of 97 μeq/l of alkalinity however, this study has been re-evaluated by Turk et al., 1988. The authors report that results presented by Lewis (1982) can be explained not by acid deposition, but by methods differences and changes in climate between sampling periods. Vertucci (In Press) found no evidence of chronic acidification for the Wyoming lakes sampled in the 1930s and in 1988 when comparable methods were used.

Screening procedures employed by the U.S.D.A. Forest Service and literature estimates of "critical" loads imply that current levels of deposition are below thresholds of expected effects. Acid deposition screening procedures developed by the Forest Service suggest that at current deposition levels lakes in the Region are not being impacted by chronic acidification (Fox, et al., 1989). Estimates of critical loads of sulfate to surface waters in

Norway, which are known to produce impacts on sensitive aquatic ecosystems, are not exceeded by current deposition or concentration levels in the Rocky Mountain Region, therefore effects are not expected (see Henriksen and Brakke, 1988).

The most likely initial effects of acidic deposition in the Region will be expressed as episodic acidification of sensitive high elevation lakes. Episodic acidification can be directly measured using high-frequency sampling and through characterization and interpretation of water chemistry. One detailed study in the Region has documented a slight episodic acidification at snowmelt of about 20 μeq/l for a lake in Wyoming (Vertucci, In press). Lake outlet pH dropped to pH 6.0 along with the 20 μeq/l alkalinity decline associated with an acid anion pulse from the melting snow-pack. Due to their remote locations and high altitudes, logistical difficulties prohibit monitoring efforts at the most at risk sites during the period of early snowmelt when acid episodes are likely. Subsequently, the extent of episodic acidification at current deposition levels is unknown.

15.9 EXTENT OF ECOSYSTEMS AT RISK

15.9.1 Aquatic Ecosystems

The most sensitive ecosystems to acid deposition in Region VIII are the poorly buffered alpine lakes and streams in the Rocky Mountains. The EPA Western Lake Survey (WLS) found that western mountain aquatic ecosystems are among the most sensitive to the effects of acidic deposition of any lakes in the world (Landers, et al., 1987). Class I wilderness lakes were especially at risk (Eilers et al., 1989).

The magnitude of the risk of acid deposition to lakes in the Region, exclusive of the Dakotas, can be partially quantified by using the results of the probability based Western lake survey. (The Western Lake Survey did not sample in either North or South Dakota. Surface water alkalinities in these States are much higher than sensitive levels. For example, the South Dakota Department of Water and Natural Resources have no alkalinity data lower than @ 1000 μeq/l (Bill Stewart, Pers. Comm.).) The number of lakes with ANC values < 50 μeq/l (considered very sensitive) and the number of lakes with ANC values < 200 ueq/l (sensitive) are reported in Table 15-1 for each State in the Region covered by the EPA survey. The numbers reported are those associated with the upper 95% confidence limit of the estimate.

The surface water survey estimates that 539 lakes in the region are very sensitive (ANC, <50 μeq/l) and 3628 lakes are sensitive (ANC <200 μeq/l). (The area of lake surface at risk may be estimated by multiplying the number of lakes by the median lake size (Table 15-1). Very sensitive lakes in the region cover 2,548 ha while sensitive lakes cover 17,359 ha. Landers, et al. (1987) reported that for the Northern (Montana, Washington, Oregon), Central (Montana, Wyoming, Idaho, Utah), and Southern (Colorado, Wyoming, New

Table 15-1
Lake Surface Area at Risk

State	Lake Median Size HA	# Lakes ANC < 50 95% ucl	# Lakes ANC < 200 95% ucl	Lake Area HA ANC < 50 95% ucl	Lake Area HA ANC < 200 95% ucl
Montana	4.6	240	1035	1104	4761
Colorado	3.5	90	739	315	2587
Utah	5.4	51	620	275	3348
Wyoming	5.4	158	1234	853	6664
South Dakota					
North Dakota					
Region VIII		539	3628	2547	17360
Northern MT, WA, OR				1792	8351
Central MT, WY, ID, UT				2584	24327
Southern CO, WY, NM				509	3232
TOTAL				4885	35910

(Landers et al., 1987)

Mexico) Rocky Mountains lakes with ANC values <50 μeq/l cover 4885 ha and lakes with ANC values < 200 μeq/l cover 35910 ha.

The miles of streams at risk from acid deposition are unknown for the Region. Presumably, sensitive lakes are fed by sensitive streams and flow into sensitive outlet streams.

15.10 VISIBILITY EFFECTS

Data on visibility impacts for the Region are available from a National Park Service visibility monitoring network and airport visibility data. Isopleths of median visual range (MVR) and the location of Park Service monitoring stations are reported in Figure 15-9. Visibility in the Region ranges from over 200 km MVR in Utah to less than 130 km MVR in eastern Colorado and the Dakotas. An estimate of median visual range using airport visual range data are presented in Figure 15-10 as presented by Trijonis (In press). The patterns in the visibility isopleths from these two data sources show some agreement. Historic "base line" visual range in the West is estimated to be 230 $\pm$ 35 km while in the Eastern U.S. the estimate is 150 $\pm$ 45 km (Trijonis, In press).

The deterioration in visibility has been analyzed in extinction budgets. For the rural West 20% of the total extinction is due to sulfates and 7% is attributed to NO_x (nitrates plus NO_2) while the values for the urban west are 13% and 20% respectively (Trijonis, In press). The isopleths of visibility are inversely related to the concentrations of fine ammonium, sulfate, nitrate and other particles monitored by IMPROVE (Cahill et al., 1990).

15.11 HEALTH EFFECTS

Current levels of acid deposition in the Region are unlikely to be associated with human health effects.

15.12 WELFARE EFFECTS

Since there are limited environmental effects of acid deposition at this time there are no economic impacts. Should deposition levels rise effects could lead to losses in fisheries, agriculture, forestry, and damage to materials.

Figure 15-9
Isopleths of Median Visual Range over the Western United States, Summer 1983

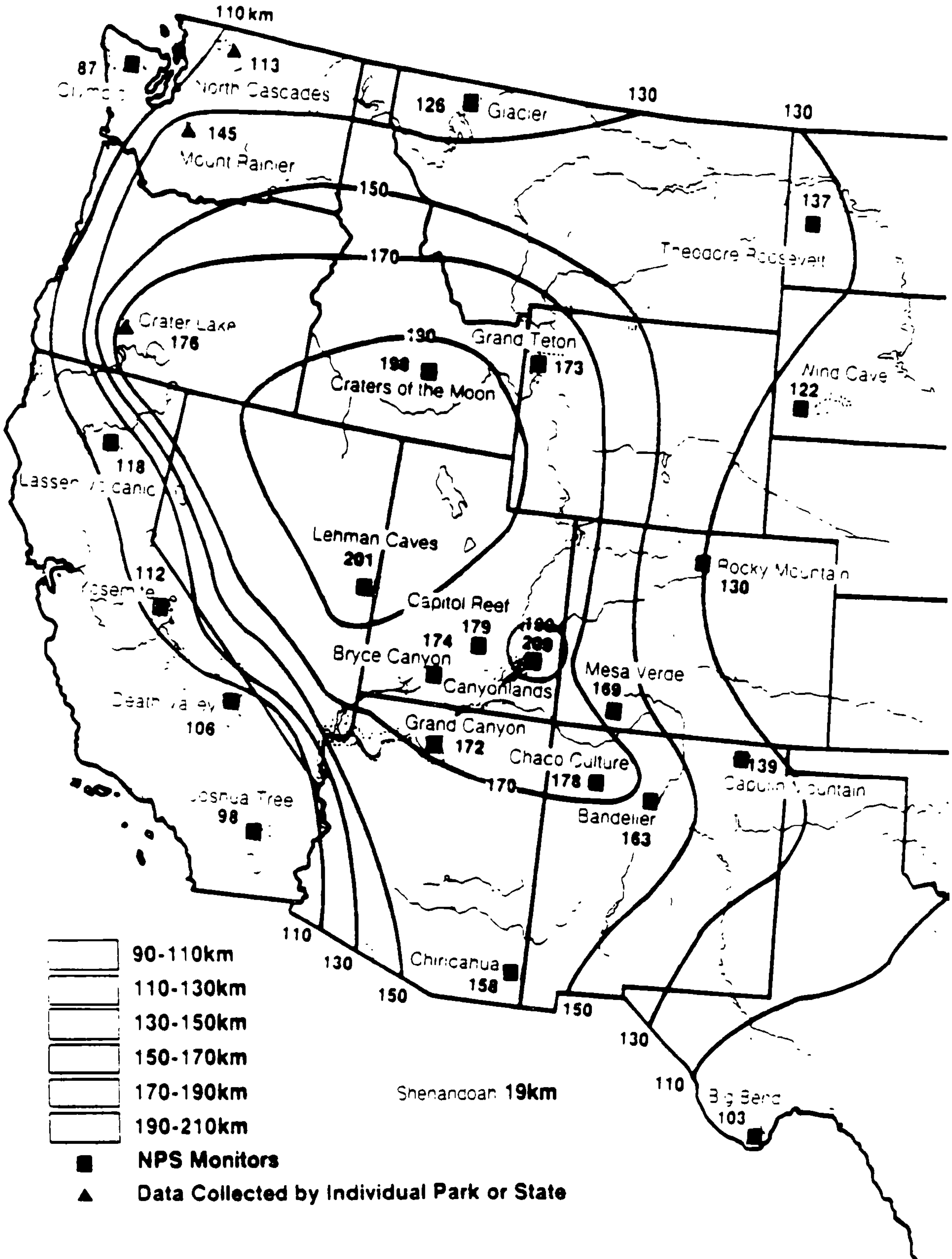
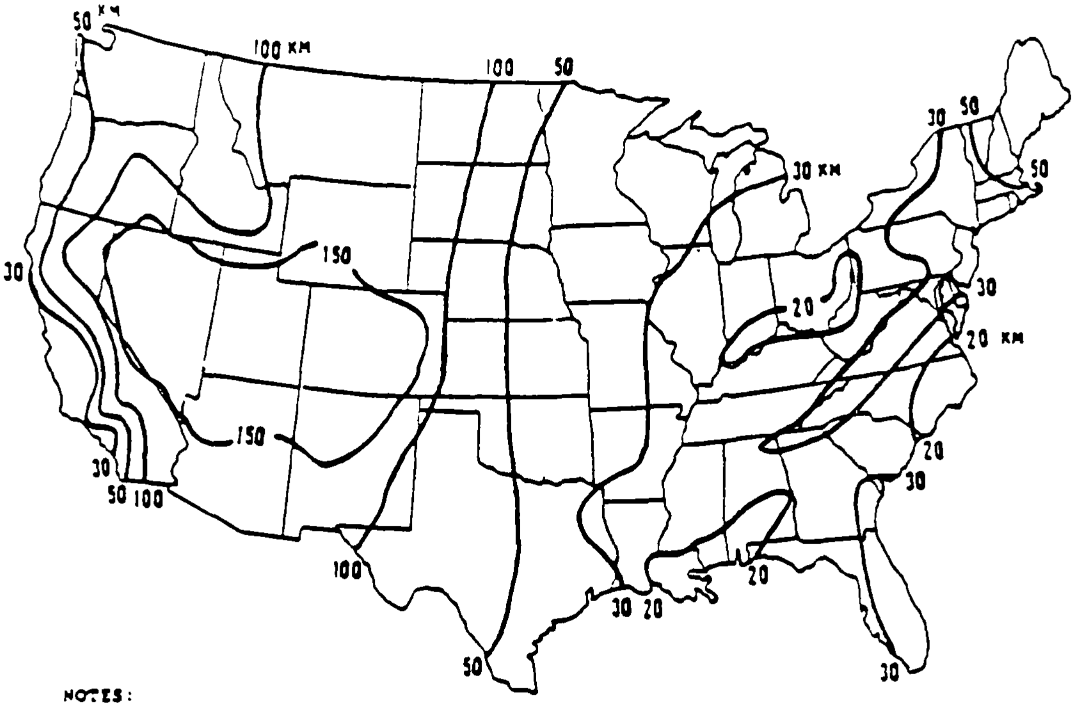


Figure 15.10
Estimated Median Visual Range (km) for Rural
Areas of the United States



NOTES:

- Standard visual range estimated by factoring median airport visual range by 1.3 to account for differences in detection thresholds.
- Data are for 1974-1976, but recent studies indicate that current conditions are approximately the same as shown here.

(Trijonis et al., in review)

15.12.1 Welfare Damages due to Visibility Impairment

Visibility Welfare Damages

The effects of increases in SO_2 and NO_x on visibility have been widely documented. SO_2 emissions indirectly reduce visibility through the formation of sulfate particles that scatter light and make distant objects harder to see. NO_x emissions produce gaseous NO_2, which combines with ammonia in the atmosphere to form ammonium nitrate particles, which also reduce visibility.

The physical effects of historical increases in SO_2 and NO_x emissions on visibility have been large. Under natural background conditions, average visual range has been estimated to be as great as 150 km in the eastern United States. By contrast, rural areas south of the Great Lakes and east of the Mississippi River are known to have standard visual ranges that average approximately 30 km. This suggests an 80 percent reduction in visibility from natural conditions.

Estimating the magnitude of visual range loss in Region VIII, however, is very difficult, as this loss is influenced by local meteorological conditions, seasonal factors, and variability associated with the long range transportation of acid aerosols into the Region.

For the purposes of this analysis, we have assumed that current Region VIII visual range can be described by visibility isopleths shown in Figure 15-10. We also assumed that natural background visibility in Region VIII is approximately 230 km, see section 15.10. This estimate is based on the current NAPAP Draft Integrated Assessment for background visibility ranged in the "arid west." While this background estimate is probably quite accurate for Wyoming, Utah, Colorado, and the majority of Montana, it probably overestimates the background visual range in the Dakotas. Consequently, even the lower bound estimate of visibility damages should be viewed as conservative. Because of uncertainties associated with these estimates and the "true" value of current visual range across the Region, these estimates should be viewed as quite speculative.

Conceptually, there are two types of welfare damage associated with visibility decrements, these are:

- Non-market damages to residents of, or visitors to, areas in Region VIII with degraded visibility, and

- Non-market damages to non-users who value good visibility in Region VIII, even though they do not currently, or plan to, reside in or visit Region VIII.

A number of studies recently documented by Rowe and Chestnut for the National Acid Precipitation Assessment Program's State of the Science Report reveal that both users and non-users value changes in visibility in the sense that they are willing to pay to prevent visibility decrements. In some cases, these willingness to pay bids are quite large. In studies of urban areas in the eastern United States, Rowe and Chestnut suggest that resident households may be willing to pay an average of $100 to $300 to avoid relatively small decrements in visual range.

These values have been obtained through the use of the contingent-valuation method. In this evaluation approach, members of a sample population are interviewed and asked how much money they would be willing to hypothetically pay to prevent degraded visibility. Answers to this question have been used to develop the "consensus damage function" that we used to estimate welfare damages associated with visibility degradation in Region VIII.

Welfare damages associated with visibility loss were estimated by two equations:

$$TWTP_l = \$50/hh * \ln(230/(x) * hh$$

$$TWTP_u = \$200/hh * \ln(230/(x) * hh$$

where:

$TWTP_l$ = the lower bound estimate of the total willingness to pay for visibility damages

$TWTP_u$ = the upper bound estimate of the total willingness to pay for visibility damages

$50/hh = lower bound estimate of individual household's willingness to pay to avoid visibility damages

$200/hh = upper bound estimate of individual household's willingness to pay to avoid visibility damages

ln = natural log

(150/(x)) = the assumed background visual range divided by the estimated current visual range bounded by a lower bound estimate of 16 and an upper bound of 50. The assumed mean of the distribution is 34.

hh = households, estimated by: (Region VIII population/2.76).

To estimate the number of households affected by visibility decrements described in Figure 15-10, we made crude assumptions regarding the Regional population distribution within each of the current visibility isopleths estimated by NAPAP. These population distribution assumptions are summarized in Table 15-2.

Table 15-2
Estimated Visibility Welfare Damages
in Region VIII

State	Current Visual Range (km)	Baseline Visual Range (km)	Population	Number of Households	Lower Bound Welfare Damage	Upper Bound Welfare Damage
North Dakota	50	230	333,500	124,906	$9,530,707	$38,122,830
	100	230	333,500	124,906	$5,201,783	$20,807,131
South Dakota	30	230	237,429	88,925	$9,056,458	$36,225,831
	50	230	237,429	88,925	$6,785,206	$27,140,826
	100	230	237,429	88,925	$3,703,310	$14,813,242
Colorado	100	230	660,200	247,266	$10,297,502	$41,190,008
	150	230	2,640,800	989,064	$21,138,467	$84,553,869
Utah	150	230	1,690,000	632,959	$13,527,723	$54,110,890
Wyoming	100	230	359,250	134,551	$5,603,420	$22,413,678
	150	230	119,750	44,850	$958,547	$3,834,189
Montana	100	230	805,000	301,498	$12,556,027	$50,224,108
TOTAL Region VIII			7,654,287	2,866,774	$98,359,150	$393,436,601

Results of the analysis are reported in Table 15-2 and are briefly summarized below. Annual damages range from a minimum of approximately $98 million to a maximum of approximately $393 million.

There are two significant uncertainties that should be taken into account when analyzing these results. First, the validity of contingent valuation to derive non-market values is currently a question of considerable debate. There are numerous methodological and theoretical problems that need to be resolved before one can be confident regarding damages estimated using this technique. Secondly, the complex nature of the physical processes associated with reductions in visibility make it difficult to allocate visibility decrements to anthropogenic factors. In addition, we were unable to obtain precise estimates of visibility changes in Region VIII.

15.13 ASSUMPTIONS

A number of assumptions were made in this analysis due to the absence of sufficient data. Assumptions were made as to the airshed of Region VIII and the amount of dry versus wet deposition. In order to evaluate risks associated with changes in emissions it was assumed that increases in emissions cause increases in deposition and effects in a linear manner.

15.14 UNCERTAINTY

In areas experiencing significant acidic deposition, effects have been well documented for aquatic ecosystems and are less clearly understood for terrestrial ecosystems. However, projections of future emissions, estimates of total deposition and models predicting impacts are highly uncertain. The amount of wet deposition to sensitive mountain ecosystems and the amount of dry deposition are not well known for the region.

While many of the effects of acidic deposition have been well researched some areas are less well known. For example, the effects of acidic deposition as an influence on other stressors, ie. insect damage to trees, is not well understood. The effects of low-dose, long-term nitrogen fertilization of terrestrial ecosystems has not been investigated and may cause significant changes in N-limited biota. The extent of episodic acidification, and the factors controlling the intensity of acidic episodes is not well known.

While the Western Lake Survey estimated the sensitivity of lakes in the Region, the miles of streams at risk to acidic deposition is unknown.

15.15 OMISSIONS

The direct effects of acidic deposition associated with gaseous pollutants is not considered in this assessment.

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16.0 HAZARDOUS/TOXIC AIR POLLUTANTS

16.1 INTRODUCTION

This problem area covers risks to human health and welfare due to outdoor exposure to airborne hazardous air pollutants from routine or continuous from point and nonpoint source emissions. Pollutants include asbestos, various toxic metals (e.g., chromium, beryllium), organic gases (benzene, chlorinated solvents), polycyclic aromatic hydrocarbons (PAHs, such as benzo(a)pyrene,primarily in particulate form), gasoline vapors, incomplete combustion products, airborne pathogens, cooling towers, and a variety of other volatile organic chemicals and toxics. This problem area also covers exposure through both inhalation and air deposition of these pollutants to land areas.

Major sources of these pollutants include large industrial facilities, motor vehicles, chemical plants, commercial solvent users, and combustion sources. This category excludes, to the extent possible, risks from pesticides, airborne lead, radioactive substances, chloroflourocarbons, emissions from waste treatment, storage and disposal facilities, storage tanks, and indoor air toxicants.

As will be discussed below, this assumption is considered to be reasonable.

$$\text{Region VIII Effects} = \text{National Data} \quad \frac{\text{Population of Region VIII}}{\text{Population of Nation}}$$

16.2 HUMAN HEALTH RISK

16.2.1 Toxicity Assessment

The carcinogens selected for evaluation include acrylonitrile, arsenic, asbestos, benzene, 1,3-butadiene, cadmium, carbon tetrachloride, chloroform, chromium (hexavalent), coke oven emissions, dioxin, ethylene dibromide, ethylene dichloride, ethylene oxide, formaldehyde, gasoline vapors, hexachlorobutadiene, hydrazine, methylene chloride, perchloroethylene, products of incomplete combustion, trichloroethylene, vinyl chloride and, vinylidene chloride.

The cancer rates presented Ln the studies used in the national report were updated, as necessary, based on unit risk factors used by EPA. Although the pollutants studied varied from proven human carcinogen to probable human carcinogen to possible human carcinogen, all were treated in the analyses as carcinogens.

Pollutants selected for evaluation of non-cancer effects include acetaldehyde, acrolein, arsenic, benzene, beryllium, carbon disulfide, carbon tetrachloride, chloroform, ethylene oxide, formaldehyde, hydrogen sulfide, methyl ethyl ketone, methyl methacrylate, methyl isocyanate, nitrobenzene, perchloroethylene, phenol, phthalic anhydride, styrene, tetramethyl lead, toluene diisocyanate, and vinyl chloride.

Exposure to airborne pollutants can result in non-cancer health effects ranging from subtle biochemical, physiological, or pathological effects to death. Various organ systems may be affected including the pulmonary, nervous, gastrointestinal, cardiovascular, and hematopoietic systems. In addition, hepatic, renal, reproductive, and developmental toxicity have been observed.

In the national study, cancer risk estimates were derived giving equal consideration to measured and modeled data, provided that one estimate was not clearly preferable. Cancer rates for a pollutant and source category were extrapolated to nationwide estimates based on the geographic scope of each study examined. Direct extrapolation to total nationwide estimates was possible for most pollutants due to their inclusion in at least one study of nationwide scope. In instances where a pollutant was included only in a study of limited geographical scope, the concentration of the pollutant/source category in the area studied relative to the national concentration was considered. This information was then utilized to extrapolate nationwide estimates.

The national population used is 243,400,000. The population used in Region VIII is 7,655,000 or, approximately 3% of the national population.

16.2.3 Human Health Risk Characterization

Cancer Risk

In the studies used in "Cancer Risk from Outdoor Exposure to Air Toxics", aggregate maximum lifetime individual risks exceeding 10^{-4} were reported in almost every case. Risks of 10^{-3} or greater from individual pollutants were reported adjacent to various types of sources. Average lifetime individual risks in urban areas from exposure to many pollutants were generally between 10^{-4} and 10^{-5} but ranged 10^{-3} to 10^{-6}. These levels were the result of combined exposure to mobile and stationary sources.

In the national study, estimates of annual cancer incidence were derived by estimating the annual cancer cases per million population for each pollutant source category combination reported in the data sources. These estimates were then modified as necessary to reflect updated unit risk and emission factors. Total nationwide annual incidence were then estimated by summing across all pollutant/source categories.

The procedure outlined above results in an estimate of 1,577 to 2,540 cancer cases per year, nationally, caused by exposure to the pollutants listed previously. With Region VIII comprising approximately 19 percent of the Nation's population, apportioning national data to the region by population results in a projection of 47 to 76 cancer cases per year in Region VIII. (It is noted that these national numbers are different than those presented in the national report since the risks due to waste treatment storage and disposal facilities, radionuclides, and radon have been subtracted. This is consistent with the problem area definition and description).

Note that cancer unit risk values used in this study are based on assumptions and are therefore somewhat uncertain. Further, the fraction of the total risk attributable to pollutants and source categories not covered in the study is unknown. Nevertheless, the study is valuable as a reasonable indication of the magnitude of potential cancer risk caused by this specific group of pollutants and is therefore, in general, considered to be moderately to highly certain.

Non-Cancer Risk

Non-cancer risks from exposure to toxic pollutants routinely emitted to the air by industrial or commercial sources are being evaluated by the Office of Air Quality Planning and Standards in a Broad Screening and Urban County Study. Based on analysis of the preliminary data available from the study, it is reasonable to conclude that environmental acute and chronic exposures to toxic air pollutants have the potential to adversely impact public health, although the exact magnitude of the increased risks is unclear.

Preliminary results of the Broad Screening portion of the study indicate that:

- approximately 48 percent of the chemicals studied exceeded the health reference levels for chronic exposures;
- long-term (annual) exposures were estimated above the Lowest Observed Effect Level (LOEL) for 3-5 percent of the chemicals studied;
- 58 percent of exposures exceeded health reference levels for short term (24-hour) exposures; and,
- in hundreds of U.S. cities, exposure to multiple pollutants was of concern, with concentrations in 260 cities exceeding the hazard index.

Preliminary results of the Urban County portion of the study indicate that:

- using long-term modeling of both average and maximum emissions, a substantial number of facilities were estimated to cause exceedances of health levels, with 31 percent of the 131 facilities exceeding chronic health effect levels for 9 chemicals;

- using short-term modeling, more pollutants and facilities were associated with exceedances of LOELs with and without uncertainty factors applied, with 75 percent of the 131 facilities exceeding acute health effect levels for 42 chemicals; and,

- for chemicals of concern, substantial numbers of facilities were associated with exceedances of the health reference level, and a small percentage of facilities emitted pollutants in quantities exceeding the LOELs.

There is considerable uncertainty associated with characterizing non-cancer health risks at exposures greater than the reference dose and less than the LOEL. Nevertheless, using the Broad Screening portion of the study, it is estimated that 50 million people and 38 million people nationally are exposed to levels of pollutants greater than health reference levels for acute effects and chronic effects respectively. Providing that regional characteristics are similar to national characteristics, an estimate of Region VIII values can be determined using population.

16.3 ECOLOGICAL RISK ASSESSMENT

Due to the absence of exposure-response relationships linking ambient concentrations of hazardous/toxic air pollutants and the response of ecosystem components, no evaluation of ecological risks was developed. The U.S. EPA Environmental Laboratory at Corvallis, Oregon currently has a limited program in place evaluating the effects of a small set of air toxics on a limited number of test species.

16.4 WELFARE RISK ASSESSMENT

Welfare risks associated with hazardous/toxic air pollution have been estimated in association with the annual cancer cases estimated in Section 16.2.

To estimate these costs, estimated annual cancer cases were multiplied by the direct medical cost and foregone earnings per cancer case:

(Annual Cancer Cases)(Direct Costs and Forgone Earnings) = HC where:

HC = health costs

Estimated direct and indirect medical cancer costs are based on a range of cost per case estimates. The lower bound estimate, based on Hartunian, et al., is $80,000, while the upper bound estimate developed by the American Cancer Society is $137,000. These estimates provide differing values for foregone earnings and medical costs. Both estimates are weighted average costs associated with all types of cancers.

Lower bound estimate

HC = (47)($80,000) = $3,760,000 (1988 $)

Upper bound estimate

HC = (76)($137,000) = $10,412,000 (1988 $).

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EPA Comparative Risk Study
Indoor Air Quality Health Risk Assessment
Region 8

EXECUTIVE SUMMARY

This analysis identifies and, for several compounds, estimates the risks posed to human health attributable to indoor air pollutants. The estimates indicate only the general range of risk to the public in sufficient detail for comparing against other environmental problems. Although these estimates are based on generally accepted toxicity, exposure, and risk characterization methodologies, the results are not appropriate for other purposes.

In addition to many health effects not quantified here, estimates of the likely range of individual lifetime risks and population risks from cancer due to indoor air pollutants in Region 8 are as follows:

Individual Lifetime Risk of Cancer = 4×10^{-3} to 2×10^{-2}
(4 in 1,000 to 2 in 100)
Population Risk of Cancer = 50 to 600 excess cases per year

These risks are caused primarily from environmental tobacco smoke (ETS), asbestos, and several volatile organic compounds (VOCs): formaldehyde, benzene, carbon tetrachloride, chloroform, and tetrachloroethylene. Among the noncancer effects, the most important appear to be a miscellany of respiratory problems known collectively as sick building syndrome (SBS) and a heightened sensitivity to chemicals known as multiple chemical sensitivity (MCS). Few data exist for these conditions, but MCS creates severe physical reactions and limitations and some believe that SBS is widespread (affecting approximately 20 percent of office buildings).

DESCRIPTION OF PROBLEM

People spend up to 90 percent of their time indoors.[1] With technological changes in the chemical, manufacturing, and construction industries, thousands of potentially dangerous pollutants have been introduced into the indoor environment. Energy conservation standards and practices have produced a large portion of our current building stock that are more effectively sealed but that may not provide adequate air to dilute or purge these indoor pollutants.[2] A result of these and other possible causes (such as smoking), concentrations for several pollutants have been found to be twice to five times more concentrated in indoor air than outdoor air.[3] The health effects of exposure to indoor pollutants have been reported to vary from mild irritation to cancer and subsequent death.

The base of available information is growing, but the multi-disciplinary and multiple chemical nature of indoor air quality (IAQ) issues makes comprehensive research difficult. There are no ecological effects that can associated with indoor air pollutants and, therefore, no ecological risk assessment for this problem area was conducted. This analysis first discusses cancerous effects, followed by discussions of noncancerous effects.

CANCER EFFECTS

Contaminants in indoor air can cause cancer (Table 1). Because the methods used to estimate effects differ, this section is organized by contaminant (VOCs and PAHs, pesticides, ETS, and asbestos). The discussion of each group of contaminants includes a summary of the toxicity of the compounds, common exposures, and a characterization of individual risks and population risks.

Table 1. Health Effects and Sources of Indoor Air Pollutants

Pollutant	Substantiated Sources	Associated Health Effects					Reference
		Cancer	Neuro	Respir	Liv/Kid	Devel	
VOCs							
Benzene	Auto Exhaust, ETS, Fuels Fumes Adhesives, Paint Remover Building Materials, Photo Processing Chemicals	A	X	X	X	X	A & S 1986
Formaldehyde	Building Materials Combustion Appliances/Heaters/Engines Adhesives Carpeting, ETS, Home & Office Furnishings Auto Exhaust	B1	X	X		X	USEPA 1987
Chloroform	Water Clothes Washer, Adhesives foam Insulation Inks	B2	X		X		A & S 1986
Carbon Tetrachloride	Grease Cleaners, Adhesives Foam Insulation Inks	B2	X		X		USEPA 1984
1 2-Dichloro-ethane	Adhesive Foam Insulation Tape	B2			X		Cornish 1980
Trichloro-ethylene	Adhesives Foam Insulation Inks Photo Processing Chemicals Tape Coatings Lubricants, Rubber	B2	X		X		Cornish 1980
Tetrachloro-ethylene	Dry Cleaning Adhesives, Foam Insulation Inks	B2	X				Cornish 1980
Benzo(a)Pyrene	ETS Building Materials HVAC Systems Combustion Appliances/Heaters/Engines Cleaners and Waxes, Pesticides Adhesives Paints and Supplies	B2	X		X		EPA 1989
Pesticides							
Aldrin	Insecticide, withdrawn from U S	B2			X		EPA 1988 1990
Alpha-BHC	Insecticide, banned in U S	B2			X		EPA 1988 1990
Chlordane	Insecticide, withdrawn in 1988	B2			X		EPA 1988 1990
Dieldrin	Insecticide, withdrawn from U S	B2			X		EPA 1988 1990
Heptachlor	Insecticide	B2			X		EPA 1988 1990
Proxpur	Insecticide, common indoor use				X		EPA 1988 1990
4 4' DDE	Insecticide	B2			X		EPA 1988 1990
Asbestos							
Chysotile	~95% of all asbestos found in buildings	A		X			EPA 1985
Amosite	Second most common found in buildings	A		X			EPA 1985
Crocidolite	Used only for high temperature applications	A		X			EPA 1985
ETS	Tobacco Smoking		X	X			EPA 1989 S & S 1983
Biological Contaminants	Viruses, bacterium, molds insect and arachnid excreta pollen animal and human dander			X			EPA 1989
Carbon Monoxide	Combustion Gases ETS Auto Exhaust		X	X			Ammann undated
Sulfur Dioxide	Combustion of fuels containing sulfur			X			EPA 1987 Ammann undated
Nitrogen Dioxide	Combustion Appliances, ETS			X			Admur 1986 Ammann undated

Key. Car EPA weight-of-evidence carcinogenicity rating
A= Known human carcinogen
B1= Probable human carcinogen (limited human data)
B2= Probable human carcinogen (no human data)
C= Possible human carcinogen
X= Reported health effect

Neuro= Neurological impairment
Resipir= Respiratory impairment including asthma
Liv/Kid= Liver and/or Kidney dysfunction
Devel= Developmental problems including reproductive and congenital

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VOCs

Toxicity Assessment

The characteristics of VOCs in the indoor environment are poorly understood. Hundreds of VOCs are commonly detected in the indoor environment and several are classified as Group A or B human carcinogens.[4] The compounds considered here were selected because they were frequently reported, usually occur in substantially higher concentrations indoors than outdoors, and they had readily available, pertinent data. Only one polycyclic aromatic hydrocarbon (PAH), Benzo(a)Pyrene, was selected because of the relative insignificance of PAHs as a group to the analysis and because of insufficient data on other PAHs. The group of VOCs commonly referered to as phthalate esters were also not included because of the lack of sufficient exposure data and the apparent insignificant contribution of the group to the risk analysis. The compounds selected for analysis and their corresponding cancer potency factors are listed below in order from highest to lowest toxicity.

Compound	Cancer Potency Factor	Compound	Cancer Potency Factor
Benzo(a)Pyrene[5]	11.5	Tetrachloroethylene[5]	0.051
Carbon tetrachloride[5]	0.13	Formaldehyde[6]	0.038′
1,2-Dichloroethane[5]	0.091	Benzene[5]	0.029
Chloroform[5]	0.081	Trichloroethylene[5]	0.011

Exposure Assessment

The range of concentrations used in the analysis are listed below. This analysis identifies likely exposure levels rather than worst-case or extreme exposures. The range of concentrations used, therefore, generally reflect the differences between median and mean values reported in published studies rather than the full range of maximum and minimum values.[8] They are listed from highest to lowest concentrations.

	Concentration Range (ug/m^3)	
Compound	Low	High
Formaldehyde	8	424
Benzene	2	204
Carbon tetrachloride	0	45
Chloroform	0.1	44
Tetrachloroethylene	5	18
Trichloroethylene	1	13
1,2-Dichloroethane	1	12
Benzo(a)Pyrene	0.001	0.003

In determining individual exposure, this analysis assumes an inhalation rate of 23 m^3/day and an average person's weight as 70 kg[9].

Risk Characterization

This analysis uses some common exposure information and generally applies those exposures on a 24-hour basis to all residents in the region. Assuming exposures are for 24 hours is reasonable considering that 80 to 90 percent of an individual's time is spent in an indoor environment. This analysis does not attempt to rigorously account for differences in exposures by location (homes, offices, and schools, for example) or to distinct groups (sensitive populations, for example), or to account for the hundreds of chemicals found in indoor air. Individual risks and annual population risks are calculated using the following equations.

Individual Lifetime Risk = **concentration** (ug/m^3) x **inhalation rate** ($23m^3$/day) ÷ 1000 (ug/mg) ÷ 70 (kg/person) x **cancer potency** $(mg/kg\text{-}day)^{-1}$

Population Risk = **individual lifetime risk** x **2.675 million** (Region 8's population) ÷ **70 years** (average life expectancy)

The results are shown below:

VOCs and PAHs

Compound	Individual Risk (lifetime risk) Low	Individual Risk (lifetime risk) High	Population Risk (annual excess cancer cases) Low	Population Risk (annual excess cancer cases) High
Formaldehyde	1×10^{-4}	5×10^{-3}	4	202
Benzene	2×10^{-5}	2×10^{-3}	1	74
Carbon tetrachloride	0	2×10^{-3}	0	73
Chloroform	3×10^{-6}	1×10^{-3}	0.1	45
1,2-Dichloroethane	3×10^{-5}	4×10^{-4}	1	14
Tetrachloroethylene	8×10^{-5}	3×10^{-4}	3	12
Trichloroethylene	4×10^{-6}	5×10^{-5}	0.1	2
Benzo(a)Pyrene	4×10^{-6}	1×10^{-5}	0.1	0.4

PESTICIDES

The data and methodology used for estimating lifetime individual risk for pesticides in indoor air is adopted from the Nonoccupational Pesticide Exposure Study (NOPES) published by the U.S. EPA in January 1990. Pesticides are commonly detected in indoor air. We include several pesticides that have been withdrawn, suspended, or banned because they are expected to remain in indoor air for decades.

Toxicity Assessment

Potency Factors are taken from the Integrated Risk Information System (IRIS).

Pesticide	Cancer Potency Factor	Pesticide	Cancer Potency Factor
Aldrin	17.0	Chlordane	1.3
Dieldrin	16.0	4 4' DDE	0.34
alpha-BHC	6.3	Proxpur (Baygon)	0.0079
Heptachlor	4.5		

Exposure Assessment

The range of concentrations to be used in the analysis are listed below and are from studies of Jacksonville, FL and Springfield, MA.[10]

Pesticide	Concentration Range (ug/m^3)		
Chlordane	197.1	to	198.7
Proxpur (Baygon)	15.0	to	185.2
Heptachlor	27.2	to	115.2
Aldrin	0.1	to	26.0
Dieldrin	0.8	to	6.4
4 4' DDE	0.6	to	3.8
alpha-BHC	0.2	to	0.8

An additional calculation allowed for a 2-year half-life of the cyclodiene termiticides (Heptachlor, Aldrin, Dieldrin, and Chlordane) that have been banned, withdrawn, or suspended. Although it is not known at what rate these pesticides degrade, this assumption helps identify the potential low end of the range for these compounds. The NOPES study assumed an inhalation rate of $21m^3$/day.

Risk Characterization

The range of estimates for lifetime individual risks as reported in the NOPES study follow, along with estimates of the number of annual excess cancer cases to the population of Region 8.

	Individual Risk (lifetime risk)		Population Risk (annual excess cancer cases)	
Pesticide	Low	High	Low	High
Heptachlor	1×10^{-6}	2×10^{-4}	0.04	8
Aldrin	2×10^{-8}	1×10^{-4}	0.001	4
Chlordane	3×10^{-6}	7×10^{-5}	0.1	3
Dieldrin	1×10^{-7}	3×10^{-5}	0.004	1
alpha-BHC	4×10^{-7}	2×10^{-6}	0.02	0.1
4 4' DDE	6×10^{-8}	4×10^{-7}	0.002	0.02
Proxpur (Baygon)	3×10^{-8}	4×10^{-7}	0.001	0.02

ENVIRONMENTAL TOBACCO SMOKE (ETS)

This analysis uses direct estimates of individual lifetime risk and population risk. The toxicity and exposure assessment sections, below, provide additional information but are not used in calculating risks.

Toxicity Assessment

Environmental Tobacco Smoke (ETS) causes a variety of health effects including lung cancer, cardiovascular effects, increased susceptibility to infectious diseases in children, chronic and acute pulmonary effects in children, mucous membrane irritation, and allergic reactions.[11] The cancer risk associated with ETS for nonsmokers has been estimated at **5×10^{-5} cancer deaths** per person per mg of tobacco exposure per day.[12,13,14] (Note that these are the estimated cancer **deaths**, compared to estimated cancer cases for the other compounds analyzed.)

Exposure Assessment

Due to the complex chemical composition of ETS, exposure studies generally focus on one component of ETS (tar) and report that nonsmokers are typically exposed to 1.4 mg of tar daily.[15]

Risk Characterization

One study's estimate of the lifetime risks of lung cancer death from ETS is between **4×10^{-3}** and **1×10^{-2}** for nonsmokers and only slightly higher for ex-smokers.[16] The same study estimates that the annual number of lung cancer deaths from ETS is between **2,500** and **5,200** nationally, depending on the methodology used. To estimate the number of deaths in Region 8, this analysis uses the midpoint of that range, **3,850** (a number also close to an estimate in a recent EPA review draft report), and Region 8's share of the national population (2.675 million÷275.7 million or 1.0%). The annual number of lung cancer deaths in Region 8 attributable to ETS is, therefore, 3,850 x 1.0% or **37**.

ASBESTOS

Asbestos is the collective name given to two groups of naturally occurring mineral fibers found in various rock formations. The two groups being amphibole (amosite, crocidolite, etc.) and serpentine (chrysotile). For decades prior to 1973, asbestos was the material of choice for a wide variety of thermal, acoustical, and abrasive applications because of its unique properties. Asbestos containing materials (ACM) are found in cement products, acoustical plaster, fireproofing textiles, wallboard, ceiling tiles, vinyl floor tiles, thermal system insulation, and numerous other materials.[17]

Toxicity Assessment

Asbestos is classified by the EPA Science Advisory Board (SAB) as a Group A known human carcinogen.[18] Asbestos-related diseases include: lung cancer, mesothelioma, and asbestosis.[19] In general, dose-response data have relied heavily on occupational exposure information from various asbestos-related industries. Extrapolation of the relationship between exposure and disease indicates that only a small proportion of people exposed to low levels of asbestos will develop asbestos-related diseases. Subpopulations at greatest risk (other than those occupationally exposed) are: smokers, children, and young adults.

EPA has reported the unit risks of lung cancer and mesothelioma from asbestos exposure. These two cancers are by far the most important causes of death among exposed individuals. (Note that these are the estimated cancer **deaths**, compared to estimated cancer cases for the other compounds analyzed.)

	Lifetime Unit Cancer Risk [20] (per 0.01 fibers/ml)	
Population	Mesothelioma	Lung Cancer
Female Smokers	2.52×10^{-3}	1.50×10^{-3}
Female Nonsmoker	2.72×10^{-3}	1.64×10^{-4}
Male Smokers	1.81×10^{-3}	2.38×10^{-3}
Male Nonsmokers	2.20×10^{-3}	1.85×10^{-4}

Exposure Assessment

EPA surveys estimate that, nationally, 31,000 (~35 percent) schools and 733,000 (~20 percent) office buildings contain ACM in varying states of disrepair.[21] The ACM in these buildings can be classified as friable (ACM with a high probability of fiber release when disturbed) or nonfriable. The average lifetime exposure to asbestos in indoor environments have typically been reported at 0.01 fibers/ml.[22] There are several studies of schools done in the late 1970s and early 1980s that showed vastly higher concentrations. These studies, however, were before the 1986 Asbestos Hazard Emergency Response Act (AHERA) was adopted into law. AHERA required Local Education Agencies (LEAs) to carry out initial response actions and have implemented an asbestos management plan in public and private schools by July 1989. We assume that most LEAs have complied with this regulation and have either removed all friable and nonfriable ACM or have it under a strict management plan that should prevent any future significant fiber release episodes. To date, Federal regulations have not required AHERA be applied to other buildings. For these reasons, these early school studies are omitted from our analysis. This study uses 0.01 fibers/ml as the upper range of exposure.

The lower limit for typical concentrations (0.0004 fibers/ml) is an arithmetic mean of several studies of public buildings. The estimate for average nonoccupational exposure concentration is, therefore, between 0.0004 and 0.01 fibers/ml.

Risk Characterization

The lifetime individual risks of death from mesothelioma and lung cancer for nonoccupational exposures to airborne asbestos fibers are shown below.

Asbestos Individual Lifetime Cancer Risk

	Low (0.0004 fibers/ml)		High (0.01 fibers/ml)	
Population	Mesothelioma	Lung Cancer	Mesothelioma	Lung Cancer
Female Smokers	1×10^{-4}	6×10^{-5}	3×10^{-3}	2×10^{-3}
Female Nonsmoker	1×10^{-4}	7×10^{-6}	3×10^{-3}	2×10^{-4}
Male Smokers	7×10^{-5}	1×10^{-4}	2×10^{-3}	2×10^{-3}
Male Nonsmokers	9×10^{-5}	7×10^{-6}	2×10^{-3}	2×10^{-4}

The estimate of individual lifetime risk, therefore, is between **7×10^{-6}** and **3×10^{-3}** and population risk is between **0.3** and **115** cases per year.

NONCANCER EFFECTS

Humans are known to respond to indoor air pollutants in a variety of ways (Table 1). The actual response of an individual depends on at least the following: the individual's tolerance limits, the type of pollutants in the air, the exposure or dose and the number of exposures, the target organ(s) potentially affected, the rate of absorption and excretion by the body, and the rate of metabolism. A precise understanding in the scientific community of these effects and their causes is lacking, partly because the pollutants appear in complex mixtures in indoor air.

Typically, the health of most people is not severely threatened by noncarcinogenic exposures to low levels of indoor contaminants. The efforts are usually limited to discomfort or mild illness but include the following (with the reported percent of people in problem buildings reporting these conditions):

- Eye irritation (23[23] to 81%[24])
- Dry throat (35[23] to 71%[24])
- Headache (31[23] to 86%[25])
- Fatigue (17[26] to 61%[25])
- Dizziness (19[25] to 46%[26])
- Sinus congestion (51%[24])
- Skin irritation (38%[22])
- Shortness of breath (9[23] to 33%[24])
- Nausea (15[24] to 51%[26])
- Nasal irritation (20[26] to 43%[25])

The prevalence of these associated symptoms led to acknowledgement of a "**Sick Building Syndrome**" (SBS). The World Health Organization estimates that 30 percent of all new buildings may have problems that can lead to occupant complaints and illness. Others have hypothesized that it is possible that 20 percent of office workers (about 108 thousand people in Region 8) work in "sick buildings." The term **Building-Related Illness** (BRI) refers to more severe responses to indoor air pollutants. Examples of BRI include Legionnaires' Disease (which occurs mainly in hospitals and usually affects patients with kidney disease) and Hypersensitivity Pnuemonitis, but there are few data on how many people may be suffering from BRI.

Another building-related diagnosis being increasingly accepted by clinicians is **Multiple Chemical Sensitivity** (MCS). MCS is a condition affecting a small subset of the population that has become sensitized to chemicals in the environment. Affected individuals appear to repeatedly suffer acute reactions upon exposure to pollutant levels commonly found in indoor environments. These exposures would not cause the majority of the population to experience discernible adverse effects.

Potential synergistic, antagonistic, and additive effects may play an important role in causing the acute symptoms associated with SBS and MCS. **Synergism** is known to exist among the following:

- PAHs and irritant gases (SO_2 and NO_2)[27]
- PAHs and ETS[27]
- SO_2 and aerosols (sodium chloride)[28]
- Asbestos and ETS[29]
- Ozone and aerosols (ammonium sulfate)[30]
- SO_2 and aerosols (ammonium sulfate)[30]
- Asbestos and BaP[31]

Complex mixtures of chemicals are ubiquitous to indoor environments and are made up, in part, of environmental tobacco smoke (ETS), VOCs, pesticides, and combustion gases. (A subset of these pollutants have been found to be carcinogenic and are discussed individually in earlier sections.)

- **Environmental tobacco smoke** has been associated with cardiovascular effects, increased susceptibility to infectious diseases in children, chronic and acute pulmonary effects in children, mucous membrane irritation, and allergic responses.[32]

- **VOCs** have been identified a potential causative agent in SBS investigations.[33] Health effects, reportedly attributable to exposure to VOCs, range from sensory irritation to behavioral, neurotoxic, and hepatoxic effects.[34] Formaldehyde has been shown to cause mucous membrane irritation at very low concentrations (0.1 to 0.2 ppm) in chamber studies.[35]

- **Pesticides** are by definition poisonous, and affect the nervous system, the hepatic system, and the reproductive system.[35]

- **Combustion gases** that have been found to accumulate in indoor environments are carbon monoxide, nitrogen dioxide, and sulfur dioxide. The effects of CO may be grossly underestimated. One study reported that sensitive populations may be highly affected by indoor exposures and misdiagnosed with symptoms related to flu, food poisoning, Alzheimer's disease, and general decrepitude.[36] Nitrogen dioxide and sulfur dioxide are lung irritants that cause respiratory difficulty in sensitive populations, particularly asthmatics.[37]

- **Airborne biological contaminants** are also ubiquitous in indoor environments. Biogenic aerosols can produce direct toxicity, or may be pathogenic or allergenic.[38]

CAVEATS

This analysis of the approximate health impacts of poor indoor air quality is designed to be used only as part of a general comparison with other environmental problems. The quantitative risk estimates are based on generally accepted toxicity, exposure, and risk characterization methodologies and, therefore, carry all of the uncertainties typical of assessing risks (high-dose to low-dose extrapolations and animal-to-human extrapolations, for example). Further, this analysis has additional uncertainties resulting from the lack of specific data, particularly on exposures. For example, this analysis uses some common exposure information and generally applies those exposures on a 24-hour basis to all residents in the region. It does not attempt to rigorously account for differences in exposures by location (homes, offices, and schools, for example) or to distinct groups (sensitive populations, for example), or to account for the hundreds of chemicals found in indoor air. As a result, **the conclusions of this analysis are not appropriate for other purposes.** This analysis does, however, probably account for the major health effects from poor indoor air quality, at least as is now known.

ADDITIONAL INFORMATION

The derivations used in this analysis are available in the Documentation Report.

SUMMARY OF QUANTIFIED CANCER RISKS

Individual and Population Risks
Carcinogenic Agents
Region 8

	Individual Risks			Population Risks		
	Lower	to	Upper	Lower	to	Upper
	---(lifetime		risk)---	(annual excess cancer cases)		
VOCs:						
Formaldahyde	1E-04	to	5E-03	4	to	202
Benzene	2E-05	to	2E-03	1	to	74
Carbon tetrachloride	0E+00	to	2E-03	0	to	73
Chloroform	3E-06	to	1E-03	0.1	to	45
1,2 Dichloroethane	3E-05	to	4E-04	1	to	14
Tetrachloroethylene	8E-05	to	3E-04	3	to	12
Trichloroethylene	4E-06	to	5E-05	0.1	to	2
Benzo(a)Pyrene	4E-06	to	1E-05	0 1	to	0 4
Pesticides:						
Heptachlor	1E-06	to	2E-04	0 04	to	8
Aldrin	2E-08	to	1E-04	0 001	to	4
Chlordane	3E-06	to	7E-05	0 1	to	3
Dieldrin	1E-07	to	3E-05	0 004	to	1
alpha-BHC	4E-07	to	2E-06	0.02	to	0 1
4 4' DDE	6E-08	to	4E-07	0.002	to	0.02
Proxpur(Baygon)	3E-08	to	4E-07	0.001	to	0 02
ETS*	4E-03	to	1E-02	37	to	37
Asbestos	7E-06	to	3E-03	0.3	to	115
Total Risk:	**4E-03**	**to**	**2E-02**	**47**	**to**	**590**

* Individual risks are for nonsmokers, population risk is computed considering additional subpopulations.

Note: Detail may not directly compute to population risk due to independent derivation of ETS risks and independent rounding.

Estimated 1990 population is 2675 thousand

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[34]*Ibid.*, p. 3-6.

[35]*Ibid.*, p. 3-7.

[36]Ammann, H., "Effects of Indoor Pollutants on Sensitive Populations," USEPA, Office of Research and Development, Research Triangle Park, N.C., Undated, p. 1.

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[38]*Report to Congress on Indoor Air Quality*, p. 3-13.

EPA Comparative Risk Study
Indoor Air Quality Welfare Effects Assessment
Region 8

Executive Summary

Poor indoor air quality can create a variety of economic costs to society including increased medical costs, losses to productivity, and damage to materials. The welfare effects of indoor air quality are estimated in this study using a damage approach (that estimates the cost of physical damage caused by a problem) to assign a value to the economic costs. Because of the lack of substantiated research in this area, the estimates are incomplete and subject to great uncertainty. The estimates are not statistically reliable and should be used only to compare the possible magnitude of the welfare effects of indoor air quality with the effects of other environmental problems.

Indoor air pollutants can cause damage to materials such as metals, paints, textiles, paper, leather, computer equipment, and electrical equipment. **Although the cost of material damage may be substantial, the value is not quantified** because of the lack of research in the area. The medical costs of indoor air relate to the cost of medical care for the health effects caused by indoor air. For Region 8, the **medical costs are estimated at $10 million to $24 million per year.** The costs of lost productivity consist of 1) reduced productive years due to major life-threatening health effects and 2) the day-to-day productivity losses of the general work force. These **productivity losses are estimated at $0.56 billion to $0.62 billion per year.** For effects quantified in this analysis, the **total welfare costs are about $0.57 billion to $0.64 billion per year** for Region 8.

Introduction

Very few studies are available on the economic costs of poor indoor air quality. In its *Report to Congress on Indoor Air Quality*[1], the U.S. Environmental Protection Agency (EPA) identified three major categories of economic costs: material costs, direct medical costs, and lost productivity costs. Using available research data, EPA quantified welfare costs for direct medical costs and lost productivity costs but was unable to assign a dollar value to the material costs. This analysis relies heavily on EPA's work as detailed in Chapter 5 of the *Report to Congress on Indoor Air Quality* for its methodologies and assumptions. Each of the three damage categories are described in detail in the following sections.

Materials Costs

Indoor air pollutants can cause adverse effects on materials and equipment. Costs associated with the adverse effects could include maintenance, repair, and replacement costs for soiling, deterioration of appearance, and reduced service life. Table 1 summarizes materials that can be affected, the types of possible damage, and the principal indoor air pollutants that can cause this damage.

As with health effects, some objects and materials can be considered a "sensitive population." Particularly sensitive objects include leather-bound books, fine art, electrical equipment, and computer equipment. The value of damage to unique art and antique books can be priceless. Telephone switching and computer equipment is susceptible to corrosion caused by air particles and gases. A representative of Bell Communications Research[2] reported that the seven regional telephone companies have spent large sums to replace, clean, or repair switches as a result of indoor air contaminants. Failures have occurred throughout the system, and range in cost from as little as $10,000 to as high as $380,000 per event. With the growing number of personal computers in use, the cost of damage to electrical equipment could be quite substantial.

EPA Comaprative Risk Study
Summary of Indoor Air Quality Issues

Regions 2, and 4-9

Air Pollution Effects on Materials

Materials	Type of Damage	Principal Air Pollutants
Metals	Corrosion tarnishing	Sulfur oxides and other acid gases
Paint and organic coatings	Surface erosion discoloration soiling	Sulfur oxides hydrogen sulfides particulate matter
Textiles	Reduced tensile strength soiling	Sulfur oxides nitrogen oxides particulate matter
Textile dyes	Fading color change	nitrogen oxides ozone
Paper	Embrittlement, soiling	Sulfur oxides particulate matter
Magnetic storage media	Loss of signal	Particulate matter
Photographic materials	microblemishes, "sulfiding"	Sulfur oxides, hydrogen sulfide
Rubber	Cracking	Ozone
Leather	Weakening, powdered surface	Sulfur oxides
Ceramics	Change of surface appearance	Acid gases, HF

Source: Report to Congress on Indoor Air Quality.
Volume II Assessment and Control of Indoor Air Pollution. August 1989 p 5-6

Medical Costs

The annual number of **excess cancer cases** attributable to indoor air pollution are estimated and presented in the health effects section. The medical costs associated with the cancer cases, however, represent a welfare effect of indoor air. As in Chapter 5 of *Report to Congress on Indoor Air Quality*, the medical costs of the excess cancer are estimated using a 1981 study by Hartunian, *et al.*[3] that estimates the present value of direct medical expenditures for various illnesses derived from actual cost experi-ences. Future medical costs were discounted to present value using a 6 percent discount rate.

The calculation of the medical costs due to excess cancer cases involves multiplying the number of excess cancer cases derived in the health effect analysis by the average cost per cancer case (available data are in 1986 dollars). Thus, the medical costs due to increased cancer cases for Region 8 equals 47 cancer cases multiplied by $24,938 per case for a total of **$1 million** at the low end of the range and 590 cases for a total of **$15 million** at the high end.

Chapter 5 of the *Report to Congress on Indoor Air Quality* calculates several other types of medical costs related to non-cancer health effects. The first cost relates to asthmatic children. A New York City study[4] found that asthmatic children from smoking households visited hospital emergency rooms more often than those from non-smoking households. The cost of the **increased emergency room visits by asthmatic children** can be calculated as a welfare effect of poor indoor air. The New York City study reported that the number of increased emergency room visits equals 1.26 visits per year per asthmatic child in smoking home. The *Report to Congress on Indoor Air Quality* estimated, based on National Center for Health Statistics data, that 5 percent of children under 18 suffer from asthma. According to the Center for Disease Control, 43 percent of children live in smoking households. The cost of the additional emergency room visits equals the percent of children with asthma (5 percent) multiplied by the population of children under 18 to derive the number of children with asthma. Next, the number of children with asthma is multiplied by the percent of children in smoking households (43 percent) to get the number of asthmatic children in smoking households. That figure is then multiplied by the additional number of emergency room visits per year (1.26) and the average cost of the visits ($90). For Region 8 the resulting cost is **$2 million.**

Besides cancer, Environmental Tobacco Smoke (ETS) is reported to cause other major diseases. For example, according to a study by Wells[5], 32,000 cases of **heart disease** per year (for the U.S.) are attributable to environmental tobacco smoke (ETS). In order to estimate the number of heart disease cases from ETS for Region 8, the number of heart disease cases are disaggregated from the country's total based on Region 8's population. The total medical costs for ETS heart disease equals the estimated number of cases for Region 8 (352) multiplied by the medical costs per case ($9,684)) or **$3 million.**

Another category of increased medical costs is due to **increased medical visits** for the white collar work force necessitated by indoor air quality problems. Based on a survey in New England[6], white collar workers have an extra .26 visits with doctors per year due to poor indoor air quality. Assuming a white collar work force of 541 million in Region 8 and an average cost per visit to the doctor of $30[7], the additional medical costs equals **$4 million.**

Productivity Losses

The value of decreased worker productivity due to poor indoor air can also be included as a welfare effect. Decreased worker productivity falls into two categories: reduced productivity within the general work force and disease-specific productivity losses.

Within the general white collar work force, poor indoor air quality may cause a reduction in worker productivity due to headaches, eye irritation, and fatigue. Workers may also spend time away from their work location by taking breaks or walks outdoors to relieve these symptoms. A study of 94 state government office buildings conducted by a coalition of employee unions[8] found that 3 percent (or 14 minutes, or .23 hours) per day is lost due to poor indoor air quality. In addition, worker days lost due to sick leave were found to increase by an average of .6 extra sick days per worker per year.

The cost, then, of the reduced daily productivity per white collar worker equals the average white collar wage rate ($15.56), multiplied by .23 hours/day times 2080 hours per year (52 weeks per year times 40 hours per week) multiplied by the Region 8 work force of 541 million. The daily productivity losses for Region 8 equals $1 billion. The productivity losses due to increased sick leave equals the wage rate multiplied by 4.8 sick hours, multiplied by the white collar work force in the region for a cost of $40 million. The total **general worker productivity** losses for Region 8 (both lost time and sick leave) is estimated at **$544 million.**

Disease-specific lost productivity is measured based on the lost earnings caused by the increased number of cancer cases and cases of heart disease. Lost productivity costs due to **excess cancer cases** equals the number of cases multiplied by the cost of lost productivity per case ($92,645) from the Hartunian Study[9] or **$4 million** at the lower end of the range and **$55 million** at the high end. Lost productivity costs due to excess **heart disease** cases equals the number of cases multiplied by the cost of lost productivity per case ($44,896) from the Hartunian Study[10] or **$16 million.**

*　　*　　*　　*　　*

Summary of Welfare Costs Attributable to Poor Indoor Air Quality
Region 8

	Costs or Losses	
	Low	High
	---------($ million)---------	
Medical Costs		
Cancer	$1	$15
Noncancer		
Emergency room visits by asthmatic children	2	2
Heart disease	3	3
Increased visits to doctors by workers	4	4
Subtotal	$10	$24
Productivity Losses		
General worker productivity	$544	$544
Cancer	4	55
Heart disease	16	16
Subtotal	$564	$615
TOTAL	$574	$638

The largest portion of the welfare costs are attributable to lost productivity among the general white collar work force. These estimates for the white collar labor force productivity losses are in the billions of dollars and should only be considered a gross estimate to be used to compare the possible magnitude of the welfare effects of poor indoor air quality with the welfare effects of other environmental problems.

Notes

[1]USEPA, *Report to Congress on Indoor Air Quality*, Office of Air and Radiation, Indoor Air Programs, EPA/400/1-89/001C, (Washington, DC: U.S. Government Printing Office), August 1989, Chapter 5, pages 5-1 - 5-21.

[2]Weschler, C., Bell Communications Research, Personal Communication with David Mudarri, EPA, June 30, 1988 as cited in *Report to Congress on Indoor Air Quality*, page 5-7.

[3]Hartunian, N. *et al.*, *The Incidence and Economic Costs of Major Health Impairments*, Lexington Books, 1981, as cited in *Report to Congress on Indoor Air Quality*, pages 5-7 - 5-8.

[4]Evans, D., *et al.*, "The Impact of Passive Smoking on Emergency Room Visits of Urban Children with Asthma", *American Review of Respiratory Diseases*, 135:567-572: summarized in *Residential Hygiene*, Vol. 4, No. 2, page 12, as cited in *Report to Congress on Indoor Air Quality*, page 5-10.

[5]Wells, A.J., "Passive Smoking Mortality: A Review and Preliminary Risk Assessment", Presented at 79th annual meeting, Air Pollution Control Association, Minneapolis, Minnesota, 1986, as cited in *Report to Congress on Indoor Air Quality*, page 3-6.

[6]*Report to Congress on Indoor Air Quality*, page 5-11.

[7]*Report to Congress on Indoor Air Quality*, pages 5-12.

[8]*Report to Congress on Indoor Air Quality*, page 5-11.

[9]Hartunian, N. *et al.*, *The Incidence and Economic Costs of Major Health Impairments*, Lexington Books, 1981, as cited in *Report to Congress on Indoor Air Quality*, pages 5-7 - 5-8.

[10]Hartunian, N. *et al.*, *The Incidence and Economic Costs of Major Health Impairments*, Lexington Books, 1981, as cited in *Report to Congress on Indoor Air Quality*, pages 5-7 - 5-8.

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Documentation Report
Indoor Air Quality
Welfare Effects Assessment

(ONLY USE WITH FULL REPORT)

Environomics, Inc.

Prepared by Environomics Inc
Design, Entry and Checking by
Rose Odom and Curtis Haymore

Revised 7/09/90

EPA Comparative Risk Study
Indoor Air Quality Issues
Regional Comparisons for Regions 2 and 4-9

Welfare Effects Worksheet
(USE ONLY WITH FULL REGIONAL REPORT. THIS WORKSHEET PERFORMS ALL CALCULATIONS NOT SHOWN IN REPORT.)

	DIRECTORY
	Use FORMULA GOTO to get to these areas
a_Directory	This is it, return for this list
Input & Computation Areas	
b_Cancer_Cases	Input Number of cancer cases by region due to indoor air
c_Cancer_Costs	Computes Medical costs by region for cancer cases
d_No._of_Children	Inputs 1989 percent of population under 18 and population by State Computes Regional population of children
e_Asthmatic_Children	Computes Costs of ER visits of asthmatic children in smoking households
f_Heart_Disease	Computes Medical costs by region forheart disease cases
g_White_Collar_Workers	Inputs 1989 workers by industry sector and State Computes Regional and total workers
h_Doctor_Visits	Computes Costs of doctor visits from general work force
i_General_Productivity_Losses	Computes Productivity losses to general white collar work force
j_Cancer_Productivity_Losses	Computes Productivity losses due to cancer cases
k_Heart_Disease_Productivity	Computes Productivity losses due to heart disease cases
z_ASSUMPTIONS	Lists several of the input assumptions
Report Areas	
Region_1	empty
Region_2	Contains welfare cost summary calculations for Region 2
Region_3	empty
Region_4	Contains welfare cost summary calculations for Region 4
Region_5	Contains welfare cost summary calculations for Region 5
Region_6	Contains welfare cost summary calculations for Region 6
Region_7	Contains welfare cost summary calculations for Region 7
Region_8	Contains welfare cost summary calculations for Region 8
Region_9	Contains welfare cost summary calculations for Region 9
Region_10	empty

Number of Cancer Cases by Region

Region	Annual Excess Cancer Cases Low	to	High
Region 2	452		5.659
Region 4	797		9.989
Region 5	816		10.223
Region 6	520		6.518
Region 7	212		2.652
Region 8	47		590
Region 9	618		7.736
Total			

Reference: See Summaries of Quantified Cancer Risks from the Health Effects Assessment or its Documentation Report.

Medical Cost of Excess Cancer Cases					
	Number of Excess Cancer Cases Annually		Health Costs Per Case	Health Costs of Excess Cancer Cases	
	Low	to High		Low	to High
Region 2	452	5,659	$24,938	$11,271,976	$141,124,142
Region 4	797	9,989	$24,938	$19,875,586	$249,105,682
Region 5	816	10,223	$24,938	$20,349,408	$254,941,174
Region 6	520	6,518	$24,938	$12,967,760	$162,545,884
Region 7	212	2,652	$24,938	$5,286,856	$66,135,576
Region 8	47	590	$24,938	$1,172,086	$14,713,420
Region 9	618	7,736	$24,938	$15,411,684	$192,920,368

Source: For "number of cases," see previous, adjoining table
For "health costs," see assumptions.

Number of Children Under 18, By Region, By State

EPA Region State	Percent of Population Under Age 18	Total Population (000 s)	Population Under Age 18 (000 s)
Region 2			
New York	24 5%	17773	4354 4
New Jersey	23 9%	7899	1887 9
Virgin Islands	0 0%		0 0
	0 0%		0 0
Total		**25672**	**6242 2**
Region 4			
North Carolina	25 4%	6690	1699 3
South Carolina	27 5%	3549	976 0
Kentucky	26 7%	3745	999 9
Tennessee	25 8%	4972	1282 8
Georgia	27 9%	6663	1859 0
Alabama	27 4%	4181	1145 6
Mississippi	26 7%	2699	720 6
Florida	22 5%	12818	2884 1
Total		**45317**	**11567 2**
Region 5			
Ohio	26 3%	10791	2838 0
Indiana	26 6%	5550	1476 3
Illinois	26 2%	11612	3042 3
Wisconsin	26 4%	4808	1269 3
Michigan	26 7%	9293	2481 2
Minnesota	26 2%	4324	1132 9
Total		**46378**	**12240 1**
Region 6			
Louisiana	29 5%	4513	1331 3
Arkansas	27 1%	2427	657 7
Oklahoma	27 3%	3285	896 8
Texas	29 7%	17712	5260 5
New Mexico	29 8%	1632	486 3
Total		**29569**	**8632 7**
Region 7			
Kansas	26 3%	2492	655 4
Missouri	25 6%	5192	1329 2
Iowa	25 8%	2758	711 6
Nebraska	26 6%	1588	422 4
Total		**12030**	**3118.5**
Region 8			
South Dakota	27 6%	708	195 4
North Dakota	27 8%	660	183 5
Montana	25 6%	805	206 1
Wyoming	30 2%	502	151 6
Total		**2675**	**736 6**
Region 9			
California	26 4%	29126	7689 3
Nevada	25 1%	1076	270 1
Arizona	27 1%	3752	1016 8
Hawaii	26 4%	1141	301 2
Guam			0 0
Total		**35095**	**9277 4**

Source 1987 Resident Population by Age and State Statistical Abstract of the United States 1989 p 22

Costs of Additional Emergency Room Visits for Asthmatic Children in Smoking Households

	Increased Number of Emergency Room Visits Per Year	Cost of Additional Visits	Percent of Children in Smoking Households	Estimated Percent of Asthmatic Children	Number of Children in Region (000s)	Number of Asthmatic Children in Region (000s) (4) x (5)	Asthmatic Children in Smoking Homes (000s) (3) x (6)	Cost of Additional Emergency Room Visits (1)x(2)x(7)x1000
	1	2	3	4	5	6	7	8
Region 2	1 26	$90 00	43 00%	5 00%	6242 2	312 1	134 2	$15,219,220
Region 4	1 26	$90 00	43 00%	5 00%	11567 2	578 4	248 7	$28,201,942
Region 5	1 26	$90 00	43 00%	5 00%	12240 1	612 0	263 2	$29,842,607
Region 6	1 26	$90 00	43 00%	5 00%	8632 7	431 6	185 6	$21,047 281
Region 7	1 26	$90 00	43 00%	5 00%	3118 5	155 9	67 0	$7,603,264
Region 8	1 26	$90 00	43 00%	5 00%	736 6	36 8	15 8	$1,795,836
Region 9	1 26	$90 00	43 00%	5 00%	9277 4	463 9	199 5	$22,619 122

Source Columns (1) (4), see assumptions
Column (5) Environomics, Inc table titled, "Number of Children Under 18 By Region By State"

Medical Costs of Heart Disease Cases Caused by ETS

Region	Percent of Population In Region	Number of Excess Heart Disease Cases Annually	Number of Excess Heart Disease Cases In Region	Health Costs Per Case	Health Costs of Excess Heart Disease Cases
	(percent)			(dollars)	(dollars)
			(1) x (2)		(3) x(4)
	- 1 -	- 2 -	- 3 -	- 4 -	- 5 -
Region 2	10.55%	32000	3376	$9,684	$32,693,184
Region 4	18.62%	32000	5958	$9,684	$57,697,272
Region 5	19.05%	32000	6096	$9,684	$59,033,664
Region 6	12.15%	32000	3888	$9,684	$37,651,392
Region 7	4 94%	32000	1581	$9,684	$15,310,404
Region 8	1.10%	32000	352	$9,684	$3,408,768
Region 9	14 42%	32000	4614	$9,684	$44,681,976

Source: Columns (2) and (4), see assumptions. Column (1) is derived from Environomics, Inc. table titled, "Number of Children Under 18, By Region, By State" by dividing the national total (see assumptions) by the regional totals

1989 White Collar Work Force by Industry Sector, By Region, by State

EPA Region, State	Finance, Insurance, and Real Estate	Services	Government	Total
		(000s)		
Region2				
New York	794 5	2346 8	1446 9	4588 2
New Jersey	242 7	951 7	558 8	1753 2
Virgin Islands	2 0	9 3	13 5	24 8
Total	1039 2	3307 8	2019 2	**6366 2**
Region 4				
North Carolina	132 3	560 3	473 4	1166 0
South Carolina	68 2	275 2	270 8	614 2
Kentucky	60 5	312 9	253 2	626 6
Tennessee	103 6	465.2	334 3	903 1
Georgia	163 5	609 5	512 7	1285 7
Alabama	70 9	302 4	314 7	688 0
Mississippi	38 9	153 4	200 2	392 5
Florida	371 5	1502 0	805 2	2678 7
Total	1009 4	4180 9	3164 5	**8354 8**
Region 5				
Ohio	252 6	1140 8	705 7	2099 1
Indiana	122 1	503 2	358 5	983 8
Illinois	372 4	1278 8	738 0	2389 2
Wisconsin	118 1	508 5	334 0	960 6
Michigan	188 6	900 2	627 3	1716 1
Minnesota	120 5	534 4	327 6	982 5
Total	1174 3	4865 9	3091 1	**9131.3**
Region 6				
Louisiana	78 7	344 9	312 2	735 8
Arkansas	38 3	173 7	154 0	366 0
Oklahoma	58 5	259 2	254 1	571 8
Texas	432 5	1610 0	1222 2	3264 7
New Mexico	26 5	139 1	144 6	310 2
Total	634 5	2526 9	2087 1	**5248 5**
Region 7				
Kansas	58 1	231 0	210 9	500 0
Missouri	135 1	552 8	358 6	1046 5
Iowa	68 4	276 1	217 0	561 5
Nebraska	48 3	167 2	140 5	356 0
Total	309 9	1227 1	927 0	**2464 0**
Region 8				
South Dakota	15 7	67 1	61 3	144 1
North Dakota	12 2	65 9	65 6	143 7
Montana	13 2	71 6	70 1	154 9
Wyoming	7 3	36 5	54 9	98 7
Total	48 4	241 1	251 9	**541 4**
Region 9				
California	836 3	3271 5	2002 1	6109 9
Nevada	25 5	251 1	70 8	347 4
Arizona	92 6	389 0	246 1	727 7
Hawaii	35 1	144 6	101 5	281 2
Guam	0 0	0 0	0 0	0 0
Total	989 5	4056 2	2420 5	**7466 2**

Source 1989 Employees on nonagricultural payrolls in States by major industry Statistical Abstract of the United States 1989 pages 128-145 Environomics, Inc selected sectors to represent white collar workers

Medical Costs of Increased Visits to Doctor's Office Due to Indoor Air

Region	Increased Visits Per Worker	Number of Workers	Cost per Visits	Total Cost of Increased Doctors Visits
		--(000's)--	--------(dollars)--------	
Region 2	0.24	6366.2	$30	$45,836,640
Region 4	0.24	8354.8	$30	$60,154,560
Region 5	0.24	9131.3	$30	$65,745,360
Region 6	0.24	5248.5	$30	$37,789,200
Region 7	0.24	2464	$30	$17,740,800
Region 8	0.24	541.4	$30	$3,898,080
Region 9	0 24	7466 2	$30	$53,756,640

Source For "increased visits" and "cost per visit," see assumptions.
For "number of workers," see Environomics table titled,
1989 White Collar Work Force by Industry Sector, By Region, By State

Productivity Losses to the General Work Force Due to Indoor Air Quality

Region	Employees	Wage Rate	Annual Lost Time Per Employee	Cost of Lost Productivity	Increased Sick Leave Per Employee	Cost of Sick Leave	Economic Cost of Poor IAQ to Personnel
	[1]	[2]	[3]	[4]	[5]	[6]	[7]
	(000s)		(hours)		(sick_days*		
			(23*260d/y)	[1]*[2]*[3]*1000	8hrs/day)	[1]*[2]*[5]*1000	[4]+[6]
Region 2	6366 2	$15 56	59 8	$5,923,672,706	4 8	$475,478,746	$6,399,151 452
Region 4	8354 8	$15 56	59 8	$7,774,041,142	4 8	$624,003,302	$8,398,044,444
Region 5	9131 3	$15 56	59 8	$8,496,565,074	4 8	$681,998,534	$9,178,563,608
Region 6	5248 5	$15 56	59 8	$4,883,666,268	4 8	$391,999,968	$5,275,666,236
Region 7	2464 0	$15 56	59 8	$2,292,722,432	4 8	$184,031,232	$2,476,753,664
Region 8	541 4	$15 56	59 8	$503,766,203	4 8	$40,436,083	$544,202,286
Region 9	7466 2	$15 56	59 8	$6,947,209,506	4 8	$557,635,546	$7,504,845,052
			assumes 260 days/year				

Source col (1) Environomics, Inc table titled, "1989 White Collar Work Force by Industry Sector, By Region, By State"
cols (2), (3), and (5) see assumptions

Region	Number of Excess Cancer Cases Annually: Low	to High	Productivity Losses Per Case	Productivity Losses of Excess Cancer Cases: Low	to High
Region 2	452	5659	$92,645	$41,875,540	$524,278,055
Region 4	797	9989	$92,645	$73,838,065	$925,430,905
Region 5	816	10223	$92,645	$75,598,320	$947,109,835
Region 6	520	6518	$92,645	$48,175,400	$603,860,110
Region 7	212	2652	$92,645	$19,640,740	$245,694,540
Region 8	47	590	$92,645	$4,354,315	$54,660,550
Region 9	618	7736	$92,645	$57,254,610	$716,701,720

Productivity Losses Due to Excess Cancer Cases

Source Cancer cases from Environomics, Inc. table titled, "Number of Cancer Cases by Region"
Productivity losses, see assumptions

Productivity Losses Due to Heart Disease Caused By ETS			
Region	Number of Excess Heart Disease Cases Annually	Productivity Losses Per Case	Productivity Losses of Excess Heart Disease Cases
Region 2	3376	$44,896	$151,568,896
Region 4	5958	$44,896	$267,490,368
Region 5	6096	$44,896	$273,686,016
Region 6	3888	$44,896	$174,555,648
Region 7	1581	$44,896	$70,980,576
Region 8	352	$44,896	$15,803,392
Region 9	4614	$44,896	$207,150,144

Source: Number of cases from ENVIRONOMICS, Inc table titled, "Medical Costs of Heart Disease Cases Caused by ETS." For productivity losses, see assumptions.

ASSUMPTIONS

	1986$	Reference
Cancer Costs:		
Cancer_Med_Cost (health care costs for cancer)	$24,938	Report to Congress, page 5-8
Cancer_Prod_Cost (lost productivity from cancer)	$92,645	Report to Congress, page 5-13
Non-Cancer Costs:		
Heart_Med_Cost (health care costs)	$9,684	Report to Congress, page 5-8
Heart_Prod_Cost (lost productivity from heart disease)	$44,896	Report to Congress, page 5-13
ER_visits (increased emergency room visits)	1.26	Report to Congress, page 5-10
Doc_Visit_cost (average cost per doctor visit)	$30.00	Report to Congress, page 5-12
ER_cost (average cost per emergency room visit)	$90 00	Report to Congress, page 5-10
wage_rate (average white collar wage rate)	$15 56	Report to Congress, page 5-15
doc_visit (average increased doctors visits per worker per year)	0.24	Report to Congress, page 5-12
sick_days (average increased sick days per worker per year)	0.6	Report to Congress, page 5-15
lost_time (average daily lost time per worker)	0 23	Report to Congress, page 5-15
percent_asthma (percent of asthmathic children)	0 05	Report to Congress, page 5-10
Per_smoking (percent of smoking households)	0.43	Report to Congress, page 5-10
Heart_cases (number of heart disease cases, U S)	32000	Report to Congress, page 5-9
US_Population (in 000s)	243400	Statistical Abstract of the United States 1989, p. 24

EPA Comaparative Risk Study
Summary of Indoor Air Quality Issues
Welfare Costs
Region 2

	Cost or Losses	
	Low to	High
	----(million	dollars)----
Health Costs		
Cancer	$11	$141
Non-Cancer		
Heart Disease	$33	$33
Emergency Room Visits of Asthmatic Children	$15	$15
Increased Worker Doctors Visits	$46	$46
Subtotal	$105	$235
Productivity Losses		
Cancer	$42	$524
Heart Disease	$152	$152
Decreased Worker Productivity	$6.399	$6.399
Subtotal	$6,593	$7,075
Total	**$6,698**	**$7,310**

EPA Comaparative Risk Study
Summary of Indoor Air Quality Issues
Welfare Costs
Region 4

	Cost or Losses		
	Low	to	High
	----(million		dollars)----
Health Costs			
Cancer:	$20		$249
Non-Cancer			
Heart Disease:	$58		$58
Emergency Room Visits of Asthmatic Children.	$28		$28
Increased Worker Doctors Visits.	$60		$60
Subtotal	$166		$395
Productivity Losses:			
Cancer:	$74		$925
Heart Disease:	$267		$267
Decreased Worker Productivity:	$8.398		$8.398
Subtotal	$8,739		$9,590
Total:	**$8,905**		**$9,985**

EPA Comaparative Risk Study
Summary of Indoor Air Quality Issues
Welfare Costs
Region 5

	Cost or Losses Low	to	High
	----(million		dollars)----
Health Costs:			
Cancer:	$20		$255
Non-Cancer			
Heart Disease:	$59		$59
Emergency Room Visits of Asthmatic Children	$30		$30
Increased Worker Doctors Visits:	$66		$66
Subtotal	$175		$410
Productivity Losses:			
Cancer:	$76		$947
Heart Disease:	$274		$274
Decreased Worker Productivity:	$9,179		$9,179
Subtotal	$9,529		$10,400
Total:	**$9,704**		**$10,810**

EPA Comaparative Risk Study
Summary of Indoor Air Quality Issues
Welfare Costs
Region 6

	Cost or Losses	
	Low to	High
	----(million	dollars)----
Health Costs		
Cancer:	$13	$163
Non-Cancer		
Heart Disease:	$38	$38
Emergency Room Visits of Asthmatic Children:	$21	$21
Increased Worker Doctors Visits:	$38	$38
Subtotal	$110	$260
Productivity Losses.		
Cancer:	$48	$604
Heart Disease:	$175	$175
Decreased Worker Productivity:	$5.276	$5.276
Subtotal	$5.499	$6,055
Total:	**$5,609**	**$6,315**

EPA Comaparative Risk Study
Summary of Indoor Air Quality Issues
Welfare Costs
Region 7

	Cost or Losses	
	Low to	High
	----(million	dollars)----
Health Costs.		
Cancer:	$5	$66
Non-Cancer		
Heart Disease:	$15	$15
Emergency Room Visits of Asthmatic Children	$8	$8
Increased Worker Doctors Visits.	$18	$18
Subtotal	$46	$107
Productivity Losses:		
Cancer:	$20	$246
Heart Disease:	$16	$16
Decreased Worker Productivity:	$2.477	$2.477
Subtotal	$2.513	$2.739
Total:	**$2,559**	**$2,846**

EPA Comaparative Risk Study
Summary of Indoor Air Quality Issues
Welfare Costs
Region 8

	Cost or Losses	
	Low to	High
	----(million	dollars)----
Health Costs:		
Cancer:	$1	$15
Non-Cancer		
Heart Disease:	$3	$3
Emergency Room Visits of Asthmatic Children:	$2	$2
Increased Worker Doctors Visits	$4	$4
Subtotal	$10	$24
Productivity Losses:		
Cancer:	$4	$55
Heart Disease:	$16	$16
Decreased Worker Productivity:	$544	$544
Subtotal	$564	$615
Total:	**$574**	**$639**

EPA Comaparative Risk Study
Summary of Indoor Air Quality Issues
Welfare Costs
Region 9

	Cost or Losses		
	Low	to	High
	----(million		dollars)----
Health Costs:			
Cancer:	$15		$193
Non-Cancer			
Heart Disease:	$45		$45
Emergency Room Visits of Asthmatic Children:	$23		$23
Increased Worker Doctors Visits:	$54		$54
Subtotal	$137		$315
Productivity Losses:			
Cancer:	$57		$717
Heart Disease:	$207		$207
Decreased Worker Productivity:	$7,505		$7,505
Subtotal	$7,769		$8,429
Total:	**$7,906**		**$8,744**

18.0 INDOOR RADON

18.1 INTRODUCTION

The Indoor Radon problem area addresses risks to human health and welfare posed by radon radioactive decay particles. Human health effects estimated are limited to annual Region VIII cancer cases. Welfare damages are based on cost of illness measures and estimated costs of radon mitigation.

Radon is radioactive gas produced by the decay of radium, which occurs naturally in almost all soil and rock. Health risks occur when radon migrates into buildings through foundation cracks or other openings such as sumps, utility ports, or uncovered crawl spaces. Radon can also enter the atmosphere of a building when it volatizes from the drinking water supply.

As radon gas undergoes radioactive decay in a building's atmosphere, it produces a series of short-lived radioactive decay products. When inhaled, some of these decay products are deposited in air passages of the respiratory system and emit alpha particles which can damage tissue of the bronchial epithelium and lead to lung cancer.

Radon is a known human carcinogen to which the entire population of Region VIII and the nation is exposed to some extent.

18.2 HUMAN HEALTH RISK ASSESSMENT

18.2.1 Toxicity Assessment

Radon is classified as a Group A human carcinogen. Studies of laboratory animals and human epidemiological studies have produced well documented evidence that exposure to radon decay products causes lung cancer. These epidemiological studies, despite widely varying exposure conditions, have demonstrated remarkably consistent dose-response relationships. Excess relative risk calculations derived from five major studies of underground miners show a range of 1.1 percent to 3.6 percent increase in lung cancer per Working Level Month (WLM) of radon exposure.

As recommended by the Science Advisory Board, the U.S. EPA uses relative risk models of the International Commission on Radiological Protection (ICRP 50) and the National Academy of Sciences' Committee on the Biological Effects of Ionizing Radiations (BEIR IV). These models assume that the incidence of excess lung cancer associated with exposure to indoor radon is proportional to the baseline incidence of lung cancer in the population as a whole. This implies that the health impact of radon is multiplicative with other risk factors which cause lung cancer (e.g. smoking) and that the incidence of lung cancer due to indoor radon will vary with other population characteristics such as age, sex and occupation. EPA's current central estimate of the lifetime rate of lung cancer deaths due to radon is 360 deaths/million persons - WLM. This is the average of the age-averaged lifetime rates calculated using lifetable analysis in conjunction with the ICRP 50 and BEIR IV models.

18.2.2 Exposure Assessment

The EPA assumes the average indoor radon exposure level in single family detached homes in the United States to be 0.25 WLM per year. This is based on an annual average indoor radon concentration of 1.3 pCi/L, assuming 75 percent residential occupancy time and 50 percent equilibrium factor between radon and its decay products.

There is now evidence available to suggest that average indoor radon levels in Region VIII exceed the national average value. EPA, in conjunction with the States of Colorado, Wyoming, North Dakota and Utah, has conducted random winter-time screening measurements of numerous homes. To determine the average annual level of exposure in the region, it is necessary to convert the basement screening measurements obtained from the surveys to housewide annual averages. This has been done by Milt Lammering, see Table 18-1.

18.2.3 Human Heath Risk Characterization

Cancer Risk

Estimated average basement radon levels for Region VIII are shown in Table 18-1. No data were available for North Dakota or Montana; for these states, we estimated radon concentrations based on an average of Radon concentrations measured in the remaining Region VIII states.

As mentioned previously, Lammering (1990) estimated living space Radon concentrations as approximately one half measured basement levels. This suggests Radon concentrations ranging from 1.8 to 3.5 pCi/l. This range corresponds to an estimated increased risk of lung cancer death of approximately 15 to 35 in a population of 1,000 individuals. Selecting the midpoint of this range suggests an estimated risk factor of $2.5x10^{-2}$.

Table 18-1
Household Radon Levels and Cancer Risk
due to Radon in Region VIII

State	Population 1986	Basement Average Level [1] (pCi/l)	Living Space Average Level [2] (pCi/l)	Lifetime Individual Cancer Risk
Colorado	3,231,000	5.9	3.0	2.5E-02
Montana	826,000	4.8	2.4	2.5E-02
North Dakota	685,000	7.0	3.5	2.5E-02
South Dakota	708,000	4.8	2.4	2.5E-02
Utah	1,645,000		2.6	2.5E-02
Wyoming	509,000	3.6	1.8	2.5E-02
TOTAL	7,604,000			

[1] No data available for South Dakota or Montana. Assume average of other four states.

[2] Assume living space level = 1/2 of basement level.

Annual cancer deaths are estimated in this report by:

$N = (WLM/yr)(360\ lcd/10^6\ WLM)(P)$

where:

N = Estimated cancer deaths
WLM/yr = Working level months/year (a function of total dose)
P = Population.

Results of these calculations are summarized in Table 18-2 on a State and Regional basis.

Ecological Risk Assessment

No ecological risk assessment has been performed for indoor radon because there are no documented ecological impacts.

18.3 WELFARE RISK ASSESSMENT

Welfare risks are based on estimates of annual cancer deaths and estimated radon mitigation costs.

18.3.1 Cancer Welfare Damages

To estimate these costs, estimated annual cancer cases were multiplied by the direct medical cost and foregone earnings per cancer case:

(Annual Cancer Cases)(Direct Costs and Forgone Earnings) = HC

where:

HC = health costs

Estimated direct and indirect medical cancer costs are based on a range of cost per case estimates. The lower bound estimate, based on Hartunian, et al., is $80,000, while the upper bound estimate developed by the American Cancer Society is $137,000. These estimates provide differing values for foregone earnings and medical costs. Both estimates are weighted average costs associated with all types of cancers.

Table 18-2
Household Radon Levels and Annual Cancer Deaths
due to Radon in Region VIII

State	Population 1986	Basement Average Level [1] (pCi/l)	Living Space Average Level [2] (pCi/l)	WLM/yr [3]	Annual Cancer Deaths [4]
Colorado	3,231,000	5.9	3.0	0.373	434
Montana	826,000	4.8	2.4	0.304	90
North Dakota	685,000	7.0	3.5	0.443	109
South Dakota	708,000	4.8	2.4	0.304	77
Utah	1,645,000		2.6	0.329	195
Wyoming	509,000	3.6	1.8	0.228	42
TOTAL	7,604,000				948

[1] No data available for South Dakota or Montana. Assume average of other four states.
[2] Assume living space level = 1/2 of basement level.
[3] WLM is working level months per year based on 75% occupancy and 50% equilibrium.
[4] Annual Cancer Deaths = WLM/yr * 360 lcd/10^6 WLM * population.

Lower bound estimate

HC=(948)($80,000)=$75,840,000 (1988 $)

Upper bound estimate

HC=(948)($137,000)=$129,876,000 (1988 $).

18.3.2 Mitigation Costs

Lammering (1990) estimated that less than 2% of the households in Region VIII have conducted some kind of Radon mitigation. A conservative estimate of mitigation cost estimates was developed by assuming costs of $1,500 for radon mitigation. Assuming an average household size of 2.67 people, yields an estimate of 2.85 million households in the Region. Thus, approximately 57,000 households have conducted radon mitigation in Region VIII at an estimated cost of approximately $8.55 million. An alternative estimate of total mitigation costs can be derived by assuming that as many as 15% of the homes in Region VIII may have annual average radon levels that exceed EPA guidelines. Assuming that the cost of mitigation is $1,500 yields a damage estimate of approximately $640 million.

18.4 [B]IBLIOGRAPHY

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EPA COMPARATIVE RISK STUDY

SUMMARY OF
HUMAN HEALTH RISKS, ECOLOGICAL IMPACTS, AND WELFARE LOSSES ASSOCIATED WITH RADIATION OTHER THAN RADON

REGION 8

July 1990

EXECUTIVE SUMMARY

This study identifies natural and manmade sources of ionizing radiation other than radon and discusses the sources and suspected effects of exposure to non-ionizing radiation. Ionizing radiation is a known carcinogen, and can also cause genetic and tetratogenic (birth defects) effects. Estimates of the human health risks, in terms of lifetime fatal cancer risks to individuals and excess and fatal cancers expected to be incurred annually in the exposed populations, are presented for occupational, medical, and environmental exposure to sources of ionizing radiation. No known ecological impacts are attributable to ionizing radiation, therefore no ecological risk assessment was conducted. Welfare effects of excess cancers are roughly estimated using a value of $100,000 per cancer.

No estimates of human health risks, ecological impacts, or welfare effects from exposure to non-ionizing radiation are given. The lack of quantitative estimates emphasizes the tentative state of our knowledge as to the significance of either occupational or environmental exposure to the ubiquitous sources of non-ionizing radiation.

The estimates of the range of individual lifetime fatal cancer risks and annual fatal cancers expected in the populations exposed to ionizing radiation other than radon are as follows:

Natural Background Radiation:

Individual Lifetime Fatal Cancer Risk = 4E-3
Excess Fatal Cancers/Year = 362 (in a population of 7.9 million persons)

Occupational Exposures:

Individual Lifetime Fatal Cancer Risk = < 1E-6 to 8E-2
Excess Fatal Cancers/Year = 1.2 (in a population of 20.2 thousand persons)

Medical Exposures:

Individual Lifetime Fatal Cancer Risk = not estimated
Excess Fatal Cancers/Year = 119 (in a population of 3.3 million persons)

Manmade and Technologically Enhanced Sources:

Individual Lifetime Risk = < 1E-6 to > 2E-4
Excess Fatal Cancers/Year = 4.4 (in a population of 7.9 million persons).

The basis and the context of these estimates is given in the following sections. The exposure and risk estimates that are presented in this report are believed to be sufficiently accurate to allow comparison with other environmental problems. However, although many of the estimates are based on monitored exposures and the others are derived using generally accepted exposure assessment methodologies, the results are not appropriate for other purposes.

DESCRIPTION OF PROBLEM

Exposure to ionizing radiation other than radon and non-ionizing radiation is ubiquitous in our technological society. Due to the significant differences in the state of our knowledge regarding the effects of ionizing and non-ionizing radiation the sources and impacts of each are addressed separately.

Ionizing Radiation

Ionizing radiation refers to radiation that strips electrons from atoms in the medium through which it passes. The adverse effects of exposure to ionizing radiation, and hence of radioactive materials, are carcinogenicity, mutagenicity, and teratogenicity. From the perspective of total societal risk, cancer induction and genetic mutations are the most important effects. Both cancer induction and genetic mutations are believed to be stochastic effects; i.e., the probability of these effects (the risk of occurrence) increases with dose, but the severity of the effect is independent of dose. Furthermore, there is no convincing evidence of a threshold of exposure below which the risks are zero.

Evidence of the deleterious effects of exposure to ionizing radiation comes from both human epidemiology and animal studies. The human epidemiologic data for cancer induction are extensive. Thus, as the EPA noted in the Environmental Impact Statement (EIS) supporting the recent radionuclide NESHAPS (National Emission Standards for Hazardous Air Pollutants) rulemaking, "the risk can be estimated to within an order of magnitude with a high degree of confidence. Perhaps for only one other carcinogen - tobacco smoke - is it possible to estimate risks more reliably." (EPA89a)

The unit used in radiation dose assessment is the rad (radiation absorbed dose). One rad is the dose corresponding to the absorption of 100 ergs per gram of tissue. Since not all forms of ionizing radiation produce the same effect per rad, the rem is used as the unit of dose equivalence. For materials taken into the body, the dose will be delivered over the period that the material remains in the body. Thus, the convention has been established to integrate the dose over the entire period that the material will remain in the body and assign the total dose to the year of exposure, resulting in the committed dose equivalent (rem). Finally, since irradiation of the organs and tissues of the body may not be uniform, the radiation protection community has introduced the concept of the effective whole-body dose equivalent (rem EDE). The EDE is calculated by weighting the doses received by the various organs by risk based factors and then summing the weighted organ doses to derive the EDE. The collective population exposure is given in person-rem EDE, and is derived by simply summing the exposures of the individuals in the population. In this report, the doses are given in rem or millirem (1/1,000th of a rem) EDE for individuals and person-rem EDE for populations. The quantification of radiation exposures and resulting cancer risks are based on the following estimates:

Lifetime exposure to 3 mrem/y EDE = 1E-4 lifetime fatal cancer risk;

1E+6 person-rem/year EDE = 400 fatal cancers/year; and

Total Cancer Incidence/Fatal Cancer Incidence = 2, a 50 percent mortality rate once a cancer has been expressed.

The risk factors used in this report are consistent with those used by the EPA in the recent radionuclide NESHAPS rulemaking (EPA89a). They are based on a linear extrapolation of the dose response exhibited by the Japanese A-bomb survivors (and other human epidemiologic evidence), using the relative risk projection model (primarily), and assuming that there is no risk threshold. The EPA believes that the estimated fatal cancer risk of 400 per 1E+6 person-rem EDE represents a best estimate, and that the actual risk likely lies within the range of 120 to 1,200 fatal cancers per 1E+6 person-rem EDE. For radiation exposure of the whole body the total incidence of cancer does not exceed the incidence of fatal cancer by more than a factor of two. It should be noted the risk coefficient has been extrapolated from high doses and high dose rates. At the lower doses and dose rates associated with levels of exposure in the environment, the possibility that the actual risk could be zero cannot be ruled out on epidemiologic grounds due to the high rate of cancer. The current consensus of scientific opinion is that no threshold exists.

Sources of Exposure to Ionizing Radiation

Sources of ionizing radiation are grouped into four major classifications: natural background; occupational exposures; medical exposures; and manmade and technologically enhanced sources. The estimated exposures and risk associated with the specific components or facilities within each of these categories are summarized in Tables 1-4, respectively. The basis for the estimates are discussed in the following sub-sections.

Natural Background Radiation

The doses and potential risks associated with exposure to naturally occurring background radiation and naturally occurring radionuclides have been estimated in a number of national and international reports (EPA81, NCRP87, UNSCEAR82). These exposures are divided into three components; external exposure to terrestrial radiation, external exposure to cosmic radiation, and internal exposure to naturally occurring radionuclides. Table 1 presents the individual and population exposures, and the resulting cancer risks from these sources. Exposures to radon and radon progeny are excluded as they are included in the Indoor Radon Problem Area. Exposures and risks to technologically enhanced sources of naturally occurring radiation are addressed in the section on Manmade and Technologically Enhanced Sources.

The estimated external exposures include shielding correction factors for the time spent indoors and take into consideration the additional indoor exposures associated with construction materials that contain elevated levels of naturally occurring radionuclides. Self-shielding is also taken into account.

The internal doses are the effective whole body dose equivalent from naturally occurring internal emitters, as reported in NCRP 93 (NCRP87). The values do not include the lung dose from radon and radon progeny. A constant value for internal dose is used, representing the national average. It was not considered feasible to estimate differences in internal dose among states. In addition, other than radon progeny, which are not addressed in this report, the dominant contributor to the internal dose from naturally occurring radionuclides is K-40, which is under homeostatic control and, as a result, does not vary significantly among individuals.

The population doses were estimated using published values of the projected 1990 population (BC87), as the 1990 census data were not available for this report.

Table 1: Natural Background Radiation - Summary of Individual and Population Exposures and Risks

	Individuals		Population			
State/Source	Average Lifetime Fatal Cancer Risk	Average Exposure (mrem/y)	Population at Risk[1]	Exposure (person-rem/y)	Fatal Cancers per Year	Total Cancers per Year
Colorado						
Cosmic[2]	2E-3	47.5	3,434,000	1.6E+5	65	130
Terrestrial[2]	1E-3	42.6	3,434,000	1.5E+5	59	117
Internal[3]	1E-3	38	3,434,000	1.3E+5	52	104
Totals[4]	4E-3	128.1	3,434,000	4.4E+5	176	352
Montana						
Cosmic	1E-3	36.3	805,000	2.9E+4	12	23
Terrestrial	1E-3	29.2	805,000	2.4E+4	9	19
Internal	1E-3	38	805,000	3.1E+4	12	24
Totals	3E-3	103.5	805,000	8.3E+4	33	67
N. Dakota						
Cosmic	1E-3	29.9	660,000	2.0E+4	8	16
Terrestrial	1E-3	29.2	660,000	1.9E+4	8	15
Internal	1E-3	38	660,000	2.5E+4	10	20
Totals	3E-3	97.1	660,000	6.4E+4	26	51
S. Dakota						
Cosmic	1E-3	30.7	708,000	2.2E+4	9	17
Terrestrial	1E-3	29.2	708,000	2.1E+4	8	17
Internal	1E-3	38	708,000	2.7E+4	11	22
Totals	3E-3	97.9	708,000	6.9E+4	28	55
Utah						
Cosmic	1E-3	41.8	1,776,000	7.4E+4	30	59
Terrestrial		29.2	1,776,000	5.2E+4	21	41
Internal	1E-3	38	1,776,000	6.7E+4	27	54
Totals	4E-3	109.0	1,776,000	1.9E+5	77	155
Wyoming						
Cosmic	2E-3	50.4	502,000	2.5E+4	10	20
Terrestrial	1E-3	29.2	502,000	1.5E+4	6	12
Internal	1E-3	38	502,000	1.9E+4	8	15
Totals	4E-3	117.6	502,000	5.9E+4	24	47
Region 8 Totals	**4E-3**	**115.4**	**7,885,000**	**9.1E+5**	**362**	**724**

1 1990 population projections taken from "Table No. 27. State Population Projections: 1987-2010" in the U.S. Bureau of Census, *Statistical Abstract of the United States: 1988*, 108th Edition, Washington, D.C., 1987.

2 From Table 1 of EPA81. The cosmic ray and terrestrial doses include shielding.

3 From Table 2-4 of NCRP Report No. 93, "Ionizing Radiation Exposure of the Population of the United States," 1987. The internal dose is the effective whole body dose from naturally occurring internal emitters. However, it does not include the lung dose from the inhalation of radon and its progeny. For the purpose of this analysis, it is assumed that the internal dose does not vary significantly among locations. This is a reasonable assumption since the dose is predominantly due to K-40, which is under homeostatic control and does not vary significantly among individuals.

4 Totals may not add due to independent rounding.

The differences among states in the individual external exposures reflect differences in the external dose rates due to (1) the differences in the concentrations of naturally occurring radionuclides in soils, and (2) the differences in cosmic radiation associated with different elevations and latitudes. The differences among the states within the region are relatively small primarily because the comparisons are made on the basis of the average conditions within each state in the region. However, the differences in terrestrial radiation, and, in some cases cosmic radiation, among areas of a smaller scale within a state, such as at the county level or smaller, can be substantial. This occurs because local differences in soil type and geology can be large and significantly affect the terrestrial radiation fields. In addition, the cosmic ray field atop a mountain is significantly different than in a valley. Both types of differences tend to average out when looking at state wide averages (population risks), but can be substantial on a smaller (individual risk) scale. Further, when considering that people spend different amounts of time indoors, and that the structural material of a building can affect the indoor radiation fields, the variability in external dose can be even greater, perhaps on the order of 10 to 20 mrem/yr, depending on the structural material of the building alone (UNSCEAR82).

Occupational Radiation Exposures

A wide variety of Federal and State agencies regulate occupational exposure to ionizing radiation, with uniformity of worker protection established by Federal Guidance developed by the EPA and issued by the President. Current Federal Guidance (FR87) establishes a basic limit of 5 rem EDE per year for occupational exposure, and Federal agencies with regulatory responsibility are in the process of conforming their regulations to this recommended limit.

The major classes of occupational exposure include: Department of Energy (DOE) weapons production of research facilities; nuclear fuel cycle facilities; Department of Defense (DOD) facilities; non-fuel cycle facilities licensed by the U.S. Nuclear Regulatory Commission (NRC) or the Agreement States to use byproduct, source, and special nuclear materials (this includes hospitals and other medical facilities); air transportation; and mineral extraction and processing industries that process materials with elevated concentrations of naturally occurring uranium or thorium and their progeny.

In this report, estimates of the exposures and cancer risks to workers at each of these types of facilities except the mineral processing facilities are given. The lack of data for mineral extraction and processing industries is not believed to present a significant underestimate of the risks, as the primary exposure is to radon and its progeny which are not included in this problem area.

Table 2 presents the estimated exposures and risks from occupational exposure. For uranium fuel cycle and DOE facilities, the estimates are presented by site, and represent exposures of individuals with measurable exposures. The values given for nuclear power plants represent averages of 5 years of exposure data. Such average data provide a better estimate of collective risk as they capture the variations in exposure during different phases of operations, e.g., at power, normal refueling, and special maintenance. For nuclear power reactors it should also be noted that the doses are assigned to the unit where the exposure was incurred. Due to the widespread use of temporary workers during outages, the individuals receiving such exposures may or may not reside in the region. For medical, DOD, and other NRC-licensed facilities, and air transportation crews, the exposure data are only available in terms of national totals. The exposures and resulting risks were apportioned to the region on the basis of population. The exposure estimates for each of these components, with the exception of air transportation crews, are based on measured exposures.

Table 2: Occupational Radiation Exposure - Summary of Individual and Population Exposures and Risks

	Individuals		Population			
Industry/Site	Average Lifetime Fatal Cancer Risk	Average Exposure (mrem/y)	Population at Risk[1]	Exposure (person-rem/y)	Fatal Cancers per Year	Total Cancers per Year
Nuclear Fuel Cycle						
Power Reactors[2]						
Fort St. Vrain	1E-3	60	131	7.9E+0	0.002	0.004
Other Fuel Cycle - None Assessed in Region 8						
Fuel Cycle Totals[4]	**1E-3**	**60**	**131**	**7.9E+0**	**0.002**	**0.004**
DOE Facilities						
Rockwell Int. Rocky Flats	1E-3	820	1,719	1.4E+3	0.3	0.6
DOD Facilities[5]	**2E-3**	**90**	**1,900**	**1.7E+2**	**0.03**	**0.06**

Table 2(cont): Occupational Radiation Exposure - Summary of Individual and Population Exposures and Risks

Industry/Site	Individuals: Average Lifetime Fatal Cancer Risk	Individuals: Average Exposure (mrem/y)	Population: Population at Risk[1]	Population: Exposure (person-rem/y)	Population: Fatal Cancers per Year	Population: Total Cancers per Year
NRC-Licensed Facilities						
Medical Facilities[5]	3E-3	150	8,700	1.3E+3	0.3	0.5
Manufacturing & Distribution[5]	5E-3	270	380	1.0E+2	0.02	0.04
Other Users[5]	4E-3	210	4,000	8.4E+2	0.2	0.3
Industrial Radiography[2]	8E-3	450	175	7.9E+1	0.02	0.03
NRC Totals	**3E-3**	**175**	**13,255**	**2.3E+3**	**0.5**	**0.9**
Air Transport[6]	**1E-2**	**630**	**3,150**	**2.0E+3**	**0.4**	**0.8**
Region 8 Totals	**5E-3**	**293**	**20,155**	**5.9E+3**	**1.2**	**2.4**

1 Based on number of workers with measurable exposures.

2 Data represents a 5-year average, 1982-1986, of data presented in BR89.

3 No data available, estimates based on average values for BWRs.

4 Totals may not add due to independent rounding.

5 Based on data in Table 4 of EPA84a, estimates are for exposures in 1980.

6 Based on data in NCRP87.

For air crews, the exposures are estimated based on average exposure of 0.7 mrem/hr to enhanced cosmic radiation, and 900 hours/year exposure. The value of 0.7 mrem/hr corresponds to the dose rate at 39,000 feet, the typical cruising altitude of modern jets, and reflects the NCRP's recent revision of the quality factor for neutrons. The value does not take into account the increased dose rates associated with either solar flares or polar latitudes. Solar flares, which range from 2 to 12 per year and last from a few minutes to a week, can increase the dose rate by several hundred times (BA89). Nine hundred hours/year exposure represents the upper range of 620 - 900 air hours per year derived from data presented in FAA90 for flight crews.

Two additional points needed to be made regarding the estimated risks. The first is that the number of fatal cancers are estimated using 200 fatal cancers per 1E+6 person-rem. This approximate value, one-half the value used for estimating risks to the general population, may be derived from Table V-26 in NAS80 and reflects two facts. One, that for the continuous lifetime exposures on which the estimate of 400 fatal cancers per 1E+6 person-rem is based, approximately 60 percent of the risk is associated with exposures received in the first 19 years of life (EPA89a). And two, virtually all occupationally exposed individuals are 18 years of age or older.

The second point concerns the lack of estimates of maximum individual risk. Unfortunately, the need to protect the confidentiality of the workers makes it impossible to derive cumulative exposures for individuals. An upper-bound for maximum individual risk can be obtained by assuming 47 years of exposure at the 5 rem per year limit. This would result in a total exposure of 235 rem. Using a risk coefficient one-half that used for members of the general population, this would correspond to a maximum lifetime fatal cancer risk of roughly 8E-2.

Medical Radiation Exposures

Radiation is one of the principal tools of diagnostic medicine and of cancer therapy. Thus, the exposure is deliberate and its benefits are thought to outweigh the potential risks. The exposure data presented in Table 3 for medical radiation are derived from NCRP Report No. 93 (NCRP87). Since there are no documented statistical data or citations in the literature which would allow for the calculation of medical exposures by state or region, the collective exposures and cancer risks have been apportioned simply on the basis of population. This is believed to be reasonably accurate, since medical health care practices do not differ greatly among different regions of the country.

Table 3: Medical Radiation Exposure - Summary of Individual and Population Exposures and Risks

	Individuals		Population			
Type of Exposure	Average Lifetime Fatal Cancer Risk[1]	Average Exposure (mrem)	Population at Risk	Exposure (person-rem/y)	Fatal Cancers per Year	Total Cancers per Year
Medical X-Rays	4E-5	87	3,300,000	2.9E+5	115	230
Radiopharmaceuticals	2E-4	320	32,000	1.0E+4	4	8
Region 8 Totals[2]			**3,332,000**	**3.0E+5**	**119**	**238**

1 Lifetime risk of a single average exposure, see text.

2 Totals may not add due to independent rounding.

Extreme caution should be exercised in interpreting the risk estimates provided for medical exposures. The estimates of the lifetime individual fatal cancer risk are based on a single average exposure, as no data are available on cumulative individual exposures. In addition, the lifetime fatal cancer risk and the estimates of excess cancers are based on the risk coefficients for the general population. However, the age distribution of those receiving medical exposures differs from that of the general population, being highly skewed towards older individuals. While older persons are generally believed to be more radio-sensitive, actual cancer induction may actually be lower due to the long latency period of cancer induction. Thus, some of the estimated excess cancers may never actually be expressed due to the death of the individual from other causes.

Manmade and Technologically Enhanced Sources

Exposures to manmade and technologically enhanced sources includes exposures of member of the general public who live in the vicinity of the sources which were identified above as causing occupational exposures and/or those members of the public who travel by airplane. The EPA's Office of Radiation Programs has estimated the exposures to both nearby individuals and the populations within 80-km of sources that are felt to pose the greatest hazard of releasing radioactive materials into the ambient air (EPA84b and EPA89b). The estimates of exposure and risk that are presented in Table 4, with the exception of air travel, are derived from those estimates and only include exposure to effluents released to air. Exposure to radioactive materials via liquid pathways is not estimated, but is roughly comparable to exposures to radioactive materials released to air from industrial sources.

Table 4: Manmade and Technologically Enhanced Radiation - Summary of Individual and Population Exposures and Risks

Industry/Site	Individuals: Range of Lifetime Fatal Cancer Risk	Individuals: Maximum Exposure (mrem/y)	Population: Population at Risk[1]	Population: Exposure (person-rem/y)	Population: Fatal Cancers per Year	Population: Total Cancers per Year
Nuclear Fuel Cycle						
Uranium Mines						
Colorado	< 1E-6 - 6E-6	2E-1	NA	2.0E+0	9E-4	2E-3
South Dakota	< 1E-6 - 2E-6	6E-2	NA	1.0E+0	4E-4	8E-4
Wyoming	< 1E-6 - 2E-5	6E-1	NA	1.0E+1	5E-3	1E-2
Mines Totals[2]	< 1E-6 - 2E-5	6E-1	NA	1.3E+1	5E-3	1E-2
Uranium Mills						
Minerals Exploration Sweetwater Mill Sweetwater Co, WY	< 1E-6	2E-2	17,000	5.0E-2	2E-5	4E-5
Pathfinder Mines Lucky Mc Mill Gas Hills, WY	< 1E-6	3E-3	22,000	1.0E-5	7E-6	1E-5
Pathfinder Mines Shirley Basin Mill Shirley Basin, WY	< 1E-6	2E-2	69,000	2.0E-1	9E-5	2E-4

Table 4(cont): Manmade and Technologically Enhanced Radiation - Summary of Individual and Population Exposures and Risks

Industry/Site	Individuals: Range of Lifetime Fatal Cancer Risk	Individuals: Maximum Exposure (mrem/y)	Population: Population at Risk[1]	Population: Exposure (person-rem/y)	Population: Fatal Cancers per Year	Population: Total Cancers per Year
Plateau Resources Shootaring Canyon Mill Shootaring Canyon, UT	< 1E-6	6E-3	1,600	2.0E-3	7E-7	1E-6
Rio Algom La Sal Mill La Sal, UT	< 1E-6 - 2E-6	6E-2	21,000	8.0E-2	3E-5	6E-5
Umetco Minerals Corp. White Mesa Mill Blanding, UT	< 1E-6	2E-2	17,000	5.0E-2	2E-5	4E-5
Mills Totals	< 1E-6 - 2E-6	6E-2	150,000	4.0E-1	2E-4	4E-4
Fuel Fab.	< 1E-6 - 4E-6	1E-1	1,560,000	5.0E-1	2E-4	4E-4
<u>Power Reactors</u>						
Fort St. Vrain - Not Assessed						
<u>Other Fuel Cycle</u> - None in Region 8						
Fuel Cycle Totals	**< 1E-6 - 2E-5**	**6E-1**	**1,560,000**	**1.4E+0**	**6E-3**	**1E-2**
DOE Facilities						
Rocky Flats Plant Jefferson Co., CO	< 1E-6	3E-4	1,900,000	2.0E-2	9E-6	2E-5
DOD Facilities - None assessed in Region 8						
NRC-Licensed Facilities						
Hospitals*	< 1E-6	2E-2	7,890,000	3.0E+0	1E-3	2E-3
Laboratories*	< 1E-6	8E-3	7,890,000	1.0E+0	6E-4	1E-3
Low-level Waste Incinerators*	< 1E-6	4E-4	7,890,000	2.0E-1	8E-5	2E-4
NRC Totals	**< 1E-6**	**2E-2**	**7,890,000**	**4.0E+0**	**2E-3**	**3E-3**
Mineral Extraction Industries						
Phosphate Rock Producers	< 1E-6 - 1E-5	3E-1	2,600,000	1.0E+1	4E-3	8E-3

Table 4(cont): Manmade and Technologically Enhanced Radiation - Summary of Individual and Population Exposures and Risks

Industry/Site	Individuals: Range of Lifetime Fatal Cancer Risk	Individuals: Maximum Exposure (mrem/y)	Population: Population at Risk[1]	Population: Exposure (person-rem/y)	Population: Fatal Cancers per Year	Population: Total Cancers per Year
Wet Process Fertilizer Plants*	< 1E-6 - 3E-6	9E-2	502,000	2.0E+0	8E-4	2E-3
Elemental Phosphorus Plants	< 1E-6 - 6E-5	2E+0	71,000	1.0E+1	5E-3	1E-2
Mineral Extraction Industries Totals	**< 1E-6 - 6E-5**	**2E+0**	**3,100,000**	**2.0E+1**	**1E-2**	**2E-2**
Air Transport	**not estimated**	**-**	**7,890,000**	**1.1E+4**	**4.4**	**8.8**
Region 8 Totals	**< 1E-6 - >6E-5**	**2E+0**	**7,890,000**	**1.1E+4**	**4.4**	**8.8**

1 Population within 80-km

2 Totals may not add due to independent rounding.

* Model or reference facility.

The estimates for the exposure of the general population to industrial sources are based on both site-specific assessments and extrapolations from reference facilities. Where reference facilities provide the basis, the site name is marked with an asterisk (*). For actual facilities, the exposure of the maximally exposed individual reflects either an actual off-site residence, or the fencepost exposure in the predominant wind direction. Where reference facilities were used, the maximum exposure is based on an individual assumed at a close-in location (typically 150 m) in the predominant wind direction. Where the original assessment used a reference facility, collective populations are estimated using the generic population distributions that were assessed and the number of facilities in the region. If the projected population obtained in this manner exceeded the regional population, the population at risk was constrained to the regional population.

In assessing the exposures and risks due to air travel, only collective exposures and risks are given. The collective risk is based on 0.7 mrem/hr, 1.5 hours/trip, and a total of 340 million trips/year (NCRP87). The collective dose was then apportioned to the region on the basis of population.

Non-Ionizing Radiation

The biological effects of non-ionizing radiation are not well understood. At this time, the risks and impacts associated with manmade non-ionizing radiation found in the environment cannot be accurately assessed.

Non-ionizing radiation is part of the electromagnetic spectrum which does not strip electrons from atoms creating ions. This non-ionizing radiation consists of a broad range of electromagnetic phenomena including long-wavelength ultra-violet light, visible light, infra-red light, microwaves, radio-waves, and the electric and magnetic fields associated with electrical power and equipment (60 Hertz).

This type of radiation has long been known to have biological effects through a so-called "thermal" mechanism. That is, a mechanism whereby the radiation absorbed by a body results in a heating of the body's tissue. Almost all present-day exposure standards for non-ionizing radiation limit exposures to below "thermal" thresholds.

In addition to the thermal effects, scientists have observed phenomena that are not explained by "thermal" mechanisms. These phenomena have variously been called "athermal" or "nonthermal" bioeffects. Although the scientific literature has published reports of nonthermal bioeffects for some time, there has been an absence of "hard" scientific data corroborating such effects. This has led to skepticism about experiments displaying nonthermal effects.

Some scientists have suggested that nonthermal effects might possess unique properties that make traditional concepts of radiation dose inappropriate for describing some types of bioeffects of non-ionizing radiation. For example, "windows" in frequency and field intensity have been suggested to explain differences found in very similar scientific experiments. It has been hypothesized that effects might occur within these windows and not outside of them. If this is true, the traditional assumption would not hold that more exposure to the field would cause a more pronounced effect.

Bioeffects and Sources of Non-Ionizing Radiation

Until recently, the only nonthermal effect observed from non-ionizing radiation were behavioral changes in animals exposed to very high intensities at higher (radio and microwave) frequencies. However, recent epidemiologic studies at extremely low frequencies (60 Hertz) have indicated potential cancer effects in children. Moreover, a limited number of cellular level experiments have been performed that indicate the carcinogenicity is a plausible but not confirmed result of exposure to extremely low electromagnetic fields.

Epidemiologic studies suggesting a correlation between power frequency exposure and cancer include:

- o elevated incidence of cancer in children exposed in residences in proximity to electrical transmission and distribution lines;
- o elevated incidence of cancer in children whose father's were occupationally exposed; and
- o occupational exposure to electromagnetic fields.

The elevated risks associated with these types of exposure are quite modest. The reported evidence is statistically significant in some case-controlled studies of cancer in children. This human evidence, though, is observational in nature, and some have suggested that these studies did not control potentially relevant factors which might also lead to these statistical differences.

What is most striking about these epidemiologic studies is the type of exposure which has been correlated with cancer. The focus of exposure has been to power frequency (60 Hertz) magnetic fields at relatively low levels (2-3 milliGauss or, equivalently, 0.2-0.3 microTesla). In comparison, this level is well below the earth's static magnetic field of about 600 milliGauss (60 microTesla). Also, an electrical wire carrying 1 ampere of current produces 0.2-0.3 microTesla at a distance of 3 feet from the wire.

Sources of this level of magnetic (and electric) fields at and near power frequencies are ubiquitous. Sources include electric blankets, fluorescent lamps, TV receivers, computer terminals, hair dryers, electric razors, microwave ovens, stereo headphones, coffee makers, subway cars and platforms, powerlines (at the edge of the right-of-way), etc. Data on exposure of the general public to these power frequencies are limited.

Cellular experiments with low frequency non-ionizing radiation have neither confirmed nor refuted the results of the epidemiologic studies. Although many studies have not linked non-ionizing radiation to bioeffects, a few studies have noted changes in brain tissue calcium efflux and some other effects after exposure to electric and crossed electric/magnetic fields.

Major sources of population exposure to high frequency sources include special radars used by the military and civilian sector for air traffic control. Some radio transmitters may constitute sources of high level population exposure. In addition, some foreign sources operating above power levels allowed in the United States likely result in high levels of exposure to populations living near the border.

Population Exposure

Almost all exposure to non-ionizing radiation cannot be physically sensed. Most exposure can be inferred by knowing the characteristics of electrical or electronic equipment that are the sources of such radiation. Power lines and power transformers are examples of such equipment. Special instruments are available to measure the electric and magnetic field components of non-ionizing radiation.

Two notable studies have examined population exposure to power frequency and radio frequency non-ionizing radiation. These are a study by Silva, *et al.* (SI85) sponsored by the Electric Power Research Institute which compared human exposure during agricultural and recreational activities near power lines to exposure during domestic activities in the home. An EPA study (HA86) has also characterized population exposure to radio frequency non-ionizing radiation.

Most types of population exposure are likely to be comparable in all regions of the United States. Individual variability in the types of electrical equipment used in the home is more likely than commercial and military sources to determine personal exposure levels. In some instances, power transmission lines, power distribution lines, large electrical generators and motors, radars and radio transmitters constitute local "hot spots" of exposure. Actual population exposure is, however, difficult to infer without detailed measurements.

At our current level of understanding, it is not possible to establish direct links between population exposure to non-ionizing radiation and cancer. In fact, we are even uncertain as to which parameters are important to assessing exposure; i.e., magnetic field component, electrical field component, level of intensity of the field, frequency of the field, duration of exposure, etc.

Ecological Impacts of Ionizing Radiation

At the levels of environmental radioactivity of concern to this project, radiation exposure has little or no adverse effects on organisms other than man or on the environment.

The adverse effects associated with low-levels of radioactivity in the environment are cancer, genetic effects, and birth defects. Such effects, even if extremely rare or undetectable, are of concern to humans. However, for organisms other than man, the concern is not with individual organisms but on the viability of the species and the function and structure of the ecosystem as a whole. The following briefly summarizes the research and demonstrates that low-level radiation is of concern only to humans and may be considered inconsequential in terms of its potential ecological effects.

During the 1960s and 1970s a vast amount of radiobiological research was performed to assess the impacts of radiation on plant and animal communities. The research included a large number of comprehensive laboratory and field studies motivated primarily by concern over fallout from weapons tests. Excellent reviews of the literature are provided by Turner (TU) and Casaretti (CA68). A more recent review was prepared by the Office of Radiation Programs in 1986 (EPA86).

In summary, it appears that at prolonged exposures of ecosystems below a few rad per day there are no detectable adverse ecological impacts. Turner concludes that, though the community interactions to prolonged exposures to ionizing radiation are complex and difficult to predict, doses on the order of several hundred rads per year would be needed to cause extinction of a species. Such exposures can occur following a major nuclear accident (e.g., Chernobyl), but are not associated with the production and use of radioactive materials. Nor are they associated with uncontrolled sites where previous activities have resulted in the contamination of the site with radioactive materials.

Welfare Effects of Ionizing Radiation

The potential welfare effects associated with radiation exposure can be divided into two broad categories:

- costs associated with effects on human health, and
- costs associated with commercial damage.

The costs associated with health effects include direct medical costs and lost productivity due to the inability to conduct normal work activities. The 1988 report *Cancer Facts and Figures*, published by the American Cancer Society, estimates that for 1985 the total economic cost of cancer was $71.5 billion. This includes direct medical costs and indirect costs associated with lost productivity. The American Cancer Society estimates that there were 985,000 new cases of cancer in the United States in 1988. Since, over a 30 year period, the per capita age adjusted cancer death rate has increased at a rate of less than one percent per year, the estimate of 985,000 cancers can be used to estimate the approximate cost per cancer. Escalating the 1985 cost by 7.5 percent per year inflation in health care services (BC87), and assuming the cancer incidence remains virtually unchanged, results in an economic cost of cancer in 1990 dollars of approximately $100,000 per case. In Region 8, the total costs of radiogenic cancer would be on the order of $100 million per year, or roughly 3.1 percent of the regional cost of all cancers.

The costs associated with commercial damage caused directly by radiation are negligible. Unlike many other categories of environmental pollutants, radioactive contaminants and background radiation do not cause direct ecological damage. However, the contamination of facilities and sites where radioactive materials have been or are produced and used, can result in considerable cleanup costs. For commercial facilities, the costs of decontaminating and decommissioning the facilities and the sites are reflected in the costs of the products or services. For sites owned by government agencies, the costs will be borne by the taxpayers. Restoration of the sites operated for the Department of Energy has been initiated. Current estimates place these restoration costs in the hundreds of billions of dollars. Whether or not such costs will actually be incurred is uncertain at this time, and no estimate is made of the costs on a regional basis.

Other welfare effects associated with other classes of pollutants are generally not applicable to ionizing radiation. Radioactive effluents do not impair visibility, result in esthetic damage, or result in recreational losses. Nor, do they, at the levels corresponding to normal operations, result in commercial harvest loses or destruction of property. Agricultural losses due to accidental releases are not assessed.

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20.0 MINING WASTES

20.1 INTRODUCTION

Mining and milling sites in Region VIII, both active and inactive, produce wastes that have significant ecologic, human health, and welfare effects. Mining related wastes impact Region VIII resources through numerous media, including: air emissions, surface runoff, point source discharges, groundwater contamination, and the destruction of aquatic and terrestrial habitats. While mining wastes have effects considered in other Problem Areas including: non-point source discharges to surface waters, physical degradation of wetlands and aquatic habitats, groundwater contamination, drinking water contamination, abandoned/superfund hazardous waste sites, radiation other than radon, lead from all sources and physical degradation of terrestrial ecosystems, it is of sufficient importance in the Region to be considered in a detailed, separate risk assessment.

The sources of mining wastes in the Region are from hard rock and coal mines, uranium mines, sand and gravel mines, milling operations and abandoned mines and milling sites. Data on the extent of these activities and their ecologic, human health, and welfare effects are limited.

The extent of mining activities and their subsequent impacts in the Region are in some cases quantitatively, while in other instances qualitatively defined, depending on the source of wastes, type of pollutant and receptors.

Ecosystem effects of mining activities occur primarily through habitat destruction of terrestrial systems, and via runoff and spills to surface waters and groundwater, which can result in acute or chronic toxicity in aquatic systems.

Health effects from mining activities occur primarily through direct contact with contaminated soils and waters which are ingested, or via inhalation of toxic air pollutants.

Welfare effects of mining activities are associated with replacement, or mitigation costs of lost resources including: 1) water resources, (loss of surface and groundwater drinking water supplies, loss of irrigation waters for agriculture and live stock, loss of recreation use and the treatment costs to re-obtain these uses), 2) land resources, (exclusion from other uses and development, depressed real estate values, subsidence damages to property over mine sites, and 3) cost of illness measures associated with human health effects.

20.2 MINING WASTE SOURCE DATA

The quantity of mining wastes and their impact is related to the number and size of active and inactive mining sites. In addition, mine location, type of mining and milling activity, the proximity to sensitive receptors, and the regulatory authority responsible for the site also determine ecological, human health, and welfare impacts.

For Region VIII, data are presented on:

- the number of coal, hard rock and sand and gravel mining properties (USDI, Bureau of Mines (BOM) MILS data, Table 20-1);
- the acres of active coal mines (USDI, Office of Surface Mining, Table 20-2);
- the number of mining properties associated with various commodities (USDI, Bureau of Mines (BOM) MILS data, Table 20-3);
- the amount of commodity produced (Minerals Yearbook, Table 20-4) and the location or major active mining sites (Figures 20-1 through 20-6);
- the number, location, capacity, status and process used for uranium mills and mines in the U.S. (USEPA, 1989, Table 20-5a,b and 20-6);
- the number and location of CERCLA abandoned mine sites (USEPA, Table 20-7); and,
- the number and location of superfund NPL mine sites (USEPA, Table 20-7).

The number of coal, hard rock and sand and gravel mining properties in Region VIII are listed in Table 20-1. These data are derived from the USDI, Bureau of Mines (BOM) MILS data set. The data are a "current" listing from 1990, however, data entree began in 1974-1981 and only new large properties have been added to the data set since 1981. The number of properties listed provides no index to the scale of the operation, and many properties have no activity associated with them. The large numbers of properties in the Region are only a crude index of the scale of regional mining activities and their risks to environmental, human health, and welfare end points.

The acres of active coal mines under 1989 permits issued by the USDI, Office of Surface Mining, are listed in Table 20-2. An unknown fraction of the areas under permit are currently being mined. However, the tabulated mine permit areas do provide a direct measure of the area of land currently at risk due to coal mining activities. In Region VIII over 660,000 acres may be affected by coal mining activities.

Table 20-1
1990 USDI Bureau of Mines Listing
of Mining Properties by States and Commodity

State	Commodity = coal Current Status			Commodity = sand & gravel Current Status			Commodity = gold, silver, copper, lead, zinc, iron, or uranium Current Status		
	Producer	Past Producer	Temp. Shutdown	Producer	Past Producer	Temp. Shutdown	Producer	Past Producer	Temp. Shutdown
Colorado	96	809	12	644	533	1	268	5896	46
Montana	17	81	0	30	95	0	222	1375	9
North Dakota	16	939	0	88	47	0	0	13	0
South Dakota	23	197	0	204	409	0	16	344	5
Utah	25	179	67	388	1043	147	137	1546	58
Wyoming	36	707	0	60	80	34	101	677	2
Total Region VIII	213	2912	79	1414	2207	182	744	9851	120

Table 20-2
USDI Office of Surface Mining
Coal Mine Permits in 1989

	Acres		
State	Surface	Subsurface	Other
Colorado	42,986	45,800	20
Montana	48,758	129	0
North Dakota	44,722	0	15
South Dakota	0	0	0
Utah	0	150,519	357
Wyoming	319,661	10,410	0
TOTAL Region VIII	456,127	206,858	392

(Adele Merchant, Pers. Comm.)

Table 20-3
Number of Properties
BOM Mills Data 1982

Commodity	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	Region VIII
Aluminum	17		0	1	33	11	62
Antimony	1		0	9	28	0	38
Asbestos	2		0	0	2	16	20
Barium	4		0	0	3	6	13
Barite	22		0	0	22	3	47
Beryllium	109		0	107	26	14	256
Chromium	0		0	0	2	10	12
Cobalt	5		0	0	1	4	10
Columbium	4		0	34	1	6	45
Copper	1310		0	11	901	176	2398
Fluorine	183		0	4	177	21	385
Gold	4275		0	280	489	152	5196
Graphite	9		0	1	1	28	39
Iron	106		0	18	230	179	533
Lead	2395		0	43	744	25	3207
Lithium	2		0	34	1	5	42
Magnesium	12		0	0	19	18	49
Manganese	261		4	12	162	18	457
Mercury	6		0	0	11	1	18
Molybdenum	57		0	0	37	9	103
Nickel	18		0	0	0	6	24
Phosphate	2		0	1	46	127	176
Platium	1		0	0	4	17	22
Potash	9		0	0	37	20	66
Rare Earth	26		0	0	1	9	36
Sand & grave	1843		193	680	1858	299	4873
Silver	3573		0	264	796	37	4670
Sulfur	38		0	6	16	19	79
Tantalum	12		0	30	0	9	51
Thorium	27		0	0	4	12	43
Tin	15		0	96	2	3	116
Titanium	10		0	0	10	44	64
Tungsten	252		0	52	111	35	450
Vanadium	2051		0	0	297	8	2356
Zinc	1969		0	5	446	11	2431
Zirconium	5		0	0	9	1	15

Table 20-4
1988 Quantity Values by State

Mineral	Units	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	REGION VIII TOTAL
Beryllium	Short tons					5,851		5,851
Cement								
Masonry	Thousand short tons				4			4
Portland	Thousand short tons				490	772		1,262
Clays	Short tons	272,790	101,194	84,787	Withheld	340,156	2,357,616	3,156,543
Copper	Metric tons	898						898
Gold	Troy ounces	164,809	294,976		449,514			909,299
Gypsum	Thousand short tons		27			Withheld		27
Lead	Metric tons		8,266					8,266
Lime	Thousand short tons			108		365	26	499
Salt	Thousand short tons					1,006		1,006
Sand and gravel								
Construction	Thousand short tons	21,566	7,241	3,772	7,929	17,843	3,413	61,764
Industrial	Thousand short tons					3		3
Silver	Troy ounces	854,413	6,186,074		84,398			7,124,885
Stone								
Crushed	Thousand short tons	10,600	1,800		5,500	7,300	2,500	27,700
Dimension	Short tons	3,450			43,297	2,004		48,751
Talc	Short tons		377,789					377,789
Vermiculite	Short tons							0
Zinc	Metric tons		18,935					18,935

Figure 20.1
Principal Mineral Producing Localities in Colorado

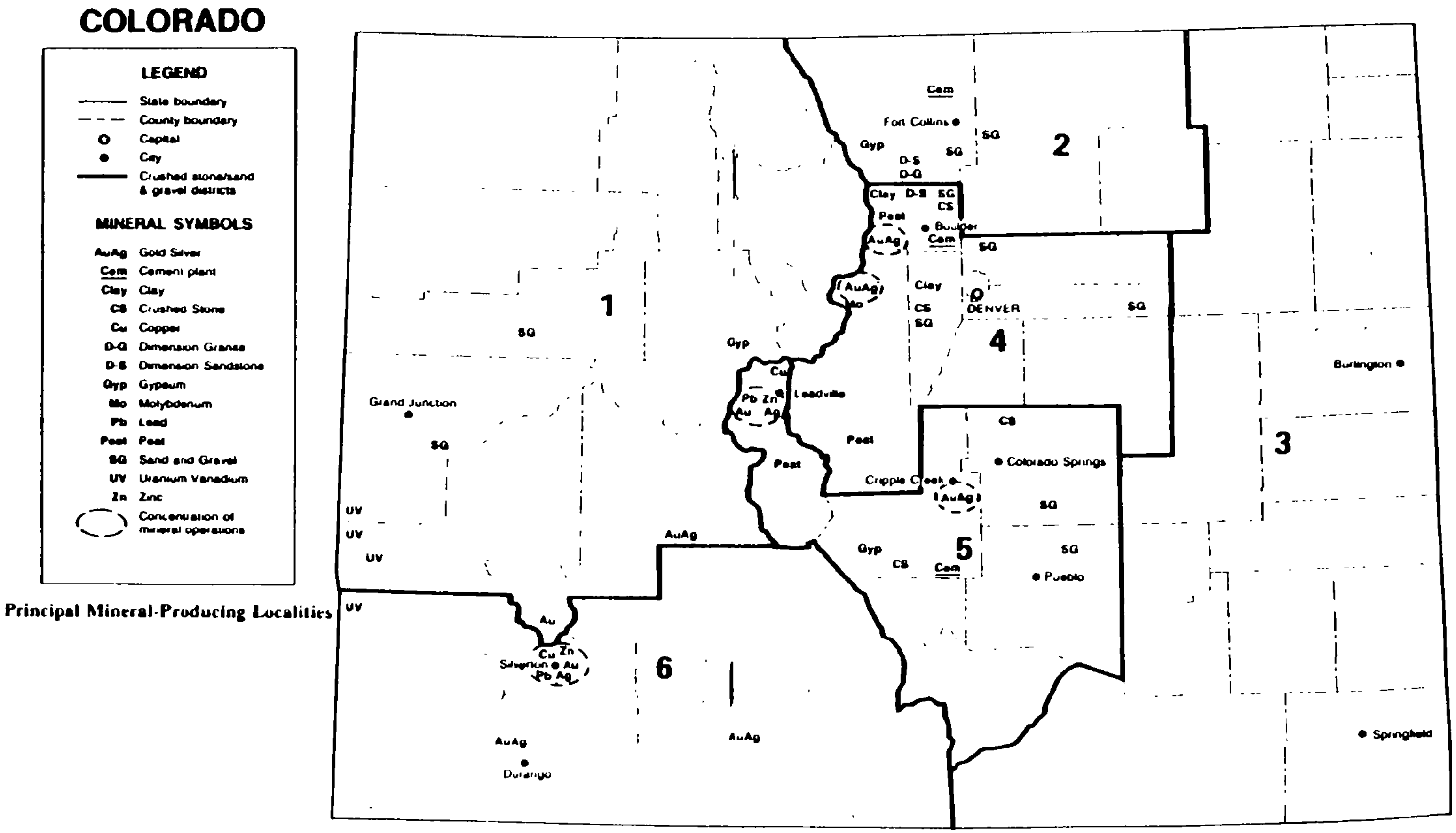
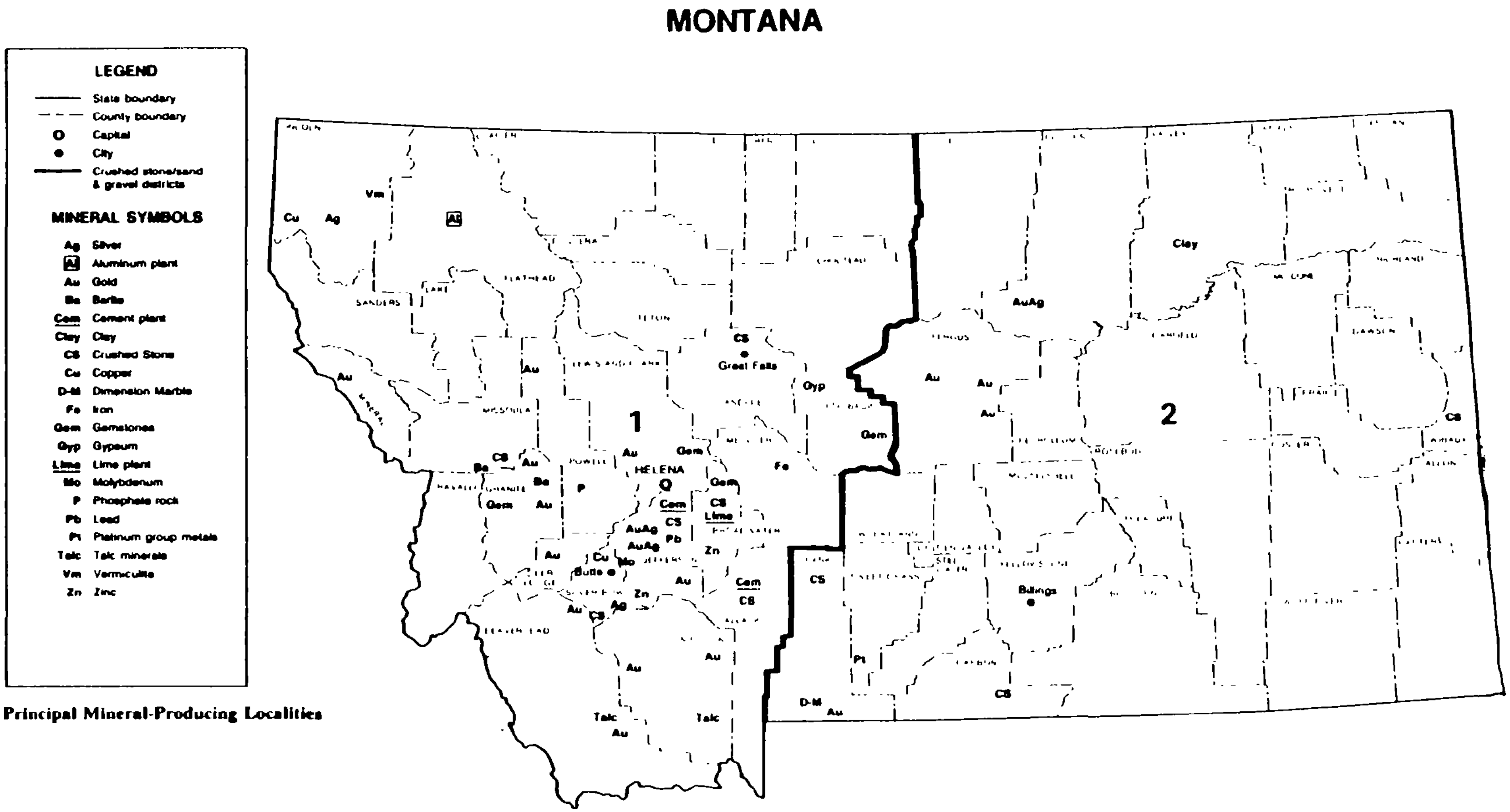
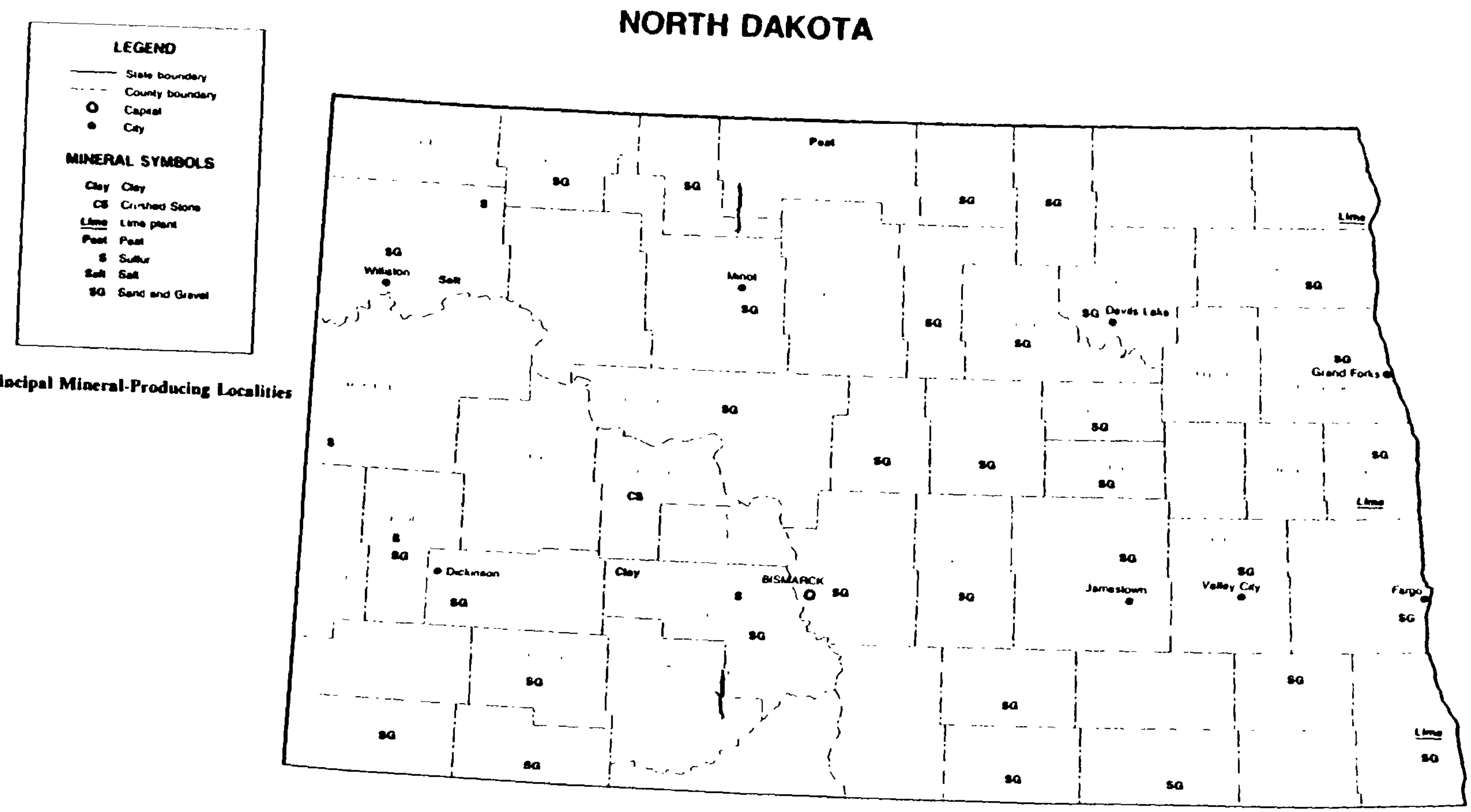


Figure 20.2
Principal Mineral Producing Localities in Montana



Principal Mineral-Producing Localities

Figure 20.3
Principal Mineral Producing Localities in North Dakota



Principal Mineral-Producing Localities

Figure 20.4
Principal Mineral Producing Localities in South Dakota

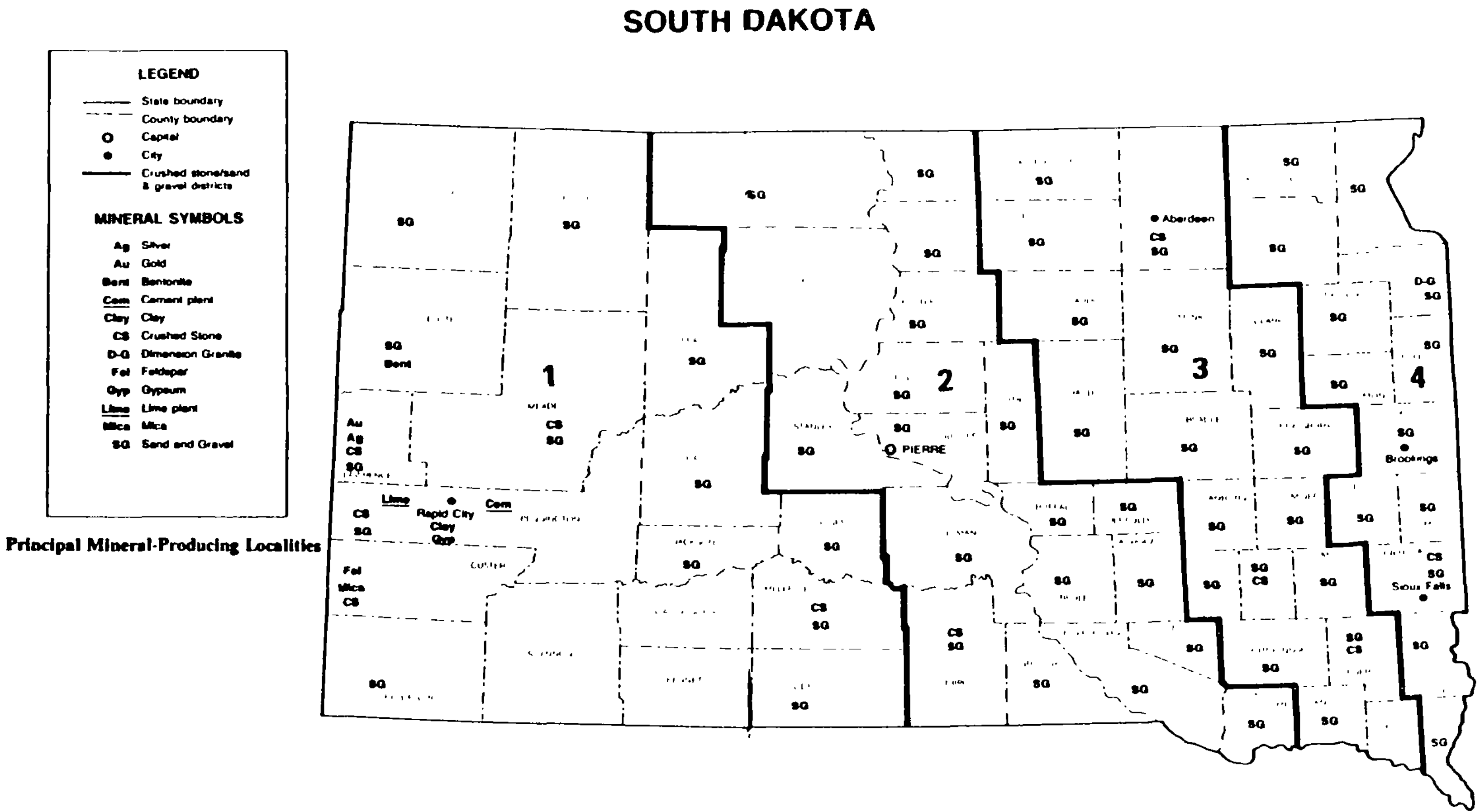
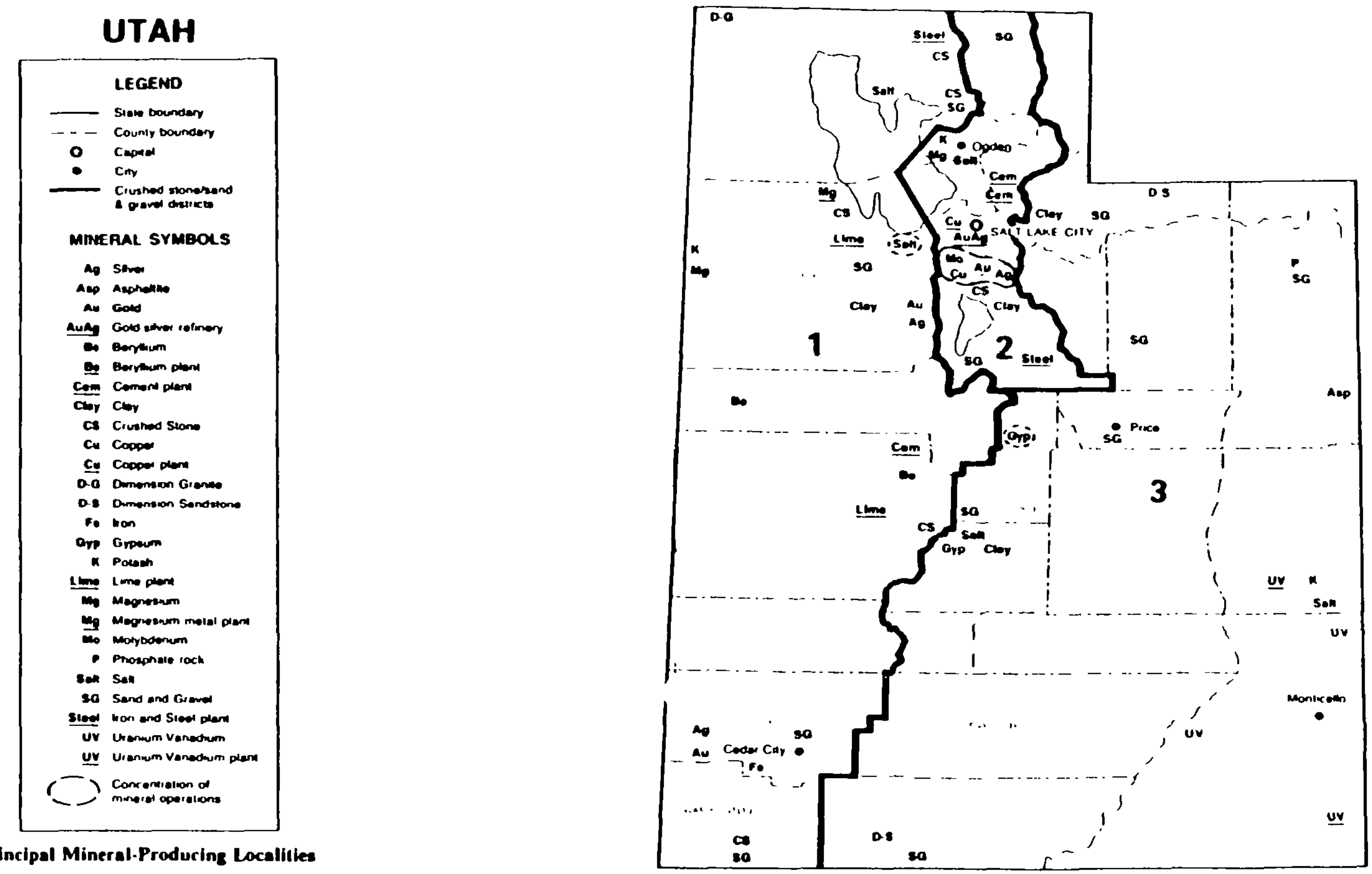
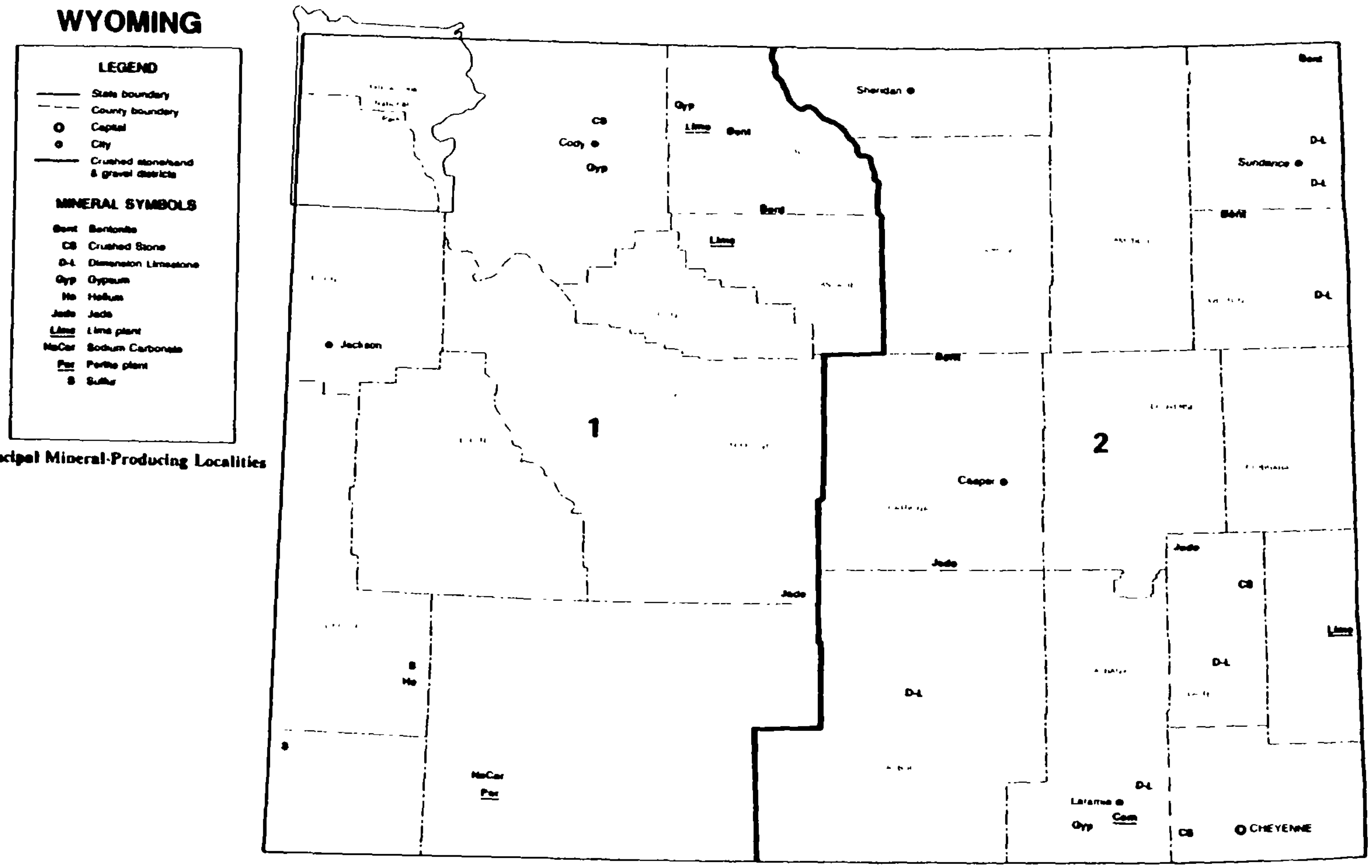


Figure 20.5
Principal Mineral Producing Localities in Utah



Principal Mineral-Producing Localities

Figure 20.6
Principal Mineral Producing Localities in Wyoming



Principal Mineral-Producing Localities

Table 20-5a
Currently Operating Underground Uranium Mines
in Region VIII

State	Mine Name	Current Ore Production Rate (MT/d) (a)
Colorado	Calliham	?
Colorado	Deremo-Snyder	280
Colorado	King Solomon	350
Colorado	NIL	50
Colorado	Schwartzenwalder	0
Colorado	Sunday	200
Colorado	Wilson-Silverbell	90
Utah	La Sal	160
Utah	Snowbell-Pandora	54
Wyoming	Sheep Mountain #1	220

(a) MT/d - metric tons per day; 1 short ton
= 0.907 metric ton

Table 20-5b
Estimated Status (a) of Surface
Uranium Mine Reclamation

State	Surface Uranium Mines with > 1,000 Tons Production		Total Ore Production 1,000- 100,000 Tons			Total Ore Production >100,000 Tons		
	1,000-100,000 Tons	Greater than 100,000 Tons	Class I (%)	Class II (%)	Unreclaimed (%)	Class I (%)	Class II (%)	Unreclaimed (%)
Colorado	12	4	5	20	75	5	20	75
Monatana	1	0						
North Dakota	10	0	0	5	95	--	--	--
South Dakota	33	2	0	5	95	0	5	95
Utah	6	0	0	0	100	--	--	--
Wyoming	66	31	5	40	55	5	40	55

(a) Status defined as:
Class I - total backfill, recontouring, and revegetation;
Class II - resloping of waste piles and pits, topsoiling, and revegetation;
Unreclaimed - property abandoned without restoration.

Table 20-6
Licensed Conventional Uranium Mills
as of June 1989 (a)

State	Mill	Owner	Operating Status (b)	Reclamation Status (c)
Colorado	Canon City	Cotter Corp.	Standby	Future
	Uravan	UMETCO Minerals	Standby	In Progress (d)
South Dakota	Edgemont	TVA	Decommission	Completed
Utah	White Mesa	UMETCO Minerals	Active	Future
	Rio Algom	Rio Algom	Standby	In Progress (e)
	Moab	Atlas	Decommission	In Progress
	Shootaring	Plateau Resources	Standby	Future
Wyoming	Lucky Mc	Pathfinder	Standby	Future
	Split Rock	Western Nuclear	Decommission	In Progress
	Umetco	UMETCO Minerals	Decommission	In Progress
	Bear Creek	Rocky Mt. Energy	Decommission	In Progress
	Shirley Basin	Pathfinder	Active	Future
	Sweetwater	Minerals Expl.	Standby	Future
	Highland	EXXON	Decommission	Cover in Place
	FAP	Amerian Nuclear Corp.	Decommission	Unknown
	Petrotomics	Petrotomics	Decommission	Design Approval Pending

Table 20-6 (cont.)
Licensed Conventional Uranium Mills
as of June 1989 (a)

(a) Data obtained from conversations with cognizant personnel in Agreement States and the NRC, comments submitted by individual companies and the American Mining Congress during the public comment period, and site visits. Does not include mills licensed but not constructed.

(b) Active mills are currently processing ore and producing yellowcake. Standby mills are not currently processing ore but are capable of restarting. At mills designated by "Decommission", the mill structure has been or is being dismantled and no future milling will occur at the site.

(c) Reclamation to the UMTRCA requirements is in various stages of completion, creating a dynamic situation. The terms used to describe the reclamation status are as follows: "Future" means that the impoundment is being maintained to accept additional tailings and that reclamation activities have not been started; "Design Approval Pending" means that the final disposal design has been submitted for regulatory approval and that preliminary reclamation activities are underway; "In Progress" means that active relamation has begun, but the final cover is not completed; "Cover in Place" designates that the final earthen cover has been completed, but final stabilization has not been completed; and "Completed" means that disposal and stabilization have been accomplished in accordance with the UMTRCA requirements.

(d) According to UMETCO, the mill is being held on standby but the entire impoundment area is being reclaimed. Thus, if future milling is done at this facility a new impoundment will have to be constructed. For the purposes of this analysis, the facility is grouped with other decommissioning mills.

(e) The upper impoundment, which is filled, is being reclaimed. The lower impoundment is being maintained to accept future tailings.

Table 20-7
Mining and Milling CERCLA Sites in Region VIII

NAME	CITY	COUNTY	STATE	EVENT TYPE
SEVEN DEVILS MINE	WATERON	JEFFERSON	CO	DS1 PA1 SI1
CAPTAIN JACK MILL	WARD	BOULDER	CO	RV1 DS1 PA1
FLATIRIONS COMPANIES PROPERTIES	BOULDER	BOULDER	CO	DS1 PA1
HENDRICKS MINING & MILLING	BOULDER	BOULDER	CO	DS1 PA1 HR SI1
CENTRAL CITY-CLEAR CREEK	IDAHO SPGS, CENT. CY, BK HA	CLEAR CR & GILPI	CO	RV1 RV2 DS1 PA1 HR NP1 NF1 SI1 CR1 CR2 AR1 WP RI1 FS1 RO RD1 MA TA1 TA2 TA3 OH AR1 FS1 RO RD1 RD2 RA1 RA2 TA1 AR1 FS1 TA1
HENDERSON MINE CLIMAX MOL	EMPIRE	CLEAR CREEK	CO	DS1 PA1
SILVER MOUNTAIN-GRACE MINE SITE	EMPIRE	CLEAR CREEK	CO	DS1 PA1
ILSE MINE	WESTCLIFFE	CUSTER	CO	DS1 PA1
LAMOTTE MINE	RICO	DOLORES	CO	DS1 PA1
RICO-ARGENTINE	RICO	DOLORES	CO	DS1 PA1 SI1
EAGLE MINE	GILMAN	EAGLE	CO	IR1 DS1 PA1 HR NP1 NF1 SI1 CR1 AR1 CO RO RD1 RA1 HA1 OH1
FREJONLEY MINE	MCCOY	EAGLE	CO	RV1 DS1 PA1
NEW RIFLE URANIUM MILL TAILINGS	RIFLE	GARFIELD	CO	DS1 PA1
OLD RIFLE URANIUM MILL TAILINGS	RIFLE	GARFIELD	CO	DS1 PA1
RIO BLANCO OIL SHALE COMPANY TRACT	RIFLE	GARFIELD	CO	DS1 PA1
HAROLD BLACKHAWK	BLACKHAWK	GILPIN	CO	RV1 DS1 PA1
INACTIVE GOLD MINING	CENTRAL CITY	GILPIN	CO	DS1 PA1 SI1
HENDERSON ML CLIMAX MOL	PARSHALL	GRAND	CO	DS1 PA1
GUNNISON MILL SITE	GUNNISON	GUNNISON	CO	DS1 PA1 SI1
KERR MINE	WALDEN	JACKSON	CO	DS1 PA1 SI1
COORS PORCELAIN CO-CLAY MINE	GOLDEN	JEFFERSON	CO	DS1 PA1
ASARCO INC LEADVILLE UNIT	LEADVILLE	LAKE	CO	DS1 PA1
CALIFORNIA GULCH	LEADVILLE	LAKE	CO	IR1 DS1 PA1 HR NP1 NF1 SI1 CR1 RM AR1 WP CO TS1 RO RD1 RD2 RA1 OM MA TO1 HA1 CR1 AR1 CO1
LEADVILLE TUNNEL	LEADVILLE	LAKE	CO	DS1 PA1 SI1
SLAG PILE (NL IND. PROP.)	LEADVILLE	LAKE	CO	DS1 PA1 SI1
GATEWAY VANADIUM MILL	GATEWAY	MESA	CO	DS1 PA1 HR SI1
GRAND JUNCTION URANIUM MILL TAILING	GRAND JUNCTION	MESA	CO	DS1 PA1
LOMA VANADIUM MILL	LOMA	MESA	CO	DS1 PA1 HR SI1
K-T MINE	MAYBELL	MOFFAT	CO	DS1 PA1
GENL ELEC URANIUM MGMT CORP	NATURITA	MONTROSE	CO	DS1 PA1
NATURITA URANIUM MILL TAILINGS	NATURITA	MONTROSE	CO	DS1 PA1

Table 20-7 (cont.)
Mining and Milling CERCLA Sites in Region VIII

NAME	CITY	COUNTY	STATE	EVENT TYPE
URAVAN URANIUM (UNION CARBIDE)	URAVAN	MONTROSE	CO	DS1 PA1 HR NP1 NF1 SI1 CR1 AR1 CO RO RD1 RA1
VANADIUM MILL SITE NEWMIRE COLORAD	TELLURIDE	MONTROSE	CO	DS1 PA1 HR1
IDARADO MINE-OURAY	OURAY	OURAY	CO	DS1 PA1 SI1
SMUGGLER MOUNTAIN	ASPEN	PITKIN	CO	RV1 DS1 PA1 NP1 NF1 SI1 CR1 CR2 AR1 FS1 FS2 CO CO RO RD1 RD2 MA TA1 TA2 AR1
ENERGY FUELS MINE NO 1	STEAMBOAT SPRINGS	ROUTT	CO	DS1 PA1
ENERGY FUELS MINE NO 2	STEAMBOAT SPRINGS	ROUTT	CO	DS1 PA1
ENERGY FUELS MINE NO 3	STEAMBOAT SPRINGS	ROUTT	CO	DS1 PA1
MIDDLE CREEK MINE	STEAMBOAT SPRINGS	ROUTT	CO	DS1 PA1
TWENTY MILE MINE	MILNER	ROUTT	CO	DS1 PA1
NL IND, MINE, MILL	BONANZA	SAGUACHE	CO	DS1 PA1
BAKER'S PARK MILL	HOWARDSVILLE	SAN JUAN	CO	DS1 PA1 PA2 HR SI1
STANDARD METALS CORP MAYFLOWER MI	SILVERTON	SAN JUAN	CO	DS1 PA1 SI1
STANDARD METALS CORP SUNNYSIDE MI	GLADSTONE	SAN JUAN	CO	DS1 PA1 SI1
ATLAS MINERALS-SUMMIT PROP		SAN MIGUEL	CO	DS1 PA1 SI1
IDARADO MINE-TELLURIDE	TELLURIDE	SAN MIGUEL	CO	DS1 PA1 SI1
N CONTINENT URANIUM MILL TAILINGS	SLICKROCK	SAN MIGUEL	CO	DS1 PA1
PLACERVILLE TRAM SITE	PLACERVILLE	SAN MIGUEL	CO	DS1 PA1 HR SI1
SAWPIT TRAM SITE (ORE STORAGE)	SAWPIT	SAN MIGUEL	CO	DS1 PA1 HR SI1
UNION CARBIDE URANIUM MILL TAILINGS	SLICKROCK	SAN MIGUEL	CO	DS1 PA1
CAMERON HEAP LEACH	CRIPPLE CREEK	TELLER	CO	DS1 PA1 SI1
APEX MILL-BANNACK STATE PARK	BANNACK	BEAVERHEAD	MT	DS1 PA1 HR SI1
ERMONT MILL-MILL TAILINGS	ARGENTA	BEAVERHEAD	MT	DS1 PA1
TUNGSTEN MILL-MILL TAILINGS	GLEN	BEAVERHEAD	MT	DS1 PA1 PA2
ANACONDA MINERALS CO, GREAT FALLS	BLACK EAGLE	CASCADE	MT	DS1 PA1 HR1
ANACONDA CO. SMELTER	ANACONDA	DEER LODGE	MT	RV1 DS1 PA1 HR1
MONTANA RADIATION-ANACONDA	ANACONDA	DEER LODGE	MT	DS1 PA1
KENDALL VENTURE MINE	HILGER	FERGUS	MT	DS1 PA1
ASBESTOS MINE (KARST)	BOZEMAN	GALLATIN	MT	DS1 PA1
PHILIPSBURG MINING AREA	PHILIPSBURG	GRANITE	MT	DS1 PA1
HIGH ORE MINE	BASIN	JEFFERSON	MT	DS1 PA1
WICKES/CORBIN MINING SITE	WICKES	JEFFERSON	MT	DS1 PA1
GOLDEN MESSENGER MINE	YORK	LEWIS AND CLARK	MT	DS1 PA1
GOLDSIL MINING CO.	MARYSVILLE	LEWIS AND CLARK	MT	DS1 PA1 SI1
KAISER CEMENT	MONTANA CITY	LEWIS AND CLARK	MT	DS1 PA1 SI1

Table 20-7 (cont.)
Mining and Milling CERCLA Sites in Region VIII

NAME	CITY	COUNTY	STATE	EVENT TYPE
MOTHER LODE GOLD & SILVER LTD.	EAST HELENA	LEWIS AND CLARK	MT	IR1 DS1 PA1 SI1 AR1
ASARCO INC TROY UNIT	TROY	LINCOLN	MT	DS1 PA1
JARDINE ARSENIC TAILINGS	JARDINE	PARK	MT	DS1 PA1
MCLAREN MILL TAILINGS	COOKE CITY	PARK	MT	RV1 DS1 PA1 PA2
ZORTMAN MINE	LEWIS & CLARK NATL FOREST	BLAINE	MT	DS1 PA1
ROCKY MOUNTAIN PHOSPHATE	GARRISON	POWELL	MT	DS1 PA1 HR1
FLATHEAD MINE AREA		SANDERS	MT	DS1 PA1
REVAIS CREEK MINE	DIXON	SANDERS	MT	DS1 PA1
SLUICE GULCH LEAKING MINE ADIT	PHILIPSBURG	SANDERS	MT	DS1 PA1
ANACONDA COPPER CO BUTTE OPERATIO	BUTTE	SILVER BOW	MT	DS1 PA1
EMPIRE SAND AND GRAVEL	BILLINGS	YELLOWSTONE	MT	DS1 PA1 SI1
LOHOFF GRAVEL PIT	BILLINGS	YELLOWSTONE	MT	DS1 PA1 SI1 SI2
BOWMAN LIGNITE ASHING	GRIFFIN	BOWMAN	ND	DS1 PA1
ARSENIC TRIOXIDE SITE	LIDGERWOOD	RICHLAND	ND	RS1 RV1 RV2 DS1 PA1 HR NP1 NF1 SI1 SI2 CR1 AR1 WP RI1 FS1 RO RD1 RA1 TA1 CR1 AR1 CO RO RD1 RD2 RA1 RA2 MA1
SARGENT COUNTY ARSENIC	FORMAN	SARGENT	ND	DS1 PA1
SLOPE COUNTY ARSENIC SITE	AMIDON	SLOPE	ND	DS1 PA1
EDGEMONT SD URANIUM MILL TAILINGS	EDGEMONT	FALL RIVER	SD	DS1 PA1 PA2
TVA SILVER KING MINES INC	EDGEMONT	FALL RIVER	SD	DS1 PA1 PA2
ANNIE CREEK MINE & PROCESSING	LEAD	LAWRENCE	SD	DS1 PA1 SI1
HOMESTAKE MINING CO GOLD DIV	LEAD	LAWRENCE	SD	DS1 PA1
MAITLAND TAILINGS IMPOUND	LEAD	LAWRENCE	SD	DS1 PA1
STRAWBERRY CREEK MINE TAILINGS	LEAD	LAWRENCE	SD	DS1 PA1
VIPONT MINE	GROUSE CREEK	BOX ELDER	UT	DS1 PA1
DRY VALLEY VANADIUM MILL	SAN JUAN	DAVIS	UT	DS1 PA1
GOLD DOME MINING AND MILLING SITE	OREM	UTAH	UT	DS1
GREEN RIVER URANIUM MILL TAILINGS	GREEN RIVER	EMERY	UT	IR1 DS1 PA1 AR1
ATLAS MINERAL CORP MILL SITE	MOAB	GRAND	UT	DS1 PA1 SI1
ORE BUYING STATION-MOAB	MOAB	GRAND	UT	DS1 PA1
THOMPSON URANIUM ORE	THOMPSON	GRAND	UT	DS1 PA1
DESERT MOUNDS MINE	CEDAR CITY	IRON	UT	DS1 PA1
EAST SUMMIT MINING CLAIMS	MODENA	IRON	UT	DS1
BINGHAM CREEK CHANNEL	COPPERTON	SALT LAKE	UT	DS1 PA1
BINGHAM CREEK/ANACONDA TAILINGS	COPPERTON	SALT LAKE	UT	DS1 PA1

Table 20-7 (cont.)
Mining and Milling CERCLA Sites in Region VIII

NAME	CITY	COUNTY	STATE	EVENT TYPE
BUTTERFIELD MINE (ST. JOE'S TUNNEL)	R3,T4, SOUTH SEC 12	SALT LAKE	UT	DS1 PA1
CHEVRON FERTILIZER AND MINING PLANT	MAGNA	SALT LAKE	UT	DS1 PA1 PA2
FRYE CANYON TAILING	HITE	SALT LAKE	UT	DS1 PA1
GENEVA ROCK PRODUCTS	SALT LAKE CITY	SALT LAKE	UT	DS1 PA1
KENNECOTT-BINGHAM	COPPERTON	SALT LAKE	UT	DS1 PA1
KENNECOTT TAILINGS	MAGNA	SALT LAKE	UT	DS1 PA1
LARK TAILINGS	LARK	SALT LAKE	UT	DS1 PA1
OLD COBALT TAILINGS POND	LAKE POINT	SALT LAKE	UT	DS1 PA1 PA2
SHARON STEEL (MIDVALE TAILINGS)	MIDVALE	SALT LAKE	UT	RS1 RV1 DS1 PA1 HR NP1 SI1 AR1 CR1 AR1 WP CO MA MA TA1 AR1 FS1
VITRO URANIUM MILL TAILINGS	SALT LAKE CITY	SALT LAKE	UT	DS1 PA1
MONTICELLO MILL TAILINGS (DOE)	MONTICELLO	SAN JUAN	UT	DS1 PA1 PA2 NP1 NF1 SI1 AR1 CO MA CO1
MONTICELLO VICINITY PROPERTIES	MONTICELLO	SAN JUAN	UT	DS1 PA1 HR NP1 NF1 SI1 CR1 AR1 CO RO RD1 RA1 MA OH1
RIO ALGOM CORP/LISBON MINE	LA SAL	SAN JUAN	UT	DS1 PA1
RICHARDSON FLAT TAILINGS	PARK CITY	SUMMIT	UT	DS1 PA1 NP1 SI1 CO1
SILVER CREEK TAILINGS	PARK CITY	SUMMIT	UT	DS1 PA1 HR NP1 SI1 NR FP1
SILVER MAPLE CLAIMS	PARK CITY	SUMMIT	UT	DS1 PA1
AMER. CONSOLIDATED MINING CLIFTON SI	CLIFTON	TOOELE	UT	DS1 PA1
ANACONDA COPPER CO-CARR FORK OPE	TOOELE	TOOELE	UT	DS1 PA1 PA2 SI1 SI2
BAUER TAILINGS	BAUER	TOOELE	UT	DS1 PA1 PA2 SI1
KEIGLEY QUARRY/US STEEL CORP	SANTAQUIN	UTAH	UT	DS1 PA1
SOAPSTONE BASIN SINKHOLE	PROVO	UTAH	UT	DS1 PA1 SI1
TROJAN CORP	SPANISH FRK	UTAH	UT	DS1 PA1 PA2
MAYFLOWER MOUNTAIN TAILINGS	MAYFLOWER MOUNTAIN	WASATCH	UT	DS1 PA1 HR NP1 SI1 NR FP1
LEEDS SILVER RECLAMATION SITE	LEEDS	WASHINGTON	UT	DS1 PA1
SOUTHWEST ASSAY SITE	LEEDS/SILVER REEF	WASHINGTON	UT	DS1 PA1
WESTERN ZIRCONIUM INC	OGDEN	WEBER	UT	DS1 PA1
K&N ENERGY-COOPER STATION	WALTMAN	NATRONA	WY	RV1
WILLIAMS STRATEGIC METALS	LARAMIE	ALBANY	WY	DS1 PA1
PORCUPINE CREEK MINE	LOVELL	BIG HORN	WY	DS1 PA1 PA2
BAGGS URANIUM MILL SITE	BAGGS	CARBON	WY	DS1 PA1
HANNA SUBSIDENCE PITS	HANNA	CARBON	WY	DS1 PA1
SPLIT ROCK URANIUM MILL ACID POND	JEFFREY CITY	CARBON	WY	DS1 PA1
SPLIT ROCK URANIUM MILL SITE	JEFFREY CITY	CARBON	WY	DS1 PA1

Table 20-7 (cont.)
Mining and Milling CERCLA Sites in Region VIII

NAME	CITY	COUNTY	STATE	EVENT TYPE
SPOOK SITE		CONVERSE	WY	DS1 PA1
ATLANTIC CITY ORE OPERATIONS	LANDER	FREMONT	WY	DS1 PA1
DUNCAN MINE-ATLANTIC CITY	ATLANTIC CITY	FREMONT	WY	DS1 PA1
RIVERTON URANIUM MILL TAILINGS	RIVERTON	FREMONT	WY	DS1 PA1
AMOCO, BLACK HILLS BENTONITE	CASPER	NATRONA	WY	DS1 PA1
ASBESTOS MINE-CASPER MOUNTAIN	CASPER	NATRONA	WY	DS1 PA1

NPL SITES

NAME	CITY	COUNTY	STATE	EVENT TYPE
SMUGGLER MOUNTAIN	ASPEN	PITKIN	CO	RV1 DS1 PA1 NP1 NF1 SI1 CR1 CR2 AR1 FS1 FS2 CO CO RO RD1 RD2 MA TA1 TA2 AR1
EAGLE MINE	GILMAN	EAGLE	CO	IR1 DS1 PA1 HR NP1 NF1 SI1 CR1 AR1 CO RO RD1 RA1 HA1 OH1
CENTRAL CITY-CLEAR CREEK	IDAHO SPGS, CENT. CY, BK HA	CLEAR CR & GILPI	CO	RV1 RV2 DS1 PA1 HR NP1 NF1 SI1 CR1 CR2 AR1 AR2 AR3 WP RI1 FS1 RO RD1 RD2 MA TA1 TA2 TA3 OH AR1 FS1 RO RD1 RD2 RA1 RA2 TA1 AR FS TA1
CALIFORNIA GULCH	LEADVILLE	LAKE	CO	IR1 DS1 PA1 HR NP1 NF1 SI1 CR1 RM AR1 WP CO TS1 RO RD1 RD2 RA1 OM MA TO1 HA1 CR1 AR1 CO1
URAVAN URANIUM (UNION CARBIDE)	URAVAN	MONTROSE	CO	DS1 PA1 HR NP1 NF1 SI1 CR1 AR1 CO RO RD1 RA1
ARSENIC TRIOXIDE SITE	LIDGERWOOD	RICHLAND	ND	RS1 RV1 RV2 DS1 PA1 HR NP1 NF1 SI1 SI2 CR1 AR1 AR2 WP RI1 FS1 RO RD1 RA1 TA1 CR1 AR1 CO RO RD1 RD2 RA1 RA2 MA1
MIDVALE SLAG	MIDVALE	SALT LAKE	UT	RS1 RV1 DS1 PA1 NP1 SI1 AR1 MA TA1
SHARON STEEL (MIDVALE TAILINGS)	MIDVALE	SALT LAKE	UT	RS1 RV1 DS1 PA1 HR NP1 SI1 AR1 CR1 AR1 WP CO MA MA TA1 AR1 FS1
MONTICELLO MILL TAILINGS (DOE)	MONTICELLO	SAN JUAN	UT	DS1 PA1 PA2 NP1 NF1 SI1 AR1 CO MA CO1
MONTICELLO VICINITY PROPERTIES	MONTICELLO	SAN JUAN	UT	DS1 PA1 HR NP1 NF1 SI1 CR1 AR1 CO RO RD1 RA1 MA OH1
RICHARDSON FLAT TAILINGS	PARK CITY	SUMMIT	UT	DS1 PA1 NP1 SI1 CO1

Because effects and their consequent risks vary with the type of mining activity, the number of mining properties associated with various commodities is of interest. From the USDI, Bureau of Mines (BOM) MILS data set the number of properties in each State associated with specific commodities is listed in Table 20-3.

A better understanding of the amount of waste generated and subsequent potential impacts can be developed by reviewing the amount of commodity produced. Generally speaking, for a given commodity, the greater the amount of production the more wastes are generated. The amount of production in 1988 for selected commodities is listed for each State in Table 20-4. Locations of each major actively producing mine is displayed in Figures 20-1 through 20-6. These figures show the type of mining activity, the density of mining activity across the States and the proximity of mines to urban populations.

The number, location, capacity, status and process used for uranium mills and mines in the U.S. is listed in Table 20-5a,b and 20-6 as compiled by the US EPA, 1989.

Many of the environmental problems associated with uranium mining and milling are associated with inactive sites. Table 20-5b also lists the status of the reclamation process for surface uranium mines in Region VIII. Most of the surface uranium mines in the Region are unreclaimed abandoned properties.

The number and location of CERCLA abandoned mine sites and the number and location of superfund NPL mine sites are listed in Table 20-7. Of the CERCLA sites related to resource extraction activities in Region VIII, 63 are mine related sites, 55 are sites associated with mills, 12 are associated with cement or fertilizer operations, and 2 sites associated with oil or ash. The nine mining related NPL superfund sites are either mines, mills or their associated tailings.

20.3 DATA DESCRIBING MINING WASTE EFFECTS

20.3.1 Pollutant Effects

Two major pollutant categories associated with mining activities are metals and pH. A variety of metallic wastes can be produced as byproducts of hardrock mining activities including: arsenic, beryllium, cadmium chromium, copper, iron, lead, manganese, mercury, selenium, tin, and zinc. The toxicity of each metal has been investigated. However, much less is known about combined impacts of several metals. Mining of sulfide ores and coal causes acid mine drainage where low pH, directly and indirectly through metals dissolution, is toxic to aquatic life. Uranium mining is associated with radioactive contamination of lands and surface waters and air emissions.

Land disturbance associated with mining activities such as the removal of vegetation cover and the piling of mill and mine tailings has produced locally significant damage to terrestrial ecosystems and is responsible for elevated loads in sediment adjacent aquatic ecosystems.

Wind transported soil and dust particles containing toxic metals are a primary pathway of mining related health effects, as is the direct ingestion of soils containing toxic metals, ie. lead. Health effects of these pollutants have been widely investigated, and standards have been set for aquatic ecosystem concentrations, Federal and State drinking water, and soil and air concentrations for many of these pollutants.

If we assume that metal, pH, and radiation pollution in surface waters are associated chiefly with mining wastes, then damage to aquatic ecosystems due to these pollutants may be related to the State 1989 319 and 305b Reports. These data are summarized in Table 20-8.

Metals account for 5,428 miles of stream impairment, while pH affects 1,577 miles, and radiation affects 2 miles of streams in Region VIII. Metal contamination causes the most stream impairment in Utah, 1,908 miles, followed by Colorado, 1,345 miles, Montana, 1,141 miles and North Dakota, 1,016 miles. In Region VIII, metals impaired 93,785 acres and pH impaired 5,600 acres of lake surface waters, with Montana exhibiting the greatest metal impairment, 57,598 acres, followed by Utah, 32,472 acres, and Colorado 3,715 acres.

20.3.2 Aquatic Ecosystem Effects

As previously noted, the extent of damage to aquatic ecosystems due to mining can be estimated from data presented in the States 319 and 305b Reports, as resource extraction is listed as a primary impact generating category. The State 319 and 305b Reports further subdivide resource extraction activities into:

- surface mining;
- subsurface mining;
- placer mining;
- dredge mining
- petroleum activities;
- mill tailings; and
- mine tailings.

Table 20-9 lists the estimated streams miles and lakes acreage impaired by resource extraction activities in Region VIII.

Table 20-8
Miles of Stream and Acres of Lake Impaired by Pollutant - Region VIII

Miles of Stream Impaired

Pollutant	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Pesticides						275	275
Metals	1345	1141	1016	11	1908	7	5428
Ammonia				823			823
Chlorine				4			4
Other Inorganics				790			790
Nutrients	756	3178	7269	232	1747		13181
pH		163		656	758		1577
Siltation	2133	6769	4375	385		3303	16965
Organic Enrichment/DO		120	1184	204	2748		4256
Salinity/TDS/chlorides	1488	3032	1818		1333	891	8562
Thermal modification		1699		875		8	2582
Flow alterations		2746	414			401	3561
Other habitat alterations		1363		43		965	2371
Pathogens	53	510	2844	1185	1623	418	6633
Radiation		2					2
Oil and Grease		64					64
Taste and odor							
Suspended solids			2563	1707			4270
Noxious aquatic plants							
Filling and draining							

Acres of Lake Impaired

Pollutant	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Pesticides							0
Metals	3715	57598			32472		93785
Ammonia					131579		131579
Chlorine							0
Other Inorganics							0
Nutrients	22554	107664	581539	88046	134453	56950	991205
pH		5600					5600
Siltation	6278	350654	500930	67753	10905	89775	1026294
Organic Enrichment/DO		11411	574014	158	112547	54772	752902
Salinity/TDS/chlorides	590	27759	425981		11255	489	466074
Thermal modification		25226	46		2874		28146
Flow alterations		83522	56324	7868		12332	160046
Other habitat alterations		6848					6848
Pathogens	325	10743					11068
Radiation							0
Oil and Grease							0
Taste and odor				27			27
Suspended solids		44282	113911	952	108627		267772
Noxious aquatic plants		61018		86501	122932		270451
Filling and draining		353					353

Table 20-9
Miles of Stream and Acres of Lake Impaired by Source Category - Region VIII

Miles of Stream Impaired

Source Category	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources				817	574	624	2015
Nonpoint Sources							0
Agriculture	4709	11276	17874	4664	5868	7176	51566
Silviculture	43	748		112	161	495	1559
Construction	7	204		26	285	1965	2487
Urban Runoff	129	131	38	262	400	315	1275
Resource Extract/explore/dev.	1359	1605	255	62	293	731	4305
Land Disposal		301		26	115	76	518
Hydromodification	221	3116	4362		216	1572	9488
Other	118	732	4616	1224	1600	2686	10975
Source Unknown		10		18		114	142

Acres of Lake Impaired

Source Category	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources		3500		1897	221443	20509	247349
Nonpoint Sources				443			443
Agriculture	19816	395435	2011717	103386	272831	206950	3010135
Silviculture		41475		1004			42479
Construction		13625			10695	76442	100762
Urban Runoff	9451			16	10011	1434	20912
Resource Extract/explore/dev.	1955	4200	60	83		40720	47018
Land Disposal	325	42345	130	22003			64803
Hydromodification	1760	37930	57910	9577	119171	49536	275884
Other		78402	571768	2028	26921	104232	783350
Source Unknown				454		1991	2445

In Region VIII 4,305 miles of streams are impaired by resource extraction activities, with Montana and Colorado exhibiting the greatest impairment, 1,605 and 1,359 miles respectively.

Stream impairment due to resource extraction is less than one tenth that of agricultural impacts and about half as extensive as hydromodification and "other" impacts according to these State data. The environmental consequences of non-attainment due to mining versus agriculture or other activities may not be the same, however.

Data are available from the State 319 reports on the "intensity" of resource impact. Table 20-10 lists the miles and acres impacted by various categories as slight, moderate, and high impairment, and Table 20-11 lists the miles and acres impacted by various sub-categories as slight, moderate, and high impairment. These largely subjective values suggest that the Region VIII States generally evaluate resource extraction as causing moderate impacts to surface waters.

Due to the subjective nature of these data firm, conclusions regarding stressor severity and environmental damage are difficult. For example, one can argue about the relative impacts of different activities based on knowledge of ecosystem impacts and recovery. Recovery from eutrophication due to agricultural practices can occur rapidly once the source of nutrients are removed from a stream. In contrast, stream ecosystems with metal contaminated sediments associated with mining activities may never fully recover with out expensive remediation, which can also cause extensive physical disturbances.

Over 47,000 acres of lakes are impaired by resource extraction activities in Region VIII, with Wyoming's lake being most affected (40,720 acres), and the balance primarily due to effects in Montana (4,200) and Colorado (1,955).

Data on the amount of impairment due to metals, pH and radiation is larger than the regional amount of mining impairment. This may be due to metal contamination (ie. selenium) as salts derived from evaporation and irrigation water reuse. The values between metal effects and mining impairment agree for Colorado and Montana but differ for Utah, North Dakota and Wyoming.

Aquatic ecosystem impairment, as suggested by impaired use categories, (aquatic fish and wildlife, warm water fisheries, cold water fisheries, public water supply, irrigation and agriculture, livestock watering, industrial, and recreation) are summarized for Region VIII in Table 20-12 and listed by State in Table 20-13. Note that the same stream reach can and often is listed as impaired by more than one stressor and receptor category.

Mining activities most often impair cold water fisheries, recreation, and public water supplies. Of the mining resource extraction activities categories, impairment is due most to subsurface mining, 1,743 miles, followed by petroleum activities, 637 miles, generic unspecified mining activities, 487 miles, surface mining, 408 miles, mill tailings, 351 miles, placer mining, 236 miles, dredge mining, 94 miles, and mine tailings, 57 miles (Table 20-12).

Table 20-10
Impact by Source Category by State in Region VIII

Miles of Stream

Source Category	Colorado Slight	Colorado Moderate	Colorado High	Montana Slight	Montana Moderate	Montana High	North Dakota Slight	North Dakota Moderate	North Dakota High	South Dakota Slight	South Dakota Moderate	South Dakota High	Wyoming Slight	Wyoming Moderate	Wyoming High
Point Sources											686	178	213	456	438
Nonpoint Sources															
Agriculture	691	876	621	191	5360	728	1542	5621	2395		1143	1127	2279	3395	2555
Silviculture		43		12	635	79						112	235	343	156
Construction		7			204						26		1337	1749	1131
Urban Runoff	36	93			83	50		38	38		262	64	292	300	112
Resource Extract/explore	574	467	316	137	1002	358	255		255		62	62	602	680	302
Land Disposal				5	176	59					26		76	76	14
Hydromodification	50	17	153	119	2044	255	906	2603	1787				407	801	743
Other		118			720	12	927	3952	656		400	860	1927	2424	1474
Source Unknown					10							18		20	114

Acres of Lake

Source Category	Colorado Slight	Colorado Moderate	Colorado High	Montana Slight	Montana Moderate	Montana High	North Dakota Slight	North Dakota Moderate	North Dakota High	South Dakota Slight	South Dakota Moderate	South Dakota High	Wyoming Slight	Wyoming Moderate	Wyoming High
Point Sources				3500	3500						27	1870	20509	20509	19100
Nonpoint Sources												443			
Agriculture	2160	9710	6716	327468	43796	14673	113713	580763	86818		643	82739	94338	110319	70053
Silviculture				38125	30800						468	162			
Construction				13625	3655								73205	76417	44399
Urban Runoff	2160	4631	2660									16	1434	1434	
Resource Extract/explore		1955			2100		60	60				83	40720	40720	13300
Land Disposal		325		12425	33425	150		130			8272	13731			
Hydromodification			1760	37930	34580		325	57519	57221		7868	1709	39824	46200	38055
Other				49895	40274		113650	569807	76197		412	1395	94338	103519	63512
Source Unknown											41	413			1991

Table 20-10 (cont.)
Impact by Source Category in Region VIII

Miles of Stream

Source Category	Slight	Moderate	High
Point Sources	213	1142	616
Nonpoint Sources	0	0	0
Agriculture	4702	16394	7425
Silviculture	247	1021	347
Construction	1337	1986	1131
Urban Runoff	328	776	264
Resource Extract/explore/dev.	1567	2210	1292
Land Disposal	81	278	73
Hydromodification	1482	5466	2938
Other	2854	7613	3002
Source Unknown	0	30	132

Acres of Lake

Source Category	Slight	Moderate	High
Point Sources	24009	24036	20970
Nonpoint Sources	0	0	443
Agriculture	537679	745231	260999
Silviculture	38125	31268	162
Construction	86830	80072	44399
Urban Runoff	3594	6065	2676
Resource Extract/explore/dev.	40780	44835	13383
Land Disposal	12425	42152	13881
Hydromodification	78079	146167	98745
Other	257883	714012	141104
Source Unknown	0	41	2404

Table 20-11
Impact by Source Subcategory - Region VIII

Miles of Stream

Source Category Subcategory	Slight	Moderate	High
Point Sources	0	0	0
Industrial	196	328	330
Municipal	17	825	297
Nonpoint Sources	0	0	0
Agriculture	7	1047	675
Non-irrigated crop prod.	2071	8987	3199
Irrigated crop prod.	2361	6637	2357
Pasture land	1513	6627	1397
Range land	2606	6119	3071
Feedlots	677	3768	393
Aquaculture	0	0	0
Animal holding areas	792	1516	352
Streambank erosion	563	2271	900
Silviculture	12	522	59
Harvesting, restoration	163	366	150
Forest management	52	93	23
Road construct/maint.	25	201	183
Construction	0	55	0
Highway/road/bridge	1329	1923	1128
Land development	132	140	87
Urban Runoff	0	82	56
Storm sewers	10	226	21
Surface runoff	328	516	202
Resource Extract/explore/dev.	61	484	65
Surface mining	383	316	60
Subsurface mining	573	834	469
Placer mining	16	176	57
Dredge mining	0	84	48
Petroleum activities	470	371	484
Mill tailings	134	147	224
Mine tailings	6	20	37
Land Disposal	0	2	0
Wastewater	0	120	0
On-site wastewater treat.	81	276	73
Hydromodification	23	71	115
Channelization	495	1431	1580
Dredging	0	0	0
Dam construction	254	75	259
Flow regulation	122	1505	269
Bridge construction	0	0	0
Removal of riparian veg.	30	296	41
Streambank modification	1002	4380	2191
Other	0	50	0
Atmospheric deposition	0	27	0
Highway maintenance	18	108	48
In-place contaminants	0	427	18
Natural	2836	7054	2936
Recreational activities	0	0	0
Source Unknown	0	30	132

Table 20-11 (cont.)
Impact by Source Subcategory - Region VIII

Acres of Lake

Source Category Subcategory	Slight	moderate	High
Point Sources	0	27	0
Industrial	0	0	0
Municipal	20509	20509	20970
Nonpoint Sources	0	0	443
Agriculture	327468	30854	82639
Non-irrigated crop prod.	113713	592213	96568
Irrigated crop prod.	84568	479478	83995
Pasture land	113972	510751	20324
Range land	93424	106830	65922
Feedlots	112771	491793	28817
Aquaculture	0	0	0
Animal holding areas	919	71938	63346
Streambank erosion	0	1955	615
Silviculture	34775	31236	162
Harvesting, restoration	3350	0	0
Forest management	0	0	0
Road construct/maint.	3350	410	0
Construction	13625	0	0
Highway/road/bridge	73205	80072	44399
Land development	25	25	0
Urban Runoff	0	0	0
Storm sewers	0	0	0
Surface runoff	3594	6065	2676
Resource Extract/explore/dev.	0	0	83
Surface mining	9480	9480	0
Subsurface mining	0	4055	0
Placer mining	0	2100	0
Dredge mining	0	0	0
Petroleum activities	31300	31300	13300
Mill tailings	0	0	0
Mine tailings	0	0	0
Land Disposal	7555	32830	0
Wastewater	0	0	0
On-site wastewater treat.	4870	9322	13881
Hydromodification	34580	34580	0
Channelization	0	897	897
Dredging	0	0	0
Dam construction	0	0	0
Flow regulation	31005	38773	25729
Bridge construction	0	80	0
Removal of riparian veg.	325	56919	56507
Streambank modification	12169	15116	15810
Other	0	55	55
Atmospheric deposition	1580	60	0
Highway maintenance	0	25	915
In-place contaminants	113095	566030	73021
Natural	143208	149780	67520
Recreational activities	0	30	58
Source Unknown	0	41	2404

Table 20-11 (cont.)
Impact by Source Subcategory by State - Region VIII

Miles of Stream Impaired

Source Category Subcategory	Colorado Slight	 Moderate	 High	Montana Slight	 Moderate	 High	North Dakota Slight	 Moderate	 High
Point Sources									
Industrial									
Municipal									
Nonpoint Sources									
Agriculture	7				888	102			
Non-irrigated crop prod.		176			1830	135	1542	5512	2395
Irrigated crop prod.	464	685	370	179	3576	508		124	15
Pasture land				67	2029	215	615	2633	222
Range land	563	572	460				699	3160	642
Feedlots							677	3078	387
Aquaculture									
Animal holding areas					236	22	699	570	255
Streambank erosion	486	700	384	55	1454	241			
Silviculture				12	522	59			
Harvesting, restoration					100	20			
Forest management									
Road construct/maint.		43			72	20			
Construction					29				
Highway/road/bridge		7			175				
Land development									
Urban Runoff					45	45			
Storm sewers					38	5			
Surface runoff	36	93			38	5		38	38
Resource Extract/explore/dev.					361	3			
Surface mining	72				22				
Subsurface mining	553	461	306	6	358	163			
Placer mining	4	18		12	158	47			
Dredge mining					81	35			
Petroleum activities					64		255		255
Mill tailings	15			119	147	224			
Mine tailings			10	6	20	28			
Land Disposal					2				
Wastewater					120				
On-site wastewater treat.				5	174	59			
Hydromodification					48	45			
Channelization		1		119	207	119	291	933	1100
Dredging									
Dam construction					75		229		234
Flow regulation		17			1126	58		109	
Bridge construction									
Removal of riparian veg.					54			199	
Streambank modification	50		153		1382	56	615	2342	1554
Other					50				
Atmospheric deposition								27	
Highway maintenance					32				
In-place contaminants								427	
Natural		118			638	12	927	3525	656
Recreational activities									
Source Unknown					10				

Table 20-11 (cont.)
Impact by Source Subcategory by State - Region VIII

Miles of Stream Impaired

Source Category Subcategory	South Dakota Slight	South Dakota Moderate	South Dakota High	Wyoming Slight	Wyoming Moderate	Wyoming High
Point Sources						
Industrial		11	11	196	317	319
Municipal		686	178	17	139	119
Nonpoint Sources						
Agriculture		49	463		110	110
Non-irrigated crop prod.		941	462	529	529	207
Irrigated crop prod.		157	47	1718	2097	1418
Pasture land		685		831	1281	960
Range land		312	455	1344	2075	1514
Feedlots		690	6			
Aquaculture						
Animal holding areas		555		94	156	75
Streambank erosion				22	118	275
Silviculture						
Harvesting, restoration				163	266	130
Forest management				52	93	23
Road construct/maint.			112	25	86	51
Construction		26				
Highway/road/bridge				1329	1741	1128
Land development				132	140	87
Urban Runoff		37	11			
Storm sewers		178	6	10	10	10
Surface runoff		47	47	292	300	112
Resource Extract/explore/dev.		62	62	61	61	
Surface mining				311	294	60
Subsurface mining				15	15	
Placer mining						10
Dredge mining					3	13
Petroleum activities				215	307	229
Mill tailings						
Mine tailings						
Land Disposal						
Wastewater						
On-site wastewater treat.		26		76	76	14
Hydromodification				23	23	70
Channelization				85	290	361
Dredging						
Dam construction				25		25
Flow regulation				122	253	211
Bridge construction						
Removal of riparian veg.				30	43	41
Streambank modification				337	655	428
Other						
Atmospheric deposition						
Highway maintenance		37	11	18	39	37
In-place contaminants			18			
Natural		389	831	1909	2385	1437
Recreational activities						
Source Unknown			18		20	114

Table 20-11 (cont.)
Impact by Source Subcategory by State - Region VIII

Acres of Lake Impaired

Source Category / Subcategory	Colorado Slight	Colorado Moderate	Colorado High	Montana Slight	Montana Moderate	Montana High	North Dakota Slight	North Dakota Moderate	North Dakota High
Point Sources									
Industrial									
Municipal									
Nonpoint Sources									
Agriculture				327468	30246				
Non-irrigated crop prod.					11450	9750	113713	580763	86818
Irrigated crop prod.	2160	7430	6716		7640	7650		368231	
Pasture land					7640	1423	112563	495567	12801
Range land		325	615				495	4360	1985
Feedlots							112771	491558	10557
Aquaculture									
Animal holding areas							919	71238	61046
Streambank erosion		1955	615						
Silviculture				34775	30800				
Harvesting, restoration				3350					
Forest management									
Road construct/maint.				3350					
Construction				13625					
Highway/road/bridge					3655				
Land development									
Urban Runoff									
Storm sewers									
Surface runoff	2160	4631	2660						
Resource Extract/explore/dev.									
Surface mining							60	60	
Subsurface mining		1955			2100				
Placer mining					2100				
Dredge mining									
Petroleum activities									
Mill tailings									
Mine tailings									
Land Disposal		325		7555	32505				
Wastewater									
On-site wastewater treat.				4870	920	150		130	
Hydromodification				34580	34580				
Channelization								197	197
Dredging									
Dam construction									
Flow regulation			1760					324	324
Bridge construction								80	
Removal of riparian veg.							325	56919	56507
Streambank modification				3350				197	391
Other								55	55
Atmospheric deposition				1520			60	60	
Highway maintenance									
In-place contaminants							113095	566030	73021
Natural				48375	40274		495	5575	3284
Recreational activities									
Source Unknown									

Table 20-11 (cont.)
Impact by Source Subcategory by State - Region VIII

Acres of Lake Impaired

Source Category Subcategory	South Dakota Slight	 Moderate	 High	Wyoming Slight	 Moderate	 High
Point Sources		27				
Industrial						
Municipal			1870	20509	20509	19100
Nonpoint Sources			443			
Agriculture		608	82639			
Non-irrigated crop prod.						
Irrigated crop prod.				82408	96177	69629
Pasture land		35		1409	7509	6100
Range land		35	99	92929	102110	63223
Feedlots		235	18260			
Aquaculture						
Animal holding areas			1600		700	700
Streambank erosion						
Silviculture		436	162			
Harvesting, restoration						
Forest management						
Road construct/maint.		410				
Construction						
Highway/road/bridge				73205	76417	44399
Land development				25	25	
Urban Runoff						
Storm sewers						
Surface runoff			16	1434	1434	
Resource Extract/explore/dev.			83			
Surface mining				9420	9420	
Subsurface mining						
Placer mining						
Dredge mining						
Petroleum activities				31300	31300	13300
Mill tailings						
Mine tailings						
Land Disposal						
Wastewater						
On-site wastewater treat.		8272	13731			
Hydromodification						
Channelization					700	700
Dredging						
Dam construction						
Flow regulation		7868	1209	31005	30581	22436
Bridge construction						
Removal of riparian veg.						
Streambank modification			500	8819	14919	14919
Other						
Atmospheric deposition						
Highway maintenance		25	915			
In-place contaminants						
Natural		412	724	94338	103519	63512
Recreational activities		30	58			
Source Unknown		41	413			1991

Table 20-12

Miles of Stream and Acres of Lake Impaired by Source Subcategory by Use Category - Region VIII

Miles of Stream

Source Category Subcategory	Aquatic Fish & Wildlife	Warm Water Fishery	Cold Water Fishery	Public Water Supply	Agriculture & Irrigation	Livestock Watering	Idus-trial	Rec-reation	TOTAL
Point Sources	0	0	0	0	0	0	0	0	0
Industrial	11	110	239	194	196	109	0	41	473
Municipal	628	795	67	244	862	806	0	902	968
Nonpoint Sources	0	0	0	0	0	0	0	0	0
Agriculture	506	709	950	334	574	567	0	678	1568
Non-irrigated crop prod.	4450	5564	1050	3386	3857	2262	231	6460	11011
Irrigated crop prod.	438	3247	4662	3179	3439	1539	0	3861	8185
Pasture land	2201	3095	2549	1806	1782	1737	0	2378	7153
Range land	2218	2534	2597	1241	3064	767	209	4779	8294
Feedlots	1809	1929	0	207	931	690	209	2296	3768
Aquaculture	0	0	0	0	0	0	0	0	0
Animal holding areas	624	810	306	604	789	563	0	1763	2165
Streambank erosion	0	1853	1655	2244	2517	1037	0	1886	3554
Silviculture	0	0	536	45	0	0	0	79	536
Harvesting, restoration	0	0	411	0	0	0	0	0	411
Forest management	0	0	67	0	0	0	0	30	97
Road construct/maint.	112	112	242	28	155	112	0	155	242
Construction	26	26	29	0	36	36	0	36	55
Highway/road/bridge	157	629	1349	209	408	0	0	76	2007
Land development	0	40	104	0	0	0	0	0	140
Urban Runoff	37	26	56	45	37	37	0	82	82
Storm sewers	178	178	43	0	178	178	0	188	231
Surface runoff	85	177	300	96	126	47	0	223	562
Resource Extract/explore/d	62	51	436	13	68	68	0	68	487
Surface mining	0	317	91	82	365	2	0	74	408
Subsurface mining	0	49	1636	1177	1216	156	0	1616	1743
Placer mining	0	0	236	22	21	3	0	68	236
Dredge mining	0	0	94	47	35	35	0	47	94
Petroleum activities	77	280	305	319	319	64	0	319	637
Mill tailings	0	0	351	188	88	73	0	300	351
Mine tailings	0	0	57	27	7	0	0	32	57
Land Disposal	0	0	2	0	0	0	0	2	2
Wastewater	0	0	120	0	0	0	0	0	120
On-site wastewater treat.	26	26	193	72	26	26	0	156	281
Hydromodification	0	0	118	68	0	0	0	45	118
Channelization	816	643	715	406	343	78	0	1052	1877
Dredging	0	0	0	0	0	0	0	0	0
Dam construction	234	234	100	0	0	0	0	75	334
Flow regulation	109	683	955	574	152	57	0	871	1633
Bridge construction	0	0	0	0	0	0	0	0	0
Removal of riparian veg.	199	0	97	199	0	0	0	0	296
Streambank modification	1892	2338	1717	1500	567	23	0	2208	5014
Other	0	0	50	0	0	0	0	0	50
Atmospheric deposition	27	0	0	0	0	0	0	0	27
Highway maintenance	37	26	82	0	37	37	0	37	108
In-place contaminants	217	18	0	322	18	18	0	123	445
Natural	2767	3000	2335	1355	2740	1260	231	4575	8745
Recreational activities	0	0	0	0	0	0	0	0	0
Source Unknown	18	18	95	0	42	28	0	23	142

Table 20-12 (cont.)

Miles of Stream and Acres of Lake Impaired by Source Subcategory by Use Category - Region VIII

Acres of Lake

Source Category Subcategory	Aquatic Fish & Wildlife	Warm Water Fishery	Cold Water Fishery	Public Water Supply	Agriculture & Irrigation	Livestock Watering	Idus-trial	Rec-reation	TOTAL
Point Sources	27	0	3500	27	0	27	0	3527	3527
Industrial	98990	98000	1470	990	99470	99470	0	98480	99470
Municipal	110860	120775	23577	13973	121973	123843	0	111948	144352
Nonpoint Sources	443	443	0	350	0	443	0	443	443
Agriculture	83122	336303	56721	295605	25639	83122	0	380554	433004
Non-irrigated crop prod.	99098	156324	16262	32973	131453	131453	0	692695	717906
Irrigated crop prod.	0	34083	17613	10400	24186	7650	0	396327	496034
Pasture land	35	13728	94348	4268	5691	5726	0	508713	516442
Range land	99124	137977	14577	24209	123763	122498	0	115553	230332
Feedlots	18495	24007	103467	10927	23287	29422	0	520360	520980
Aquaculture	0	0	0	0	0	0	0	0	0
Animal holding areas	1600	16347	0	0	0	1600	0	63380	73538
Streambank erosion	10000	10965	10934	10804	21899	19329	0	21549	21899
Silviculture	594	0	35369	53	0	594	0	1644	35369
Harvesting, restoration	0	0	3350	0	0	0	0	0	3350
Forest management	0	0	0	0	0	0	0	0	0
Road construct/maint.	410	0	3760	32	0	410	0	410	3760
Construction	10000	10011	9509	5484	10695	10695	0	10695	24320
Highway/road/bridge	0	25797	66297	0	0	0	0	9505	76417
Land development	0	0	25	0	0	0	0	0	25
Urban Runoff	10000	10011	0	0	10011	10011	0	10011	10011
Storm sewers	0	0	0	0	0	0	0	0	0
Surface runoff	16	2327	8574	7691	7691	16	0	9467	10901
Resource Extract/explore/d	83	83	0	0	0	83	0	83	83
Surface mining	0	9480	0	0	0	0	0	0	9480
Subsurface mining	0	0	4055	1955	1955	0	0	4055	4055
Placer mining	0	0	2100	0	0	0	0	2100	2100
Dredge mining	0	0	0	0	0	0	0	0	0
Petroleum activities	0	13300	31300	0	0	0	0	0	31300
Mill tailings	0	0	0	0	0	0	0	0	0
Mine tailings	0	0	0	0	0	0	0	0	0
Land Disposal	0	0	36730	325	325	0	0	3980	36730
Wastewater	0	0	0	0	0	0	0	0	0
On-site wastewater treat.	22003	21729	6344	1503	1749	22003	0	23163	28073
Hydromodification	108000	119171	34580	11171	119171	119171	0	108266	15371
Channelization	0	897	0	0	0	0	0	0	897
Dredging	0	0	0	0	0	0	0	0	0
Dam construction	0	0	0	0	0	0	0	0	0
Flow regulation	9077	17612	26257	1209	0	9077	0	10837	45078
Bridge construction	0	80	0	0	0	0	0	0	80
Removal of riparian veg.	0	919	0	0	0	0	0	56919	56919
Streambank modification	500	6991	12169	0	0	500	0	694	19160
Other	0	55	480	0	480	480	0	2055	535
Atmospheric deposition	0	60	1520	0	0	0	0	0	1580
Highway maintenance	940	851	89	671	0	940	0	940	940
In-place contaminants	108	27597	24146	0	0	0	0	553203	566078
Natural	2103	29060	108114	62667	14832	15378	0	76311	202067
Recreational activities	83	11	12140	12057	12068	12151	0	12151	12151
Source Unknown	454	454	1962	41	0	454	0	483	2445

Table 20-13
Source Subcategory by State - Region VIII

Miles of Stream Impaired

Source Category Subcategory	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources							0
Industrial				11		462	473
Municipal				806		162	968
Nonpoint Sources							0
Agriculture	7	945		506		110	1568
Non-irrigated crop prod	176	1965	7036	1305		529	11011
Irrigated crop prod.	1480	4104	124	157		2321	8185
Pasture land		2264	2633	685		1572	7153
Range land	1517		3797	767		2214	8294
Feedlots			3078	690			3768
Aquaculture							0
Animal holding areas		249	1206	555		156	2165
Streambank erosion	1530	1750				275	3554
Silviculture		536					536
Harvesting, restoration		120				291	411
Forest management						97	97
Road construct/maint.	43	92				107	242
Construction		29		26			55
Highway/road/bridge	7	175				1825	2007
Land development						140	140
Urban Runoff		45		37			82
Storm sewers		43		178		10	231
Surface runoff	129	43	38	47		305	562
Resource Extract/explore/dev.		364		62		61	487
Surface mining	72	22				314	408
Subsurface mining	1242	486				15	1743
Placer mining	21	205				10	236
Dredge mining		81				13	94
Petroleum activities		64	255			318	637
Mill tailings	15	336					351
Mine tailings	10	48					57
Land Disposal		2					2
Wastewater		120					120
On-site wastewater treat.		179		26		76	281
Hydromodification		48				70	118
Channelization	1	326	1162			388	1877
Dredging							0
Dam construction		75	234			25	334
Flow regulation	17	1184	109			323	1633
Bridge construction							0
Removal of riparian veg.		54	199			43	296
Streambank modificatio	203	1429	2659			723	5014
Other		50					50
Atmospheric deposition			27				27
Highway maintenance		32		37		39	108
In-place contaminants			427	18			445
Natural	118	650	4161	1169		2647	8745
Recreational activities							0
Source Unknown		10		18		114	142

Table 20-13 (cont.)
Source Subcategory by Use Category by State: Aquatic Fish & Wildlife

Miles of Stream Impaired

Source Category Subcategory	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources							0
Industrial				11			11
Municipal				628			628
Nonpoint Sources							0
Agriculture				506			506
Non-irrigated crop prod.			3243	1127		80	4450
Irrigated crop prod.			124	157		157	438
Pasture land			1694	507			2201
Range land			1294	767		157	2218
Feedlots			1297	512			1809
Aquaculture							0
Animal holding areas			248	377			624
Streambank erosion							0
Silviculture							0
Harvesting, restoration							0
Forest management							0
Road construct/maint.				112			112
Construction				26			26
Highway/road/bridge						157	157
Land development							0
Urban Runoff				37			37
Storm sewers				178			178
Surface runoff			38	47			85
Resource Extract/explore/dev.				62			62
Surface mining							0
Subsurface mining							0
Placer mining							0
Dredge mining							0
Petroleum activities						77	77
Mill tailings							0
Mine tailings							0
Land Disposal							0
Wastewater							0
On-site wastewater treat.				26			26
Hydromodification							0
Channelization			816				816
Dredging							0
Dam construction			234				234
Flow regulation			109				109
Bridge construction							0
Removal of riparian veg.			199				199
Streambank modification			1892				1892
Other							0
Atmospheric deposition			27				27
Highway maintenance				37			37
In-place contaminants			199	18			217
Natural			1441	1169		157	2767
Recreational activities							0
Source Unknown				18			18

Table 20-13 (cont.)
Source Subcategory by Use Category by State: Warm Water Fisheries

Miles of Stream Impaired

Source Category Subcategory	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources							0
Industrial						110	110
Municipal				795			795
Nonpoint Sources							0
Agriculture		119		480		110	709
Non-irrigated crop prod.	176	1053	2719	1305		311	5564
Irrigated crop prod.	805	1728	109	157		449	3247
Pasture land		1019	1374	685		18	3095
Range land	650		836	767		281	2534
Feedlots			1239	690			1929
Aquaculture							0
Animal holding areas			255	555			810
Streambank erosion	676	1067				110	1853
Silviculture							0
Harvesting, restoration							0
Forest management							0
Road construct/maint.				112			112
Construction				26			26
Highway/road/bridge						629	629
Land development						40	40
Urban Runoff				26			26
Storm sewers				178			178
Surface runoff	50			47		80	177
Resource Extract/explore/dev.				51			51
Surface mining	6					311	317
Subsurface mining	47	2					49
Placer mining							0
Dredge mining							0
Petroleum activities			255			25	280
Mill tailings							0
Mine tailings							0
Land Disposal							0
Wastewater							0
On-site wastewater treat.				26			26
Hydromodification							0
Channelization			629			14	643
Dredging							0
Dam construction			234				234
Flow regulation		569	109			5	683
Bridge construction							0
Removal of riparian veg.							0
Streambank modification	144	494	1686			14	2338
Other							0
Atmospheric deposition							0
Highway maintenance				26			26
In-place contaminants				18			18
Natural	118		1073	1160		649	3000
Recreational activities							0
Source Unknown				18			18

Table 20-13 (cont.)
Source Subcategory by Use Category by State: Cold Water Fisheries

Miles of Stream

Source Category Subcategory	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources							0
Industrial				11		228	239
Municipal				11		56	67
Nonpoint Sources							0
Agriculture	7	807		26		110	950
Non-irrigated crop prod.		912				138	1050
Irrigated crop prod.	676	2376				1611	4662
Pasture land		1245				1305	2549
Range land	867					1730	2597
Feedlots							0
Aquaculture							0
Animal holding areas		249				57	306
Streambank erosion	854	683				118	1655
Silviculture		536					536
Harvesting, restoration		120				291	411
Forest management						67	67
Road construct/maint.	43	92				107	242
Construction		29					29
Highway/road/bridge	7	175				1167	1349
Land development		4				100	104
Urban Runoff		45		11			56
Storm sewers		43					43
Surface runoff	79	43				178	300
Resource Extract/explore/dev.		364		11		61	436
Surface mining	66	22				3	91
Subsurface mining	1137	484				15	1636
Placer mining	21	205				10	236
Dredge mining		81				13	94
Petroleum activities		64				241	305
Mill tailings	15	336					351
Mine tailings	10	48					57
Land Disposal		2					2
Wastewater		120					120
On-site wastewater treat.		179				14	193
Hydromodification		48				70	118
Channelization	1	326				388	715
Dredging							0
Dam construction		75				25	100
Flow regulation	17	615				323	955
Bridge construction							0
Removal of riparian veg.		54				43	97
Streambank modification	59	935				723	1717
Other		50					50
Atmospheric deposition							0
Highway maintenance		32		11		39	82
In-place contaminants							0
Natural		650		9		1676	2335
Recreational activities							0
Source Unknown						95	95

Table 20-13 (cont.)
Source Subcategory by Use Category by State: Public Water Supply

Miles of Stream

Source Category Subcategory	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources							0
Industrial						194	194
Municipal				178		66	244
Nonpoint Sources							0
Agriculture	7	217				110	334
Non-irrigated crop prod.	15	1616	1548	207			3386
Irrigated crop prod.	824	2227				128	3179
Pasture land		1346	115	207		138	1806
Range land	871		370				1241
Feedlots				207			207
Aquaculture							0
Animal holding areas		87	255	207		55	604
Streambank erosion	805	1172				267	2244
Silviculture		45					45
Harvesting, restoration							0
Forest management							0
Road construct/maint.	28						28
Construction							0
Highway/road/bridge	7	69				133	209
Land development							0
Urban Runoff		45					45
Storm sewers							0
Surface runoff	78					18	96
Resource Extract/explore/dev.		13					13
Surface mining	60	22					82
Subsurface mining	831	346					1177
Placer mining	18	4					22
Dredge mining		47					47
Petroleum activities		64	255				319
Mill tailings	15	173					188
Mine tailings	5	22					27
Land Disposal							0
Wastewater							0
On-site wastewater treat.		54				18	72
Hydromodification		45				23	68
Channelization		78	328				406
Dredging							0
Dam construction							0
Flow regulation	16	558					574
Bridge construction							0
Removal of riparian veg.			199				199
Streambank modification	104	678	718				1500
Other							0
Atmospheric deposition							0
Highway maintenance							0
In-place contaminants			322				322
Natural	118	243	793			201	1355
Recreational activities							0
Source Unknown							0

Table 20-13 (cont.)
Source Subcategory by Use Category by State: Irrigation and Agriculture

Miles of Stream

Source Category Subcategory	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources							0
Industrial				11		185	196
Municipal				806		56	862
Nonpoint Sources							0
Agriculture	7	61		506			574
Non-irrigated crop prod.	176	957	1197	1276		251	3857
Irrigated crop prod.	1390	1361		157		532	3439
Pasture land		1052		656		74	1782
Range land	1476		693	767		128	3064
Feedlots			269	661			931
Aquaculture							0
Animal holding areas		8	255	526			789
Streambank erosion	1480	1037					2517
Silviculture							0
Harvesting, restoration							0
Forest management							0
Road construct/maint.	43			112			155
Construction		10		26			36
Highway/road/bridge	7					401	408
Land development							0
Urban Runoff				37			37
Storm sewers				178			178
Surface runoff	79			47			126
Resource Extract/explore/dev.		6		62			68
Surface mining	72	2				291	365
Subsurface mining	1060	156					1216
Placer mining	18	3					21
Dredge mining		35					35
Petroleum activities		64	255				319
Mill tailings	15	73					88
Mine tailings	7						7
Land Disposal							0
Wastewater							0
On-site wastewater treat.				26			26
Hydromodification							0
Channelization	1	78	264				343
Dredging							0
Dam construction							0
Flow regulation	17	57				78	152
Bridge construction							0
Removal of riparian veg.							0
Streambank modification	203	23	264			77	567
Other							0
Atmospheric deposition							0
Highway maintenance				37			37
In-place contaminants				18			18
Natural	118		957	1169		497	2740
Recreational activities							0
Source Unknown		10		18		14	42

Table 20-13 (cont.)
Source Subcategory by Use Category by State: Livestock Watering

Miles of Stream

Source Category Subcategory	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources							0
Industrial				11		98	109
Municipal				806			806
Nonpoint Sources							0
Agriculture		61		506			567
Non-irrigated crop prod.		957		1305			2262
Irrigated crop prod.		1361		157		21	1539
Pasture land		1052		685			1737
Range land				767			767
Feedlots				690			690
Aquaculture							0
Animal holding areas		8		555			563
Streambank erosion		1037					1037
Silviculture							0
Harvesting, restoration							0
Forest management							0
Road construct/maint.				112			112
Construction		10		26			36
Highway/road/bridge							0
Land development							0
Urban Runoff				37			37
Storm sewers				178			178
Surface runoff				47			47
Resource Extract/explore/dev.		6		62			68
Surface mining		2					2
Subsurface mining		156					156
Placer mining		3					3
Dredge mining		35					35
Petroleum activities		64					64
Mill tailings		73					73
Mine tailings							0
Land Disposal							0
Wastewater							0
On-site wastewater treat.				26			26
Hydromodification							0
Channelization		78					78
Dredging							0
Dam construction							0
Flow regulation		57					57
Bridge construction							0
Removal of riparian veg.							0
Streambank modification		23					23
Other							0
Atmospheric deposition							0
Highway maintenance				37			37
In-place contaminants				18			18
Natural				1169		91	1260
Recreational activities							0
Source Unknown		10		18			28

Table 20-13 (cont.)
Source Subcategory by Use Category by State: Industrial

Miles of Stream

Source Category Subcategory	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources							0
Industrial							0
Municipal							0
Nonpoint Sources							0
Agriculture							0
Non-irrigated crop prod.			231				231
Irrigated crop prod.							0
Pasture land							0
Range land			209				209
Feedlots			209				209
Aquaculture							0
Animal holding areas							0
Streambank erosion							0
Silviculture							0
Harvesting, restoration							0
Forest management							0
Road construct/maint.							0
Construction							0
Highway/road/bridge							0
Land development							0
Urban Runoff							0
Storm sewers							0
Surface runoff							0
Resource Extract/explore/dev.							0
Surface mining							0
Subsurface mining							0
Placer mining							0
Dredge mining							0
Petroleum activities							0
Mill tailings							0
Mine tailings							0
Land Disposal							0
Wastewater							0
On-site wastewater treat.							0
Hydromodification							0
Channelization							0
Dredging							0
Dam construction							0
Flow regulation							0
Bridge construction							0
Removal of riparian veg.							0
Streambank modification							0
Other							0
Atmospheric deposition							0
Highway maintenance							0
In-place contaminants							0
Natural			231				231
Recreational activities							0
Source Unknown							0

Table 20-13 (cont.)
Source Subcategory by Use Category by State: Recreation

Miles of Stream

Source Category	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources							0
Industrial				11		30	41
Municipal				806		96	902
Nonpoint Sources							0
Agriculture	7	165		506			678
Non-irrigated crop prod	176	1007	3972	1305			6460
Irrigated crop prod.	1480	2000	124	157		100	3861
Pasture land		477	977	685		240	2378
Range land	1517		2438	767		57	4779
Feedlots			1605	690			2296
Aquaculture							0
Animal holding areas		174	959	555		76	1763
Streambank erosion	1530	356					1886
Silviculture		79					79
Harvesting, restoration							0
Forest management						30	30
Road construct/maint.	43			112			155
Construction		10		26			36
Highway/road/bridge	7	69					76
Land development							0
Urban Runoff		45		37			82
Storm sewers				178		10	188
Surface runoff	129			47		47	223
Resource Extract/explore/dev.		6		62			68
Surface mining	72	2					74
Subsurface mining	1242	375					1616
Placer mining	21	47					68
Dredge mining		47					47
Petroleum activities		64	255				319
Mill tailings	15	285					300
Mine tailings	10	23					32
Land Disposal		2					2
Wastewater							0
On-site wastewater treat.		54		26		76	156
Hydromodification		45					45
Channelization	1	219	832				1052
Dredging							0
Dam construction		75					75
Flow regulation	17	689	109			56	871
Bridge construction							0
Removal of riparian veg.							0
Streambank modificatio	203	651	1354				2208
Other							0
Atmospheric deposition							0
Highway maintenance				37			37
In-place contaminants			105	18			123
Natural	118	463	2782	1169		44	4575
Recreational activities							0
Source Unknown				18		5	23

Table 20-13 (cont.)
Source Subcategory by State - Region VIII

Acres of Lake Impaired

Pollutant	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources		3500		27			3527
Industrial					99470		99470
Municipal				1870	121973	20509	144352
Nonpoint Sources				443			443
Agriculture		349882		83122			433004
Non-irrigated crop prod.		21200	580763		115943		717906
Irrigated crop prod.	16306	15290	368231			96207	496034
Pasture land		9063	495567	35	4268	7509	516442
Range land	940		4360	134	122364	102534	230332
Feedlots			491558	18495	10927		520980
Aquaculture							0
Animal holding areas			71238	1600		700	73538
Streambank erosion	2570				19329		21899
Silviculture		34775		594			35369
Harvesting, restoration		3350					3350
Forest management							0
Road construct/maint.		3350		410			3760
Construction		13625			10695		24320
Highway/road/bridge						76417	76417
Land development						25	25
Urban Runoff					10011		10011
Storm sewers							0
Surface runoff	9451			16		1434	10901
Resource Extract/explore/dev.				83			83
Surface mining			60			9420	9480
Subsurface mining	1955	2100					4055
Placer mining		2100					2100
Dredge mining							0
Petroleum activities						31300	31300
Mill tailings							0
Mine tailings							0
Land Disposal	325	36405					36730
Wastewater							0
On-site wastewater treat.		5940	130	22003			28073
Hydromodification		34580			119171		153751
Channelization			197			700	897
Dredging							0
Dam construction							0
Flow regulation	1760		324	9077		33917	45078
Bridge construction			80				80
Removal of riparian veg.			56919				56919
Streambank modification		3350	391	500		14919	19160
Other			55		480		535
Atmospheric deposition		1520	60				1580
Highway maintenance				940			940
In-place contaminants			566078				566078
Natural		76882	5575	1005	14373	104232	202067
Recreational activities				83	12068		12151
Source Unknown				454		1991	2445

Table 20-13 (cont.)
Source Subcategory by Use Category by State: Aquatic Fish & Wildlife

Acres of Lake Impaired

Source Category Subcategory	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources				27			27
Industrial					98990		98990
Municipal				1870	108990		110860
Nonpoint Sources				443			443
Agriculture				83122			83122
Non-irrigated crop prod.			108		98990		99098
Irrigated crop prod.							0
Pasture land				35			35
Range land				134	98990		99124
Feedlots				18495			18495
Aquaculture							0
Animal holding areas				1600			1600
Streambank erosion					10000		10000
Silviculture				594			594
Harvesting, restoration							0
Forest management							0
Road construct/maint.				410			410
Construction					10000		10000
Highway/road/bridge							0
Land development							0
Urban Runoff					10000		10000
Storm sewers							0
Surface runoff				16			16
Resource Extract/explore/dev.				83			83
Surface mining							0
Subsurface mining							0
Placer mining							0
Dredge mining							0
Petroleum activities							0
Mill tailings							0
Mine tailings							0
Land Disposal							0
Wastewater							0
On-site wastewater treat.				22003			22003
Hydromodification					108000		108000
Channelization							0
Dredging							0
Dam construction							0
Flow regulation				9077			9077
Bridge construction							0
Removal of riparian veg.							0
Streambank modification				500			500
Other							0
Atmospheric deposition							0
Highway maintenance				940			940
In-place contaminants			108				108
Natural			108	1005	990		2103
Recreational activities				83			83
Source Unknown				454			454

Table 20-13 (cont.)
Source Subcategory by Use Category by State: Warm Water Fisheries

Acres of Lake Impaired

Source Category Subcategory	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources							0
Industrial					98000		98000
Municipal				1870	118905		120775
Nonpoint Sources				443			443
Agriculture		253599		82704			336303
Non-irrigated crop prod.		11360	35443		109521		156324
Irrigated crop prod.	13983					20100	34083
Pasture land			7593	35		6100	13728
Range land	615		2610	134	109521	25097	137977
Feedlots			5397	18260	350		24007
Aquaculture							0
Animal holding areas			14047	1600		700	16347
Streambank erosion	615				10350		10965
Silviculture							0
Harvesting, restoration							0
Forest management							0
Road construct/maint.							0
Construction					10011		10011
Highway/road/bridge						25797	25797
Land development							0
Urban Runoff					10011		10011
Storm sewers							0
Surface runoff	2311			16			2327
Resource Extract/explore/dev.				83			83
Surface mining			60			9420	9480
Subsurface mining							0
Placer mining							0
Dredge mining							0
Petroleum activities						13300	13300
Mill tailings							0
Mine tailings							0
Land Disposal							0
Wastewater							0
On-site wastewater treat.			130	21599			21729
Hydromodification					119171		119171
Channelization			197			700	897
Dredging							0
Dam construction							0
Flow regulation			324	7868		9420	17612
Bridge construction			80				80
Removal of riparian veg.			919				919
Streambank modification			391	500		6100	6991
Other			55				55
Atmospheric deposition			60				60
Highway maintenance				851			851
In-place contaminants			27597				27597
Natural			2634	713	616	25097	29060
Recreational activities					11		11
Source Unknown				454			454

Table 20-13 (cont.)
Source Subcategory by Use Category by State: Cold Water Fisheries

Acres of Lake Impaired

Source Category Subcategory	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources		3500					3500
Industrial					1470		1470
Municipal					3068	20509	23577
Nonpoint Sources							0
Agriculture		56303		418			56721
Non-irrigated crop prod.		9840			6422		16262
Irrigated crop prod.	2323	15290					17613
Pasture land		903			4268	89177	94348
Range land	325				12843	1409	14577
Feedlots				235	10577	92655	103467
Aquaculture							0
Animal holding areas							0
Streambank erosion	1955				8979		10934
Silviculture		34775		594			35369
Harvesting, restoration		3350					3350
Forest management							0
Road construct/maint.		3350		410			3760
Construction		8825			684		9509
Highway/road/bridge						66297	66297
Land development						25	25
Urban Runoff							0
Storm sewers							0
Surface runoff	7140					1434	8574
Resource Extract/explore/dev.							0
Surface mining							0
Subsurface mining	1955	2100					4055
Placer mining		2100					2100
Dredge mining							0
Petroleum activities						31300	31300
Mill tailings							0
Mine tailings							0
Land Disposal	325	36405					36730
Wastewater							0
On-site wastewater treat.		5940		404			6344
Hydromodification		34580					34580
Channelization							0
Dredging							0
Dam construction							0
Flow regulation	1760					24497	26257
Bridge construction							0
Removal of riparian veg.							0
Streambank modification		3350				8819	12169
Other					480		480
Atmospheric deposition		1520					1520
Highway maintenance				89			89
In-place contaminants		24146					24146
Natural				293	13757	94064	108114
Recreational activities				83	12057		12140
Source Unknown						1962	1962

Table 20-13 (cont.)
Source Subcategory by Use Category by State: Public Water Supply

Acres of Lake Impaired

Source Category Subcategory	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources				27			27
Industrial					990		990
Municipal					13973		13973
Nonpoint Sources				350			350
Agriculture		293579		2026			295605
Non-irrigated crop prod.		15510			17463		32973
Irrigated crop prod.	2750	7650					10400
Pasture land					4268		4268
Range land	325				23884		24209
Feedlots					10927		10927
Aquaculture							0
Animal holding areas							0
Streambank erosion	1955				8849		10804
Silviculture				53			53
Harvesting, restoration							0
Forest management							0
Road construct/maint.				32			32
Construction		4800			684		5484
Highway/road/bridge							0
Land development							0
Urban Runoff							0
Storm sewers							0
Surface runoff	7691						7691
Resource Extract/explore/dev.							0
Surface mining							0
Subsurface mining	1955						1955
Placer mining							0
Dredge mining							0
Petroleum activities							0
Mill tailings							0
Mine tailings							0
Land Disposal	325						325
Wastewater							0
On-site wastewater treat.				1503			1503
Hydromodification					11171		11171
Channelization							0
Dredging							0
Dam construction							0
Flow regulation				1209			1209
Bridge construction							0
Removal of riparian veg.							0
Streambank modification							0
Other							0
Atmospheric deposition							0
Highway maintenance				671			671
In-place contaminants							0
Natural		47848		157	14373	289	62667
Recreational activities					12057		12057
Source Unknown				41			41

Table 20-13 (cont.)
Source Subcategory by Use Category by State: Irrigation and Agriculture

Acres of Lake Impaired

Source Category Subcategory	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources							0
Industrial					99470		99470
Municipal					121973		121973
Nonpoint Sources							0
Agriculture				25639			25639
Non-irrigated crop prod.		15510			115943		131453
Irrigated crop prod.	16306	7650				230	24186
Pasture land		1423			4268		5691
Range land	940				122364	459	123763
Feedlots				12360	10927		23287
Aquaculture							0
Animal holding areas							0
Streambank erosion	2570				19329		21899
Silviculture							0
Harvesting, restoration							0
Forest management							0
Road construct/maint.							0
Construction					10695		10695
Highway/road/bridge							0
Land development							0
Urban Runoff					10011		10011
Storm sewers							0
Surface runoff	7691						7691
Resource Extract/explore/dev.							0
Surface mining							0
Subsurface mining	1955						1955
Placer mining							0
Dredge mining							0
Petroleum activities							0
Mill tailings							0
Mine tailings							0
Land Disposal	325						325
Wastewater							0
On-site wastewater treat.				1749			1749
Hydromodification					119171		119171
Channelization							0
Dredging							0
Dam construction							0
Flow regulation							0
Bridge construction							0
Removal of riparian veg.							0
Streambank modification							0
Other					480		480
Atmospheric deposition							0
Highway maintenance							0
In-place contaminants							0
Natural					14373	459	14832
Recreational activities					12068		12068
Source Unknown							0

Table 20-13 (cont.)
Source Subcategory by Use Category by State: Livestock Watering

Acres of Lake Impaired

Source Category Subcategory	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources				27			27
Industrial					99470		99470
Municipal				1870	121973		123843
Nonpoint Sources				443			443
Agriculture				83122			83122
Non-irrigated crop prod.		15510			115943		131453
Irrigated crop prod.		7650					7650
Pasture land		1423		35	4268		5726
Range land				134	122364		122498
Feedlots				18495	10927		29422
Aquaculture							0
Animal holding areas				1600			1600
Streambank erosion					19329		19329
Silviculture				594			594
Harvesting, restoration							0
Forest management							0
Road construct/maint.				410			410
Construction					10695		10695
Highway/road/bridge							0
Land development							0
Urban Runoff					10011		10011
Storm sewers							0
Surface runoff				16			16
Resource Extract/explore/dev.				83			83
Surface mining							0
Subsurface mining							0
Placer mining							0
Dredge mining							0
Petroleum activities							0
Mill tailings							0
Mine tailings							0
Land Disposal							0
Wastewater							0
On-site wastewater treat.				22003			22003
Hydromodification					119171		119171
Channelization							0
Dredging							0
Dam construction							0
Flow regulation				9077			9077
Bridge construction							0
Removal of riparian veg.							0
Streambank modification				500			500
Other					480		480
Atmospheric deposition							0
Highway maintenance				940			940
In-place contaminants							0
Natural				1005	14373		15378
Recreational activities				83	12068		12151
Source Unknown				454			454

Table 20-13 (cont.)
Source Subcategory by Use Category by State: Industrial

Acres of Lake Impaired

Source Category Subcategory	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources							0
Industrial							0
Municipal							0
Nonpoint Sources							0
Agriculture							0
Non-irrigated crop prod.							0
Irrigated crop prod.							0
Pasture land							0
Range land							0
Feedlots							0
Aquaculture							0
Animal holding areas							0
Streambank erosion							0
Silviculture							0
Harvesting, restoration							0
Forest management							0
Road construct/maint.							0
Construction							0
Highway/road/bridge							0
Land development							0
Urban Runoff							0
Storm sewers							0
Surface runoff							0
Resource Extract/explore/dev.							0
Surface mining							0
Subsurface mining							0
Placer mining							0
Dredge mining							0
Petroleum activities							0
Mill tailings							0
Mine tailings							0
Land Disposal							0
Wastewater							0
On-site wastewater treat.							0
Hydromodification							0
Channelization							0
Dredging							0
Dam construction							0
Flow regulation							0
Bridge construction							0
Removal of riparian veg.							0
Streambank modification							0
Other							0
Atmospheric deposition							0
Highway maintenance							0
In-place contaminants							0
Natural							0
Recreational activities							0
Source Unknown							0

Table 20-13 (cont.)
Source Subcategory by Use Category by State: Recreation

Acres of Lake Impaired

Source Category	Colorado	Montana	North Dakota	South Dakota	Utah	Wyoming	TOTAL
Point Sources		3500		27			3527
Industrial					98480		98480
Municipal				1870	110078		111948
Nonpoint Sources				443			443
Agriculture		297432		83122			380554
Non-irrigated crop prod.		21050	567947		103698		692695
Irrigated crop prod.	16306	11790	368231				396327
Pasture land		9063	495347	35	4268		508713
Range land	940		4360	134	110119		115553
Feedlots			491288	18495	10577		520360
Aquaculture							0
Animal holding areas			61780	1600			63380
Streambank erosion	2570				18979		21549
Silviculture		1050		594			1644
Harvesting, restoration							0
Forest management							0
Road construct/maint.				410			410
Construction					10695		10695
Highway/road/bridge		9505					9505
Land development							0
Urban Runoff					10011		10011
Storm sewers							0
Surface runoff	9451			16			9467
Resource Extract/explore/dev.				83			83
Surface mining							0
Subsurface mining	1955	2100					4055
Placer mining		2100					2100
Dredge mining							0
Petroleum activities							0
Mill tailings							0
Mine tailings							0
Land Disposal	325	3655					3980
Wastewater							0
On-site wastewater treat.		1030	130	22003			23163
Hydromodification					108266		108266
Channelization							0
Dredging							0
Dam construction							0
Flow regulation	1760			9077			10837
Bridge construction							0
Removal of riparian veg.			56919				56919
Streambank modification			194	500			694
Other			55		480		535
Atmospheric deposition							0
Highway maintenance				940			940
In-place contaminants			553203				553203
Natural		56744	5529	1005	13033		76311
Recreational activities				83	12068		12151
Source Unknown				454		29	483

Data on the effects of surface mining on fish and wildlife resources were reported by Spaulding and Ogden (1968) using 1967 State fish and game department reports. The miles and surface acres of streams, number and acres of natural and man-made lakes, and the acres of wildlife habitat adversely affected by surface mining are reported in Table 20-14 as taken from Spaulding and Ogden, 1968. Comparison of these data with more recent data suggest that effects of mining activities have become more extensive. As the reliability of these data are unknown, further quantitative comparisons may not be justified.

20.3.3 Terrestrial Ecosystem Effects

Quantitative data on the extent of terrestrial ecosystem damage due to mining activities are lacking. Qualitative data on the potential magnitude of this problem can be derived from the data describing mining waste sources, described in Section 20.2.

We assume that terrestrial ecosystem effects are correlated with the number and size of surface mining operations, for example (Tables 20-1 through 20-7). This assumption is evaluated by comparing data on known impacts and data quantifying mining waste sources. Colorado and Montana have the greatest number of mines and the most miles of impact. Even though there are no active hard rock mines listed in Table 20-1 for North Dakota, abandoned mines are still affecting stream water quality. The acres of 1989 coal mine permits listed for each State (Table 20-2) is linearly correlated ($R^2 = 0.994$) with the amount of land disturbance listed in Table 20-15. The correspondences seen between measured impacts and indices of mining activity suggest that these may be surrogate measures of impact potential where measured impacts are lacking.

The amount of impact on terrestrial ecosystems from surface mining activities was reported in the EPA Unfinished Business Report using 1977 U.S.D.A. data (EPA, 1987). The amount of land area disturbed by coal mines, sand and gravel, and "other" mines is reported both for lands requiring and not requiring reclamation (Table 20-15). Of the total land area disturbed, 25% was unprotected by reclamation laws. For Region VIII over 100,000 acres of land were disturbed by 1977 for which reclamation was not legally mandated, or about 4% of the National total.

Region VIII states with the greatest disturbance were Colorado, Montana and Wyoming, followed by South Dakota, Utah and North Dakota. Coal mines and sand and gravel mines disturbed as much land as all other forms of mining activity.

Impacted wildlife habitat area, for all Region VIII States except Wyoming, is reported in Table 20-14 from the study by Spaulding and Ogden, 1968. These authors reported that by 1967 115,498 acres of wildlife habitat had been disturbed by surface mining activities in the Region, representing nearly 6% of the National total.

Table 20-14
Fish and Wildlife Habitat Adversely Affected
by Surface Mining (1968)

Pre 1968 Data USFWS

State	Number of Streams	Miles	Number of Lakes	Acres	Number of Reservoirs	Acres	Wildlife Habitat	Fish & Wildlife Habitat
Colorado	880	1,930	0	0	13	600	21,515	24,045
Montana	136	234	0	0	0	0	10,830	11,064
North Dakota	0	0	0	0	0	0	33,140	33,140
South Dakota	640	3,250	0	0	33	9,275	23,000	35,525
Utah	16	90	0	0	0	0	11,434	11,524
Wyoming	10	200	0	0	0	0	Unknown	200
Region VIII	1,682	5,704	0	0	46	9,875	99,919	115,498
USA	12,898	135,970	281	103,630	168	41,516	1,687,288	1,968,404
Region VIII as % of USA	13.04%	4.20%	0.00%	0.00%	27.38%	23.79%	5.92%	5.87%

(Spaulding and Ogden, 1968)

Table 20-15
Land Disturbed by Mining

State	No Reclamation Required				Reclamation Required			
	Coal	Sand and Gravel	Other Areas	Total Land Without Reclamation	Coal	Sand and Gravel	Other Areas	Total Land Disturbed
Colorado	7,089	8,334	15,861	31,284	1,195	11,672	6,513	64,687
Montana	1,955	4,655	18,340	24,950	4,766	4,492	6,598	53,334
North Dakota	1,050	2,010	200	3,260	6,725	0	0	48,580
South Dakota	890	10,153	5,259	16,302	0	6,826	695	30,972
Utah	635	3,999	4,414	9,048	133	4,637	10,216	31,555
Wyoming	9,657	3,673	12,376	25,706	62,028	7,665	12,787	113,697
Region VIII	21,276	32,824	56,450	110,550	74,847	35,292	36,809	342,825
USA	1,097,088	799,042	830,407	2,726,537	570,088	257,851	267,097	5,719,776
Region VIII as % of USA	1.94%	4.11%	6.80%	4.05%	13.13%	13.69%	13.78%	5.99%

(USDA, 1977, In: EPA, 1987)

20.4 ENVIRONMENTAL RISKS ASSOCIATED WITH MINING SITES AND WASTES

Data quantitatively and qualitatively describing the extent of mining waste effects in the Region (Sections 20.2-20.3) were combined with knowledge of the ecological effects of mining wastes (eg. Down and Stocks, 1977) to qualitatively define the ecological risks of mining sites and wastes in Region VIII.

Mining related activities have had a demonstrable impact on terrestrial and aquatic ecosystems in the Region. Specific ecological damages depend on the type of mining operation and the degree to which a regulatory framework addressing those processes is in place and enforced.

20.4.1 Terrestrial Ecosystem Degradation

The environmental risks associated with loss of terrestrial habitat from mining activities are extreme in the sense that habitat loss can be irreversible and permanent. Reclamation of some mined lands is legally mandated and technically possible. However, reclamation in some environments is impossible or difficult (ie. mountainous terrain) and may not be required by existing regulations.

Many mine waste piles are phytotoxic due to elevated metal concentrations and subsequent re-vegetation of phytotoxic lands is limited. Generally speaking, effects from hard rock metal mines in mountainous terrain will be more intensive, more difficult to remediate, and more long lasting than other mining activities. Potential impacts from coal mining can be extensive but less intensive since coal mines are associated with more gentle terrain, and remediation requirements are set by State and Federal laws.

Successful reclamation may be impaired by a lack of understanding of the best mix of vegetation required for proper remediation of habitat, as habitat requirements are not fully known and techniques of reclamation are in development. Under already stressful circumstances, effects of disturbance on wildlife can be especially severe.

Effects of sand and gravel mining occur at more locations but at smaller scales than other mining operations. Federal regulations regarding remediation are lacking, and State laws vary with the size of sand and gravel mine operation. Effects are generally limited to disruption and loss of terrestrial habitat.

Effects of surface mining activities and tailings piles are obvious and directly consume terrestrial habitat, while the effects of subsurface mining can be indirect and may only become apparent due to subsidence or through local alterations of hydrology.

20.4.2 Aquatic Ecosystem Degradation

Ecosystem effects of mining activities on aquatic ecosystems occur primarily via runoff and spills to surface waters and groundwater, which can result in acute or chronic toxicity in aquatic systems, and secondarily through habitat destruction. Ecosystem effects are site specific. The kinds of pollutants and their chemical speciation dramatically affect toxicity.

Metal Mining Effects

Primary aquatic ecosystem effects of metal mining are due to acid mine drainage and elevated metal concentrations. Some sediment production from bare soil on steep slopes also contributes to siltation and sedimentation in surface waters as well.

Data are available to evaluate the aquatic toxicity of most of mining related metals. The following discussion is based on the Pennsylvania Comparative Risk Project: Ecological Risk Hazard Finding, State of Pennsylvania (1988), unless otherwise cited.

Although lower pH has been reported to increase the toxicity of some metals (e.g., chromium VI), there are few data relating toxicity to pH for most metals. There also are few data concerning community and ecosystem effects of metals, such effects are likely to be very site-specific. Data available to evaluate the potential effects of various levels of sediment metal contamination on rooted plants, benthic invertebrates, and fish are limited. There are few data available to relate fish tissue residue levels of metals to possible adverse effects on the fish.

Various metals and metal species produce different types of toxic effects.

Species level effects of metals in fish include:

- neurotoxicity;
- impaired reproduction;
- reduced growth;
- damage to gill surfaces and impaired respiration;
- mortality; and
- other effects.

Ecosystem-level effects include:

- reduced primary and secondary productivity;
- loss of top carnivores;
- changes in community composition; and
- modification of nutrient cycling.

The effects of heavy metals in the environment depend on their concentrations and chemical form(s). The chemical form(s) of metals are determined by complex suites of both abiotic and biotic factors including pH, Eh, salinity, alkalinity, the presence of other metals and ligands, dissolved oxygen, and the presence or absence of specific types of bacteria. Toxic compounds that are persistent, such as metals, and that bioaccumulate can have serious adverse effects on species at high trophic levels (e.g., trout) despite low environmental concentrations.

Table 20-16 lists in the EPA acute and chronic Ambient Water Quality Criteria (AWQC) for metals. These toxicity values indicate that iron, nickel, and zinc are unlikely to cause problems except at high surface water concentrations. On the other hand, mercury, cadmium, lead, and beryllium can produce adverse effects at low environmental concentrations. Chromium VI and copper are also highly toxic, although they do not often reach toxic concentrations in surface water for several reasons.

Representative bioconcentration factors for aquatic invertebrates or fish are also listed in Table 20-16. The chronic AWQC are designed to protect against bioaccumulation to levels that would be toxic to fish. Mercury, lead, and cadmium have a high potential for bioaccumulation to toxic levels in aquatic food chains.

The expert panel convened by the Cornell Ecosystems Research Center (EPA, 1987) in the National Comparative Risk Project estimated that decades or centuries would be required for surface water bodies to recover from metal contamination. Sediments contaminated with metals continue to be a source of contamination to biota, particularly benthic invertebrates and bottom feeding fish. Animals that have been exposed to heavy metals and that have developed significant body burdens will remain contaminated for years or for life.

Because the natural "flushing" of some metals from sediments is a very slow process, metal-contaminated sediments can produce adverse effects on aquatic life for decades or centuries after the sources of contamination are eliminated. The recovery time for lakes and ponds should be longer than that for flowing surface waters (e.g., rivers and streams) because the "flushing" process is slower (i.e., longer residence time).

Table 20-16
Water Quality Criteria

	EPA Acute Freshwater AWQC (ug/liter) (1)		EPA Chronic Freshwater AWQC (ug/liter) (1)		Biocon-centration Factor log(BCF) (1)	
Aluminum						
Arsenic III	360	a	190	a	1.2	
Arsenic V	850		48		1.2	
Beryllium	130	a	5.3	a	2	
Chromium III	1800		210		1-2	
Chromium VI	16	*	11	*	1-2	
Copper I	18	*	12	*	2.3	b
Copper II						
Cadmium	3.9	*	1.1	*	3.6	
Iron	--		1000		--	
Lead	82	*	3.2	*	3.4	
Manganese	--		--		--	
Mercury	2.4		0.012		3.4	
Nickel	1400	*	160	*	2.3	
Selenium	280		36		1.3	
Zinc	120	*	110	*	2	
Tin	--		--		--	

References:

(1) U.S. EPA (1986), Quality Criteria for Water;
U.S. EPA (1979), Water-Related Fate of 129 Priority Pollutants.

Notes:

a: Data insufficient to develop and AWQC. Value listed is a LOEL.

b: Oysters strongly accumulate copper, but copper does not appear to biomagnify.

*: Criterion is hardness dependent (100 mg/liter used).

The exposure of biota to multiple metals and the bioaccumulation of metals are two means by which metals can produce more severe effects than what might be expected from laboratory toxicity tests alone. Other conditions that would alter the toxicity of metals to aquatic life are discussed below.

- Methylation of metals by bacteria. Certain bacteria are capable of transforming inorganic metal compounds to methylated organic compounds, which are often more toxic and are bioconcentrated to a greater degree than are their inorganic precursors. Bacterial methylation occurs with mercury, selenium, lead, tin, and arsenic.

- Acidification. Low pH levels release sediment-bound metals and increases their concentrations in the water column (EPA, 1979). Thus, the association of low pH with metals in runoff from abandoned mine drainage increases the exposure of aquatic organisms to metals in the water column.

To better evaluate environmental risks due to individual metals some specific considerations are listed below.

- Arsenic. The acute and chronic toxicity of arsenic depends upon its valence state (Table 20-16). The chemistry of arsenic in water is particularly complex and the form present in solution depends upon pH, organic content, suspended solids, and sediment concentrations (EPA 1984a).

- Beryllium. Beryllium has low aqueous solubility and can be found in high concentrations adsorbed to particulate matter in turbid waters. Water hardness has a substantial effect on the acute toxicity of beryllium (EPA, 1980a).

- Cadmium. The impact of cadmium on aquatic organisms depends upon its chemical form. In well-oxygenated fresh waters low in organic carbon, free divalent cadmium will be the predominant form while in turbid waters, dissolved organic material can bind a substantial portion of the total cadmium. As water hardness decreases, the toxicity of cadmium increases (EPA, 1984b).

- Chromium. Chromium exists in two oxidation states in aqueous systems, chromium III and chromium VI. The hexavalent form of chromium is quite soluble and is not sorbed to any significant degree by clays or hydrous metal oxides. Hexavalent chromium is a moderately strong oxidizing agent and reacts with reducing materials to form trivalent chromium. Trivalent chromium reacts with aqueous hydroxide ions to form the insoluble chromium hydroxide. Hexavalent chromium is substantially more toxic than the trivalent form. Water hardness affects the toxicity of chromium III. Insufficient data were available to relate the toxicity of chromium VI to water hardness, but the toxicity of chromium VI appears to increase with decreasing pH (EPA, 1984c).

- Copper. The cupric ion, responsible for most of copper's toxic effects, is highly reactive, forms moderate to strong complexes, and precipitates with many inorganic and organic constituents of natural waters. Thus, in eutrophic waters, copper complexing predominates, and most organic and inorganic copper complexes and precipitates appear to be much less toxic than free cupric ion.

- Iron. Iron is an essential trace element required by both plants and animals. High iron loading in alkaline conditions can produce precipitates that coat the natural bottom of a surface water body, smothering existing benthic flora and fauna and making the substrate unsuitable for recolonization by the species originally present (EPA, 1984d).

- Lead. Lead toxicity to aquatic organisms increases as water hardness decreases (EPA, 1986a).

- Manganese. Manganese does not occur naturally as an uncomplexed metal but is found in various salts and minerals, frequently in association with iron compounds. Permanganates have been reported to kill fish at concentrations of 2.2 to 4.1 mg/liter, but permanganates are not persistent; they rapidly oxidize organic materials and are thereby reduced and rendered less toxic (EPA, 1986a).

- Mercury. Mercury (II) can be methylated by both aerobic and anaerobic bacteria. Methylmercury is more toxic than mercury (EPA, 1984e).

- Selenium. Selenium occurs naturally in surface water from the weathering of parent rock material and exists in several forms. The inorganic selenites (+4) and selenates (+6) are soluble. Because the ratios between the concentrations of selenium in water that are acutely and chronically toxic to aquatic species are small (EPA 1980), surface water bodies with high background levels of selenium would be particularly at risk if additional selenium loading occurred (EPA, 1980b).

- Tin. Tin is not usually considered to pose a major problem as a heavy metal contaminant. However, under reducing conditions, tin can be methylated, and alkyl tin compounds are central nervous system toxins (WHO, 1980).

- Zinc. Zinc is an essential micronutrient, and organisms have evolved mechanisms for accumulation of zinc from water and excretion of zinc, at least within limits of ambient zinc concentrations. As water hardness decreases, zinc toxicity increases. Most zinc introduced into aquatic environments is partitioned into sediments by sorption onto hydrous iron and manganese oxides, clay minerals, and organic materials. As sediments change from a reduced to an oxidized state, more zinc is mobilized and released in a soluble form (EPA, 1987).

It is important to note that while much is known about the toxic effects of individual metals on certain aquatic species, community and ecosystem level effects may occur at lower concentrations than those specified in the standards.

Coal Mining Effects

Surface mining is the dominant form of coal mining in the Region. As with metallic mines, acid mine drainage is also associated with active and inactive coal mines. Metal concentrations can be elevated in surface and groundwaters, and increased erosion can yield high concentrations of suspended sediments (TSS and TDS) and increased sedimentation. Coal mining activities can disrupt hydrologic flow paths and cause extensive aquatic habitat loss. Effects are site specific.

Sand and Gravel Mining Effects

The magnitude of effects from sand and gravel mining are related to the proximity of the mining activity to surface waters and the mines specific location. Mines associated with steep slopes adjacent to streams and rivers can contribute significant levels of suspended sediments to streams. Some mining activity occurs within stream beds and most sand and gravel mines are historic fluvial deposits which are often near existing waterways. Habitat loss is the primary effect of sand and gravel mining on aquatic ecosystems.

Uranium Mining and Mill Tailings Effects

The effects of uranium mining and mill tailings differ between surface and underground mining operations, and inactive and licensed uranium mill tailing operations. Given the well documented mutagenic, teratogenic, and carcinogenic effects of radiation on humans, the effects of uranium mining and mill tailings find their greatest expression in human health impacts. Environmental impacts of radiation have not been well documented. Typical effects are similar to other land disturbing mining activities: loss of terrestrial habitat and increased sediment and pollutant loads to surface waters. Remediation efforts associated with mill tailing "disposal" also results in permanent loss of terrestrial habitats.

20.5 MINING HUMAN HEALTH EFFECTS

This section presents a discussion of the health effects due to active and inactive mining and milling sites in Region VIII. Associated health risks are principally due to direct ingestion of contaminated soil and water, and inhalation of toxic air pollutants. Toxicants include heavy metals (ie. lead and cadmium), arsenic and radioactive mine wastes. Exposure pathways both are direct and indirect.

Direct human contact and misuse of mining waste usually occurs at unrestricted sites. Direct impacts on mine employees while at work are not considered in this assessment. Abandoned sites can be used by children as play areas or by other individuals for outdoor recreational activities such as hiking, mountain biking or motorized dirt biking. Dust generating activities can increase inhalation exposures. Inactive mining sites contain physical hazards, (ie.abandoned mine shafts) which are annually a source of mortality in the Region. Mine waste materials can be moved from the mine site and improperly used as building materials, for children's sandboxes, or as garden soil supplements. Tailings added to gardening or agricultural soils can result in crops with elevated metal levels that may pose a health risk when ingested (Chaney et al. 1984).

Indirect exposure pathways are through wind and water borne transport of toxic substances from mine waste sites to humans off site.

Airborne exposures are primarily from fugitive dusts associated with transport and placement of wastes, mine waste piles, dried tailings piles and haul roads (USEPA, 1985). Inactive mines may produce fewer airborne emissions due to the lack of movement of wastes and road use. Deposition of air transported toxicants can be a source of contamination of domestic, garden and agricultural soils.

Water can carry contaminants from mine wastes in overland flow, stream flow and in groundwaters. Precipitation onto tailings piles can leach pollutants as the water infiltrates the waste piles. Mine activities can include pumping water from mine excavations, leaching with waterborne chemicals etc. Contaminated surface waters can contaminate groundwaters.

Health effects occur when the contaminated surface or groundwaters are ingested directly or contaminants enter the food chain and are subsequently ingested with food. The ingestion of high concentrations of mine waste toxicants in contaminated game, fish, or livestock may result from the bioaccumulation of specific toxicants in the food chain.

The severity of the threat to humans is a function of the toxicity of the waste and the dose. Dose is related to the concentration of toxicant and the extent of direct contact, inhalation or ingestion. The potential dose usually lessens with distance from the source as both concentrations and amount of contact declines.

20.5.1 <u>Data on the Health Effects of Mining Related Wastes</u>[1]

Health effects vary with the type of hazard associated with particular mining wastes. Data on the dose-response of individual pollutants have lead to the establishment of action levels or environmental "levels of concern" for lead, cadmium, arsenic and radon in various media.

[1] This section is taken from Colorado Environment, 2000

Ongoing research may change some of these levels in the future and the currently accepted levels listed below do not take into account multiple effects or more than one pollutant.

- Lead

National Ambient Air Quality Standard	1.5 ug/m3
Current MCL for drinking water	50 ug/L
Proposed MCL for drinking water	5 ug/L

There is currently no consensus regarding soil lead levels of concern. Children who live on properties with unnaturally high soil lead values, however, are considered to be the population at highest risk due to their normal soil ingestion habits. Attempts to evaluate soil lead levels have resulted in considerable research into the relationships between soil lead and blood lead, soil lead and house dust lead, and blood lead and adverse health effects.

Some research has also been done to evaluate the effectiveness of public health intervention programs (behavior modification) in reducing blood lead levels in children.

As a result of this research, EPA has determined that blood lead levels of 10-15 g/dL may cause irreversible health effects. Using 10-15 g/dL as a target blood lead level, the proposed MCL as an "acceptable" ingestion level, information from several soil lead/blood lead studies, and EPA's biokinetic model, it is possible to estimate soil lead action levels based on different land uses. The estimated soil lead action level necessary to protect children under a residential scenario is in the range of 200-500 mg/Kg. Studies at a mining site in Idaho, however, with children living on properties with soil lead values of 3000-5000 mg/Kg have shown that public health intervention and education programs may also have a demonstrable effect in reducing blood lead concentrations.

- Arsenic

MCL for drinking water	50 ug/L
Proposed MCLG for drinking water	50 ug/L
Carcinogenic Potency Factor (CPF)	1.75 $(mg/Kg/day)^{-1}$

Using the CPF and assuming a lifetime residential exposure scenario, it is possible to estimate a range of soil action levels for arsenic of .03 - 30 mg/Kg which corresponds to a risk range of 10-7 - 10-4.

- Cadmium

MCL for drinking water	10 ug/L
Proposed MCLG for drinking water	5 ug/L
Carcinogenic Potency Factor (CPF) (via inhalation only)	6.1 $(mg/Kg/day)^{-1}$
Reference Dose (RfD)	$5x10^{-4}$ mg/Kg/day

Because cadmium occurs with lead and is removed when lead is removed, action levels for cadmium in soil are typically not set for mining sites in Colorado.

- Radon

EPA has promulgated standards for concentrations of radium-226 for open land and concentrations of radon progeny for habitable buildings as follows:

Land: The concentration of radium-226 in land averaged over an area of 100 m^2 shall not exceed the background level by more than 5 pCi/g, averaged over the first 15 cm of soil below the surface.

Buildings: 1. An annual average radon decay product concentration (including background) shall not exceed 0.02 W.L., and

2. The level of gamma radiation shall not exceed the background level by more than 20 uR/hour.

MCLs for radionuclides in drinking water include the following:

Radium-226 and -228	5 pCi/L
Gross alpha activity	15 pCi/L

20.5.2 Data on Health Risks Due to Mining Related Wastes

Data on the health risks associated with mining wastes have been compiled from two sources; 1) A national study prepared for the U.S. EPA Office of Solid Waste by ICF (1987), "Risk Screening Analysis of Mining Wastes"; and 2) A national study of health risks associated with Uranium mining and milling EPA (1989), "Risk Assessments Methodology. EIS NESHAPS for Radionuclides Volume I-III."

A quantitative health risk analysis associated with metal mining, asbestos, phosphate and uranium mining for contaminants following several pathways was completed for selected mines throughout the U.S. (ICF, 1987).

Results estimating the human health effects associated with mining a variety of ore types are presented, including: molybdenum, titanium, copper, iron, lead/zinc, gold and silver, uranium/vanadium and phosphate.

The number of Region VIII mine sites included in this national assessment provides an indication of the relevance of this assessment to Region VIII mining activities. The following ratios associated with each ore type are the number of Region VIII sites/total sites in the national data set.

molybdenum	3/66
copper	1/12
iron	1/26
lead + zinc	6/25
gold and silver	32/127
uranium	19/25
phosphate	1/27

We assume that risks defined from the national data set will reflect relative risks in Region VIII. Risks at individual sites are site specific. This discussion should be interpreted as a guide to the relative health risks to the maximally exposed individual associated with mining the listed ore types. Data are presented from the ICF study for the maximum and minimum risk identified for each ore type via each water-borne pathway of exposure, see Tables 20-17 and 20-18.

Non-cancer risks due to the offsite inhalation pathway for each ore segment exceeded the standard for only one site associated with an open pit uranium mining operation in Region VIII, Table 20-19. The maximum modeled doses and associated risks are listed in Table 20-19.

Table 20-17
Carcinogenic Risk

Ore Type	Ground Water High	Ground Water Low	Ground Water to Surface Water High	Ground Water to Surface Water Low	Surface Water High	Surface Water Low
Molybdenum	1E-02	1E-09	1E-04	1E-09	1E-07	1E-09
Titanium	1E-04	1E-09	1E-05	1E-09	1E-09	1E-09
Copper	1E-01	1E-09	1E-01	1E-09	1E-03	1E-09
Iron	1E-02	1E-09	1E-03	1E-09	1E-05	1E-09
Lead/zinc	1E-03	1E-09	1E-05	1E-09	1E-04	1E-09
Gold & silver	1E-01	1E-09	1E-03	1E-09	1E-03	1E-09
Uranium/vanadium	1E-02	1E-09	1E-03	1E-09	1E-05	1E-09
Phosphate	1E-02	1E-09	1E-03	1E-09	1E-04	1E-09

Table 20-18
Non-Carcinogenic Risk

Ore Type	Ground Water High	Ground Water Low	Ground Water to Surface Water High	Ground Water to Surface Water Low	Surface Water High	Surface Water Low
Molybdenum	1E+01	1E-09	1E-01	1E-09	1E-03	1E-09
Titanium	1E+02	1E-01	1E+01	1E-01	1E-09	1E-09
Copper	1E+02	1E-09	1E+02	1E-09	1E-02	1E-09
Iron	1E+00	1E-09	1E-01	1E-09	1E-02	1E-09
Lead/zinc	1E-01	1E-09	1E-04	1E-09	1E+00	1E-09
Gold & silver	1E+01	1E-09	1E-01	1E-09	1E-01	1E-09
Uranium/vanadium	1E+02	1E-09	1E+01	1E-09	1E-02	1E-09
Phosphate	1E+01	1E-09	1E+01	1E-09	1E-02	1E-09

(ICF, 1987)

Table 20-19
Offsite Inhalation Pathway
Non-Cancer Risks

Ore Type	Maximum Dose Modeled		Risk Threshold	Dose/Risk Threshold
Copper	4.84E-03		6E-03	8.07E-01
Gold/Silver	2.34E-03		6E-03	3.90E-01
Iron	5.43E-03		6E-03	9.05E-01
Lead/Zinc	1.16E-04		6E-03	1.93E-02
Molybdenum	7.35E-04		6E-03	1.23E-01
Phosphate	1.17E-03		6E-03	1.95E-01
Titanium	1.00E-07		6E-03	1.67E-05
Uranium/Vanadium	1.31E-02	*	6E-04	2.18E+01

* Exceeded standard

(ICF, 1987)

The offsite inhalation pathway range of cancer risks for each ore segment are listed in Table 20-20. Uranium, phosphate, gold, silver and copper mining operations posed the highest cancer risks.

Offsite direct contact (ingestion) pathway risks were modeled from deposition of mine derived particles to the site boundary. Human health risks estimated via this pathway were negligible in all cases since very low levels of deposition of fugitive dusts were estimated at site boundaries.

Onsite direct contact (ingestion) pathways for non-cancer risks maximum dose values exceeded standards for two segments, gold/silver and lead/zinc extraction sites, Table 20-21. In each case lead standards were exceeded.

Onsite direct contact (ingestion) pathways for maximum and minimum estimated cancer risks for each ore type are listed in Table 20-22. For all mining segments except uranium, arsenic is the major toxicant responsible for increased cancer risks. For uranium mining, radon is the primary stressor.

Summary of ICF Results

A wide variety of risks were estimated for the mining sites studied. Variations in calculated risk levels were due to differences in commodity types and their associated toxicants, exposure pathways, and site specific factors related to individual mine sites. Even with this variation, we conclude that for each segment of concern in Region VIII, the study showed at least one pathway/receptor combination with risk over threshold values.

While maximum and minimum range values were presented here, note that only a small percentage of model runs showed cancer risks greater than 10^{-6}. The highest cancer risks were associated with the groundwater-well pathways. Offsite direct contact pathway were associated with low risks, while onsite direct contact pathways produced very low noncancer and variable cancer risk results.

The inhalation risks for noncarcinogens was very low, while carcinogenic risks were variable and in some cases, significant. Estimates of cancer risks from uranium mining and milling activities are available for specific sites in Region VIII. Risks were defined for radon and non-radon health effects associated with several activities including:

- Active Licenced Mills
    - Non Radon Effects
    - Radon Effects
        - Pre UMTRCA
        - Post UMTRCA

Table 20-20
Offsite Inhalation Pathway
Cancer Risk

Ore Type	Minimum Risk	Maximum Risk
Copper	5.15E-08	1.53E-03
Gold/Silver	8.04E-07	2.08E-03
Iron	1.07E-05	4.29E-04
Lead/Zinc	4.79E-08	3.86E-05
Molybdenum	2.15E-06	1.15E-04
Phosphate	5.18E-08	3.76E-03
Titanium	5.83E-09	9.90E-08
Uranium/Vanadium	3.40E-08	3.88E-03

(ICF, 1987)

Table 20-21
Onsite Direct Contact Pathway
Non-Cancer Risks

Ore Type	Maximum Dose Modeled		Risk Threshold	Dose/Risk Threshold
Copper	1.77E-04		6.0E-04	3.0E-01
Gold/Silver	9.53E-04	*	6.0E-04	1.6E+00
Iron	1.69E-05		6.0E-03	2.8E-02
Lead/Zinc	2.05E-03	*	6.0E-04	3.4E+00
Molybdenum	3.28E-05		6.0E-03	5.5E-02
Phosphate	2.55E-04		5.0E-03	5.1E-02
Titanium	6.44E-07		6.0E-04	1.1E-03
Uranium/Vanadium	3.38E-02		5.1E-02	6.6E-01

* Exceeded Standard

(ICF, 1987)

Table 20-22
Onsite Direct Contact Pathway
Cancer Risk

Ore Type	Minimum Risk	Maximum Risk
Copper	1.06E-06	5.95E-04
Gold/Silver	1.39E-06	3.33E-03
Iron	1.08E-06	1.40E-04
Lead/Zinc	4.76E-07	2.42E-04
Molybdenum	1.82E-06	3.61E-06
Phosphate	3.53E-07	1.80E-04
Titanium	2.27E-07	1.81E-06
Uranium	3.76E-08	1.14E-04

(ICF, 1987)

- Inactive Mills
    Radon Effects

- Underground Uranium Mines

- Surface Uranium Mines

- Phosphorous Mine

- Phosphogypsum Stacks

- Active Surface Mines

There are 16 active licenced uranium mills in Region VIII, Table 20-23 (EPA, 1989). Modeled non-radon health risks are lower in most cases than the radon related health risks (Table 20-23). The highest non-radon risk was 0.00009 deaths/year for the population within an 80 km radius of Shirley Basin Mill, Wyoming. The highest radon risk (before any remediation) was estimated to be 0.0066 deaths/year for the Canon City Mill, Colorado. Following planed UMTRCA remediation this risk declines to 0.00043 deaths/year. Even after UMTRCA disposal radon emissions from the Moab Utah mill are projected to cause 0.0013 deaths/year (Table 20-23).

There are 16 inactive uranium mill tailings sites in Region VIII, (EPA, 1989). The quantity of tailings, the proposed remediation action and the estimated radon health risks are listed in Table 20-24. The maximum risk identified was 0.00099 deaths/year associated with the site at Grand Junction, CO (Table 20-24).

There are 10 operating underground uranium mines in Region VIII. The maximum cancer risk identified was 0.7 deaths per year for the Schwartzwalder, Colorado mine (Table 20-25).

Of the 128 small (1,000-100,000 tons/yr) and 37 large (> 100,000 tons/yr) surface uranium mines listed in Table 20-5b, only 15 have radon health risk estimates (Table 20-26). The maximum cancer risk to the most exposed individual was given as $5x10^{-5}$.

There is one phosphorous mine listed in Region VIII where health effects were estimated (EPA, 1989). Risk to the most exposed individual was $6x10^{-5}$, and the population risk was 0.005 deaths/yr associated with the Stauffer mine in Silver Bow, Montana (EPA, 1989). Cancer causing agents associated with phosphorous mines are: U-238, U234, Th-230, Ra-226, Ra-222, Pb-210 and Po-210.

Table 20-23
Health Effects Model for Licensed Conventional
Uranium Mills as of June 1989

		Non-Radon Emissions		Radon Emissions		Post-UMTRCA Disposal Radon Emissions	
State	Mill	Nearby Individuals Lifetime Fatal Cacer Risk	Regional (0-80km) Population Deaths/Yr	Nearby Individuals Lifetime Fatal Cacer Risk	Regional (0-80km) Population Deaths/Yr	Nearby Individuals Lifetime Fatal Cacer Risk	Regional (0-80km) Population Deaths/Yr
Colorado	Canon City			2E-05	6.6E-03	2E-06	4.3E-04
	Uravan					9E-07	4.2E-05
South Dakota	Edgemont					1E-05	3.7E-04
Utah	White Mesa	6E-07	2E-05	2E-05	1.1E-03	2E-06	9.1E-05
	Rio Algom	2E-06	3E-05	9E-06	2.8E-04	8E-06	2.5E-04
	Moab					8E-05	1.3E-03
	Shootaring	2E-07	7E-07	5E-06	2.2E-05	2E-06	6.5E-06
Wyoming	Lucky Mc	1E-07	7E-06	1E-05	6.0E-04	6E-06	3.1E-04
	Split Rock					4E-05	3.2E-04
	Umetco					6E-06	3.3E-04
	Bear Creek					2E-06	2.8E-04
	Shirley Basin	6E-07	9E-05	2E-05	1.8E-03	1E-05	9.2E-04
	Sweetwater	7E-07	2E-05	6E-06	1.2E-04	2E-06	5.3E-05
	Highland					7E-06	6.8E-04
	FAP					4E-06	1.9E-04
	Petrotomics					2E-05	4.5E-04

Table 20-24
Inactive Uranium Mill Tailings Sites (a)

Site	Quantity of Tailings (10^6 tons)	Proposed Action	Schedule Start	Finish	Radon: Nearby Individuals Lifetime Fatal Cancer Risk	Radon: Regional (0-80km) Population Deaths/yr
Durango, CO	1.6	Removal to Bodo Canyon site	UW(c)	FY90	5E-05	6.7E-04
Grand Junction, CO	1.9	Removal to Cheney site	UW	FY93	8E-06	9.9E-04
Gunnison, CO	0.5	Removal to Landfill site	FY90	FY92	1E-06	7.5E-05
Maybell, CO	2.6	Stabilization in place	FY91	FY92	8E-06	1.0E-04
Naturita, CO	0.6	Removal to Dry Flats site	FY91	FY92	5E-05	3.5E-05
New Rifle, CO	2.7	Removal to Estes Gulch site	UW	FY92	1E-05	5.3E-04
Old Rifle, CO	0.4	Removal to Estes Gulch site	UW	FY92	1E-05	5.3E-04
Slick Rock, (NC) (d), CO	0.04	Removal to Slick Rock (UC)	--	DONE	1E-05	6.4E-06
Slick Rock (UC) (e), CO	0.35	Stabilization in place	--	DONE	1E-05	6.4E-06
Belfield, ND	--	Removal to Bowman site	FY92	FY93	3E-06	4.0E-06
Bowman, ND	--	Stabilization in place	FY92	FY93	3E-06	4.0E-06
Green River, UT	0.12	Stabilization in place	UW	DONE	9E-07	3.3E-06
Mexican Hat, UT	2.2	Stabilization in place	UW	FY91	6E-05	3.4E-04
Salt Lake City, UT	1.7	Removel to S. Clive site	--	DONE	4E-07	4.9E-05
Converse County, WY	0.19	Stabilization in place	UW	FY89		
Riverton, WY	0.9	Removal to UMETCO's Gas Hills site	UW	FY91		

(a) DOE88
(b) The start and finish dates refer to construction activities to stabilize and cover the tailings. The finish dates do not include development and implementation of the Surveillance and Monitoring Program or certification that the remedial action is complete.
(c) UW = underway, i.e., remedial actions to stabilize the tailings have been initiated.
(d) North Continent pile
(e) Union Carbide pile

Table 20-25
Cancer Risk and Cancer Death due to Currently Operating
Underground Uranium Mines in Region VIII

State	Mine Name	Maximum Lifetime Fatal Cancer Risk to Individual	Committed Fatal Cancers per Year (0-80 km)
Colorado	Calliham	1E-03	4E-04
Colorado	Deremo-Snyder	2E-03	1E-03
Colorado	King Solomon	4E-04	5E-03
Colorado	NIL	7E-05	2E-03
Colorado	Schwartzenwalder	1E-03	7E-01
Colorado	Sunday	3E-04	4E-03
Colorado	Wilson-Silverbell	3E-04	1E-03
Utah	La Sal	4E-03	3E-03
Utah	Snowbell-Pandora	1E-03	4E-03
Wyoming	Sheep Mountain #1	6E-06	2E-04

Table 20-26
Mines Characterized in the Field Studies

State	Mine	Size (Tons Ore)	Recla-mation Status	Estimated Exposures and Risks to Individuals Living Near Surface Uranium Mines. (Radon): Maximum Lifetime Fatal Cancer Risk to Individual	Estimated Lifetime Fatal Cancer Risks from Particulate Emissions: Nearby Individuals Lifetime Fatal Cancer Risk	Estimated Lifetime Fatal Cancer Risks from Particulate Emissions: Regional (0-80km) Population Deaths/yr
Wyoming					2E-05	5E-03
	Morton Ranch #1704	L	F	1E-06		
	Lucky Mc 70-1, 7E	L	U	3E-06		
	Lucky Mc 4X, 4P	L	U	3E-06		
	Lucky Mc W. Gas Hills	L	U	2E-06		
	Shirley Basin	L	O	5E-05		
South Dakota					2E-06	4E-04
	Darrow #1	S	U	2E-07		
	Darrow #2, 3	L	U	5E-07		
	Darrow #4	S	U	2E-07		
	Darrow #5	L	U	2E-06		
	Freezeout	S	U	7E-07		
Colorado					6E-06	9E-04
	Gert #4-7	L	U	3E-05		
	Johnson	S	U	6E-06		
	Sage	S	U	3E-05		
	Marge #1-3	S	U	2E-05		
	Rob	L	U	2E-05		

F= Fully reclaimed
U= Unreclaimed
O = Operating

L= >100,000
S= 1,000 - 100,000

(EPA, 1989)

Emissions from two phosphogypsm stacks, located in Rock Springs, Wyoming and Magna, Utah have associated health risks of $5x10^{-5}$ for the most exposed individual, and 0.02 cancer deaths/yr if the emissions are not remediated (EPA, 1989). The cancer causing agents associated with phosphogypsm stacks are: U-238, U234, Th-230, Ra-226, Ra-222, Pb-210 and Po-210.

The health risks of mine employees are not considered here except to list the number of people employed in the mining industry in each state during 1988 as reported in the State Minerals Year Books:

State	number
Colorado	5,100
Montana	6,200
North Dakota	350(a)
South Dakota	2,760
Utah	8,612

(a) nonfules sector only

20.6 MINING WELFARE EFFECTS

This section discusses welfare damages due to active and inactive mining and milling sites in Region VIII. There are many different types of welfare effects that might be associated with mining and milling activities in Region VIII. These include:

- Replacement or treatment of contaminated drinking water;
- Loss of groundwater option value;
- Reduced suitability of surface water for agriculture;
- Reduced suitability of property for development;
- Property damage due to mine subsidence;
- Cost of illness due to ingestion of contaminated media;
- Cost of remedial actions at abandoned mine and mill sites;

- Loss of recreation opportunities; and
- Loss of valued habitats.

Data are not available to allow a quantitative analysis of each of these potential welfare effects. In some cases data are available on the extent of the problem and no cost estimates, (ie. miles of recreational fishing streams impaired by mining activities), in others cases studies of damages have been estimated for a State, but can not be extrapolated to the Region, (ie. property damage costs due to mine subsidence in Colorado), and yet in another case, data derived from one State can be extrapolated to the Region, ie., survey data on recreation impacts per mile of stream heavily impaired due to mining for one mine can be extrapolated to all Regional stream impacts due to mining activities.

Replacement or Treatment of Contaminated Drinking Water

In Region VIII fully 1,875 miles of public water supply streams were impaired due to mining activities in 1989 according to the State 319 reports summarized here in Table 20-12. (Data are not presented for Utah, as the State reports do not analyse the data into specific impaired uses.) In 1989, Colorado had 929 miles of impaired public water supply streams, while Montana had 691 miles and North Dakota had 255 miles impaired due to mining activities. In Colorado in 1989 1,955 acres of surface waters were impaired from drinking water uses (Table 20-13).

Data are not available to convert miles of impacted streams to the cost of replacement or treatment. The magnitude of these costs should be related to the availability of alternative potable water supplies. If alternative drinking water is not available, then the cost of remediation contaminated water could be quite high.

Loss of Groundwater Option Value

No quantitative or qualitative data are available to asses the costs associated with loss of groundwater option value. The costs will be highest where larger populations reliant on groundwater are nearest mine sites and alternative water supplies are limited.

Reduced Suitability of Surface Water for Agriculture

In Region VIII fully 2,119 miles of streams were impaired from irrigation and agriculture uses in 1989 due to mining activities according to the State 319 reports summarized here in Table 20-12. (Again, Utah data are not available.) In 1989 Colorado had 1,172 miles of streams impaired from agro-irrigation uses while Montana had 339 miles, Wyoming had 291 miles and North Dakota had 255 miles, and Utah had 62 miles impaired due to mining activities (Table 20-13). The miles of impairment of agricultural and irrigation waters also were impaired of live stock use in Montana and South Dakota.

Data are not available to convert miles of impacted streams to the cost of replacement or treatment. In Colorado in 1989 the same 1,955 acres of surface waters were impaired from irrigation agricultural and drinking water uses (Table 20-13).

Reduced Suitability of Property for Development

In areas adjacent to land impacted by mine wastes real estate values drop. Lands directly contaminated with mine wastes may be forever unsuited to new development. Remediation costs can be very high. Examples of remediation costs at some Regional CERCLA sites are listed below. The costs of relocation of homesteads found to be on contaminated lands can be high. The areal extent and specific costs associated with these issues are not known.

Property Damage Due to Mine Subsidence

Mine subsidence results from the removal of rock from underground mining sites and subsequent disturbance of the ground surface. Ground deformations including, sags, cracks and sink holes may severely damage residential or commercial buildings. Abandoned coal mines are a particular hazard. For Colorado, it has been estimated that over 5,000 homes and 13,000 people may be affected by mine subsidence in the front range urban corridor (Colorado Environment, 2000). Cost estimates of total potential subsidence damages were placed at 6.5 million dollars for the Colorado front range.

The extent of subsidence in the Region is unknown as are cost estimates of total potential damages. Wyoming currently has only 2 active underground coal mines. The extent of historic underground coal mines is unknown.

Cost of Illness Due to Ingestion of Contaminated Media

The costs of illness due to human uptake of contaminated mine wastes are unknown but may well be significant. The absence of data on this issue represents a critical element in the uncertainty of our assessment. Populations at risk include those living on or near historic mining sites and tourists attracted to abandoned mine sites. Education and public awareness programs can effectively reduce exposure and risk.

Cost of Remedial Actions at Mine and Mill Waste Sites

The total costs of remedial actions at abandoned mine and mill sites throughout the Region are largely unknown. Several examples have been compiled, where remedial actions have been mandated and implemented.

Some data on costs of remediation and reclamation were presented in the State Minerals Year Books and other data are available from EPA Records of Decisions (RODS) for Superfund sites and remediation activities associated with uranium mining and milling sites.

A summary of listed costs is presented for each State, as published in the Minerals Yearbook, for exemplary purposes. Costs mentioned in the Minerals Yearbook total over $500 million for Region VIII States.

Superfund remediation costs for Region VIII associated with mining and milling operations, the type of toxicant(s), waste volume, methods of remediation and cleanup goals are listed in Table 20-27. For Region VIII published Superfund remediation costs associated with mining and milling activities are $37,851,034 dollars in capital costs, $7,264,600 in present worth costs, and annual operation and maintenance costs of $1,084,837 per year (Table 20-27). Credible annual damages connot be developed from this data.

Costs associated with selected uranium mining and milling activities are listed in Tables 20-28 through 20-30. Estimated costs of reducing radon-222 flux rates to the EPA UMTRCA standard of 20 pCi/m^2 and $2pCi/m^2$ for active uranium mill sites are listed in Table 20-28. as millions of 1988 $. Estimated costs of reducing radon-222 flux rates to the EPA UMTRCA standard of 20 pCi/m^2 and $2pCi/m^2$ for inactive uranium mill sites are listed in Table 20-29 as millions of 1988 $. Estimated costs to extend underground uranium mine exhaust stacks by 10 and 60 meters for 10 Region VIII mines are listed in Table 20-.30.

Costs listed below represent some minimal value for the States and the Region, and are some unknown fraction of total costs associated with remediation efforts extant and planned. Data are from the State minerals yearbooks unless otherwise indicated.

- Colorado

  For the Eagle Mine, Gilman, Eagle County, CERCLA site $4.55 million has been paid by Gulf and Western Industries, Inc. related to remediation of this hard rock mining site.

Table 20-27
Superfund Mining Sites
FY82-FY88 Record of Decision Summary Table

Region	Site Name, State/Type/ Signature Date/ Remedial Action	Threat/Problem	Waste Volume	Components of Selected Remedy	Cleanup Goals	Present Worth/ Capital and O&M Costs
VIII	Anaconda Smelter, MT Smelter Facility/ 160-Acre Mill Creek Community 10/02/87 1st	Air contaminated with metals including arsenic, cadmium, and lead	Not specified	Relocation of all remaining residents (8 homes) with temporary erosional stabilization using a vegetative soil cover; demolition, consolidation, and temporary onsite storage of debris; implementation of institutional controls including deed and access restrictions; and site maintenance	Risk-based performance goals for arsenic and cadmium appear technically unattainable and were less than background levels. Consequently, background levels for arsenic 0.01 ug/m^3 and cadmium 0.01 ug/m^3 will be met. The NAAQS for lead 1.5 ug/m^3 also will be met	$300,000 (present worth)
VIII	California Gulch, CO Mining District 03/29/88 1st-Final	SW, sediments, and GW contaminated with metals including cadmium, copper, lead, and zinc	210 tons (waste discharged per year)	Construction of surge ponds at Yak Tunnel portal; construction of concrete plugs at three tunnel locations; sealing of shafts and drill holes; diversion of surface water away from tunnel recharge areas and grouting of highly fractured rock; implementation of a monitoring network to detect leakage, seeps, or GW migration; and installation of pump and interim treatment should surface seepage occur	This operable unit invokes an interim remedy waiver	$11,982,770 (capital) $460,307 (annual O&M)
VIII	Central City/ Clear Creek, CO 09/30/87 1st	Possible contamination of sediments, and downstream SW and GW with inorganics	Not specified	Passive/active treatment system for acid mine drainage discharge	Interim remedy. ARARs will be determined in future O.U.	$1,663,000 (capital) $511,000 (annual O&M)
VIII	Central City/ Clear Creek, CO Mining District 03/31/88 2nd	Soil and SW contaminated with metals	Not specified	Slope stabilization at Big Five Tunnel and Gregory Incline; and runon controls at all five tailings and waste rock piles	Final ARAR determinations will be addressed in the final operable unit	$1,049,600 (present worth) $20,992 (annual O&M)

Table [redacted]27 (cont.)
Superfund Mining Sites
FY82-FY88 Record of Decision Summary Table

Region	Site Name, State/Type/ Signature Date/ Remedial Action	Threat/Problem	Waste Volume	Components of Selected Remedy	Cleanup Goals	Present Worth/ Capital and O&M Costs
VIII	Milltown, MT 04/14/84 1st	GW and soil contaminated with metals including arsenic	Not specified	Construction of a new well and distribution system; and flushing and testing residential plumbing systems	GW will be treated to EPA drinking water standards for arsenic 0.050 mg/l	$262,714 (capital) $4,238 (annual O&M)
VIII	Milltown, MT 08/07/85 2nd	GW and soil contaminated with metals including arsenic	Not specified	Replacement of household water supply appurtenances; and on-going testing of residential plumbing systems	Not specified	Not specified
VIII	North Dakota Arsenic Trioxide, ND 09/26/86 1st-Final	GW contaminated with metals including arsenic	Not specified	Expansion and hook-up of homes to GW treatment and distribution system; and evaluation of possible institutional controls	Water supplied for domestic and agricultural purposes will attain the MCL for arsenic 25 ug/l	$2,212,600 (capital) $57,400 (annual O&M)
VIII	Smuggler Mountain, CO 09/26/86 1st	GW and soil contaminated with metals including cadmium and lead	410,000 yd^3	Excavation and permanent onsite RCRA disposal of soils; soil capping; and alternate water supply	Excavation and onsite isolation of soil with lead greater than 5,000 mg/kg. Soils between 1,000-5,000 mg/kg will be covered with 6-12 inches of topsoil. GW will be monitored to comply with SDWA Standards	$1,816,550 (capital) $30,900 (annual O&M)

Table 20-28
Estimated Costs of Reducing Average Radon-222
Flux Rate to 20pCi/m^2/s (a) or 2pCi/m^2/s (a)
(Millions of 1988 Dollars)

State	Mill	20 pCi/m^2/s (a) Total Cost	2 pCi/m^2/s (a) Total Cost
Colorado	Canon City		
	Primary	$13.87	$21.82
	Secondary	$6.04	$9.58
	Uravan	$11.20	$17.39
South Dakota	Edgemont	$20.74	$31.60
Utah	White Mesa	$24.75	$36.24
	Rio Algom		
	Upper	$7.05	$11.12
	Lower	$7.21	$11.36
	Moab	$24.72	$37.71
	Shootaring	$0.94	$1.56
Wyoming	Lucky Mac		
	Piles 1-3	$27.57	$45.50
	Evap. Ponds	$3.54	$3.54
	Split Rock	$16.20	$29.98
	Umetco Gas Hills	$33.93	$53.19
	Bear Creek	$8.52	$16.47
	Shirley Basin	$37.38	$61.68
	Sweetwater	$5.07	$8.34
	Highland	$32.63	$50.30
	FAP	$18.40	$28.74
	Petrotomics	$23.80	$36.17

(a) Costs are Calculated for the lower of the given flux rate or the design flux.

(EPA, 1989)

Table 20-29
Estimated Costs of Achieving the UMTRCA Limit
for Inactive Mill Tailings

	Average Limit of 20 pCi/m^2/s (Millions of 1988 Dollars)	Average Limit of 2 pCi/m^2/s (Millions of 1988 Dollars)
Mill	Total Cost	Total Cost
Durango, CO	$6.39	$9.70
Grand Junction, CO	$12.47	$15.09
Gunnison, CO	$8.25	$8.25
Maybell, CO	$12.48	$16.11
Naturita, CO	$2.61	$3.38
New/Old Rifle, CO	$11.73	$17.58
Slick Rock, CO	$0.82	$1.05
Bowman/Belfield, ND	$1.47	$1.76
Green River, UT	$1.89	$1.89
Mexican Hat, UT	$1.19	$1.62
Salt Lake City, UT	$7.37	$11.47

(EPA, 1989)

Table 20-30
Estimated Costs to Extend the Heights
of Ventilation Exhaust Stacks
at Each Underground Uranium Mine (Pi88b)

State	Mine Name	Stack Height	
		10 Meter	60 Meter
Colorado	Calliham	31,200	291,400
Colorado	Deremo-Snyder	343,200	3,205,400
Colorado	King Solomon	405,600	3,788,200
Colorado	NIL	55,500	467,100
Colorado	Schwartzwalder (a)	93,900	874,200
Colorado	Sunday	374,400	3,496,800
Colorado	Wilson-Silverbell	218,400	2,039,800
Utah	La Sal	124,300	1,117,500
Utah	Snowball-Pandora	99,400	894,000
Wyoming	Sheep Mountain #1	70,000	612,000
TOTALS		1,815,900	16,786,400

(a) Estimates do not include converting vents that exhaust horizontally through canyon walls.

(EPA, 1989)

The Globe Plant, Denver, operated by ASARCO, Inc., has paid $625,000 to cover past and future "response costs" associated with cadmium and lead contamination and effects at this CERCLA site. ASARCO, Inc. has also spent $750,000 for a waste water treatment plant to protect down stream contamination and ASARCO built a fence to protect the local population from exposure to their industrial drainage ditch.

To mitigate wastes entering the Arkansas River from the Yak tunnel and California Gulch CERCLA sites in Leadville, a $2,000,000 pond treatment facility has been constructed with EPA funds to control wastes. ASARCO, Inc. and others are defendants in this case.

The estimated remediation costs for uranium mill sites in Colorado were estimated as part of "Colorado Environment 2000" at 418 million (1988) dollars. These costs are not equal to welfare damages caused by the sites, and were not meant to reflect environmental, health, and property damages. Such remediation costs can, however, be viewed as welfare damages using a cost-avoided approach. Damages are considered equal to the costs that could have been avoided without the uranium mill tailings pollution. The cost estimates are considered a lower bound since remediation activities are slow and cost increase over time.

- Montana

In the Clark River Basin there are three Superfund sites where the Anaconda Co. is involved in a $50 million lawsuit. The Montana Departments of Heath and Wildlife and Parks estimates that 100 square miles and 30,000 people are affected. By 1988, the U.S. EPA had spent about $20 million in soil and water treatment and remediation at the Clark Fork sites. Of this amount, $9 million was used at Silver Bow Creek in Butte, $4.1 million was used to clean up a smelter related tailing pond in the town of Anaconda, $2.7 million was used for the Milltown Reservoir due to metals contamination problems, and $1.3 million on a study of the Clark Fork River. Bob Fox, EPA Helena Montana, confirmed that these "Yearbook" estimates are in "the ball park". A total of 28 million dollars had been spent at the Clark River sites by the EPA by 1989 (B. Fox, Pers. Comm.). The Montana State Minerals Yearbook quotes a "private" source's estimate that future clean up costs at these sites could cost an estimated $1.5 billion. The accuracy and reliability of this speculation is unknown.

The Federal Office of Surface Mining has given Montana a $5 million grant to clean up abandoned mine sites. About $1 million dollars were spent to cap and fill abandon mines near the city of Butte.

- North Dakota

  The State Minerals Yearbook reported that wastes from coal combustion in North Dakota amounted to 2.2 million short tons in 1988 with a disposal cost of $5 to $15 per ton.

- South Dakota

  Costs associated with the remediation of the Whitewood Creek Super Fund site were not given in the Yearbook. High levels of arsenic, (2,500ppm) cadmium and mercury have been found associated with the 10.4 millions tons of old gold mine tailings in this drainage.

- Utah

  State legislation was passed which provides for a trust fund for the reclamation of abandon mines. No costs were estimated.

  Reclamation at the recently closed Uranium mill at Moab owned by Atlas Corp. will take 6-7 years and cost an estimated 7 million dollars.

  A 1989 Record of Decision exists for the Monticello Vicinity Properties in Monticello Utah (USEPA, 1990). Tailings associated with the milling of vanadium and uranium during 1944-1960 were used for construction purposes in the city. Mill tailings were used as: fill for open lands, backfill around water, sewer and electrical lines, sub-base for driveways, sidewalks, and concrete slabs; backfill against basement foundations; and a sand mix in concrete, plaster ad mortar. Surveys indicated that 91 properties required remedial action. The cite also includes the dismantled mill and stabilized mill tailings piles. The costs associated with remedial action for the 91 "included" properties is $65,000 per property or $5,915,000. The millsite is not included in the 91 properties.

- Wyoming

  The Department of Environmental Quality's abandoned mine land program, has spent $39 million reclaiming 214 sites covering 7,500 ares of old bentonite mines.

  Cost to reclaim old gold mine sites have not been estimated, however, reclamation efforts are in conflict with historic mine site preservation efforts.

Uranium mill tailings were moved from an Indian Reservation to another location at a cost of $24 million.

Loss of Recreation Opportunities

Degradation of stream water quality due to resource extraction activities was documented in Section 20.3 and ecological effects were detailed in Section 20.4. Of the 4,305 miles of streams impaired in the Region, 3,206 miles were impaired from cold water fishery use. Fully 1,292 miles of streams were listed as having "high" impacts from mining activities in Region VIII.

Stream reaches with high severity rankings are unlikely to support healthy reproducing fish populations, which will effect recreational participation (Owens, 1989).

One study has estimated recreation opportunity losses due to mining (Rowe and Schulze, 1985) using the Recreation User Day Method. An estimate of the loss in recreation user days associated with natural resource injury, ie., water pollution and the loss of stream habitat, and then uses existing estimates of the willingness to pay of users for alternative types of recreation per day to measure economic damage. This specific study was done for the Eagle Mine Site in Colorado where recreational participation along the Eagle river was reduced by 9,600 recreation visitor days per stream mile per year. If other highly impaired streams experience similar reductions in recreation participation due to reduced water quality in the Region then 12,403,200 recreation visitor days are lost annually due to mining and milling related water pollution. Based on a review of recreation visitor day values, Rowe et al. (1987) estimated that one water related recreation visitor day could range in value from a low of $13 to a high of $28. Thus, annual damages for the 1,292 miles of highly impacted streams could range from 161 million to 347 million dollars per year.

These estimates are highly uncertain. The extrapolation from one study (Eagle Mine Colorado and the Eagle river) to the whole Region assumes that the recreation participation measured for this stream is similar to participation at all highly impacted streams in the Region. The fact that the Eagle river is close to several towns, has good road access, and has experienced severe habitat damage from mine drainage suggests that the participation losses might be lower in other highly impacted stream reaches. The estimates derived here may be considered as overestimate. If the participation Region wide is 1/4 the participation at the Eagle river then the cost estimates would range from 40 million to 87 million dollars per year.

Loss of Valued Habitats

The amount of lost habitat due to surface mining activities is not precisely known and neither are the values of these lost habitats. The areal extent of potential and measured disturbance can be approximated with existing data. For example, the extent of surface coal mining permits in the Region in 1989 covered 456,000 acres. In 1968 115,500 acres of wildlife habitat in the Region had been disturbed by surface mining activities (Table 20-14). By 1977 estimates of the area of lands disturbed by mining were 342,825 acres, with 110,550 acres of these disturbed lands without mandatory remediation. No attempt is made here to estimated the value of these amounts of habitat loss.

20.7 ASSUMPTIONS

In order to use data on the amount of mining activity; number of mines, amount of commodity produced, area under mine permits to infer the extent of potential risks we must assume that these data are correlated with mine waste generation and impacts. We evaluated this assumption with limited data and found that a good relationship can exist between impacts and amounts of mining activity.

Use of the State 319 data assumes that non-attainment is an indication of ecologic damage. We also characterized impacts due to metals, pH and radiation, as listed in the State 319 reports, as being associated with mining activities. The subjective impairment levels listed in the 319 reports were assumed to indicate something of the severity of impacts and environmental damage.

By using health risk data from a National study of mining health risks we are assuming that these results apply to Region VIII. The fraction of the National study sites, from Region VIII were listed so this assumption can be in part evaluated.

20.8 UNCERTAINTY

Many of the effects of mining activities are certain. The combined influence of multiple stressors on ecosystems or human health is not well known. Effects predicted from individual pollutants usually are underestimates when multiple pollutants are stressing the ecosystem.

While the 319 data give interesting "quantitative" numbers on the miles and acres of surface waters impaired, the actual extent and intensity of impacts are not known. This is because the same stream or lake can be listed as impaired from more than one use category by more than one stressor. Furthermore, the amount of impaired water bodies reflects results from a non-random qualitative assessment of water quality by each State.

Differences exist between States in their implementation of 319 reporting.

Very little data exist which documents the extent of terrestrial habitat disturbance due to mining. The applicability of the older data, 1968 to 1990 conditions is unknown. Very limited data on the amount of health risks due to uranium mines were available compared with the number of mines in the Region. The estimates presented may or may not reflect all mines in the Region. Of the economic risks associated with mining activities, the health costs associated with mining induced health problems may represent a major unknown.

20.9 OMISSIONS

Quantitative up-to-date information on the amount of mining activity in the Region are lacking. The BOM data base is not current and we were not able to get a copy of the Mine Safety and Health Administration (MSHA) current listing of mines in the Region. The Utah 319 report does not list impairment by severity or by use class impaired. This assessment does not include any estimate of health effects to mine workers.

20.10 RECOMMENDATIONS FOR IMPROVING RISK ASSESSMENT-REDUCING UNCERTAINTY

Quantitative statistically valid data on the areal extent of mining impacts would be most useful.

20.11 REFERENCES

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The Globe Plant, Denver, operated by ASARCO, Inc., has paid $625,000 to cover past and future "response costs" associated with cadmium and lead contamination and effects at this CERCLA site. ASARCO, Inc. has also spent $750,000 for a waste water treatment plant to protect down stream contamination and ASARCO built a fence to protect the local population from exposure to their industrial drainage ditch.

To mitigate wastes entering the Arkansas River from the Yak tunnel and California Gulch CERCLA sites in Leadville, a $2,000,000 pond treatment facility has been constructed with EPA funds to control wastes. ASARCO, Inc. and others are defendants in this case.

The estimated remediation costs for uranium mill sites in Colorado were estimated as part of "Colorado Environment 2000" at 418 million (1988) dollars. These costs are not equal to welfare damages caused by the sites, and were not meant to reflect environmental, health, and property damages. Such remediation costs can, however, be viewed as welfare damages using a cost-avoided approach. Damages are considered equal to the costs that could have been avoided without the uranium mill tailings pollution. The cost estimates are considered a lower bound since remediation activities are slow and cost increase over time.

- Montana

In the Clark River Basin there are three Superfund sites where the Anaconda Co. is involved in a $50 million lawsuit. The Montana Departments of Heath and Wildlife and Parks estimates that 100 square miles and 30,000 people are affected. By 1988, the U.S. EPA had spent about $20 million in soil and water treatment and remediation at the Clark Fork sites. Of this amount, $9 million was used at Silver Bow Creek in Butte, $4.1 million was used to clean up a smelter related tailing pond in the town of Anaconda, $2.7 million was used for the Milltown Reservoir due to metals contamination problems, and $1.3 million on a study of the Clark Fork River. Bob Fox, EPA Helena Montana, confirmed that these "Yearbook" estimates are in "the ball park". A total of 28 million dollars had been spent at the Clark River sites by the EPA by 1989 (B. Fox, Pers. Comm.). The Montana State Minerals Yearbook quotes a "private" source's estimate that future clean up costs at these sites could cost an estimated $1.5 billion. The accuracy and reliability of this speculation is unknown.

The Federal Office of Surface Mining has given Montana a $5 million grant to clean up abandoned mine sites. About $1 million dollars were spent to cap and fill abandon mines near the city of Butte.

- North Dakota

The State Minerals Yearbook reported that wastes from coal combustion in North Dakota amounted to 2.2 million short tons in 1988 with a disposal cost of $5 to $15 per ton.

- South Dakota

Costs associated with the remediation of the Whitewood Creek Super Fund site were not given in the Yearbook. High levels of arsenic, (2,500ppm) cadmium and mercury have been found associated with the 10.4 millions tons of old gold mine tailings in this drainage.

- Utah

State legislation was passed which provides for a trust fund for the reclamation of abandon mines. No costs were estimated.

Reclamation at the recently closed Uranium mill at Moab owned by Atlas Corp. will take 6-7 years and cost an estimated 7 million dollars.

A 1989 Record of Decision exists for the Monticello Vicinity Properties in Monticello Utah (USEPA, 1990). Tailings associated with the milling of vanadium and uranium during 1944-1960 were used for construction purposes in the city. Mill tailings were used as: fill for open lands, backfill around water, sewer and electrical lines, sub-base for driveways, sidewalks, and concrete slabs; backfill against basement foundations; and a sand mix in concrete, plaster ad mortar. Surveys indicated that 91 properties required remedial action. The cite also includes the dismantled mill and stabilized mill tailings piles. The costs associated with remedial action for the 91 "included" properties is $65,000 per property or $5,915,000. The millsite is not included in the 91 properties.

- Wyoming

The Department of Environmental Quality's abandoned mine land program, has spent $39 million reclaiming 214 sites covering 7,500 ares of old bentonite mines.

Cost to reclaim old gold mine sites have not been estimated, however, reclamation efforts are in conflict with historic mine site preservation efforts.

Uranium mill tailings were moved from an Indian Reservation to another location at a cost of $24 million.

Loss of Recreation Opportunities

Degradation of stream water quality due to resource extraction activities was documented in Section 20.3 and ecological effects were detailed in Section 20.4. Of the 4,305 miles of streams impaired in the Region, 3,206 miles were impaired from cold water fishery use. Fully 1,292 miles of streams were listed as having "high" impacts from mining activities in Region VIII.

Stream reaches with high severity rankings are unlikely to support healthy reproducing fish populations, which will effect recreational participation (Owens, 1989).

One study has estimated recreation opportunity losses due to mining (Rowe and Schulze, 1985) using the Recreation User Day Method. An estimate of the loss in recreation user days associated with natural resource injury, ie., water pollution and the loss of stream habitat, and then uses existing estimates of the willingness to pay of users for alternative types of recreation per day to measure economic damage. This specific study was done for the Eagle Mine Site in Colorado where recreational participation along the Eagle river was reduced by 9,600 recreation visitor days per stream mile per year. If other highly impaired streams experience similar reductions in recreation participation due to reduced water quality in the Region then 12,403,200 recreation visitor days are lost annually due to mining and milling related water pollution. Based on a review of recreation visitor day values, Rowe et al. (1987) estimated that one water related recreation visitor day could range in value from a low of $13 to a high of $28. Thus, annual damages for the 1,292 miles of highly impacted streams could range from 161 million to 347 million dollars per year.

These estimates are highly uncertain. The extrapolation from one study (Eagle Mine Colorado and the Eagle river) to the whole Region assumes that the recreation participation measured for this stream is similar to participation at all highly impacted streams in the Region. The fact that the Eagle river is close to several towns, has good road access, and has experienced severe habitat damage from mine drainage suggests that the participation losses might be lower in other highly impacted stream reaches. The estimates derived here may be considered as overestimate. If the participation Region wide is 1/4 the participation at the Eagle river then the cost estimates would range from 40 million to 87 million dollars per year.

Loss of Valued Habitats

The amount of lost habitat due to surface mining activities is not precisely known and neither are the values of these lost habitats. The areal extent of potential and measured disturbance can be approximated with existing data. For example, the extent of surface coal mining permits in the Region in 1989 covered 456,000 acres. In 1968 115,500 acres of wildlife habitat in the Region had been disturbed by surface mining activities (Table 20-14). By 1977 estimates of the area of lands disturbed by mining were 342,825 acres, with 110,550 acres of these disturbed lands without mandatory remediation. No attempt is made here to estimated the value of these amounts of habitat loss.

20.7 ASSUMPTIONS

In order to use data on the amount of mining activity; number of mines, amount of commodity produced, area under mine permits to infer the extent of potential risks we must assume that these data are correlated with mine waste generation and impacts. We evaluated this assumption with limited data and found that a good relationship can exist between impacts and amounts of mining activity.

Use of the State 319 data assumes that non-attainment is an indication of ecologic damage. We also characterized impacts due to metals, pH and radiation, as listed in the State 319 reports, as being associated with mining activities. The subjective impairment levels listed in the 319 reports were assumed to indicate something of the severity of impacts and environmental damage.

By using health risk data from a National study of mining health risks we are assuming that these results apply to Region VIII. The fraction of the National study sites, from Region VIII were listed so this assumption can be in part evaluated.

20.8 UNCERTAINTY

Many of the effects of mining activities are certain. The combined influence of multiple stressors on ecosystems or human health is not well known. Effects predicted from individual pollutants usually are underestimates when multiple pollutants are stressing the ecosystem.

While the 319 data give interesting "quantitative" numbers on the miles and acres of surface waters impaired, the actual extent and intensity of impacts are not known. This is because the same stream or lake can be listed as impaired from more than one use category by more than one stressor. Furthermore, the amount of impaired water bodies reflects results from a non-random qualitative assessment of water quality by each State.

Differences exist between States in their implementation of 319 reporting.

Very little data exist which documents the extent of terrestrial habitat disturbance due to mining. The applicability of the older data, 1968 to 1990 conditions is unknown. Very limited data on the amount of health risks due to uranium mines were available compared with the number of mines in the Region. The estimates presented may or may not reflect all mines in the Region. Of the economic risks associated with mining activities, the health costs associated with mining induced health problems may represent a major unknown.

20.9 OMISSIONS

Quantitative up-to-date information on the amount of mining activity in the Region are lacking. The BOM data base is not current and we were not able to get a copy of the Mine Safety and Health Administration (MSHA) current listing of mines in the Region. The Utah 319 report does not list impairment by severity or by use class impaired. This assessment does not include any estimate of health effects to mine workers.

20.10 RECOMMENDATIONS FOR IMPROVING RISK ASSESSMENT-REDUCING UNCERTAINTY

Quantitative statistically valid data on the areal extent of mining impacts would be most useful.

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21.0 LEAD

21.1 INTRODUCTION

This chapter assesses human health, ecological, and welfare risks from lead. Human exposure to lead can occur from air, soil, food and drinking water. Primary sources of lead discharges include gasoline, solder, water distribution pipes, paint, as well as mining, smelting, and refining operations. Of these sources, mining, smelting and refining operations are assumed to generate the majority of ecological risks.

It should be understood that the estimates presented for this problem area are meant to be illustrative, rather than numerically precise. The risk assessments are based on extrapolations from national distributions, average values, and, in some cases, personal communications. Many of the published data and approaches used have not been subject to peer-review. Thus, the estimates presented herein are meant to provide the reader with a general feel for the order-of-magnitude of risk. In addition, the analysis does not consider solder and lead-based paint as potential exposure

21.2 HUMAN HEALTH RISK ASSESSMENT

21.2.1 Toxicological Profile

Lead substitutes for a number of essential minerals in biological processes, particularly iron and calcium (Luckey, 1977). The principal toxic effects of lead include inhibition of heme synthesis (used for carrying oxygen in hemoglobin), kidney disfunction, and central nervous system (CNS) effects (ATSDR, 1988). Symptoms of these impacts are quite broad, and can include increased blood pressure, anemia, fatigue, depression, mental illness, irritability, memory loss, dullness, impaired motor control, reduced learning ability and reduced growth.

Of special concern is the impact of lead exposure on children, since they have greater sensitivity to lead than adults. This sensitivity includes increased brain penetration, higher skeletal uptake, and greater CNS impairment for a given level of uptake. Table 21-1 lists lead-related health effects associated with specific blood lead levels (PbB).

Out of this suite of potential effects, risks are assessed for the following specific responses:

- Newborn mortality. Elevated levels of PbB in pregnant women has been shown statistically to be associated with reduced birth weight in infants. Reduced birth weight, in turn, has been linked with increased likelihood of infant mortality. Thus, the probability of infant death can be assessed with respect to maternal PbB (EPA, 1989).

Table 21-1
Health effects associated with blood lead levels (PbB)

Blood Lead (μg/dL)	Potential Health Effect	Sensitive Population	Reference
4	Reduced growth	Fetus/young Children	Schwartz et al. (1986)
5	Hypertension	Middle-aged Males	Victery et al. (1988)
6	Electrophysiological Dysfunction	Children	Schwartz and Otto (1987)
10	Enzyme Inhibition	Children	Angle et al. (1982)
10	Hypertension	Middle-aged Males	Neri et al. (1988)
12	Interference with Vitamin D Metabolism	Children	Mahaffey et al. (1982)
10-15	Cognitive Dysfunction	Infants	EPA (1986)

- Circulatory effects in adult males. Elevated PbB levels in adult males has been linked statistically to several adverse health effects associated with the circulatory system, including hypertension, strokes, and heart attacks.

- I.Q. reductions. Of the health effects related to lead in children, one of the most tractable from the standpoint of quantification is the relationship between PbB and intelligence, typically measured in I.Q. points.

It should be noted that there may be a threshold for acute neurologic effects; however, no threshold has been observed to-date for effects on heme synthesis or on learning ability (CDC, 1985; EPA, 1989).

21.2.2 Exposure Assessment

Exposure Scenarios

Human health risks are estimated for the three toxicological endpoints described above according to two alternative exposure analyses:

- Average risks are estimated for the population of Region VIII based on the national distribution of blood lead.

- Risks to higher-than-average exposed populations are assessed based on exposure to lead from superfund sites.

Based on the Second National Health and Nutrition Estimation Study (NHANES II) conducted from 1976-1980, EPA (1989) characterized national distributions of PbB as being lognormal. When adjusted for subsequent reductions in leaded gasoline, Abt (1989) estimated that the geometric mean (GM) of this national distribution of PbB in 1990 will be 3-5 μg/dL, with a geometric standard deviation (GSD) of 1.42. This analysis was refined further to include a distributional breakdown by age and sex (Table 21-2).

Population Exposed

The total exposed population of the six states in Region VIII is 7.65 million, based on 1986 census data. 1984 census data indicate that of this total, approximately 700,000 are 5 years and under. Moreover, it was estimated that approximately 10% of the population of Colorado was comprised of middle-aged males (40-59 yrs) (State of Colorado, 1989). Applying this same proportion to the entire region yields an assumed exposed middle-age male population of 765,000 (Table 21-3). The population of women of child-bearing age (ages 14-44) was estimated from 1984 census data by assuming that 50% of all individuals within the appropriate age brackets were female. This population was estimated to be 1.9 million (Table 21-3).

Table 21-2
Distribution of 1990 blood lead concentrations (µg/dL) for different sub-populations. Value used in analysis in bold-face, range in parenthesis

	Geometric Mean	Geometric Standard Deviation
Children (2 yrs)	**3.9** (3.0 - 4.7)	1.42
White Men (40-59 yrs)	**4.3** (3.8 - 4.9)	1.39
Overall	**4.0** (3.0 - 5.0)	1.42

Source: Abt (1989)

Table 21-3
Exposed population in Region VIII

State	Total Population[1]
Colorado	3,267,000
Montana	819,000
North Dakota	680,000
South Dakota	707,000
Utah	1,665,000
Wyoming	507,000
Total	7,646,000
Average Exposure Scenario	
Men (40-59)	765,000
Women (14-44)	1,900,000
Children (5 and under)	700,000
High-Exposure Scenario	
Total	115,000
Men (40-59)	11,500
Women (14-44)	28,750
Children (5 and under)	10,350

[1] Based on 1986 U.S. Census data.

The population of the high-exposure scenario was estimated roughly by summing the populations of communities in which mine-related National Priority List (NPL) sites are located[2]. Assuming that 100% of individuals living in these communities can be classed within the high-exposure group yields a population of approximately 115,000, or 1.5% of the total population. The breakdown of this high-exposure population into the three target subpopulations (women of childbearing age, adult males (40-59 years), and children aged 5 and under) was accomplished by applying the same ratios as apply in the overall population (Table 21-3). Although this estimate is quite conservative because of the assumption of 100% exposure in NPL-site communities, it may present a rough picture of the magnitude of a high-exposure sub-population within the region.

Rough estimates of the distribution of PbB in the high-exposure group were made by shifting the national distribution of PbB upwards (see Abt, 1989). This shift was made using the results of three studies of PbB in mining communities located in Region VIII (from Steele, et al., 1990). In the first study, conducted in Telluride, CO by Bornschein, et al. (1988), a relationship was found indicating an increase in PbB of 2.2 μg/dL per 1000 ppm Pb in soil. For the Telluride site (with average soil lead of 178 ppm) this suggests increasing the PbB distribution by 0.4 μg/dL. A second study conducted in Park City, UT by Perrotta and Stafford (ND) (cited in Steele et al., 1990) showed a GM PbB of 7.8 μg/dL, an upwards shift of nearly 4 μg/dL over the national GM. A third study, conducted in Leadville, CO by the Colorado Department of Health (CDH, 1990) calculated the GM of PbB in children and in adult males to be 8.7 μg/dl (GSD=1.8), and in women of childbearing age to be 1.1 μg/dl (GSD=1.66). A fourth, unrelated, study of mining communities in the UK calculated PbB of 8.9 μg/dL. For lack of more rigorous analyses of PbB in mining communities in Region VIII, two scenarios were assumed from the above: a "high-risk" scenario with GM PbB of 8 μg/dL, and a "low-risk" scenario in which national GM were shifted upwards by 0.4 μg/dL. In both cases, the GSD was applied from the national PbB distribution.

21.2.3 Human Health Risk Characterization

Fetal Effects

Fetal effects of blood lead, expressed in terms of decreases of >2 points in Bayley MDI scores of neurobehavioral performance are based on a threshold effects model (Abt, 1989). This threshold model suggest that pregnant women with PbB in excess of 10 μg/dL would have expected MDI scores lower than the population average. In addition, it was estimated by Abt (1989) that pregnant women with PbB > 10 μg/dL can be expected to give birth to children with lower expected IQ scores.

[2] The following localities were included: UT (Anaconda, Butte, Milltown, E. Helena); CO (Leadville, Aspen, Central City, Eagle, Telluride); UT (Monticello, Midvale, Park City, W. Jordan). Site selection based on personal communication by J. Levall, U.S. EPA, Region VIII.

Average Case

The total number of cases of fetal effects was assessed by estimating the probability of exceeding the 10 μg/dL threshold from the national distribution of PbB for women. This probability, 0.27%, was then multiplied by the total population of women of childbearing age (ages 14 to 44) in Region VIII (1.9 million) and by 6.8%, the proportion of this subpopulation expected to give birth to a child in a given year (Abt, 1989). Using this technique, 349 expected cases were estimated (Table 21-4).

High-Exposure Case

Applying the above methodology to the two high-exposure scenarios yields an estimated 156 cases for the high-risk scenario, and 2 cases for the lower-risk scenario (Table 21-4).

Neurological and Developmental Effects (Children)

Average Case

A similar threshold model was proposed by Abt (1989) (based on study results of Schwartz (1987) and Fulton et al. (1987)) to estimate the number of annual childhood cases of either stunted growth or reduced CNS development. Once again, the applied threshold level was 10 μg/dL, while the number of expected cases was estimated by multiplying the probability of exceeding the threshold (based on the national distribution of PbB in children), 0.27%, by the number of children in Region VIII. The total expected number of cases is estimated to be 1,890 (Table 21-4).

High-Exposure Case

For the high exposure group, an expected 828 cases were estimated for the high-risk scenario, and an expected 17 cases for the lower-risk scenario (Table 21-4).

Cardiovascular Effects--Adult Males

An alternative approach was used to estimate expected frequencies of hypertension in adult males as a result of exposure to lead. This latter approach was based on the assumption of a non-threshold dose-response relationship (EPA, 1989). Pirkle, et al. (1987), as cited by Abt (1989), proposed a logistic equation relating the log of an individual's blood lead to the probability that the individual's diastolic pressure would exceed 90 mm Hg:

$$p = 1/\{1 + e^{-[0.793\,(\ln PbB) - 2.72]}\} \qquad (1)$$

Table 21-4
Results of health risk analysis for blood lead in Region VIII

	Exposure Scenario		
Health Endpoint	Average Case	High Exposure/High Risk	High Exposure/Low Risk
Fetal Effects: Neurobehavior	349	156	2
Fetal Effects: IQ Decrement	349	156	2
Developmental Effects: Children	1,890	828	17
Cardiovascular Effects: Adult Men	30,000 - 77,000	14,000	8,750

where p is the probability that an individual's diastolic pressure exceeds 90 mm Hg, and *PbB* is the individual's blood lead level (μg/dL). This logistic equation is depicted in Figure 21-1.

The total number of expected cases was then extrapolated using the joint probability of exceeding a given level of PbB, and the probability of developing hypertension for that blood lead concentration:

$$E(CVC) = \max [Pr (H_i) * Pr (PbB_i) * EP] \qquad (2)$$

where *E(CVC)* is the most likely estimate of the number of cardiovascular "cases", $Pr(H_i)$ and $Pr(PbB_i)$ are, respectively, the probability of developing hypertension and the probability of exceeding a given blood lead level (based on the national distribution of PbB in adult men) for i concentrations of PbB, and *EP* is the size of the exposed population. This joint relationship is shown in Figure 21-2. Based on this analysis, it was estimated that most likely occurrence of cardiovascular cases is 77,000, or 11% of the exposed population (Table 21-4)[3].

Given this extreme result, it must be noted that an alternative estimation method was used by Abt (1989) which involved application of a 7 μg/dL threshold concentration for hypertension. Application of this metric to the distribution of PbB yields an expected probability of 4.3%, or 32,895 cases. Given current uncertainties about the true dose-response relationship, however, it can only be supposed that the expected number of cases would likely fall within the range of 30,000 to 80,000.

High Exposure Case

Applying the logistic regression equation to the high exposure/high-risk case yields an estimated 14,000 cases, or 20% of the assumed population of 70,000. For the high exposure/low-risk case, 8,750 cases (12.5% of the exposed population) were estimated (Table 21-4).

21.3 ECOLOGICAL RISK ASSESSMENT

21.3.1 Toxicological Profile

Lead is a cumulative toxicant with relatively low acute toxicity, but a wide variety of potential chronic responses, including:

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[3] It must be recalled that the cardiovascular endpoint assessed using the foregoing dose-response relationship is the likelihood of diastolic BP exceeding 90 mm Hg.

Figure 21.1 Relationship between [PbB] in adult men and probability of hypertension

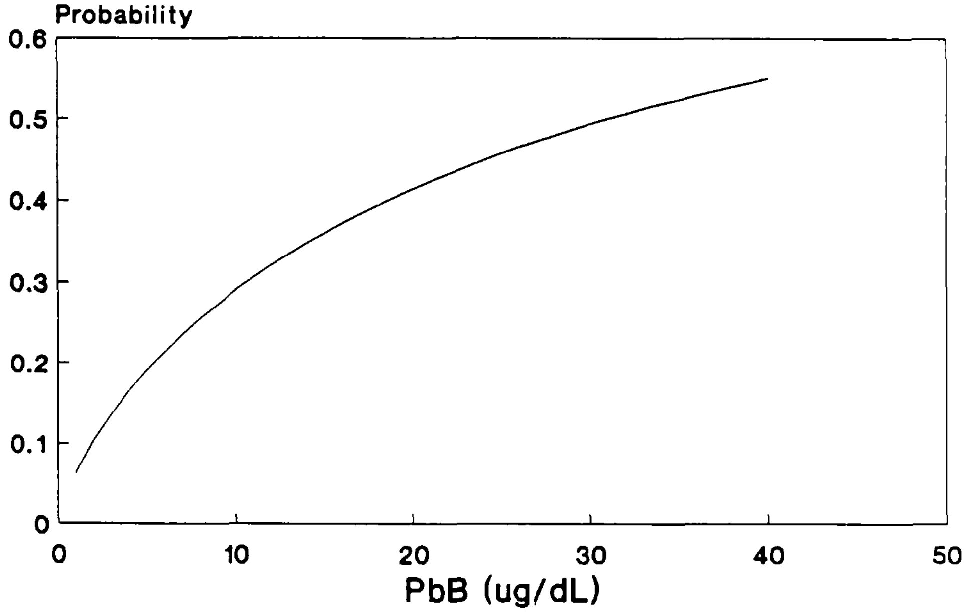
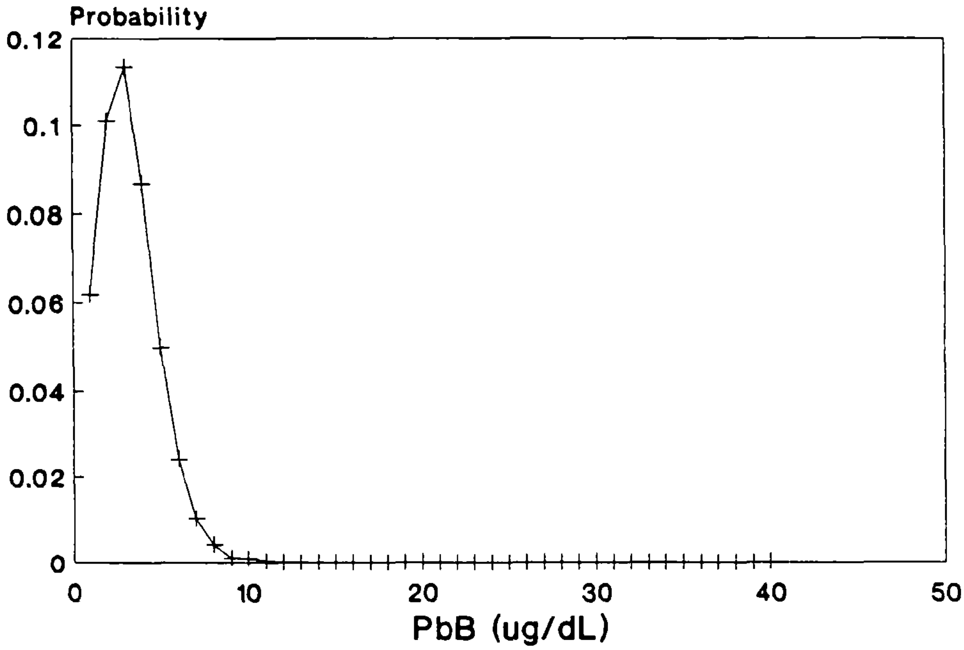


Figure 21.2. Joint probability of blood lead (PbB) and hypertension.



- inhibition of aminolevulinic acid dehydratase (ALAD) (involved in synthesis of hemoglobin), reducing oxygen carrying capacity of blood;
- degenerative spinal curvature (scoliosis, lordosis) in fish;
- neurological and behavioral effects in mammals, including hyperactivity in rats and mice, and impaired learning ability in monkeys;
- reproductive effects in mammals and amphibians (including post-implantation mortality, skeletal abnormalities, decreased growth rates);
- behavioral effects in fish; and
- reproductive impairment and impairment of chemoreception in fish and zooplankton (Canada Ministry of the Environment, No Date).

Lead toxicity is primarily attributable to free Pb^{2+}. Acute toxicity (LC_{50}) values for lead range from approximately 1 - 400 mg/l for aquatic species. For plant species, toxicity values are extremely variable, and depend on soil makeup. In loblolly pine and red maple, for example, lead levels of 100-500 ppm resulted in accelerated leaf dropping and an increase in red pigmentation in the maple, and a decrease in needle size in the pine. In carrots and lettuce, however, significant growth inhibition was shown to occur at concentrations between 0.5 and 5 ppm.

Chronic effects in aquatic species may occur at significantly lower concentrations, however. For example, chronic responses have been demonstrated at lead concentrations (dissolved Pb) between 0.0041 and 0.032 mg/l for rainbow trout, 10 mg/l in catfish, and 30 mg/l in *Daphnia magna* (Canada Ministry of the Environment, No Date).

21.3.2 Exposure Assessment

The absence of environmental concentration data for lead in different media in Region VIII prevents a detailed exposure assessment for this problem area. However, environmental exposures will occur via atmospheric deposition (primarily from leaded gasoline and from smelting operations), and from mining runoff.

21.3.3 Ecological Risk Characterization

Absence of exposure assessment data prevents quantification of ecological risks. However, it is likely that primary ecological effects of lead will occur in mining/smelting sites, where environmental concentrations can attain levels in tens of thousands of ppm. Moreover, sites with low ambient alkalinity will tend to promote more severe ecological damage because of the mitigating effect of alkalinity on lead toxicity.

21.4 WELFARE RISK ASSESSMENT

Welfare effects resulting from exposure to environmental lead can include:

- costs of illness and lost wages associated with hypertension;
- costs of illness associated with fetal effects;
- psychological damages associated with infant mortality; and
- forgone earning potential and addition education associated with I.Q. decrement.

Non-health related welfare effects can include:

- forgone benefits (recreational, aesthetic and other non-use benefits) associated with injured natural resources;
- reductions in property values in areas with high lead concentrations;
- social effects (e.g., social and economic stratification) related to the fact that the preponderance of effects may occur in lower-income groups because of high exposures to leaded paint and gasoline fumes in urban areas, poorer health care, etc.

There is little published information available to monetize the above welfare effects. Mathtech (1986) estimated the "costs" of hypertension (medical treatment, lost wages, medication) to be approximately $24 - $252 per case (1986 dollars). Assuming the total number of cases to be 30,000 - 80,000, this yields a range of .7 to 20 million dollars. Abt (1989), in a similar analysis, suggest a per/case cost of $277, or 8 to 22 million dollars.

Fetal mortality-effects were valued by RCG (1990) using a value-of-life approach. A range of values of a "statistical life" were obtained from the available literature (1.7 to 8.8 million

(1988 dollars)). Applying these values to the expected number of cases yields an estimated 593 million to 3 billion dollars.

I.Q. decrement was valued by Abt (1989) as being approximately $2500 per affected child. Applying this cost figure to the risk results yields a welfare cost of 0.9 million dollars.

It should be noted that the above studies provide extremely rough benchmarks of welfare costs. For example, monetization of hypertension in terms of medical care, lost income and medication may ignore significant psychological impacts, and application of "value of a statistical life" and I.Q. decrement approaches are both highly controversial. Finally, it must be recalled that only a fraction of welfare-related effects are included in this approach. Thus, the monetized estimates provided above (ranging from hundreds of millions to billions of dollars) should be deemed a lower bound of the actual welfare effects of lead.

21.5 CONCLUSIONS

The ubiquity of lead (as a result of emissions from leaded gasoline, widespread historical use of leaded paints, leaded pipes and solder in water supply, and elemental lead in soil), coupled with the significant (and varied) chronic health effects of lead, points to the potential for considerable human health impacts from this problem area. Specifically, health impacts to sensitive populations (children, middle-aged males) may be highly significant in areas of extreme exposure (inner cities, mining communities). Because of the potential for extensive health effects, welfare-related impacts from lead may be extensive. Finally, the relatively low acute toxicity of lead suggests that large-scale ecological effects are unlikely to occur in Region VIII. However, the variability of chronic effects in both aquatic and terrestrial species could lead to substantial impacts in localized areas of high concentration (e.g. NPL sites).

21.6 PRINCIPAL CONTACTS

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22.0 PHYSICAL DEGRADATION OF TERRESTRIAL ECOSYSTEMS/HABITATS

22.1 INTRODUCTION

The Physical Degradation of Terrestrial Ecosystems and Habitats problem area covers risks to the environment and human welfare. Human health effects are not estimated for this problem area. Risks in this problem area are associated with physical modifications of the environment, for example, construction, mining, logging, and agricultural drainage; wind and water caused soil erosion; and habitat fragmentation. Effects of desertification were not addressed due to a paucity of data. However, we believe that anecdotal evidence suggests that this may be a significant problem in Region VIII. Only welfare effects associated with both off and on-site soil erosion damages were considered in this analysis. The effects of agricultural drainage on wetland resources are also discussed in the Wetlands problem area.

Loss of terrestrial habitat occurs through changes in land use, highway construction, urbanization, agriculture, silviculture, mining and related practices that "consume" or alter physical landscape features. For example, direct loss of habitat and dramatic alteration of ecosystem structure and function results when lands are converted from natural ecosystems to roads and urban areas.

Terrestrial ecosystems, including agro-ecosystems, are degraded by physical means such as soil loss, erosion, desertification, by timber harvesting, and grazing activities.

Landscape alterations are in some cases permanent (urbanization and road construction), with long-term and irreversible effects. Other physical modifications such as grazing and timber harvest can result in short term and reversible effects. Under poor management practices, however, silvicultural and grazing impacts can be extensive and relatively permanent.

Habitat loss due to this problem area may be the major cause of reduced local and regional biodiversity. Species reliant on a specific habitat are forced into local extinction with habitat loss. Interruption of migration pathways and habitat fragmentation may also affect species distributions at Regional scales.

22.2 DATA DESCRIBING THE EXTENT OF PHYSICAL HABITAT AND ECOSYSTEM DEGRADATION IN REGION VIII

Data on the losses of physical habitat in Region VIII are lacking. An indication of the magnitude of habitat loss and ecosystem physical degradation has been derived from several sources for this assessment. The source of data differs for Federal and non-Federal lands in the Region. The relative area of Federal versus non-Federal lands for Region VIII States is listed in Table 22-1 as reported by the Soil Conservation Service (SCS) (1987). For Region VIII just over 30% of the land area is Federal. The amount of Federal land in each State varies by State from 4.4% in North Dakota to 60% in Utah.

22.2.1 Non-Federal Lands Data

For non-federal lands the Soil Conservation Service's, statistically based National Resources Inventories (NRI) of 1982 and 1987 are used to estimate the amount of terrestrial habitat physical degradation due to land development and soil erosion (SCS, 1989).

22.2.2 Scope of Land Development

The amount of land area developed ("urban and built up lands") was estimated by the NRI for all non-Federal lands in both the 1982 and 1987 surveys. The acres of developed land, the total land area, the percentage of the total area developed and the change in developed land area since 1982 are listed in Table 22-2. For Region VIII about 1.5 % of the total non-Federal land area has been developed compared with the national average of 4%. For states within the Region values of percentage development range from a low of 0.8 % in Utah and Wyoming to a high of 2.7% in North Dakota.

Each State has shown an increase in the area of developed lands since 1982; Colorado has seen the largest increase in developed land area, 91,900 acres while South Dakota has increased developed lands least, 4,900 acres. The Regional increase in the area of developed lands between the survey years was 174,500 acres.

22.2.3 Soil Loss

The SCS estimates the amount of soil loss and erosion on cropland, pastureland, range land, forest land, and other minor rural land classes (SCS, 1989). Soil loss by sheet and rill erosion are estimated for each land class while wind erosion is only estimated from cropland.

We used SCS data to derive the amount of soil loss (tons per year) in the Region and in each state as:

$$\text{Soil Loss (tons per acre)} = \text{Sum}[(\text{ALCC})(\text{SLLCC})]$$

where:

ALCC = acres of land cover/class
SLLCC = soil loss(tons/acre/yr)/land cover class

Table 22-1
Area of Federal and Non-Federal Lands

State	Acreage of Federal Lands	Acreage of Non-Federal Lands	Acreage of Total Lands	Percent of Federal Lands
Colorado	19,781,207	46,704,553	66,485,760	29.75%
Montana	27,445,436	65,825,604	93,271,040	29.43%
North Dakota	1,958,284	42,494,196	44,452,480	4.41%
South Dakota	2,676,039	46,205,881	48,881,920	5.47%
Utah	31,636,133	21,060,827	52,696,960	60.03%
Wyoming	29,005,724	33,337,317	62,343,040	46.53%
Region VIII	112,502,823	255,628,377	368,131,200	30.56%
USA	688,253,346	1,583,090,014	2,271,343,360	30.30%
Region VIII as % of USA	16.35%	16.15%	16.21%	

(SCS, 1987)

Table 22-2
Development on Non-Federal Lands

State	Year	Acres Developed	Total Area	Percent Developed
Colorado	1982	1,283,000	66,618,200	1.90%
	1987	1,374,900		2.06%
	Change	(91,900)		
Montana	1982	991,800	94,109,200	1.05%
	1987	999,300		1.06%
	Change	(7,500)		
North Dakota	1982	1,224,300	45,249,500	2.71%
	1987	1,242,200		2.75%
	Change	(17,900)		
South Dakota	1982	1,059,100	49,354,000	2.15%
	1987	1,064,000		2.16%
	Change	(4,900)		
Utah	1982	428,100	54,335,500	0.79%
	1987	465,000		0.86%
	Change	(36,900)		
Wyoming	1982	485,700	62,598,000	0.78%
	1987	501,100		0.80%
	Change	(15,400)		
USA	1982	73,557,800	1,940,059,700	3.79%
	1987	77,553,900		4.00%
	Change	(3,996,100)		
Region VIII	1982	5,472,000	372,264,400	1.47%
	1987	5,646,500		1.52%
	Change	(174,500)		

(SCS, 1989)

The amount of soil loss due to water and wind erosion in 1982 and 1987 is presented in Figures 22-1 and 22-2, respectively. Soil loss via wind erosion is of similar magnitude as the water born losses.

Regional soil loss approaches 1 billion tons of soil per year (SCS, 1989). States vary in the amount of wind and water erosion; Wyoming and Utah have the smallest soil loss, while Colorado and Montana exhibit the greatest losses. Region VIII accounts for about 13-17% of the total U.S. soil loss. By erosion type, the Region accounts for 41% of total wind born losses and 6% of water born soil loss in the U.S. in 1987.

Trends in habitat degradation from soil loss can be estimated from SCS data, as habitat degradation is associated with total soil loss (SCS, 1989). Between 1982 and 1987 three States in the Region (Colorado, Utah, and North Dakota) showed an increase in total soil loss while the other States (South Dakota, Montana, and Wyoming) demonstrated a decrease in soil loss (Figure 22-3).

The observed changes in total soil loss resulted from an increase in wind erosion in all States except Montana and Wyoming, and a decrease in water erosion for all but Montana (Figure 22-3). For the Region and each State, except Montana, total estimated annual soil loss from sheet and rill erosion was significantly less in 1987 than NRI found in 1982 (Figures 22-4 through 22-6).

While the general pattern is toward reductions in soil loss from water erosion, some land use classes in several states have seen increased soil loss from water erosion. Soil loss from croplands has increased since 1982 in Montana and North Dakota by 3,000,000 and 2,000,000 tons of soil per year, respectively. Colorado has also seen an increase in soil loss from forest lands of about 1,000,000 tons of soil per year (Figure 22-6).

The amount of habitat damage from water born soil loss varies with land use. A more detailed assessment of the degradation of the various SCS land cover types due to water born soil loss is shown in Figures 22-4 through 22-6. Soil loss varies with land cover class. Crop and range lands evidence more soil loss than forest and pasture lands. Within the Region loss amounts differ between States. For example, cropland losses are small in Wyoming and Utah compared with other States while range land soil loss is relatively more important for these States.

Colorado and South Dakota have nearly two times the water born soil loss of the other States due to the apparent contribution from minor lands. The magnitude of contribution from minor lands is uncertain due to the smaller sampling size attained for minor land classes and variability in soil loss from minor land class constituents (George, 1990). These minor class constituents include barren lands, urban areas, farmsteads, and feed lots. Soil losses estimated due to these land use types can be very large if the random sample falls at a site with a steep slope on highly erodible barren land or a feed lot. Extrapolation to the region from such samples can yield disproportionately high loss estimates.

Figure 22.1
Soil Loss From Wind and Water Erosion

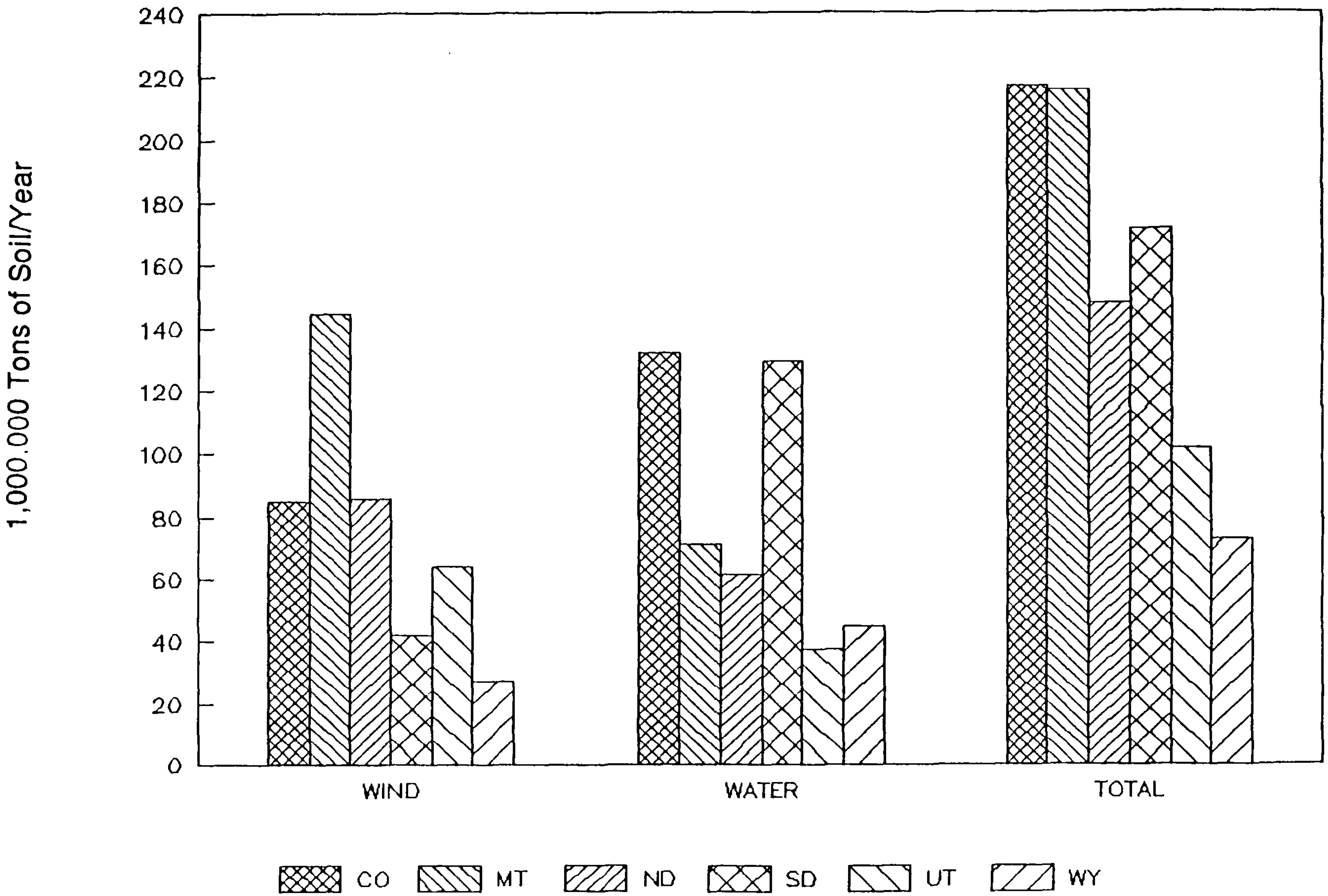


Figure 22.2
Soil Loss From Wind and Water Erosion

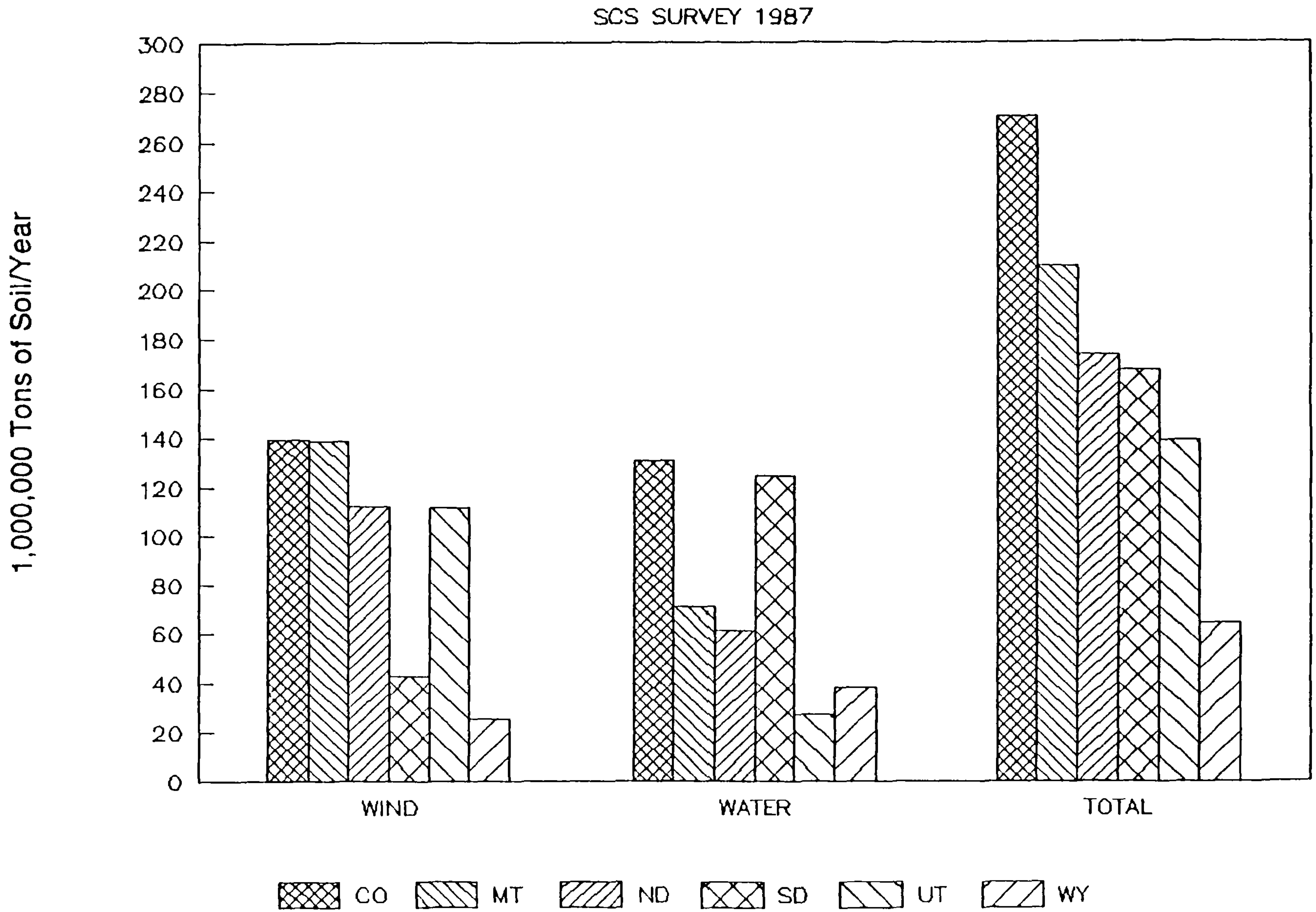
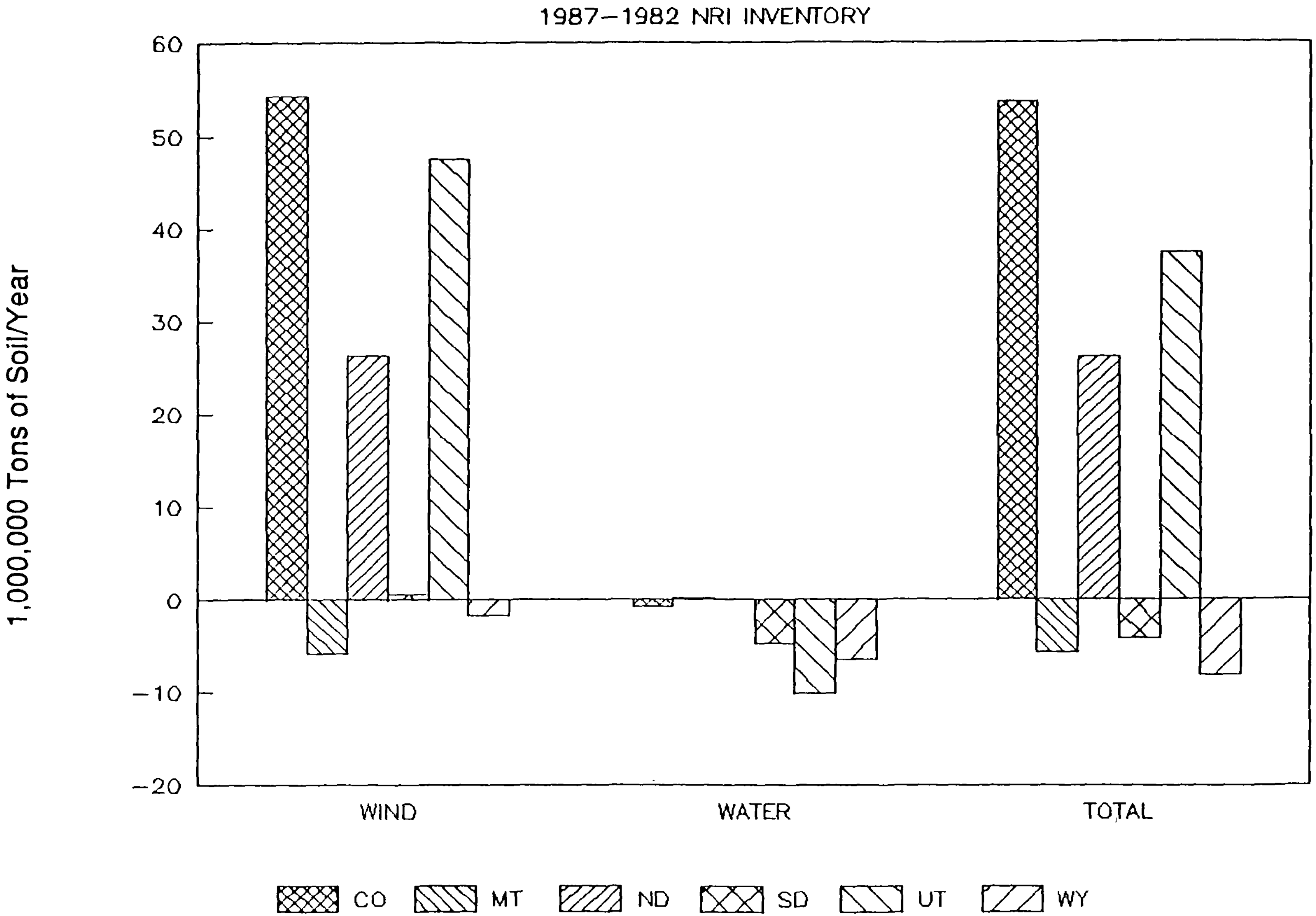


Figure 22.3
Change in Soil Loss From Wind and Water Erosion



(SCS, 1987, 1989)

Figure 22.4
Soil Loss From Sheet and Rill Erosion

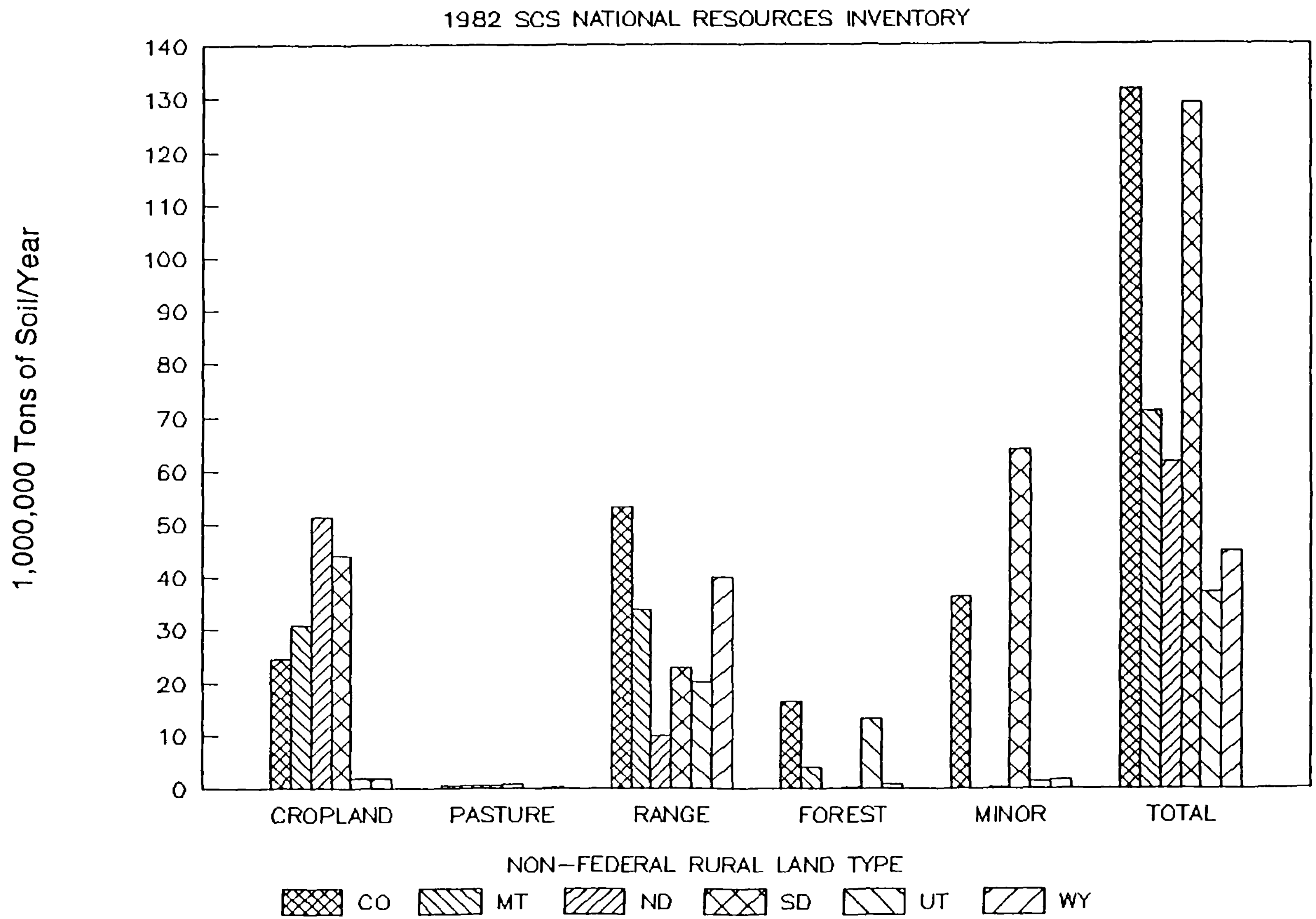


Figure 22.5
Soil Loss From Sheet and Rill Erosion

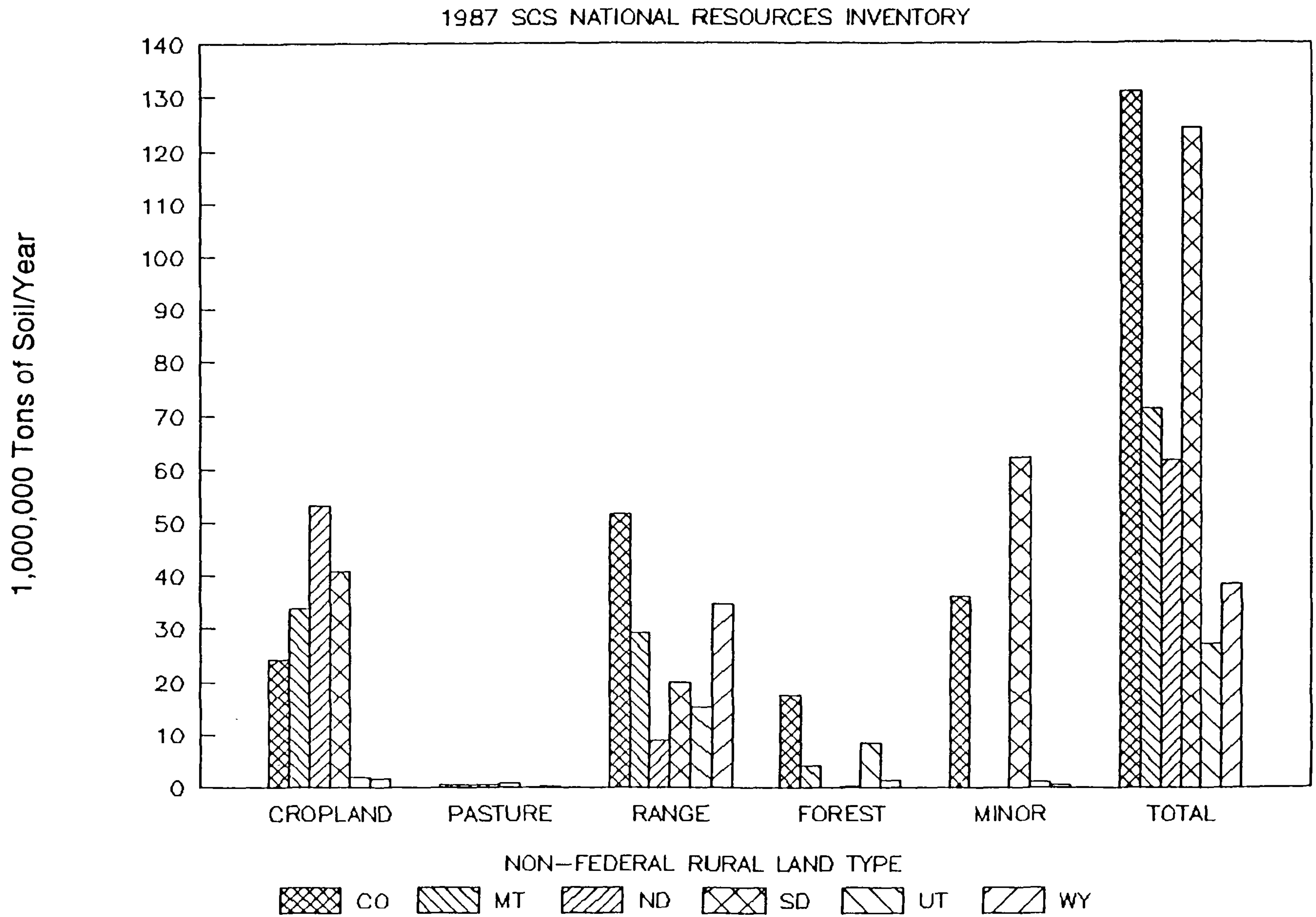
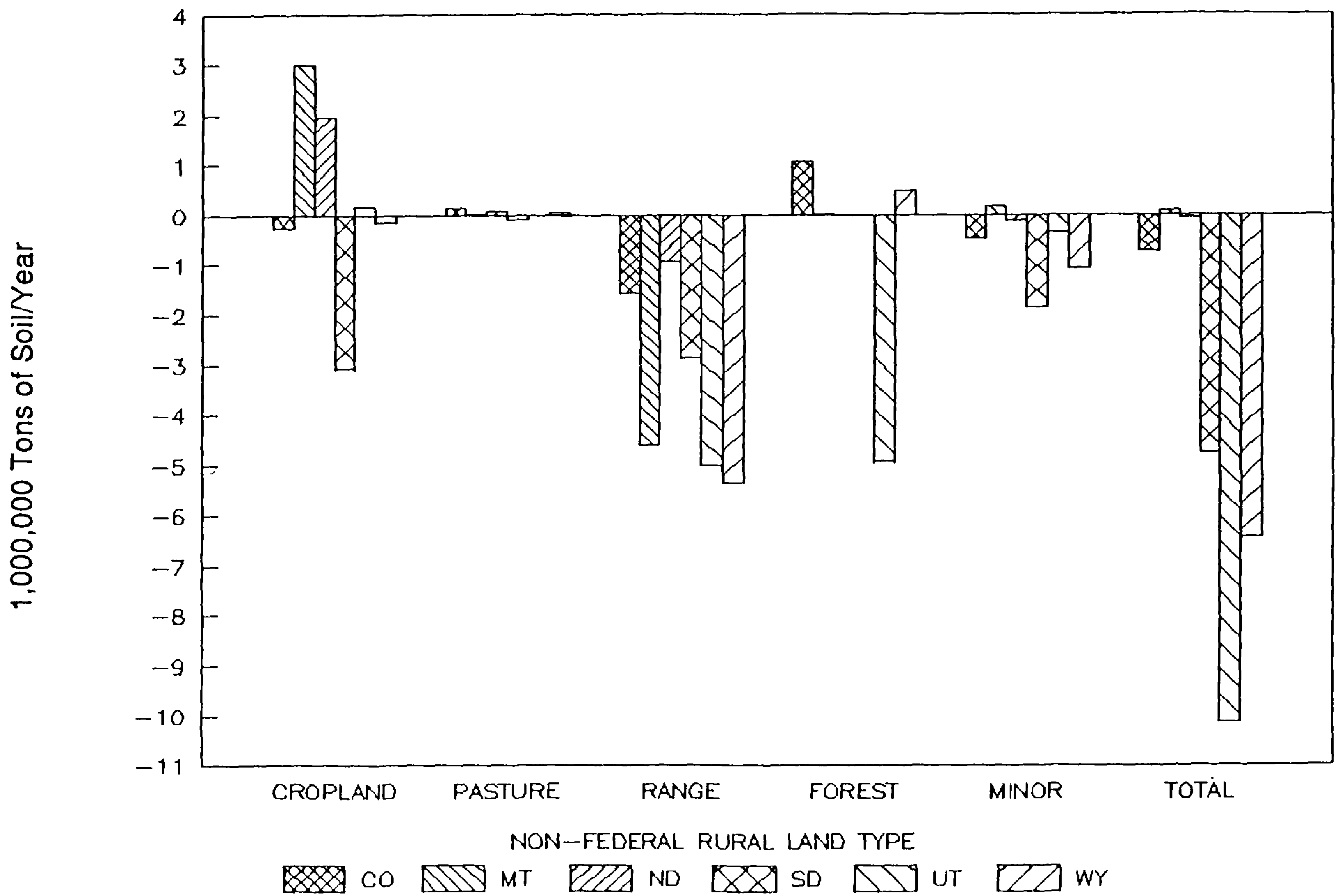


Figure 22.6

Change in Soil Loss From Sheet and Rill Erosion

1987–1982 NRI INVENTORY



22.3 FEDERAL LANDS DATA

For Federal lands controlled by the U.S.D.A. Forest Service, U.S.D.I. Bureau of Land Management and Park Service, quantitative data on the loss of habitat or the amount of physical ecosystem degradation are lacking. An index to the potential amount of physical disturbance to Federally managed landscapes is derived from USDA (1990a) and BLM (1990). Similar data for Park Service lands were not available.

The Forest Service and BLM annual statistical summaries provide data on: the condition of BLM grazing lands, the amount of grazing and timber harvesting, and the amount of habitat disturbed by fire.

22.3.1 Grazing

Data on grazing impacts on range lands are maintained by the BLM. (BLM, 1990). The amount of habitat degradation on grazing lands managed by BLM is quantified in Table 22-3 as the percentage of range lands exhibiting poor, fair, good or excellent condition. Condition is expressed as the degree of similarity of present vegetation to the potential natural, or "climax", plant community where Excellent = 76-100% similarity, Good = 51-75% similarity, Fair = 26-50% similarity; and Poor = 0-25% similarity. About 45% of Region VIII BLM range lands are in fair or poor condition.

The amount of habitat at risk from grazing activity is related to the amount of grazing. The actual amounts of BLM and Forest Service lands under grazing are not published. For BLM land, grazing data are indexed by dollar amount of grazing leases and licenses (Table 22-4). For Forest Service lands, the number of animal unit months (AUM) are published (Table 22-4). (An animal unit month is the amount of forage required by a 1,000-pound cow, or the equivalent for 1 month.)

For Region VIII BLM lands, about 7.5 million dollars in grazing leases are let each year. This corresponds to 41.5% of the total grazing receipts for BLM lands nationwide. By this index Montana and Wyoming have the most grazing activity, and North Dakota the least (Table 22-4).

The amount of grazing activity on Forest Services lands, measured by the number of AUM for Region VIII, is 3,596,214 AMUs (Table 22-4). On Forest Service lands the amount of grazing is greatest in Colorado, followed by Utah, Wyoming, Montana, South Dakota, and North Dakota.

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Table 22-3
Habitat Condition on BLM Grazing Lands

State	% by Range Condition Class (a) Ecellent	Good	Fair	Poor	Unclass- ified (b)
Colorado	3	15	39	24	19
Montana	6	57	21	1	15
North Dakota	----	----	----	----	----
South Dakota	----	----	----	----	----
Utah	4	28	40	13	15
Wyoming	5	48	35	6	6
Region VIII	4.5	37	33.75	11	13.75
BLM	3	30	36	16	14

a Expressed in degree of similarity of present vegetation to the potential natural, or climax, plant community: Excellent=76-100% similarity Good= 51-75% similarity, Fair = 26-50% similarity; Poor = 0-25% similarit
b This category includes rangelands for which neither data nor estimates ar

(BLM, 1990)

Table 22-4
Grazing and Silviculture Activity
on BLM and Forest Service Lands

State	Timber Sales BLM Lands	Grazing Lease, Licenses BLM Lands	Grazing AUM FS Lands	Volume (MBF) Timber Sales FS Lands	Value of Timber Sales FS Lands	Value of Timber/MBF FS Lands
Colorado	$143,896	$929,722	938,894	189,305	$5,117,813	$27
Montana	$418,406	$2,258,772	516,966	444,880	$40,056,671	$90
North Dakota	$0	$16,551	422,152	65	$600	$9
South Dakota	$1,873	$140,077	444,092	93,399	$7,249,007	$78
Utah	$63,319	$1,577,585	663,738	72,056	$1,773,898	$25
Wyoming	$182,084	$2,573,827	610,372	104,056	$3,385,228	$33
Region VIII	$809,578	$7,496,534	3,596,214	903,761	$57,583,217	$64
USA Total	$253,281,601	$18,071,483	8,073,204	8,414,587	$1,077,534,474	$128
Region VIII as % of USA	0.3	41.5	44.5	10.7	5.3	

(MBF= thousand board feet)

22.3.2 Timber Harvesting

The amount of lands disturbed by timber harvesting is not published by the BLM or Forest Service; however, data on the amount of timber sales or volume of timber sold are published and can serve as indicators of the land amount disturbed by timber harvesting (BLM, 1990; USDA, 1990a).

Over $800,000 worth of timber was harvested in FY 1989, on BLM lands in Region VIII. This represents only 0.3% of the national BLM timber sales (Table 22-4). On Forest Service lands in Region VIII, $57.5 million worth of timber were harvested in FY 1989. This represents 5.3% of national Forest Service timber sales. These data suggest that North Dakota is potentially the least vulnerable Region VIII state to timber harvesting, while Montana has potentially the largest impacts (Table 22-4).

22.3.3 Fire

The amount of habitat disturbed by fire in any given year varies greatly. For BLM lands in 1989 less than 50,000 acres burned in Region VIII (Table 22-5). On Forest Service lands in 1988 over 400,000 acres burned (Table 22-5). The Yellowstone fires on Park Service lands in 1988 affected over one million acres.

22.3.4 Surface Mining

The amount of lands disturbed in Region VIII by surface mining activities where no reclamation is required, was quantified in 1977 by the USDA and is presented here as reported by EPA (1987) (Table 22-6). For Region VIII, over 110,000 acres of lands were disturbed by mining in 1977 representing 0.3% of the land area (Table 22-6). Physical disturbances of lands due to mining are greatest in Colorado and Wyoming, and smallest in North Dakota and Utah (when expressed as a percentage of the total land area). The amount of lands disturbed by mining activities is further documented in problem area 20.

22.3.5 Road Building

Data on the destruction of terrestrial habitat by road building and development of Federal lands is limited. For Forest Service lands in Region VIII, approximately 5,000 acres of forest lands were disturbed by road building activities in FY 1989 (USDA, 1990a). Estimates for other Federal lands were not found.

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Table 22-5
Habitat Disturbed by Fire

State	Acreage Burned BLM	1989 Acreage Burned Non-BLM	Net Resource Value BLM Loss $	1988 Acreage Burned FS Lands	Net Resource Value FS Loss $ (a)	BLM Loss/Acre Burned	BLM+FS Land Burned
Colorado	11,819	2,928	$203,000	33,037	$454,771	$13.77	47,784
Montana	431	498	$8,000	68,206	$587,350	$8.61	69,135
North Dakota				84,803	$719,129	$8.48	84,803
South Dakota				69,512	$589,462	$8.48	69,512
Utah	28,634	3,157	$169,000	25,400	$135,026	$5.32	57,191
Wyoming	1,446	957	$43,000	124,127	$2,221,166	$17.89	126,530
Region VIII	42,330	7,540	$423,000	405,085	$3,435,953	$8.48	454,955
BLM Total	204,857	101,647	$2,760,000	2,613,868	$23,537,297	$9.00	2,920,372
Region VIII as % of BLM	20.66%	7.42%		15.50%			15.58%

(a) FS lands resource value loss uses FS acres and BLM estimates of loss/acre

(BLM, 1990; USDA, 1990)

Table 22-6

Area (acres) of Land Disturbed by Mining (a)

State	Coal Mines	Sand and Gravel Mines	Other Mined Areas	Total Land
Colorado	7,089	8,334	15,861	31,284
Montana	1,955	4,655	18,340	24,950
North Dakota	1,050	2,010	200	3,260
South Dakota	890	10,153	5,259	16,302
Utah	635	3,999	4,414	9,048
Wyoming	9,657	3,673	12,376	25,706
Region VIII	21,276	32,824	56,450	110,550
USA	1,097,088	799,042	830,407	2,726,537
Region VIII as % of USA	1.94%	4.11%	6.80%	4.05%

(a) Area listed for lands disturbed where no reclamation required.

From USDA, 1980. Soil and Water Resource Conservation Act: Appraisal 80. Review Draft. Part 1.

22.4 ECOLOGICAL IMPACTS

Data from each of the sources presented above can be used to indicate the areal extent or magnitude of losses of habitat due to physical disturbance. Since these estimates are largely qualitative in nature, quantification of the extent of ecological impacts due to habitat disturbance from the various sources is limited, and when presented highly uncertain.

22.4.1 Land Development Effects

The environmental impacts associated with complete habitat and ecosystem loss due to development are clear. The measured loss of habitat to development represents a permanent loss of about 1.5 % of the Region's natural or agro-ecosystem non-Federal lands (Table 22-2). The national average is 4% developed lands. The ecosystems are not impacted per se, but simply no longer exist. Recovery of these destroyed ecosystems is not likely.

More subtle environmental effects of habitat loss include fragmentation of habitat, disruption of migratory pathways of animals and biodiversity changes. These indirect impacts are difficult to quantify. Disruption of corridors of migration may also influence species ability to respond to climate change. Drainage or prairie pot hole Wetlands in North and South Dakota is responsible for significant waterfowl migratory habitat loss.

Habitat destruction by development is a major problem and is difficult to mitigate since it is inexorably linked to population and economic growth.

22.4.2 Soil Loss Effects

Soil loss is an important vehicle of habitat loss and physical destruction of terrestrial ecosystems in the Region. SCS data for non-Federal lands indicate massive soil loss due to wind and water erosion (Figures 22-1; 22-2; 22-4; and 22-5). Associated with these losses, are reduced agro-ecosystem productivity and degradation of rangeland habitat. Trends since the 1982 SCS survey suggest that water erosion is being mitigated by proper land use practices, while wind erosion from crop lands has increased (Figures 22-3; 22-6).

Quantitative estimates of ecological damage from soil erosion are illusive. However, one estimate for the western mountain States suggests that only a small fraction of lands, 0.4 million acres, will experience greater than a 25% reduction in productivity due to soil erosion over the next 100 years (USDA, 1990b).

22.4.3 Grazing Effects

Range lands are extensively grazed in the Region (Table 22-4) and habitat condition of nearly half the grazing lands, according to BLM, is fair or poor (Table 22-3). Grazing may represent a major physical disturbance to the range land ecosystems of the Region. Poor management practices can lead to long-term irreversible damage to range lands, especially riparian areas. Grazing activities can contribute to soil loss. Extensive loss of soil from range lands has been documented by the SCS (Figures 22-4, 22-5). Since 1982 the soil loss from Range lands has decreased, however. (Figure 22-6). Shifts in species composition of vegetation, loss of productivity and effects on game species are likely at high levels of grazing activity.

22.4.4 Timber Harvesting Effects

The physical disturbance of forested lands via timber harvesting is well known. The amount of lands disturbed in the Region is not known. Most silvicultural activities in the Region occur on Forest Service lands. We can assume that under proper silvicultural practices long-term habitat disruption will be minimal. However, indications are that poor silvicultural practices can lead to long-term disruption of forest ecosystem structure and function. Forest regrowth may be permanently hampered on steep slopes where harvesting activities have contributed to soil loss.

22.4.5 Fire Effects

For this assessment, habitat "loss" from fire is considered a natural phenomena. Wild fires have had a major role in the structuring of many natural terrestrial ecosystems in the Region. Recovery and succession following fires mitigates most long-term effects of habitat change induced by fire except under extreme and rare circumstances.

22.4.6 Surface Mining Effects

Surface mining activities occur in patches of various scales throughout the region. The extent of physical habitat disruption due to surface mining varies from several square feet to square miles. The areas disturbed by surface mines where no remediation is required has been tabulated (Table 22-6). We can assume a permanent loss of natural habitat for these lands. The other effects of surface mining activities are considered elsewhere in this assessment, Problem 20.

22.4.7 Road Building Effects

Road construction consumes habitat directly and indirectly. The amount of road surface is a direct measure of the amount of lost habitat. Depending on the type of road, habitat loss can be permanent or temporary. Roads indirectly facilitate loss of habitat and habitat destruction by providing access to otherwise remote areas. With access comes the increased disturbance to terrestrial ecosystems associated with development, logging, off road vehicle use, and litter.

22.5 WELFARE DAMAGES

This section estimates current welfare damages associated with soil erosion in Region VIII. Calculated welfare effects estimate both on and off-site economic damages. Damage estimates related to rill and sheet erosion are based on 1982 National Resource Inventory data and estimates of U.S. and regional on and off-site economic damages (Colacicco, et al., 1989 and Ribaudo, 1986; 1989). Wind erosion damage estimates are based on Piper (1989).

22.5.1 On-Site Damages

On-site damages caused by soil erosion are the value of reduced agricultural yields and increased costs of inputs, such as fertilizers that result from soil losses due to wind and sheet and rill erosion processes. Yields may be reduced due to reductions in water-holding capacity, infiltration rates, nutrient availability, organic matter, and other beneficial topsoil characteristics.

Colacicco, et al. and Alt, et al. (1989) used the Erosion Productivity Impact Calculator and erosion rates from the 1982 NRI data to estimate regional and national damages from soil erosion over the next 100 years. They assumed that future yield losses would occur only on land losing soil at a rate greater than the soils tolerance rate (T-value). Economic damages were developed by quantifying the value of yield and fertilizer losses from soil erosion by simulating price changes in crops and fertilizers and discounting to present (1982) values. This procedure estimated an average value of the on-site loss per ton of cropland and pastureland as being $0.20 in the Mountain farm Production Region. Specific estimates were not developed for Region VIII States. The Mountain Region includes: Montana, Idaho, Wyoming, Nevada, Utah, Colorado, Mexico, and Arizona.

By assuming that the $0.20/ton value is adequate for Region VIII and the purpose of this assessment, estimates of on-site damage can be developed by multiplying this value by the total cropland and pasture erosion noted in the 1987 NRI tables:

(156,060,700 crop + 2,910,500 pasture) (.20) = $31,794,240

Converting to 1988 dollars, the estimated present value of on-site erosion in Region VIII is $39,901,771.

22.5.2 Off-Site Damages

Soil erosion from farmland and other lands increases sediment, nutrient, and pesticide loadings in surface waters. Sediments, nutrients, and pesticides cause sedimentation problems in reservoirs, affect aquatic plant and animal life, affect the quality of wetland and riparian habitats, reduce recreation opportunities, and may be related to human health effects.

Ribaudo (1986) estimated the off-site damages due to water caused erosion for each of the Farm Production Regions and the U.S. His estimates do not include damages caused by wind erosion. Based on his calculations, erosion causes $0.81 (1983 dollars) of damages per ton of soil loss in the Mountain Region. In a recent evaluation of the off-site benefits of the Conservation Reserve Program, Ribaudo estimated that water erosion causes $1.12 (1986 dollars) per ton of damages in the Mountain Region (Ribaudo, 1989). We propose to use the more recent damage figure, as Ribaudo believes that to be more accurate than the 1986 estimate.

Total Region VIII sheet and rill erosion from all sources was estimated in the 1987 NRI as approximately 453,671,900 tons per year. To calculate economic damages:

$1.20 (1989 $) * 453,671,900 = $544,406,280

This damage estimate includes estimated damages to recreational fishing, water storage facilities, flood damage, drainage ditches and irrigation canals, water treatment facilities, municipal and industrial water uses, electric power plants, and irrigated agriculture.

22.5.3 Wind Erosion

Low average rainfall, frequent drought, and relatively high wind velocities characterize much of Region VIII's landscape. These conditions, combined with fine soils and sparse vegetation, make some Region VIII lands very susceptible to wind erosion problems. The Soil Conservation Service estimated that average annual soil erosion on non-federal land in Region VIII due to wind erosion was about 570,422 tons.

Wind erosion creates two types of welfare damages: on-site and off-site. On-site costs are imposed on all farmers and ranchers who own or lease the land exposed to wind erosion. These damages are primarily productivity impacts. Other on-site costs include emergency tillage operations to reduce blowing soil, damage to growing crops, and damage to farm equipment. Off-site damages are particulate-related damages imposed on those who live or work downwind from blowing soil. These damages include increases cleaning and maintenance for businesses and households, damages to nonfarm machinery, and adverse health impacts. According to Piper (1989) on-site damages of wind erosion are only 2.1% to 3.5% of the off-site household sector damages in New Mexico. Other data reviewed in Piper (1989) suggest that on-site crop productivity losses in the Western United States are small compared to off-site damages, perhaps less than 5% of the estimated off-site wind erosion damages.

Piper (1989) estimated off-site household damages from all sources of wind erosion in New Mexico. He found that total off-site damages were estimated to be $465.8 million annually, averaging $980 per household per year in 1984 dollars. Concerting the household damage estimate to 1988 dollars using the GNP implicit price inflator yields a household damage estimate of $1,107. To estimate per capita Region VIII damages:

$1107/2.66 people per household, or
per capita damages are approximately $425.

Total estimated annual damages due to wind erosion equal $425 x the Region VIII population (7,655,000), or 3.25×10^{10}

This estimate does not include cost of illness measures for emphysema cases or other health effects potentially attributable to wind erosion. In addition, it does not include damage to non-residential structures or sectors of the economy. However, estimated damages seem far too great to be plausible.

22.5.4 Uncertainty

This estimate was based on one survey of New Mexico residents to determine the incremental costs of cleaning residential property associated with wind erosion. No other studies of off-site damages associated with wind erosion were located. Using the per household damage estimate calculated for New Mexico to estimate damages in Region VIII assumes that:

- Region VIII States experience similar wind erosion; and
- Region VIII residents are equally impacted (damaged) by wind erosion.

This estimate does not include on-site damages or damages to non-residential sectors of the economy. However, Piper (1989) cites evidence that on-site wind erosion damages are small when compared with off-site damages.

22.6 ASSUMPTIONS

The areal extent of terrestrial habitat degradation can be related to the amount of land use modification as documented in government documents cited above.

The amount of past and future physical degradation of terrestrial habitats in the Region can be related to Regional economic and population growth. The extent of urbanization and road construction, for example, are clearly related to population and economic growth. We can assume that increased ecological impacts will co-occur with increased growth.

For Federally managed lands the assumption can be made that the NEPA process and the National Forest Management Act (Forest Service), the Federal Land Policy and Management Act (BLM), and the Taylor Grazing Act (BLM) will limit and regulate environmental, health and economic impacts due to physical degradation on Federal lands.

Our assessment of impacts on non-Federal lands is primarily derived from SCS NRI data. We assume that the statistical design of the NRI provides an adequate index to the amount of habitat disruption due to soil erosion in the region and that the 1977 USDA assessment reported in EPA, 1987 is related to current impacts due to surface mining.

22.7 UNCERTAINTY

There is an unknown amount of uncertainty in the estimates that can be derived as to the effects of terrestrial habitat degradation in the Region. Where ecosystems are lost, effects are certain and permanent. Effects due to soil erosion are also well known.

22.8 OMISSIONS

This assessment is limited by the quantity and quality of data available to estimate regional habitat loss and terrestrial ecosystem degradation.

We have not considered impacts on National Park Lands. This omission is not serious, however, since Parks do not participate in consumptive activities, ie. timber harvest, new

Table 22-7
Soil Erosion (1000 tons/year)

State	Year	Wind (a)	Water	Total
Colorado	1982	84,970	131742	216,712
	1987	139,287	131,025	270,312
	Change	54,317	-717	53,600
Montana	1982	144,340	71,070	215,410
	1987	138,562	71,150	209,712
	Change	-5,778	80	-5,698
North Dakota	1982	85,975	61,584	147,559
	1987	112,260	61,520	173,780
	Change	26,285	-64	26,221
South Dakota	1982	42,215	129,088	171,303
	1987	42,895	124,329	167,224
	Change	680	-4,759	-4,079
Utah	1982	64,200	37,274	101,474
	1987	111,676	27,158	138,834
	Change	47,476	-10,116	37,360
Wyoming	1982	27,458	44,930	72,388
	1987	25,741	38,489	64,230
	Change	-1,717	-6,441	-8158
USA	1982	1,306,349	3,253,537	4,559,886
	1987	1,395,377	2,817,637	4,213,014
	Change	89,028	-435,900	-346,872
Region VIII	1982	449,158	154,424	603,582
	1987	570,421	156,061	726,482
	Change	121,263	1,637	122,900
Region VIII as % USA	1982	34%	5%	13%
	1987	41%	6%	17%

(a) 1987 total wind erosion calculated using 1987 wind erosion from crop lands (SCS, 1989) and 1982 ratio of wind erosion from crop lands to total wind erosion, 1982 (SCS, 1987).

Table 22-8
Soil Erosion via Water on
Non-Federal Rural Land (1,000 tons/year)

State	Year	Cropland	Pasture	Range	Forest	Minor	Total
Colorado	1982	24,387	502	53,112	16,469	36,416	131,742
	1987	24,128	633	51,540	17,540	35,954	131,025
	Change	-259	131	-1,573	1,071	-462	-717
Montana	1982	30,954	607	34,013	4,177	0	71,070
	1987	33,973	634	29,415	4,202	161	71,150
	Change	3,019	27	-4,598	25	161	81
North Dakota	1982	51,375	510	9,879	132	265	61,584
	1987	53,321	603	8,940	129	138	61,520
	Change	1,946	93	-939	-3	-127	-65
South Dakota	1982	44,062	811	22,790	281	64,054	129,088
	1987	40,984	706	19,937	283	62,188	124,329
	Change	-3,078	-105	-2,853	2	-1,865	-4,758
Utah	1982	1,835	49	20,316	13,223	1,392	37,274
	1987	2,002	56	15,312	8,303	1,027	27,158
	Change	167	7	-5,004	-4,920	-365	-10,116
Wyoming	1982	1,811	225	40,172	786	1,685	44,930
	1987	1,653	278	34,819	1,279	610	38,489
	Change	-158	53	-5,353	493	-1,074	-6,441
USA	1982	1,812,032	172,006	529,964	354,211	393,582	3,253,537
	1987	1,606,797	168,967	482,022	315,524	317,539	2,817,637
	Change	-205,235	-3,039	-47,943	-38,687	-76,043	-435,900
Region VIII	1982	154,424	2,704	180,283	35,068	103,811	475,688
	1987	156,061	2,910	159,963	31,735	100,078	453,672
	Change	1,637	206	-20,320	-3,333	-3,733	-22,016
Region VIII	1982	9%	2%	34%	10%	26%	15%
as % of US	1987	10%	2%	33%	10%	32%	16%

construction activities are limited, and only fires, which are largely a natural phenomena, result in habitat alteration and loss.

We have not evaluated the effects of fractionation of habitat, and the interruption of migration paths that have occurred since the aboriginal landscape mosaic has been re-patterned by anthropogenic influences. The scale of natural landscape disruption by agriculture and urban development has had a large, yet unknown influence, on terrestrial ecosystem function, and population and community dynamics. These questions are currently major concerns of the new discipline of landscape ecology.

22.9 RECOMMENDATIONS FOR IMPROVING RISK ASSESSMENT-REDUCING UNCERTAINTY

22.10 BIBLIOGRAPHY

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22.11 CONTACTS

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23.0 GLOBAL CLIMATE CHANGE AND STRATOSPHERIC OZONE DEPLETION

23.1 INTRODUCTION

Anthropogenic gaseous emissions are altering the chemistry of the global atmosphere in such a way as to potentially induce global climate change and deplete stratospheric ozone. Physical laws predict that these chemical changes will result in global warming due to the greenhouse effect of certain gases, particularly carbon dioxide, methane, nitrous oxide, and chloroflurocarbons, as well as other species. Stratospheric ozone depletion is caused, in large part, by chlorine and bromine radicals in the upper atmosphere derived from chloroflurocarbons (CFCs) and halons. Reductions in stratospheric ozone allow larger amounts of biologically dangerous ultraviolet (UV) radiation to reach earth surfaces and also contributes to global warming.

Global climate change will potentially have broad effects on the biosphere including effects on water resources, agriculture, forestry, natural ecosystems, sea level, energy use, transportation, and many other aspects of life on earth. Effects of ozone depletion and subsequent increased UV light intensity include human health issues, principally skin carcinomas and melanomas, cataracts and other eye diseases, and immune system effects. A number of studies have estimated eye losses associated with increased UV-B radiation. Ecological implications, including impacts on aquatic life at the base of the global food chain, are also anticipated related in increased levels of UV-B radiation.
The information in this assessment is derived from a number of sources including: Hansen, et al. 1987, 1984; Hoffman and Wells 1987; Houghton and Woodwell, 1989; Titus, 1986; Environment 2010, 1990 and others as listed.

This assessment briefly reviews and evaluates the literature associated with these issues. The scale of and uncertainties associated with these problems is vast, and global circulation models can not accurately predict climate change effects at regional scales. In addition, the various models currently in use do not produce similar predictions for regions. For example, model predictions of changes in soil moisture with a doubling of atmospheric CO_2 for the Region VIII area range from increases > 2cm to decreases of 4cm (EPRI, 1990). A detailed assessment of "predicted" changes for the Region can not be credibly performed at this time. However, current research efforts may provide the information needed to provide adequate detailed studies to inform policy making.

23.2 DATA DESCRIBING GLOBAL CLIMATE CHANGE

The greenhouse effect results from the trapping of radiant energy in the lower atmosphere by greenhouse gases. Greenhouse gases include carbon dioxide, methane, nitrous oxide, chloroflurocarbons and ozone. The principal greenhouse gas, carbon dioxide, accounts for approximately 50% of the current anthropogenic greenhouse effect. The secondary gases account for the remaining effect, principally methane (20%), CFCs and halons (15%), nitrous oxide (10%) and tropospheric ozone (5%). These gases and their current concentrations in the atmosphere are the result of numerous biogeochemically and anthropogenically derived emissions. Without these gases the Earth's surface would be about 30 degrees cooler than it is now and life as we know it would be prohibited. Anthropogenic emissions have significantly affected the concentrations of greenhouse gases greatly over a relatively short time scale.

There are no data which specifically quantify the amount of greenhouse gas emissions in Region VIII. The principal anthropogenic source of CO_2 in the Region is the burning of carbon fuels (coal, petroleum, and natural gas). The contribution of CO_2 from deforestation is minor, while prescribed and natural forest fires may contribute significant amounts of CO_2 in any given year.

The primary source of methane is derived from biological respiration including sheep and cattle production, and swamps and marshes. The combustion of biomass, coal mining, and natural gas also make contributions to total methane emissions. CFCs and halons have no natural source, all are manufactured. CFCs are used as aerosol propellants, solvents, blowing agents for insulating foams, and in a number of other industrial processes. Halons are used as fire extinguishing agents. The residence time of CFCs once in the atmosphere can exceed 100 years and the radiative forcing (the change in temperature/ppb of compound) is 20,000 times higher than that of CO_2 (Ramanathan et al. 1985).

Projected and measured increases in greenhouse gas concentrations and their effects have convinced that scientific community that:

- Carbon dioxide and other greenhouse gases are accumulating in the atmosphere.
- As these gases accumulate, they will cause a gradual increase in global average temperature; an effective doubling of CO_2 could occur as early as 2030.
- An effective doubling of CO_2 will eventually cause global average temperature increases of at least 1.5 degrees C and no more than 4.5 degrees C over the next 60 years.

- With this gradual warming will also come changes in wind, precipitation, and other climatic patterns.

- There will be substantial regional variability. In general, temperature increases will be greater in the polar latitudes and lesser in the equatorial latitudes; some areas may be cooler than at present.

- Global precipitation will increase; regional precipitation may increase or decrease.

- Stream flow amount and seasonal pattern will be altered.

- Sea level will rise due to warming and expansion of the oceans plus ice and snow melt; most scenarios predict changes in the range of 0.5 to 2.0 meters increase by 2100.

23.3 DATA DESCRIBING THE ECOLOGICAL EFFECTS OF GLOBAL CLIMATE CHANGE FOR REGION VIII

Climate affects everything on the planet. Climate change will induce many major changes in the global and Regional ecosystems. The implications for the Region can not be quantitatively described at this time. Even qualitative discussions are of limited meaning given the absence of data and predictive tools. The following discussion attempts to identify some areas of possible concern.

23.3.1 Effects on Ecosystem Distributions and Biodiversity

Region VIII includes ecosystems exposed to a diverse array of climatic conditions from deserts to alpine tundra, great plains grasslands to lush forests. The biodiversity of the Region is high. Past and current climatic conditions have shaped the boundaries of the ecosystems of the Region. The ecosystems in this Region may have evolved under greater stress than those in other regions since drought, severe cold, heat and strong winds are not uncommon climatic stressors to Region VIII landscapes. The Region contains numerous terrestrial ecosystems and associated organisms at the edges of their climatically defined distributions. Changing climatic conditions can greatly alter current ecosystem distributions throughout the Region in ways and to an extent which is unknown at this time. Given climatic change, Region VIII ecosystem distribution will be significantly altered and biodiversity will likely be reduced.

23.3.2 Effects on Agriculture

As the greenhouse effect increases the average temperature, changes the magnitude and frequency of precipitation, and ultimately alters the hydrology in the Region, the nature of agricultural production could change. While direct fertilization may occur with enhanced CO_2 concentrations and individual plant water use efficiency may increase in Region VIII, subtle changes in water supply could overwhelm any direct CO_2 related crop benefits. Rangeland production is also greatly influence by water supply such that increased drought frequency could take many range lands out of animal production. Many Region VIII range lands could become deserts with relatively small changes in precipitation patterns and quantities. Climate change could induce shifts in crop pest and disease infestations. Expansion of irrigation and shifts in regional agricultural production patterns could imply more competition for water resources, and larger potential for ground and surface water pollution, loss of wildlife habitat, and increased soil erosion. Precipitation, wind speed, and evaporation rate are major factors in soil loss from croplands which could each be effected by climate change.

23.3.3 Effects on Forestry

The impact of climatic changes on the growth and health of forests in Region VIII is unknown. Forest species will not survive climatic changes which put the climate outside their specific tolerance levels. Tree species tolerance levels are not known precisely. Individual plant response will depend on the plants' reaction to various stresses in combination with an increased carbon dioxide atmosphere. For example, the response of plants to heat stress is related to CO_2 concentrations. The optimum temperature for photosynthesis increases by about 5 degrees C in an atmosphere with double the present levels of CO_2. Thus, within the range of projected temperature increases, elevated levels of CO_2 could partially compensate for higher temperatures without unduly stressing plants directly.

There are a number secondary and tertiary possible effects of doubled CO_2 and global warming on forest plants that were summarized in Environment 2010 (1989):

- Rapid leader elongation may predispose trees to wind damage.
- Warmer, wetter autumns could prevent "hardening off" leaving trees more vulnerable to frost damage.
- Increased CO_2 could cause earlier flowering and increased seed production due to the increase in ratio of carbon to nitrogen.

- Plants may require more nitrogen and in some areas phosphorus to obtain maximum benefits from the CO_2 increase.

- Tolerance to air pollution could increase due to partial closure of stomata in response to increased levels of CO_2.

- Increased potential for wildfire is projected to be associated with less spring and summer precipitation.

- A drier climate and increased water stress are likely to increase attacks by boring insects.

- Rising carbon dioxide levels could alter the types and magnitude of pest problems.

- Competition with shrubs or grass may substantially change and severely restrict natural regeneration in some areas.

- Conifers have fixed growth and may suffer in relation to plants with free growth.

- In general, the competitive capacity of C_3 relative to C_4 plants should be increased by increasing concentrations of CO_2. However, all forest trees have the C_3 carbon pathway and the differences in competitive capacity among species are likely to be smaller among trees than in communities of annual plants.

23.3.4 Effects on Water Resources and the Hydrologic Cycle

The forested mountains in Region VIII are the source of most of the water used to support midwestern agriculture and numerous growing urban areas within and outside the Region. We can not predict, as yet, how Regional precipitation patterns might change with greenhouse warming. The fraction of annual precipitation as snow and rain may change. Evaporation rates will increase with temperature, reducing runoff even if precipitation levels stay the same.

Increased drought can have severe effects over much of the Region as many natural plant communities and agro-ecosystems are near the lower limit of tolerance to precipitation amount. Increased demand for water for agriculture, industry and population centers within and down stream of the Region will be associated with drought and elevated temperatures. The current competition for water will be intensified if drought conditions become more common in the future.

Snowmelt is the dominant hydrologic event responsible for much of the variation in inter-annual stream flow. Patterns of snowmelt will change with changing climatic conditions. Increases in temperature may result in faster snowmelt with less sustained mid summer flows. Winter stream flow may increase with peek flows moving closer to winter months. Flood frequency, intensity, and recurrence intervals may change with changing climate. Numerous biologic effects will be associated with changes in hydrology of the region induced by climate change. Specific data are not available, however.

The effects of climate change on sea level rise is of little direct consequence for Region VIII and is not discussed here.

23.4 DATA DESCRIBING OZONE DEPLETION

Monitoring of stratospheric ozone concentrations has detected annual average total ozone column concentration decreases of about 2-3% or 0.35% annually between 1978 and 1985 (Ozone Trends Panel, 1988). The actual numbers will vary with latitude and specific estimates for Region VIII are not available. The depletion of stratospheric ozone is thought to be caused by CFCs and halons and their production of chlorine and bromine radicals in the stratosphere which then undergo reactions that consume ozone.

23.4.1 Data Describing the Ecological Effects of Ozone Depletion

The ecological implications of ozone depletion are not yet well studied; most efforts have addressed human health issues. There is an important interaction between ozone depletion and global warming. The existing ozone layer screens out more than 99% of the incoming ultraviolet energy between 200 and 320 nanometers and reradiates energy in the infrared wavelengths. As the ozone layer decreases, the stratosphere cools, and the energy balance of the earth is effected. How these events affect global climate is not precisely known.

23.4.2 Effects on Terrestrial Ecosystems

Data on the effects of increased UV radiation on terrestrial ecosystems of Region VIII is lacking. Increased UV radiation can affect plants in a number of ways. Of the 200 different plant species and varieties screened, two thirds were reported to react adversely to elevated levels of UV/B radiation (Teramura 1986).

UV light effects have included physiological, biochemical, morphological and anatomical plant responses. Plant growth, productivity, reproduction, competition and disease resistance may be influenced by enhanced UV/B radiation. Most studies to date have been quite limited and possible interactive effects have not been sufficiently studied. Few field studies have been done.

While some data are available on the effects of UV radiation and other stresses, such as water stress and mineral deficiency, no information on the effects of other atmospheric stressors (ozone, sulfur dioxide or CO_2) are available. Also most plants screened were crop plants, less in known about responses of natural plant communities. No studies have been conducted relevant to several Region VIII terrestrial ecosystems. While studies have been done on UV effects on agricultural lands, tundra and alpine ecosystems, temperate forests and grasslands, no studies have been done on desert and semidesert ecosystems, savanna lands, woodlands and scrublands (Teramura, 1986).

23.4.3 Effects on Aquatic Ecosystems

Direct evidence on the potential ecological effects of increased UV-B radiation on aquatic ecosystems is not available for Region VIII. Experimental data have shown, however, that UV-B radiation can damage larval and juvenile fish, copepods and aquatic plants (Worrest, 1986). Effects have included decreases in fecundity, growth, and survival. Since UV-B radiation is readily absorbed by proteins and nucleic acids many effects are thought to be through degradation of these important biochemicals.

Reported effects vary considerably by species. Species sensitivity may relate to the depth at which the organisms are normally found and their UV-B absorbance properties. Avoidance of increased UV-B in surface waters may be accomplished by some organisms through vertical migration in the water collum. Changes in the vertical distribution of organisms could potentially have numerous implications. The penetration of UV-B radiation into natural waters is a key variable in assessing the potential impact of this radiation on aquatic ecosystems. Avoidance of surface waters by phytoplankton can reduce productivity by limiting the volume of water available for primary production and reducing the amount of light available for photosynthesis. Effects at lower trophic levels, and direct effects on fishes may combine to influence important fish populations and production.

23.5 HUMAN HEALTH EFFECTS OF GLOBAL CLIMATE CHANGE AND OZONE DEPLETION

23.5.1 Health Effects of Climate Change

It is very difficult to predict specific regional impacts of global climate change on human health, as few studies have been completed. The approach used in this assessment is to review the results of studies of how current climate is interrelated to human health as described in White and Hertz-Picciotto (1985). Two questions are briefly addressed. 1) How may increases in temperature affect human health? 2) How may increased variability in weather conditions affect human health?

The amount and kinds of endemic diseases currently evident in the Region may change with an increase in temperature. Bacteria, viruses, allergens and fungi distributed throughout the atmosphere and soils are affected by atmospheric conditions, temperature, precipitation, humidity, sunlight and wind. These climatic factors contribute to the dispersal and survival of many disease organisms. Human disease organisms carried by other vectors may also be influenced by changes in climate which affect the range of the vector and disease organisms. The geographic range of diseases may change in some as yet unpredictable manner with climatic changes.

Changes in the variability of weather patterns are projected to occur with climate change. Certain climatic variations are known to directly or indirectly affect human health by effects on disease bearing or causing organisms. Increased humidity adds to human susceptibility to disease in cold weather. Hot weather aids the survivability of many pathogenic organisms. Temperature extremes stress the body's thermoregulatory system. Chronically ill, elderly and infant populations have difficulty adapting to rapid, prolonged temperature changes and increased mortality and morbidity may result during either heat or cold waves. Healthy individuals may also suffer increased stress due to overexposure to temperature extremes.

23.5.2 Human Health Effects of Ozone Depletion

Ozone depletion is predicted to affect human skin, eyes and the immune system. The stratospheric ozone protects human health by effectively absorbing ultraviolet radiation between 200 and 320 nm (UV-B and UV-C). A 1% decrease in stratospheric ozone can result in a 2% increase in UV-B light exposure.

UV-B is a major factor in human skin cancers, basal and squamous cell carcinomas and malignant melanomas (Scheibner, et al., 1986). Increased exposure to all UV light is related to an increased risk of developing such skin cancers (Armstrong, et al., 1988). Basal and squamous cell carcinomas are the most common cancer found in the United States with 400,000 to 500,000 cases reported each year (Koh, et al., 1989). They typically occur on sun exposed body sites of fair skinned Caucasians. Their incidence increases with increased age and cumulative lifetime exposure to sunlight. (Scotto, et al. 1988). While rarely fatal, a 3-6% increase in these common skin cancers can be reliably predicted for each 1% decrease in ozone (Hoffman, 1987).

Malignant melanomas are the ninth most common form of cancer, with their incidence rising at a faster rate (93% increase during last 8 years) than any cancer except male lung cancer (Kripke, 1988a).

Mortality from these cancers is also increasing with 6000 deaths out of an estimated 27,300 cases reported in 1988 (Koh, et al., 1989). They result from UV induced cellular damage which, under laboratory conditions, contributes to both their induction and subsequent growth. They occur throughout the body and appear related not only to lifetime total sun exposure, but also to acute episodes of sun exposure or sunburn (Kripke, 1988a). Research now indicates some relationship between malignant melanomas and UV induced damage to the immune system. A 1% decrease in ozone can be predicted to cause a 1-1.5% increase in malignant melanomas (Hoffman, 1987).

UV-B radiation is suspected of contributing to three types of ocular changes: cortical cataract formation (Taylor et al. 1988), macular degeneration of the retina (Young, 1988), and Pterygium, a degeneration of the epithelial conjunctiva, (Prendergast, 1989).
Limited information exists on the mechanistic connection between excess UV-B radiation exposure and disease. Immuno-function response to UV-B exposure has been studied only recently. The significance of such immune changes on the incidence of skin cancers and human infectious diseases is, as yet undetermined (Kripke, 1988b). Laboratory research indicates three perturbations in immune response, occurring both locally in irradiated skin and systemically at sites distant from the irradiated area (Kripke, 1988a). 1) UV radiation alters Langerhans cells morphologically and decreases their numbers, destroying the skin's capability to respond to foreign substances or infective organisms (Kripke, 1988a). 2) Increased exposure to UV light greatly increases the systemic proportion of T-suppressor cells in relation to T-helper cells with a resulting decrease in the immune system's ability to fight disease. This change in T cell ratio may bear a role in the appearance of malignant melanoma on sites distant from sun exposed body surfaces. The suppressed immune response may also affect other infectious diseases such as herpes and parasitic infections (Kripke, 1988b). 3) Cellular DNA can also be directly damaged by exposure to UV radiation. Increased spontaneous cellular mutation and a decreased ability to repair damage created by either UV exposure or disease processes may have an as yet undetermined effect on human health (Kripke, 1988a).

23.6 ASSUMPTIONS

Many of the effects of global change defined at global and national scales will be important in Region VIII.

23.7 OMISSIONS

Quantitative assessments are avoided in this assessment due to the lack of data on Regional effects.

23.8 UNCERTAINTY

Uncertainty is the dominant characteristic of this assessment.

23.8.1 Economic Effects of Global Climate Change

The economic effects of global climate change have not been evaluated at Regional scales; however, some national and global estimates have been made (eg. Adams et al. 1988). This assessment will not attempt to estimate economic impacts of global climate change on the Region. A reading of the potential ecological affects does suggest avenues of economic effects related to agriculture, forestry and water resource issues.

23.8.2 Economic Effects of Ozone Depletion

The economic effects of ozone depletion are not known at either global or local scales. A comprehensive quantitative estimation of economic effects of ozone depletion is not possible at this time. Several ecological and health effects have economic consequences. Changes in productivity of agricultural crops or fisheries will surely have economic consequences. One study estimates changes in welfare in the US attributable to the depletion of stratospheric ozone (Adams and Rowe, 1988). These authors suggest that depletion of stratospheric ozone will directly affect crop yield and also increase the amount of tropospheric ozone which then further decreases crop yields. They project that a 15 percent reduction in stratospheric ozone will give rise to a 13 percent increase in tropospheric ozone. Together the estimated decrease in economic welfare to the U.S. would be $2.6 billion annually.

23.9 RECOMMENDATIONS FOR IMPROVING RISK ASSESSMENT-REDUCING UNCERTAINTY

The results of the international research initiative on global change issues may provide information which will aid in the assessment of the risks of global change. Enhancement of the spacial resolution of global circulation models may provide information to predict climate change the finer scales needed for Regional assessments.

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