Cooperative Extension Service, Colorado State University, Lowell H. Watts, Director

AN ANALYSIS OF NON-POINT SOURCE POLLUTION IN THE ROCKY MOUNTAIN-PRAIRIE REGION

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PART I

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Region VIII Environmental Protection Agency
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Cooperative Extension Service
Colorado State University
Lowell H. Watts, Director

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AN ANALYSIS OF NON-POINT SOURCE POLLUTION IN THE ROCKY MOUNTAIN-PRAIRIE REGION

Preface

The purpose of this report is to provide a description of the identified non-point sources of pollution within the six-state area of Colorado, Utah, Wyoming, Montana, North Dakota, and South Dakota which comprises Region VIII (Figure 1) under the jurisdiction of the Environmental Protection Agency's Denver office. Due to time constraints and limited staff available to the preparation of the report, much of the research deals with the State of Colorado. However, wherever data could be gathered and analyzed relative to non-point source problems of similar kind and nature within the other five Region VIII states, such information has been included in the report.

The areas of concern which have been investigated and reported upon include:

- Irrigation Return Flows (on-farm management for salinity control)
- Range and Watershed Management
- Logging and Forestry (erosion, slashburning, etc.)
- Rural-Domestic Wastes (septic tanks)
- Livestock and Waste Disposal
- Pesticides and Fertilizers
- Land Disposal (sludge and municipal sewage)
- Surface and Groundwater Problems (as appropriate)

The description of the identified non-point source pollution problem areas as well as the description of available technological and managerial practices presently in use, identification of areas of needed additional research, and needs for improved mechanisms for information transferral make up the first portion of the report.

The second portion of the report provides recommendations for a staged program for transferring the known solutions for managerial and technological

EPA REGION VIII

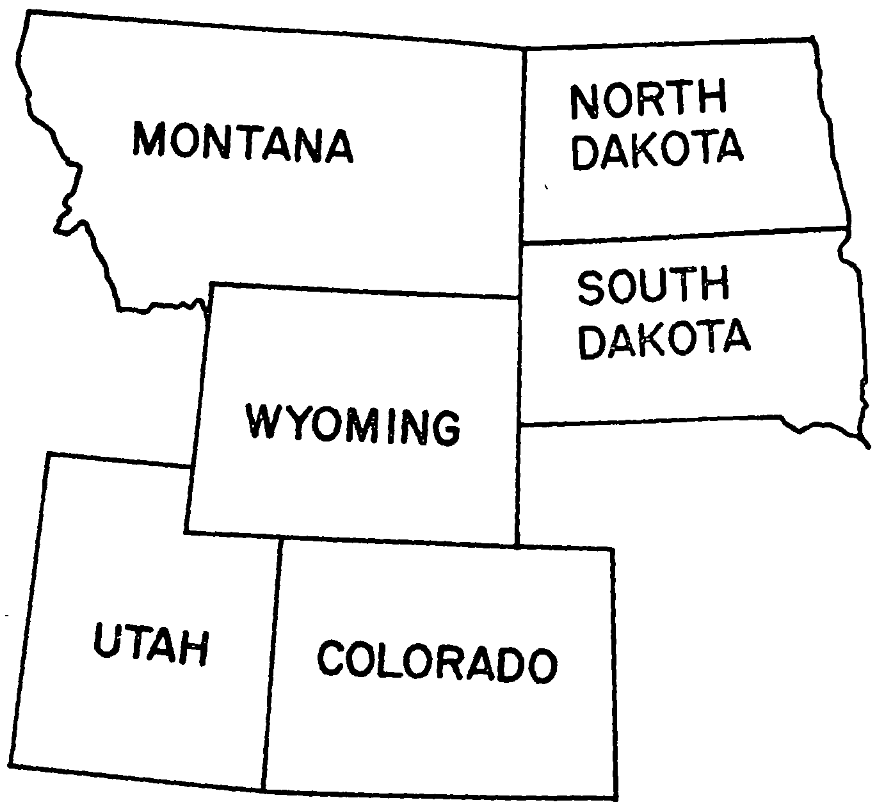

Figure 1

pollution control to concerned individuals and groups throughout the existing Cooperative Extension system.

As many readers of this report are aware, the Federal Water Pollution Control Act Amendments of 1972 became law during the final months of 1972. The objective of the Act is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters. Its National goals are: (1) to obtain an interim goal of water quality by July 1 of 1983 which will provide for the protection and propagation of fish, shellfish, and wildlife and for recreation in and on the water, and (2) the elimination of discharge of pollutants into navigable waters by 1985. Navigable waters are defined as "Waters of the United States, including the territorial seas." Pollutants include, among other items, such various materials as "...heat, wrecked or discarded equipment, rock, sand, and cellar dirt, and industrial, municipal, and agricultural wastes discharged into water."

There are several sections of the Bill which are of particular interest to those concerned with non-point source pollution control. An important one of these is Section 101(b) where it states that the Policy of Congress is to recognize, preserve and protect primary responsibilities and rights of states to prevent, reduce, and eliminate pollution and to plan the development and use of water and land resources. This philosophy is sprinkled throughout the Act where Congress has given the states primary responsibility or the option of accepting the primary responsibility for pollution control programs. In addition, the states, local governments, and often times, industries, have been given strong advisory roles in developing the pollution control programs. However, at the same time Congress maintained the ultimate responsibility for the control programs should the states fail to meet their responsibilities.

Congress has given the Administrator of the Environmental Portection Agency the responsibility to administer this Act (Section 102(a)). He is directed to prepare and develop comprehensive National programs for preventing, reducing, or eliminating the pollution of navigable waters and groundwaters, after careful investigation and in cooperation with other Federal agencies, State Water Pollution Control agencies, interstate agencies, municipalities, and industries involved.

Also, the Administrator shall encourage cooperative activities by the state and the enactment of improved and, so far as practicable, uniform state laws relating to the prevention, reduction and elimination of pollution (Section 103(a)).

Research

In carrying out his responsibilities for establishing National programs for the prevention, reduction, and elimination of pollution, the Administrator is required, among other things, to: in cooperation with other Federal, state and local agencies, conduct and promote coordination and acceleration of research, investigations, experiments, demonstrations, and studies related to the causes, effects, extent, prevention, reduction, and elimination of pollution. Render technical services to appropriate agencies in carrying out these programs and establish advisory committees composed of recognized experts to assist in the examination and evaluation of research progress and proposals and to avoid duplication of research (Section 104(a)).

To meet the provisions just discussed, the Administrator is authorized, again among other things, to: (1) develop effective and practical processes, methods and prototype devices for control and elimination of pollution (Section 104(b) (7)); (2) collect and disseminate, in cooperation with Federal, state, and other pollution control agencies, basic data on chemical, physical and biological effects of varying water qualities and the information related to pollution and its control (Section 104(b) (6)): and (3) cooperate with other Federal Departments and Agencies, other public and private agencies, institutions, organizations, industries involved, and individuals, in the preparation and conduct of the research and studies on the causes, effects, extent, prevention, reduction and elimination of pollution.

Planning

To accomplish the objectives of the Bill within the required schedule, numerous deadlines must be met. For example, with regard to non-point sources of various kinds, Section 208 gives the Administrator only 90 days after the effective date of the Act (October 18, 1972) to publish guidelines for identifying areas which, as a result of urban-industrial concentrations or other factors, have substantial water quality control problems. The Governor of each state then has 60 days following the publication of the guidelines to identify these areas and 120 days after such identification to assign the boundaries and designate a single representative organization capable of developing effective area-wide waste treatment management plans for such an area. Within one year after the designation by the Governor, this organization is to have in operation a continuing area-wide water treatment management planning process, applicable to all wastes generated in the areas involved. The waste treatment management plans and practices shall provide for the application of the "best practicable" waste treatment technology ...and to the extent practicable, waste treatment management shall be on an area-wide basis and provide control or treatment of all point and non-point sources of pollution, including in place or accumulated pollution sources (Section 102). Any plan under such process shall include, but not be limited to, processes to: (1) identify, if appropriate, agriculturally and silviculturally related non-point sources of pollution, mine and construction-related, and the related non-point sources of pollution, and (2) set forth procedures and methods to control to the extent feasible, such sources (Section 208(b) (2)). The plan shall be certified by the Governor of the State, or his designee, and submitted to the Administrator of EPA for his approval.

Section 304 is closely related to Section 208. It requires the Administrator within one year of the effective date of the Act, and from time to time thereafter, to publish and issue to the appropriate Federal agencies, the States, water pollution control agencies, and other designated agencies mentioned before, information including <u>guidelines for identifying and evaluating the nature and extent of non-point sources</u> of pollutants and processes, procedures, and methods for effecting control of pollution from agricultural and silvicultural activities, mining activities and construction activities. Consultation with appropriate Federal and State agencies and other interested persons is required during the development of these guidelines. The information disseminated in accordance with the requirements of Section 304 of the Act will be used by the states in developing their area-wide management plans required under Section 208.

Section 303(e) of the Act, requiring the States to establish a continuing planning process, provides for state-wide river basin planning. The States will analyze each stream in the state, determine whether or not each stream segment will meet applicable water quality standards, and if not, plan for a coordinated approach that will lead to the meeting of standards. If point source controls, as spelled out by the Act, will not lead to a meeting of the standards, then feasible non-point controls should be considered.

Another pertinent section of the Act is 305(e) which requires each state to prepare and submit to the Administrator by January 1, 1975 and bring up to date each year thereafter a description of the nature and extent of non-point sources of pollutants, and recommendations as to the programs which must be undertaken to control each category of such sources, including an estimate of costs of implementing such programs. These state reports together with an analysis will be submitted to Congress by the Administrator on or before October 1, 1975 and annually thereafter.

<u>Summation</u>

Effective control of non-point source pollution can be fully achieved only by vigorous and aggressive action by all levels of government with the complete cooperation and support of concerned members of the community.

There is a definite need to make people in communities aware of how these non-point source pollution processes can effect conditions around them. In this same vein, it is important to make people aware that their activities can contribute to these problems and that they should be willing to assist in responsible prevention and control of harmful practices.

Local organizations and their officials have to acknowledge their share of the responsibility. State and Federal Governments can provide broad guidelines, planning assistance and guidance, and some financial assistance for local areas. The principle tasks of developing proper management techniques, establishing adequate implementation procedures, and requiring effective enforcement methods must fall upon state and local officials and within the context of Federal law as provided. The empetus to adopt effective control measures must be provided by concerned and informed members of the state or community involved.

Federal lands and their administering agencies, too, must recognize and plan for the needed control and abatement of non-point pollution problems. Federal lands and activities, because of their influence and importance to resource and environmental management in Region VIII, must be an integral part of any long-term non-point pollution control program.

REPORT SUMMARY

General Conclusions

Ideally, this nation's water resources should be of pristine quality-unaltered by any intrusion of nature or man. Unfortunately, this is not now, nor never has been the case. Alterations to our nation's water resources are the result of the combined impact of natural and man-influenced processes. Natural processes, by their very nature, are diffuse and nondiscrete and are not readily susceptible to treatment. Man's contribution to water quality degradation comes from both direct and indirect sources. The former, we call "point sources", the latter, "non-point" sources. The point sources are amenable to isolation and treatment. Whether or not non-point sources are as amenable to treatment and can be dealt with as effectively as point sources will be ascertained in the future.

Non-point sources for which man can be held partially responsible include mining; urban and rural construction; agriculture; storm runoffs; recreational activity-especially in non-metropolitan areas; and land disposal of municipally treated wastes. It will be difficult to reach water quality goals that have been established for this country if these and other non-point pollution causes are left unchecked. The 1972 Water Pollution Control Act amendments, as was discussed in the introduction to this report, are directed to this end. They specifically state that non-point sources of pollution from all causes are to be characterized and plans for their demise formulated.

This study has undertaken to synthesize much of the presently available knowledge that characterizes sources of non-point pollution within the Region VIII EPA States. During the time frame permitted and with the limited funding available., it was not possible to specifically quantify the degrees or intensity of each major source within the six Region VIII Stages, nor to specifically identify geographically where each source is located.

This report attempts to provide descriptions of identified sources of non-point pollution, and identify major geographic concentrations and potential pollution problems based on existing data. The report also tries to identify technological and managerial practices, currently available, that appear to be adequate from a control standpoint. Part II of the report provides recommendations for a staged program for transferring knowledge of existing solutions for pollution control to individuals or groups that contribute, directly or indirectly, to the problems.

Readers of this report can readily conclude that, in terms of Region VIII alone, the contributions are substantial when considered on an aggregate basis. There are, within the study area, literally thousands of individuals whose actions, in some way, affect water quality. In reality, there are very few inhabitants of the region who are not contributors. To provide the educational experiences to offset these problems and lessen them to a meaningful degree will require a sizeable commitment in terms of financial and human resources. Governmental agencies focusing in on these problems will be required to provide considerable financial support to on-going informational and educational efforts, including control methodology dissemination and technology transfer, to get the job done.

Need for Broad-Based Educational Attack

Throughout the report references have been made relative to needs for additional research and technology transfer mechanisms. It has been suggested in Part II of this report that existing and well established informational systems can be immediately utilized to accomplish part of this task.

In the report "Intergovernmental Uses of Federal R&D Centers and Laboratories" prepared and issued by the Council of State Governments and funded by the National Science Foundations, it has been emphasized that the "spectrum of problem-related capabilities of the laboratories covers transportation, water quality standards, radiation, environmental biology, occupational health, mineral conservation, marine science, air pollution, weather modification, land use, wildlife management, coastal protection, pesticides, energy resources, solid waste management, water supply management, soil conservation, and so on." The list is indicative rather than exhaustive. Much of the knowledge produced by these laboratories is underutilized in terms of the problem solving information they possess. This vast data bank represents a technical assistance to state and local officials concerned with managing, legislating resources, and implementing policies and programs under conditions of uncertainty. However, there are very few well established mechanisms systematically transferring this reservoir of knowledge to users for implementation of non-point source control programs. Add to this the tremendous amounts of research data that are available through EPA's National Environmental Research Centers and at universities and private institutions around the country, partly funded by the Environmental Protection Agency, and you begin to gain some perspective of the vast amounts of pollution control technology that exists.

One of the purposes of the NSF technology transfer study and report was to suggest workable approaches for the optimum utilization of technological resources for assisting state governments in treating domestic problems. In reference to the utilization of established informational transfer systems it said: "ALTHOUGH THE EFFECTIVENESS OF THE AGRICULTURAL EXTENSION SERVICE HAS BEEN EVIDENT FOR DECADES, NO CONSIDERATION IS BEING GIVEN TO EXPLORING AN EXPANSION OF THIS PROVEN STRATEGY FOR TECHNOLOGY TRANSFER." Since the report was published, however, the National Science Foundation has been exploring the possibility of testing three state Extension systems - Colorado, Tennessee, and Oklahoma, for this very purpose.

It has become increasingly apparent to those engaged in research and development of pollution control technology that the breakdown occurs at the user leve. There is an urgent need for more direct informational efforts, facilitated with appropriate levels of funding, that will reach to the user leve. It follows, then, that there is also a need to facilitate the user's awareness of, and access to, the available technology and a need to provide the technical assistance that will asist the user in applying that technology to solve specific problems.

This report acknowledges the fact that, in some instances, controls will be necessary. The need for controls can be rationalized in terms of the beneficial outcomes that will result. However, a great deal of educational groundwork must be laid to facilitate the acceptance of necessary controls and, if need be, regulations. The writers of this report are convinced that if these educational efforts are allowed to happen, those affected by controls and regulations will gain a deeper understanding of existing and potential environmental problems and, if provided, useful knowledge of the improved methodologies and control practices available to them. Of prime consideration must be the economics of installing improved management practices and the cost benefits that will accrue. It will be difficult to gain user acceptance of new and untried (on their part) control technology if these cost benefits cannot be cited.

In their report "Research Needs for Irrigation Return Flow Quality Control" (EPA 1973) Dr. James P. Law and Mr. Gaylord V. Skogerboe include this statement: "Local acceptance of proposed control measures will require demonstration projects and an extensive educational program to demonstrate local, regional, and interstate benefits to be gained."

Part II of this report will describe proposed action steps to conduct an educational program designed to create a high level of awareness in relation to non-point pollution problems and related control technology.

IRRIGATION RETURN FLOWS

Irrigation of agricultural crops involves applying water to the field in such a manner as to insure a salt balance--salt in equals salt out. Much of this water evaporates or transpires through the plants leaving a more concentrated water to return to the stream. Also in many areas of the west the water picks up additional salts as it passes through the soil. Because of the consumptive use of water in the irrigation process there is less water in the stream from which it was directed thereby causing a concentration of salt in the stream. This salt concentration effect is a major factor in Western salinity problems.

Since irrigation return flows constitute a large portion of the flow of many streams in the Western U.S., increasing importance is being placed on the ways and means of better managing irrigation water use as a way to control excessive salt build-up that is occurring in these streams. The major geographic areas of concern in the Rocky Mountain-Prairie region are in the Arkansas, Rio Grande, and Colorado River Basins and of these three, the problems of salt build-up (and its economic consequences) are probably greatest in the Colorado River Basin simply due to the size of the river and the population and foreign country affected.

Irrigated Areas

The irrigated acreages for the six states in Region VIII of EPA are given in Table 1 for the years 1968 and 1969 (Skogerboe and Law, 1971). Table 2 contains the irrigated land for 1959 and 1969 by river basin (Skogerboe and Law, 1971). Projections of irrigated acreages are given in Table 3 by river basin (Pavelis, 1967). Although only portions of most of the basins are in Region VIII, the table does indicate increasing irrigated acreages in all basins. From 1969 to 2000 irrigated acreages in the Upper Colorado Basin, which lies almost entirely in Region VIII, are projected to increase by 26.5%. The Upper Colorado Region State-Federal Inter-Agency Group (1971) identifies with large

Table 1.
Irrigated acreage by states for Region VIII of the Enviornmental Protection Agency (Skogerboe and Law, 1971).

State	Irrigated Acreage 1968	Irrigated Acreage 1969	Percent Increase or Decrease
Montana	3,200,000	3,200,000	0
Colorado	3,280,000	3,310,000	+1
North Dakota	89,100	89,100	0
South Dakota	414,000	414,000	0
Utah	1,348,624	1,348,624	0
Wyoming	1,608,500	1,642,500	+2

Table 2.
Irrigated acreages by river basins partially in Region VIII of the Environmental Protection Agency (Skogerboe and Law, 1971).

	1959 Acres 1,000	1969 Acres 1,000
Missouri Basin	5,802	6,985
Arkansas-White-Red	2,806	5,357
Rio Grande	1,638	2,020
Upper Colorado	1,361	1,700
Great Basin	1,426	2,240
Souris-Red-Rainy	9	20

Table 3.
Long-term projections of irrigated acreages in the river basins partially contained in Region VIII of the Environmental Protection Agency (Pavelis, 1967).

Basin	1980 1,000 Acres	2000 1,000 Acres	2020 1,000 Acres
Missouri	8,050	8,950	9,600
Arkansas-White-Red	5,600	6,400	6,690
Rio Grande	2,050	2,180	2,200
Upper Colorado	1,900	2,150	2,250
Great Basin	2,340	2,510	2,570
Souris-Red-Rainy	90	230	250

Table 4.
Status and extent of saline and sodic areas in the six states of Region VIII of the Environmental Protection Agency as of 1960 (Skogerboe and Law, 1971).

State	Area Reported	Total Acreage[1]	Salt-free Acres	%	Saline--all classes	%
Colorado	Statewide	2,811,532	1,829,704	65.1	981,828	34.9
Montana	4 areas	1,242,728[2]	1,045,057	84.1	197,671	15.9
North Dakota	6 areas	2,636,500[2]	1,819,870	69.0	816,630	31.0
South Dakota	Statewide	1,697,974	501,708	29.5	1,196,266	70.5
Utah	7 areas	1,390,222	877,440	61.1	512,782	36.9
Wyoming	Statewide	1,261,132	981,429	77.8	279,703	22.2

[1]Irrigable [2]Arable

maps irrigated land and potentially irrigated land, discusses adequacy of water supplies, and projects future conditions.

As mentioned earlier, many western soils also add salts to irrigation water as it passes through the profile. Table 4 shows the extent of these saline and sodic areas in the Rocky Mountain-Prairie Region. From Table 4 it can be seen that Colorado, Utah, and South Dakota have more than a third of their soils affected by highly saline conditions--South Dakota is well above a third. Not only do these soils add salt to return flows, but crop production is reduced on one-fourth of the irrigated acres due to saline conditions. In the entire West, salinity is a problem on half of the irrigated acreage.

The National Academy of Sciences (1966) projected a net increase of 5% in the amount of water diverted for irrigation from 1954 to 2000, while the irrigated acreage in this time span is expected to double. This implies an increase in the efficiency of irrigation water use. In fact, this same study projects that in 1980, the Colorado River Basin, due to this increasing efficiency, will divert 2,172,000 acre-feet less than it did in 1957; whereas, if the efficiency were not increased, the diversions would increase 73,000 acre-feet. By 2000, the study indicates the Colorado River Basin, due to increasing efficiency, will divert 2,482,000 acre-feet less than it did in 1957; whereas, if the efficiency were not increased the diversions would increase 446,000 acre-feet. Thus increasing irrigation efficiencies will result in a net decrease of water diverted.

As noted earlier, when water is diverted for irrigation, the return flow quality is degraded. As the process is repeated at various points downstream, the water's quality degrades more and more. If the amount of pollutants contained in the return flows is small in comparison to the volume of flow in the river, the downstream users would probably not be greatly affected. However, if the return flows contain a large volume of pollutants in relation to the flow, the downstream users are adversly affected. As the water resources of the river are developed the water quality may be so poor that many downstream uses are not possible. EPA currently utilizes a program to calculate exact dollar dis-benefits accruing to downstream users in the Colorado River Basin based on salinity increases below Lake Mead.

In the Rocky Mountain-Prairie Region, several river basins are experiencing high utilization of their water resources resulting in the above described situation. The lower Colorado River water users (particularly in Mexico, Imperial Valley and Coachella Valley) are experiencing difficulties in using Colorado River water due to the high salt concentrations. Recently completed and planned water resource development projects in the Colorado River Basin will only tend to increase the salinity problem. The Rio Grande River Basin is also experiencing a rapid development of the water available creating water quality problems. The same is true for the Arkansas Valley in Colorado.

Existing technology is not adequate to predict the quality of irrigation return flows. Consequently, it is very difficult to make accurate projections on the effect a new project would have on the quality of water in a river basin. Also as attempts are made to manage water quality in a river basin, the need for more difinitive information on irrigation return flows becomes crucial.

Specific Conditions

Within the Environmental Protection Agency's Region VIII there are a number of areas where irrigation return flows are a problem. In the Upper Colorado River Basin there are twelve irrigated areas which contribute to the salinity problem of the river and five major natural sources of salinity. These areas are identified in Figure 2 and are described in detail in Colorado River Board of California (1970). All sources result in a mean annual salt tonnage of roughly 8 million reaching Hoover Dam (Skogerboe and Law, 1971).

The Colorado River Board of California (1970) has identified projects which, if constructed, would substantially reduce the salt load in the Colorado River. The salt sources subject to control are identified in Figure 2 while the average annual costs, including capital, operation and maintenance costs, are summarized

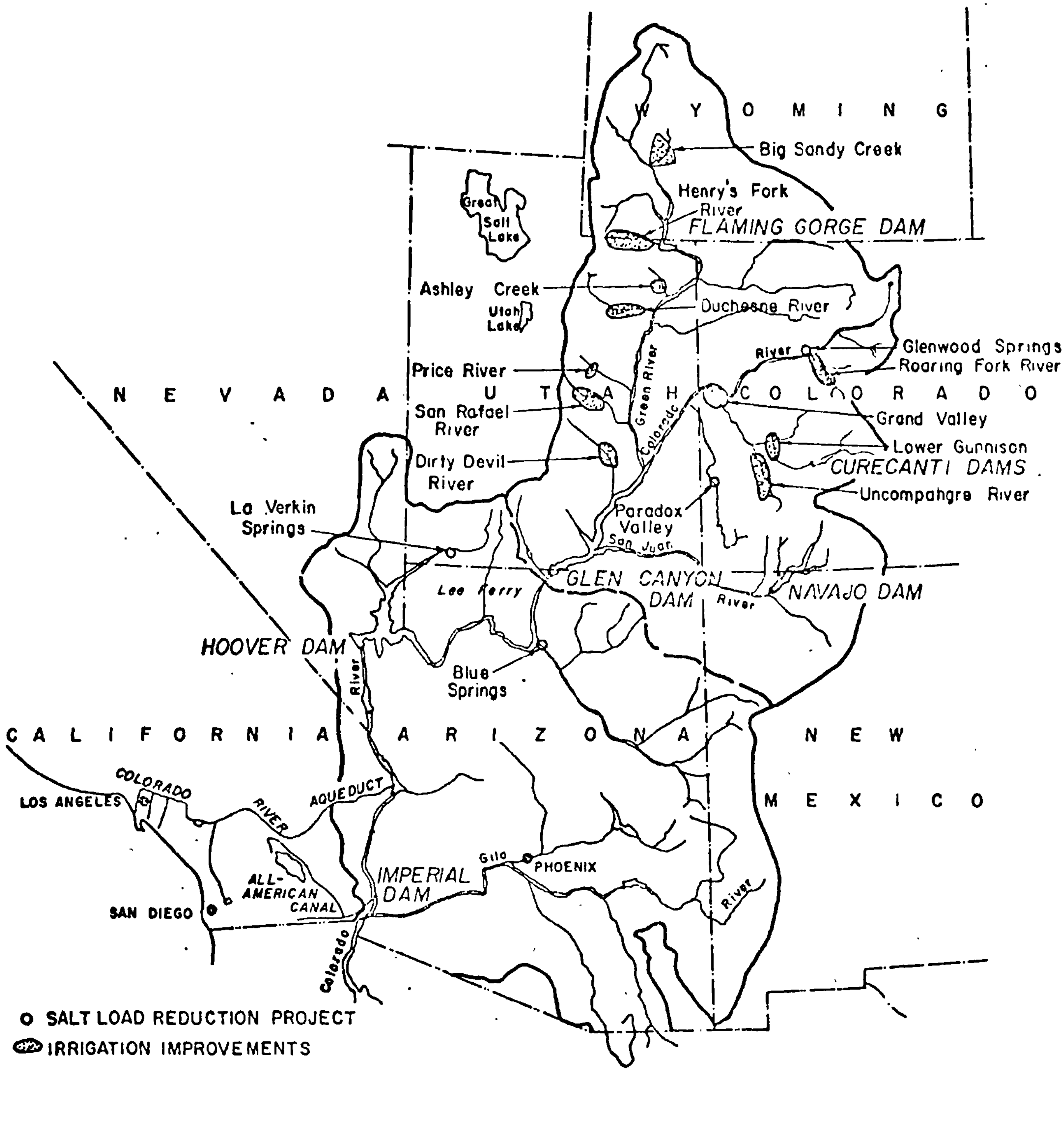

Figure 2. Proposed salinity control projects in the Colorado River Basin (Skogerboe and Law, 1971)

in Table 5 (Skogerboe and Law, 1971). Completion of the listed projects would result in a projected removal of 2.8 million tons of salt annually from the Colorado River and its tributaries upstream from Hoover Dam. This amounts to 25% of the total annual projected salt load of 11.4 million tons at Hoover Dam in the year 2000. As a result of these projects there would be 22,000 acre-feet of brine to be disposed of annually. Approximately 79% of the salt reduction would be achieved from sources in the Upper Basin (Region VIII).

Projected salinity to be expected at Hoover Dam and other points along the river is given in Table 6 for the years 1980, 2000, and 2030. The values are given for both conditions, with and without the projects. It is assumed half the projects would be completed by 1980 with the remainder completed by 2000. The Bureau of Reclamation (1972) has proposed a program to improve water quality conditions in the Colorado. Maletic (1972) describes the purpose and goals of the Bureau's program.

From the above information and references it is possible to get an overview of the impact the various irrigated areas are having on the salinity problem in the Colorado River Basin. Also the projections give an indication of what can be expected in the future. The energy development (coal and oil shale) may radically alter this picture.

Turning to the Rio Grande, it is noted that only a very small area of the basin lies in Colorado and, thus, Region VIII. However, of the water that leaves the Upper Basin of the Rio Grande, 50% comes from Colorado's San Luis Valley. The flow leaving Colorado amounts to an average of 445,000 acre-feet per year (Clark, 1972). The northern half of the valley is a closed basin, thus the water generated or used in this area does not reach the Rio Grande and is not a part of the above figure. The total dissolved solids in the Rio Grande as it leaves Colorado averages 250 ppm (Ward, 1973). Thus, much of the salinity problem in the Rio Grande, except for that associated with stream-flow depletion, begins outside of Region VIII.

Table 5. Estimated costs of salinity control projects (Skogerboe and Law, 1971).

Project	Salt Removed (Thousands Tons/Year)	Annual Project Costs [a] (Thousands Dollars)	Unit Cost [b] (Dollars/ Ton/Year)
Irrigation Improvements [c]			
Grand Valley	310	3,100	5.00
Lower Gunnison River	330	3,600	5.40
Price River	90	1,000	5.70
Uncompahgre River	320	4,000	6.30
Big Sandy Creek	40	490	6.30
Roaring Fork River	50	880	8.50
Upper Colorado River	80	1,400	8.90
Henrys Fork River	40	710	8.90
Dirty Devil	40	710	8.90
Duchesne River	270	5,700	10.40
San Rafael River	70	1,400	10.50
Ashley Creek	40	800	11.60
Subtotal	1,680	23,790	
Stream Diversion			
Paradox Valley	180	700	3.90
Impoundment and Evaporation			
La Verkin Springs	80	600	7.50
Desalination			
Glenwood and Dotsero Springs	370	5,000	13.50
Blue Springs	500	16,000	32.00
Totals	2,810	46,100	
Weighted Average Unit Cost			12,30

[a] Annual project costs include amortized construction, operation and maintenance costs.

[b] The unit costs only include costs allocated to salinity control.

[c] Annual project costs for irrigation improvements incorporate all costs, including those allocated to the irrigation function. Costs allocated to salinity control projects were estimated to be one-half of total annual project costs.

Table 6. Projected salinity in the Lower Colorado River with and without proposed salinity control projects.[a] (In Parts per Million)

Station (Along Colorado River)	Average 1963-67	1980		2000		2030	
		Without Projects	With Projects	Without Projects	With Projects	Without Projects	With Projects
Below Hoover Dam	730	830	790	1,050	790	1,090	810
At Parker Dam	740	860	820	1,110	830	1,150	840
At Palo Verde Dam	b	910	860	1,190	890	1,230	910
At Imperial Dam	850	1,070	990	1,340	1,010	1,390	1,030
At Northerly International Boundary	1,300[c]	1,350	1,290	d	d	d	d

[a] Based on Upper Basin depletions as projected by the Colorado River Board for 1980 and the U.S.B.R. for subsequent years.

[b] Record not available.

[c] Source: International Boundary and Water Commission.

[d] Not estimated.

In the San Luis Valley there are 444,921 irrigated acres using 825,905 acre-feet per year according to the 1969 Census of Agriculture. This compares to a total of 2,020,000 acres for the whole basin.

There is a quantity problem in the Rio Grande as the water resources are approaching full development in downstream sections. The San Luis Valley has confined and unconfined aquifers containing at least 2 billion acre-feet of water in storage. Mineral concentrations in the shallow groundwater of the closed basin range to nearly 14,000 mg/l. The unconfined aquifer is mainly irrigation water and leakage from the distribution system (Clark, 1972). Any attempts to use the groundwater to increase flows must be carefully evaluated in light of the above facts.

As with the Rio Grande, the headwaters for the Arkansas form in Colorado; however, unlike the Rio Grande, the Arkansas water is highly saline as it leaves Colorado and Region VIII. The last sampling point of the Arkansas as it leaves Colorado averages 3700 mg/l of TDS with a standard deviation of 640. This creates serious problems with attempts to use the water for any purpose. Table 7 summarizes the water quality conditions of the Arkansas in Colorado and indicates that as the water flows through the agricultural areas of the valley, it picks up a large amount of salt. The data was taken from Colorado Water Pollution Control Division (WPCD) records and covers through mid-1971. The river also loses much of its volume passing through the irrigated areas, thus concentrating the salt.

The economy of the Arkansas Valley is largely based on irrigated agriculture with the major municipal uses of water occurring at the juncture of the plains and foothills at Pueblo. It can be noted in Table 7 that the consumptive use of the water mainly occurs past the urban areas. Due to the economy being so heavily based on irrigated agriculture, the problem of salinity control is compounded.

The Upper Missouri River Basin contains numerous examples of irrigation return flow problems as the previously presented statistics show. The problems,

Table 7. Arkansas Main Stem Stream Characterization Data

Sta No	Location	DO (mg/1)			BOD (mg/1)		pH			TDA (mg/1)			Flow[4] (cfs)
		M[1]	S D[2]	S S	M	S D	M	S D	S S	M	S D	S S	M
1P[5]	Holly	7.5	1.9	5.0	2.0	0.8	8.0	0.5	6.5-8.5	3700	640	Agric	233
2S[6]	Lamar	8.2	2.0	3.0	1.8	0.8	7.9	0.3	5.9-9.0	3500	1300	Agric	224
3S	Las Animas	7.9	2.1	3.0	2.1	1.0	7.9	0.3	5.9-9.0	2500	1000	Agric	214
4P	La Junta	7.4	1.9	3.0	6.5	5.6	8.0	0.4	5.9-9.0	1300	360	Agric	251
5P	Nepesta	6.4	1.7	3.0	6.1	2.4	7.9	0.4	5.9-9.0	650	220	Agric	683
6S	Pueblo	7.6	1.1	5.0	1.8	1.0	8.1	0.4	6.5-8.5	480	220	<500	707
7S	Canon City	8.0	2.4	5.0	1.5	0.7	8.1	0.4	6.5-8.5	180	58	<500	718
8S	Salida	8.1	2.1	6.0	1.6	0.5	7.9	0.4	6.5-8.5	130	34	<500	626
9S	Leadville	7.9	1.3	6.0	2.6	2.8	7.6	0.7	6.5-8.5	120	34	<500	70.8

[1] Mean

[2] Standard Deviation

[3] Stream Standard

[4] USGS Data, Surface Water Records

[5] WPCD Station Number, with P Indicating Primary Station Designation

[6] WPCD Station Number, with S Indicating Secondary Station Designation

however, are not readily apparent for two reasons. First, the water supplies in the basin are fairly plentiful and this tends to mask quality degradation. Secondly, there is a real lack of documented studies in the basin regarding irrigation return flow quality. The present knowledge is due primarily to irrigation system failures (situations where excessive sodic conditions make land reclamation economically unfeasible) or recent investigations undertaken to expand irrigated agriculture in the area (Skogerboe and Law, 1971).

In Region VIII's portion of the Missouri River Basin, the South Platte River presents one of the more critical areas as far as water quality is concerned. The river's flow has been extensively developed in all areas with agriculture using a large portion of the water. Table 8 contains data indicating the extensiveness of the quality problem in the South Platte. The TDS of 1438 mg/l at Julesburg displays the salinity problem and the flow readings indicate where the water is used along the river. The return flows cause the flow to increase as it leaves Colorado. The return flows below Denver are primarily municipal and industrial while those further downstream are due mainly to agriculture. An Environmental Protection Agency (1972) study indicates the above is true, but concentrates mainly on the effects of municipal and industrial waste sources on South Platte quality.

As for other areas in Region VIII's Missouri River Basin where irrigation return flows are documented, Wyoming has had a number of examples of irrigation project failures or near failures. The Riverton Project is an example where sodic conditions now make land reclamation economically unfeasible for many farms. Skogerboe and Law (1971) state that much of this problem could have been alleviated if canals had been lined, on-the-farm water management practices instituted, and drains constructed at the initiation of the project. A large extension role would be involved in implementing such measures. Projected large-scale energy development in the Missouri River Basin and associated water consumptions may drastically effect this situation in the near future.

Table 8. South Platte Main Stem Stream Characterization Data.

Sta No	Location	DO (mg/l)			BOD (mg/l)		pH			TDS (mg/l)			Flow (cfs)
		M	S D	S S	M	S D	M	S D	S S	M	S D	S S	M
20	Julesburg	7.7	1.7	4.0	4.2	3.4	8.1	0.4	6.0-9.0	1438	282	<500	458
21	Balzac	8.2	2.0	4.0	3.5	2.3	8.1	0.5	6.0-9.0	1287	296	<500	359
22	Kersey	6.6	1.8	4.0	9.6	4.9	7.9	0.4	6.0-9.0	1045	290	<500	130
23	Henderson	5.2	1.6	4.0	13.8	9.4	7.7	0.4	6.0-9.0	584	221	<500	328
24	Littleton	9.2	0.3	6.0	2.2	0.7	7.7	0.2	6.5-8.5	218	54	<500	217
25	South Platte	9.8	1.7	6.0	1.9	0.2	7.6	0.2	6.5-8.5	126	47	<500	474

In North and South Dakota there is much irrigation development underway on lands that are underlain by soils high in natural salts (for example, the Garrison Diversion Unit in North Dakota). Due to low permeability, drainage will be required for successful operation of the irrigation project. As their projects are completed, irrigation return flows will increasingly cause water quality problem. Madden (1969) discusses several factors which must be considered in irrigating South Dakota soils while Fine (1972) and Bloodworth (1972) discuss salinity problems in the northern and southern plains, respectively.

The Snake River has its head waters in Western Wyoming; however, there is little irrigation occurring there nor is there much irrigable land (Skogerboe and Law, 1971). For this reason, the Snake River problems are not discussed in this Region VIII report.

In the Great Basin, Region VIII has two basic areas of concern for irrigation return flows. The Bear River flows from its headwaters in northeastern Utah through small portions of Wyoming and Idaho and terminates in the Great Salt Lake in Utah. Irrigation along the upstream lands creates the return flows utilized again for irrigation downstream. The water quality is degraded with periods of low flow finding the water limited in its usefulness. The Sevier River in Utah experiences water qualtiy problems from irrigation return flows (40-50% of diverted water is irrigation return flows). The Sevier River is located in southwestern Utah and agricultural use of the Sevier River accounts for approximately 25% of Utah's irrigated acreage. Water in the river is completely utilized for irrigation--no water reaches Sevier Lake, the natural end of the river (Walker and Walker, 1972). For this reason, water quality in lower reaches creates problems for users.

Water Quality Problems

As noted in the introduction, the water quality problems associated with irrigation return flows result from: (1) the concentrating effect of the plants using the water, and (2) the leaching of additional pollutants from the soil. The return flows carry the concentrated salts and other pollutants to the streams.

Exactly what are the water quality problems associated with irrigation return flows? One of the major problems (and the one receiving most attention) is the increased salinity. This characteristic of return flows has been discussed earlier in citing the impact of irrigation on water quality. However, salinity or salt load tends to be a catch-all term which excludes the impact of other pollutants.

Law and Skogerboe (1972) discuss the nutrients, sediment and soil erosion, and pesticides associated with irrigation return flows. With most nutrients there is a strong relationship between water use efficiency and fertilizer use efficiency. Nitrogen is a good example in that considerable nitrate may be in return flows from irrigated land. This is especially true if the levels of applied nitrogen exceeds the crop requirement and leaching is necessary to control salinity in the root zone (Peterson, Bishop and Law, 1970).

With phosphorus, most of the fertilizer compounds are absorbed to soil particles and little downward movement occurs. Thus phosphorus builds up in the upper soil layer and is carried to the streams by erosion of soil particles. As a result, erosion control provides a means of controlling phosphorus pollution of surface waters. Also erosion control provides a means of controlling the sediment load imposed on streams by irrigation return flows. Surface return flows may carry large sediment loads; however, evaluation of the exact amount depends upon the soil type.

The use of pesticides on irrigated fields and along irrigation canals and open drains presents an opportunity for the chemicals to enter the return flows. Given this opportunity exists, along with nutrient and sediment problems, control of irrigation return flows must consider more than only salinity. The problems of nutrients and biocides are discussed elsewhere in the report.

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IRRIGATION RETURN FLOW CONTROL TECHNOLOGY

Irrigation has been practiced in some form since the earliest recorded history of agriculture. The irrigation practices that have been developed over the years have been passed down more as an art than a science. For example, water management on the farm has been based more on protection of water rights than on sound technology. The water requirements of the crop come second to the conveneince of the operator, and the legal structure within which he operates, as to the amount and time of irrigation.

Economic considerations also play a major role in the efficiency of irrigation. The scarcity and/or high cost of water results in high irrigation efficiencies and vice versa. Jensen, Swarner, and Phelan (1967) note that farm management involves balancing the immediate cost of water against the higher labor and investment costs required to use it more efficiently. Oftentimes the costs of inefficient water use are not recognized immediately but may be reflected in reduced yields due to nutrient losses or increased salinity, or in extra drainage facilities needed to control rising water tables. Also inefficiency of water use occurs when excess quantities of water are substituted for labor costs or time savings (Law, et.al, 1972).

The technology to be described herein relates to the ways and means by which irrigation practices may be improved and, consequently, the pollution from return flows reduced. The irrigation system can be subdivided into three major subsystems: (1) the water delivery system; (2) the farm; and (3) the water removal system (Law, Skogerboe, and Denit, 1972). The water delivery system can be broken into two additional components: (1) the transport of water and pollutants from the headwaters of the watershed to the cross-section along the river where water is diverted to irrigate croplands, and (2) the transport of water and pollutants from the river diversion works to the individual farm. The water is normally delivered to the highest point on the farm and leaves the farm at the lowest point. Also within the farm subsystem the water moves vertically from the ground surface to the bottom of the root zone. The water removal can be one of two ways: (1) surface runoff at the lower end of the farm or (2) water moving below the root zone.

In most cases, the quality control problems associated with irrigation return flows are minimized by utilizing efficient water delivery and farm subsystems. By minimizing the surface runoff volumes, problems associated with sediments, phosphates, and pesticides can be reduced. By controlling deep percolation losses from irrigated lands, the salinity problem can be minimized in areas where salt pickup occurs.

Law, et.al (1972) have prepared a concise and thorough review of the existing technology associated with irrigation return flows. The following is taken from their report.

Water Delivery System

The importation of high quality water from adjacent river basins, weather modification to increase precipitation and runoff from the watersheds, bypassing mineralized springs, evaporation reduction from water surfaces, and phreatophyte eradication are some of the available measures for improving the quality of water diverted from a river. Consequently, they play a role in the management of the irrigation return flow system. More feasible approaches may be found in the control of losses from storage and conveyance systems.

Canal and lateral lining. Many unlined irrigation canals traverse long distances between the diversion point and the farm land. Seepage losses may be considerable, resulting in low water conveyance efficiencies. Canal lining has traditionally been employed to prevent seepage and the economics of lining have been justified primarily on the basis of extending the usefulness of water at a particular location. The possibility that water seeping from canals may greatly increase the total contribution of dissolved solids to receiving waters has only recently been given serious attention. Bower (1966) showed that average seasonal canal losses varied from 13% of the diversion on the Uncompahgre Project, Colorado, to 48% of the diversions on the Carlsbad Project, New Mexico. If we assume a very conservative estimate that 20% of the total water diverted for irrigation in the United States is lost by canal seepage, the loss to the intended users would be 24 million acre-feet per year. This quantity of water would either contribute an additional dilution effect to the benefit of downstream users, or it would irrigate eight million additional acres, using three acre-feet per acre.

If soils along the canals are high in residual salts, the salt pickup contribution from this source could easily exceed that leached from the irrigated land to maintain a salt balance. The time required to leach these residual salts would depend upon the quantity of seepage and the quantity of salts. In addition to the quantity of water saved, the salt from this source could be largely eliminated by canal lining. The value of improved water qualtiy is another benefit to be claimed in the economic justification of canal lining.

Closed conduit water transportation systems. Evaporation losses from canals commonly amount to a few percent of the diverted water. The installation of a closed conduit (pipeline) conveyance system has the advantage of minimizing both seepage and evaporation losses. Either lined open channels or closed conduits will reduce evapotranspiration losses due to phreatophytes and other non-economic vetetation along canals. The closed conduit system uses less land and provides for better water control than a canal system. Water quality improvement may very well prove to be the greatest economic justification for closed conduit systems because of minimal seepage losses and considerable flexibility in water control.

Improved flow control and measurement. A key element that must be provided in the water delivery system is flow measurement. The amount of water passing key points in the irrigation delivery system must be known in order to provide water control and attain a high degree of water use efficiency. Many present day systems emnloy no flow measuring devices, and, in some cases, the individual farmer operates his own turnout facility with no close control of the amount diverted to the farm. In addition, constant flow rates must be maintained at each turnout from the water delivery system into the farm subsystem to maximuze achievable irrigation efficiencies. Thus, automatic water controls may be required for many open channel and closed conduit conveyance systems. Obtaining the necessary flow control and measurement for achieving high efficiencies of water use would require the rehabilitation of many irrigation systems.

Only a few of the irrigated valleys are operated as a single management unit. In many valleys, several irrigation companies exist, with each company responsible for water delivery to a portion of the valley. In many cases, separate institutions exist to handle the water removal (drainage system). Numerous examples could be cited where 20-30 irrigation companies operate in a single valley. In order to develop effective irrigation return flow quality control programs, the quality degradation resulting from the entire irrigated valley must be ascertained. Then alternatives for controlling irrigation return flow must be developed, which will be primarily valley-wide alternatives. Thus, there is a real need to work with a group representing the agricultural interests of the entire valley. The consolidation of the separate irrigation companies into a single entity would have many advantages to local interests in improving agricultural development in the area, as well as providing a single entity for more effectively bringing about imporved water management programs to reduce quality degradation in receiving streams due to irrigation return flow (Skogerboe, Radosevich, and Vlachos, 1973).

On-The-Farm Water Management

The most significant improvements in controlling irrigation return flow quality will potentially come from improved on-the-farm water management. This will be particularly true for areas containing large quantities of natural pollutants, such as salts, in the soil profile. In such situations, the key is to minimize the subsurface return flow, thereby minimizing the quantity of pickup. Irrigation practices on the farm are the primary source of present return flow quality problems. Besides improvments at the source, other improvements can be accomplished in the water removal system. Due to the nature of irrigated agriculture, whereby salts must be leached from the root zone, an optimum solution will, in most cases, require improvements in on-the-farm- water management. Numerous technological and institutional concepts could be utilized to accomplish improved water quantity and quality management. Some of the technological possibilities are cited immediately below.

Cultural practices. When the soils to be irrigated are tight (low infiltration rate and low permeability), and the water supply delivered to the farm is highly saline, cultural practices become extremely significant if crops are to be grown successfully. Under these conditions, the management alternatives become: (a) use more salt tolerant plants (which are usually lower in cash value); (b) use special soil tillage practices (which cost more); (c) leach in the off-season; (d) leach the field one year and plant a crop the next year; (e) prepare the seed-bed more carefully; or (f) control the timing and amount of water being applied. Usually, these problems must be faced in the lower regions of a river basin, where the accumulative effects of upstream water quality degradation, along with having finer soils resulting from river deposition, create difficult management conditions.

In general, the deeper water is stored in the soil, the more slowly it will be removed by evapotranspiration. Soil structure, texture and stratification are the principal properties that control distribution of water storage in the soil. In extreme cases, deep tillage may be required to disrupt slowly permeable layers and permit greater water storage capacity as well as deeper root penetration. At the same time, excessive or unnecessary tillage can be detrimental to stored soil water, increasing evaporative losses when the crop needs it most. Cultural practices can play a major role in overall farm water management.

Fertilizers. There is a strong relationship between water use efficiency and fertilizer use efficiency. Applying excessive quantities of water to the croplands results in leaching of fertilizer materials below the root zone, where they are unavailable for plant growth. One real potential for improving nitrogen use efficiency over some present management practices would be the use of slow-release fertilizers. There is still a need for improved technology for slow-release fertilizers to match nitrogen release with nitrogen needs by various plants. If penalties for nitrogen discharge were imposed, slow-release fertilizers would be predominant in areas where nitrogen problems occurred. The use of slow-release fertilizers also has the advantage that by a proper match between nitrogen release and nitrogen needs by plants, only one fertilizer application would be required per season, rather than two, on vegetable crops. When applying fertilizer to crops which are not very salt tolerant, it then becomes necessary to limit the amount of fertilizer being applied. Another solution to this problem would be the application of fertilizer in small amounts with the irrigation water throughout the growing season, essentially spoon-feeding to meet crop requirements. Continual application of nitrogen fertilizer may impair ripening of certain crops.

Water control. In order to attain high irrigation application efficiencies, positive control of the timing and amount of water being delivered to the farm is required. The irrigator must be able to control the water supply as it moves across the farm. The water delivery rate must be subject to regulation as well as the quantity applied at any given irrigation. Reducing seepage losses from farm ditches, preventing tailwater losses, improving water distribution over the field, and reducing unnecessary deep percolation losses are probably the most significant areas for improvement (Robins, 1967). Related to distribution system losses is water use by non-economic vegetation in or adjacent to farm ditches. Such plants not only extract water directly from the supply, but also from the soil under and adjacent to the ditch. This extraneous vegetation retards flow in the ditch and increases seepage and evaporative losses, and in extreme cases, may cause water waste by overflowing or breaking the ditchbank. Reduction of these losses is essential to water control on the farm. It should be noted, however, that this vegetation may also be beneficial--windbreaks, shade, wildlife, asthetics.

Irrigation scheduling. One of the more interesting areas of water management control presently being explored is that of optimum irrigation scheduling. The purpose of irrigation scheduling is to advise a farmer when to irrigate and how much water should be used (Jensen, 1969 and Jensen, Robb, and Franzoy, 1970). Primarily, a farmer relies on visual indications of crop response to decide when to irrigate, or he may have to irrigate on a fixed water rotation system. Irrigation scheduling is geared towards taking soil moisture measurements, along with computing potential consumptive use for the crops being grown, to determine when to irrigate and the quantity of water to be applied. As an example, in the Twin Falls-Burley area of Idaho, there were no acres of land being studied for irrigation scheduling in 1969, whereas 10,000 acres were under irrigation scheduling in 1970, and 40,000 acres are under the irrigation scheduling program during 1971. It is anticipated that this acreage will increase to at least 100,000 acres during 1972, and hopefully the acreage will include all of the area in a few years time.

The reason for the success of the program is that measurements are being made by irrigation district personnel or commercial firms, which are then supplying the needed information to the farmers. This has saved the farmer the effort of going out and making these same measurements himself and then having to make decisions regarding the timing and quantity of irrigation water to be applied. Because of the busy schedule of the farmer, and the difficulty he might have in the initial interpretation of the data, the problem of irrigation scheduling has met with little success in the past. The efforts in Idaho look very promising and the farmers are claiming a significant benefit from irrigation scheduling. Yields have been increased due to the fact that water was applied when needed rather than after the crops were stressed. In most cases to date, there has been very little reduction in water use, although it would seem likely that a decrease in water use would occur with time as the farmer gains more knowledge of what is actually occurring in the soil profile. Another benefit to the farmer from this program is that he can anticipate the dates when irrigation is to be accomplished. This allows him to schedule irrigation along with the other duties that must be performed on the farm and relieves him of the responsibility of deciding exactly when is the best time to irrigate. The Bureau of Reclamation (1972) has proposed irrigation scheduling for the Colorado River Basin which affects the Rocky Mountain-Prairie Region.

Application methods. The effect of methods of application on the quality and quantity of return flow has not received detailed study. Conventional surface methods are most commonly used because of their low initial cost, while sprinkler methods are used because of their adaptability to a wide range of field and surface conditions and possibilities for reduced labor costs. In most areas, there is a real need to "tune-up" the existing irrigation systems, thereby attaining the highest practicable irrigation application efficiency that can be achieved with these systems. New and unique approaches to application methods need to be found. Two that appear to offer promise in the control of both quantity and quality of return flows are subsurface application and drip or "trickle" methods.

With subsurface irrigation, water can be applied to the crop in small amounts and at frequent intervals so that evaporation and resultant increase in salt concentration are reduced. The average water content of the soil can be maintained below field capacity (at points of moisture application, the water content is above field capacity), so that some precipitation can be stored in the soil. Comparable crop yields have been produced with as much as 40 to 50 percent less water than is required with furrow irrigation. Application rates can be closely controlled and the methods can be readily automated.

The drip irrigation technique has been developed in Israel and received enthusiastic interest among many researchers throughout the arid regions of the world. The major advantages include increased crop yield, reduced salinity damage, and shortened growing season and earlier harvest. The method involves the slow release of water on the surface near the base of the plants. Evaporation losses are greatly reduced and moisture release is confined to the area of the plant root system. Salts will accumulate in certain portions of the root zone during the growing season, which must eventually be leached. Some very different, but little understood, salt problems may result from this system.

Tailwater recovery and reuse. One excellent technique for managing irrigation return flows would be the use of a pumpback system for tailwater control. Such a system would increase irrigation efficiency and minimize pesticides, phosphorus, and heavy metals returning to the return flow system. This would also serve as a self-policing system since the farmer would be more prone to be careful about harmful pollutants being placed on the land or in the water.

The pumpback system can be highly advantageous for controlling sediment. Rather than allowing the water and sediment from surface irrigation return flow to be transported to the next farm, or back to the river, the surface return flow may be collected and recirculated. A tailwater pit for collection and storage will also serve as a sediment trap, where must of the suspended material will be deposited. Thus improved irrigation practices would likely result in order to minimize the quantity of water and sediment leaving the cropland. Enforceable regulations may be required to effectively control tailwater losses.

Water Removal System

The water removal sub-system consists of removing surface runoff from agricultural lands (if not captured and pumped back on the farm) and receiving deep percolation losses from irrigation. The surface runoff, or tailwater, from one farm may become all or part of the water supply for an adjacent farm, may flow back into the water delivery system st some downstream location, or may be transported back to the river via an open drain, either natural or man-made.

Drainage and salinity control. Waterlogging and salinity pose a serious threat to many irrigated areas. Any expansion upslope from existing irrigated lands becomes a direct threat to the waterlogging of downslope areas (Donnan and Houston, 1967). For example, many of the fertile lands in the San Joaquin Valley of California are now threatened by upslope irrigation development, and some areas in the Yuma Valley of Arizona have been rendered unproductive by irrigation development on the Yuma Mesa. Equally dangerous threats exist from the salt balance problem of these areas. Recirculation of water by pumping or reuse of return flows results in a buildup of salinity. Concomitant with increased salinity are corresponding increases in the leaching requirement and drainage needs. Irrigation development, including impoundment, conveyance, and application, upset the natural hydrologic cycle of an area. Recognition and solution of drainage and salinity problems in such areas requires an intensive application of control measures based on sound scientific knowledge.

For deep percolation losses, there are a few possibilities for managing the effect of water quality degradation upon receiving streams. In certain special situations, an impermeable barrier placed a short distance below the root zone would be effective in preventing moisture movement deeper into the soil profile or subsurface strata which might contain large amounts of natural salts. Thus, the deep percolation losses could be collected and diverted to the surface water removal system without being unnecessarily degraded by subsurface salinity.

Tile drainage is a very effective means for removing the less saline waters in the upper portions of the groundwater reservoir, thereby reducing the mass of salts returning to the river. By using tile drainage, salts are allowed to accumulate below the drains. This is particularly true for soils high in natural salts. Tile drainage will not completely remove all of the water moving below the root zone unless the water table is lowered below the natural groundwater outlet. Usually, some water will still move through the groundwater reservoir and return to the surface river, but the quantity of such groundwater return flows can be reduced considerably by tile drainage. The quality degradation to receiving streams from tile drainage outflow can be minimized by treating the outflow. This points out another advantage of tile drainage. Tile drains allow the collection of subsurface return flows into a master drainage system for ease of control and treatment.

Water Treatment and Control Measures

Before surface return flows reach the receiving stream, there are essentially three alternatives for preventing or minimizing the quantity of pollutants discharged into the river. First, a bypass channel could be constructed to some location where the flows can be discharged without returning to the river. Second, return flows can be stored in shallow storage reservoirs and allow the water to evaporate, leaving behind the pollutants. Seepage must be controlled in bypass channels or storage reservoirs; otherwise the groundwater may become contaminated. This second alternative has the disadvantage that pollutants are being collected, rather than discharged to the river, which may eventually create a real disposal problem.

The third alternative for minimizing the quality degradation in the receiving stream would be to treat the return flow. The third alternative is the course of action most often practiced today for disposal of waste waters, particularly those from municipal and industrial sources. Most wastewater treatment methods require a more complex technology to be effective. This makes them more difficult to implement. One significant difference occurs in the characteristics of municipal and industrial waste waters and those discharged from irrigated farm lands.

Municipal and industrial wastewaters occur at point sources. Here, the water is concentrated at specific locations, is easily collected, and is generally amenable to treatment processes because of its degradable nature, or if of a toxic nature is generally a small flow rate.

Irrigation return flow waters, on the other hand, are not easily collected at specific locations. The diffuse nature of deep percolating flows makes their collection difficult. Further, the non-degradable nature of the wastes and high flow rates make treatment more difficult and expensive. One additional factor of consideration is the fact that most methods for treatment of irrigation return flows require some loss of water which could be used for additional flow dilution.

Several treatment measures could be used for irrigation return flows. Desalination processes could be used to restore the water supply to a desired quality level, but methods for disposing of brine wastes must be considered. If the problem is to remove nitrates, then the results of the research program at Firebaugh, California conducted by the Environmental Protection Agency, U.S. Bureau of Reclamation, and California Department of Water Resources could be used. In these studies, both algae stripping and bacterial denitrification proved to be the lease costly nitrate removal methods.

Evaluation of Technology and Alternatives

To provide insight to the importance of the various technological alternatives it is necessary that some form of effectiveness evaluation be made. The evaluation is restricted to the physical improvements that can be technically accomplished within irrigation systems. The most feasible and economic technological alternatives will vary from area to area. However, utilizing knowledge and experience obtained from the analysis of numerous irrigation systems in the Western U.S, it is possible to discuss the change in water quantity and quality that could be accomplished with different physical improvements. This analysis of possible change is structured in a similar manner to the foregoing discussion in terms of the three sub-elements comprising the irrigation system; the technological alternatives under each subsystem are evaluated relative to their potential effect on water use. The range of effectiveness of the various technologies in terms of net water saved, salt load reduction decrease in sediments and associated pollutants returning to the river is quantified in Table 9. In addition, a subjective evaluation is also made of these technologies which portrays the effectiveness, level of use, and state of the art of the different technologies.

The term "net water saved" as used in Table 9 is defined to mean the physical saving of water as a percentage of the total water in the irrigation system that accures from a reduction in evapotranspiration. This savings occurs by reduced water surface evaporation, evapotranspiration by phreatophytes, and soil evaporation. The rest of the irrigation water remains in the system with only the place and time of use affected. The salt load reduction values in Table 9 are given in terms of the percentage reduction in salt pick-up. Salt load pick-up in the Western U.S. varies considerably, ranging from about ½ ton/irrigated acre around Twin Falls, Idaho to 5-8 tons/irrigated acre in the Upper Colorado River Basin. The reduction of phosphates is assumed to be directly proportional to a decrease in sediment loads. The same is true of pesticides, although some pesticides are taken into solution and carried by the water. The nitrogen transformations that occur are extremely complex. Consequently, no evaluation was made for nitrogen; but in general, nitrate reductions would be similar in magnitude to those of the decrease in salt pick-up.

A wide range of values in the percentage salt load reduction may occur for the irrigation scheduling and tail water recovery and reuse technologies (Table 9). This range depends on whether the water delivered to the farm remains the same or is reduced. A reduction in diversions would be the logical course of action followed at the farm level.

The method of water application (i.e., flood, sprinkler, trickle, etc.) have a significant affect on water saved and reduction in salt loads. This type of water quality control measure is of a preventative nature. An approach of this

TABLE 9

EVALUATION AND RANGE OF EFFECTIVENESS ON WATER USES OF TECHNOLOGICAL ALTERNATIVES

Technology or Practice	Net Water Saved, Percentage	Salt Load Reduction, Percentage	Sediment Load Reduction, Percentage	Phosphate and Pesticide Reduction, Percentage	Status of Technology	Level of Use	Relative Cost
WATER DELIVERY SYSTEM							
Canal and lateral lining	0-5	1-25	0-5	(-25)*-5	Available	moderate	moderate-high
Closed conduit water transportation systems	2-10	1-25	0-5	(-25)*-5	Available	very low	high
Improved flow measurement and control		0-15	0-5	0-5	Available	low	low
ON FARM WATER MANAGEMENT							
Cultural practices	(-2)*-2	(-20)*-10	0-100	0-80	Research-Available	low to moderate	low
Application methods	2-30	15-50	10-100	10-30	Available	low	moderate-high
Irrigation Scheduling	1-10	0-30	0-15	0-15	Available	low	low
Tailwater recovery and reuse	(-2)*-(-6)*	(-20)*-20	10-100	0-80	Available	low	moderate
WATER REMOVAL SYSTEM							
Improved drainage	2-15	2-20	0-5	0-5	Available	low to moderate	moderate-high
WATER TREATMENT							
Desalination	(-2)*-(-15)*	10->100	10-100	10-80	Available	none	very high
Impoundment and evaporation	(-2)*-(-25)*	10->100	10-100	10-100	Available	none	high
Nutrient removal	(-2)*-(-8)*	5-15	25-75	20-80	Pilot	none	moderate-high

* Indicates negative percentage

kind limits the water application rate.

The variation is salt load reduction values for cultural practices is determined primarily by the depth of soil tillage. Deep tillage practices save water but increase salt loads. Minimum tillage practices have the opposite effects.

The desalting and impoundment and evaporation treatment measures indicated in Table 9 have a potential salt load reduction that exceeds 100%. Collection and treatment of all irrigation return flows would remove not only the salt pickup from the irrigated lands but the salts contained in the water originally diverted from the rivers. In the case of the desalination technology alternative the percentage salt load reduction is dependent upon the capacity of the treatment plant in relation to the total flows within the irrigated system.

Summary and Recommendations

The irrigation return flow control technology is currently reaching the point where implementation is possible. However, the economics and social factors have not been adequately evaluated to support the implementation of this technology. It is at this point that a very strong extension effort will be needed to assist implementation.

Within the Rocky Mountain-Prairie Region several irrigation return flow control demonstration projects have brought the technology up to this implementation phase. EPA, USDA, and the Bureau of Reclamation all have demonstration programs in the Grand Valley of Colorado. Utah State University has a demonstration project at Vernal, Utah. There is an additional need for pilot demonstration programs in the Region to assist with the technology transfer. These technology demonstrations would greatly assist an Extension program of the type described in the second volume of this report.

CONCLUSIONS AND RECOMMENDATIONS

SUMMARY OF MANAGERIAL PRACTICES AND RESEARCH NEEDS

Salt concentration in source waters can be decreased by a variety of methods that have been or can be developed. Diversion of water with high salt concentrations to less critical areas as well as plugging or water treatment can reduce the severity of the problem. Management of flows from reservoirs can be utilized for mixing and diluting water from various sources to obtain irrigation water of suitable quality.

Evaporation from reservoirs and evapotranspiration from canals and watersheds can be reduced by various means. This reduction increases the available water supply but not the total salt. The result is a lower salt concentration in the water. Opportunities also exist for increasing water yields through scientific management practices on source watersheds. Such increases can serve to dilute salt concentrations in irrigation water.

Improved irrigation-management practices can reduce the excessive amounts of water used. This decreases the salt burden in the water and provides a more favorable salt balance during the growing season. For example, improvement of irrigation practices gives better control of the amount of the irrigation water that is passed through the soil and leaching requirements can be more efficiently met. Improvement of drainage also reduces the salt concentrations in the soil. These two practices, while reducing or preventing a buildup of the salt in the soil, paradoxically increase the salt content of the return flow to the basic water supply. Studies of methods to reduce evapotranspiration from irrigated fields also offer promise of reducing consumptive use of water and hence the accumulation of salt.

Return flows inevitably have a much higher concentration of salts than the irrigation water. If these are returned to the stream, salt concentrations in the stream are increased. Diversion of return flows can keep the salts out of the streams, but it also reduces the amount of water downstream that is available for other uses. Additional methods of treatment are needed to remove salts from irrigation water.

Although emphasis should be placed on preventing the degradation of soil and water by excessive concentrations of salts or minerals, this approach is not always feasible. Increased plant tolerance to salinity, alkalinity, or metals may be a logical alternative. Much remains to be learned about the mechanism of damage to plants from inorganic salts and minerals. Breeding for tolerance will reduce this damage and will be more efficient when the mechanism of the damage is better understood.

The following areas encompass the major approaches useful in reducing pollution caused by inorganic salts and minerals.

1. Decreasing salt concentration of the irrigation supply source

The Department of Agriculture has both research and action programs underway to increase water yields through reduction of evapotranspiration and the more effective capture of precipitation.

Research also is underway on the control of seepage and evaporation from reservoirs and on management of waters of varying quality by practices such as mixing to keep the salt concentration in the most favorable balance during the irrigation season.

Extension programs to increase public awareness of the problems and potential solutions are underway in the 11 Western States.

The Department of the Interior, by virtue of various congressional acts, has responsibility to plan and develop supplemental water supplies to increase the quality of the resultant water supply system.

The Clean Water Restoration Act of 1966 gives USDI the responsibility for establishing water-quality standards for all water uses, including agricultural requirements. As such, USDI provides both direct technical assistance and comprehensive regional planning to effect the best quality of available water resources. It also provides impoundment and distribution resources to augment local supplies for irrigation waters and to enhance the quality of these water supplies. In addition, it has an extensive program for the removal of salts from supply waters that are applicable to agricultural uses.

2. Improving irrigation and drainage practices to minimize the effects of salts and minerals on soils and return-water quality

Department of Agriculture action programs include assistance to soil conservation districts to increase water-use efficiency by proper irrigation design and operation. Practices such as levelling and changing the length of irrigation runs are commonly needed to reduce salt concentration in the rooting zone and to reduce excessive water application. Over-irrigation commonly is the result of poorly designed distribution systems and improper irrigation practices.

Extension education is underway in the fields of agronomy, horticulture, and agricultural engineering to acquaint the public with the problems and methods for meeting them. Loans are made to finance drainage and improve irrigation systems.

USDA also conducts research on practices to increase water-use efficiency and minimize salt accumulation. It has research programs underway to study the effects of salinity on the soils, leaching requirements, effects of heavy metals and trace elements, critical water-use periods during plant development and fruiting, nutrient requirements under irrigation, water intake and transmission qualities of soils, indicators of when to apply water, automation of water application, irrigation scheduling, drainage materials and system design criteria, plant aeration requirements, methods to prevent tile clogging by mineral oxides and sediment, and methods to improve water flow to and into tile systems.

The Department of the Interior has an intensive program to develop optimal irrigation practices for those regimes that are supplied through the Bureau of Reclamation's programs.

3. Treating or disposing of salts and minerals in return flows

The Department of Agriculture considers its authority adequate for research in this field but inadequate for action programs.

Research is needed on the use of salt sinks where salty water is impounded and evaporated by solar energy, on injection systems for disposal of highly concentrated salt water into underground cavaties where ground water would not be contaminated (areas from which crude oil has been pumped, coal mined, etc.), and on open or closed conduit systems for conveyance to inland salt sinks or to the ocean.

The only action program underway is a field evaluation of current programs of other agencies.

Under proposed authority, USDA would install 5 to 10 pilot systems to test methods of reducing salinity by control of return flows. The present theory needs to be tested before widespread action programs are started.

The Department of the Interior has extensive programs for the removal of gross quantities of salts from brackish water or from return flows as well as for the removal of municipal, industrial, or special pollutants, such as acid mine drainage. In addition, it has initiated projects to remove specific contaminants such as boron by either membrane or ion-exchange techniques.

Deep-well injection of brine-laden waters is standard practice in oil production and is used extensively for the disposal of noxious industrial plant effluents. These methods are also applicable to the disposal of treated agricultural effluents. The problems associated with deep-well disposal are part of an overall program in USDI.

4. Improving plant tolerance and utilization of salts and minerals

The Department of Agriculture has research underway on the tolerance and physiological reactions of plants to salinity, the breeding of plants for both salt tolerance and reduced transpiration, the use of grafting techniques to provide salt-tolerant fruit crops, and the determination of toxicity levels and nutritional needs of the plant for specific ions. Closely related is research on the relation of salinity to condition and transport of water and ions in soils and plants.

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RANGE AND WATERSHED MANAGEMENT

Erosion and Sedimentation

Geologically speaking, erosion and sedimentation are naturally occurring processes. Vegetative cover protects soil. However, in lands where vegetation is laking due to lack of moisture or other factors impeding fertility, the land is susceptible to wide-scale erosion by heavy rains. Wherever activities result in removing vegetative cover, i.e. soil tilling, overgrazing, crop harvesting, vegetation burning, construction and mining activities, the forces of wind and water take over acting to loosen and transport the exposed soil particles.

Sheet, rill, and gully erosion are all common consequences of poor soil management. Many times, these consequences are felt "downstream" of where the source problems occur resulting in excessive sedimentation of reservoirs and streams, drainage blockages, stream turbidity and the transportation of fertilizers and pestidices into waterways.

Factors affecting soil erosion in the Region VIII area are varied and complex. In arid areas wind erosion and lack of rainfall are major contributors. Where precipitation is high, in the Dakotas, parts of Utah, Montana, and Wyoming, and northeastern Colorado, sudden downfalls of rain of high intensity can be more damaging on inadequate groundcover than similar rainfals where the ground is protected. Land use, conservation tillage, and similar conservation measures are subject to management controls and decisions.

Region VIII Range and Watershed Conservation Needs

Range and watershed management problems shall be reviewed for Region VIII in two parts; one part concerning those areas that lie within the Upper Colorado Region which takes in large areas of Colorado, Wyoming and Utah, the other part will concern those areas that lie within the Missouri River Basin which includes Montana, Wyoming, South Dakota, more than half the land area of North Dakota, and the central and northeastern part of Colorado.

In providing an overview of the watershed management practices and concerns related to so vast a region as the Region VIII states one must be cognizent that only a general description can be provided within the limitations of this report. Much of the information that will be put forth here is to be found in greater detail in the appendices dealing this this subject area in both the Upper Colorado Region Comprehensive Framework Study and the Missouri River Basin Comprehensive Framework Study, as well as the individual Conservation Needs Inventories published by each of the six Region VIII States.

A review of these inventories, all published in 1970, shows approximately 97% of privately owned, non-federal rural land within EPA Region VIII having soil limitations or conservation problems. Soil erosion was a limitation on more than 50% of all the inventoried land. On cropland alone, erosion was a dominant limitation on 55%. These percentages are based on all the S & E subclasses totaled for the six Region VIII States.

Although PL 566 projects were widely applied for treatment and control of soil conservation and erosion problems, they were not utilized exclusively. Other projects and programs were necessary and, in several areas, employed. Projects under RC & D, REAP-type polling agreements, and group enterprises by major irrigation companies played an important role. The reader of this report will find several references to the PL 566 projects since the bulk of the data are synthesized from the Soil Conservation Inventories which were compiled under the leadership of the Soil Conservation Service in each of the six Region VIII states.

Current Watershed Conditions and Problems in the Upper Colorado Region

The map of present sediment yield rates released June, 1971 (Fig. 3) shows the general location of sediemtn yield classes within the Upper Colorado region and is only reliable for broad planning purposes. The sediment yield values shown include both natural and man-induced the capability of streams to transport sediment.

The five classes of sediment yield are:

Yield class 1	More than 3.0 acre-feet per square mile per year
Yield class 2	1.0 - 3.0 acre-feet per square mile per year
Yield class 3	0.5 - 1.0 acre-feet per square mile per year
Yield class 4	0.2 - 0.5 acre-feet per square mile per year
Yield class 5	Less than 0.2 acre-feet per square mile per year

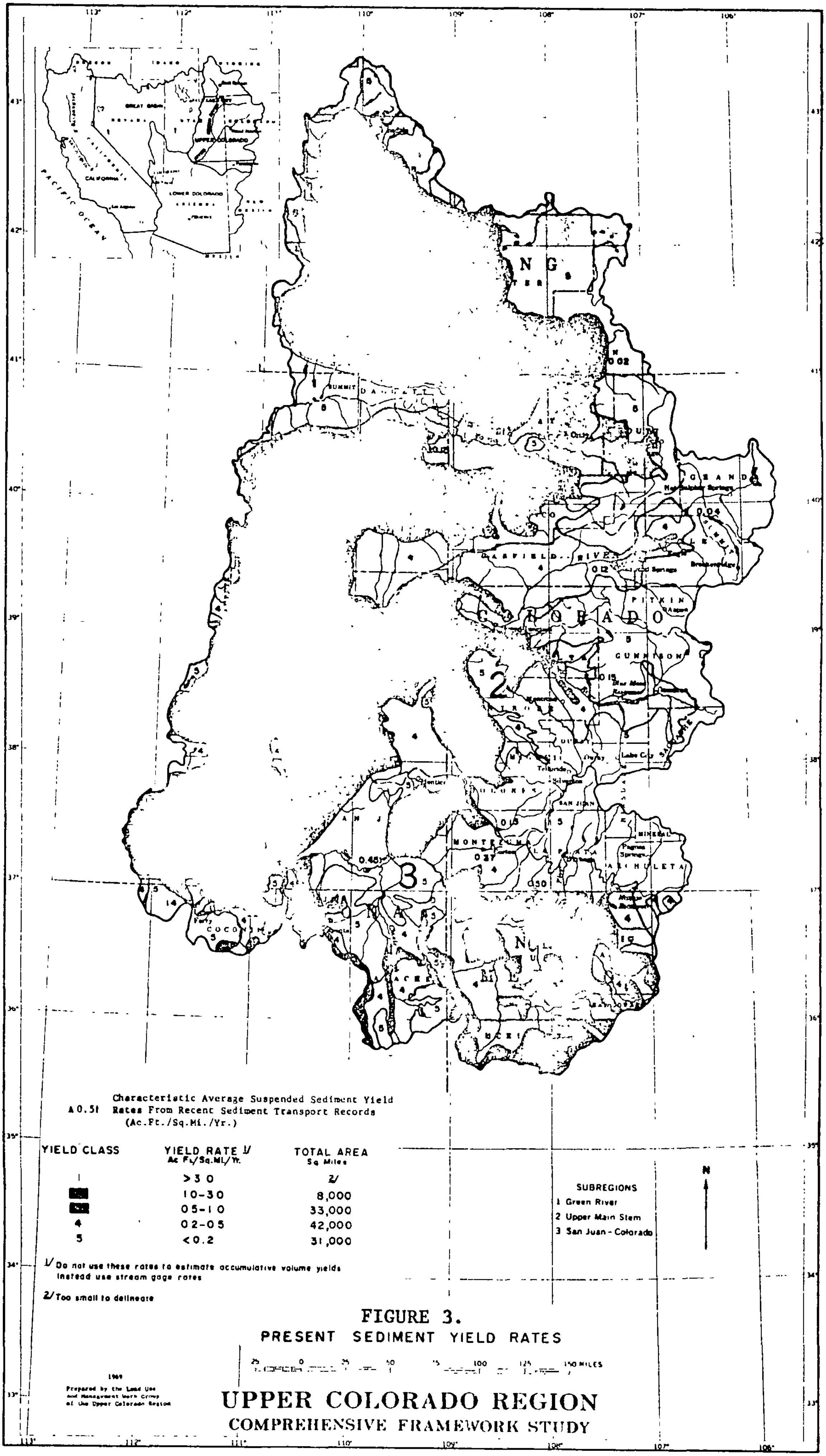


FIGURE 3.
PRESENT SEDIMENT YIELD RATES

UPPER COLORADO REGION
COMPREHENSIVE FRAMEWORK STUDY

The map also shows actual suspended sediment discharged by streams at several measuring points (stream sediment stations shown by arrows). Suspended sediment is shown as an average annual yield rate in acre-feet per square mile of drainage area above that measuring point. The suspended sediment rates represent an integration of yield rates from the many diverse areas within that drainage area. Table 10 shows state areas in yield rate classes.

Table 10. Percent of area in sediment yield rate classes, Upper Colorado Region, 1965.

State	Class 1	2	3	4	5
Colorado	*	2	12	39	47
Utah	*	16	58	18	8
Wyoming	*	*	4	64	32

* The data does not permit delineation of the area in this class.

The Upper Colorado River drainage basin embraces 109,580 square miles of land. This excludes the 3,916 square mile Great Divide closed basin which is included in the Upper Colorado Region for this study. The average annual sediment yield (years 1914-1957 adjusted to 1957 condition) of this basin at "Lee Ferry", its discharge point, was .58 acre-feet per square mile per year. See Table 11 for suspended sediment discharge at selected stations for various periods. This yield has historically varied considerably from year to year, but on the basis of period averages it is apparent that a significant change in the average rate occurred in the early 1940's. At Lee's Ferry on the Colorado, for the years 1930-42 average yield was .77 acre-feet per square mile per year. The apparent low rate for the period 1953-62 was due largely to low precipitation for most of the period and partly to deposition in the many recently constructed sediment catchment basins and other structures. The reduction from the 1930-42 period to the 1943-52 period was the result of changes in the factors which affect sediemtn yield. Specifically, vegetal

Table 11 --Suspended sediment discharge, Upper Colorado Region, 1965

Station number	River and location	Drainage area Sq. Mi.	Period	No. yrs.	Average annual: Runoff (Acre-feet)	Average annual: Suspended sediment (Tons)	Suspended sediment: Tons Sq. Mi.	Suspended sediment: Acre-feet Sq. Mi.
	Tributaries of St. Louis Creek, Colo.		1950-52	-	-	- 1/	36	0.02
9-0580	Colorado River near Kremmling, Colo.	2,360	A	-	-	150,000	64	.04
9-0725	Colorado River at Glenwood Springs, Colo.	4,560	A	-	1,738,000	486,000	107	.07
9-0850	Roaring Fork at Glenwood Springs, Colo.	1,460	A	-	980,200	287,000	197	.12
9-1295	Iron Creek near Crawford, Colo.	67	1948-52	5	12,200	16,400	245	.15
9-1525	Gunnison River near Grand Junction, Colo.	7,928	A	-	1,884,000	2,067,000	260	.16
9-1665	Dolores River at Dolores, Colo.	556	A	-	356,400	119,000	214	.13
9-1800	Dolores River near Cisco, Utah	4,580	1951-62	12	506,400	2,254,000	492	.30
9-1805	Colorado River near Cisco, Utah	24,100	1930-42	13	5,156,000	19,270,000	800	.50
			1943-52	10	5,726,000	10,300,000	427	.27
			1953-62	10	4,789,000	9,020,000	375	.24
9-1885	Green River at Warren Bridge near Daniel, Wyo.	468	A	-	391,200	19,000	41	.03
9-2165	Green River at Green River, Wyoming	7,670	A	-	1,305,000	625,000	82	.05
			1951-63	13	1,186,000	413,000 2/	54	.03
9-2510	Yampa River near Maybell, Colo.	3,410	1951-57	7	1,057,000	366,000	107	.06
9-2600	Little Snake River near Lily, Colo.	3,730	1959-64	6	295,000	1,297,000	348	.21
9-2610	Green River near Jensen, Utah	25,400	1951-62	12	3,027,000	7,405,000 3/	292	.18
9-3070	Green River near Ouray, Utah	35,500	1951-62	12	3,984,000	12,620,000 3/	355	.22
9-3150	Green River at Green River, Utah	40,600	1930-42	13	3,654,000	24,580,000	605	.37
			1943-62	20	4,244,000	16,920,000	417	.26
			1951-62	12	4,005,000	15,790,000	389	.24
9-3285	San Rafael River near Green River, Utah	1,690	1949-58	10	111,200	1,480,000	876	.54
9-3335	Dirty Devil River near Hite, Utah	4,360	1949-58	10	85,100	5,600,000 4/	1,280	.78
9-3395	Escalante River near Escalante, Utah	1,770	1951-55	5	61,700	1,757,000	993	.61
9-3555	San Juan River near Archuleta, N. M.	3,260	1955-61	7	891,000	2,273,000 5/	698	.35
9-3565	San Juan River near Blanco, N. M.	3,560	1949-54	6	799,400	1,796,000	504	
9-3645	Animas River at Farmington, N. M.	1,360	1952-61	10	572,200	919,000	676	.42
9-3665	La Plata River at State line	331	A	-	27,900	28,000	85	.05
9-3680	San Juan River at Shiprock, N. M.	12,900	1952-61	10	1,448,000	10,510,000 5/	816	.51
9-3715	McElmo Creek near Cortez, Colo.	233	A	-	38,800	141,000	605	.37
9-3795	San Juan River near Bluff, Utah	23,000	1930-42	13	1,972,000	46,340,000	2,010	1.24
			1943-52	10	1,666,000	19,090,000	830	.52
			1953-62	10	1,492,000	16,200,000	704	.45
9-3800	Colorado River at Lees Ferry, Ariz.	107,900	1930-42	13	11,330,000	133,700,000	1,240	.77
			1943-52	10	12,500,000	80,000,000 6/	742	.45
			1953-62	10	9,980,000	56,320,000	522	.32
9-3820	Paria River at Lees Ferry, Ariz.	1,570	1948-65	18	17,790	3,536,000	2,250	1.41

A/ Estimated for water years 1914-57, adjusted to 1957 conditions; USGS Professional Paper 441.
1/ Data from U. S. Forest Service as reported in USGS Professional Paper 441.
2/ Fontenelle Dam closed in August 1963.
3/ Flaming Gorge Dam closed November 1, 1962.
4/ Partly estimated.
5/ Navajo Dam closed June 27, 1962.
6/ Glen Canyon Dam closed March 13, 1963.

cover improved and land use and management favored reduction of erosion. Similar reductions are apparent at all points in the region for which long-term sediment records are available indicating that the changes in controlling factors have been general throughout the region.

Of the total average annual sediment yield at Lee Ferry for the years 1914-1957 about 20% was derived from the Main Stem Subregion, 27% was derived from the Green River Subregion and 53% was derived from the San Juan-Colorado Subregion (38% from the San Jaun drainage alone). Current records as of 1962 indicate that these approximate percentages are applicable at least through 1962. Actual delivery of sediment to Lee Ferry was reduced considerably subsequent to 1962 with the completion of several major reservoirs.

Sediment Yield Problem

The past, present, and projected sediment yeild situation is shown in Fig. 4 on the following page. The sketch of past yields represents the generalized conditions which prevailed at the time watershed management programs and certain land use controls were initiated. This did not occur simultaneously throughout the region. It began around the turn of the century and spread to most ownerships over the next 30 to 35 years.

The areas presently yielding 1.0 to 3.0 ac.ft./sq.mi./year are generally closely associated with easily erodible marine shales such as the Mancos shale. Although they are in near critical condition they could be improved under careful management if they have some soil cover and moderate slopes. However, they have the potential to deteriorate severely under poor management.

The forested high country is generally the lowest sediment yield class. On the other hand, it does have a potential for sediment production as high as 1.0 to 3.0 ac.ft//sq.mi/year. This indicates that continued careful management on these lands is mandatory. These high forest lands can be further im-

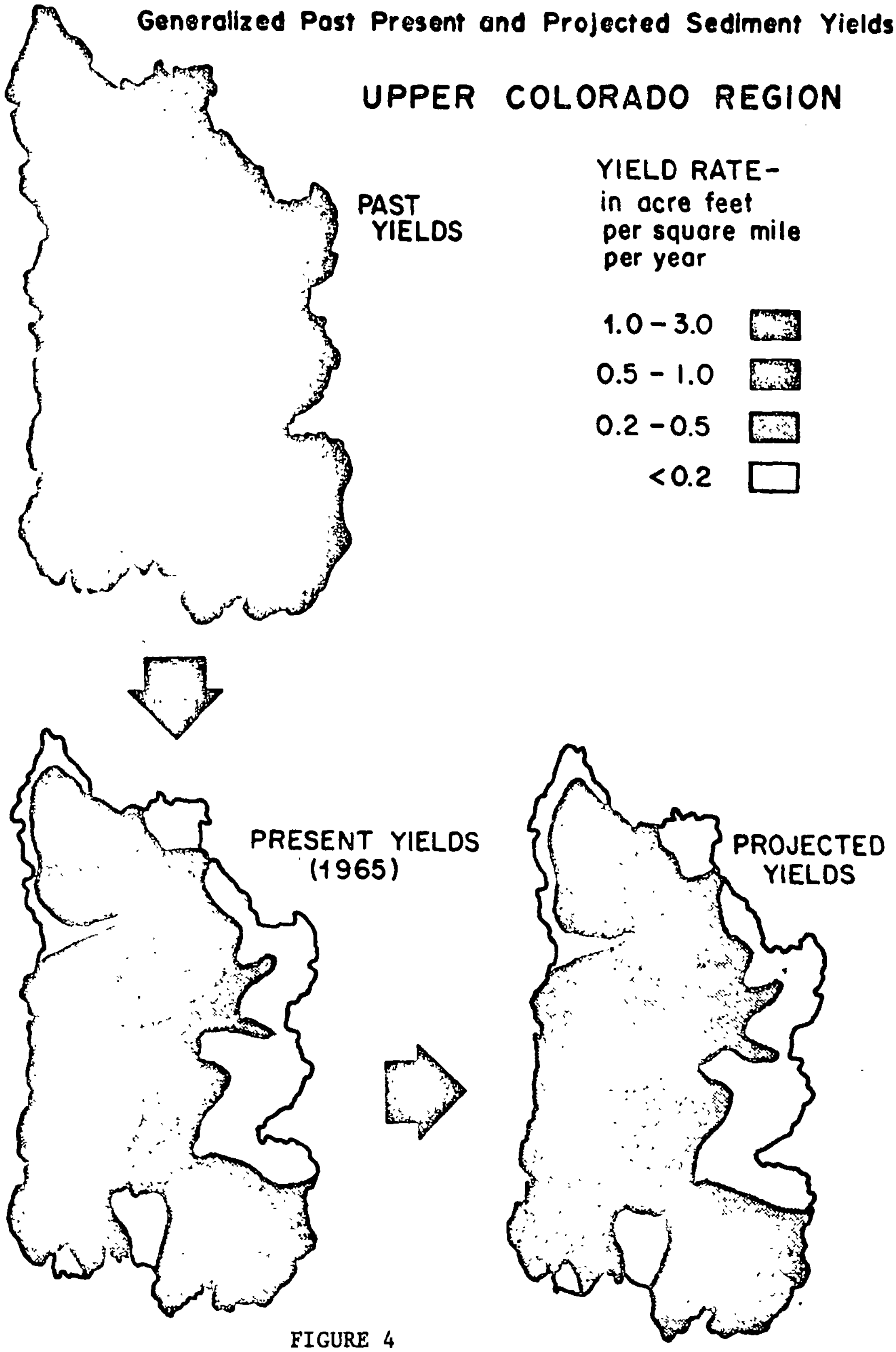

Generalized Past Present and Projected Sediment Yields
UPPER COLORADO REGION
YIELD RATE-
in acre feet
per square mile
per year
1.0 - 3.0
0.5 - 1.0
0.2 - 0.5
<0.2
PAST
YIELDS
PRESENT YIELDS
(1965)
PROJECTED
YIELDS

FIGURE 4

proved to produce even less sediment than at present although they are already one of the lowest yeilding areas.

Much land which is presently rated 0.2 to 0.5 ac.ft./sq.mi./year, shows little potential for reduced sediment yield rates. Yields could increase considerably under conditions of uncontrolled use such as occurred prior to the implementation of management.

The land which is presently yielding 0.5 to 1.0 ac.ft./sq.mi./year are primarily in the marine shale and sandstone areas of Utah and the extreme western edge of Colorado. They exhibit a considerable potential for improvement to rates of perhaps 0.2 to 0.5 ac.ft/sq.mi./year. Likewise, they show a high potential for deterioration under conditions of uncontrolled use as indicated by past yields. From a broad perspective this land generally appears to be responsive to improved management.

Yields exceeding 3.0 ac.ft./sq.mi./year are known to exist within the region, but the small size and scattered locations of these areas precluded their specific delineation on the maps. Project planning can reflect and must give detailed consideration to these problem areas and take advantage of opportunities for improvement of their condition.

Flood and Sediment on Forest and Rangeland

Flodo and sediment damage is a problem on approximately 173,000 acres of forest and rangeland within the region. About 41% of the affected acreage is in the Green River Subregion, 45% in the San Juan-Colorado Subregion, and the remaining 14% is in the Upper Main Stem Subregion. Flash floods which are fairly common are a hazard to man, beast, and property. Major flood damage is reflected in losses of highway improvements, fences, livestock, wildlife habitat and recreation facilities. There is also a significant loss of forage production on flooded sites and a reduction in storage capacity and life of stockwater ponds and reservoirs due to sedimentation.

Flood and Sediment on Cultivated and Pasture Land

Flood and sediment damage is a problem on 348,000 acres of cultivated and pasture land in the region. Approximately 42% of the affected area is in the Green River Subregion, 40% in the Upper Main Stem, and the remaining 18% is in the San Juan-Colorado Subregion.

Upstream watersheds are subject to high intensity thunderstorms. Precipitation from these storms sometimes falls at rates greatly exceeding the infiltration capacity of the soils and there is surface runoff. Damages result from floodwater and sediment when this type of storm occurs on drainages above irrigated land. Storms during the harvesting period may damage harvested crops and the deposited sediment and debris reduces land productivity. Irrigation distribution systems are often damaged or filled with sediment. Other fixed improvements such as fences, buildings and roads are subject to damage. Flooding of this type is typical in the watersheds where detailed studies led to works of improvement under the Watershed Protection and Flood Prevention Act.

Other Damages: Fire on Forest and Rangeland

Fire damage is an annual problem on approximately 27,000 acres of forest and rangeland. About 63% of the acreage is in the Green River Subregion, 26% in the Upper Main Stem, and the remaining 11% is in the San Juan-Colorado Subregion.

The problem of fire on forest and rangeland centers on two unique factors -- (1) the low value per acre of typical vegetation on these lands and (2) their remoteness. Forest fires destroy timber and produce a devastated landscape, while rangeland fires do not usually alter the landscape appearance as noticeably. There is need for public education on the real costs of fires, not only in aesthetic damage and lost livestock forage and wildlife habitat, but also in the costs of erosion and sediment production following the fires.

With increasing numbers of persons using the federal land there has been a corresponding increase in the number of fires started. Fewer acres are actually burned than previously, however, due to improved fire fighting capability. The remoteness of many fires and the lack of roads to them sometimes causes long delays in reaching the scene. Federal agencies are attempting to achieve a maximum delay time of 60 minutes to any fire. This can be achieved by road construction and increased use of air facilities.

The actual costs of fires are a combination of presuppression, suppression and rehabilitation costs, plus resource losses. The result of this complexity is that there is difficulty in developing an economic evaluation system applicable to fire costs. An adequately financed basic research and development program designed to produce reliable economic evaluation is needed to permit appraisal of opportunities to lower acreage burned and reduce dollars of damage.

Forest and rangeland damaged by fire need emergency treatment to reduce flood and erosion damage in and below the watershed after denudation by fire. The sudden and complete denudation of large areas by fire poses a particularly serious threat to watershed and downstream values. Where fire consumes both the plant cover and the litter, the soil is wholly unprotected. Infiltration is decreased, overland flow occurs, and the erosion is accelerated. Damage from floods and sediment deposition may occur both locally and downstream, but this damage can be reduced by emergency land treatment.

Location of Watershed Treatment

The watershed treatment map on the following page illustrates the watershed problem areas which have been treated by 1965. It also shows areas with current problems that will require treatment by 2020. Federal lands shown include those areas that have problems including erosion, flood, and sediment deposition. The means for treating these problems have already been discussed in other sections.

The area shown for private land includes completed watersheds which have problems of erosion, floodings, sediment or water shortages somewhere within the drainage. The following tabulation is a summary of the potential watershed projects by subregions. The following tabulation also shows estimates of numbers of watersheds within which problems may be solved by kinds of watershed project action.

Table 12. Summary of potential watershed projects, Upper Colorado Region.

Status and Kinds of Potential Projects	Green River Subregion	Upper Main Stem Subregion	San Juan-Colorado Subregion	Total Region
Applications for planning received	6	7	7	20
Flood control potential project	7	7	2	16
Agricultural water management potential projects	42	21	26	89
Total potential projects	49	28	28	105

A summary of watershed management needs and projected costs appear in Table 13.

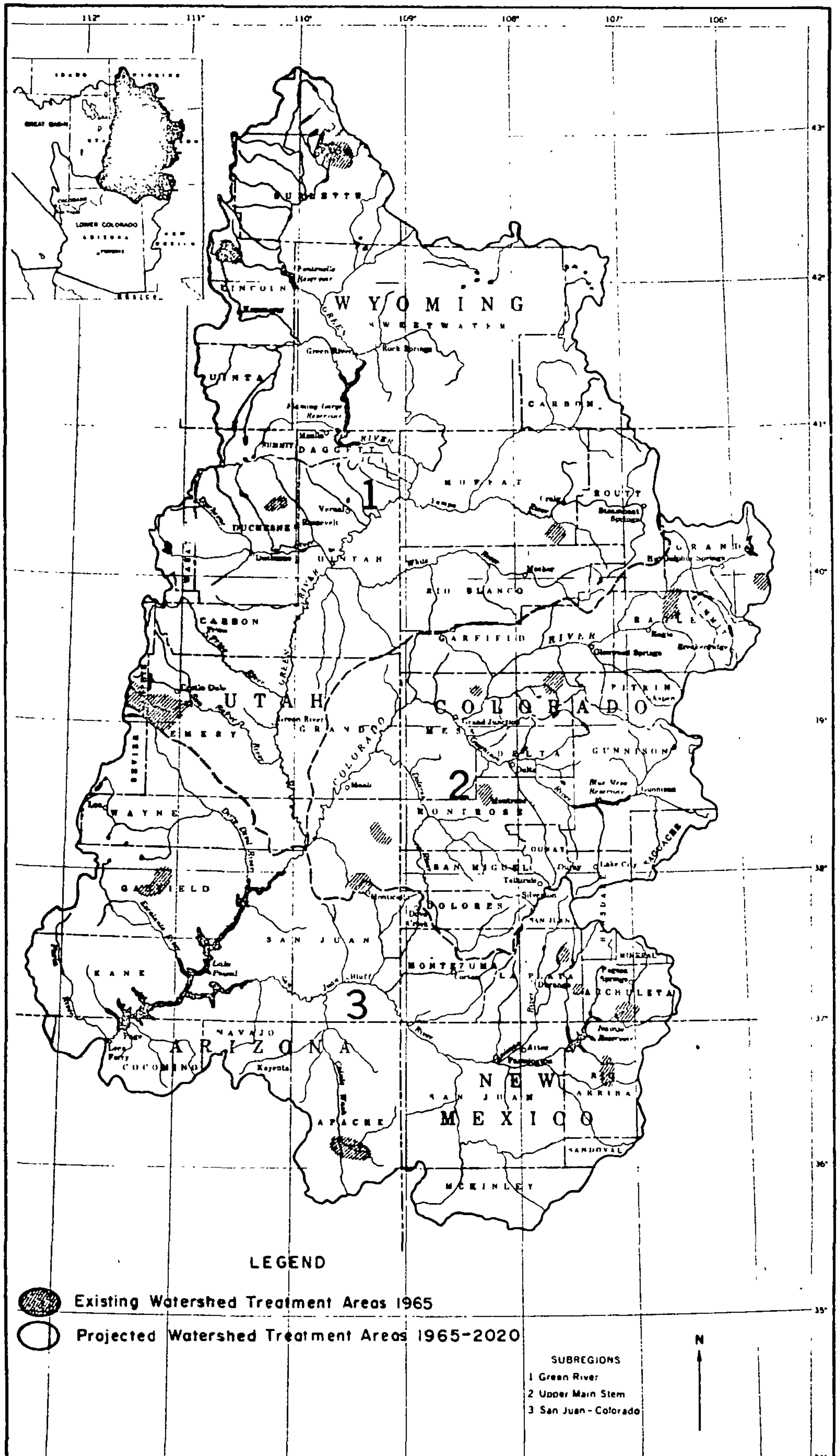


FIGURE 5.

WATERSHED TREATMENT

UPPER COLORADO REGION
COMPREHENSIVE FRAMEWORK STUDY

Table 13.--Summary table of watershed management problems, treatment needs, and cost projected to 2020, Framework Plan, Upper Colorado Region

Watershed Problems	Land Category	Area Affected (1,000 Ac.)	Treatment: Kinds	Treatment: Amounts	Cost (1,000 Dollars): Install.	Cost (1,000 Dollars): Acc. OM&R
Erosion Sediment & Runoff Control					111,991	5,897
Erosion	Forest and Range	29,119	Tree and Shrub Planting	2,744 ac.		
	Cultivated &		Stabilization	208,104 ac.		
	Pasture	1,075	Detention Dams	2,128 no.		
	Urban	183	Check & Drop Structures	67,174 no.		
	Other	103	Diversion Dams	3,993 no.		
	Subtotal	30,480	Water Spreading	383,685 ac.		
			Grade Stabilizing Structures	1,244 no.		
			Floodways	42,700 ft.		
Flood and	Forest and Range	69	Debris Sediment Basin	3,298 no.		
Sediment	Cultivated &		Brush and Weed Control	2,587,831 ac.		
	Pasture	348	Watershed Tillage	643,133 ac.		
	Urban	12	Seeding	1,110,268 ac.		
	Other	-	Gully Control	4,364 mi.		
	Subtotal	429	Sheet Erosion Control	332,600 ac.		
			Dikes	467 no.		
			Streambank and Lakeshore			
	Total	30,909	Stabilization	1,189 mi.		
Water Yield Improvement					15,046	752
Water Shortage			Vegetation Type Conversion	831,562 ac.		
Total					127,037	6,649

Note: Watershed treatment amounts to 78,300 water control facilities, land treatment on 5,268,400 acres, and gully and streambank stabilization of 5,550 miles. Improvement practices primarily for increased production which also provide protection are outlined in Appendix VI, Land Resources and Use. Watershed land treatment in Appendix X, Flood Control, includes the above acreage and an acreage directly affected by water control facilities.

Human Use and Animal Grazing Impact on Mountain Watersheds

As an illustration of land use impact on water quality in mountain watersheds, a chief source of domestic water supplies, we refer the reader to a study completed in 1965 on Mountain Watersheds in the Colorado Front Range. The primary objective of the study was to assess water quality characteristics at varying natural flow regimes under conditions of limited land use.

Grazing-Irrigation Impact: Pennock-Little Beaver Creeks

The combined impact of grazing and irrigation of a mountain meadow on water quality was observed by comparing a pair of similar sub-watersheds from the study area--one with approximately the lower half grazed and irrigated by surface spreading in summer (Pennock Creek), the other essentially "natural" (Little Beaver).

A comparison of suspended sediment for the two streams did not show higher values for the grazed drainage, i.e., the analyses of sediment (or turbidity) did not detect the land use impact. Despite no significant sediment differences between the two streams, all three bacteria groups clearly defined the grazing-irrigation impact in 1965; nearly every observation showed higher coliform counts on the grazed catchment than on the ungrazed. The much drier year of 1964 did not show such distinct differences between watersheds in coliform counts. Measurements for the other bacteria groups--fecal coliforms and fecal streptococci--were not in use in 1964.

In addition to a distinct coliform count difference between the grazed and ungrazed drainages, the fecal coliform (FC) and fecal streptococci (FS) counts also emphasized the land use pattern. The moving mean values of FC and FS bacteria show consistently higher values on the grazed (Pennock) creek as opposed to the ungrazed stream (Little Beaver). The bacteria concentrations of all three groups attained higher values in July and August, a period of low flows and warmer water temperatures when grazing and irrigation probably had the largest effect.

The ratio of fecal coliforms to fecal streptococci (FC/FS) ranged from less-than-1 to 4.5 on the natural catchment but less than 1 to a maximum of 44 on the grazed-irrigated watershed. The average 1965 FC/FS ratios were 1.3 for the natural as opposed to 7.6 for the grazed watershed, neglecting samples where either FC or FS was zero.

The "ability to detect cattle pollution" is evaluated for each indicator group--coliforms, FC, and FS--as well as for the FC/FS ratio, by comparing yearly means of each bacteria group for the grazed as opposed to the ungrazed catchments. This grazed-to-natural comparison or "impacted: natural" factor is presented in Table 14. The fecal coliform (FC) group shows the highest value or greatest sensitivity to this type of pollution; for the FC group the grazed watershed's mean is 16.1 times greater than the ungrazed. The high sensitivity of the FC group increases the "rating" of the FC/FS indicator as well (FC being the numerator), as shown in Table 14. The coliforms rate somewhat less sensitive, while the FS group is ranked least perceptive as a pollution detector.

The irrigation-grazing impact appears once more in Figure 6, where FC/FS ratios from the grazed and irrigated Pennock Creek drainage are compared again--this time to ratios from sites along the main stem of the Little South Fork (Stations 1, 3, 4, 10, and 11, averaged). Grazing above the main stem stations was less intensive in relation to flow volumes. A definite rise of FC/FS values appeared on Pennock during the June-July "flushing" period of peak flows, while the main stem values remained much lower, actual levels of FC/FS reached 22.0 on Pennock, only 5.4 on the main stem. As flows receded, FC/FS ratios for Pennock decreased, but still remained twice as high as values for the main stem stations.

Areas above Stations 8, 4, 3, and 1 were grazed most heavily, while on areas above Stations 10 and 11 grazing was less common, and Stations 2, 15, and 17 had little or no grazing effect by cattle. The relationship of FC to FS counts bears resemblance to the grazing intensity patterns, with heavily grazed stations generally showing higher FC/FS ratios.

In the time period means of Figures 7 and 8 , a distinct difference is seen for the fecal coliform counts in regard to the location of a sampling station respective to intensity of land use impact. In both time periods, higher elevation stations such as 17, 15, 10, and 11 were clearly lower in FC bacteria concentrations than Pennock Creek (8) or the main stem stations below Pennock (1, 3, and 4). This pattern was also exhibited by FS counts in TP II, but not distinctly in TP I. The lower concentrations at the higher elevations evidently was due to the lack of grazing in the hilly areas.

TABLE 14--Grazed site to natural site factors (Pennock: Little Beaver) for the bacteria indicator groups used in 1965.

Bacteria Group	"grazed : natural" factor
Coliform	3.2
Fecal coliform	16.1
Fecal streptococcus	1.7
FC/FS ratio	5.8

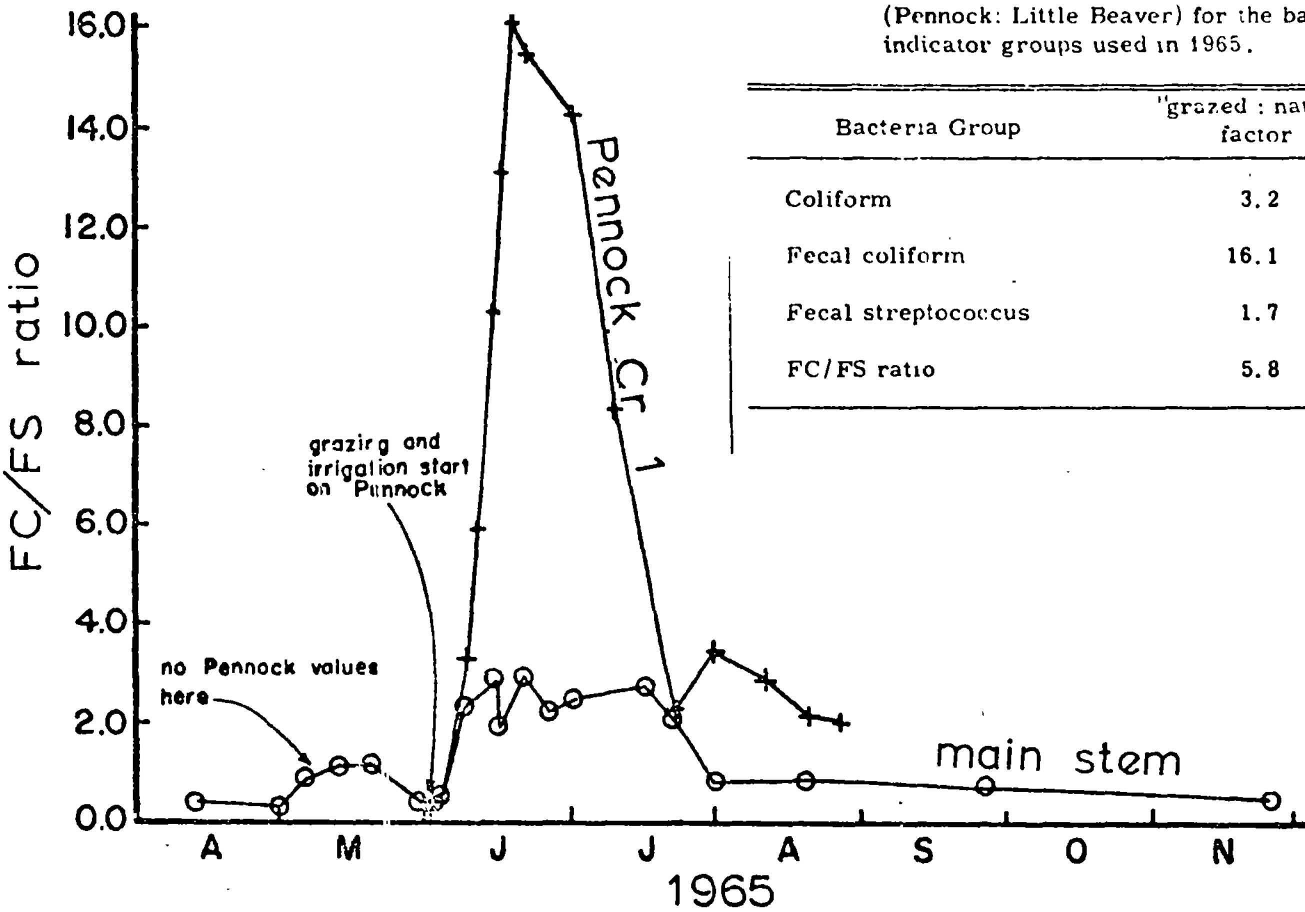


Figure 6. --Fecal coliform/fecal streptococcus ratios for heavily grazed Station 8 (Pennock) compared to values for the main stem stations. Main stem ratios are an average for Stations 1, 3, 4, 10, and 11.

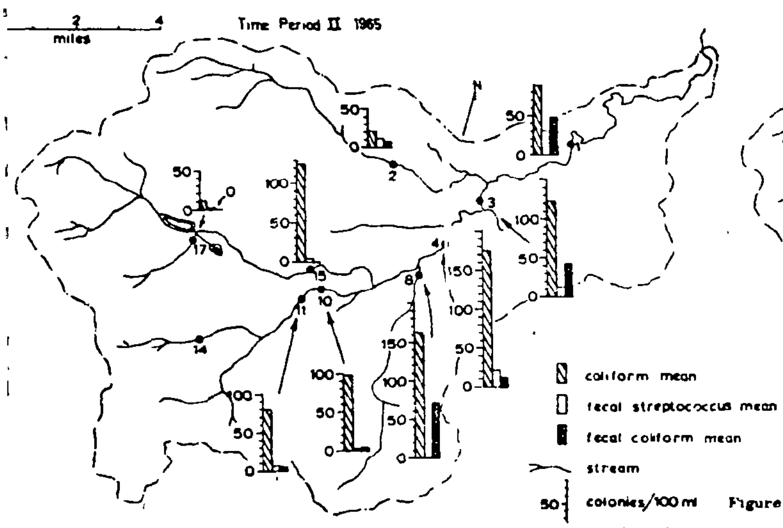


Figure 8--Means for bacterial groups in Time Period II 1965, at individual sampling sites on watershed.

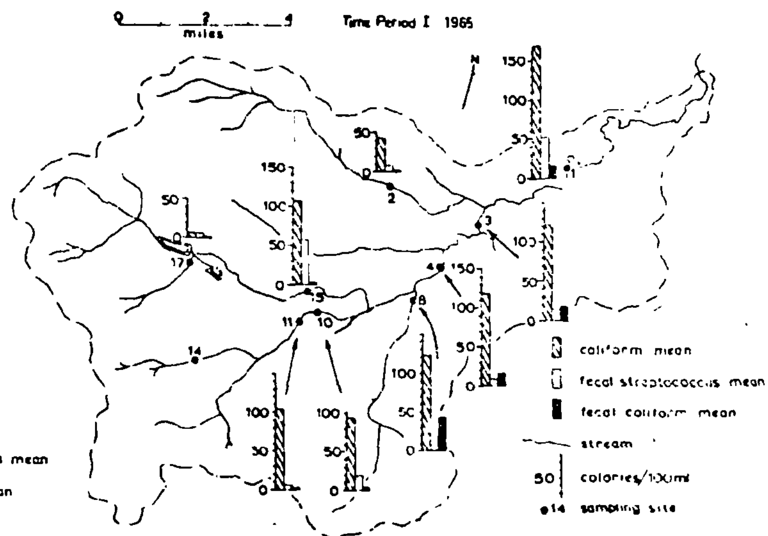


Figure 7 --Means for bacterial groups in Time Period I, 1965, at individual sampling sites on watershed.

Sediment Yields in the Missouri River Basin

The Missouri River Basin covers a very large and diverse area varying from flat, essentially non-draining land to high mountains; from highly erodible soils to rock; and from subhumid to semi-arid climate. Region VIII states located within the basin area are Montana, Wyoming, Colorado, North Dakota, and South Dakota. Detailed data concerning range and watershed management within the basin is to be found in the Missouri River Basin Comprehensive Framework Study. Within the diversities of the Basin, there are areas of localized characteristics, thus it is not possible to develop simple formulae nor an overall relationship for sediment yields within this basin. Sediment yields, representing all sediment carried by the streams, in tons per square mile per year, range from near zero in streams draining the mountainous areas to 10,000 or more in streams entrenched in the more erodible soils of the central basin area.

Figure 9 shows the areas included within the subbasin boundaries.

Figure 10 shows land and water ownership by subbasin.

FIGURE 9

SUBBASIN BOUNDARIES

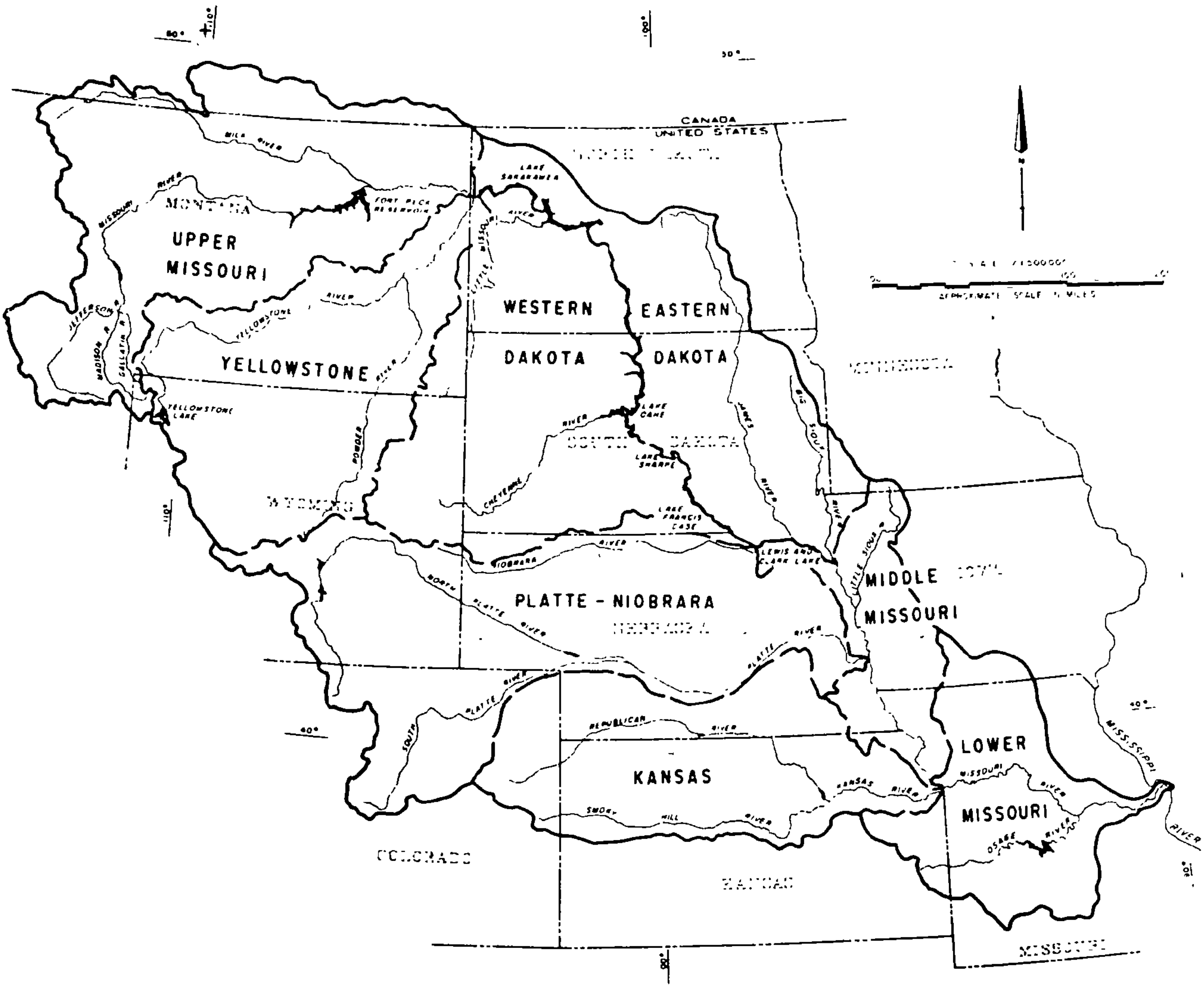
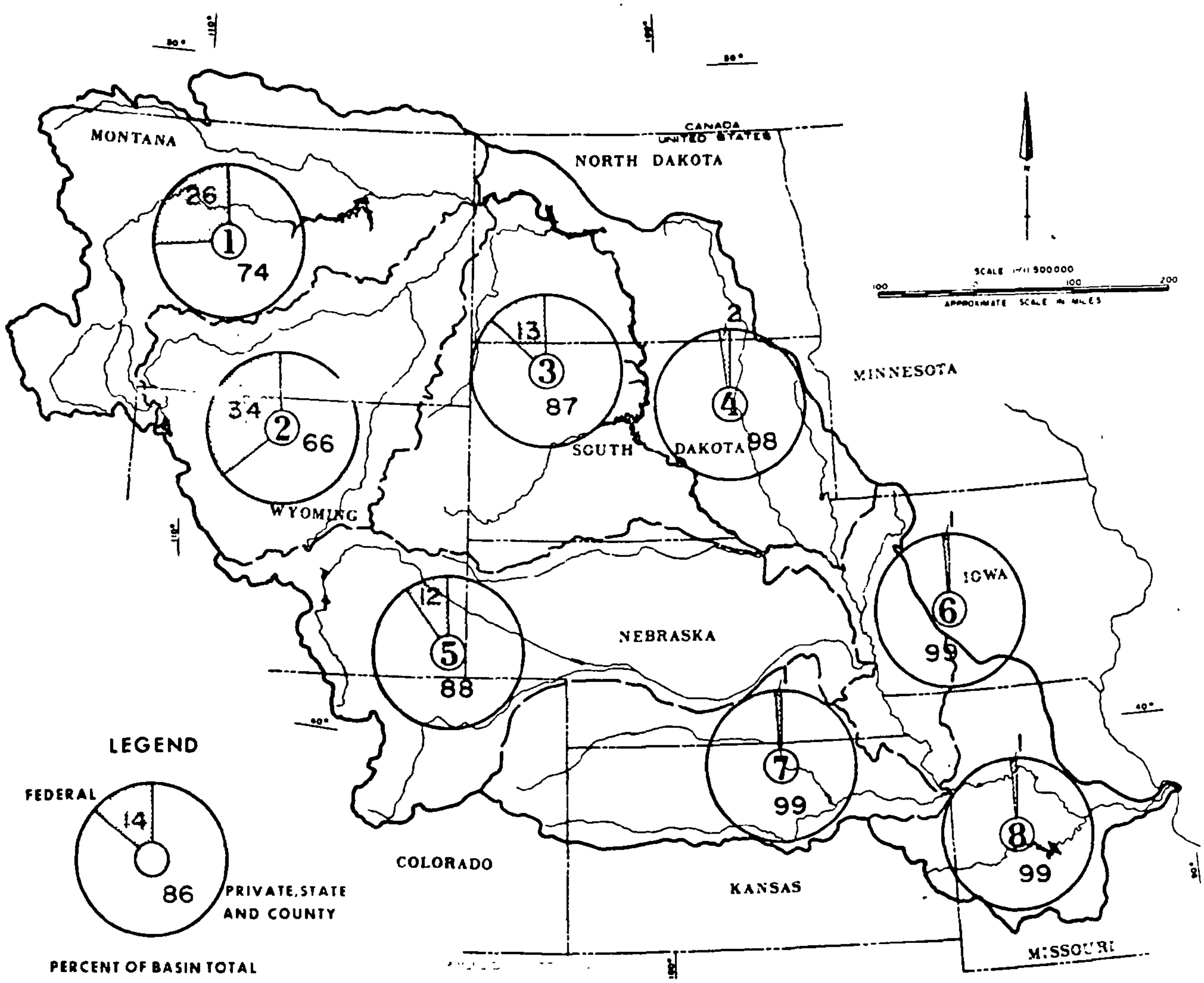


FIGURE 10

LAND AND WATER OWNERSHIP



SUBBASINS

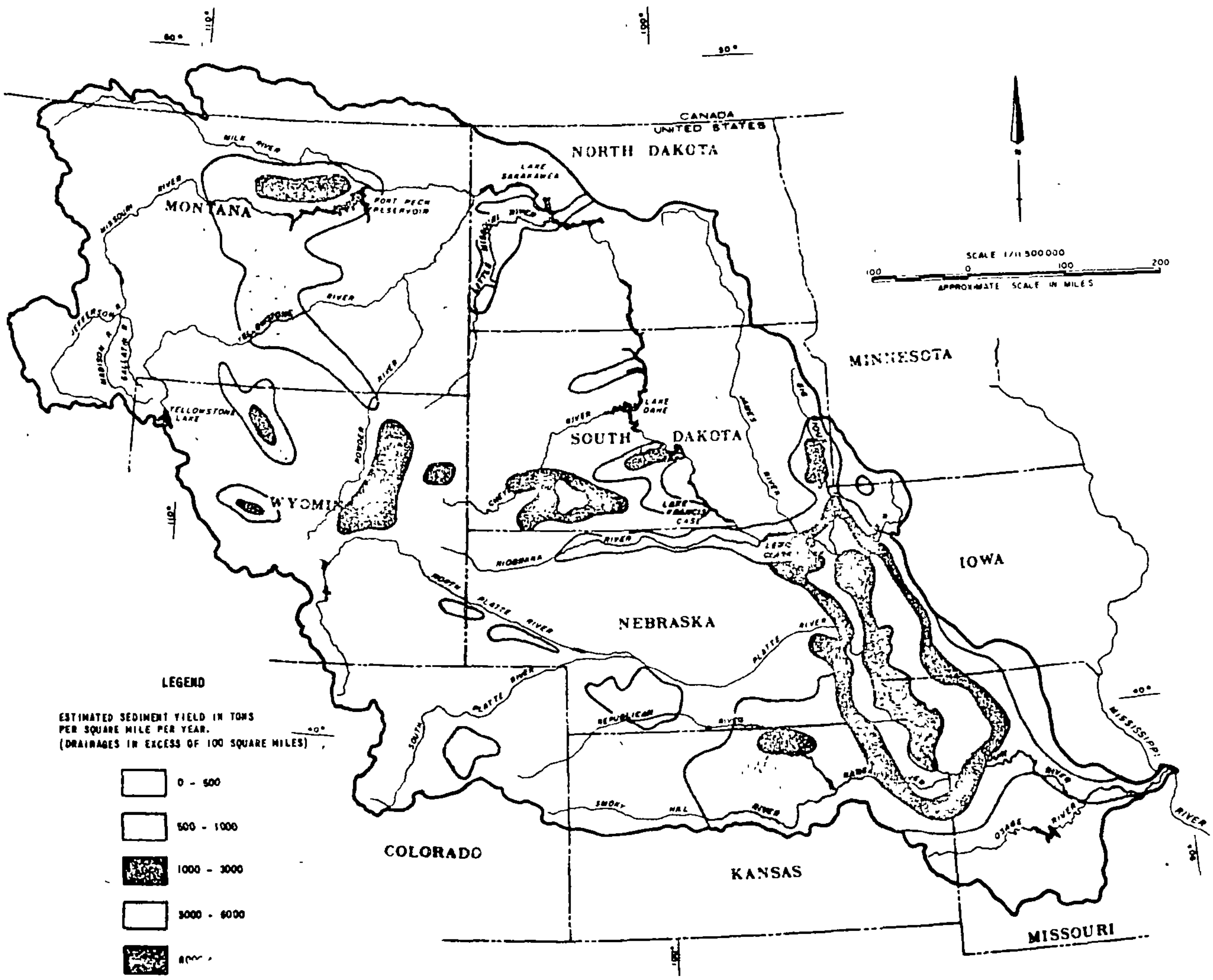
1	Upper Missouri	5	Platte-Niobrara
2	Yellowstone	6	Middle Missouri
3	Western Dakota	7	Kansas
4	Eastern Dakota	8	Lower Missouri

There are 176 million acres of public and private grazing land in the Missouri River Basin.

We have pointed out the difficulty in developing simple formulae in an effort to determine sediment yields within the basin. Data are available for selected areas based on suspended sediment sampling, reservoir sedimentation surveys, physiographic and geologic information, soils, topography, climate, runoff, vegetation, land use, upland erosion, channel erosion, and sediment transport and delivery. This information has served as a basis for estimating the average annual sediment yield in tons per square mile applicable to drainages in excess of 100 square miles. Figure 11 shows the probable ranges of average annual sediment yield for the various areas within the Missouri River Basin.

FIGURE 11

SEDIMENT YIELD



Sediment yield at all available sediment sampling stations throughout the Missouri Basin are listed in the following table.

Table 15- SUSPENDED SEDIMENT DISCHARGE

USGS Station Number	Subbasin and Location	Drainage Area Gross Sq. Mi.	Drainage Area Contributing Sq. Mi.	Period of Record Years	Years of Record	Average Annual Sediment Period of Record Tons	Average Annual Sediment Standard Period 1948-1963 Tons	Average Annual Sediment Tons Per Sq. Mi.
Upper Missouri Subbasin								
0185	Beaverhead River at Blaine, Mont.	3,619		1963-64	2	33,600		9
0255	Big Hole River near Melrose, Mont.	2,476		1957, 61-64	5	26,900		11
0265	Jefferson River near Twin Bridges, Mont.	7,632		1958-59 1961-62	4	93,700		12
0545	Missouri River at Toston, Mont.	14,669		1950-53	4	396,000		27
0711	Little Prickly Pear Cr. at Sieben Ranch near Wolf Cr., Mont	270		1963	1	1,420		5.3[1]
0713	Little Prickly Pear Creek at Wolf Creek, Mont.	381		1963	1	2,690		7.1[1]
0995	Marias River near Shelby, Mont.	3,242		1950-51	2	1,000,000[2]		310[2]
1080	Teton River near Dutton, Mont.	1,308		1955-57	3	92,100[2]		.70[2]
1150	Missouri River at Power Plant Ferry, Mont.		13,000[3]	1949-51 1958-63	9	5,829,000		448
1276	Musselshell River near Mosby, Mont.	5,941		1949-50 1963-65	3	431,000[2]		73[2]
1740	Willow Creek near Glasgow, Mont.	538		1954-63	10	892,000		1,660
1745	Milk River at Nashua, Mont.		18,300[3]	1949-58 1961-63	12	1,505,000		82
1770	Missouri River at Wolf Point, Mont	24,734[4]		1949-63	15	3,995,000		162
1855	Missouri River at Culbertson, Mont.	34,000[4]		1948-51[5] 1959-63	9	5,354,000		207

[1] Yields for 1964-65 were much higher, but were affected by highway construction.
[2] Yield affected by diversions to offstream reservoir(s).
[3] Approximate.
[4] Drainage Area below Fort Peck Reservoir.
[5] At Snowden, Mont. in 1948 and 1949.

USGS Station Number	Subbasin and Location	Drainage Area Gross Sq. Mi.	Drainage Area Contributing Sq. Mi.	Period of Record Years	Years of Record	Average Annual Sediment Period of Record Tons	Average Annual Sediment Standard Period 1948-1963 Tons	Average Annual Sediment Tons Per Sq. Mi.
Yellowstone Subbasin								
	Butcher Creek near Luther, Mont	9		1960-62	3	120[1]		13
	Butcher Creek near Roscoe, Mont.			1960-62	3	1,100[1]		44
	Butcher Creek near Fishtail, Mont.			1960-62	3	1,900[1]		58
2043	Butcher Creek near Absarokee, Mont.	39.6		1960-62	3	3,000[1]		76
2077	North Fork Bluewater Creek, near Bridger, Mont.	7.5		1961-63	3	250[1]		34
2078	Bluewater Creek near Bridger, Mont.	27 5		1960-63	4	2,300[1]		84
2078.5	Bluewater Creek at Sanford Ranch near Bridger, Mont.	43.9		1961-63	3	5,000[1]		115
2078.7	Bluewater Creek near Fromberg, Mont.	46.6		1961-63	3	6,500[1]		140
2079	Bluewater Creek at Fromberg, Mont	53.2		1960-63	4	20,000[1]		380
2280	Wind River at Riverton, Wyo.	2,309		1949-56	8	448,000	470,000	204
2350	Beaver Creek near Arapaho, Wyo.	354		1951-53	3	124,000	130,000[10]	367[10]
2355	Little Wind River near Riverton, Wyo.	1,904		1949-53 1956	6	244,000	220,000	116
2360	Kirby Draw near Riverton, Wyo.	182		1951-53	3	4,500		25
2390	Muskrat Creek near Shoshoni, Wyo.	733		1950-58 1960-63	13	194,000	160,000	220
2445	Fivemile Creek near Pavillion, Wyo.	118		1949-58 1961-63	13	34,000[2]	37,000[2]	314[2]

[1] Computed on basis of twice weekly samples.
[2] Not representative of natural yield because of development of upstream controls. Estimated delivery of 70,000 tons per year, or 600 tons per square mile per year prior to control and 6,000 tons per year, or 50 tons per square mile per year under present conditions.
[10] Approximate.

Table 15 (Continued)

USGS Station Number	Subbasin and Location	Drainage Area Gross Sq. Mi.	Drainage Area Contributing Sq. Mi.	Period of Record Years	Years of Record	Average Annual Sediment: Period of Record Tons	Average Annual Sediment: Standard Period 1948-1963 Tons	Average Annual Sediment: Tons Per Sq. Mi.
Yellowstone Subbasin (Continued)								
2500	Fivemile Creek near Riverton, Wyo.	356		1950-58 1960-63	13	660,000[3]	660,000[3]	
2530	Fivemile Creek near Shoshoni, Wyo.	418		1949-63	15	1,080,000[4]	1,100,000[4]	
2555	Poison Creek near Shoshoni, Wyo.	500		1949-53 1956	6	13,900	20,000[10]	40[10]
2570	Badwater Creek near Bonneville, Wyo.	808		1948-53 1955-63	15	239,000	227,000	281
2575	Muddy Creek near Pavillion, Wyo.	267		1949-53 1955-58 1961-63	12	150,000[5]	140,000	524[5]
2580	Muddy Creek near Shoshoni, Wyo.	332		1949-63	15	286,000[6]	300,000[6]	
2585	Dry Cottonwood Creek near Bonneville, Wyo.	165		1951-53	3	94,000		570
2595	Bighorn River at Thermopolis, Wyo.	8,020 319[7]		1947-51 1952	5 1	4,700,000 239,000		580 750
2670	Gooseberry Creek at Neiber, Wyo.	361		1952	1	271,000		750
2685	Fifteen Mile Creek near Worland, Wyo.	518		1951-63	13	583,000	600,000	1,160
2690	Bighorn River near Manderson, Wyo.	11,020 3,319[7]		1947-51 1952-53 1956	5 3	7,560,000 1,730,000		695 500
2765	Greybull River at Meeteetse, Wyo.	681		1955-56	2	162,000		238
2780	Dry Creek at Greybull, Wyo.	433		1952-53	2	97,000		224
2795	Bighorn River at Kane, Wyo.	15,846 8,145[7]		1947-51 1952-63	5 12	10,680,000 4,020,000	4,300,000[8]	674 528
2855	Sage Creek near Lovell, Wyo.	381		1951-53	3	200,000		525
2862	Shoshone River at Kane, Wyo.	2,989		1960-63	4	1,543,000[9]		516[9]
2947	Bighorn River at Bighorn, Mont.	22,885 15,184[7]		1948-51 1952-54 1956-58 1960-63	4 10	11,100,000 5,300,000	5,700,000	485 375
3085	Tongue River at Miles City, Mont.	5,379		1947-51	5	568,000	420,000	78[10]
3090	Yellowstone River at Miles City, Mont.	48,253		1949-51	3	16,583,000		343
3095	Middle Fork Powder River above Kaycee, Wyo.	450		1949-53	5	53,000	60,000[10]	133[10]
3125	Powder River near Kaycee, Wyo.	980		1950-53	4	214,000	240,000[10]	245[10]
3130	South Fork Powder River near Kaycee, Wyo.	1,150		1951-53	3	1,115,000	1,800,000[10]	1,560[10]
3135	Powder River at Sussex, Wyo.	3,090		1950-53	4	2,690,000	3,500,000[10]	1,130[10]
3165	Crazy Woman Creek near Arvada, Wyo.	956		1950-53	4	150,000	175,000[10]	180[10]
3170	Powder River at Arvada, Wyo.	6,050		1947-57	11	4,850,000	5,500,000	910
3240	Clear Creek near Arvada, Wyo.	1,110		1950-53	4	120,000	150,000[10]	135[10]
3265	Powder River near Locate, Mont.	13,189		1950-53	4	5,000,000	7,000,000	530[10]
3295	Yellowstone River near Sidney, Mont.	69,103		1938-63	26	27,380,000	20,982,000	304

[3] Not representative of natural yield because of irrigation return flow. Estimated 200,000 T/yr. under present conditions.
[4] Not representative of natural yield because of irrigation return flow. Estimated 250,000 T/yr. under present conditions.
[5] Not representative of natural yield because of development of upstream controls. Estimated delivery of 60,000 tons per year or 225 tons per square mile per year under present conditions.
[6] Not representative of natural yield because of irrigation return flow.
[7] Contributing area below Boysen Reservoir.
[8] Estimated yield for standard period under conditions of upstream control as of 1963.
[9] Not representative of natural yield owing to storage in Buffalo Bill Reservoir and irrigation developments.
[10] Approximate.

Table 15 (Continued)

USGS Station Number	Subbasin and Location	Drainage Area Gross Sq. Mi.	Drainage Area Contributing Sq. Mi.	Period of Record Years	Years of Record	Average Annual Sediment: Period of Record Tons	Average Annual Sediment: Standard Period 1948-1963 Tons	Average Annual Sediment: Tons Per Sq. Mi.
Western Dakota Subbasin								
3340	Little Missouri River near Alzada, Mont.	904		1949-51	3	130,000	150,000[1]	165[1]
3355	Little Missouri River at Marmarth, N. D.	4,570		1953-54	2	1,460,000	1,800,000[1]	395[1]
3360	Little Missouri River at Medora, N. D.	6,190		1946-51	6	3,620,000	3,000,000[1]	485[1]
3370	Little Missouri River near Watford City, N. D.	8,490		1948-63	16	5,850,000	5,850,000	689
3395	Knife River near Golden Valley, N. D.	1,230		1947-49	3	151,000	100,000[1]	81[1]
3405	Knife River at Hazen, N. D.	2,350		1948-63	16	150,000	150,000	64
3430	Heart River near S. Heart, N. D.	315		1947-51	5	26,300	17,000[1]	54[1]
3455	Heart River near Richardton, N. D.	1,240		1947-52	6	324,000	200,000[1]	238[1]
3490	Heart River at Mandan, N. D.	1,600[5]		1950-54	5	1,020,000		673
				1955-63	9	559,000		350
3510	Cannonball River near New Leipzig, N. D.	1,140		1947-50	4	336,000	200,000[1]	175[1]
3525	Cedar Creek near Pretty Rock, N. D.	1,340		1947-49	3	49,100	45,000[1]	34[1]
3540	Cannonball River at Breien, N. D.	4,100		1949-51				
				1960-63	7	625,000	456,000	113
3550	N. Fork Grand River, Haley, N. D.	509		1962-63	2	9,530	29,010	57
3575	Grand River at Shadehill, S. D.	3,120		1946-50	5	605,000	---[2]	
3580	Grand River at Wakpala, S. D.	2,390		1951	7	451,000[6]	920,000	384
				1958-63				
3590	Moreau River at Bixby, S. D.	1,570		1949-51	3	476,000		200[1]
3595	Moreau River near Faith, S. D.	2,660		1947-49	3	649,000	450,000[1]	200[1]
3605	Moreau River, Whitehorse, S. D.	5,223[4]		1948-51	10	2,651,000	3,140,000	606
		4,880		1958-63				
3860	Lance Creek at Spencer, Wyo.	2,070		1951-54	4	830,000	800,000[1]	385[1]
3940	Beaver Creek near Newcastle, Wyo.	1,320		1950-57	8	139,000	200,000	150
4000	Hat Creek near Edgemont, S. D	1,044		1951-54	4	112,000		100[1]
4005	Cheyenne River near Hot Springs, S. D.	8,710		1946-63	18	1,707,000	1,662,000	191
4015	Cheyenne River below Angostura Dam, S. D.			1952-53				
			9,100[3]	1955-63	11	1,230		
4265	Belle Fourche River below Moorcroft, Wyo.	1,730		1950-51	2	43,000		60[1]
4370	Belle Fourche River near Sturgis, S. D.	5,870		1956-58	3	653,000		200[1]
4395	Cheyenne River, Eagle Butte, S. D.	24,500		1948-51	10	7,952,000	7,772,000	317
				1958-63				
4415	Bad River, Fort Pierre, S. D.	3,107		1948-63	16	4,225,000	4,225,000	1,350
4460	White River near Ogala, S. D.	2,200		1947-52	6	267,000	190,000	86
4470	White River near Kadoka, S. D.	5,000		1950-54	5	7,463,000	7,500,000	1,500
4505	So. Fk. White River below White River, S. D.			1951-54				
		1,570		1956-58	7	204,000	190,000	120
4520	White River, Oacoma, S. D.	10,200		1940-63	23	13,000,000	12,000,000	1,177
4535	Ponca Creek at Anoka, Nebr.	410		1951-52	2	200,000	150,000[1]	370[1]

[1] Approximate; available data are insufficient to permit a reliable estimate of yield.
[2] Shadehill Reservoir closed June 30, 1950. Natural yield for period 1948-63 probably did not exceed 350,000 tons per year.
[3] Outflow from reservoir.
[4] At Promise, S. D. prior to 1959.
[5] Below Heart Butte Dam.
[6] Additional record by Corps of Engineers.
[7] Subsequent to storage in Shadehill Reservoir.

Table 15 (Continued)

USGS Station Number	Subbasin and Location	Drainage Area Gross Sq. Mi.	Drainage Area Contributing Sq. Mi.	Period of Record Years	Years of Record	Average Annual Sediment: Period of Record Tons	Average Annual Sediment: Standard Period 1948-1963 Tons	Average Annual Sediment: Tons Per Sq. Mi.
6379.1	Rock Cr. at Atlantic City, Wyo.	21.3		1958-63	6	1,560[3]		
6430	Bates Cr. near Alcova, Wyo.	393		1957-58	2	100,200		
6435	No. Platte River near Goose Egg, Wyo.		10,745	1951-53 1957-58	5	314,200[4]		
6450	No. Platte River below Casper, Wyo.		11,733	1948-52	5	527,000[4]		
6500	No. Platte River near Douglas, Wyo		13,180	1948-52	5	699,000[4]		
6540	No. Platte River near Cassa, Wyo.		14,621	1948-53	6	919,000[4]		
6560	No. Platte River below Guernsey Res., Wyo.		15,021	1948-53	6	57,400[4]		
6700	Laramie River near Uva, Wyo.		3,818	1953-57	5	14,900[4]		
7100	So. Platte R. at Littleton, Colo.	3,069		1942-48	7	384,000[7]		125
7120	Cherry Cr. near Franktown, Colo.	169		1942-45 1947-48	6	39,100[7]		231
7125	Cherry Cr. near Melvin, Colo.	360		1942-48	7	260,000[7]		722
7180	Clear Cr. below Idaho Springs, Colo.	264		1953-55	3	33,000		
7185	No. Clear Cr. near Blackhawk, Colo	55.8		1953-55	3	2,300		
7205	So. Platte R. near Henderson, Colo.	4,713		1942-44 1946-48	6	1,129,000[7]		299
7570	So. Platte R. at Sublette, Colo.	12,170		1944-48	5	729,000[7]		60
7580	Kiowa Cr. at Elbert, Colo.	28.6		1957-64	8	740		
7581	West Kiowa Cr. at Elbert, Colo.	35.9		1963-64	2	800		
7582	Kiowa Cr. at Kiowa, Colo.	111		1957-64	8	1,710		
7590	Bijou Cr. near Wiggins, Colo.	1,314		1951-55	5	953,000		
7595	So. Platte R. at Fort Morgan, Colo.	14,810		1944-48	5	1,827,000[7]		124
7600	So. Platte R at Balzac, Colo.	16,852		1942-48	7	1,328,000[7]		79

1 Stream flow unusually low in this period.
2 Yield affected by storage in Box Butte Reservoir and by large noncontributing areas.
3 Affected by storage in Rock Creek Reservoir, and by mining operations, since October 1961.
4 Sediment discharge greatly affected by storage and diversions.
5 Total sediment load about 500,000 tons per year, (285 T/Y/Sq. Mi.).
6 Partly estimated.
7 Records considered poor to fair.

TABLE 16—*Area and status of land within grazing districts, 1972*

State	Lands administered by the Bureau of Land Management								Lands administered by other owners			Grand total
	Vacant public lands	Reserved lands		Other Federal lands from which		Non-Federal lands administered		Total	Federal lands	Private, State, etc. lands	Total	
		LU	Other	Fees to BLM	Fees to other agencies	Under the Pierce Act	By other agreement					
	Acres	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*
Arizona	9,873,762	37,072	866,352	789,956	289,598			11,856,740	1,990,389	5,037,599	7,027,988	18,884,728
California	2,226,850		426,773	1,130,097			59,913	3,843,633	19,104	2,824,470	2,843,574	6,687,207
Colorado	5,896,738	36,017	1,856,498	182,043	840		45,440	8,017,576	41,155	8,907,315	8,948,470	16,966,046
Idaho	11,090,937	72,758	323,728	366,392	369,688		499,599	12,723,102	514,779	9,489,099	10,003,878	22,726,980
Montana	4,974,963	1,869,482	43,683	724,202	68,451		34,499	7,715,180	249,776	23,666,079	23,915,855	31,631,035
Nevada	43,484,354	3,167	965,614	1,273,959	1,660		1,453,673	47,182,427	2,249,713	6,923,667	9,173,380	46,355,807
New Mexico	11,092,087	224,603	275,865	650,066	58,838		397	12,201,866	2,767,654	7,621,218	10,388,872	22,590,728
Oregon	12,575,215	81,542	107,312	10,716	44,305		1,082,719	13,901,809	243,553	5,990,086	6,233,639	20,135,448
Utah	20,133,396	18,487	1,878,766	1,738,842	50,303	2,360	1,399,896	25,222,050	363,342	13,017,861	13,381,203	38,603,253
Wyoming	10,897,269		3,256,621	177,045	298,171	1,368		14,630,474	92,095	7,896,575	7,988,670	22,619,144
Total	132,245,571	2,343,128	10,001,112	6,943,318	1,181,854	3,728	4,576,136	157,294,847	8,531,560	91,373,969	99,905,529	257,200,376

TABLE 17—*Permitted use of grazing district lands, calendar years, 1967-71*

State	1967	1968	1969	1970	1971
	A. Animal units				
Arizona	151,816	137,365	108,756	95,050	81,971
California	93,062	80,572	86,188	78,442	71,607
Colorado	335,455	327,030	329,953	332,564	329,566
Idaho	392,147	389,215	391,727	399,945	411,881
Montana	359,362	368,443	363,008	349,807	367,832
Nevada	434,252	445,823	447,640	432,224	413,400
New Mexico	317,039	343,644	295,698	285,347	247,257
Oregon	217,817	213,179	214,317	201,279	201,899
Utah	322,489	319,310	311,639	299,394	246,883
Wyoming	469,315	476,415	493,523	437,701	483,636
Total	3,093,764	3,100,996	3,042,449	2,911,753	2,855,932
	B. Animal unit months				
Arizona	711,128	723,273	644,285	593,236	617,337
California	249,515	236,859	225,462	199,580	167,422
Colorado	643,797	670,487	637,055	623,809	630,164
Idaho	1,174,903	1,181,544	1,172,028	1,187,369	1,180,740
Montana	1,266,942	1,258,217	1,250,837	1,229,851	1,237,306
Nevada	2,155,576	2,158,483	2,108,171	2,098,351	2,005,355
New Mexico	1,738,421	1,807,746	1,639,176	1,631,962	1,343,082
Oregon	915,408	899,242	888,662	879,889	911,459
Utah	1,273,286	1,238,493	1,201,244	1,171,789	933,092
Wyoming	1,605,530	1,490,680	1,470,786	1,364,709	1,360,617
Total	11,364,505	11,665,024	11,237,706	10,980,535	10,286,574

TABLE 18—*Summary of permitted use (does not include nonuse permits or exchange-of-use permits) of grazing district lands, calendar year 1971*

State	Cattle and horses	Sheep and goats	Total
	Number	*Number*	*Number*
Number of operators			
Arizona	503	7	510
California	266	46	312
Colorado	1,258	322	1,580
Idaho	1,801	251	2,052
Montana	2,435	248	2,683
Nevada	761	107	868
New Mexico	1,409	318	1,727
Oregon	837	18	855
Utah	1,477	423	1,900
Wyoming	909	415	1,324
Total operators	11,656	2,156	13,811
Number of livestock			
Arizona	79,202	13,845	93,047
California	48,716	114,459	163,175
Colorado	228,310	466,282	694,592
Idaho	305,146	533,678	838,824
Montana	327,970	199,310	527,280
Nevada	349,737	318,316	668,053
New Mexico	209,137	190,600	399,737
Oregon	194,808	37,956	232,263
Utah	126,303	602,900	729,203
Wyoming	286,218	987,098	1,273,311
Total livestock	2,166,047	3,454,438	5,619,485
Animal-unit-months of use			
Arizona	512,833	4,504	517,337
California	142,929	24,493	167,422
Colorado	438,947	191,217	630,164
Idaho	931,233	249,507	1,180,740
Montana	1,110,188	127,118	1,237,306
Nevada	1,728,244	277,111	2,005,355
New Mexico	1,128,719	214,363	1,343,082
Oregon	897,735	13,724	911,459
Utah	570,529	412,563	983,092
Wyoming	823,887	687,230	1,860,617
Total animal-unit-months of use	8,234,744	2,051,830	10,286,574

TABLE 19—*Grazing permits in force on grazing district lands, calendar year 1971*

State	Permits		Total
	Cattle and horses	Sheep and goats	
	Number	*Number*	*Number*
Regular permits			
Arizona	498	3	501
California	263	34	297
Colorado	1,152	249	1,401
Idaho	1,761	219	1,980
Montana	2,412	239	2,651
Nevada	749	95	844
New Mexico	1,290	164	1,454
Oregon	833	11	844
Utah	1,434	370	1,804
Wyoming	857	222	1,079
Total regular permits	11,249	1,606	12,855
Free use permits			
Arizona	1		1
California	1		1
Colorado	1		1
Idaho			
Montana			
Nevada	4		4
New Mexico	113	150	263
Oregon			
Utah	2		2
Wyoming	2		2
Total free use permits	124	150	274
Crossing permits			
Arizona	4	4	8
California	2	12	14
Colorado	105	73	178
Idaho	40	32	72
Montana	23	9	32
Nevada	8	12	20
New Mexico	6	4	10
Oregon	4	7	11
Utah	41	53	94
Wyoming	50	193	243
Total crossing permits	283	399	682
Exchange of use permits			
Arizona	3		3
California	16	2	18
Colorado	55	17	72
Idaho	812	41	853
Montana	479	14	493
Nevada	78	5	83
New Mexico	3	5	8
Oregon	341	6	347
Utah	238	128	366
Wyoming	117	50	167
Total exchange of use permits	1,642	268	1,910
Grand Total	13,298	2,423	15,721

TABLE 20—*Permitted livestock (by types of permit) on grazing district lands, calendar year 1971*

State	Cattle and horses	Sheep and goats	Total
	Number	*Number*	*Number*
Regular permits (active use)			
Arizona	78,745	7,495	86,240
California	48,713	95,369	144,072
Colorado	205,627	363,854	569,481
Idaho	290,300	474,698	764,998
Montana	315,215	189,350	504,565
Nevada	347,318	300,728	648,046
New Mexico	203,801	173,107	376,908
Oregon	192,789	27,405	220,194
Utah	120,326	536,837	657,163
Wyoming	248,585	562,894	811,479
Total regular permits (active use)	2,051,419	2,731,727	4,783,146
Regular permits (nonuse)			
Arizona	12,123	1,210	13,333
California	13,907	68,653	82,560
Colorado	29,794	100,030	129,824
Idaho	16,029	44,244	60,273
Montana	2,859	2,380	5,239
Nevada	72,166	138,406	210,572
New Mexico	28,432	17,209	45,641
Oregon	27,748	2,700	30,448
Utah	29,825	157,504	187,329
Wyoming	42,139	205,860	247,999
Total regular permits (nonuse)	275,022	738,196	1,013,218
Free use permits			
Arizona	2	--------	2
California	3	--------	3
Colorado	1	--------	1
Idaho	--------	--------	--------
Montana	--------	--------	--------
Nevada	27	--------	27
New Mexico	943	7,073	8,016
Oregon	--------	--------	--------
Utah	7	--------	7
Wyoming	12	--------	12
Total free use permits	995	7,073	8,068
Crossing permits			
Arizona	455	6,350	6,805
California	--------	19,100	19,100
Colorado	32,682	92,428	125,110
Idaho	14,846	58,980	73,826
Montana	12,755	9,960	22,715
Nevada	2,392	17,588	19,980
New Mexico	4,393	10,420	14,813
Oregon	1,519	10,550	12,069
Utah	5,970	66,063	72,033
Wyoming	37,621	424,199	461,820
Total crossing permits	112,633	715,638	828,271
Exchange of use permits			
Arizona	161	--------	161
California	2,624	3,500	6,124
Colorado	4,392	8,571	12,963
Idaho	16,500	56,225	72,725
Montana	9,491	2,341	11,832
Nevada	13,614	7,105	20,719
New Mexico	86	120	206
Oregon	26,017	5,060	31,077
Utah	8,896	65,104	74,000
Wyoming	10,643	53,984	64,627
Total exchange of use permits	92,424	202,010	294,434
Grand Total	2,532,493	4,894,644	6,927,137

TABLE 21—*Animal unit months (by type of permits) of permitted use of grazing district lands, calendar year 1971*

State	Cattle and horses	Sheep and goats	Total
	AUM's	*AUM's*	*AUM's*
Regular permits (active use)			
Arizona	512,785	4,102	516,887
California	142,920	22,810	165,730
Colorado	438,174	189,811	627,985
Idaho	929,683	246,595	1,176,278
Montana	1,109,488	124,685	1,234,173
Nevada	1,727,847	274,371	2,002,218
New Mexico	1,121,406	202,606	1,324,012
Oregon	897,643	13,447	911,090
Utah	519,471	408,613	928,084
Wyoming	820,682	518,623	1,339,305
Total regular permits (active use)	8,220,099	2,005,663	10,225,762
Regular permits (nonuse)			
Arizona	94,967	944	95,911
California	30,927	21,729	52,656
Colorado	56,352	43,839	100,191
Idaho	104,511	122,467	226,978
Montana	14,725	1,429	16,154
Nevada	471,746	169,836	641,582
New Mexico	212,074	45,043	257,117
Oregon	113,982	460	114,442
Utah	162,441	147,540	309,981
Wyoming	88,537	342,801	431,338
Total regular permits (nonuse)	1,350,262	896,088	2,246,350
Free use permits			
Arizona	24	--------	24
California	9	--------	9
Colorado	5	--------	5
Idaho	--------	--------	--------
Montana	--------	--------	--------
Nevada	178	--------	178
New Mexico	7,002	11,587	18,589
Oregon	--------	--------	--------
Utah	39	--------	39
Wyoming	33	--------	33
Total free use permits	7,290	11,587	18,877
Crossing and trailing permits			
Arizona	24	402	426
California	--------	1,683	1,683
Colorado	768	1,406	2,174
Idaho	1,550	2,912	4,462
Montana	700	2,433	3,133
Nevada	219	2,740	2,959
New Mexico	311	170	481
Oregon	92	277	369
Utah	1,019	3,950	4,969
Wyoming	2,672	18,607	21,279
Total crossing and trailing permits	7,355	34,580	41,935
Exchange of use permits			
Arizona	1,924	--------	1,924
California	4,988	3,500	8,488
Colorado	4,922	8,571	13,493
Idaho	57,024	56,225	113,249
Montana	72,984	2,341	75,325
Nevada	40,142	7,105	47,247
New Mexico	726	120	846
Oregon	103,686	5,060	108,746
Utah	35,730	65,104	100,834
Wyoming	38,383	53,984	92,367
Total exchange of use permits	360,509	202,010	562,519
Grand total	9,945,515	3,149,928	13,095,443

TABLE 22—*Estimated use of Taylor Grazing Act grazing lease lands, calendar year 1971*

	Operators	Cattle and horses	Sheep and goats	Estimated actual use	Estimated capacity available
	Number	*Number*	*Number*	*AUM's*	*AUM's*
Arizona	500	13,400	500	161,400	180,100
California	600	60,000	140,400	174,400	215,300
Colorado	500	97,200	236,500	63,700	75,000
Idaho	800	61,600	140,600	56,900	59,300
Kansas		1,500		100	100
Montana	1,200	302,400	163,000	196,200	199,300
Nebraska	100	10,000	100	1,500	1,500
Nevada		3,500		34,900	61,600
New Mexico	900	21,600	29,600	252,400	282,600
North Dakota	100	3,000	5,000	10,200	11,000
Oklahoma				300	300
Oregon:					
O&C lands	200	10,300	2,300	26,300	26,300
Public lands [1]	1,000	67,400	21,500	108,500	101,200
South Dakota	300	10,300	24,900	71,500	71,500
Wyoming	1,800	490,300	887,500	637,900	701,800
Total	8,000	1,157,500	1,651,900	1,826,200	1,986,900

[1] Includes Washington data.

TABLE 23—*Grazing leases in force, calendar year 1971*

State	Number	Acres	Annual rental
Alaska [1]	32	1,510,870	$8,777 18
Arizona	496	1,488,216	102,936 46
California	659	4,090,812	118,801.68
Colorado	563	457,161	39,935.79
Idaho	672	293,419	34,336 26
Kansas	5	640	21.52
Montana	1,282	1,179,849	116,281 88
Nebraska	51	3,849	805.34
Nevada	19	2,365,235	22,920.94
New Mexico	881	1,390,930	156,558.92
North Dakota	99	53,707	6,496.64
Oklahoma	6	648	238.57
Oregon:			
O&C lands [2]	181	449,643	22,440.47
Public lands	1,052	845,692	66,115 84
South Dakota	361	294,965	45,788.00
Wyoming	1,959	3,313,907	305,913 34
Total grazing leases	8,318	17,739,543	1,048,368.83

[1] Authority for the issuance of grazing leases in Alaska is found in the act of Mar. 4, 1927 (44 Stat. 1452).
[2] Issued pursuant to the authority contained in the act of Aug. 28, 1937 (50 Stat. 874).

NOTE.—All leases shown in this table except those in Alaska and on the O&C lands in Oregon, were issued pursuant to the authority contained in sec. 15, act of June 28, 1934 (48 Stat. 1269).

TABLE 24—*Soil and watershed conservation program accomplishments, 1972*

Practice	Unit of measurement	Arizona	California	Colorado	Idaho	Montana [1]	Nevada	New Mexico	Oregon [2]	Utah	Wyoming	Total
Soil Stabilization & Improvement												
Brush Control	Acres					1,876	200		8,295		100	10,471
Seeding	do	1,985	686	3,865	50,547	181	13,591		23,044	265		94,164
Other Soil Stabilization	do			3,558		220	189					3,967
Water Management												
Detention and Diversions	Cu. Yds	86,669	100		50,900						60,903	198,572
Do	Number	7	6		1						2	16
Do	Acre Ft	590			16						203	809
Dikes	Cu. Yds		3,180	168,573					8,384			180,137
Pipelines	Miles	26		23	32	5	50	27	38	54	12	267
Reservoirs	Cu. Yds	5,950	1,875	2,400	13,259	302,592	6,000	71,362	50,114	36,614	276,417	766,593
Do	Number	1	1	2	6	72	3	18	15	9	55	182
Do	Acre Ft	3	1	2	16	569	6	63	26	43	249	978
Springs	Number			31	22	7	12		36	17	3	128
Water Catchments	do	1		3		3			2			9
Do (storage)	Gallons	50,000		193,000		75,000			50,000			368,000
Supplemental Water Facilities	Number	9		6	14	12	15	16	55	12	4	143
Wells	do			2	3	4	5	2	6		9	31
Do (Ave. Depth)	Feet			757	1,124	2,718	2,736	1,056	1,280		8,975	18,646
Program Facilities												
Cattleguards	Number	6	1	2	15	9	13	4	5	13	12	80
Fencing	Miles	46	24	50	139	68	223	76	96	86	56	864
Trails	do			10								10

[1] Includes South Dakota.
[2] Includes Washington.

TABLE 25—*Range improvement program accomplishments, 1972*

Practice	Unit of measurement	Arizona	California	Colorado	Idaho	Montana [1]	Nevada	New Mexico	Oregon [2]	Utah	Wyoming	Total
Soil Stabilization & Improvement												
Brush Control	Acre					160		4,415	825			5,400
Seeding	do				320		4,760		404	300		5,784
Water Management												
Pipelines	Miles	16	1	1	4	5	37	57	32	37	30	220
Reservoirs	Cu. Yds	12,425		43,780		155,774	4,816	9,374	58,334	48,741	93,968	427,212
Do	Number	2		13		37	1	2	21	30	21	127
Do	Acre Ft	4		29		396	2	13	39	62	59	604
Springs	Number		4	11	35	17	19		8	5	15	114
Water Catchments	do	1		3								4
Do (storage)	Gallons	28,000		141,000								169,000
Supplemental Water Facilities	Number	14		1	2	8	14	55	14	9		117
Wells	do	3		2		6	8	1	1	4	16	41
Do (Ave. depth)	Feet	987		122		1,122	1,544	600	50	1,100	4,750	10,275
Program Facilities												
Cattleguards	Number	8	2	4	18	15	27	9	8	6	13	100
Exclosures and Corrals	do						1					1
Fencing	Miles	42	12	39	50	34	89	20	48	25	71	430
Trails	do								2	5		7

[1] Includes South Dakota.

[2] Includes Washington.

TABLE 26—*Private range improvements constructed on public lands, 1972*

Practice	Unit of measurement	Arizona	California	Colorado	Idaho	Montana [1]	Nevada	New Mexico	Oregon [2]	Utah	Wyoming	Total
Soil Stabilization & Improvement												
Brush Control	Acres			25		1,110						1,135
Seeding	do		30					200				220
Water Management												
Pipelines	Miles	6			1	1		74				82
Reservoirs	Cu. Yds	13,900		213,077	12,210	40,534		61,500		6,840	48,285	396,346
Do	Number	9		124	7	14		17		7	15	193
Do	Acre Ft	4		74	20	60		37		14	38	247
Springs	Number			4	2	2		2	3	1	1	15
Water Catchments	do		1									1
Do (storage)	Gallons		900									900
Supplemental Water Facilities	Number		1						1			2
Wells	do	3		3	1	2		6	1		4	20
Do (Ave. depth)	Feet	870		481	200	2,987		2,390	350		3,339	10,617
Program Facilities												
Cattleguards	Number	2		2	2	2		3	2		2	15
Exclosures and Corrals	Miles									4		4
Fencing	do	3		29	4	11	2	7	5	25	41	127
Trails	do			13			1			5		19

[1] Includes South Dakota.

[2] Includes Washington.

TABLE 27—*Total conservation and improvement accomplishments, 1972*

Practice	Unit of measurement	Arizona	California	Colorado	Idaho	Montana [1]	Nevada	New Mexico	Oregon [2]	Utah	Wyoming	Total
Soil Stabilization & Improvement												
Brush Control	Acres			25		3,146	200	4,415	9,120		100	17,008
Seeding	do	1,985	706	3,865	50,868	181	18,351		23,448	565		99,969
Other Soil Stabilization	do			3,558		220	189					3,967
Water Management												
Detention and Diversions	Cu. Yds	86,669	100		50,900						60,903	198,572
Do	Number	7	6		1						2	16
Do	Acre Ft	590	1		16						203	810
Dikes	Cu. Yds		3,180	168,573					8,334			180,087
Pipelines	Miles	48	1	24	37	11	87	158	70	91	42	569
Reservoirs	Cu. Yds	322,285	1,875	259,257	25,469	498,900	10,816	142,236	108,448	92,195	418,670	1,880,151
Do	Number	12	1	139	13	123	4	37	36	46	91	502
Do	Acre Ft	11	1	103	56	1,025	8	113	63	119	346	1,845
Springs	Number		4	42	57	26	33	2	47	23	19	253
Water Catchments	do	2	1	6		3			2			14
Do (storage)	Gallons	78,000	900	334,000		75,000			50,000			537,900
Supplemental Water Facilities	Number	23	1	7	17	12	29	71	70	21	10	261
Wells	do	6		7	4	13	13	9	8	4	29	93
Do (Ave. depth)	Feet	1,837		1,360	1,324	6,827	4,280	4,046	1,680	1,100	17,082	39,536
Program Facilities												
Cattleguards	Number	11	3	8	30	26	40	16	15	19	27	195
Fencing	Miles	91	36	118	193	113	314	103	149	136	168	1,421
Trails	do			23			2		2	10		37

[1] Includes South Dakota.

[2] Includes Washington.

COLORADO

Introduction

The 1967 Conservation Needs Inventory includes 42,406,000 acres of non-federal land or about 64% of the total land area of the State. Most of the excluded land is administered by Federal agencies which have previously made studies of the land's conservation needs. Urban and built-up areas of 10 acres or more and all water areas also are excluded. The inventory acreage consists of 11,786,000 acres of cropland, 22,644,000 acres of pasture and range, 6,964,000 acres of forest and woodland and 1,012,000 acres of other land. (Figure 12.)

Major changes in land use as shown in the inventory since 1958 are:

1. Increases of about 433,000 acres in irrigated cropland. The increase in irrigated acreage is primarily from the development of wells and sprinkler irrigation from the underground water resource in eastern Colorado. The conversion to irrigated land has been on previously non-irrigated cropland and range.

2. Non-irrigated cropland has decreased about 644,000 acres because of increased irrigation and the conversion of cropland to pasture and range under the Soil Bank program and the Great Plains Conservation Program.

3. There was a net increase in range of about 433,000 acres even though some rangeland was converted to irrigated cropland.

4. Forest and woodland showed a decrease of 824,000 acres. This is mostly because a different method was used in the 1967 inventory for estimating forest and woodland acreage. However, records for each county since 1962 indicate that some of the brushy lands classed as woodland are now in other uses including range, recreation, urban and suburban tracts.

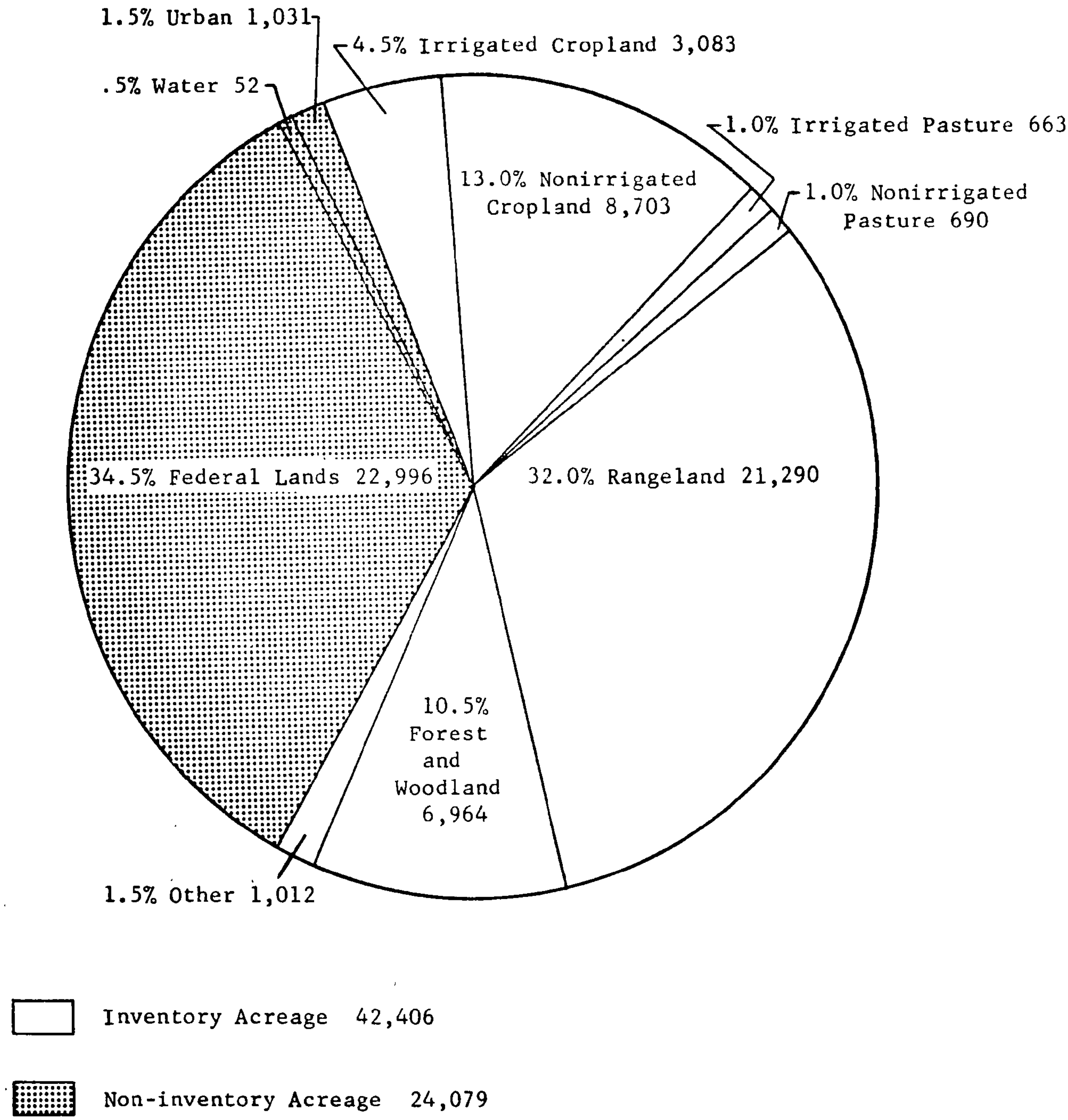
5. Other land and urban land increased about 557,000 acres as a result of industrial expansion, housing and other facilities for a continuously increasing population at the expense of all previous land use.

Fifty-two percent of the cropland acres in the 1967 Inventory are estimated to be needing treatment. The 1958 Inventory estimated treatment needs of 69%. Forty-seven percent of the pasture and range needs treatment according to the present Inventory compared with an estimate of 73% in 1958. On all forest and woodland, the estimated acreage needing treatment amounts to 19%. However, 73% of the grazed woodland needs management practices to improve forage cover.

FIGURE 12

LAND USE AND INVENTORY ACREAGES
COLORADO (1967)

1000's of Acres



LAND RESOURCE AREAS

Colorado contains all or parts of 15 nationally recognized land resource areas. These are Central Desertic Basins, Mountains, and Plateaus; Colorado and Green Rivers Plateaus; San Juan River Valley Mesas and Plateaus; Wasatch and Uinta Mountains; Southern Rocky Mountains, Southern Rocky Mountain Alpine Meadows and Rockland; Southern Rocky Mountain Foothills; San Luis Valley; High Intermountain Valleys; Central High Plains; Irrigated Upper Platte River Valley; Upper Arkansas Valley Rolling Plains; Pecos-Canadian Plains and Valleys; Central High Tableland; and Southern High Plains. However, grouping of the 15 resource areas into four permits a more easily understood discussion of the conservation needs of the State. The four areas of consideration are:

1. A grouping of Central High Plains; Irrigated Upper Platte River Valley; Pecos-Canadian Plains and Valleys; and Southern High Plains groups the lands of the eastern Colorado plains that receive more than 13 inches mean annual precipitation. About 60% of the area is suitable for cultivation. Agriculture is based on dry crop farming, irrigated cropping, and grazing or rangelands. Soils are dominantly deep and loamy and on slopes of less than 6%. They are neutral to mildly alkaline in reaction and are moderate to high in plant nutrients. The semi-arid climate with major fluctuations in annual precipitation lead to most of the agricultural and conservation problems of the area.

2. The Upper Arkansas Valley Rolling Plains Resource Area, also on the eastern Colorado plains is distinctive because of its low (less than 13") mean annual precipitation. In general, the only lands successfully cropped are those that are irrigated. Dry cropping is marginal and is of minor extent except in parts of Prowers and Kiowa Counties. Agriculture of the area is based on grazing of the extensive rangelands and cropping of the irrigated valley land. Soils are dominantly loamy, but many are shallow and most are light-colored and low in organic matter. The low and erratic precipitation of the area accompanied with severe dust storms in many years is the primary agricultural and conservation problem of the area.

3. Grouping of land resource areas. Southern Rocky Mountain Alpine Meadows and Rockland; Wasatch and Uinta Mountains; Southern Rocky Mountains; Southern Rocky Mountain Foothills; San Luis Valley; and High Intermountain Valleys group the foothill, mountain, and intermountain valley lands of the State. Agriculture of this part of the State is based on cropping and haying of the irrigated valley lands and the grazing of the range and grazable woodlands of the adjacent slopes, mesas and mountains. Major parts of the area are federal lands managed by the U.S. Forest Service, the U.S. Bureau of Land Management, and the National Park Service, and these federal lands are excluded from the inventory. Soils of most of the area are steep and rocky; however, the irrigated valley lands are dominantly gently sloping loamy soils that are underlain with gravel and cobble at depths of 20 to

40 inches. Elevations range from about 5,500 to over 14,000 feet, and the climate is cool to cold. A short growing season for crops, the management and proper use of irrigation water, and the proper grazing use of the steep range areas are the major agricultural and conservation problems of the area.

4. Combining Central Desertic Basins, Mountains and Plateaus; Colorado and Green Rivers Plateaus; and San Juan River Vallay Mesas and Plateaus, land resource groups, the desertic basins, valleys, mesas, plateaus and mountains of the western slope of the State. Except for areas along the major streams that are irrigated, this group is uses primarily for grazing of sheep and cattle. Successful cropping is not possible without irrigation. Irrigated lands produce a variety of crops, including fruits. More than half the rangelands are federally-owned and are not a part of this inventory. Irrigated lands are comprised mainly of gently sloping deep and medium depth loamy soils that are moderately saline. Range areas are mainly comprized of sloping and steep, shallow and medium depth soils underlain by sandstone and shale. Management of irrigation water and the prevention and reduction of excess salinity are the major agricultural and conservation problems of the irrigated areas. Management of livestock to prevent over-grazing is the prime problem of the range area. Once the grasses and forbes of this desertic area are damaged they are very slow to recover.

CONSERVATION TREATMENT NEEDS

Rangeland - Colorado landowners manage and adequately treat 11,311,768 acres of rangeland. This is well over half the total rangeland. Rangeland needing treatment amounts to 9,931,476 acres or approximately 47% of the total.

Proper grazing management, which will maintain adequate cover for soil protection and maintain or improve the quantity and quality of desirable vegetation, is the most urgent conservation need on range. This represents three-fourths of the rangeland needing treatment. This kind of range is presently vegetated but has been damaged due to lack of grazing management.

Rangeland needing (1) an adapted type of mechanical treatment or (2) brush control makes up a little more than one out of every eight acres of rangeland needing treatment. Sagebrush, greasewood rabbitbrush, oak, pinyon, or juniper interfere with grazing use, erosion control, water conservation, and forage production on 1,321,392 acres. It should be noted, however, that the removal of shrub from public lands affects deer populations as well as small game. Whatever benefits are to be derived from such management practices must be weighed against the resultant consequences to wildlife. This is a controversial issue on private land as well. The Federal/private land ownership pattern often share similar control programs.

A little less than 10% of the rangeland needing treatment will require the reestablishment of vegetative cover for soil protection and forage production. This will necessitate planting adapted species and protection until they are fully established. Some range needing reestablishment of cover will require a combination of brush control and reseeding.

Forest and Woodland - There are 6,963,501 acres in woodland, of which 2,696,875 are commercial species and 4,266,626 non-commercial woodland. If the commercial forest area is to be fully developed, 269,703 acres would require supplemental extablishment or reestablishment and 1,029,282 acres would require timber stand improvement for improved production. Approximately 14,000 acres of non-commercial forest are in need of stand establishment or reestablishment as woodland. Eighty-one percent of the forests and woodland is adequately treated.

A total of 5,126,202 acres, or 74% of the forest and woodland is grazed. Fifty-one percent of the grazed woodland needs management practices to improve forage production, 22% is in need of grazing reduction or elimination and 27% is adequately treated.

Other Land - About 300,000 acres of other land are in need of conservation treatment to prevent erosion. Because much of this acreage is in such exposed usses such as roads, ditches, waste, barren, or mineral lands, it is probably the most difficult area to treat.

WATERSHED PROJECT NEEDS

Almost 1.5 million acres in the Colorado watershed inventory are subject to floodwater and sediment damages (Table 14). The inventory also shows that local people need some type of project action to solve problems on 1.3 million acres of agricultural and 23,000 acres of urban area subject to floodwater and sediment damages, and 8.4 million acres of erosion damage. Of the almost 500 watersheds under 250,000 acres in size in the inventory, 406 indicated a need for assistance in recreational developments, 310 have water quality problems, and 227 have rural water supply problems.

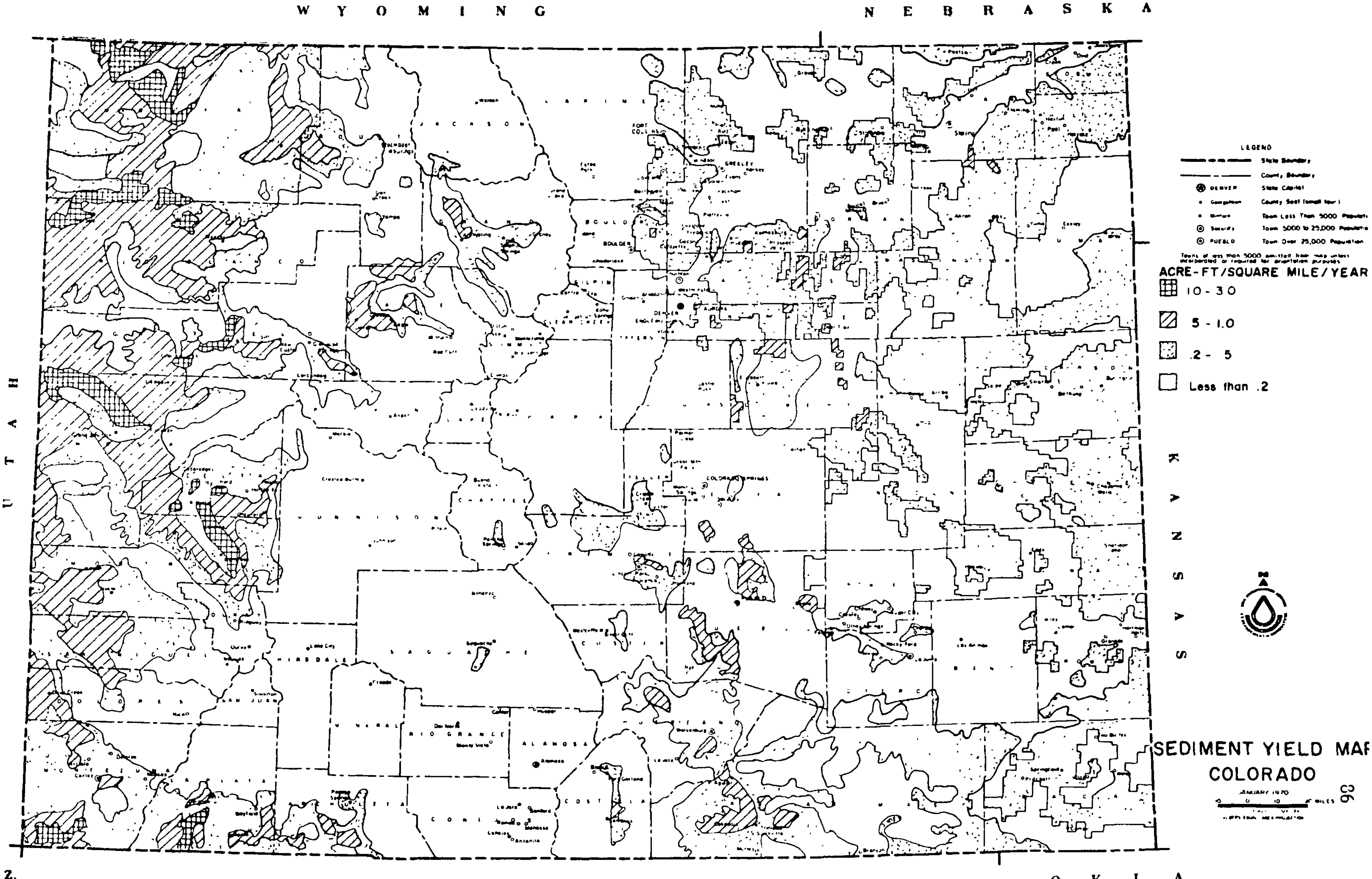
A total of 164 watersheds need some type of project action covering 32% of the Colorado inventory acreage. These watersheds collectively show floodwater and sediment damages to 672,000 acres of agricultural and 18,000 acres of urban land and erosion damage on over 3 million acres (Table 15). An accurate estimate of the potential feasibility of these watershed areas for PL 566 projects could only be made after an exhaustive study of the treatment and structural costs and benefits. Past experience indicates that less than 10% of these watersheds can be expected to become authorized PL 566 projects. Therefore, it is very important that all other available programs should be used to the fullest extent to solve or reduce damages in these watersheds.

The Soil Conservation Service has just recently completed an intensive study of sediment yields for each county in Colorado. The accompanying map (Fig. 13) presented here is a compilation of that data into one comprehensive state sediment yield map. The dark, lined areas indicate high yield, the lightly dotted areas, low yield. The SCS attributes many of the sediment yield problems evident in the state to man's influence on the environment. Though intensive investigation might produce specific cause and effect situations, it is difficult with existing data to pin-point with unassailable accuracy where man contributes more to the problem than nature.

Tables 27 and 28 show summary of reservoir sedimentation surveys.

Tables 29, 30, and 31 show suspended sediment and salt load discharges by region and subregion.

FIGURE 13



NOTE:
Sediment yield is defined as the amount of sediment transported by water from source areas into local drainage systems. The quantities shown are annual averages over a fairly long period, such as 25 years or more and are derived from the following sources (1) reservoir surveys by SCS, USGS, and USCE; (2) suspended sediment load measurements by USGS, USBR and USCE and (3) estimates of sediment ... made ... g pro... s dev... by t... ific... ast... gency ... affec...

Table 28. SUMMARY OF RESERVOIR SEDIMENTATION SURVEYS

BY REGION AND SUBREAGION FOR THE STATE OF COLORADO

Reservoir Stream	Drainage Area (sq.mi.)	Original Storage Capacity (ac.ft.)	Reservoir Age (Yrs.)	Average Annual Sediment Deposit (ac.ft/sq.mi.)	Average Annual Capacity Loss (percent)
issouri Region					
South Platte (1019)					
Lake Cheesman	1,766	79,064	31	.02	.05
Englewood	9.40	1,282	20	.36	.26
Evergreen	106	--	34	.08	--
Castlewood	167	3,834	43	.10	.43
Willow Creek W-1	7.60	387.0	4	1.63	3.21
Kenwood	387	9,802	3	.30	1.19
Round Butte	11.7	831	60	.07	.09
Slab Canyon CCC	3.15	311.4	30	.25	.25
Coalbank Creek CB-1	27.0	2,147	9	.05	.06
Kiowa Creek K-79	3.20	129.5	10	.24	.59
Kiowa Creek J-33	1.07	42.5	9	.05	.13
Kiowa Creek B-9	.65	49.4	9	.09	.11
Kiowa Creek Q-51	.56	32.3	9	.42	.74
Kiowa Creek R-3	2.92	147.6	10	.32	.64
Reichelt Stock Pond	.72	22.1	7	.28	.92
epublican (1025)					
Wray W-6	1.70	204.3	12	.38	.32
rkansas-White-Red Region					
Upper Arkansas (1102)					
Teller	78.8	4,005	29	.68	1.33
Cucharas	608	38,274	27	.93	1.47
Hardesty	13.48	563	60	.05	.11
Brown Reservoir No. 1	74.6	758	39	.23	2.16
Fishers Peak FPC-1	1.14	346.3	7	1.61	.53
Muddy Creek	154	16,918	20	.54	.48
Horse Creek	52	36,203	39	.24	.03
John Martin	18,915	701,755	26	.175	.45
Big Sandy S-1	5.4	326	3	1.48	2.48
pper Colorado Region					
Gunnison (1404)					
Roatcap Wash RW-1	11.6	829.6	6	.28	.39
Colorado Main Stem (1405)					
CCC Reservoir No. 6	1.75	16.73	23	.85	8.89
Badger Detention (14)	1.53	201.52	5	1.62	1.23
East Basin (11)	.089	5.34	6	1.61	2.63
Lower Hanks (1-B)	.084	19.80	16	1.78	.76
Lower Oil Well (3-A)	.059	12.92	17	3.05	1.39
Middle Basin (12)	.092	16.93	6	3.30	1.79
North Basin (3-B)	.048	8.10	17	2.50	1.48
Prairie Dog (4-A)	.022	3.05	17	4.05	2.95
Southeast (13)	.484	27.25	6	1.87	3.32
Upper Hanks (1-A)	.066	8.30	16	2.72	2.16
West Twin	.148	6.30	16	3.04	7.14
Windy Point (4-B)	.019	4.52	16	2.63	1.11
Yucca (2-B)	.158	8.45	16	[illegible]	[illegible]

WYOMING

Introduction

Although Wyoming's population has not grown as it has in most states in recent years, projections point to an increased population in the next decade. A growing population will place a greater emphasis and demand on natural resources of soil and water for the requirements of everyday living. An inventory of these resources and an analysis of needs was made between 1958 and 1960. This inventory of needs was updated between 1966 and 1968 and published in printed form in 1970. A review of this inventory follows. For specific details one should consult the Wyoming Conservation Needs Inventory (1970).

Development of energy resources in Wyoming, coal, uranium, oil shale, will probably change this situation to a great extent. It will have much potential effect on land use and erosion problems.

Table 29 **LAND USE ACRES**

Wyoming

NON-INVENTORY

Federal Noncropland	Urban and Built-up	Small Water Areas	Total
29,206,871	762,342	184,010	30,153,223

INVENTORY

Cropland Irrigated	Cropland Dry	Pasture	Range	Forest	Other	Total
1,932,211	1,111,612	320,240	27,009,363	1,554,421	224,905	32,152,752

Table 30 **LAND USE COMPARISON**

Wyoming

Land Use	1958	1967
Federal Noncropland	29,104,740	29,206,871
Urban and Built-up	239,620	762,342
Small Water Areas	91,195	184,010
Total Non-Inventory	29,435,555	30,153,223
Cropland	2,493,900	3,043,823
Pasture	467,400	320,240
Range	28,170,900	27,009,363
Forest	1,585,820	1,554,421
Other	152,400	224,905
Total Inventory	32,870,420	32,152,752

Table 31 **LAND USE CAPABILITY CLASSES**

Wyoming

IRRIGATED

Cap. Class	Cropland	Pasture	Range	Forest	Other	Total
I	99,986					99,986
II	379,983					379,983
III	870,662	2,478				873,140
IV	304,920					304,920
V	112,899					112,899
VI	121,161					121,161
VII	41,874					41,874
VIII	726					726
Total	1,932,211	2,478				1,934,689

Wyoming

Table 32 **IRRIGATED AND DRY**

Cap. Class	Cropland	Pasture	Range	Forest	Other	Total
I	100,818	--	--	--	1,258	102,076
II	432,413	7,235	23,381	1,104	10,780	474,913
III	1,415,614	68,701	1,275,768	26,735	42,153	2,828,971
IV	685,301	76,963	3,411,105	66,117	31,846	4,271,332
V	112,931	2,049	53,253	5,839	2,351	176,423
VI	235,527	72,614	11,100,253	486,889	62,815	11,958,098
VII	60,490	90,832	8,549,978	525,701	53,545	9,280,546
VIII	729	1,846	2,595,625	442,036	20,157	3,060,393
Total	3,043,823	320,240	27,009,363	1,554,421	224,905	32,152,752

Cropland

The inventory shows a total of 3,043,823 acres of cropland in Wyoming. 828,078 acres are adequately treated which represents 27.3% of the rotated cropland.

Rotated cropland totaling 2,209,111 acres is in need of conservation treatment to protect and improve the land. 254,117 acres are in need of annual cover crops, crop residues, or other annual recurring measures; 27,521 acres are in need of sod in the rotation; 29,134 acres are in need of contouring; 276,444 acres are in need of stripcropping, diversions, and terraces to treat and protect the land in addition to measures that may be used to supplement these practices; 72,027 acres need a change in land use to perennial vegetation; 200 acres need an adequate drainage system to remove excess surface or internal water; 126,372 acres of irrigated cropland need improved cultural or management measures; 608,000 acres need improved irrigation systems; and 815,296 acres need proper irrigation water management. (Table 33)

Table 33 **CONSERVATION TREATMENT NEEDS FOR ROTATED CROPLAND**

Treatment	Acres	Percent
Treatment adequate (irrigated and dry)	828,078	27.3
Residue and annual cover	254,117	8.4
Sod in rotation	27,521	0.9
Contouring	29,134	0.9
Stripcropping, terracing, and diversions	276,444	9.1
Permanent cover	72,027	2.4
Drainage	200	--
Cultural management practices only on irrigated land	126,372	4.2
Improved systems on irrigated land	608,000	20.0
Water management on irrigated land	815,296	26.8
Total	3,037,189	

Soil Erosion

Soil erosion is the dominant limitation on 1,443,870 acres. Treatment is adequate on 428,210 acres, but the other 1,015,660 acres need conservation treatments that will control erosion and improve these soils.

Soils vary in their susceptibility to erosion and to the amount of loss that can be tolerated. Soil factors such as textrue, permeability, infiltration rate, and soil slope influence the susceptibility to erosion. Soil loss tolerance is influenced by soil depth and the number and arrangement of contrasting horizons.

This land is nearly level to steep and the erosion hazard is slight to severe. In most dry farming areas cultivation is generally limited to 0 to 10 percent slopes. Irrigated row crops are best suited to 0 to 2 percent slopes, but 3 to 6 percent slopes can be used if adequate conservation measures are used. Slopes of 6 to 10 percent are best suited to close-growing crops when irrigated. Ten to 15 percent slopes can be used for irrigated hay and pasture.

In many parts of Wyoming high wind velocities are common and with erosion is a serious problem on cultivated land and overgrazed rangeland.

Wind stripcropping and stubble mulch are the principal conservation practices used on dry cropland to control wind erosion. Ridges left by deep furrow drills aid in the control of wind erosion on the sandier soils.

In the irrigated areas wind erosion is a problem on most soils but is most prevalent on sandy soils left bare by row crops which produce little or no residue. Rough tillage on bare land, maximum use of crop residues, close-growing crops, and alternate strips of row crops with high residue-producing crops are important conservation practices for control of wind erosion on irrigated land.

In many parts of the State short durations of intense rainfall results in serious erosion problems on cultivated or unprotected land. Improperly designed irrigation systems and careless irrigation methods are responsible for much of the water erosion on irrigated land. Conservation practices such as good irrigation water management, coutour furrows, bench leveling, close-growing crops, and sod-forming crops in the rotation are useful in the control of water erosion on irrigated land.

To control water erosion on dry cropland conservation practices such as terraces, contour stripcropping, and maximum utilization of crop residues can be used.

Rangeland can be protected from both wind and water erosion by maintaining a good grass cover. This requires good range management to prevent over-grazing and reseeding of native range when needed.

Excess Water

Excess water caused by permanent and fluctuating water tables is a dominant problem on 405,142 acres. Some of these water tables are natural, but some are caused by poor irrigation water management and seepage from irrigation canals and ditches. Flooding is a minor cause of excess water in Wyoming. Treatment is adequate on 62,530 acres, but the other 243,612 acres need treatment to improve the land.

This land is nearly level to gently sloping and is moderately well to very poorly drained. It is used for grazing, and production of native hay. Alfalfa is grown on the better drained areas. Erosion is a minor problem but can be serious if the vegetation is destroyed and the soil left bare.

In some areas drainage is feasible, but the value of the forage or crop that can be grown after the soil is drained should be considered in developing a drainage system. Proper irrigation water management and lining canals and ditches would help to decrease this problem.

Pasture

The Inventory shows a total of 320,240 acres of pasture in Wyoming. Of all the pasture, 7,235 acres are class II land; 68,701 acres are class III land; 76,963 acres are class IV land; 2,049 acres are class V land; 72,614 acres are class VI land; 90,832 acres are class VII land; and 1,846 acres are class VIII land.

The conservation needs on pasture land related to establishment and maintenance of cover are expressed as follows: 74,331 acres are adequately treated; 1,846 acres are not feasible to treat; 195,012 acres need protection only; 19,898 acres need improvement only; 18,433 acres need brush control and improvement; 6,815 acres need reestablishment of vegatative cover; and 3,905 acres need re-establishment of vegetative cover with brush control (Table 34)

Table 34
CONSERVATION TREATMENT NEEDS FOR PASTURE LAND

Treatment	Acres	Percent
Adequate	74,331	23.2
Not feasible	1,846	0.6
Protection only	195,012	60.9
Improvement only	19,898	6.2
Brush control	18,433	5.8
Re-establishment of vegetative cover	6,815	2.1
Re-establish with brush control	3,905	1.2
Total	320,240	

Range

The inventory shows a total of 27,009,363 acres of rangeland in Wyoming. Of all the range, 23,381 acres are class II land; 1,275,768 acres are class III land; 3,411,105 acres are class IV land; 53,253 acres are class V land; 11,100,253 acres are class VI land; 8,439,978 acres are class VII land; and 2,595,625 acres are class VIII land.

The conservation needs on rangeland related to establishment and maintenance of cover are expressed as follows: 4,697,117 acres are adequately treated;

1,703,103 acres are not feasible* to treat; 3,328 acres need a change in land use to trees; 13,300,125 acres need protection only; 2,088,582 acres need improvement only; 4,916,095 acres need brush control and improvement; 170,236 acres need reestablishment of the vegetative cover, and 130,717 acres need reestablishment of the vegetative cover with brush control.

Table 35 CONSERVATION TREATMENT NEEDS FOR RANGELAND

Treatment	Acres	Percent
Adequate	4,697,177	17.4
Not feasible	1,703,103	6.3
Change in use	3,328	--
Protection only	13,300,125	49.3
Improvement only	2,088,582	7.7
Brush control	4,916,095	18.2
Re-establishment of vegetative cover	170,236	0.6
Re-establish with brush control	130,717	0.5
Total	27,009,363	

*Land "Not Feasible" to treat generally falls within the 7 or 8 land classification. These are lands called "shallow stony" or "shallow shale", on 40^{o} or more slope than produce high runoff. To treat them would not enhance their productivity in an economic sense.

Protection

The pasture or range is in an overgrazed contition, but the desired vegetation is still present. Only livestock management and distribution is needed to enable it to recover and reseed naturally.

Improvement

The forage cover on pasture and range is inadequate but can be improved or restored by applying recommended management practices and following recommended grazing systems. The desired vegetation is present but is so thin and in such poor condition that it needs an application of minerals, weed control, and mechanical measures to obtain a satisfactory stand.

Brush Control

Encroachment of woody and noxious plants on pasture and range has destroyed or threatens the grass cover. It can be improved by chemical or mechanical measures.

Reestablishment of Vegetative Cover

The pasture or range is in such poor condition it needs complete re-establishment. The desired type of vegetation is missing and must be re-established with protection from grazing damage until it is established.

Forest and Woodland

A very high percentage of the forest and woodland acreage in Wyoming is Federally-owned. Since the acreage of privately-owned forest is small and scattered in most counties, it was apparent that the sample areas did not supply a very realistic figure for forest and woodland acres. In this report privately-owned forest and woodland acreages supplied by the Rocky Mountain Forest Experiment Station forest survey were used.

In this Inventory every acre of woodland in Wyoming has been classified as either commercial or noncommercial, and conservation needs have been estimated separately for each category.

Almost 30% (460,164 acres) of the total Inventory acreage of forest land is considered to be noncommercial. Treatment is neither needed nor justifiable on much of this land, either because it is devoted to watershed, wildlife, or recreational uses, or because the site is too poor to be either planted or re-planted (where previous plantings have failed) in order to provide adequate surface cover; and there are 32,545 acres on which domestic livestock are causing damage detrimental to conservation interests. The cattle must be excluded in order to permit the regeneration of the forest.

Over 49% of the total area of commercial forest land is now sufficiently well managed. These 539,276 acres of woodland require only protection and good management to keep them productive. This is not true, however, of 167,142 acres of tree-covered land which is producing below its potential because of inadequate stocking. The woodlands in this category should either be planted or be treated to encourage natural regeneration of the forest.

Damage from grazing by domestic livestock is considered to be a conservation problem on 83,485 acres of forest land. Grazing in woodlands can damage trees and their roots by trampling, compact the soil, and destroy small trees and other ground cover. As a result, the growth rate and quality of the timber are reduced, rainfall percolation is decreased, runoff and soil erosion are increased, and future timber crops are destroyed. On much of the area in this category the conservation need is to exclude livestock, allowing a natural return to productivity, but on areas which have been heavily grazed for long periods of time, more positive surface renovation measures must be taken. Often the quality of the existing timber is poor; and because of surface soil compaction, unaided natural regeneration is either very slow to develop, very sparse, or both.

TABLE 36
CONSERVATION TREATMENT NEEDS FOR GRAZED FOREST LAND

Treatment	Acres	Percent
Adequate	788,772	57.9
Needs to improve forage	491,034	36.0
Reduction or elimination of grazing	83,485	6.1
Total	1,363,291	

Watershed Project Needs

Wyoming contains 372 watersheds of 250,000 acres or less. Tributaries to three of the major river basins in the United States -- Colorado, Columbia, and Missouri -- have their source in Wyoming. Land areas, when delineated as watersheds, become base units for solving soil and water conservation problems in an effective manner. Within these units or watersheds the conservation and development of water and related land resources and the economic growth of communities are interrelated.

The basic reference used for delineating the major and principal drainage areas and subbasins was the "Atlas of River Basins of the United States" prepared by the Soil Conservation Service in 1963. Each subbasin was further divided into smaller watersheds through the use of U.S.G.S. topographic maps.

Important needs in small watersheds are the protection from floodwater damage and the development of agricultural and nonagricultural water resources. The needs are defined in the following sections of the report.

FLOOD PREVENTION

Floodwater and Sediments (Agricultural and Urban) - Flood damage to agricultural and urban areas is not a major problem in Wyoming. Flow in the major streams is controlled by a series of irrigation water storage reservoirs. About one percent (642,800 acres) of the total land area is subject to floodwater and sediment damage.

Sediment deposits of silt, sand, and gravel can cause as much damage as the associated floodwater. Although limited to smaller streams, such damage can be quite severe, expecially in urban areas.

Erosion damage in this Inventory is in terms of acres of land which have been damaged by gully and roadbank erosion. Some 520,000 acres of land are included in this category.

AGRICULTURAL WATER MANAGEMENT

Only the needs which cannot be met by individual action were included.

<u>Drainage</u>

Drainage needs reflect those areas that have a drainage problem. Only those needs that cannot be met by individual farm drainage systems are included. Some 70,100 acres need treatment.

Water Quality Management

Water for all purposes needs to be protected from pollution because, as the population increases, the need for a greater volume of good quality water increases. Water quality improvement is needed in 81 watersheds.

To determine the needs and problems of the 372 watersheds, a review of the areas in each county was made, interviews were made with Federal and State agency representatives, soil and water conservation district supervisors, and residents of each watershed. All information was checked and verified by area firld SCS Engineers through observations. While the estimates are based on a broad reconnaissance-type survey, the Inventory is considered to be reasonably reliable and indicates the location, type, and relative magnitude of problems and need

Flood prevention and other watershed problems all require a combination of private and public action to reduce losses effectively. Local people through their soil and water conservation districts and county and city governments have solved a number of these and similar problems, but aid from State or Federal agencies is frequently needed to alleviate problems on watersheds. Public Law 566, the Watershed Protection and Flood Prevention Act, as amended, makes it possible to reduce these damages through a cooperative program between the Soil Conservation Service and a local sponsoring group. Recently, the resource conservation and development effort of USDA has been added as a means of assisting group action toward solving watershed-type problems.

RESUME OF WATERSHED ACTIVITIES

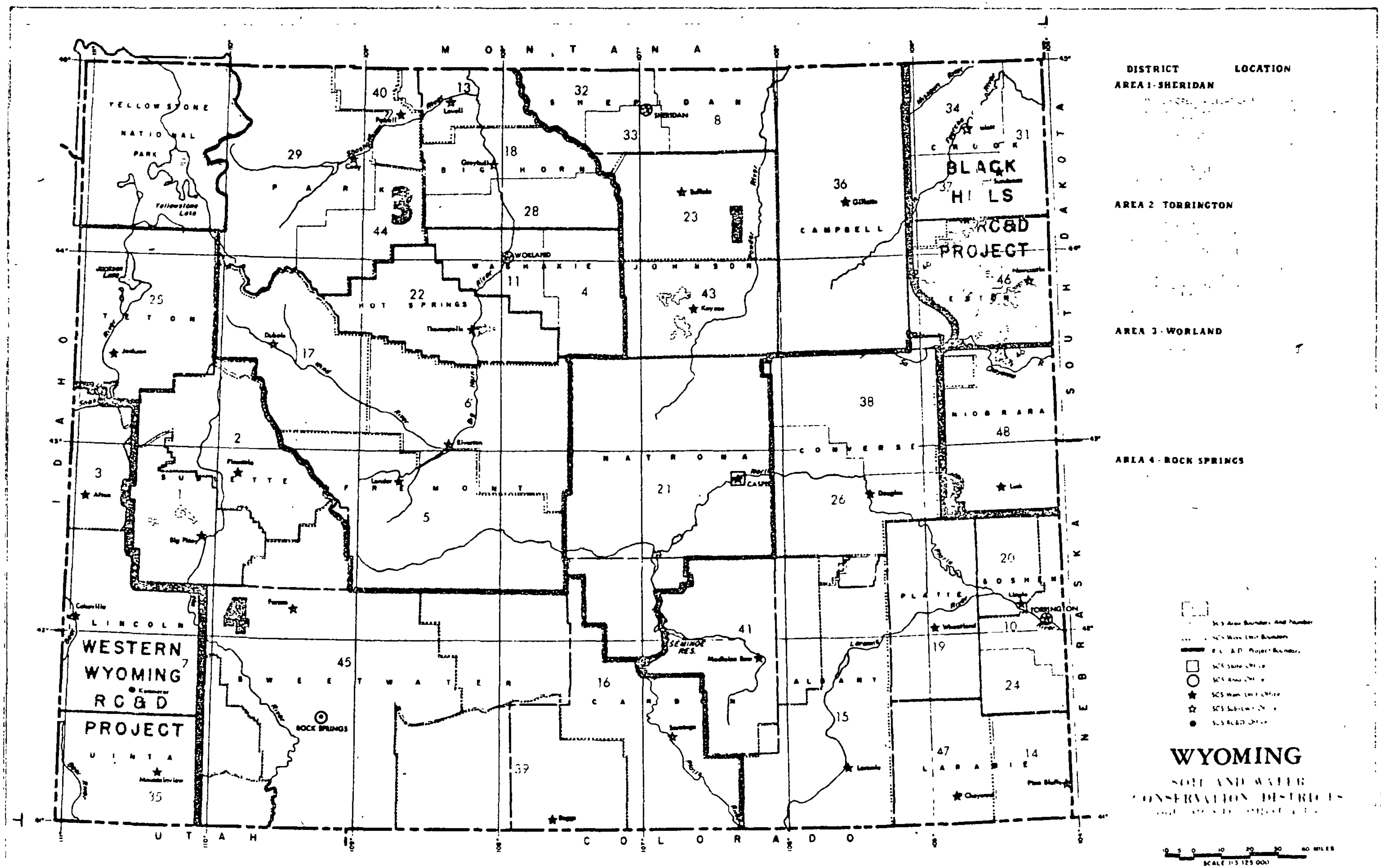
Of the 372 watersheds identified in the Inventory, 108 have been selected for an early action program. Of these early action projects, applications have been received and approved for 40.

Preliminary investigations have been completed on 32 of these projects, and 18 projects have been approved for planning. There are 11 projects authorized for operations, of which five projects are complete.

Figure 14 shows Wyoming soil and water conservation districts and RC&D Projects.

Tables 41, and 42 list Wyoming watersheds less than 400 square miles in area and the kinds and extent of problems needing action.

FIGURE 14



MONTANA
IDAHO
UTAH
COLORADO
SOUTH DAKOTA
NEBRASKA
YELLOWSTONE NATIONAL PARK
PARK
BIG HORN
SHERIDAN
CAMPBELL
CROOK
BLACK HILLS RC&D PROJECT
WESTON
WASHAKIE
JOHNSON
HOT SPRINGS
TETON
FREMONT
SUBLETTE
NATRONA
CONVERSE
NIOBRARA
LINCOLN
WESTERN WYOMING RC&D PROJECT
UINTA
SWEETWATER
CARBON
ALBANY
PLATTE
GOSHEN
LARAMIE
SHERIDAN
WORLAND
CASPER
ROCK SPRINGS
TORRINGTON
Powell
Lovell
Greybull
Cody
Buffalo
Gillette
Sundance
Newcastle
Thermopolis
Kaycee
Dubois
Jackson
Riverton
Lander
Pinedale
Afton
Big Piney
Douglas
Lusk
Wheatland
Medicine Bow
Saratoga
Laramie
Cheyenne
Pine Bluffs
Kemmerer
Mountain View
Cokeville
Farson
Baggs
Lingle
SEMINOE RES.
DISTRICT LOCATION
AREA 1 - SHERIDAN
AREA 2 TORRINGTON
AREA 3 - WORLAND
AREA 4 - ROCK SPRINGS
WYOMING
1 2 3 4 5 6 7 8 10 11 13 14 15 16 17 18 19 20 21 22 23 24 25 26 28 29 31 32 33 34 35 36 37 38 39 40 41 43 44 45 46 47 48

Table 37

INVENTORY OF WATERSHEDS LESS THAN 400 SQUARE MILES IN AREA WITH THE KINDS AND EXTENT OF PROBLEMS NEEDING PROJECT ACTION

MAJOR DRAINAGE AREA, PRINCIPAL DRAINAGE BASIN, SUBBASINS		TOTAL WATERSHEDS DELINEATED		TOTAL AREA WITH FLOODWATER AND SEDIMENT DAMAGE1/	KIND AND EXTENT OF PROBLEMS: FLOOD PREVENTION: FLOODWATER AND SEDIMENT DAMAGE: AGRICULTURAL	FLOOD PREVENTION: FLOODWATER AND SEDIMENT DAMAGE: URBAN	FLOOD PREVENTION: EROSION DAMAGE	AGRICULTURAL WATER MANAGEMENT: DRAINAGE	AGRICULTURAL WATER MANAGEMENT: IRRIGATION	AGRICULTURAL WATER MANAGEMENT: RURAL WATER SUPPLY	NONAGRICULTURAL WATER MANAGEMENT: MUNICIPAL OR INDUSTRIAL WATER SUPPLY	NONAGRICULTURAL WATER MANAGEMENT: RECREATIONAL DEVELOPMENT	NONAGRICULTURAL WATER MANAGEMENT: FISH AND WILDLIFE DEVELOPMENT	NONAGRICULTURAL WATER MANAGEMENT: WATER QUALITY MANAGEMENT
		NUMBER	1,000 ACRES	1,000 ACRES	1,000 ACRES	1,000 ACRES	1,000 ACRES	1,000 ACRES	1,000 ACRES	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER
Colorado River														
Green River	5	29	7,466.8	38.3	14.2	2.0	223.4	2 2	210.6	--	--	10	11	12
New Fork River	5A	5	835.3	--	--	--	--	2.4	47.6	--	--	--	1	--
Big Sandy Creek	5B	4	715.8	0.5	--	--	--	--	25.5	--	--	1	2	--
Little Sandy Creek	5B1	3	477.9	--	--	--	0 2	--	1.2	--	--	1	1	--
Blacks Fork	5C	10	1,679.0	21.1	10.7	0.9	55.5	--	56.0	1	2	4	4	5
Muddy Creek	5C'	4	610.5	6.0	--	--	7.0	--	7.0	--	1	--	--	--
Vermilion River	5D	2	321.1	3.0	--	--	--	--	--	--	--	--	--	--
Little Snake River	5E1	6	957.6	3.5	--	--	--	0.7	18.2	--	1	3	3	3
Muddy Creek	5E1A	4	602.4	5.6	--	--	2.5	--	4.7	--	2	3	3	2
Colorado River Drainage Area Total		67	13,666.4	78.0	24.9	2.9	288.6	5.3	370.8	1	6	22	25	22
Great Basin														
Great Salt Lake														
Bear River	1A	7	1,108.9	25.9	14.9	--	98.3	4.6	64.2	--	3	4	5	1
Columbia River														
Snake River	14	14	2,039.8	8.3	4.2	--	1.8	5.5	46.9	--	--	1	2	2
Gros Ventre River	14A	2	471.7	3.7	1.5	--	--	--	23.0	--	1	--	--	--
Salt River	14B	6	439.1	9.3	7.2	--	1.5	--	48.3	--	--	--	1	1
Henrys Fork	14C	1	192.2	1.3	--	--	--	--	--	--	--	--	--	--
Teton River	14C1	1	44.2	--	--	--	--	0.6	3.5	--	1	--	--	--
Columbia River Drainage Area Total		24	3,187.0	22.6	12.9	--	3.3	6.1	121.7	--	2	1	3	3
Missouri River														
Jefferson River														
Madison River	1F	1	157.4	--	--	--	--	--	--	--	--	--	--	--
Yellowstone River	14	7	1,551.8	3.1	--	--	--	--	--	--	--	--	1	--
Clark Fork	14C	6	1,093.3	5.8	0.8	--	--	--	30.4	--	--	--	--	--
Big Horn River	14E	28	4,394.1	61.5	29.0	0.2	12.5	5.9	67.3	3	1	4	4	8
Wind River	14E1	12	1,780.7	35.1	7.1	0.3	30.1	7.0	49.1	--	1	3	3	1
Popo Agie River	14E1A	7	1,191.5	19.2	9.0	0.3	0.1	0.3	30.9	1	2	1	1	--
Muskrat Creek	14E2	3	520.6	6.9	--	--	--	--	--	--	--	--	--	--
Badwater Creek	14E3	4	569.9	6.3	--	--	--	--	2.4	2	--	--	--	1
Nowood Creek	14E4	7	1,317.6	12.2	5.9	--	24.0	0.2	17.0	1	1	2	1	1
Greybull River	14E5	4	764.9	19.5	3.6	--	0.1	26.5	53.5	--	1	1	1	1
Shoshone River	14E6	8	1,398.7	11.0	3.8	--	2.4	4.2	34.6	4	3	2	--	2
N. Fork Shoshone River	14E6A	2	478.6	3.0	0.8	--	--	--	--	--	--	--	--	--
Little Big Horn River	14E7	2	279.3	0.9	0.2	--	--	2.8	6.0	--	--	2	2	1
Tongue River	14G	8	1,120.7	11.0	3.6	0.4	--	0.1	40.2	--	2	2	--	--
Powder River	14H	13	2,253.4	24.4	7.3	--	6.0	--	11.0	2	1	1	1	8
S. Fork Powder River	14H1	5	830.2	4.8	0.8	--	--	--	1.0	1	--	--	--	1
Mid. Fork Powder River	14H2	3	664.8	9.1	0.1	--	0.1	--	12.2	--	2	--	--	--
Crazy Woman Creek	14H3	3	601.7	21.0	0.5	--	--	--	13.0	2	--	--	--	--
Clear Creek	14H4	4	773.5	15.4	3.7	0.5	--	0.2	14.6	--	2	--	--	--
Little Powder River	14H5	4	849.9	10.1	2.1	--	--	--	0.2	--	--	--	--	4
Missouri River														
Yellowstone River Drainage Area														
Subtotal		130	22,435.2	280.3	78.3	1.7	75.3	47.2	383.4	16	16	18	14	28
Missouri River														
Little Missouri River	16	3	396.9	7.3	2.6	--	--	--	2.5	--	--	--	--	3
Missouri River														
Cheyenne River	24	1	226.1	0.9	0.9	--	8.0	--	3.2	1	--	--	--	1
S. Fork Cheyenne River	24A	11	1,879.7	10.7	4.2	--	3.0	--	6.6	1	--	--	--	5
Lance Creek	24B	6	1,288.5	7.0	3.8	0.7	13.4	--	5.9	4	--	--	--	5
Beaver Creek	24C	4	781.6	13.7	7.8	0.2	1.6	--	4.2	--	1	3	3	2
Hat Creek	24D	1	144.3	2.3	2 3	--	5.0	--	2.8	1	--	--	--	1
Belle Fourche River	24E	12	2,117.1	35.3	13.2	1.0	0.3	--	4.7	--	1	3	8	2
Redwater Creek	24E1	3	317.7	1.6	0.5	--	--	--	1.0	--	--	1	2	2
Missouri River														
Cheyenne River Drainage Area														
Subtotal		38	6,755.0	71.5	32.7	1.9	31.3	--	28.4	7	2	7	13	18
Missouri River														
Niobrara River	28	2	280.5	1.2	1.1	--	0.4	--	0.5	--	--	--	--	--

1/Includes acres other than those needing project action.

Table 37 (continued)

MAJOR DRAINAGE AREA, PRINCIPAL DRAINAGE BASIN, SUBBASINS		TOTAL WATERSHEDS DELINEATED		TOTAL AREA WITH FLOODWATER AND SEDIMENT DAMAGE 1/	KIND AND EXTENT OF PROBLEMS									
					FLOOD PREVENTION			AGRICULTURAL WATER MANAGEMENT			NONAGRICULTURAL WATER MANAGEMENT			
					FLOODWATER AND SEDIMENT DAMAGE		EROSION DAMAGE	DRAINAGE	IRRIGATION	RURAL WATER SUPPLY	MUNICIPAL OR INDUSTRIAL WATER SUPPLY	RECREATIONAL DEVELOPMENT	FISH AND WILDLIFE DEVELOPMENT	WATER QUALITY MANAGEMENT
					AGRICULTURAL	URBAN								
		NUMBER	1,000 ACRES	1,000 ACRES	1,000 ACRES	1,000 ACRES	1,000 ACRES	1,000 ACRES	1,000 ACRES	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER
<u>Missouri River</u>														
North Platte River	35A	50	7,057.8	52.1	43.7	0.8	16.4	3.7	121 1	7	--	17	28	5
Medicine Bow River	35A1	5	838.9	2.9	2.9	--	1.0	--	30.1	1	--	1	1	--
Little Medicine Bow Riv.	35A1A	3	644.0	1.0	1.0	--	--	--	5 9	--	--	--	2	--
Sweetwater River	35A2	11	1,807.1	29.1	0.1	--	--	--	9.9	--	1	--	3	--
Laramie River	35A3	16	2,741.9	35.2	29.0	0.7	2.9	1.6	125.4	1	--	7	13	1
Horse Creek	35A4	6	992.6	14.9	11.3	--	--	--	29.5	--	--	1	1	--
Cache LaPoudre River	35B4	3	178.0	1.1	0.3	--	--	--	3.4	--	--	--	--	--
Crow Creek	35B5	2	375.1	5.5	3.1	0.2	--	0.5	3.1	--	1	2	2	--
Lodgepole Creek	35B7	4	638.2	14.6	7.7	0.1	2.5	1.2	5.2	--	--	--	--	--
Missouri River North Platte River Drainage Area Subtotal		100	15,273.6	156.4	99.1	1.8	22.8	7.0	333.6	9	2	28	50	6
<u>Missouri River</u> Total		274	45,298.6	516.4	213.8	5.4	129.8	54.2	748.4	32	20	53	77	55
Wyoming State No. 52 Total		372	63,260.9	642.8	266.5	8.3	520.0	70.1	1,305.1	33	31	80	110	81

Table 38

INVENTORY OF POTENTIALLY FEASIBLE WATERSHEDS LESS THAN 400 SQUARE MILES IN AREA
WITH THE KINDS AND EXTENT OF PROBLEMS NEEDING PROJECT ACTION

MAJOR DRAINAGE AREA, PRINCIPAL DRAINAGE BASIN, SUBBASINS		WATERSHEDS FEASIBLE FOR PROJECT ACTION		KIND AND EXTENT OF PROBLEMS									
				FLOOD PREVENTION			AGRICULTURAL WATER MANAGEMENT		NONAGRICULTURAL WATER MANAGEMENT				
				FLOODWATER AND SEDIMENT DAMAGE		EROSION DAMAGE	DRAINAGE	IRRIGATION	RURAL WATER SUPPLY	MUNICIPAL OR INDUSTRIAL WATER SUPPLY	RECREATIONAL DEVELOPMENT	FISH AND WILDLIFE DEVELOPMENT	WATER QUALITY MANAGEMENT
				AGRICULTURAL	URBAN								
		NUMBER	1,000 ACRES	1,000 ACRES	1,000 ACRES	1,000 ACRES	1,000 ACRES	1,000 ACRES	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER
Colorado River													
Green River	5	8	1,580.1	--	--	109.6	0.2	146.6	--	--	2	3	3
New Fork River	5A	4	735.3	--	--	--	2.4	46.6	--	--	--	1	--
Blacks Fork	5C	4	794.8	10.7	0.9	33.3	--	50.0	1	2	2	2	3
Vermilion River	5D	1	160.4	--	--	--	--	--	--	--	--	--	--
Colorado River-Green River Total		17	3,270.6	10.7	0.9	142.9	2.6	243.2	1	2	4	6	6
Great Basin													
Great Salt Lake Bear River and Total	1A	4	664.7	9.5	--	50.0	4.1	60.4	--	2	4	4	1
Columbia River													
Snake River	14	4	484.3	4.2	0.1	1.8	5.5	44.3	--	--	--	1	2
Salt River	14B	6	439.2	7.2	--	1.5	--	48.3	--	--	--	1	1
Columbia River-Snake River Total		10	923.5	11.4	0.1	3.3	5.5	92.6	--	--	--	2	3
Missouri River-Yellowstone River													
Clark Fork	14C	2	385.9	0.8	--	--	--	21.4	--	--	--	--	--
Big Horn River	14E	10	1,690.0	10.6	0.2	5.5	0.3	32.1	1	1	3	3	3
Wind River	14E1	5	738.0	6.6	0.2	30.0	2.0	42.3	--	1	2	2	1
Popo Agie River	14E1A	4	709.2	9.0	0.3	0.1	--	26.7	--	2	1	1	--
Badwater Creek	14E3	1	137.9	--	--	--	--	1.4	--	--	--	--	--
Nowood Creek	14E4	5	1,010.9	5.3	--	24.0	0.2	17.0	1	1	2	1	1
Greybull River	14E5	3	559.2	3.0	--	0.1	26.5	53.0	--	1	1	1	1
Shoshone River	14E6	3	642.3	2.9	--	2.1	1.9	20.3	1	2	2	--	1
Little Big Horn River	14E7	1	193.4	--	--	--	--	1.2	--	--	1	1	1
Tongue River	14G	4	557.9	2.5	0.4	--	0.1	13.2	--	1	1	--	--
Crazy Woman Creek	14H3	1	248.0	0.5	--	--	--	4.5	1	--	--	--	--
Clear Creek	14H4	3	546.4	3.4	0.5	--	0.2	12.3	--	2	--	--	--
Missouri River-Yellowstone River Total		42	7,419.1	41.6	1.6	62.1	31.2	243.9	4	11	13	9	8
Missouri River													
Little Missouri River Total	16	2	319.1	1.6	--	--	--	1.5	--	--	--	--	2
Missouri River-Cheyenne River													
Lance Creek	24B	2	374.9	1.0	--	10.1	--	2.5	1	--	--	--	2
Beaver Creek	24C	2	383.0	1.9	0.2	1.6	--	3.5	--	--	2	2	2
Belle Fourche River	24E	3	410.2	2.1	--	0.3	--	3.2	--	--	2	3	1
Redwater Creek	24E1	1	205.0	0.4	--	--	--	0.1	--	--	1	1	1
Missouri River-Cheyenne River Total		8	1,373.1	5.4	0.2	12.0	--	9.4	1	--	5	6	6
Missouri River-Platte River													
North Platte River	35A	12	1,669.5	16.2	0.2	2.0	2.0	51.0	1	--	6	10	1
Laramie River	35A3	4	737.9	9.8	0.1	1.0	--	11.5	1	--	2	4	--
Horse Creek	35A4	3	556.9	4.3	--	--	--	19.0	--	--	1	1	--
Crow Creek	35B5	1	176.4	1.0	0.2	--	--	1.7	--	1	1	1	--
Lodgepole Creek	35B7	2	417.4	6.7	0.1	2.0	1.2	5.2	--	--	--	--	--
Missouri River-Platte River Total		22	3,558.1	38.0	0.6	5.0	3.2	98.4	2	1	10	16	1
Missouri River Total		74	12,669.4	89.6	2.4	79.1	34.4	348.2	7	12	28	31	17
Wyoming State 52 Total		105	17,528.2	121.2	3.4	275.3	46.6	744.4	8	16	36	43	27

MONTANA

Introduction

The following discussion of conservation needs in relation to range and watershed management is based upon data furnished by the 1970 Conservation Needs Inventory.

Since the initial Conservation Needs Inventory for Montana in 1958, several changes have occurred (Figure 15):

a) Land area was reduced slightly as a result of water development

b) Inventoried acreages changed as a result of changes in Federal Ownership, urban development and water areas

c) Land use changes--namely cropland, range, and woodland--are partly due to change in difinition of native grasses cut for hay

d) Land area was reduced as a result of increased mining operations in the eastern Montana coal fields.

Treatment needs for soil and water resources in a given watershed includes all lands.

During the next decade, acreage in pasture and range in Montana is expected to decrease slightly, with the shift being to cropland. An increase in 6,000 acres is expected between now and 1980. This acreage increase will come primarily from range and pasture lands that are suitable for farming. Irrigated cropland in Montana is expected to reach 2.2 million acres by 1980.

Land and Water Area

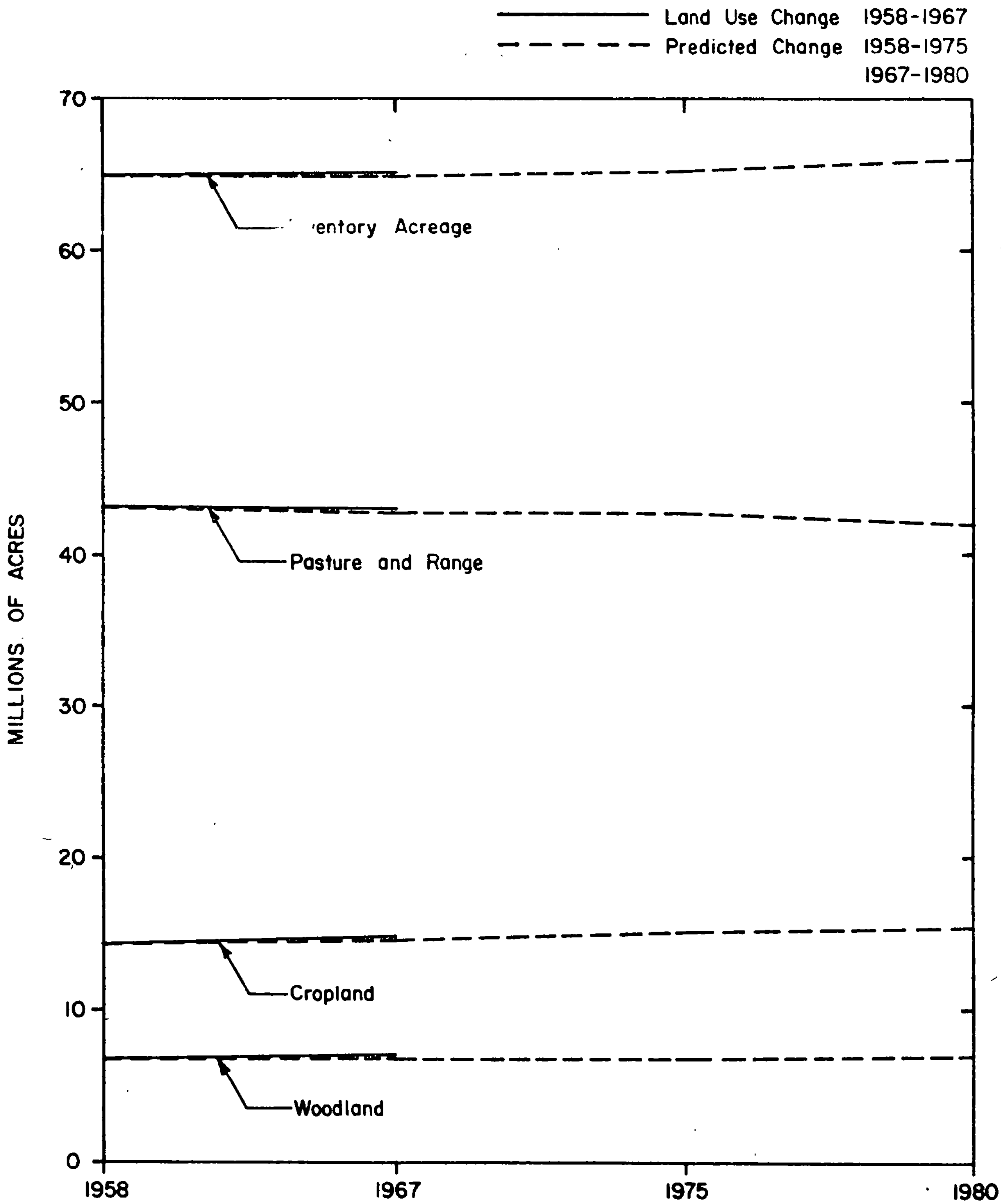
The 1967 Conservation Needs Inventory shows that Montana has a total land area of 93,089,323 acres, which is 34,144 acres less than the acreage shown in the 1958 inventory. This reduction in land area resulted from the construction of reservoirs larger than 40 acres in size and now classed as inland water areas. These large inland waters comprise 1,016,544 acres. The total land area for each of the fifty-six counties was taken from the 1964 Agricultural Census. About 30% of the land area in the State was excluded from the inventory (Figure 16).

Non-Inventory Acreage

The total non-inventory acreage amounts to 27,571,145 acres, of which 96%

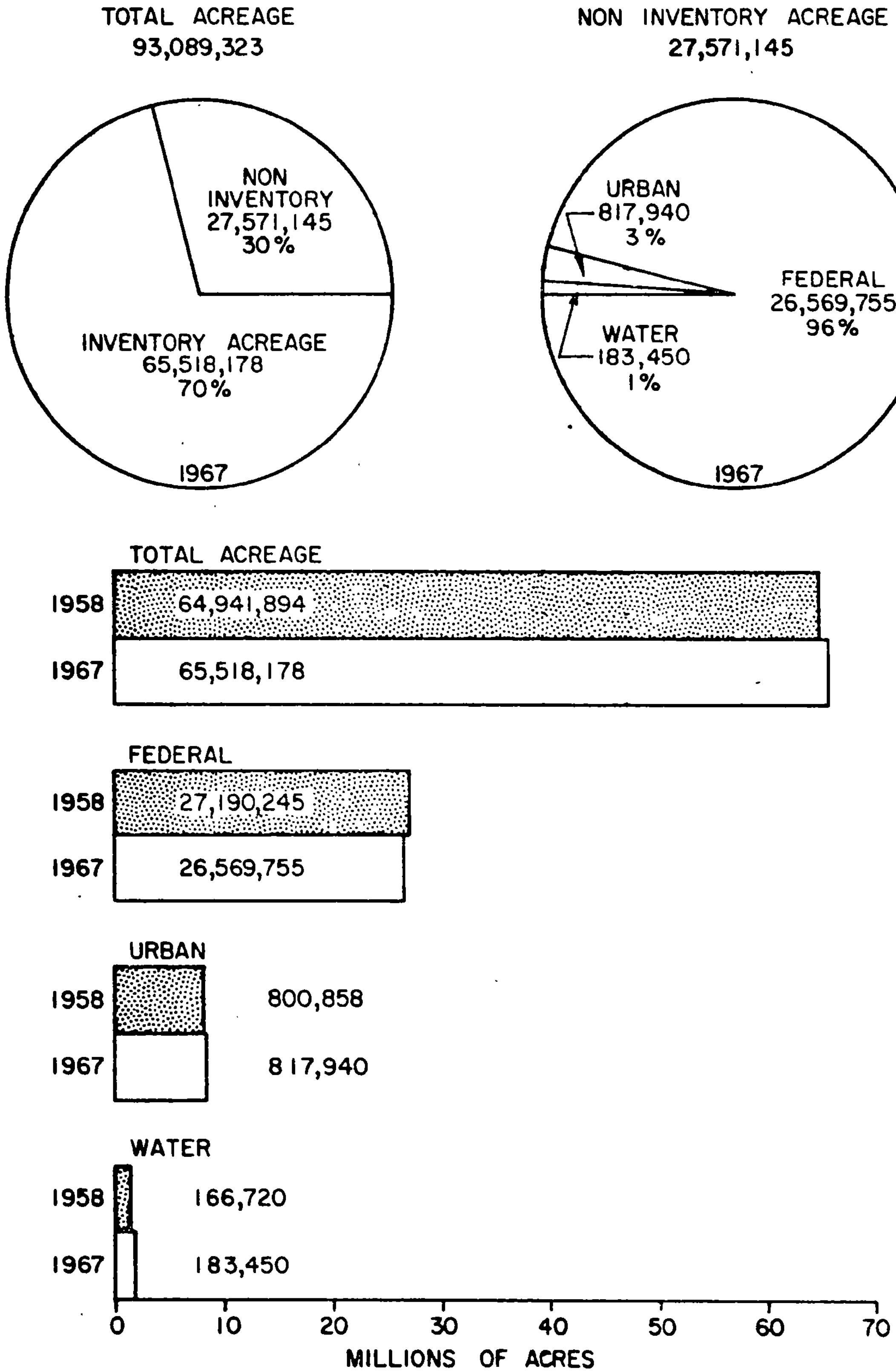
TRENDS IN LAND USE FOR MONTANA

Figure 15



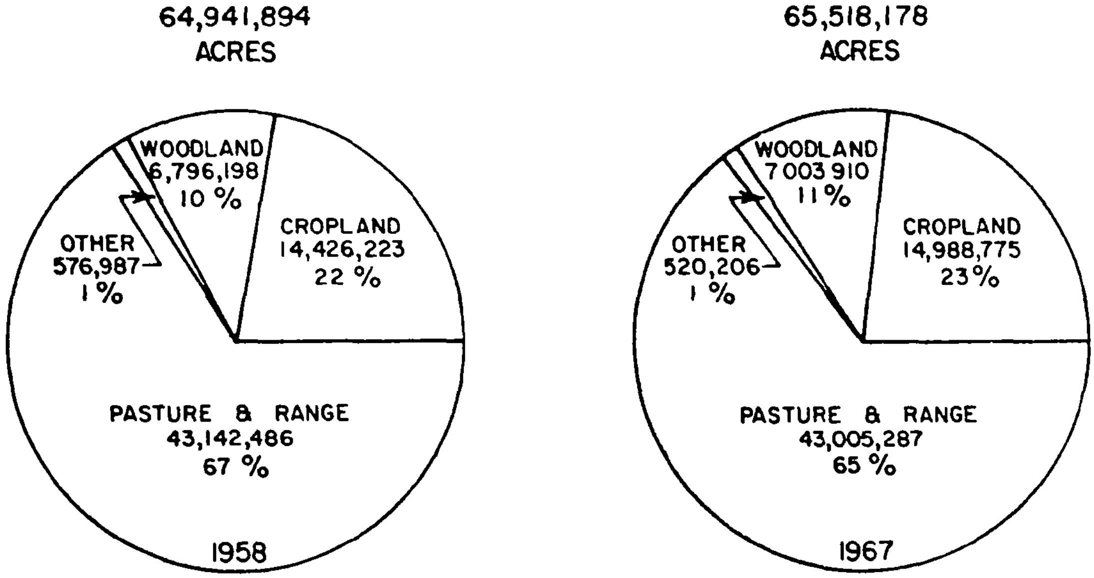
MONTANA LAND - 1967

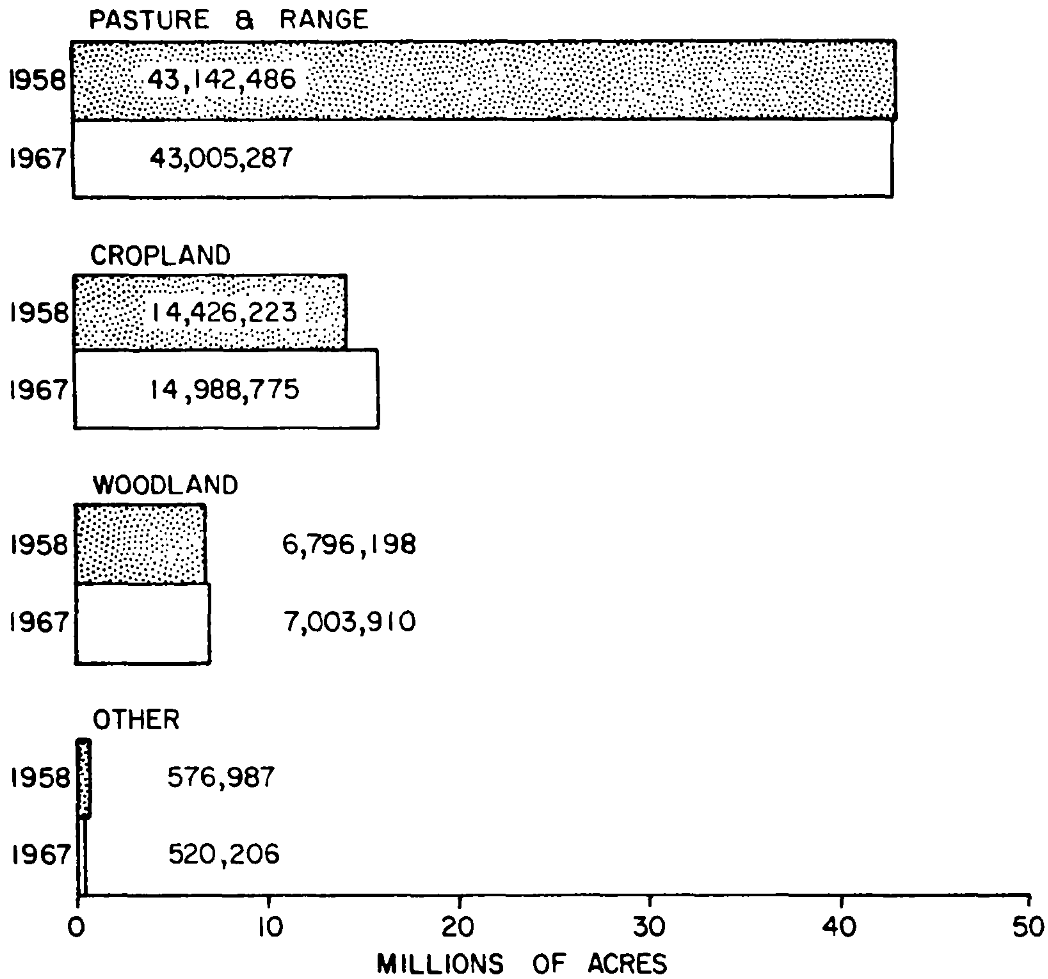
Figure 16



INVENTORIED LAND USE

Figure 17





is in Federal ownership and comprises 26,569,755 acres. The total non-inventory acreage decreased by 620,490 acres during the period 1958 to 1967. The decrease is due to the sale of isolated tracts of Federal lands to private owners and some Federal lands were inundated by water. (Figure 16)

The urban and built-up areas have increased by 17,082 acres since the 1958 study and now total 817,940 acres. This includes all cities, towns and built-up areas of more than 10 acres in size. Industrial sites (except for strip mine and borrow areas) railroad yards, airports, cemeteries, golf courses, primary and secondary roads and railroads are considered as built-up areas.

Small water areas have increased by 16,730 acres since the 1958 inventory and now total 183,450 acres. These small water areas are 2 to 40 acres in size and include ponds, lakes and reservoirs, as well as small streams that are less than 660 feet wide. The increased water area is due in part to the inclusion of small streams passing through private lands that were omitted in the previous inventory and the construction of a number of small reservoirs.

Inventory Acreage

The inventory acreage for Montana comprises 65,518,178 acres or about 70% of the State. This is an increase of 576,284 acres from the 1958 inventory, most of which came from the sale of isolated tracts in Federal ownership, the inclusion of Indian lands within reservation boundaries, and cropland in Federal ownership under lease. Land use within the inventory acreage consists of:

Cropland	14,988,775 acres or 22 percent	
Range & Pasture	43,005,287 acres or 66 percent	
Woodland	7,003,910 acres or 11 percent	
Other land*	520,206 acres or 1 percent	(See Figure 17)

* Other land includes farmsteads, private roads, feedlots, ditch banks, rural non-farm residences, mine wastes, borrow pits and investment tracts.

Treatment Needs for Range and Pasture Land

The conservation treatment needs for range and pasture land were expanded from the random sample used to identify the kind of soil, land use and treatment.

The data were reviewed and adjusted by county committees to reflect their best estimates of conditions in each of the fifty-six counties. The 1967 study shows 17,233,932 acres (42%) of the rangeland in Montana is in good to excellent condition and is adequately treated based on the ecological aspects of the site. This is an increase of more than 6 million acres over the 1975 projected estimates given in the 1958 study.

The amount of tame pastureland adequately treated is 638,424 acres (38%) of the total pastureland, which far exceeds the 1975 projected estimate of 493,000 acres given in the 1958 study.

The treatment needs for pasture and range to reduce soil loss and protect the forage resource from deterioration are identified in terms of systems of management needed to meet the problem. These are identified in terms of decreasing severity in order to improve and protect the forage resource.

Protection only is needed to improve the plant cover on 16,462,904 acres of rangeland, and 367,884 acres of pastureland. Here the forage is in an overgrazed condition but can be corrected by livestock management and/or the installation of watering facilities to improve grazing distribution. With proper management, the vegetation will recover and reseed naturally.

Improvement only is needed on 2,977,728 acres of range and 542,234 acres of pasture. Under dryland conditions, the forage cover is inadequate but can be improved or restored by applying recommended management practices and following grazing systems to protect the resource. Some of the desired types of vegetation are present but the stand is so thin that natural revegetation needs additional management to provide a satisfactory cover. Mechanical measures and weed control are often needed to obtain a satisfactory recovery of the stand.

Brush and weed control are needed on 2,560,078 acres of range and 18,525 acres of pasture. Where the encroachment of woody and some less desirable plants threatens the destruction of grass cover, there is usually more than 15% coverage by weight of the total plant cover. This acreage represents less than 25% of the total range resource in the State having 5% or more of Big Sagebrush invasion. Brush control measures, along with proper livestock management, are needed to provide a better balance of forage needed for both domestic and wildlife use.

Reestablishment of vegetative cover (without brush control) is needed on 427,203 acres of range and 114,974 acres of pasture. Under these conditions, the plant cover is thin and of such poor quality that it needs complete reestablishment. Following reestablishment, protection and proper management are essential.

Reestablishment with brush control is needed on 96,457 acres of range and 2,571 acres of pasture. Prior to reestablishment, brush control is needed to prevent competition to the new seedlings. Protection and proper use are essential to the success of the new seeding.

Change in land use to trees is recommended on 707 acres of range and 214 acres of pasture. Here a combination of trees, shrubs and grass is needed to protect the soil resource and provide the kind of cover needed to protect the land from erosion.

Land treatment is not feasible on 1,659,897 acres of range and 673 acres of pasture. Nearly 85% of this kind of land is in Class VIII and consists primarily of shale and rock outcrops with some river wash.

Forest and Woodland

The 1967 inventory acreage of woodland for Montana is 7,003,910 acres, of which 87% is commercial forest. This acreage represents an increase of 207,712 acres over the 1958 study. The Forest Service Experiment Station provided the basic data for the timber resource study on private and State owned lands in Montana. In a few eastern counties where the timber resources are not extensive, some adjustments in acreage were made to account for a known acreage of woodland.

Forest lands that are poorly stocked provide a grazing resource on nearly two thirds of the woodland area. This dual use is important to both the timber and livestock industry as well as its influence on the water regime and recreation potential of woodland areas.

The following table shows the distribution of inventory commercial and non-commercial forest lands (both grazed and not grazed) by land capability class. The subclass shows the dominant problem associated with each use.

Table 39

	Commercial Forest		Noncommercial Forest		
	Grazed	Not Grazed	Grazed	Not Grazed	Total
Class I	0	0	0	0	0
Class II	44,163	7,497	3,752	406	55,818
Class III	173,117	10,051	36,047	914	220,129
Class IV	343,928	103,656	24,131	13,099	484,814
Class V	7,109	2,317	23,267	6,980	39,673
Class VI	2,017,274	1,179,295	320,996	47,223	3,564,788
Class VII	1,179,356	1,043,718	197,089	57,155	2,477,318
Class VIII	6,095	7,380	68,795	79,100	161,370
Total	3,771,042	2,353,914	674,077	204,877	7,003,910

The subclass letters of e, w, s and c relate to the dominant kind of problem in each of the land capability Classes II through VIII. The degree of severity increases with each land class.

Table 40

Kind of Problem	Commercial	Noncommercial	Total
e - erosion	4,786,947	443,922	5,230,869
w - wetness	85,108	66,181	151,289
s - soil	1,075,853	342,991	1,148,844
c - climate	177,048	25,860	202,908
	6,124,056	878,954	7,003,910

Sloping lands and sandy soils are the dominant factors affecting the erosion potential on 75% of the woodland area. Forest lands that are properly managed and protected have little soil loss.

Excess water is the dominant problem on 1% of the woodland acreage. Much of the forest having this problem occurs on the flood plains along perennial streams where the tree cover affords excellent protection against streambank and sheet erosion that may occur during flood stage.

Unfavorable soil conditions such as excessive amounts of stone, limited soil depth and clay textures are the dominant problems on 21% of the woodland acreage. Slopes are not generally excessive except for some Class VIII land, where rock or shale outcrops are dominant problems.

Climate is limiting on some forest lands in terms of low annual precipitation and short growing season. Soils classified as having only a climatic limitation are of high quality and are not subject to erosion under proper management. About 3% of the woodland area has climate as the major limitation.

Treatment Needs of Forest Lands

The conservation treatment needs for the inventoried acreage of forest lands (grazed and not grazed) were based on estimates in terms of the conservation problem associated with the development and management of the forest and forage resource. The needs were expanded from the random sample data and adjusted by each county committee to reflect their best estimates. The 1967 study shows 1,894,268 acres (31%) of the commercial forest are adequately treated, and 853,164 acres (97%) of the noncommercial woodland are adequately treated or not feasible to treat from the standpoint of timber production. Based on the 1958 study, the adequately treated acreage is 80,100 acres below the projected estimate for 1975. Over 2 million acres (55%) of the grazed commercial woodland and 315,502 acres (47%) of the grazed noncommercial woodland are adequately treated for grazing purposes, which is a dual use of the more lightly stocked stands of timber.

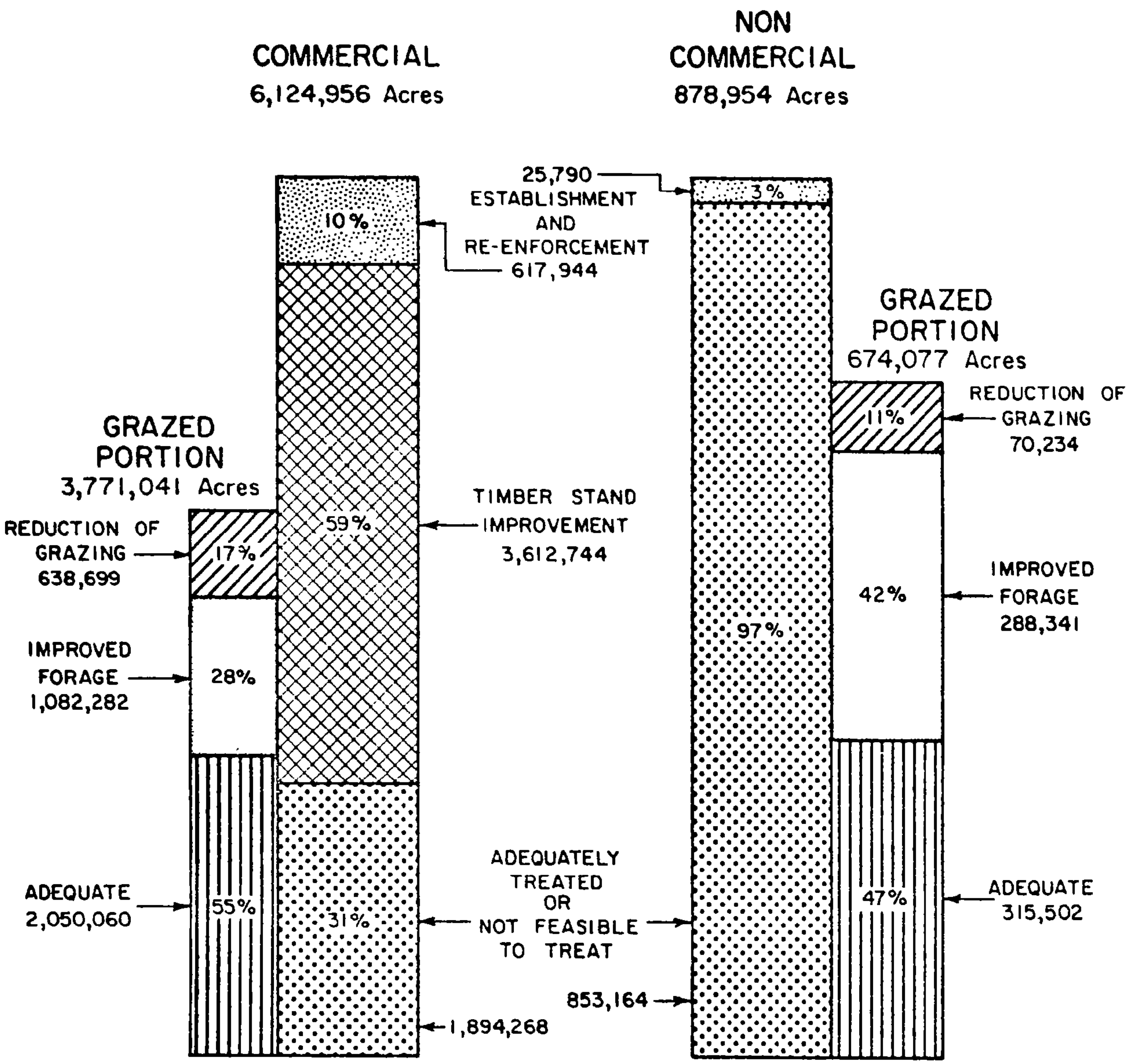
The treatment needs for the inventoried acreage of woodland for both the grazed and non-grazed portion of commercial and noncommercial forest do not consider protection from fire, insects and disease since these treatments apply to all categories of woodland.

Grazed Woodland Needing Treatment

Conservation treatment to improve forage for grazing is needed on 1,370,623 acres (31%) of the forest land being grazed. Treatment can be accomplished by

TREATMENT NEEDS
FOREST AND WOODLAND

Figure 18



applying the same management type practices needed for rangeland. Some reduction of timber and brush may be desirable on noncommercial stands but seeding to grass is generally not required. Nearly 288,341 acres (42%) of the noncommercial forest and 1,082,282 acres (28%) of the commercial forest lands could improve the grazing resource with proper livestock management and yet maintain or even improve the timber resource.

Reduction or the elimination of grazing is needed on 708,928 acres (16%) of the forest land being grazed. It is desirable to reduce or eliminate grazing from all forested areas requiring establishment or reinforcement of timber stands to protect new seedlings. There should be a minimum disturbance of critical areas needing maximum cover to protect the soil resource from erosion.

Watershed Project Needs

Land and water areas in Montana's 672 watersheds comprise 93,679,263 acres in delineated areas consisting of 250,000 acres or less. Each of the delineated watersheds includes all the surface area of the drainage basin regardless of ownership and becomes the base unit for land treatment needed in solving soil and water problems. This acreage does not represent all the land and water area in the State, since portions of watersheds joining other states may have been excluded, particularly if the majority of land in a given watershed lies outside thestate. The conservation measures and development needs of the soil and water resources for a given watershed are major factors in the economic growth of the State.

The basic reference used for delineating the major and principal drainage areas and sub-basins was the "Atlas of River Basins of the United States" prepared by the Soil Conservation Service in 1963. Each sub-basin was further sub-divided into waterhseds of 250,000 acres or less with the use of topographic maps prepared by the U.S. Geological Survey. In 1954, the Watershed Protection and Flood Prevention Act PL-566 was enacted by Congress to provide local organization with federal assistance in the development of feasible projects. PL-566 makes it possible to plan and apply many conservation measures needed for flood prevention, improved water management, recreation and other agricultural related uses that cannot be planned and financed as efficiently under other programs. As of June 1, 1970, there have been 57 applications approved for planning in Montana out of 240 feasible watersheds. Construction has been completed on four watersheds and is underway on four others.

Feasible Watersheds

In the 240 feasible watersheds covering 33,239,271 acres (35%) of the land and water area, there is a need for protection from flood water and sediment damage to both agricultural and urban land. There are 400,695 acres of agricultural land with a flood problem, of which 189,021 acres (47%) need project action. Urban lands having a flood problem comprise 7,890 acres with project action for flood prevention needed on 6,938 acres (87%). Erosion damage from floodwaters occurs on 125,981 acres and there has been severe damage to 22,474 acres which need project action.

Agricultural water management needs which cannot be met by individual action include 238,932 acres with a drainage problem, of which 174,498 acres need project action. There are 1,274,902 acres of irrigated land needing improvement and 860,834 acres need project action. There are at least seven communities with a rural water supply inadequate to meet the present needs.

The need for non-agricultural water management in the 240 feasible watersheds exists on:

a. 45 municipal and industrial units
b. 166 recreational developments
c. 151 fish and wildlife developments
d. 83 water quality control areas

Most of these needs can be fulfilled under Public Law 566.

UTAH

Introduction

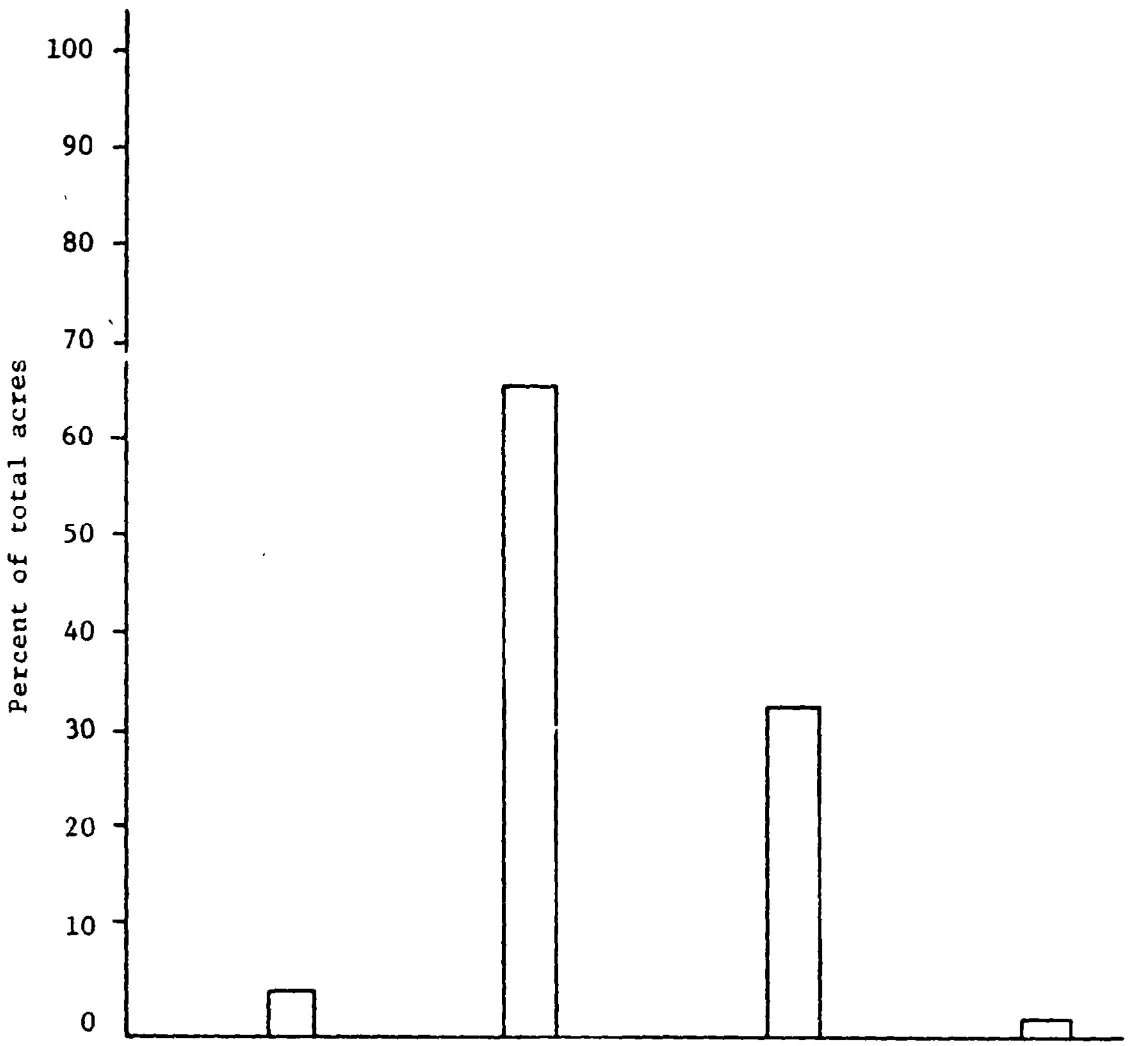
The urban and built-up area has increased since 1958 in Utah. Since that time, when the initial conservation needs inventory was made, cities have grown appreciably and major changes have occurred in the state's highway system. This expansion has taken place at the expense of cropland which has decreased by more than 64,000 acres since 1958. The changes in the area of pasture range, forest, and other land mainly resulted from redefining the forest. Future changes are likely to occur as a result of the projected oil shale development activities.

The present inventory of needs covers two major types of estimates: (1) current data on land use and conservation treatment needs by land class and subclass on non-federal rural land; and (2) inventory of watershed project needs for the total acreage of the state regardless of ownership.

The 1967 conservation needs inventory shows that Utah has a total land and water area of 54,346,240 acres. This is total acreage which includes 1,624,690 acres for all reservoirs and lakes with more than 40 surface acres. The water area increases of Lake Powell, Flaming Gorge and other new reservoirs were offset by surface area decreases of Great Salt Lake and Sevier Lake. The inventory covers 16,879,884 acres of private, state, and Indian lands. The remaining area consists of 35,397,274 acres of federal land, 430,014 acres of urban and built-up area and 1,639,068 acres for water areas 2 to 40 acres in size. (Figure 20)

The inventory acreage consists of 2,155,186 acres of cropland of which 1,348,627 are irrigated, 322,407 acres of nonirrigated pasture, 8,705,116 acres or rangeland, 4,665,227 acres of forest, and 1,031,948 acres of other land. In 1967 there were 124,000 acres of cropland than has been idle for 3 7ears or longer. (Figure 21)

The inventory shows that 79% of the irrigated lands still need treatment to attain full use of the water and soil resources. 59% of the nonirrigated cropland area still needs treatment which will make better use of the soil and conserve more of the rainfall for crop use. The conservation job remaining on



	Water area larger than 2 acres	Federal noncrop-land	State, Indian, private lands	Urban and built-up
1967	1,639,068	35,397,274	16,879,884	430,014
Percent	3.0	65.1	31.1	0.8

Figure 19. Water area and land ownership distribution in Utah -- Total area 54,346,240 acres

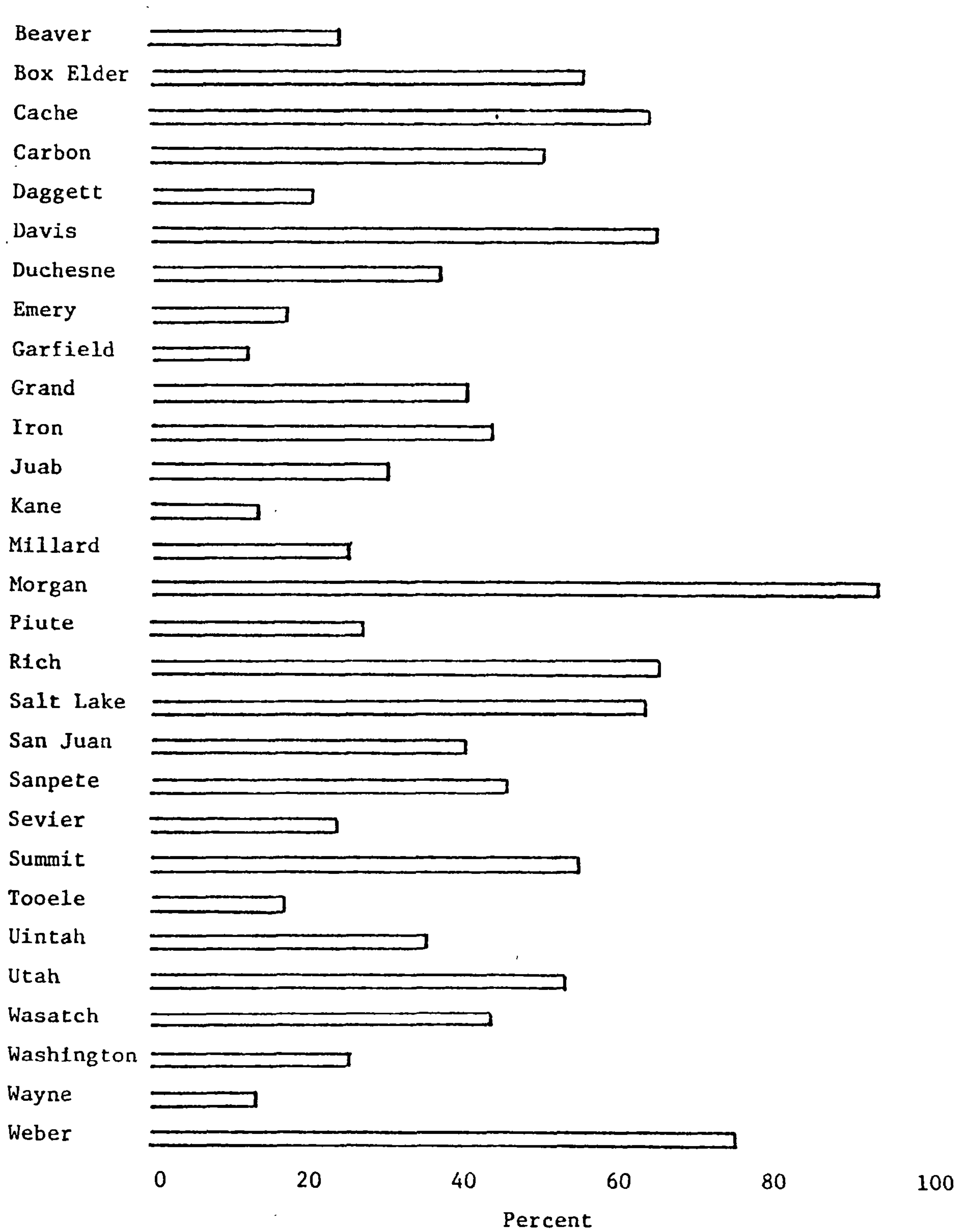
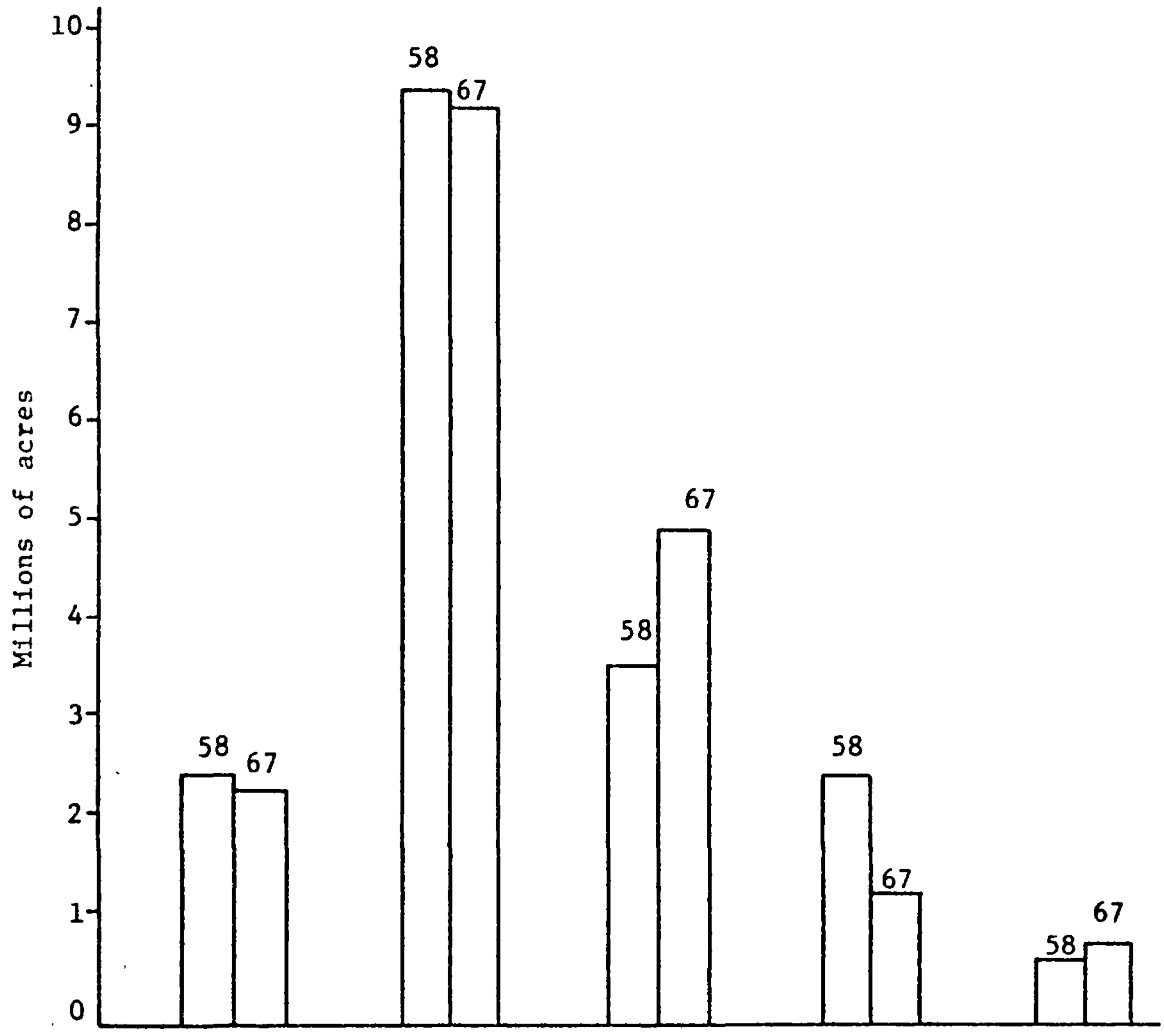
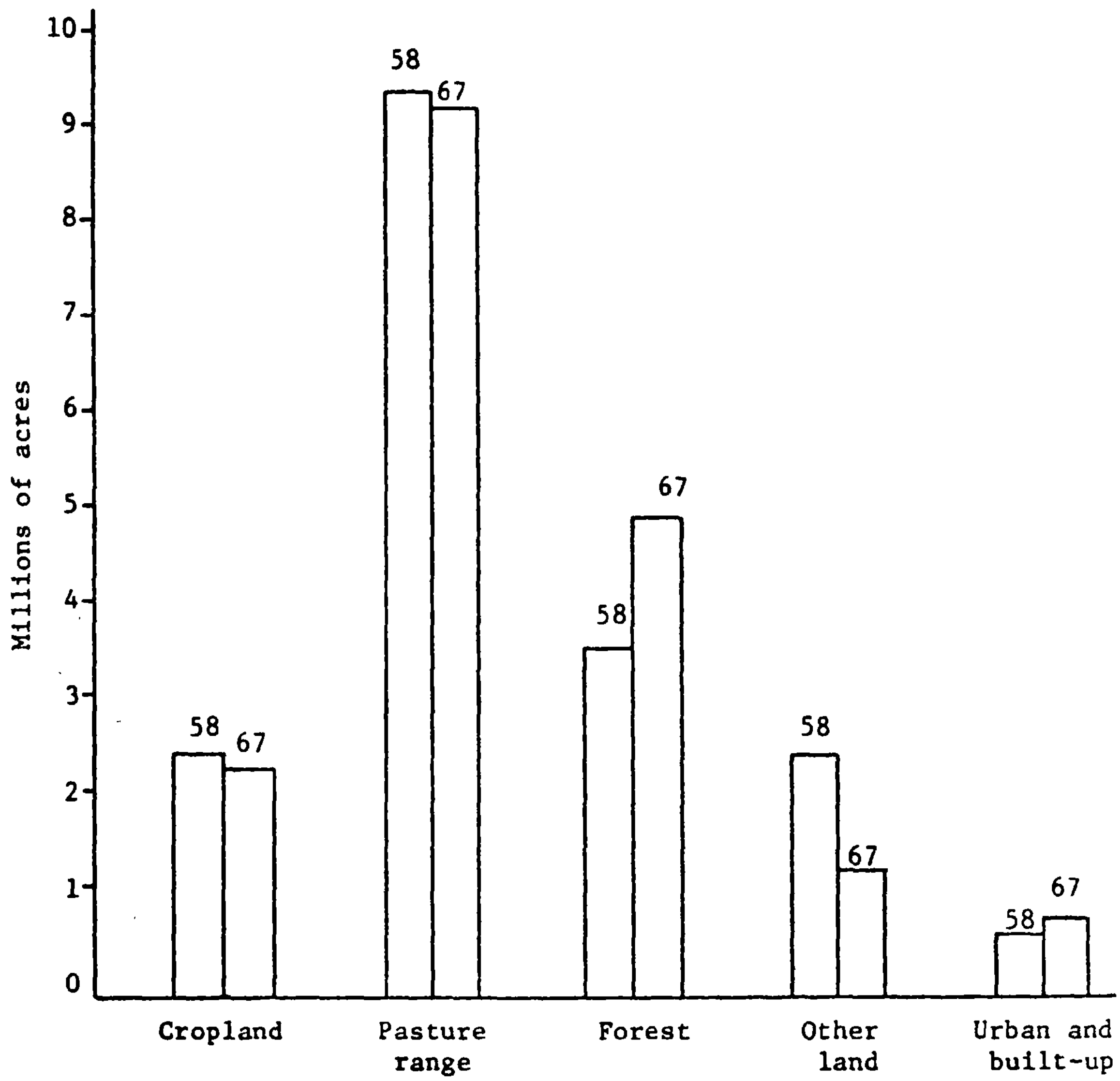


Figure20 · Percent of county land area in inventory - Utah 1967



	Cropland	Pasture range	Forest	Other land	Urban and built-up
1958	2,219,000	9,171,900	3,292,200	2,213,100	260,322
1967	2,155,186	9,037,523	4,665,227	1,031,948	430,014

Figure 21. Use of inventory acreage in Utah -- 1958 and 1967



	Cropland	Pasture range	Forest	Other land	Urban and built-up
1958	2,219,000	9,171,900	3,292,200	2,213,100	260,322
1967	2,155,186	9,037,523	4,665,227	1,031,948	430,014

Figure 21 Use of inventory acreage in Utah -- 1958 and 1967

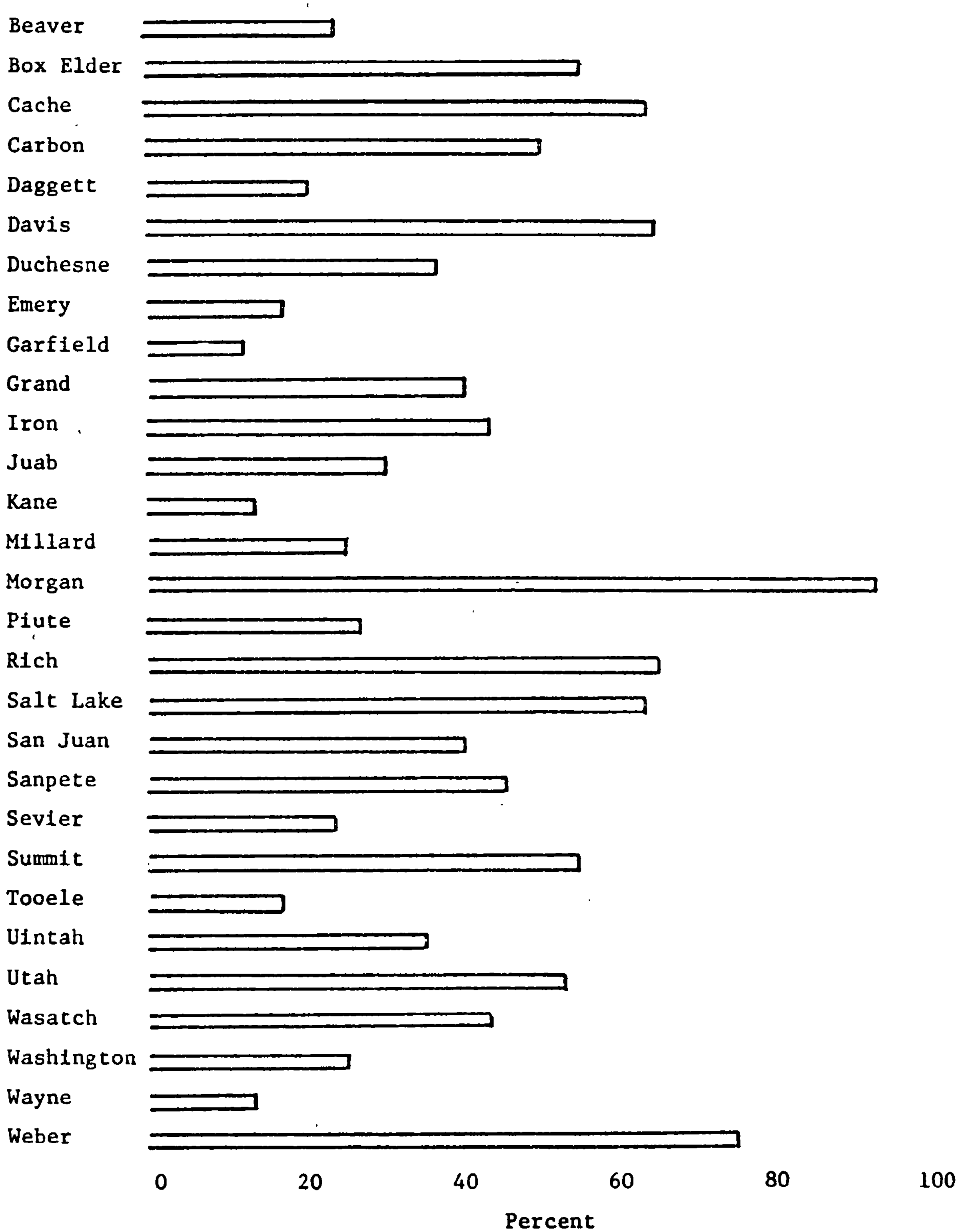


Figure 22 Percent of county land area in inventory - Utah 1967

the nonirrigated pasture and rangeland of the state is a big one. Estimates in this inventory indicate 81% of the pasture and range needs treatment. Management of the present plant cover on pasture and range is the major treatment needed. Most of the need for seeding the brush controlled areas exists on the spring-fall forage production rangelands. It is estimated that 40% of the commercial forests in the state needs forestry improvement practices. In the noncommercial forest areas, which includes pinyon-juniper, the major emphasis is placed on forage improvement to provide soil protection and improve the grazing resource. Conservation treatment including reduction or elimination of grazing, and forage improvement is needed on three-fourths of the grazed forest area. Other land in the inventory includes strip mines, nonfarm residential areas, farmsteads, feedlots and other areas not used for agricultural production. The inventory indicated that 25% of this other land needs conservation improvement.

Pasture and Range

More than 67 percent of the pasture and rangeland in the state needs some type of treatment. There are 322,000 acres of nonirrigated pasture. About 50 percent of the pasture acreage needs protection from overgrazing. Brush control, improvement, and re-establishment are needed on 34 percent of the pasture land.

Half of the total rangeland needs protection from overgrazing. Brush control and improvement are needed on about 25 percent. Re-establishment and re-establishment with brush control are needed on 6 percent of the range.

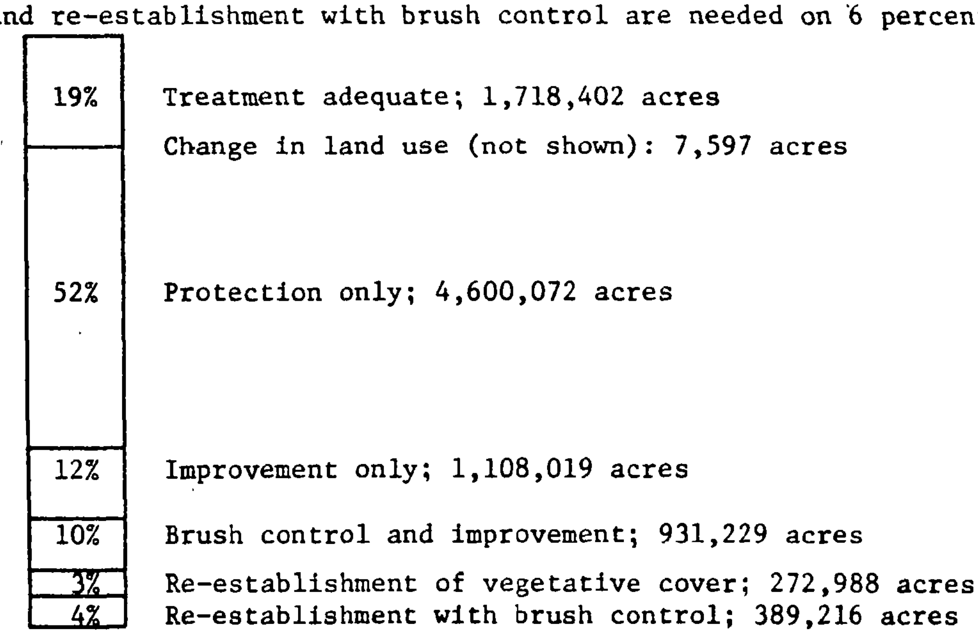


Figure 23. Total pasture and rangeland; 9,027,523 acres

WATERSHED NEEDS

The watershed projects inventory identifies 116 watersheds as economically and physically feasible for treatment in relation to (1) seriousness of the problem and (2) affected areas downstream, out of 221 watersheds in the state. The feasible watersheds cover an area of 15.6 million acres or about 30% of the state land area. The Watershed Protection and Flood Prevention Act (Public Law 566) was enacted in 1954. Through PL-566, six watersheds have been completed. The needed structures and land treatment are being applied on another six watersheds. Plans outlining structural and land treatment needs have been developed for four additional watersheds.

The 1967 Watershed Projects Inventory drew heavily on experience gained through several years of operation under the PL-566 Watershed Protection and Flood Prevention Porgram. The watershed inventory covered all land in Utah, private and public. Public Law 566 was used as the base to establish the needs that can best be met through joint action of local groups, state, and federal agencies.

The state was divided into 221 project-size watersheds for evaluation purposes. Of the 221 watersheds, 116 are economically and physically feasible for project action. There are significant erosion and productivity problems present in the other 105 watersheds, but present development and benefits do not qualify them for project action.

Problems

About 2.8 billion acres of agricultural and urban lands are damaged by flood water and sediment. Project-type action is feasible on about 1,000,000 acres. Frequent flooding is caused by localized high-intensity summer storms. Damage also is caused by snowmelt floods when unusual climatic and hydrologic conditions exist. Many of Utah's urban areas are extablished along streams and on alluvial fans which are subject to flood damage. Because of this pattern, some structural treatment is essential to reduce future damage. Additional zoning laws also may be needed to prevent greater intensification of damages as new urban

Forest Land

The inventory shows that about 94 percent of the forest acreage is grazed by domestic livestock. Forage improvement is needed on 53 percent of the area and reduction or elimination of grazing on 19 percent.

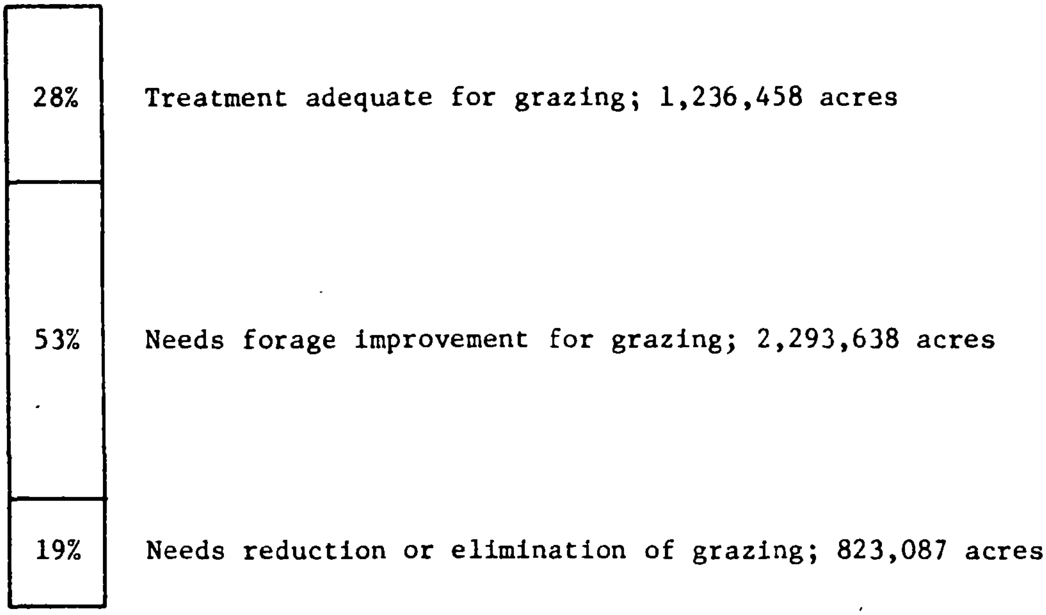


Figure 24. Total grazed commercial and noncommercial forest; 4,353,183 acres

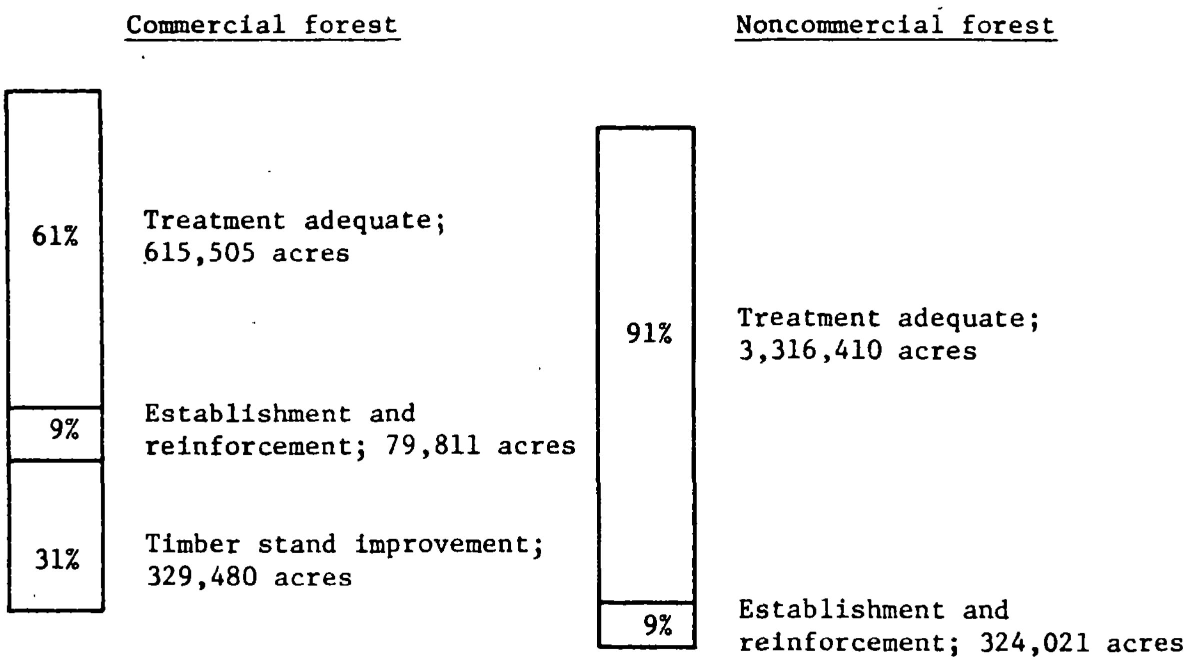


Figure 24 · Total forest land; 4,665,227 acres

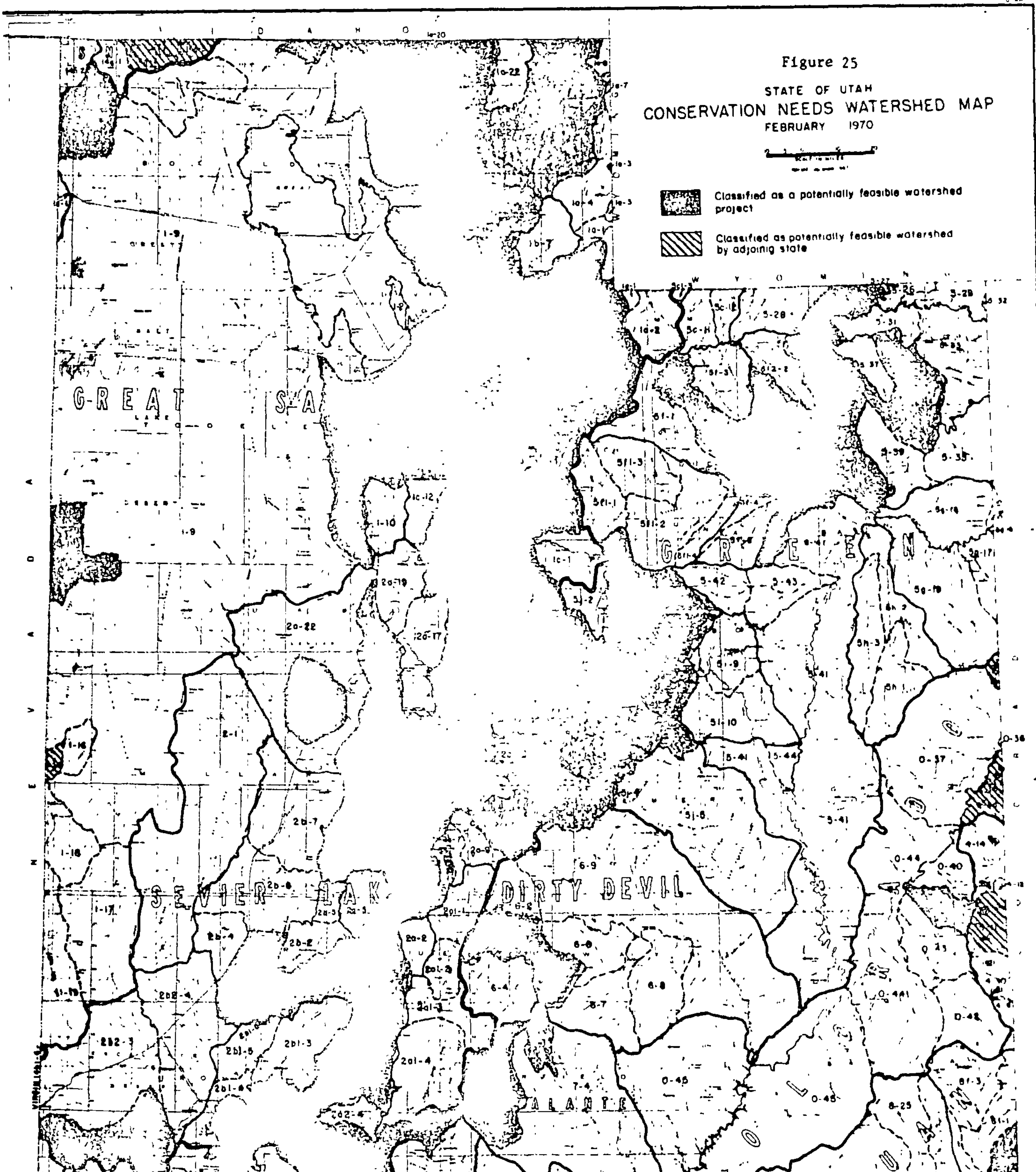


Figure 25
STATE OF UTAH
CONSERVATION NEEDS WATERSHED MAP
FEBRUARY 1970
Classified as a potentially feasible watershed project
Classified as potentially feasible watershed by adjoinig state
IDAHO
WYOMING
NEVADA
ARIZONA
GREAT SALT LAKE
SEVIER LAKE
DIRTY DEVIL
GREEN
COLORADO
SAN JUAN
PARIA
VIRGIN
ESCALANTE

and suburban areas are developed.

Significant erosion occurs on 21.2 million acres of land in the state with about 33% of this acreage in the feasible watersheds. Soil loss reduces the productive capacity of the eroding area, pollutes the water and creates other problems as sediment is redeposited downstream.

The single most important problem of agricultural water management is irregular water supply. Lack of storage, inefficient water distribution systems, and inefficient irrigation contribute to the problem. In addition, drainage is needed in some watersheds to dispose of excess water.

The need for additional municipal and industrial water was found in 37 watersheds. Additional rural water supply developments, including water for livestock and on-farm use, are needed in 106 watersheds.

Recreation problems were identified on 169 watersheds. This reflects a further need for private and public recreational facilities.

Fish and wildlife problems were identified on all watersheds. These include the need for additional fish and wildlife development, improved fish and wildlife habitat, and habitat management to meet the needs of an expanding population.

Sediment produced from erosion contributes to poor water quality in 157 of the watersheds. Pesticides, insecticides, fertilizers, and feedlots also contribute to the water quality problem.

In the following tables the state is divided into three major drainage areas (example below, line 1), Colorado River, Columbia River, and Great Basin. These are in turn divided into principal drainage basins (line 2), which are considered as second order streams within a drainage area. The second order streams are further broken down into third and fourth order streams (lines 3 and 4). The second order streams are identified as basins and the third order as subbasins with Arabic numerals and lower case letters.

1. Colorado River Area
2. Green River (5)
3. Duchesne River (5f)
4. Strawberry River (5f1)

There are four entry items in the tables:

Watershed with problems	(1)
Needs project action	(2)
Feasible watershed with problems	(3)
Suitable for project action	(4)

These items are repeated by the numbers for ease of typing and for ready perception in following the tables.

INVENTORY OF WATERSHEDS INCLUDING THE KINDS AND EXTENT OF PROBLEMS NEEDING AND FEASIBLE FOR PROJECT ACTION

MAJOR DRAINAGE AREA / PRINCIPAL DRAINAGE BASIN / SUBBASINS	WATERSHEDS		KIND AND EXTENT OF PROBLEMS: FLOOD PREVENTION: FLOODWATER AND SEDIMENT DAMAGE			AGRICULTURAL WATER MANAGEMENT		NONAGRICULTURAL WATER MANAGEMENT					FARMS IN WS
	NO.	ACRES	AGRICULTURAL ACRES	URBAN ACRES	EROSION DAMAGE ACRES	DRAINAGE ACRES	IRRIGATION ACRES	RURAL WATER SUPPLY NUMBER	MUNICIPAL OR INDUSTRIAL WATER SUPPLY NUMBER	RECREATIONAL DEVELOPMENT NUMBER	FISH & WILDLIFE DEVELOPMENT NUMBER	WATER QUALITY MANAGEMENT NUMBER	NUMBER
State of Utah Summary													
Watershed with prob (1)	221	54265100	2710016	70714	21262282	496965	1550255						21697
Needs proj action (2)			996639	63020	7076142	270340	1153125	106	37	169	205	157	
Feasible WS with prob (3)	116	15610115	990734	69105	7319914	482232	1177654						19471
Suitable for proj action (4)			739089	62185	5062190	269300	1123925	80	29	93	115	96	
GREAT BASIN AREA													
Great Salt Lake Basin													
Great Salt Lake 1													
Watershed with prob (1)	18	12009542	1315000	4590	2552988	22830	72036						1063
Needs proj action (2)			273600	4205	750633	16200	40770	3	2	14	16	12	
Feasible WS with prob (3)	9	1339778	70900	3850	731333	20230	51316						891
Suitable for proj action (4)			49200	3830	495633	15200	37070	3	2	8	9	8	
Bear River 1a													
(1)	13	1867175	83188	2950	644698	139920	268165						3748
(2)			50288	2650	160480	78500	174455	9	6	10	12	12	
(3)	10	1389060	77688	2950	436691	134500	207165						3698
(4)			44988	2650	151480	78400	173455	9	6	8	10	10	
Bear Lake 1a1													
(1)	1	178626	500	0	60130	2700	6500						38
(2)			200	0	5000	0	5000	0	0	1	1	1	
(3)	1	178626	500	0	60130	2700	6500						38
(4)			200	0	5000	0	5000	0	0	1	1	1	
Third Order 1a Summary													
(1)	14	2045801	83688	2950	704828	142620	274665						3786
(2)			50488	2650	165480	78500	179455	9	6	11	13	13	
(3)	11	1567686	78188	2950	496821	137200	213665						3736
(4)			45188	2650	156480	78400	178455	9	6	9	11	11	
Weber River 1b													
(1)	10	1469963	60217	4950	1047935	59550	160443						2223
(2)			57767	4750	678369	53400	109330	9	1	10	10	10	
(3)	8	1280681	57917	4850	892643	59450	153693						2100
(4)			56467	4650	643369	53400	108030	7	1	8	8	8	
Jordan River 1c													
(1)	16	1947324	226845	40205	929427	76206	206690						5032
(2)			181730	38205	728227	52650	161840	11	5	14	15	13	
(3)	14	1723434	224545	40205	814327	76206	206390						5017
(4)			181430	38205	663127	52650	161450	11	5	13	14	12	
Provo River 1c1													
(1)	3	468323	44831	8200	293636	14700	48211						971
(2)			33831	8200	81876	7600	45942	3	1	3	3	3	
(3)	3	468323	44831	8200	293636	14700	48211						971
(4)			33831	8200	81876	7600	45942	3	1	3	3	3	
Third Order 1c Summary													
(1)	19	2415647	271676	48405	1223063	90906	254901						6003
(2)			215561	44405	810103	60250	207782	14	6	17	18	10	
(3)	17	2191757	269376	48405	1107963	90906	254601						5988
(4)			215261	44405	745003	60250	207482	14	6	16	17	15	
Great Salt Lake Basin Summary													
(1)	61	17940993	1730591	60895	5528814	315906	762045						13075
(2)			597416	56010	2404585	208350	537337	35	15	52	57	51	
(3)	45	6379902	476381	60055	3228760	307786	673275						12715
(4)			366116	55535	2040485	207250	531037	33	15	41	45	42	
Sevier Lake Basin													
Sevier Lake Basin 2													
(1)	1	1145273	235000	0	275000	0	400	0	0	0	1	0	1
(2)	0	0	0	0	0	0	0	0	0	0	0	0	
(3)	0	0											
(4)	0	0											
Sevier River 2a													
(1)	25	3664360	404798	3545	1432676	78996	249040						2396
(2)			224648	3545	360529	10100	197014	12	3	16	24	13	
(3)	17	2210395	255898	3545	698049	78996	241320						2259
(4)			224648	3545	360529	10100	197014	9	2	11	17	10	
East Fork Sevier River 2a1													
(1)	5	792670	4410	0	348263	3680	15340						107
(2)			50	0	78670	0	0	1	0	4	5	2	
(3)	1	78670	50	0	78670	0	0						5
(4)			50	0	78670	0	0	0	0	1	1	1	
So Fork Sevier River 2a2													
(1)	5	721000	3230	0	331500	1200	21780						280
(2)			2930	0	318000	200	19600	3	0	3	5	5	
(3)	4	650500	2230	0	301500	1200	20580						265
(4)			1930	0	288000	200	18400	3	0	3	4	4	
San Pitch River 2a3													
(1)	4	429050	27400	2500	203180	20500	71890						636
(2)			12950	400	74240	10100	48000	3	1	4	4	3	
(3)	4	429050	27400	2500	203180	20500	71890						633
(4)			12950	400	74240	10100	48000	3	1	4	4	3	
Third Order 2a Summary													
(1)	39	5607080	439838	6045	2315619	104376	358050						3421
(2)			240578	3945	811439	20400	263614	19	4	27	38	23	
(3)	26	3368615	285568	6045	1281399	100696	333790						3167
(4)			239578	3945	801439	20400	263414	15	3	19	26	18	

TABLE 42 WATERSHED PROJECTS INVENTORY - 1967

INVENTORY OF WATERSHEDS INCLUDING THE KINDS AND EXTENT OF PROBLEMS NEEDING AND FEASIBLE FOR PROJECT ACTION

MAJOR DRAINAGE AREA PRINCIPAL DRAINAGE BASIN SUBBASINS	WATERSHEDS		KIND AND EXTENT OF PROBLEMS: FLOOD PREVENTION: FLOODWATER AND SEDIMENT DAMAGE		FLOOD PREVENTION: EROSION DAMAGE	AGRICULTURAL WATER MANAGEMENT: DRAINAGE	AGRICULTURAL WATER MANAGEMENT: IRRIGATION	AGRICULTURAL WATER MANAGEMENT: RURAL WATER SUPPLY	NONAGRICULTURAL WATER MANAGEMENT: MUNICIPAL OR INDUSTRIAL WATER SUPPLY	RECREATIONAL DEVELOPMENT	FISH & WILDLIFE DEVELOPMENT	WATER QUALITY MANAGEMENT	FARMS IN WS
			AGRICULTURAL	URBAN									
	NO.	ACRES	ACRES	ACRES	ACRES	ACRES	ACRES	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER
GREAT BASIN AREA													
Beaver River 2b													
Watershed with prob (1)	7	1453644	108330	349	569766	500	36430						306
Needs proj action (2)			6530	340	310041	0	19485	1	1	2	5	0	
Feasible WS with prob (3)	2	444859	7130	340	281186	500	33070						277
Suitable for proj action (4)			6230	340	247041	0	18045	1	0	2	2	0	
Cedar Valley 2b1													
(1)	6	694888	18000	0	174680	0	18200						210
(2)			18000	0	174680	0	16700	1	1	5	5	1	
(3)	2	212259	15000	0	101000	0	15000						154
(4)			15000	0	101000	0	15000	1	1	1	2	1	
Escalante Desert 2b2													
(1)	5	1456902	7150	0	259225	0	22150						279
(2)			6950	0	146725	0	6950	2	1	4	5	2	
(3)	3	317672	4800	0	87150	0	6800						89
(4)			4800	0	87150	0	6800	2	1	2	3	2	
Third Order 2b Summary													
(1)	18	3605434	133480	349	1003671	500	76780						795
(2)			31480	340	631446	0	43135	4	3	11	15	3	
(3)	7	974790	26930	340	469336	500	54870						520
(4)			26930	340	435191	0	39845	4	2	5	7	3	
Sevier Lake Basin Summary													
(1)	58	10357787	808318	6394	3594290	104876	435230						4217
(2)			272058	4285	1462885	20400	307749	23	7	38	54	26	
(3)	33	4343405	312498	6385	1750735	101196	388560						3687
(4)			265608	4285	1236630	20400	303259	19	5	24	33	21	
Great Basin Area Summary													
(1)	119	28298780	2538899	67289	9123104	420782	1197275						17292
(2)			869474	60295	3867470	228730	845086	58	22	90	111	77	
(3)	78	10723307	788879	66440	4979495	408982	1061935						16402
(4)			631724	59820	3277115	227650	834296	52	20	65	78	63	
COLUMBIA RIVER AREA													
Raft River 14g													
(1)	1	92923	220	0	6500	100	1900						16
(2)			0	0	0	0	0	1	0	1	1	1	
(3)	0	0											
(4)	0	0											
COLORADO RIVER AREA													
Colorado River Main Stem 0													
(1)	7	4934957	1600	1200	1824037	1000	4100						113
(2)			400	1200	28000	1000	800	2	1	3	5	2	
(3)	1	94247	600	1200	45000	1000	1300						50
(4)			400	1200	20030	1000	800	1	1	1	1	1	
Dirty Devil River 6													
(1)	9	2823898	6650	0	1888112	2140	27126						314
(2)			3250	0	695818	1840	25330	6	1	9	9	8	
(3)	3	454823	1800	0	218765	1500	23600						256
(4)			1700	0	160900	1500	23600	3	1	3	3	3	
Escalante River 7													
(1)	4	1306659	950	0	1159425	0	3870						76
(2)			950	0	284000	0	3800	2	0	4	4	1	
(3)	3	357769	950	0	284000	0	3800						65
(4)			950	0	284000	0	3800	2	0	3	3	1	
Green River Main Stem 5													
(1)	14	4079044	21280	900	1277910	10350	61760						748
(2)			16970	400	219000	5750	52160	6	3	12	14	14	
(3)	4	561122	13950	700	89500	9150	48900						589
(4)			13250	200	59100	5750	48900	4	1	3	4	4	
Blacks Fork River 5c													
(1)	2	152480	26000	0	10000	0	0						0
(2)			5900	0	5600	0	0	0	0	2	2	2	
(3)	0	0											
(4)	0	0											
Duchesne River 5f													
(1)	8	1075838	5225	0	135800	13100	55460						353
(2)			4275	0	84309	6600	52460	4	0	5	7	6	
(3)	4	471574	4400	0	46800	13000	52160						301
(4)			3450	0	25300	6500	49160	3	0	3	3	3	
Strawberry River 5f1													
(1)	4	742604	670	0	184151	0	2850						34
(2)			370	0	136151	0	2700	1	0	3	4	4	
(3)	0	0											
(4)	0	0											
Uintah River 5f2													
(1)	5	681225	1050	20	50000	34500	71000						495
(2)			700	20	30000	14000	69000	4	0	5	5	5	
(3)	4	345343	1050	20	45000	34500	71000						495
(4)			700	20	28000	14000	69000	4	0	4	4	4	

TABLE 43 WATERSHEDS PROJECTS INVENTORY

MAJOR DRAINAGE AREAS PRINCIPAL DRAINAGE BASINS SUBBASINS	SUBBASIN NUMBER	LAND AND WATER AREA (ACREAGE)
Colorado River Area		25,873,397
Colorado River Basin	(0)	4,934,957
Dirty Devil River	(6)	2,823,898
Escalante River	(7)	1,306,659
Green River Basin		11,035,477
Green River	(5)	4,079,044
Blacks Fork River	(5c)	152,480
Duchesne River	(5f)	1,075,838
Strawberry River	(5f1)	742,604
Uintah River	(5f2)	681,225
White River	(5g)	928,922
Willow Creek	(5h)	612,989
Price River	(5i)	1,218,783
San Rafael River	(5j)	1,543,592
Kanab Creek	(11)	367,052
Paria River	(9)	666,626
San Juan River Basin		3,020,094
San Juan River	(8)	2,207,889
Montezuma Creek	(8f)	752,384
Chinle Creek	(8g)	59,821
Virgin River Basin		1,718,634
Virgin River	(14)	1,708,605
Fort Pierce Wash	(14a)	10,029
Columbia River Area		92,923
Snake River Basin		92,923
Raft River	(14g)	92,923
Great Basin Area		28,298,780
Great Salt Lake Basin		17,940,993
Great Salt Lake	(1)	12,009,582
Bear River	(1a)	1,867,175
Bear Lake	(1a1)	178,626
Weber River	(1b)	1,469,963
Jordan River	(1c)	1,947,324
Provo River	(1c1)	468,323
Sevier Lake Basin		10,357,787
Sevier Lake Basin	(2)	1,145,273
Sevier River	(2a)	3,364,360
East Fork Sevier River	(2a1)	792,670
South Fork Sevier River	(2a2)	721,000
San Pitch River	(2a3)	429,050
Beaver River	(2b)	1,453,644
Cedar Valley	(2b1)	694,888
Escalante Desert	(2b2)	1,456,902
UTAH TOTAL		54,265,100

TABLE 44 WATERSHED PROJECTS INVENTORY - 1967

INVENTORY OF WATERSHEDS INCLUDING THE KINDS AND EXTENT OF PROBLEMS NEEDING AND FEASIBLE FOR PROJECT ACTION

MAJOR DRAINAGE AREA / PRINCIPAL DRAINAGE BASIN / SUBBASINS	WATERSHEDS		KIND AND EXTENT OF PROBLEMS: FLOOD PREVENTION: FLOODWATER AND SEDIMENT DAMAGE			AGRICULTURAL WATER MANAGEMENT			NONAGRICULTURAL WATER MANAGEMENT				FARMS IN WS
			AGRICULTURAL	URBAN	EROSION DAMAGE	DRAINAGE	IRRIGATION	RURAL WATER SUPPLY	MUNICIPAL OR INDUSTRIAL WATER SUPPLY	RECREATIONAL DEVELOPMENT	FISH & WILDLIFE DEVELOPMENT	WATER QUALITY MANAGEMENT	
	NO.	ACRES	ACRES	ACRES	ACRES	ACRES	ACRES	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER
COLORADO RIVER AREA													
Third Order 5f Summary													
Watershed with prob (1)	17	2499667	6945	20	369931	47600	129300						832
Needs proj action (2)			5345	20	250451	20600	124160	9	0	13	16	15	
Feasible WS with prob (3)	8	1016917	5450	20	91800	47500	123160						795
Suitable for proj action (4)			4150	20	53300	20500	118160	7	0	7	7	7	
White River 5g													
(1)	3	928922	1300	0	634171	40	450						3
(2)			1000	0	288171	0	0	1	2	2	3	3	
(3)	0	0											
(4)	0	0											
Willow Creek 5h													
(1)	3	612989	1100	0	216000	100	3800						17
(2)			900	0	37000	0	3300	0	0	2	3	3	
(3)	0	0											
(4)	0	0											
Price River 5i													
(1)	10	1218783	33320	840	784324	9100	32000						552
(2)			33200	840	359200	7700	22800	3	5	10	10	8	
(3)	7	651391	30920	690	605650	8900	29400						503
(4)			30900	680	323200	7700	20600	3	3	7	7	6	
San Rafael River 5j													
(1)	5	1543592	19750	100	1334291	5200	33500						334
(2)			19600	100	414400	5200	21000	4	0	4	5	4	
(3)	4	665511	19750	100	456210	5200	33500						334
(4)			19600	100	414400	5200	21000	4	0	3	4	3	
Green River Summary													
(1)	54	11035477	109695	1860	4626647	72590	260810						2536
(2)			82915	1360	1572822	39250	223420	23	10	45	53	49	
(3)	23	2894941	70070	1500	1043160	70750	234360						2221
(4)			67900	1000	850000	39150	208860	18	4	20	22	20	
Kanab Creek 11													
(1)	2	367052	400	100	348067	0	2790						51
(2)			400	100	14000	0	2790	0	0	1	1	1	
(3)	1	179365	200	100	167580	0	2490						39
(4)			200	100	8000	0	2490	0	0	1	1	1	
Paria River 9													
(1)	2	666626	3130	0	659996	0	3830						49
(2)			3130	0	60400	0	3130	1	0	0	2	1	
(3)	1	67030	3130	0	60400	0	3130						41
(4)			3130	0	60400	0	3130	1	0	0	1	1	
San Juan River 8													
(1)	6	2207889	3392	200	314857	250	4042						165
(2)			1800	0	99357	0	0	4	0	3	5	4	
(3)	0	0											
(4)	0	0											
Montezuma Creek 8f													
(1)	4	752384	6090	15	375951	0	25040						482
(2)			5420	15	192246	0	23140	4	1	1	3	3	
(3)	1	209867	4205	15	153948	0	21220						147
(4)			4195	15	139746	0	21020	1	1	1	1	1	
Chinle Creek 8g													
(1)	1	59821	20	0	6000	3	20						10
(2)			0	0	0	0	0	0	0	0	0	0	
(3)	0	0											
(4)	0	0											
San Juan River 8 Summary													
(1)	11	3020094	9502	215	696808	253	29152						657
(2)			7220	15	291603	0	23140	8	1	6	8	7	
(3)	1	209867	4205	15	153948	0	21220						147
(4)			4185	15	139746	0	21020	1	1	1	1	1	
Virgin River 14													
(1)	11	1708605	37770	50	919557	0	28202						583
(2)			27700	50	252000	0	24629	5	2	9	10	9	
(3)	4	618737	29770	50	357557	0	24629						445
(4)			27700	50	252000	0	24629	2	2	4	4	4	
Fort Pierce Wash 14a													
(1)	1	10029	1200	0	10029	0	1200						5
(2)			1200	0	10029	0	1200	0	0	1	1	1	
(3)	1	10029	1200	0	10029	0	1200						5
(4)			1200	0	10029	0	1200	0	0	1	1	1	
Virgin River 14 Summary													
(1)	12	1718634	38970	50	929586	0	[illegible]						[illegible]
(2)			28900	50	262029	0	[illegible]	5	2	10	11	10	
(3)	5	628766	[illegible]	50	367586	0	[illegible]						[illegible]
(4)			28900	50	262029	0	[illegible]	2	2	5	5	5	
Colorado River Area Summary													
(1)	101	25871397	170597	3425	[illegible]	75983	[illegible]						4399
(2)			127165	2725	3208672	47090	[illegible]	67	15	78	93	70	
(3)	39	4886808	111855	2862	2340339	73250	315729						3259
(4)			107365	2365	1785075	41650	[illegible]	28	9	[illegible]	57	33	

TABLE [illegible] SUMMARY TABULATIONS OF TOTAL AND FEASIBLE WATERSHEDS (1967)

WATERSHED PROJECT PROBLEMS	TOTAL WATERSHEDS			FEASIBLE WATERSHEDS		
	ACRES	WITH PROBLEMS	NEED PROJECT ACTION	ACRES	WITH PROBLEMS	NEED PROJECT ACTION
Number of watersheds	221			116		
Area - acres	54,265,100			15,610,115		
Floodwater-sediment damage						
Agriculture		2,710,016	996,639		900,734	739,089
Urban		70,714	63,020		69,305	62,185
Erosion damage		21,262,282	7,076,142		7,319,934	5,062,190
Drainage		496,865	270,840		482,232	269,300
Cropland		220,593			218,951	
Pasture		267,615			254,727	
Irrigation		1,560,255	1,153,325		1,377,664	1,123,825
Rural water supply		106	115		80	36
Municipal and industrial		37	184		29	87
Recreation		169	52		99	17
Fish and wildlife		205	16		115	1
Water quality control		157	64		96	20

Table 45 B

[redacted] WATERSHED PROJECTS INVENTORY - 1967

INVENTORY OF WATERSHEDS INCLUDING THE KINDS AND EXTENT OF PROBLEMS NEEDING AND FEASIBLE FOR PROJECT ACTION

MAJOR DRAINAGE AREA PRINCIPAL DRAINAGE BASIN SUBBASINS	WATERSHEDS		KINDS AND EXTENT OF PROBLEMS											FARMS IN WS
			FLOOD PREVENTION			AGRICULTURAL WATER MANAGEMENT		NONAGRICULTURAL WATER MANAGEMENT						
			FLOODWATER AND SEDIMENT DAMAGE											
			AGRICULTURAL	URBAN	[illegible] DAMAGE	DRAINAGE	IRRIGATION	RURAL WATER SUPPLY	MUNICIPAL OR INDUSTRIAL WATER SUPPLY	RECREATIONAL DEVELOPMENT	FISH & WILDLIFE DEVELOPMENT	WATER QUALITY MANAGEMENT		
	NO.	ACRES	ACRES	ACRES	ACRES	ACRES	ACRES	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER		NUMBER
State of Utah Summary														
Watershed with prob (1)	221	54265100	2710016	70714	21262282	496945	1560255							21697
Needs proj action (2)			995639	63023	70751-2	2703-0	1153325	106	37	169	205	157		
Feasible WS with prob (3)	116	15610115	900734	69305	7319934	482232	1377664							19671
Suitable for proj action (4)			739089	62185	5062190	269300	1123825	80	29	99	115	96		
GREAT BASIN AREA														
Great Salt Lake Basin														
Great Salt Lake 1														
Watershed with prob (1)	15	12309582	1315000	4590	2552988	22830	72036							1063
Needs proj action (2)			273600	4205	750633	16200	40770	3	2	14	16	12		
Feasible WS with prob (3)	9	1339778	70900	3850	731333	20230	51316							891
Suitable for proj action (4)			69200	3830	495633	15200	37070	3	2	8	9	8		
Bear River 1a														
(1)	13	1867175	83188	2950	644698	139920	268165							3748
(2)			50258	2650	160480	78500	174455	9	6	10	12	12		
(3)	10	1389060	77683	2950	436691	134500	207165							3698
(4)			44985	2650	151480	78400	173455	9	6	8	10	10		
Bear Lake 1a1														
(1)	1	178626	500	0	60130	2700	6500							38
(2)			200	0	5000	0	5000	0	0	1	1	1		
(3)	1	178626	500	0	60130	2700	6500							38
(4)			200	0	5000	0	5000	0	0.	1	1	1		
Third Order 1a Summary														
(1)	14	2045801	83688	2950	704828	142620	274665							3786
(2)			50488	2650	165480	78500	179455	9	6	11	13	13		
(3)	11	1567686	78183	2950	496821	137200	213665							3736
(4)			45188	2650	156480	78400	178455	9	6	9	11	11		
Weber River 1b														
(1)	10	1469963	60217	4930	1047935	59550	160443							2223
(2)			57767	4750	678369	53400	109330	9	1	10	10	10		
(3)	8	1280681	57917	4850	892543	59450	153693							2100
(4)			56467	4650	643369	53400	103030	7	1	8	8	8		
Jordan River 1c														
(1)	16	1947324	226845	40205	929427	76206	206690							5032
(2)			181730	38205	728227	52650	161840	11	5	14	15	13		
(3)	14	1723434	224545	40205	814327	76206	206390							5017
(4)			181430	38205	663127	52650	161450	11	5	13	14	12		
Provo River 1c1														
(1)	3	468323	44831	8200	293636	14700	48211							971
(2)			33831	8200	81876	7600	45942	3	1	3	3	3		
(3)	3	468323	44831	8200	293636	14700	48211							971
(4)			33831	8200	81876	7600	45942	3	1	3	3	3		
Third Order 1c Summary														
(1)	19	2415647	271676	48405	1223063	90906	254901							6003
(2)			215561	44405	810103	60250	207782	14	6	17	18	10		
(3)	17	2191757	269376	48405	1107963	90906	254601							5988
(4)			215261	44405	745003	60250	207482	14	6	16	17	15		
Great Salt Lake Basin Summary														
(1)	61	17940993	1730581	60895	5528814	315926	752045							13075
(2)			597416	56010	2404585	208350	537337	35	15	52	57	51		
(3)	45	6379902	476381	60055	3228760	307756	673275							12715
(4)			366116	55535	2040485	207250	531037	33	15	41	45	42		
Sevier Lake Basin														
Sevier Lake Basin 2														
(1)	1	1145273	235000	0	275000	0	400	0	0	0	1	0		1
(2)	0	0	0	0	0	0	0	0	0	0	0	0		
(3)	0	0												
(4)	0	0												
Sevier River 2a														
(1)	25	3664360	404798	3545	1432676	75996	249040							2396
(2)			224648	3545	360529	10100	197014	12	3	16	24	13		
(3)	17	2210395	255868	3545	6980-9	78996	241320							2259
(4)			224648	3545	360529	10100	197014	9	2	11	17	10		
East Fork Sevier River 2a1														
(1)	5	792670	4410	0	348263	3680	15140							107
(2)			50	0	78670	0	0	1	0	4	5	2		
(3)	1	78670	50	0	78670	0	0							5
(4)			50	0	78670	0	0	0	0	1	1	1		
So Fork Sevier River 2a2														
(1)	5	721000	3230	0	331500	1200	21780							280
(2)			2930	0	313000	200	13600	3	0	3	5	5		
(3)	4	650500	2230	0	301500	1200	20580							255
(4)			1930	0	238000	200	18400	3	0	3	4	4		
San Pitch River 2a3														
(1)	4	429050	27400	2500	203180	20500	71890							638
(2)			12950	400	74240	10100	48000	3	1	4	4	3		
(3)	4	429050	27400	2500	203180	20500	71890							638
(4)			12950	400	74240	10100	48000	3	1	4	4	3		
Third Order 2a Summary														
(1)	39	5607080	439838	6045	2315619	104376	359030							3-21
(2)			240578	3945	831-39	20400	264614	19	4	27	38	23		
(3)	26	3368615	285568	6045	1281399	100696	333790							3167
(4)			239578	3945	801-39	20400	263414	15	3	19	26	18		

Table 45 Continued

[redacted] WATERSHED PROJECTS INVENTORY - 1967

INVENTORY OF WATERSHEDS INCLUDING THE KINDS AND EXTENT OF PROBLEMS NEEDING AND FEASIBLE FOR PROJECT ACTION

MAJOR DRAINAGE AREA PRINCIPAL DRAINAGE BASIN SUBBASINS	WATERSHEDS		KIND AND EXTENT OF PROBLEMS										FARMS IN WS
			FLOOD PREVENTION			AGRICULTURAL WATER MANAGEMENT		NONAGRICULTURAL WATER MANAGEMENT					
			FLOODWATER AND SEDIMENT DAMAGE		EROSION DAMAGE	DRAINAGE	IRRIGATION	RURAL WATER SUPPLY	MUNICIPAL OR INDUSTRIAL WATER SUPPLY	RECREATIONAL DEVELOPMENT	FISH & WILDLIFE DEVELOPMENT	WATER QUALITY MANAGEMENT	
			AGRICULTURAL	URBAN									
	NO.	ACRES	ACRES	ACRES	ACRES	ACRES	ACRES	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER
GREAT BASIN AREA													
Beaver River 2b													
Watershed with prob (1)	7	1453644	108330	349	569766	500	36430						306
Needs proj action (2)			6530	340	310041	0	19495	1	1	2	5	0	
Feasible WS with prob (3)	2	444859	7130	340	281186	500	33070						277
Suitable for proj action (4)			6230	340	247041	0	18045	1	0	2	2	0	
Cedar Valley 2b1													
(1)	6	694888	18000	0	174680	0	18200						210
(2)			18000	0	174680	0	16700	1	1	5	5	1	
(3)	2	212259	15000	0	101000	0	15000						154
(4)			15000	0	101000	0	15000	1	1	1	2	1	
Escalante Desert 2b2													
(1)	5	1456902	7150	0	259225	0	22150						279
(2)			6950	0	146725	0	6950	2	1	4	5	2	
(3)	3	317672	4800	0	87150	0	6800						89
(4)			4800	0	87150	0	6800	2	1	2	3	2	
Third Order 2b Summary													
(1)	18	3605434	133480	349	1003671	500	76780						795
(2)			31480	340	631446	0	43135	4	3	11	15	3	
(3)	7	974790	26930	340	469336	500	54670						520
(4)			26930	340	435191	0	39845	4	2	5	7	3	
Sevier Lake Basin Summary													
(1)	58	10357787	809318	6394	3594290	104876	435230						4217
(2)			272058	4285	1462855	20400	307749	23	7	38	54	26	
(3)	33	4363405	312498	6385	1750735	101196	388660						3687
(4)			265608	4285	1236630	20400	303259	19	5	24	33	21	
Great Basin Area Summary													
(1)	119	28298780	2538899	67289	9123104	420782	1197275						17292
(2)			869474	60295	3867470	228750	845086	58	22	90	111	77	
(3)	78	10723307	788879	66440	4979495	403982	1061935						16402
(4)			631724	59820	3277115	227650	834296	52	20	65	78	63	
COLUMBIA RIVER AREA													
Raft River 14g													
(1)	1	92923	220	0	6500	100	1900						16
(2)			0	0	0	0	0	1	0	1	1	1	
(3)	0	0											
(4)	0	0											
COLORADO RIVER AREA													
Colorado River Main Stem 0													
(1)	7	4934957	1600	1200	1824037	1000	4100						113
(2)			400	1200	29000	1000	800	2	1	3	5	2	
(3)	1	94247	600	1200	45000	1000	1300						50
(4)			400	1200	20000	1000	800	1	1	1	1	1	
Dirty Devil River 6													
(1)	9	2823898	6550	0	1688112	2140	27126						314
(2)			3250	0	695818	1840	25330	6	1	9	9	8	
(3)	3	454823	1800	0	218765	1500	23600						256
(4)			1700	0	160900	1500	23600	3	1	3	3	3	
Escalante River 7													
(1)	4	1306659	950	0	1159425	0	3870						76
(2)			950	0	284000	0	3800	2	0	4	4	1	
(3)	3	357769	950	0	284000	0	3800						65
(4)			950	0	284000	0	3800	2	0	3	3	1	
Green River Main Stem 5													
(1)	14	4079044	21280	900	1277910	10350	61760						748
(2)			16970	400	219000	5750	52160	6	3	12	14	14	
(3)	4	561122	13950	700	89500	9150	48900						588
(4)			13250	200	59100	5750	48900	4	1	3	4	4	
Blacks Fork River 5c													
(1)	2	152480	26000	0	10000	0	0						0
(2)			5900	0	5600	0	0	0	0	2	2	2	
(3)	0	0											
(4)	0	0											
Duchesne River 5f													
(1)	8	1075838	5225	0	135900	13100	55460						353
(2)			4275	0	84300	6600	52460	4	0	5	7	6	
(3)	4	471574	4400	0	46800	13000	52160						301
(4)			3450	0	25300	6500	49160	3	0	3	3	3	
Strawberry River 5f1													
(1)	4	742604	670	0	194151	0	2540						34
(2)			370	0	136151	0	2700	1	0	3	4	4	
(3)	0	0											
(4)	0	0											
Uintah River 5f2													
(1)	5	681225	1050	20	50000	34500	71000						495
(2)			700	20	30000	14000	69000	4	0	5	5	5	
(3)	4	545343	1050	20	45000	34500	71000						495
(4)			700	20	28000	14000	69000	4	0	4	4	4	

Table 45 Continued

[redacted] WATERSHED PROJECTS INVENTORY - 1967

INVENTORY OF WATERSHEDS INCLUDING THE KINDS AND EXTENT OF PROBLEMS NEEDING AND FEASIBLE FOR PROJECT ACTION

MAJOR DRAINAGE AREA PRINCIPAL DRAINAGE BASIN SUBBASINS	WATERSHEDS		KIND AND EXTENT OF PROBLEMS: FLOOD PREVENTION: FLOODWATER AND SEDIMENT DAMAGE			AGRICULTURAL WATER MANAGEMENT		NONAGRICULTURAL WATER MANAGEMENT					FARMS IN WS
			AGRICULTURAL	URBAN	EROSION DAMAGE	DRAINAGE	IRRIGATION	RURAL WATER SUPPLY	MUNICIPAL OR INDUSTRIAL WATER SUPPLY	RECREATIONAL DEVELOPMENT	FISH & WILDLIFE DEVELOPMENT	WATER QUALITY MANAGEMENT	
	NO.	ACRES	ACRES	ACRES	ACRES	ACRES	ACRES	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER
COLORADO RIVER AREA													
Third Order 5f Summary													
Watershed with prob (1)	17	2499667	6945	20	369951	47500	129300						882
Needs proj action (2)			5345	20	250451	20400	124160	9	0	13	16	15	
Feasible WS with prob (3)	8	1016917	5450	20	91800	47500	123160						796
Suitable for proj action (4)			4150	20	53300	20500	118160	7	0	7	7	7	
White River 5g													
(1)	3	928922	1300	0	634171	40	450						3
(2)			1000	0	288171	0	0	1	2	2	3	3	
(3)	0	0											
(4)	0	0											
Willow Creek 5h													
(1)	3	612989	1100	0	216000	100	3800						17
(2)			900	0	37000	0	3300	0	0	2	3	3	
(3)	0	0											
(4)	0	0											
Price River 5i													
(1)	10	1218783	33320	840	784326	9100	32000						552
(2)			33200	840	359200	7700	22800	3	5	10	10	8	
(3)	7	651391	30920	680	405650	8900	28800						503
(4)			30900	680	323200	7700	20800	3	3	7	7	6	
San Rafael River 5j													
(1)	5	1543592	19750	100	1334291	5200	33500						334
(2)			19600	100	414400	5200	21000	4	0	4	5	4	
(3)	4	665511	19750	100	456210	5200	33500						334
(4)			19600	100	414400	5200	21000	4	0	3	4	3	
Green River Summary													
(1)	54	11035477	109695	1860	4526647	72590	260810						2536
(2)			82915	1360	1572822	39250	223420	23	10	45	53	49	
(3)	23	2894941	70070	1500	1043160	70750	234360						2221
(4)			67900	1000	850000	39150	208860	18	4	20	22	20	
Kanab Creek 11													
(1)	2	367052	400	100	348067	0	2790						51
(2)			400	100	14000	0	2790	0	0	1	1	1	
(3)	1	179365	200	100	167580	0	2490						39
(4)			200	100	8000	0	2490	0	0	1	1	1	
Paria River 9													
(1)	2	666626	3130	0	659996	0	3630						49
(2)			3130	0	60400	0	3130	1	0	0	2	1	
(3)	1	67030	3130	0	60400	0	3130						41
(4)			3130	0	60400	0	3130	1	0	0	1	1	
San Juan River 8													
(1)	6	2207889	3392	200	314857	250	4042						165
(2)			1800	0	99357	0	0	4	0	3	5	4	
(3)	0	0											
(4)	0	0											
Montezuma Creek 8f													
(1)	4	752384	6090	15	375951	0	25090						482
(2)			5420	15	192246	0	23140	4	1	3	3	3	
(3)	1	209867	4205	15	153948	0	21220						147
(4)			4185	15	139746	0	21020	1	1	1	1	1	
Chinle Creek 8g													
(1)	1	59821	20	0	6000	3	20						10
(2)			0	0	0	0	0	0	0	0	0	0	
(3)	0	0											
(4)	0	0											
San Juan River 8 Summary													
(1)	11	3020094	9502	215	696808	253	29152						657
(2)			7220	15	291603	0	23140	8	1	6	8	7	
(3)	1	209867	4205	15	153948	0	21220						147
(4)			4185	15	139746	0	21020	1	1	1	1	1	
Virgin River 14													
(1)	11	1708605	37770	50	919557	0	28202						588
(2)			27700	50	252000	0	24629	5	2	9	10	9	
(3)	4	618737	29770	50	357557	0	24629						445
(4)			27700	50	252000	0	24629	2	2	4	4	4	
Fort Pierce Wash 14a													
(1)	1	10029	1200	0	10029	0	1200						5
(2)			1200	0	10029	0	1200	0	0	1	1	1	
(3)	1	10029	1200	0	10029	0	1200						5
(4)			1200	0	10029	0	1200	0	0	1	1	1	
Virgin River 14 Summary													
(1)	12	1718634	38970	50	929586	0	29402						593
(2)			28900	50	262029	0	25829	5	2	10	11	10	
(3)	5	628766	30900	50	367586	0	25829						450
(4)			28900	50	262029	0	25829	2	2	5	5	5	
Colorado River Area Summary													
(1)	101	25873397	170897	3625	12132678	75983	361080						4359
(2)			127165	2725	3208672	42090	308239	47	15	78	93	79	
(3)	38	4886808	111855	2365	2340439	73250	315729						3209
(4)			107365	2363	1785075	41650	289329	28	9	34	37	33	

TABLE 45 WATERSHEDS PROJECTS INVENTORY

MAJOR DRAINAGE AREAS PRINCIPAL DRAINAGE BASINS SUBBASINS	SUBBASIN NUMBER	LAND AND WATER AREA (ACREAGE)
Colorado River Area		25,873,397
Colorado River Basin	(0)	4,934,957
Dirty Devil River	(6)	2,823,898
Escalante River	(7)	1,306,659
Green River Basin		11,035,477
Green River	(5)	4,079,044
Blacks Fork River	(5c)	152,480
Duchesne River	(5f)	1,075,838
Strawberry River	(5f1)	742,604
Uintah River	(5f2)	681,225
White River	(5g)	928,922
Willow Creek	(5h)	612,989
Price River	(5i)	1,218,783
San Rafael River	(5j)	1,543,592
Kanab Creek	(11)	367,052
Paria River	(9)	666,626
San Juan River Basin		3,020,094
San Juan River	(8)	2,207,889
Montezuma Creek	(8f)	752,384
Chinle Creek	(8g)	59,821
Virgin River Basin		1,718,634
Virgin River	(14)	1,708,605
Fort Pierce Wash	(14a)	10,029
Columbia River Area		92,923
Snake River Basin		92,923
Raft River	(14g)	92,923
Great Basin Area		28,298,780
Great Salt Lake Basin		17,940,993
Great Salt Lake	(1)	12,009,582
Bear River	(1a)	1,867,175
Bear Lake	(1a1)	178,626
Weber River	(1b)	1,469,963
Jordan River	(1c)	1,947,324
Provo River	(1c1)	468,323
Sevier Lake Basin		10,357,787
Sevier Lake Basin	(2)	1,145,273
Sevier River	(2a)	3,364,360
East Fork Sevier River	(2a1)	792,670
South Fork Sevier River	(2a2)	721,000
San Pitch River	(2a3)	429,050
Beaver River	(2b)	1,453,644
Cedar Valley	(2b1)	694,888
Escalante Desert	(2b2)	1,456,902
UTAH TOTAL		54,265,100

TABLE 47 SUMMARY TABULATIONS OF TOTAL AND FEASIBLE WATERSHEDS (1967)

WATERSHED PROJECT PROBLEMS	TOTAL WATERSHEDS			FEASIBLE WATERSHEDS		
	ACRES	WITH PROBLEMS	NEED PROJECT ACTION	ACRES	WITH PROBLEMS	NEED PROJECT ACTION
Number of watersheds	221			116		
Area - acres	54,265,100			15,610,115		
Floodwater-sediment damage						
Agriculture		2,710,016	996,639		900,734	739,089
Urban		70,714	63,020		69,305	62,185
Erosion damage		21,262,282	7,076,142		7,319,934	5,062,190
Drainage		496,865	270,840		482,232	269,300
Cropland		220,593			218,951	
Pasture		267,615			254,727	
Irrigation		1,560,255	1,153,325		1,377,664	1,123,825
Rural water supply		106	115		80	36
Municipal and industrial		37	184		29	87
Recreation		169	52		99	17
Fish and wildlife		205	16		115	1
Water quality control		157	64		96	20

SOUTH DAKOTA

Introduction

In preparation of the South Dakota Conservation Needs Inventory, the affect of various environmental factors, and the potential uses of land and water resources for different purposes, were given consideration in estimating feasible land use and conservation treatment needs.

The advance in production technology and increases in yields of farm products has been very evident in the last decade. This advance is expected to continue at a similar rate to 1980. In South Dakota there will continue to be an export of the farm products to other areas. The demand-supply situation will mean that average prices will stay close to the 1961-65 average. The continued increase in production cost of farm products, with prices remaining at the average levels noted above, will create a tendency for more intensive use of the land and water resources. It is also expected that there will be some shift from range to cropland use on the better soils in western counties of the state. The landowners, generally, are concerned about highly damaging practices brought about by this intensive use. Therefore, they have adopted a conservation concept which will, with acceleration of needed treatment, provide protection to the basic resources.

The amount of additional land required for recreational use during the next decade is not expected to significantly reduce the acreages now in cropland or pasture and range. Most of the expected increase of about 17,000 acres would come on land presently in woodland or grasslands adjacent to water areas.

Inventory and Non-Inventory

The 1976 Conservation Needs Inventory lists a total land area of 48,611,904. The land area as reported in the 1960 Census of Agriculture for each county was used as the basic land area for the county. The land areas given in the 1960 Census were adjusted to the 1964 Census data to exclude areas inundated since

1959 by the construction of new lakes and reservoirs of 40 acres, or more, in size. Most of this adjustment occurred in counties adjacent to Oahe and Fort Randall (Lake Francis Case) Reservoirs. It does not include lands flooded by the Big Bend Reservoir (Lake Sharpe).

The total land area consists of two principal parts, namely, inventory and non-inventory acres. These are further broken down into several principal categories, or uses, as shown in Figure 26.

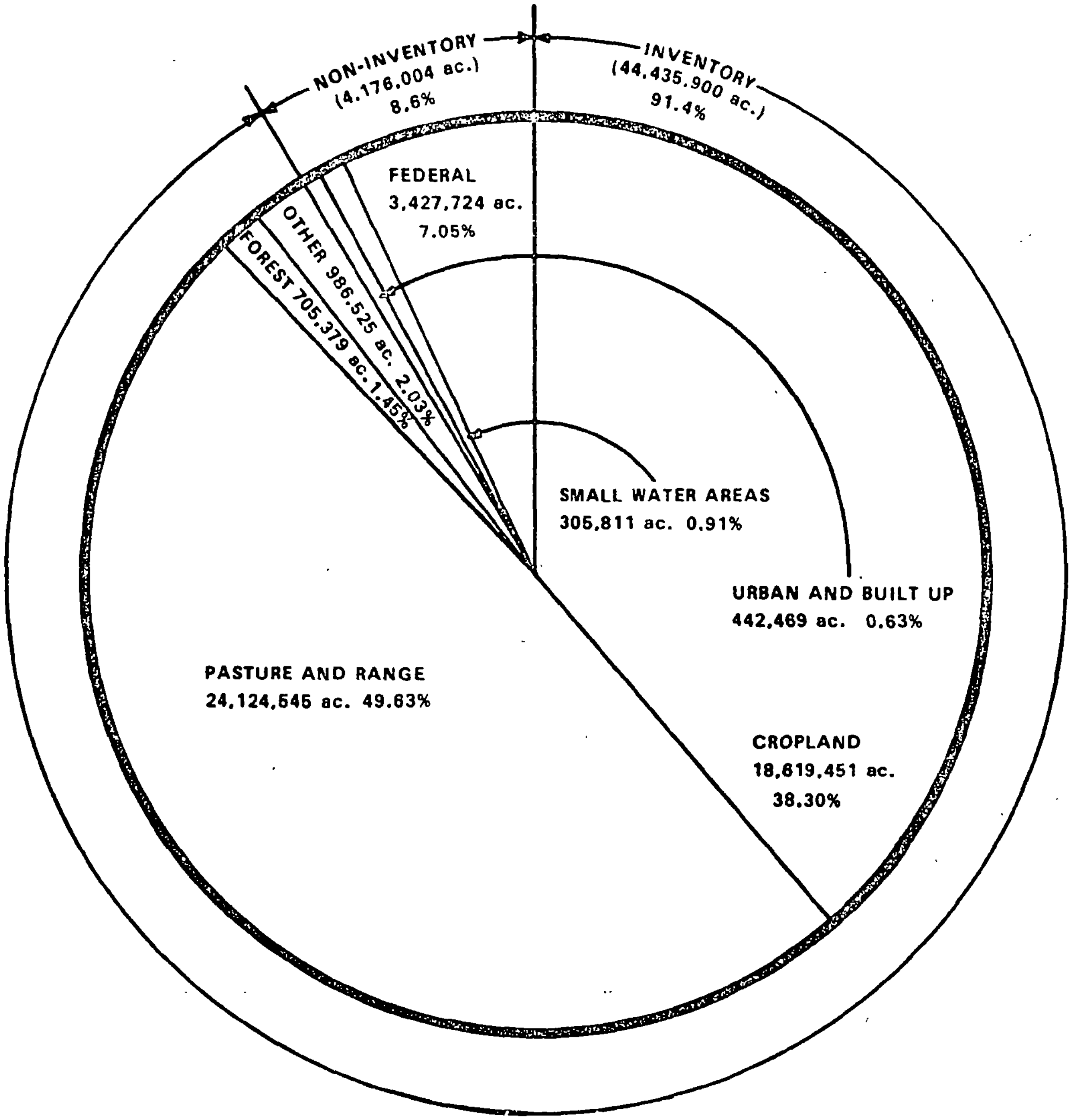


Figure 26.

INVENTORY AND NON-INVENTORY ACRES OF SOUTH DAKOTA 1967

From 1958 to 1967 there have been changes in inventory and non-inventory acres which are of special interest. Federal land has increased by 172,979 acres. Water areas of over 2 acres and less than 40 acres in size have accounted for a reduction of 28,167 acres in land area. Urbanization has taken 43,366 acres out of inventory and mainly out of agricultural use. The total of these, 244,512 acres, represents the increase in non-inventory since 1958. There has also been a reduction of 270,288 acres in land area due, primarily, to an increase in water areas larger than 40 acres. Most of this, according to United States Census figures, is the result of the impoundments on the Missouri River.

Land Use

The changes in use of inventory acres from 1958 to 1967 are illustrated in Figure 27.

The Inventory shows an increase of about 1.5 million acres in cropland since 1958. This is accounted for, in part, by the inclusion of wild hay as cropland in this inventory as contrasted to acres in range and pasture in the 1958 Inventory.

A review of counties shows that the cropland increase from 1958 to 1967 is most significant in the Central and West River area because of the inclusion of wild hay as cropland and the breaking up of some grassland on the better soils. The increase in cropland is primarily reflected in a reduction of pasture and range.

The Inventory shows 170,666 acres of irrigated cropland in the state. This is based on figures from 41 counties having about 200, or more, acres irrigated. Most of this acreage is accounted for in several of the West River counties where the Belle Fourche and Angostura Irrigation Projects are located. The central and southeastern parts of the state show quite an increase in irrigation during the past ten years.

There has been a reduction from 26,699,134 acres of pasture and range in 1958 to 24,124,545 acres in 1967. This is due, primarily, to the changes noted under cropland. However, in some counties, notably Shannon and Washabaugh, with a large acreage of barren badlands reported as range in the 1958 Inventory, much of this was shifted to "Other" land in the 1967 Inventory as it was considered to more appropriately fall into this use.

The Inventory shows 705,379 acres of forest land. This is commercial, consisting of 562,477 acres and non-commercial, 142,902 acres. Most of the commercial forest is found in the Black Hills area. The area of forest land, by counties, in the state is based on information provided by the United States Forest Service.

There 986,525 acres of "Other" land in this Inventory as contrasted to 566,175 acres in 1958. It varies quite widely by counties. Those having a significant amount in relationship to the 1958 Inventory were those where specific shifts were made as noted under pasture and range, or some other factor. This latter group included several counties where the State of South Dakota has made purchases of land for the purpose of retaining wetland areas for wildlife purposes.

Land Treatment

The Conservation Treatment Needs portion of the Inventory indicates that on all cropland, 47.4 percent, or nearly nine million acres, are adequately treated. The principal needs still to be accomplished on the dry cropland are for the more intensive treatments. These are: Sod in rotation, strip cropping, terracing, and diversions.

On the irrigated cropland, about 29,000 acres are adequately treated. Treatments needed are for cultural management practices, improvement of the systems, and for water management.

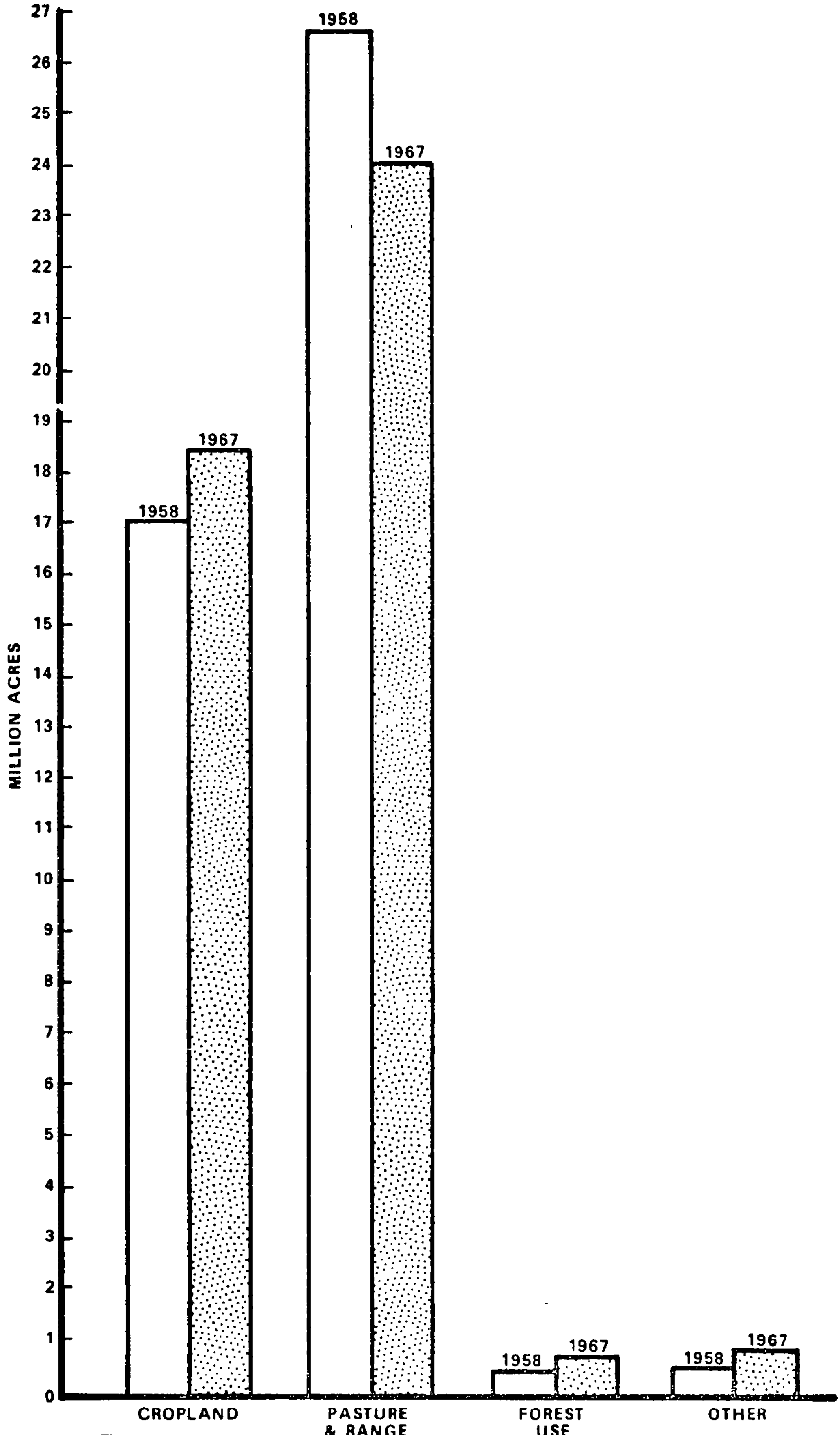
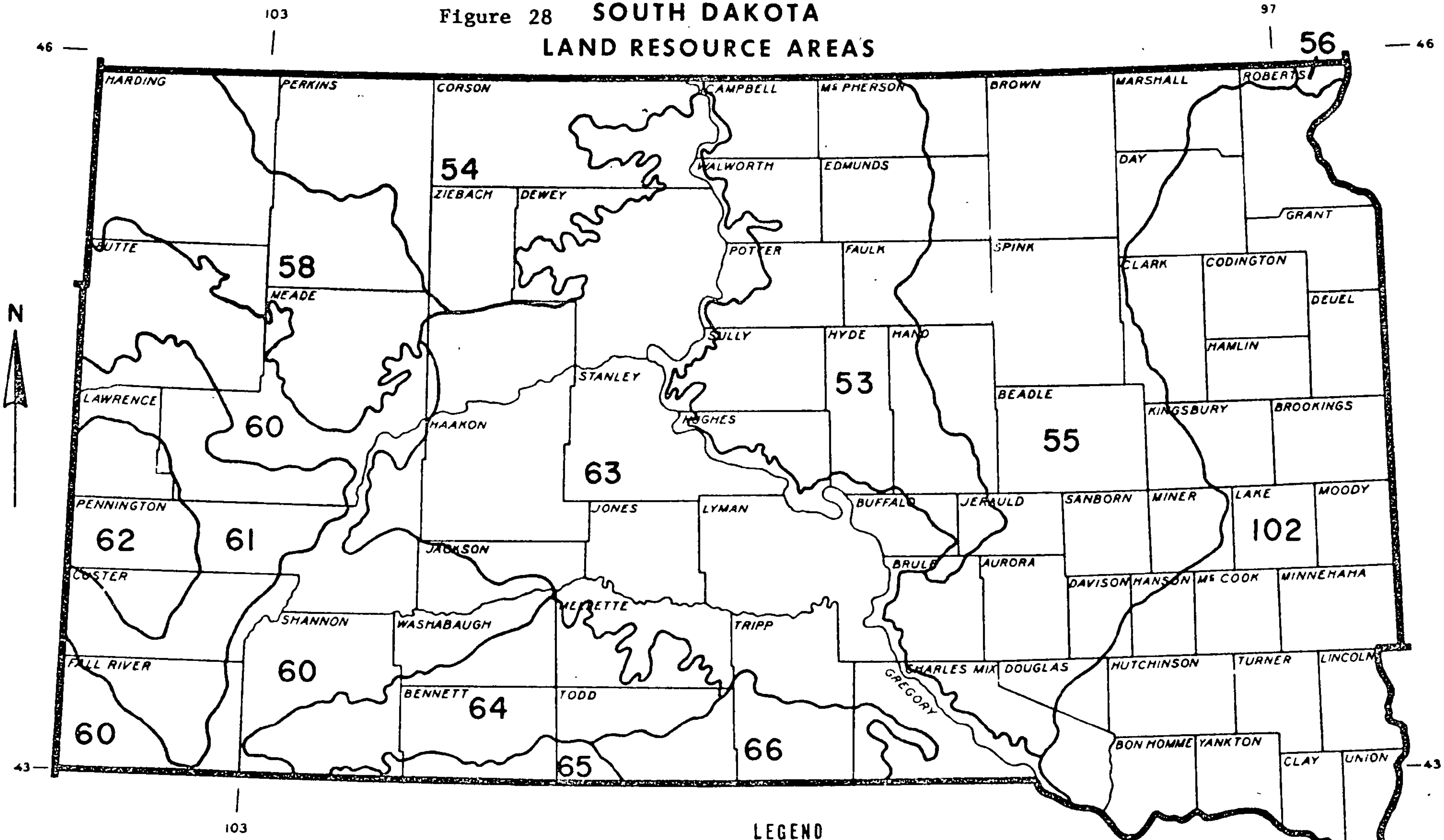


Figure 27.

USE OF INVENTORY ACREAGE IN 1958 AND 1967

Figure 28 SOUTH DAKOTA
LAND RESOURCE AREAS



LEGEND

Scale 1/2,700,000

Scale 0 10 20 30 40 50 Miles

ALBERS EQUAL AREA PROJECTION

53 Dark Brown Glaciated Plain
54 Rolling Soft Shale Plain
55 Black Glaciated Plains
56 Red River Valley of the North
58 Northern Rolling High Plains
60 Pierre Shale Plains and Badlands
61 Black Hills Footslopes
62 Black Hills
63 Rolling Pierre Shale Plains
64 Mixed Sandy and Silty Tableland
65 Nebraska Sand Hills
66 Dakota-Nebraska Eroded Tableland
102 Loess, Till, and Sandy Prairies

SOURCE: Soils Memorandum SCS-49, National Resource Map, January, 1963.

USDA SCS LINCOLN NEBR 1970

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The Pasture and Range Inventory shows that about 38 percent is adequately treated. Protection is needed on over 12 million acres and improvement only is needed on 1.6 million acres.

On the Forest land, about 55 percent is still in need of treatment. The greatest treatment need is for timber stand improvement on about 300,000 acres. There are about 631,500 acres of forest land grazed and 287,801 acres of this shows a need for reduction or elimination of grazing as a major treatment.

On Other land, only 266,393 acres, or 27 percent, shows a need for treatment. This is due, in part, to the fact that the conservation treatment applied on the adjacent lands will provide needed protection to the Other land area. Also, some areas in the Badlands are considered not feasible to treat.

Major Land Resource Areas

A land resource area is a geographic area of land characterized by a particular combination or pattern of soils (including slope and erosion), climate, water resources, land use, and types of farming. The map and descriptions give us in brief form data on soil and resources. Similar soils in a land resource area have similar interpretations of capability and treatment needs.

A map of such scale is used in general planning between counties or statewide, but it omits many details of great local significance.

Loess, Till, and Sandy Prairies (102) the largest resource area in South Dakota, is located along the eastern portion and comprises about 18 percent of the state. Ground water of fair to good quality is available along outwash areas and streams, but is scarce in glacial till areas. Many permanent and intermittent lakes and ponds are important sources of water for livestock and recreation.

Seventy-five to 90 percent of the soils are used for cropland. Wheat and other small grains are the major crops in the north with corn, soybeans, and small grains grown in the southern part. Water and wind erosion control practices are needed on sloping or sandy areas.

The soils in this land resource area are well adapted to cropland or grassland. They have none to moderate limitations for building sites, urban development and recreation development.

Dark Brown Glaciated Plain (53) is located in the central portion of the state east of the Missouri River, and comprises about 10 percent of the state. Groundwater of fair to good quality is available in some of the glacial drift area, glacial outwash areas and streams. Irrigation water is available from the Oahe Reservoir of the Missouri River. Irrigation is expected to develop rapidly on the suitable soils adjacent to the Reservoir.

The percentage of cropland in the various counties in this land resource area ranges from about 40 to 65 percent. Wheat, oats, and flax are the major crops along with corn, silage, and alfalfa hay. Because rainfall is low and erratic, conservation of moisture is essential. Moisture conservation practices, along with wind erosion control, is needed on all cropland areas and water erosion control on sloping areas. Fertility maintenance is necessary to maintain adequate yields.

The soils in this land resource area are mostly well adapted to cropland or grassland. They have only slight to moderate limitations for building sites, urban development, and recreation development.

Rolling Soft Shale Plain (54) is west of the Missouri River adjacent to the North Dakota-South Dakota boundary, and it makes up about 7 percent of the state.

Nearly all the land is in farms and ranches. Less than one-fourth of the land is used for cropland. The principal crops grown are spring wheat, oats, feed grains, and hay. Rangeland is the principal land use. The principal limiting factor to agriculture in this land resource area is the lack of moisture. Farming methods that make the most efficient use of moisture are required. Wind erosion is a serious hazard on sandy areas in cropland. Moisture conservation practices, fertility maintenance, and wind erosion control practices are needed management practices. The more gentle slopes of the sandy and loamy soils have moderate to severe limitations of urban development or building sites while the steep slopes and thin claypan soils have severe limitations.

Black Glaciated Plains (55) occupy the east central portion and comprise about 16 percent of the state. Groundwater of fair to good quality is available along glacial outwash areas and streams, but the water from aquifers in the glacial drift is often highly mineralized. The soils are used almost entirely for dryland agriculture with a few scattered irrigation systems. It is expected that irrigation will rapidly develop with a delivery system of irrigation waters from the Oahe Reservoir. The percentage of cropland in the various counties of this area ranges from about 25 to 50 percent. Spring wheat and other small grains are the principal crops in the north while corn, sorghum, and winter wheat are grown mostly in the southern portion. Moisture conservation practices along with wind and water erosion control are the most important management needs. Some of the saline or clayey soils will affect the choice of crops. The soils in this land resource area are generally well suited to cropland or grassland. The silty and loamy soils have only slight to moderate limitations for building sites and urban development.

Red River Valley of the North (56) is mostly in North Dakota and Minnesota and occupies less than one percent of South Dakota in the northeast corner of the state. Ground water of fair to good quality is available.

Most of the soils are used for cropland. Spring wheat, flax and other small grains are the principal crops. Wind erosion control practices are needed on cropland.

The soils in this land resource area are well adapted to cropland or grassland. They have none to moderate limitations for building sites, urban development, and recreation development.

Northern Rolling High Plains (58) in the northwester portion make up about seven percent of the state. Groundwater is not available except in local sandy or gravelly areas and alluvium along drainageways. Water for livestock is stored in small reservoirs.

The land use is almost entirely for rangeland except locally on deep loamy soils. Some small grains and alfalfa are grown on these areas. The low rainfall and undesirable soil characteristics result in limited agricultural production. Barren, salty spots are common in the claypan soils. Good management practices of moisture conservation are necessary to maintain cover so water erosion and sedimentation are kept under control.

Most of these soils have severe to very severe limitations for building sites, recreation or urban uses. The impermeable subsoils and substratum severely limits the use for septic tank disposal fields. Minor areas of deep, sandy and loamy soils developing in alluvium along drainageways and sandy upland areas have only slight to moderate limitations for these uses.

Pierre Shale Plains and Badlands (60) comprise about nine percent of the state. Ground water is not available except in local areas of sandy or gravelly soils. Small reservoirs and a few artesian wells provide most of the water for livestock.

The land is used mostly for rangeland, but some of the gentler slopes are cultivated for production of small grains, alfalfa, and sorghum. The physical nature of these soils is such that water erosion and sedimentation are severe hazards. Low rainfall is the limiting factor for yields of grasses and cropland. Moisture conservation practices are necessary. The soils have severe to moderate limitations for recreational purposes, camp sites, roads or urban development. The drainageways dissecting the soil areas give only slight or moderate limitations for wildlife habitat. The rugged landscape of the badlands area furnishes a favorite tourist attraction as well as a panorama of geologic history. Soils and topography in the badlands have severe limitations for agricultural use, building sites, or urban development.

Black Hills Footslopes (61) land resource area makes up about five percent of the state. Artesian water is available in part of this area from underlying limestone beds that furnish good quality water. Streamflow provides water for livestock, while reservoirs on a few of the major rivers provide water for irrigation.

The major part of this land resource area is under private ownership and is used principally for rangeland. Part is owned by the state and federal government and is used for recreational purposes. Wooded areas occur on north facing slopes and in many of the deep ravines. Water erosion and sedimentation are severe hazards on these soils. Rangeland management is essential for water erosion control and stabilization of gullies.

The steep slopes and shallow soils have severe to moderate limitations for building sites or urban development. However, much of the area is scenic and has desirable features for use for recreational facilities and wildlife habitat.

Black Hills (62) area makes up about two percent of the state. The natural springs and streams in the narrow stream valleys furnish water for livestock and recreational purposes.

Much of this resource area is owned by the state and federal government and is a part of the Black Hills National Forest. The rugged topography and geologic variation has resulted in this being an established park and recreation area. Management is necessary to prevent water erosion and sedimentation, and to maintain woodland cover.

Rolling Pierre Shale Plains (63) is located in the central part of the state west of the Missouri River and comprises about 18 percent of the state. Ground water is scarce and of poor quality except in some local sandy and gravelly areas. Water for livestock is stored in farm ponds and small reservoirs. The percent of cropland in the various counties ranges from about 50 percent in Tripp

County to about 15 percent in counties to the north. The principal crops grown are winter wheat and milo. Water erosion and sedimentation are severe hazards on cropland. The land use is mostly rangeland and moisture conservation practices are necessary.

The soils have severe to moderate limitations for recreational purposes, campsites, roads, or urban development.

Mixed, Sandy and Silty Tableland (64) is in the south-central part of the state and makes up about four percent of the state. Ground water is scarce and of poor quality in most of the area; locally, sands and gravels yield moderate to large amounts of good water.

About 75 percent of the land is used for rangeland. The principal dryland crops grown are oats, winter wheat, barley and alfalfa. Water erosion and sedimentation are severe hazards on cropland. Wind erosion is also a significant hazard on cropland and rangeland if an adequate vegetative cover is not maintained. Moisture conservation is essential for dryland farming in this resource area.

The deep, silty upland soils only have slight to moderate limitations for urban and recreational development. The steeper areas have moderate to severe limitations for most uses.

Nebraska Sandhills (65) in the southwestern part of the state adjoining Nebraska makes up less than one percent of the state. Groundwater is abundant and of good quality to meet domestic requirements and part of the livestock and other needs. Wind erosion is the principal problem of the area on both the rangeland and on the small amount of cropland. The loose, sandy, soils are not suited for building sites or urban development.

Dakota-Nebraska Eroded Tableland (66) is located in south-central South Dakota and comprises about two percent of the state. Groundwater is scarce and of poor quality except along the southern fringe where an abundance of groundwater is available in the very sandy soils.

About 75 percent of the soils are used for rangeland. On the cropland, winter wheat, other small grains, and sorghums are the principal crops. Wind erosion is a severe hazard on cropland. Poor waterholding capacity and low rainfall make these soils droughty. Rangeland needs management for moisture conservation, wind erosion control, and fertility maintenance.

These soils have slight to moderate limitations for rangeland and wildlife. They graduate to severe limitations for urban, recreation, and camping areas.

Watershed Inventory - Problems and Needs

The Watershed Project Needs Inventory provides data for the number and acreage of all watersheds delineated. This data indicates that there were 449 such watersheds. Of these, 205 indicated project feasibility.

Figure 30 provides diagrammed information for the watersheds as to project feasibility and the kinds and extent of problems requiring project action.

Significant watershed problems often exist which cannot be solved adequately or in a timely manner with assistance available to local people or other federal programs but which can be solved or alleviated by assistance authorized under the Watershed and Flood Prevention Act (PL 566). These watershed problems are considered to be those which affect and require action for their solution by groups of landowners, communities, and the general public through cooperation of local, state, and federal governments.

Si-nificant watershed problems are those which require installation of such measures as floodwater retarding structures, levees, floodways, irrigation and drainage improvements, recreation or fish and wildlife development, municipal and industrial water supply, other water management measures, and those for stabilization, and revegetation of critical runoff and sediment producing areas.

Four hundred and forty-nine watersheds covereing 49,662,392 acres were evaluated. This acreage is greater than that given for the total land area of the state because parts of several watersheds evaluated crossed into adjacent states and this area is also included in the total watershed inventory acreage. The potential feasibility of each watershed for project development has been estimated giving consideration to both physical and economic conditions.

The watershed project inventory shows there are 205 feasible watershed projects covering 23,008,941 acres. Floodwater and sediment damages are problems needing project action on 1,232,764 acres of agricultural land and 1,515 acres of urban land. Erosion damages needing project action cover 301,472 acres.

The inventory further shows that agricultural water management to remove excess water from the surface or subsurface by project action is needed on 484,380 acres. Project action is also needed on 285,145 acres of arable land to conserve and utilize irrigation water for the economic production of crops now being grown on these lands.

Rural water supply development is needed in 89 of these watersheds; municipal and industrial water in 64; recreation in 214; fish and wildlife developments in 198; and water quality control in 135.

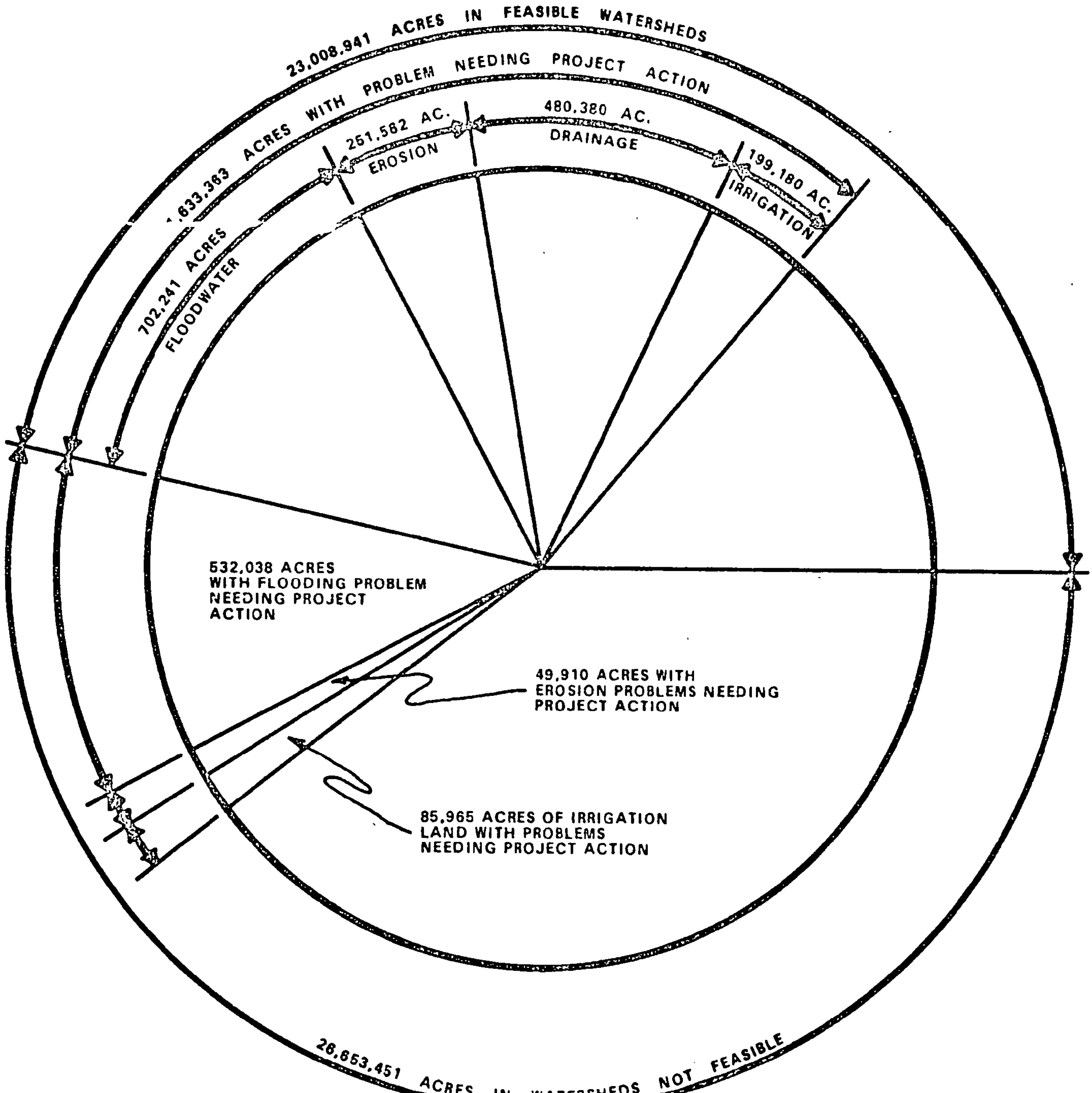


Figure 29
SOUTH DAKOTA WATERSHED PROJECT NEEDS

NORTH DAKOTA

Introduction

The 1967 Conservation Needs Inventory shows that North Dakota has a total land area of 44,442,136 acres after excluding large lakes and rivers. From this total was subtracted 1,572,869 acres of federal land; 1,083,019 acres of urban and built-up land; and 199,621 acres of small streams and ponds to arrive at an inventory acreage of 41,586,617 acres. The inventory acreage consists of 27,501,537 acres of cropland, 12,517,430 acres of pasture and range; 649,497 acres of forest land; and 918,153 acres of other land.

Trends affecting land use since the 1958 inventory:

1. The inventoried acreage was reduced 248,583 acres. The most significant change in the non-inventoried acreage was the increase in federal land for water storage and wildlife purposes. The Oahe project - one example - added considerable water storage in North Dakota. Urban and built-up areas also contributed to the acreage reduction.

2. The trend to larger farms, with more mechanization and a greater level of agricultural efficiency, influences the management of the soil, water, plant, and wildlife resources, the number of farms has declined from 54,928 in 1958 to 45,000 in January 1968.

3. Cropland increased by 1,151,137 acres with most of the acreage coming from pasture and range.

4. Pasture and range was reduced by converting 1,704,570 acres to cropland, other land, and to non-inventory acreage.

5. Woodlands of North Dakota, occurring mainly along major streams in the Tuttle and Pembina Mountains and in the Badlands, were reduced 29,803 acres. They consist principally of hardwoods and are not used extensively for commercial purposes. Clearing for water impoundments, irrigation development areas along the Missouri, and conversion to pasture or cropland in the Turtle and Pembina Mountains continues to reduce the acreage.

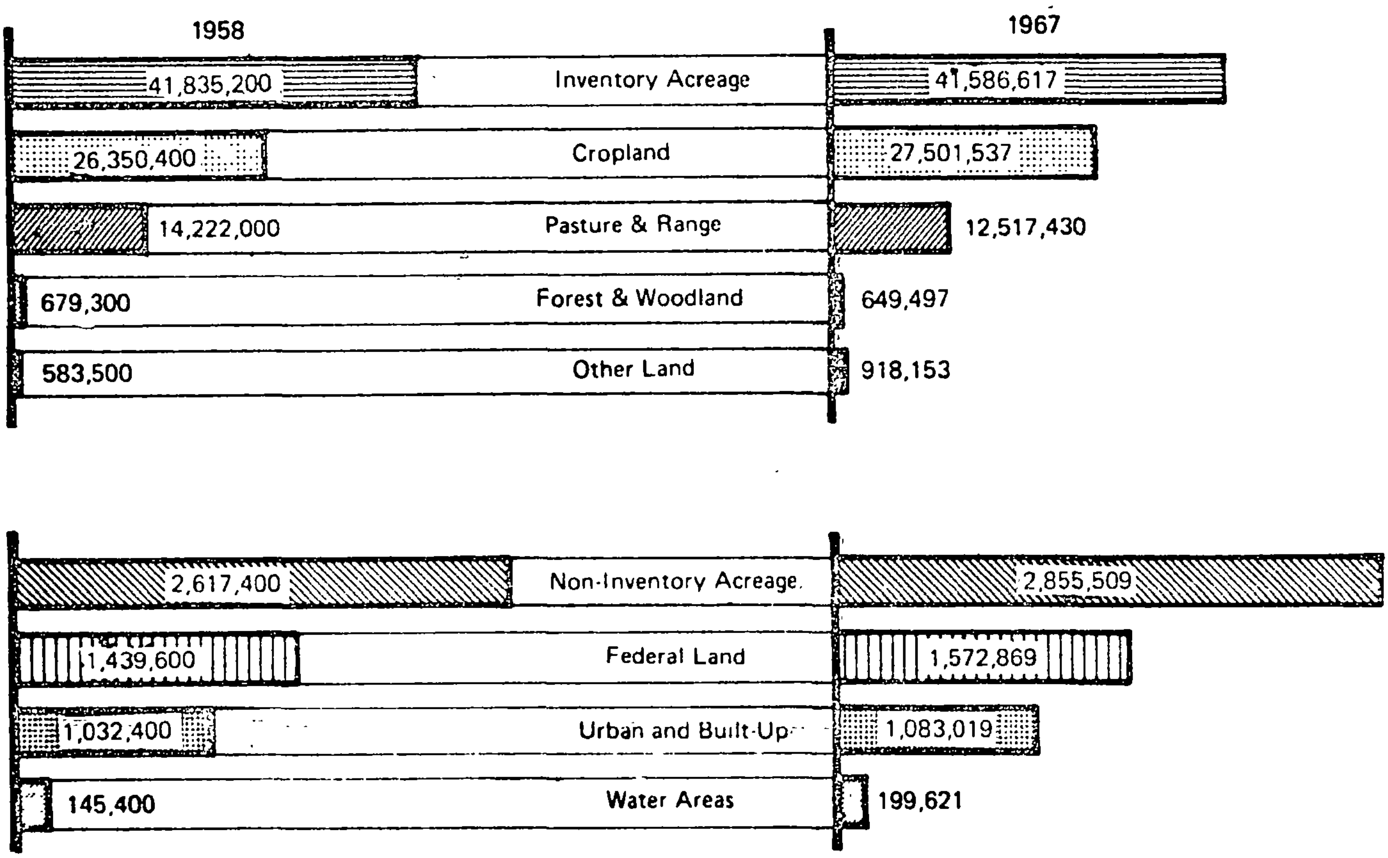
6. The study shows that 46.4% of the cropland and 48.8% of the pasture and range is adequately protected from erosion, denoting that the land is used within its capabilities and that the conservation practices essential to its protection and improvement are applied.

7. North Dakota contains 336 watersheds of 250,000 acres or less. Fifty-seven watersheds comprising 8,668,080 acres need project treatment. An estimated 1,087,090 acres of agricultural and urban areas need flood protection.

Land Use

Figure 30 summarizes the non-inventory and inventory acreages for the state and county by land area for 1958 and 1967. The state inventory and its comparisons with 1958 are shown below.

Figure 30 **LAND USE COMPARISONS**



The County Needs Committees, under the supervision of the State Committee, were responsible for determining land use and conservation treatment needs estimates for their county. The estimates of land use are summarized in Table Land use estimates are based on soil surveys provided by the Soil Conservation Service and other information provided by the Forest Service, and data available from other federal and state agencies.

Land Capability Classes

A soil survey map shows the location of different kinds of soil on the landscape. The land capability classification is one of a number of interpretative groupings made primarily for agricultural purposes. It facilitates planning soil and water conservation. The lands suitable for cultivation are placed in Classes I to IV, according to their potentialities and limitations for sustained production of the common cultivated crops. Soils not suited for cultivation are placed in Classes V to VIII, according to their potentialities and limitations for production of permanent vegetation and according to their risks of soil damage if mismanaged. Class VIII land is not capable of producing useful vegetation. The soil map information is intended to meet the needs of users with widely different interests and therefore contains considerable detail to show soil differences.

The table shown below groups all eight land classes into four land uses accounting for all of the Inventory acres.

Table 48.

Land Class	Total	Cropland	Pasture and Range	Forestland	Other Land
I	25,139	25,139			
II	21,728,867	18,362,265	2,758,702	206,218	401,682
III	9,575,679	6,664,710	2,443,787	134,938	332,244
IV	2,203,409	1,077,844	1,038,743	57,394	29,428
V	191,315	48,230	100,212	1,505	41,368
VI	6,458,622	1,284,426	4,885,991	208,575	79,630
VII	1,296,289	38,341	1,212,297	39,900	5,751
VIII	107,297	582	77,698	967	28,050
	41,586,617	27,501,537	12,517,430	649,497	918,153

Conservation Treatment Needs

Conservation needs for cropland, pasture and range, forest land, and other land were determined by inventorying those acres having conservation problems and those needing treatment.

The problems on cropland and other land are related primarily to the conservation of the soil resource; therefore, land capability units, singly or in groups, were the basis for these estimates. The problems on pasture, range and forest land are related to the conservation of the plant cover as well as the conservation of the soil resource. The treatment estimates for these land uses were based on actual condition of the vegetative cover and were made with no direct reference tc land capability units.

The other land was inventoried and treatment needs determined for that acreage needing conservation treatment. Approximately 65% of this land needs no treatment and was shown as such. The other land included both land in farms and land not in farms. Treatment was evaluated on the present condition of land that is economically and physically feasible to treat.

Cropland

The inventory shows a total of 27,501,537 acres of cropland in North Dakota, of which 43,171 acres are being irrigated. Of the total cropland, Table 48 shows 208,625 acres as temporarily idle, with 39,527 acres having been idle for more than three years. Federal programs provided an additional 1,657,671 acres of grass, legumes or small grains that were neither harvested or pastured. The sampling procedure did not record any acreage for orchards, vineyards and bush fruit because the acreage used for these purposes is small.

Land Adequately Treated - There are 12,748,563 acres of cropland adequately treated, representing 46.4% of the land under tillage rotation. This land has adequate management and sufficient conservation practices presently installed for erosion control and maintenance of soil condition.

Land Needing Treatment - The acreage figure under tillage rotation indicates 14,752,974 acres of cropland need conservation treatment to protect and improve the land. Table 51 shows that 6,821,235 acres need only improved residue management and annual cover crops; 1,833,581 acres need sod crops in rotation; 810,821 acres should be contoured; 3,681,419 acres should be farmed with intensive treatments such as stripcropping, terraces, and diversions; 740,728 acres need to be shifted to permanent cover; 1,432,727 acres need improved drainage systems to permit a better choice of crops and optimum yields on existing cropland; 24,822 acres need improved soil and crop management practices under irrigation; 8,371 acres need improved irrigation systems; and 9,683 acres need improved irrigation water management.

Pasture and Range

Of the 12,517,430 acres of pasture and range land, 48.8% are adequately treated for maintenance of cover and soil protection. Conservation treatments are needed on 6,111,025 acres. For example: 3,647,242 acres need protection only from overuse; 1,810,140 acres need treatment to improve plant vigor and production; 431,260 acres require control of brush which has invaded the grassland; and 222,383 acres need reestablishment of vegetative cover. Proper grazing of pasture and range is the practice most needed to assure desired vegetative cover.

Forest

The conservation needs for commercial and non-commercial forest land were estimated in acres needing treatment. Total forest land, excluding windbreaks, is 649,497 acres, of which 535,352 acres are adequately treated. Establishment and reinforcement of commercial and non-commercial forests is needed on 20,046 acres; timber stand improvement is necessary on 85,099 acres.

The conservation needs inventory also evaluated multiple use of the forest land for livestock grazing. Of the 237,954 acres used for both forest and grazing, 47,109 acres need reduction or elimination of grazing, and 55,323 acres need selective cutting and brush removal to protect the stand of trees and allow managed grazing. The remaining grazed forest land of 135,522 acres is adequately treated.

Other Land

The conservation needs inventory of other land includes farmsteads, farm roads, small unused knolls and grass areas, non-farm residences and similar areas. This area of North Dakota encompasses some 918,153 acres of which 700,380 acres are now adequately treated. The treatment needs reports that 217,773 acres need soil protection and prevention of damage to adjacent land.

Watershed Project Needs

Most of the soil and water conservation needs discussed in this inventory can be solved by either individual effort or by small groups with limited resources. However, many resource problems are of a magnitude that exceed local resources and need to be approached by many local and federal agencies. Water resource related problems of the state consist primarily of flood prevention, agriculture water management, irrigation, municipal or industrial water supply, fish, wildlife and recreation. Such problems require action of local units of government such as soil conservation districts, counties, municipalities, and park boards. Assistance from state and federal agencies may also be needed.

Public Law 566, the Watershed Protection and Flood Prevention Act, as amended, provides local people with the possibility of solving many of the soil and water conservation needs that cannot be met under other programs of assistance to agriculture or through federal public works projects on major rivers planned and constructed by such agencies as the Corps of Engineers or Bureau of Reclamation. The Department of Agriculture administers this law which provides a means by which local organizations can apply for and obtain assistance in the planning and installation of works of improvement for flood prevention and the conservation, development, utilization, and disposal of water in watershed areas not exceeding 250,000 acres in size.

The watershed inventory gives the nature and scope of the water management problems that can be met by project action, such as those authorized by Public Law 566. It does not give an evaluation of the economic feasibility of the projects.

There are 336 watersheds in North Dakota containing 250,000 acres or less. Of all the watersheds studies in the state, 57 embracing 8,668,080 acres were found to be potentially feasible for project treatment. Flood control, agricultural water management, fish, wildlife, and recreation are shown as primary needs and will require group project action.

Table 55 reports the total watersheds delineated in the state. Many watersheds cross state lines. By agreement and based upon location of watershed problems state responsibility was assigned. It is for this reason that the acreage for total watersheds, although including all land irrespective of ownership does not reconcile with other state totals.

Flood Prevention

Project action for flood prevention is needed on 1,086,480 acres of agricultural land and 610 acres of urban land. Erosion damage within the feasible watersheds affects 1,620 acres of land that has been severely damaged by gullying.

Agricultural Water Management

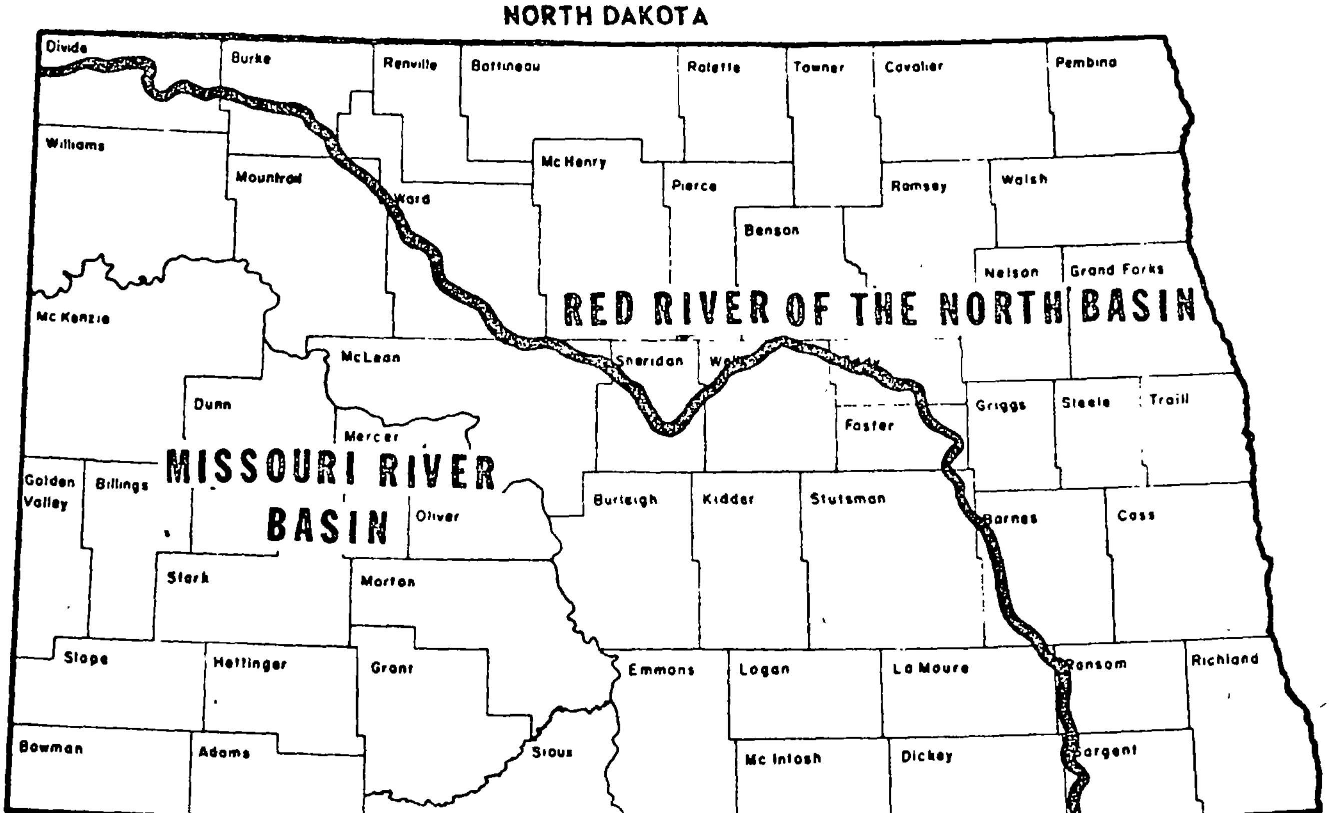
Only the needs which cannot be met by individual action were included in the inventory and shown in Table 56 . Drainage includes 706,480 cropland acres not adequately drained and for which project action is required to provide outlets. Irrigation includes 15,290 acres shown for which water supply systems, distribution systems, or both are inadequate. Rural water supply was inventoried as the number of inadequate water supply systems from either surface or ground water to meet present and future domestic needs, including fire protection, requiring group or community developments.

Nonagricultural Water Management

The number of municipal or industrial water supplies in the state were determined to be inadequate for present and estimated future needs and can be met by impoundment of surface runoff, This estimate was made by the county needs committees.

Recreation, fish, wildlife, and water quality management estimates were reported in number needed to improve each need or increase the recreational facility or fish and wildlife population and needed water quality to serve these purposes within a watershed.

Figure 31 WATERSHED PROJECT INVENTORY NORTH DAKOTA



RED RIVER OF THE NORTH BASIN – 146 watersheds less than 400 square miles; 42 feasible for project action.

MISSOURI RIVER BASIN – 190 watersheds less than 400 square miles; 15 feasible for project action.

Table 49 - LAND USE ACRES IN INVENTORY - 1958 and 1967

STATE AND COUNTY	TOTAL INVENTORY 1958	TOTAL INVENTORY 1967	CROPLAND 1958	CROPLAND 1967	PASTURE 1958	PASTURE 1967	RANGE 1958	RANGE 1967	FOREST 1958	FOREST 1967	OTHER LAND 1958	OTHER LAND 1967
NORTH DAKOTA	41 835 105	41 586 617	26 350 375	27 501 537	632 724	1 441 418	13 589 292	11 076 012	679 261	649 497	583 45[illegible]	918 1[illegible]
Adams	620 012	619 832	316 838	354 519	0	14 136	298 623	242 592	200	1 200	4 351	7 385
Barnes	907 706	905 763	716 136	773 812	70 698	60 167	100 000	34 025	12 128	12 033	8 744	[illegible]
Benson	866 492	865 048	648 120	672 379	13 933	42 430	180 100	109 107	16 620	16 700	7 719	24 432
Billings	397 778	381 171	105 755	112 742	0	0	255 923	245 715	32 382	19 410	3 718	3 304
Bottineau	1 032 384	1 031 568	820 896	849 649	6 247	10 059	139 276	80 900	52 806	55 330	13 159	35 630
Bowman	705 157	699 379	344 437	321 210	15 000	30 408	333 385	342 193	0	1 800	12 335	3 768
Burke	667 726	651 974	461 225	483 610	6 219	12 541	185 267	132 437	1 498	1 400	13 517	21 986
Burleigh	1 015 710	1 010 557	496 038	536 181	12 577	40 476	471 649	385 869	13 106	13 850	22 340	34 181
Cass	1 076 040	1 076 005	996 778	979 060	2 597	33 998	42 135	11 331	19 235	19 300	15 295	32 316
Cavalier	937 918	934 692	756 000	792 520	39 467	20 000	79 985	55 948	52 466	35 207	10 000	31 017
Dickey	709 938	705 252	467 855	495 301	56 000	39 159	169 441	139 132	5 740	9 581	10 902	22 079
Divide	813 539	804 248	552 121	585 037	2 591	11 100	227 489	192 504	768	1 800	30 570	13 807
Dunn	1 248 784	1 248 624	415 000	423 425	31 438	38 356	755 845	753 412	9 977	21 263	36 524	12 168
Eddy	402 592	402 369	246 775	307 464	8 077	53 249	126 546	12 669	14 718	12 668	6 476	16 319
Emmons	948 035	919 953	455 274	594 973	5 769	10 198	459 396	299 171	23 365	6 301	4 231	9 310
Foster	401 698	398 769	288 239	309 168	0	31 090	106 021	41 885	2 926	1 080	4 512	15 546
Golden Valley	539 998	539 965	241 398	231 614	0	20 906	294 840	281 709	282	300	3 478	5 436
Grand Forks	884 974	873 578	698 311	750 748	20 000	33 046	131 159	42 460	23 128	23 200	12 376	24 124
Grant	1 042 268	1 035 147	464 367	461 903	6 557	29 355	561 419	522 181	5 431	5 400	4 494	16 308
Griggs	441 077	439 442	332 794	362 776	0	13 276	101 564	46 259	4 205	4 068	2 514	13 063
Hettinger	710 973	710 872	504 272	490 830	0	35 763	196 511	171 355	0	200	10 190	12 724
Kidder	859 760	858 236	451 738	454 602	39 567	81 799	348 327	295 631	1 085	1 100	19 043	25 104
LaMoure	707 406	703 605	554 607	562 216	73 000	104 793	72 005	7 485	3 605	3 700	4 189	25 411
Logan	621 701	618 756	317 558	376 071	10 351	24 100	284 995	209 319	729	600	8 066	8 666
McHenry	1 133 041	1 133 002	621 605	690 585	4 853	30 956	475 913	377 409	17 862	17 800	12 808	16 252
McIntosh	615 193	613 585	383 432	414 691	0	7 279	219 278	176 380	926	2 000	11 557	13 235
McKenzie	1 205 006	1 204 996	490 057	524 656	6 731	0	673 102	643 037	27 907	31 626	7 209	5 677
McLean	1 286 341	1 285 256	862 000	847 675	0	32 394	386 248	357 031	17 724	25 394	20 379	22 762
Mercer	648 899	631 054	274 307	294 038	507	4 210	349 587	303 558	12 927	13 000	11 571	16 248
Morton	1 217 878	1 211 615	479 669	502 546	6 519	16 852	698 707	657 652	11 989	6 481	21 094	28 085
Mountrail	1 130 569	1 125 428	539 110	565 741	11 365	7 [illegible]	556 326	537 [illegible]	1 429	30[illegible]	21 739	14 806
Nelson	615 731	611 126	475 465	486 316	144	[illegible]	[illegible]	[illegible]	[illegible] 471	3 590	8 208	8 870
Oliver	450 838	450 807	[illegible]	192 271	6 624	16 3[illegible]	156 92[illegible]	31 [illegible]	1 902	2 047	2 646	8 134
Pembina	700 038	695 522	425 00[illegible]	614 809	1 678	[illegible]	[illegible]	[illegible]	[illegible]	43 792	10 077	19 749
Pierce	643 997	643 592	437 30[illegible]	487 156	0	27 9[illegible]	498 478	[illegible]	[illegible]	1 600	6 497	7 437
Ramsey	755 082	752 866	605 323	620 343	11 1[illegible]	8 [illegible]	116 337	[illegible]	[illegible]	11 687	10 648	43 598
Ransom	494 833	494 823	356 672	396 322	22 660	9 [illegible]	81 [illegible]	62 947	[illegible]	17 20[illegible]	17 201	9 492
Renville	539 701	542 228	453 625	454 940	938	14 [illegible]	75 [illegible]	59 [illegible]	3 998	446	5 576	12 495
Richland	869 884	869 375	693 645	690 885	48 931	97 5[illegible]	[illegible]	31 165	13 733	13 300	14 399	35 983
Rolette	553 944	553 456	326 651	369 477	12 841	[illegible]	111 573	[illegible]	95 906	95 024	6 973	18 659
Sargent	531 357	526 726	359 044	383 461	12 367	70 9[illegible]	144 656	47 [illegible]	4 907	4 900	10 383	19 555
Sheridan	611 076	602 765	333 000	350 500	5 025	11 635	262 551	35 773	2 500	1 000	8 000	3 657
Sioux	704 481	698 192	154 651	133 691	0	29 345	546 723	530 192	640	1 700	2 467	3 261
Slope	626 390	635 272	290 181	299 220	0	23 927	329 357	307 415	1 112	6 100	5 740	8 610
Stark	822 975	810 631	537 556	507 648	0	19 143	279 635	265 531	566	6 657	5 188	11 652
Steele	440 720	437 360	372 247	386 472	0	8 623	58 138	26 704	5 578	5 600	4 757	9 961
Stutsman	1 390 109	1 363 329	887 764	980 114	13 348	38 787	470 949	329 280	6 768	6 900	11 280	8 248
Towner	647 783	647 079	538 873	567 949	0	38 83[illegible]	100 [illegible]	17 841	2 747	1 900	5 546	20 559
Traill	533 423	533 146	493 802	499 357	235	14 164	28 113	4 856	7 889	7 539	3 384	7 233
Walsh	796 409	794 305	613 343	678 070	46 730	15 238	72 295	30 586	52 224	50 173	11 817	20 233
Ward	1 243 701	1 225 780	866 933	849 698	0	5 111	344 336	331 359	3 585	2 100	28 847	37 512
Wells	807 696	800 236	623 076	625 480	0	35 117	172 563	109 481	2 821	1 450	9 236	26 [illegible]
Williams	1 258 344	1 258 260	820 728	805 616	0	35 260	417 027	399 754	1 108	0	19 481	17 630

Table 50

IRRIGATED AND DRY PASTURE AND RANGE, FOREST AND OTHER LAND ACRES BY LAND CAPABILITY CLASSES - 1967

STATE NORTH DAKOTA

LAND CAPABILITY CLASS SUB-CLASS	PASTURE AND RANGE			FOREST						OTHER LAND			TOTAL LAND IN INVENTORY
	PASTURE	RANGE	TOTAL	COMMER-CIAL	NON-COM-MERCIAL	TOTAL	COMMER-CIAL GRAZED	NON-COM MERCIAL GRAZED	TOTAL GRAZED	IN FARMS	NOT IN FARMS	TOTAL	
1	0	0	0	0	0	0	0	0	0	0	0	0	25139
2E	364570	1352110	1716680	42306	34659	76965	2026	14988	17014	233229	10785	244014	13521681
3E	287971	1392492	1680463	58758	40901	99659	14043	17381	31424	101362	10383	111765	6348742
4E	133720	852117	985837	43133	14261	57394	15081	6486	21567	23541	2210	27751	2074952
6E	113619	3539359	3652978	101247	101782	203029	32782	53127	85909	47948	4863	52811	4644812
7E	10572	869793	880365	10610	27169	37779	6440	11181	17621	1920	278	2198	930697
8E	3000	66309	69309	0	967	967	0	517	517	0	10944	10944	81367
2W	94896	286172	381068	7456	4020	11476	2152	788	2940	61332	2390	63722	2319761
3W	62348	331068	393416	14747	17192	31939	1164	12299	1[illegible]463	191217	1173	192390	1223574
4W	2343	5985	8328	0	0	0	0	0	0	809	0	809	45545
5W	15617	76544	92161	522	983	1505	130	300	430	40958	410	41368	182025
6W	293	2479	2772	0	0	0	0	0	0	0	0	0	6360
8W	0	0	0	0	0	0	0	0	0	17106	0	17106	17106
2S	3730	13553	17283	8486	4229	12715	0	2711	2711	3997	0	3997	190545
3S	71512	285886	357398	1358	1882	3240	9	67	76	24336	1662	25998	1928667
4S	434	44144	44578	0	0	0	0	0	0	868	0	868	82912
5S	3199	4852	8051	0	0	0	0	0	0	0	0	0	9290
6S	96329	1133912	1230241	2372	3174	5546	1208	1524	2732	18527	8292	26819	1807450
7S	13306	318626	331932	691	1430	2121	465	1422	1887	3136	417	3553	365592
8S	0	8389	8389	0	0	0	0	0	0	0	0	0	8804
2C	161450	482221	643671	47895	57167	105062	3534	36029	39563	77850	12099	89949	5696860
3C	2509	10001	12510	0	100	100	0	100	100	2091	0	2091	74696
TOTAL	1441418	11076012	12517430	339581	309916	649497	79034	158920	237954	852247	65906	918153	41586617

Table 51

CONSERVATION TREATMENT NEEDS - CROPLAND IN TILLAGE ROTATION (ACRES) - 1967

STATE NORTH DAKOTA

LAND CAPABILITY CLASS SUB-CLASS	TREATMENT ADEQUATE (IRRIGATED AND NON-IRRIGATED)	NON-IRRIGATED CROPLAND						IRRIGATED CROPLAND			TOTAL TILLAGE ROTATION
		RESIDUE AND ANNUAL COVER	SOD IN ROTATION	CONTOUR-ING ONLY	STRIP CROPPING TERRACING DIVERSIONS	PERMANENT COVER	DRAINAGE	CULTURAL MANAGEMENT PRACTICES ONLY	IMPROVED SYSTEMS	WATER MANAGE-MENT	
1	0	0	0	0	0	0	0	16778	5724	2637	25139
2E	5501491	3823833	341803	322447	1219175	4400	258476	3434	565	1628	11477452
3E	1683665	550516	428075	301571	1471684	5531	8901	383	200	100	4450626
4E	358741	74123	70541	55599	426804	13165	1753	926	384	221	1002257
6E	257698	13341	40478	2678	15257	402106	1514	0	0	0	733372
7E	6635	0	2159	0	0	1561	0	0	0	0	10355
8E	167	0	0	0	0	0	0	0	0	0	167
2W	573373	200894	84974	0	90989	3475	899541	10	8	4	1853266
3W	334452	55931	26138	715	6229	5778	169313	1525	911	432	601424
4W	17737	653	0	0	0	0	18018	0	0	0	36408
5W	24307	7642	0	0	0	42	15000	0	0	0	46991
6W	1588	0	0	0	0	2000	0	0	0	0	3589
2S	66282	27050	10821	7544	40585	0	1275	1550	394	206	155707
3S	746649	450086	103698	44047	172307	1712	22909	126	53	31	1541618
4S	22367	6243	6608	0	892	1356	0	0	0	0	37466
5S	1239	0	0	0	0	0	0	0	0	0	1239
6S	200477	5816	25793	3233	17304	287068	433	0	0	0	540124
7S	13870	0	2959	0	0	11157	0	0	0	0	27986
2C	2902829	1584467	39534	72539	216282	1377	35594	150	132	4224	4857128
3C	34996	20640	0	448	3911	0	0	0	0	0	59995
TOTAL	12748563	6821235	1183581	810821	3681419	740728	1432727	24882	8371	9683	27462010

Table 52

STATE NORTH DAKOTA

CONSERVATION TREATMENT NEEDS - OTHER CROPLAND AND TOTAL CROPLAND (ACRES) - 1967

LAND CAPABILITY CLASS SUBCLASS	ORCHARDS, VINEYARDS, AND BUSH FRUIT TOTAL	TREATMENT ADEQUATE	TREATMENT NEEDED	KIND OF TREATMENT CODE	OPEN LAND AND FORMERLY CROPPED TOTAL	TREATMENT ADEQUATE	TREATMENT NEEDED	KIND OF TREATMENT CODE	TOTAL CROPLAND
1	0	0	0		0	0	0		25139
2E	0	0	0		6570	5109	1461	6	11484022
3E	0	0	0		6229	2810	3419	5 4 2	4456855
4E	0	0	0		1713	1713	0		1003970
6E	0	0	0		2922	0	2922	5	735994
7E	0	0	0		0	0	0		10355
8E	0	0	0		0	0	0		167
2W	0	0	0		10247	3423	6824	6	1863515
3W	0	0	0		4405	2916	1489	6	605829
4W	0	0	0		0	0	0		36408
5W	0	0	0		0	0	0		46991
6W	0	0	0		0	0	0		3588
2S	0	0	0		843	0	843	2	156550
3S	0	0	0		413	413	0		1542031
4S	0	0	0		0	0	0		37466
5S	0	0	0		0	0	0		1239
6S	0	0	0		4720	861	3859	5	544844
7S	0	0	0		0	0	0		27986
8S	0	0	0		415	0	415	5	415
2C	0	0	0		1050	630	420	6	4858178
3C	0	0	0		0	0	0		59995
TOTAL	0	0	0		39527	17875	21652		27501537

Table 53

STATE NORTH DAKOTA

CONSERVATION TREATMENT NEEDS - PASTURE (ACRES) - 1967

LAND CAPABILITY CLASS SUBCLASS	TOTAL	TREATMENT ADEQUATE	NO TREATMENT FEASIBLE	CHANGE IN LAND USE	TOTAL NEEDING TREATMENT	TREATMENT NEEDS PROTECTION ONLY	IMPROVEMENT ONLY	BRUSH CONTROL AND IMPROVEMENT	TOTAL NEEDING IMPROVEMENT	REESTABLISHMENT OF VEGETATIVE COVER	REESTABLISHMENT WITH BR CONTROL	TOTAL NEEDING REESTABLISHMENT
2E4E	786261	318656	0	0	467605	138022	256178	0	394200	73405	0	73405
2W4W	159587	85651	0	0	73936	31430	26754	0	58184	15752	0	15752
2S4S	75676	34473	0	0	41203	17023	22205	0	39228	1975	0	1975
2C4C	163959	59595	0	0	104364	40671	56128	0	96799	7565	0	7565
5E8E	127191	50925	628	0	75638	32234	27527	0	59761	15877	0	15877
5W8W	15910	11976	0	0	3934	2777	293	0	3070	864	0	864
5S8S	112834	58430	619	0	53785	25298	21692	0	46990	6795	0	6795
TOTAL	1441418	619706	1247	0	820465	287455	410777	0	698232	122233	0	122233

Table 54

STATE NORTH DAKOTA

CONSERVATION TREATMENT NEEDS - RANGE (ACRES) - 1967

LAND CAPABILITY CLASS SUBCLASS	TOTAL	TREATMENT ADEQUATE	NO TREATMENT FEASIBLE	CHANGE IN LAND USE	TOTAL NEEDING TREATMENT	TREATMENT NEEDS PROTECTION ONLY	IMPROVEMENT ONLY	BRUSH CONTROL AND IMPROVEMENT	TOTAL NEEDING IMPROVEMENT	REESTABLISHMENT OF VEGETATIVE COVER	REESTABLISHMENT WITH BR CONTROL	TOTAL NEEDING REESTABLISHMENT
2E4E	3596719	1537289	4736	0	2054694	926345	826141	250522	2003008	51686	0	51686
2W4W	623225	395572	435	0	227218	123517	77018	16438	216973	7565	2680	10245
2S4S	343583	151215	443	0	191925	129808	40502	18914	189224	2701	0	2701
2C4C	492222	237063	1254	0	253905	142043	88236	20918	251197	2708	0	2708
5E8E	4475461	2396687	201877	0	1876897	1478716	279272	91498	1849486	26702	709	27411
5W8W	79023	52777	542	0	25704	20630	4141	433	25204	500	0	500
5S8S	1465779	737372	68190	0	660217	538728	84053	32537	655318	4899	0	4899
TOTAL	11076012	5507975	277477	0	5290560	3359787	1399363	431260	5190410	96761	3389	100150

Table 55

Inventory of watersheds less than 400 square miles in area with the kinds and extent of problems needing project action

Major drainage area, principal drainage basin, subbasins	Total watersheds delineated		Total area w/ floodwater & sediment damage 1/	Kind and extent of problems: Flood prevention: Floodwater and sediment damage: Agricultural	Urban	Erosion damage	Agricultural water management: Drainage	Irrigation	Rural water supply	Nonagricultural water management: Municipal or industrial water supply	Recreational development	Fish & wildlife development	Water quality management
	No.	1,000 acres	1,000 acres	1,000 acres	1,000 acres	1,000 acres	1,000 acres	1,000 acres	No.	No.	No	No	No.
Missouri River Drainage Area													
Apple Creek	5	941.51	2.93	-	-	-	-	-	-	-	5	5	-
Beaver Creek	5	616.90	17.71	17.39	0.02	-	-	-	-	-	5	5	-
Cannonball River	18	1,593.29	37.31	17.31	0.03	0.40	-	2.00	3	1	18	18	2
Cedar Creek	12	1,143.99	35.08	35.08	-	-	2.00	-	-	-	12	12	-
Grand River	4	509.74	19.41	19.41	-	-	-	-	-	-	4	4	-
Heart River	21	2,134.37	51.76	43.71	0.06	0.90	0.20	0.30	2	2	21	21	3
James River	16	2,492.25	13.59	13.59	-	-	-	-	-	-	16	16	-
Pipestem Creek	3	493.87	2.99	2.99	-	-	-	-	-	-	3	3	-
Elm River	3	518.54	4.80	4.20	-	-	0.20	0.20	-	-	3	3	-
Noncontributing Area	1	958.37	-	-	-	-	-	-	-	-	1	1	-
Knife River	20	1,608.46	25.38	20.98	-	0.40	-	6.00	1	3	16	16	-
Little Muddy Creek	3	503.65	-	-	-	-	-	-	-	-	3	3	-
Little Missouri River	22	3,029.89	67.92	31.09	-	0.02	-	3.07	3	-	21	22	2
Box Elder Creek	1	240.30	3.03	0.87	-	-	-	-	-	-	1	-	-
Beaver Creek	2	206.53	7.75	7.55	-	-	-	-	-	-	2	2	-
Missouri River	50	5,048.82	71.76	51.63	0.01	-	1.20	-	6	-	50	50	1
Noncontributing Area	1	3,201.78	-	-	-	-	-	-	-	-	1	1	-
Yellowstone River	3	227.04	15.12	15.12	-	0.20	-	17.80	2	-	-	-	-
Subtotal	190	25,469.30	376.54	280.92	0.12	1.92	3.60	29.37	17	6	182	182	8
Red River of the North Drainage Area													
Bois-de-Sioux River	2	65.59	2.16	2.16	-	-	-	-	-	-	2	2	-
Forest River	4	666.13	114.71	114.71	-	0.42	67.30	-	-	-	4	4	-
Goose River	6	692.95	19.50	-	-	-	-	-	-	-	6	6	-
Park River	4	623.67	171.38	171.38	0.40	-	47.65	-	-	1	4	4	-
Pembina River	10	1,124.37	69.40	69.40	-	-	48.33	-	-	1	10	10	-
Red River of the North	19	1,798.52	257.10	246.11	0.02	0.50	189.90	-	-	-	19	19	-
Sheyenne River	23	3,579.90	13.50	10.00	-	-	31.10	-	-	-	23	23	-
Devils Lake	12	2,330.36	130.10	130.10	0.01	-	111.63	-	-	1	12	12	-
Maple River	5	999.50	124.00	124.00	-	-	148.00	-	-	-	5	5	-
Souris River	29	2,676.42	59.67	54.17	0.07	-	23.60	-	-	-	27	27	-
Des Lacs River	10	594.67	-	-	-	-	-	-	-	-	10	10	-
Willow Creek	7	1,123.80	54.34	52.34	-	-	34.20	-	-	-	7	7	-
Little Deep Creek	5	966.71	4.00	-	-	-	-	-	-	-	5	5	-
Noncontributing Area	1	888.71	-	-	-	-	-	-	-	-	1	1	-
Wild Rice Creek	9	1,216.20	44.14	36.54	-	0.20	76.50	0.12	-	-	9	9	2
Subtotal	146	19,347.30	1,064.00	1,010.91	0.50	1.12	778.21	0.12	-	3	144	144	2
North Dakota State Total	336	44,816.80	1,440.54	1,291.83	0.62	3.04	781.81	29.49	17	9	326	326	10

1/ Includes areas other than those needing project action.

Table 56

- Inventory of potentially feasible watersheds less than 400 square miles in area with the kinds and extent of problems needing project action 1/

Major drainage area, principal drainage basin, subbasins	Watersheds feasible for project action		Kind and extent of problems: Flood prevention: Floodwater and sediment damage: Agricultural	Urban	Erosion damage	Agricultural water management: Drainage	Irrigation	Rural water supply	Nonagricultural water management: Municipal or industrial water supply	Recreational development	Fish & wildlife development	Water quality management
	No.	1,000 acres	1,000 acres	1,000 acres	1,000 acres	1,000 acres	1,000 acres	No.	No.	No.	No.	No.
Missouri River Drainage Area												
Beaver Creek	1	22.75	0.16	0.01	-	-	-	-	-	1	1	-
Cannonball River	1	2.90	-	0.03	-	-	-	1	-	1	1	1
Cedar Creek	1	116.40	20.00	-	-	-	-	-	-	1	1	-
Heart River	3	233.93	19.96	0.06	0.50	-	0.30	-	2	3	3	2
James River	1	107.09	5.72	-	-	-	-	-	-	1	1	-
Pipestem Creek	1	189.38	-	-	-	-	-	-	-	1	1	-
Knife River	1	161.21	2.16	-	-	-	-	-	-	1	1	-
Little Missouri River	1	220.61	3.24	-	-	-	3.07	-	-	1	1	1
Missouri River	3	360.44	16.52	0.01	-	-	-	2	-	3	3	1
Yellowstone	2	180.52	13.02	-	0.20	-	11.80	1	-	-	-	-
Subtotal	15	1,595.23	80.78	0.11	0.70	-	15.17	4	2	13	13	5
Red River of the North Drainage Area												
Bois-de-Sioux River	1	30.22	2.16	-	-	-	-	-	-	1	1	-
Forest River	4	666.13	114.71	-	0.42	67.30	-	-	-	4	4	-
Park River	4	623.67	171.38	0.40	-	47.65	-	-	1	4	4	-
Pembina River	2	434.71	67.20	-	-	47.30	-	-	1	2	2	-
Red River of the North	8	1,320.10	246.11	0.02	0.50	187.70	-	-	-	8	8	-
Sheyenne River	1	166.24	10.00	-	-	22.90	-	-	-	1	1	-
Devils Lake	7	1,486.75	130.10	0.01	-	111.63	-	-	1	7	7	-
Maple River	5	999.50	124.00	-	-	148.00	-	-	-	5	5	-
Souris River	4	388.28	54.16	0.07	-	23.60	-	-	-	3	3	-
Willow Creek	3	629.92	52.34	-	-	34.20	-	-	-	3	3	-
Wild Rice Creek	3	327.33	33.54	-	-	16.20	0.12	-	-	3	3	2
Subtotal	42	7,072.85	1,005.70	0.50	0.92	706.48	0.12	-	3	41	41	2
North Dakota State Total	57	8,668.08	1,086.48	0.61	1.62	706.48	15.29	4	5	54	54	7

1/ Each delineated watershed was appraised by experienced planners as to potential physical and economic feasibility for developments. A watershed was considered potentially feasible if it was estimated that potential benefits would be equal to or greater than estimated costs for flood prevention or agricultural water management.

RANGE AND WATERSHED CONTROL TECHNOLOGY

SELECTION AND EVALUATION OF MEASURES FOR REDUCTION OF EROSION AND SEDIMENT YIELD IN THE REGION VIII STATES

Introduction

The following material is intended to provide guidance in the selection and evaluation of measures for erosion and sediment reduction in Region VIII. The recommendations are for broad planning purposes only and not for specific projects where detailed evaluations would be required.

The evaluation of treatment needs considered in this report are for purposes of erosion and sediment reduction without regard to other benefits that may or may not be gained by the improvements. While it is true that several purposes are frequently achieved by the same treatment, priorities of need and opportunities for success in treatment may not coincide for the alternative purposes. The highest priority for sediment control is, of course, the application of erosion control measures to the major sources. However, in the case of some grazing lands, treatment of low contributing or non-contributing sediment source areas having the potential for increased forage production may be of benefit in reducing the stress exerted on adjacent high sediment contributing areas.

For purposes of identifying erosion and sediment sources, reference is made to the report of the Water Management Subcommittee, PSIAC, titled "Factors Affecting Sediment Yield in the Pacific Southwest Area". When the erosion and sediment source areas have been determined, erosion sites are broadly classified as to whether they are the uplands or channels. In the former instance the measures that are applicable are easily identified as "management" and "land treatment" and the latter is "structural measures" and associated vegetative controls. Management measures include proper uses of the land and related resources to minimize erosion and sediment yield. Land treatment measures usually include the purpose of holding the soil in place by whatever means, including a reduction in rainfall impact and runoff, and by increasing the resistance of the soil. The general purposes of structural measures are to retard erosion at the site, (head cutting, bank cutting, degradation) and to provide a trap for sediment moving into the reach from upstream.

RANGE AND WATERSHED CONTROL TECHNOLOGY

The following list of measures and their definitions include most of those now being used in many of the Region VIII states.

Measures for Range and Forest

Brush Control - Eradication of pinyon-juniper, sage, and other brush, and replacement with more desirable vegetation.

Contour Furrowing and Trenching - Making furrows and/or trenches on the contour at intervals varying with the precipitation, slope, soil and cover.

Contour Terracing - Development of water storage capacity along the contour by excavation and placement of soil as an embankment along the downstream side. Intervals vary with the precipitation, slope and soil.

Critical Area Planting - Stabilizing severely eroded areas by establishing vegetative cover.

Fire Prevention and Suppression - Employment of a variety of measures for the control and prevention of fires on range and forest land, including personnel, roads, trails, fire breaks, water facilities, aircraft and other equipment.

Livestock Exclusion - Excluding livestock from any area where grazing is harmful or otherwise undesirable.

Pitting - Making shallow pits or basins of suitable capacity and distribution to retain water and increase infiltration.

Proper Grazing Use - Grazing at an intensity which will maintain adequate cover for soil and maintain or improve the quantity and the quality of desirable vegetation.

Range Seeding - Establishing adapted plants by seeding.

Rotation - Deferred Grazing - Grazing under a system where one or more grazing units are rested at planned intervals throughout the growing season of key plants. Generally no unit is grazed at the same time in successive years.

<u>Tree and Shrub Planting</u> - Planting tree or shrub seedlings or cuttings to establish desirable cover.

<u>Trespass Control</u> - To prevent unauthorized uses detrimental to the land.

<u>Measures for Cultivated Land</u>

<u>Chiseling and Subsoiling</u> - Loosening the soil, without inversion and with a minimum of mixing of the surface soil, to shatter restrictive layers below the normal plow depth that inhibit water movement or root development.

<u>Contour Farming</u> - Conducting farming operations on sloping cultivated land in such a way that plowing, land preparation, planting and cultivating are done on the contour.

<u>Contour Terracing</u> - Development of water storage capacity along the contour by excavation and placement of soil as an embankment along the downstream side. Intervals vary with the precipitation and slope.

<u>Cover and Green Manure Crop</u> - A crop of close-growing grasses, legumes, or small grain used primarily for seasonal protection and for soil improvement.

<u>Critical Area Planting</u> - Stabilizing severely eroded areas by establishing vegetative cover.

<u>Crop Residue and Mulching</u> - Utilizing and managing crop residues for soil protection on a year round basis or when critical erosion periods usually occur.

<u>Field Diversion</u> - An interception channel near the contour to carry runoff to a waterway, Intervals vary with the precipitation, slope and cropping.

<u>Grassed Waterway or Outlet</u> - A natural or constructed waterway or outlet shaped or graded and establishment of suitable vegetation as needed for the safe disposal of runoff.

<u>Proper Cropping and Use</u> - The use of close growing crops on erodible land.

<u>Strip Cropping</u> - Growing crops in a systematic arrangement of strips or bands across the general slope or on the contour to reduce water erosion. Strips approximately at right angles to the prevailing winds to reduce wind erosion.

Structural Measures

The following list of measures and their definitions include most of those now being used in the Region VIII states.

Channel Lining - Protection of the channel bottom and banks with concrete or riprap.

Debris Basins - Storage for sediment provided by a dam with spillway above channel grade; by excavation below grade, or both. Water retention is not an intended function of the structure.

Diversions and Dikes - Devices used to divert water away from eroding areas.

Drop Structures - Concrete, masonry, sheet piling or earth structures placed in eroded channels below the top of the bank to control grade, prevent further erosion and provide sediment storage.

Jacks and Jetties - Projections built in the stream channel to divert currents away from a vulnerable bank.

Reservoirs - To provide for permanent storage of sediment and either temporary or permanent water storage.

Revetments - Materials placed on the stream bank to protect it from erosion by stream flow.

Sills - Structures of rock, masonry, rails, etc., placed at channel grade to prevent stream downcutting.

Disturbed Area Protection - This measure may include any of the above treatments and structures. In addition, it often includes stablizing steep slopes, lining road ditches, etc.

Applicability of Management and Land Treatment Measures for Erosion and Sediment Control

The soils, climate, topographic and other factors which tend to create the most severe erosion and sediment problems also increase the difficulty of control. Similarly, many measures are usually more successful under conditions of low or moderate erosion and sediment yield than they are under high yield. The broad trends in the principal factors affecting erosion indicate the reasons for this. Vegetative measures are dependent on favorable moisture conditions and proper grazing control Although there are some notable exceptions, the more humid sections usually show less sediment yield than more arid sections, as more favorable moisture furnished greater support to vegetation. Similarly, the mechanical treatment measures which require disturbing, molding, or reshaping the soil are most successful where the soils have properties which inherently make them resistant to erosion. The other factors operate in much the same way and in an interdependent fashion. As the slope increases, for instance, problems of establishing and maintaining vegetation, applying mechanical treatment and obtaining proper grazing use also increase.

The measures that are used for erosion and sediment control in Region VIII may be classified by purpose into several groups: (1) to intercept and/or conserve moisture; (2) to increase infiltration capacity; (3) to reduce or eliminate stress on existing cover; (4) to preserve existing cover regarded as adequate or in the process of becoming adequate with time; (5) to increase the protection of the soil by a change in the type as well as density of vegetation.

1. In this group are such measures as contour furrowing, contour terracing, diversions, pitting, and chiseling or subsoiling. Contour terracing is frequently used in semi-arid and sub-humid climatic environments under high hazard site conditions and low to moderate soil hazard. The measure has been most useful and effective in breaking up gully patterns on steep slopes. Field diversions are used in semi-arid and sub-humid environments on sites having high to moderate soil hazards and moderate to low topographic hazard. In order to maintain an effective capacity on cultivated land, vegetative strips for interception of sediment are needed on moderate slopes above the diversions. Furrowing and pitting are being tested under arid and semi-arid conditions with soils ranging from low to high erosion and sediment yield potential and topographic sites in the low to moderate topographic hazard. Their success in arid climates with high and moderate hazard soil conditions has not yet been established.

2. Crop residue use and stubble mulching are widely used under a variety of soil, topographic site and climatic conditions. They are effective for erosion control as a soil binder and for increased infiltration capacity, particularly in semi-arid and sub-humid climatic environments and under moderate and high topographic and soil hazards. Contour furrowing, trenching, chiseling and subsoiling aid indirectly in improving or increasing total infiltration into the soil.

3. Measures to reduce or eliminate stress on existing cover are used under all site, soil and climatic conditions. Proper grazing use, rotation-deferred grazing, exclusion, trespass control and other management practices have the effect of increasing the density of cover or reducing eroding runoff by improvement of the soil infiltration capacity. Under arid conditions, vegetative cover improvement by range (grazing) management alone usually does not have sufficient impact on existing conditions to reduce erosion significantly unless a slight or moderate change in cover is critical to a site. However, livestock exclusion under arid or semi-arid climatic environments and high soil erosion potential has shown a substantial reduction in soil loss. Where plant density under observed conditions has not noticeably increased, it is presumed that reductions in soil loss are due to absence of continued compaction due to trampling.

4. Measures which are for preservation of existing adequate cover or cover which will become adequate with time include those for fire suppression, proper grazing use, and trespass control. These measures are used in a variety of topographic, site, soil and climatic conditions. They are most effective under semi-arid to sub-humid climatic environments and high hazard soil and topographic conditions. They are usually measures of low priority under arid and humid climatic environment with gentle to moderate slopes and low to moderate hazard soil conditions.

5. Revegetation is one of the most widely applied land treatment measures. It usually consists of seeding adapted grasses where natural cover has deteriorated, such as where juniper and pinyon pine occupy or have encroached upon soils suitable for grasses. In the latter instance eradication precedes revegation. Fine textured soils which may be in the high erosion potential classification are more favorable for this purpose since they retain moisture in the shallow root zone. Greater ground cover density is achieved by replacing brush and small trees with grasses. In arid and semi-arid areas seeding has in some cases been effective on low hazard topographic sites. Its effectiveness for reducing erosion on high hazard sites in these climatic environments has not been established. It is recommended for sub-humid and humid climatic environments, high and moderate hazard site conditions and moderate hazard soils, particularly where quick cover protection is needed following a brush or forest fire.

Table 57 lists some of the more specific management and treatment measures for erosion and sediment control under various site conditions. Climatic environments are listed first, being the key to the success or effectiveness of vegetation which is intimately related to all land treatment measures.

Structural Measures for Erosion and Sediment Control

Structural measures have met with more uniform effectiveness than land treatment measures. Achievement of the purpose for which they were designed is not dependent upon nature. Their design, construction and maintenance have a variable flexibility to meet demands of the local situation.

TABLE 57- MANAGEMENT AND LAND TREATMENT MEASURES RECOMMENDED FOR REDUCTION OF EROSION AND SEDIMENT YIELD UNDER VARIOUS SITE CONDITIONS

Measures	Climatic Environment				Soils *			Upland Slope Topography		
	Arid	Semi-Arid	Sub-Humid	Humid	Fine Textured	Medium Textured	Coarse Textured	Steep	Moderate	Gentle
	A	B	C	D						
Forest and Range Lands										
Brush control	x	x			x	x	x		x	x
Contour furrowing and trenching		x	x		C	B		x	x	
Contour terracing		x	x			x	x	x	x	
Critical area planting		x	x	x	x	x		x	x	
Fire prevention and suppression		x	x	x	x	x	x	x	x	
Livestock exclusion	x	x	x	x	x	x	x	x	x	x
Proper grazing use - trespass control	x	x	x	x	x	x	x	x	x	x
Range seeding		x	x		C	B			x	x
Rotation-deferred grazing		x	x		x	x	x	x	x	x
Tree and shrub planting		x	x	x		x	x		x	x
Cultivated Land										
Chiseling and subsoiling			x	x		x			x	x
Contour farming		x	x	x	x	x	x		x	x
Contour terracing		x	x	x	C-D	x			x	x
Critical area planting		x	x	x	x	x		x	x	
Crop residue and mulching		x	x		x	x		x	x	x
Field diversion		x	x		x	x			x	x
Proper cropping and use		x	x	x	x	x	x		x	x
Strip cropping		x	x		x	x	x		x	x

* Mechanical treatments are not applicable on shallow soils.

The structural measures as defined are primarily intended for use where channel erosion and sedimentation are the major problems. Debris basins are constructed to prevent sediment, usually coarse textured, from entering a downstream reach where damages may occur because of its accumulation. The degree of control over the sediment problem depends upon the available capacity relative to the sediment yield and on the stability of the channel downstream. The latter must be able to resist scour where the erosion potential is renewed by debris retention.

Reservoirs usually provide storage capacity for sediment likely to enter the reservoir during the project life in addition to the capacity needed for the design flood. Sediment storage is a secondary purpose unless the damsite is chosen so as to reduce stress on a downstream eroding channel. In the Pacific Southwest (including Wyoming, Utah and Colorado) where valley trenching in fine grained alluvium is common, erosion and sediment transport is frequently limited only by the magnitude of the discharge. Reduction of discharge by controlled release above an extended reach of valley trenching can have a substantial influence on channel erosion and sediment yield.

Drop structures are widely used in dissected alluvial channels and mountain channels to prevent continued unraveling of the bottoms and sides. They are also used near or at a headcut to prevent its further movement. Chutes and drop inlets are used for the same purpose. Drop structures are frequently used in a series. Scour below structures can most effectively be controlled by appropriate spacing in the series. Isolated drop structures in a reach with extensive erosion are not very effective except to control the problem at the specific site.

Channel lining is used to protect the bed and/or banks when it has been determined that excessive erosion will occur without this protection. This measure is usually effective in preventing erosion to the level of the flood frequency for which it is designed.

Sills have little impact on sedimentation except to prevent additional sediment from being derived from channel degradation. Their single purpose is to prevent further degradation or a new cycle of erosion.

Jacks are used roughly parallel to and in front of the bank to direct the flow to a specific width and direction and to furnish protection to the bank. In some instances deposition behind a series of jacks provides a coating to the bank and encouragement to the development of levees.

Jetties, usually projecting at an angle into the streamflow, are intended to protect only a local segment of the bank. The artificial change in direction of flow may tend to create a similar problem at another place unless it is part of an integrated plan.

Revetments protect the specific site where the installation is made. They are most appropriately used when adjacent banks are stable, such as in a vulnerable bend or where the revetments will provide a comprehensive treatment of all banks in the reach.

Structural measures for erosion and sediment control should be evaluated individually on the basis of purpose, site suitability and on the projected benefits as related to costs.

Evaluation of Management and Land Treatment Measures

Recommendations pertaining to erosion and sediment control may be very broad or very specific. Some of the more specific measures have been defined above. They may need to be combined or modified to match the scope of the recommendations. In Table 57 are given some of the management and land treatment measures considered favorable for application on land with site conditions listed.

In estimating the probable effect of individual or groups of measures on erosion for any one delineated area, the following steps are recommended: (1) identify the major source or cause of sediment; i.e., land use, upland erosion, channel erosion, by referring to columns G, H, and I in Table 58 on "Factors Influencing Sediment Yield in the Pacific Southwest"; (2) from the aforementioned

Table 58

FACTORS AFFECTING SEDIMENT YIELD IN THE PACIFIC SOUTHWEST

Sediment Yield Levels	A SURFACE GEOLOGY	B SOILS	C CLIMATE	D RUNOFF	E TOPOGRAPHY	F GROUND COVER	G LAND USE	H UPLAND EROSION	I CHANNEL EROSION & SEDIMENT TRANSPORT
High	(10)* a. Marine shales and related mudstones and siltstones.	(10) a. Fine textured; easily dispersed; saline-alkaline; high shrink-swell characteristics. b. Single grain silts and fine sands	(10) a. Storms of several days' duration with short periods of intense rainfall. b. Frequent intense convective storms c. Freeze-thaw occurrence	(10) a. High peak flows per unit area b. Large volume of flow per unit area	(20) a. Steep upland slopes (in excess of 30%) High relief; little or no floodplain development	(10) Ground cover does not exceed 20% a. Vegetation sparse; little or no litter b. No rock in surface soil	(10) a. More than 50% cultivated b. Almost all of area intensively grazed c. All of area recently burned	(25) a. More than 50% of the area characterized by rill and gully or landslide erosion	(25) a. Eroding banks continuously or at frequent intervals with large depths and long flow duration b. Active headcuts and degradation in tributary channels
**									
Moderate	(5) a. Rocks of medium hardness b. Moderately weathered c. Moderately fractured	(5) a. Medium textured soil b. Occasional rock fragments c. Caliche layers	(5) a. Storms of moderate duration and intensity b. Infrequent convective storms	(5) a. Moderate peak flows b. Moderate volume of flow per unit area	(10) a. Moderate upland slopes (less than 20%) b. Moderate fan or floodplain development	(0) Cover not exceeding 40% a. Noticeable litter b. If trees present understory not well developed	(0) a. Less than 25% cultivated b. 50% or less recently logged c. Less than 50% intensively grazed d. Ordinary road and other construction	(10) a. About 25% of the area characterized by rill and gully or landslide erosion b. Wind erosion with deposition in stream channels	(10) a. Moderate flow depths, medium flow duration with occasionally eroding banks or bed
**									
Low	(0) a. Massive, hard formations	(0) a. High percentage of rock fragments b. Aggregated clays c. High in organic matter	(0) a. Humid climate with rainfall of low intensity b. Precipitation in form of snow c. Arid climate, low intensity storms d. Arid climate; rare convective storms	(0) a. Low peak flows per unit area b. Low volume of runoff per unit area c. Rare runoff events	(0) a. Gentle upland slopes (less than 5%) b. Extensive alluvial plains	(-10) a. Area completely protected by vegetation, rock fragments, litter Little opportunity for rainfall to reach erodible material	(-10) a. No cultivation b. No recent logging c. Low intensity grazing	(0) a. No apparent signs of erosion	(0) a. Wide shallow channels with flat gradients, short flow duration b. Channels in massive rock, large boulders or well vegetated c. Artificially controlled channels

THE NUMBERS IN SPECIFIC BOXES INDICATE VALUES TO BE ASSIGNED APPROPRIATE CHARACTERISTICS.
THE SMALL LETTERS a, b, c, REFER TO INDEPENDENT CHARACTERISTICS TO WHICH FULL VALUE MAY BE ASSIGNED.

IF EXPERIENCE SO INDICATES, INTERPOLATION BETWEEN THE 3 SEDIMENT YIELD LEVELS MAY BE MADE.

table, extract the topographic and soils characteristics listed in columns E and B for upland erosion areas; (3) determine the climatic environments for the area on the broad basis of arid, semi-arid, sub-humid, and humid. If the treatments listed in Table 58 are checked as appropriate for each of the variables of climate, soils and topography for the area considered, the treatment would likely reduce erosion in the area.

Those areas which may be identified geographically as "cliffs" or "badlands" should not be considered suitable for land treatment measures. All areas are affected by geologic erosion, the amount depending upon the geologic, topographic, and climatic conditions peculiar to the site. This is a "background" rate of erosion unaffected by man's level of use either directly or indirectly. High geologic erosion sites are characterized by an arid environment and/or by periods of exceptionally heavy rainfall and runoff.Detached or easily dispersed soils on very steep slopes in an unfavorable climate furnish an unstable medium for veg - tative growth. In humid or subhumid areas landslides and land slips may be the characteristic expression of geologic erosion, although land use can be a contributing or even major cause.

Management measures applied alone are termed an extensive treatment. When these are combined with land treatment measures, they are termed intensive treatment. (See Table 58). Whether or not extensive and intensive measures are recommended depends on treatments indicated as appropriate in Table 58 and on other possible limiting factors, including economics.

Evaluation of Structural Measures

The scope and method of evaluating structural measures is similar to that for treatment of the land in that off-site and on-site benefits may accrue by application of some of the measures. For example, prevention of continued bank erosion by a stabilization structure can reduce the sediment yield as well as prevent the loss of more land along the bank. On the other hand, land treatment measures usually apply to broad areas whereas structural measures for the purposes herein described are placed in stream systems where specific sites may be involved. Evalustion is thus more on a specific site basis.

Debris basins are designed for specific purposes. These may include prevention of land destruction or deterioration by overwash, reduction of cleanup costs, prevention of channel aggradation, and resulting overbank flooding. A reduction in sediment yield based on debris basin construction is justified only when coarse sediment is the major constituent.

Detention or mulit-purpose reservoirs retain all sizes of sediment behind the structure and sediment yield downstream is dependent on the trap efficiency of the reservoir. Reservoirs may be placed above a valley trench to reduce stress on the eroding channel by a reduction in flood peaks. However, long duration low flow releases may render a channel more vulnerable to erosion. Such a condition can exist when fine, lightly cemented or cohesive soils lose their resistance to erosion with the extended wetting.

A system of drop structures and bank revetments can reduce sediment yield when channel erosion is a major source. However, it is unlikely that one or a small number of measures installed in channels will result in a substantial reduction unless a particularly favorable situation occurs. This might include a drop structure located to stop a headcut from trenching an extensive valley.

Evaluation of Land Treatment and/or Structural Measures

Considered here are the potential off-site benefits from treatment under high or moderate yield potential for both Upland Erosion and Channel Erosion and Sediment Transport, Columns H and I in Table 58 "Factors Affecting Sediment Yield". When both are in the high classification, treatment of uplands but not channels is less likely to result in a significant reduction in total yield. The reason is that material is readily available in the channel and the stream may become loaded to capacity from this source without regard to contributions from hill slopes.

Measures applied to one of the other combinations of upland and channel erosion conditions should have a greater impact on sediment yield with the possible exception of the treatment of high channel erosion but not that on the upland. The topography, cover and precipitation patterns determine to a large degree what sediment load the upland eroding areas furnish when the flow reaches the channel.

Procedure for Evaluating Effect of Application of Measures on Erosion and Sediment Yield

Table 59 presents numerical values for estimating the effect of measures on sediment yield. As in Table 58, climatic environment is subdivided into four types to facilitate classification in accord with more or less favorable vegetative response to varying moisture conditions.

The factors which can be affected by treatment are Ground Cover, Land Use, Upland Erosion and Channel Erosion. Table 59 reflects changes in the numerical ratings in Table 58 "Factors Affecting Sediment Yield in the Pacific Southwest". Based on the treatment to be applied, the new rating uses the same numbers as given on the chart for factors A through E and new values in accord with Table59 for columns F through I.

TABLE 59 - EVALUATION OF MEASURES

Sediment Yield Levels	Climatic Environment	F. GROUND COVER Extensive Treatment	F. GROUND COVER Intensive Treatment	G. LAND USE Extensive Treatment	G. LAND USE Intensive Treatment	H. UPLAND EROSION Extensive Treatment	H. UPLAND EROSION Intensive Treatment	I. CHANNEL EROSION & SEDIMENT TRANSPORT Extensive Treatment	I. CHANNEL EROSION & SEDIMENT TRANSPORT Intensive Treatment
High	Arid	8	5	8	5	20	15		
	Semi-arid	5	0	5	0	15	10		
	Sub-humid	0	-5	0	-5	10	5		
	Humid	-5	-10	-5	-10	5	0		
								20	5
Moderate	Arid	0	-3	0	-3	10	7		
	Semi-arid	-3	-5	-3	-5	7	5		
	Sub-humid	-5	-7	-5	-7	5	3		
	Humid	-7	-10	-7	-10	3	0		
								5	0

CONCLUSIONS AND RECOMMENDATIONS

SUMMARY OF MANAGERIAL PRACTICES AND RESEARCH NEEDS

Stabilization of the sediment source by proper land management and erosion control measures is the most direct and usually the most satisfactory approach in dealing with most sediment problems. Such erosion control practices conserve land and vegetation resources and at the same time reduce sediment yield. Where the sediment is derived from sheet and rill erosion on agricultural, forest, or range lands, certain agronomic and forest and range management practices as well as mechanical and structural measures effectively reduce sediment yields. For instance, changing cultivated fields from row crops to small grain may reduce the soil loss due to sheet erosion 60 to 90 percent, depending on cover conditions, soils, and seasonal distribution of rainfall.

Rotating crops to include meadow in the cropping sequence may reduce the soil loss from fields 75 percent. Such practices as mulching, stripcropping, and contour cultivation have been shown to be highly effective in reducing soil erosion on farmland. Graded cropland terraces may reduce erosion on fields 75 percent and in combination with crop rotations, mulching, minimum tillage, etc., can further reduce soil loss from cultivated fields.

Converting cropland to good grassland, pasture, or woodland can reduce soil erosion 90 percent or more.

The control of streambank and streambed erosion usually requires emphasis on structural measures. Grade stabilization structures, riprap on streambanks, installing jacks to induce deposition, and sloping and vegetating eroding banks are among the measures to be considered.

There is ample evidence to support using such structures to reduce sediment yields. Agronomic and supporting mechanical field practices have reduced the amount of sediment reaching reservoirs by amounts ranging from 28 to 73 percent. Good conservation practices on cultivated watersheds have reduced sediment yields almost 90 percent. The protection of existing forest and range lands by these measures has reduced sediment yields as much as 90 percent. Streambank-protection work on Buffalo Creek, New York, reduced sediment delivery to Buffalo Harbor,during flood flows, 40 percent. It is anticipated that the sediment yields from logging operations in the Middle Fork Eel River, California, will be reduced about 80 percent with proper planning and management

Grazing management practices that restrict livestock use to the carrying capacity of range or pasture reduce water erosion and sedimentation. Some of these practices are:

1. Rotation grazing permits intensive use of fields or portions of fields on an alternating basis. The nonuse period encourages vegetation recovery and renewed vigor prior to the return to livestock use.

2. Water supply dispersal provides better distribution of livestock use, reduces overuse or overgrazing in the vicinity of water supplies, and reduces erosion hazard.

3. Seasonal grazing that is compatible with the most productive period for the particular vegetation permits recovery and reseeding.

4. Range revegetation and pasture improvement increase the density, vigor, and desirable composition of the vegetative cover, thereby reducing runoff and erosion.

5. The dispersal and occasional relocation of salt, mineral, and feed supplement sites avoids concentrated overuse of these areas.

6. Ponds in pastures conserve water while providing water for livestock.

Benefits accrue from the control of sediment pollution in many ways. They include (1) reduction in the cost of removing sediment from channels, harbors, and reservoirs; (2) reduction in the cost of treating water for municipal and industrial uses; (3) reductions in maintenance costs associated with power production, water distribution systems, and highways; (4) reductions in damage to wildlife habitat; (5) prevention of damage to flood plains; and (6) enhancement of recreational facilities. Corollary to the reduction of damage caused by sediment, effective control maintains the productivity of the soil resource and prevents the loss of land.

Research Needs

Research studies are needed. Sources of sediment and dissolved solids which enter the stream system due to mans' activities are not fully documented. In many instances, it is difficult to differentiate between man-related, and geologic or natural problems. Source areas should be located and identified as to the cause and effects of problems such as: improper land use, inadequate treatment measures, and poor management. More definitive information is needed on the dissolved solid pollution factor.

The present practice of tabulating information from measured sources and assessing the remaining, unaccounted for, portion of the load to irrigated lands is too general, and may be inaccurate. Movement of sediment out of the region has been curtailed by reservoirs; however, the in-basin movement of sediment needs to be controlled. Improved vegetal cover conditions and land use and management reduce sediment, but detailed information as to the effects of measures and practices is needed for effective planning.

The Federal programs for erosion and sedimentation research, including the cost thereof, are under continuing review, together with other aspects of water resources research, by the Committee on Water Resources Research (COWRR) of the Federal Council for Science and Technology. This committee has developed and is updating long-range programs for research in this area. A work group assigned to substantive review of efforts, plans, and goals for research in the general field of surface water hydrology (SURHY Work Group), in reporting to COWRR in June 1967, confirmed the need for increased emphasis on erosion and sedimentation research and presented detailed recommendations that should be consulted.

The following areas should receive principal research emphasis. Research to develop new and improved technology essential to program effectiveness must be considered in connection with each action program.

1. Minimizing soil erosion and curbing sediment delivery from agricultural, range, and forest lands

Existing legislation authorizes the Department of Agriculture to provide technical assistance to farmers, ranchers, and other private landowners to achieve erosion control and also to provide forest management and fire control programs. Existing legislation also authorizes cost-sharing (principally on an annual basis through the Agricultural Conservation Program) and payments for diversion of cropland acreage to conserving uses of the land.

Contractual arrangements are authorized under several USDA programs, including the Great Plains Conservation Program, the Appalachian Land Stabilization and Conservation Program, the Cropland Converstion Program, and the Cropland Adjustment Program, to achieve erosion control and other conservation benefits. The Department of Agriculture anticipates proposing similar arrangements under the Soil Conservation and Domestic Allotment Act as amended. Existing and proposed legislation constitute a satisfactory basis for working with owners and operators of private lands in establishing those erosion control measures that can be justified on the basis of returns to the owners and operators.

Existing loan programs within USDA make funds available to individuals and associations to aid in the establishment of soil and water conservation practices. With additional funds, these programs could be expanded.

Existing legislation for effective erosion control on public lands as well as on Indian lands is generally adequate. The lack of adequate programs in erosion control on these lands stems from the need for increased funding to conduct needed programs.

It must be recognized, however, that many critical sediment source areas, on both privately owned lands and certain public lands, such as landslides, badly eroding logging roads and hillsides, and deep gullies, are not treated because onsite benefits are insufficient to justify costs. Most of such critical source areas should be stabilized or brought under control to reduce sedimentation that may adversely affect downstream water users. Numerous offsite benefits derive from such work reduction of sediment damage to lands both adjacent and far removed and to the aquatic habitat; preservation of stream-channel flow capacity and reservoir storage capacity; reduction in turbidity and in pollution of water in streams and lakes; maintenance of attractive water-based recreation opportunity. Under existing legislative authority the necessary work is not possible for every situation requiring it. Additional legislation or funds, or both, are required to cover the cost of such measures over and above the amounts that can be justified on the basis of onsite returns.

Controlling Sediment in Stream Channel Systems

Unlike the treatment of many erosion problems that can be done by individual landowners, the control of streambank erosion requires consideration of an entire stream or major reach involving many landowners and communities. The vegetative and structural measures that have been devloped have wide application in solving stream erosion problems. Adequate legislative authority or funding, or both, are needed to attack the problem on an estimated 3,000,000 miles of streambank.

Channel erosion within the rangeland watersheds of public and Indian lands can be controlled to a substantial degree through watershed treatment. The authority to condcut the programs needed on these lands is considered adequate but the rates of investment must be accelerated to accomplish them.

The USDA Agricultural Conservation Program includes a streambank-stabilization practice for which cost-sharing assistance for voluntary performance would be available to most farms and ranches (including Indian lands and farms owned by State or local governments),either by individual farms or through multiple-farm pooling agreements. Assistance is not available under this program to a nonfarmer and usually not for federally owned land. Nor is it available to an organization such as drainage districts, etc., which are essential for equitable financing and required maintenance, that assesses landowners for these purposes, collects taxes (or if uncollected establishes a lien against the land), and pays for the work with these funds.

Soil and moisture conservation funds are available to a number of Federal agencies to prevent erosion of Government-owned lands and to control eroding streambanks that endanger Federal property. Additionally, the Department of the Interior performs certain streambank stabilization and related sediment control work under specific authorizations of Congress.

Limited amounts of streambank stabilization work can be done under provisions of the USDA-administered Watershed Protection and Flood Prevention Act, PL-566, which requires that the entire watershed of a stream be brought into the plan.

Department of Defense projects,[1] designed for other purposes, contribute significant incidental benefits in preventing or controlling sediments already being transported by streams or in reducing erosion of riverbanks and riverbeds. Thus, Department of Defense and Department of the Interior reservoirs for flood control, hydropower, recreation, and other purposes also serve as highly effective sediment traps and, by controlling and reducing peak flows, also reduce stream erosion and sediment transport. In some upstream reservoirs, incremental storage capacity is provided beyond that required for the effective operation of those reservoirs over their designed economic or technological life, as a means of reducing sedimentation of downstream reservoirs, locks and dams, or channels. Along certain reaches of the Mississippi, Missouri, Arkansas, Red, Sacramento, Willamette, and other rivers, bank stabilization is an integral component of specifically authorized Department of Defense flood control or navigation projects or project-systems and is provided as a means of stabilizing channel dimensions and alignments or to protect levees and floodwalls.

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[1]Refers to Civil Works Program of the Corps of Engineers.

Under its "Emergency Bank Protection" program authorized by Section 14 of the 1946 Flood Control Act, the Department of Defense constructs works to protect endangered highways, highway bridge approaches, and other essential or important public works, such as municipal water supply systems and sewage disposal plants, which are threatened by flood-caused bank erosion. A Section 14 project must be complete in itself and must not require additional work for effective operation. Each project must be economically justified, and the maximum Federal expenditure per project is $50,000. The local sponsoring agency must agree to provide, without cost to the United States, all lands, easements, and rights-of-way, and all required alterations and relocations of utility facilities; to hold and save the United States free from damages; to maintain the project after completion; to assume all project costs in excess of the Federal cost limit of $50,000; and to provide a cash contribution in proportion to any special benefits to on public property.

In accordance with Section 120 of the River and Harbor Act of 1968, the Corps of Engineers is conducting a study of the nature and scope of damages resulting from streambank erosion throughout the United States, with a view toward determining the need for and the feasibility of a coordinated program of streambank protection, in the interest of reducing damages from the deposition of sediment in reservoirs and waterways, the destruction of channels and adjacent lands, and other adverse effects of streambank erosion. The report on this study is to include recommendations on an appropriate division of responsibility between Federal and non-Federal interests.

Executive Order 11288 of July 2, 1966, provides for broad responsibilities and authorities in every phase of water-quality management. This authority extends to the activity regardless of the form of improvement, ie., sediment. The heads of agencies are held responsible for sediment pollution caused by all operations of the Federal Government, such as water-resource projects and operations under Federal loans, grants, or contracts.

Under the Water Quality Act of 1965 and the Clean Water Restoration Act of 1966, the Department of the Interior has responsibility for . . . "developing and demonstrating. . . : Practicable means of treating . . . waterborne wastes to remove physical, chemical, and biological pollutants in order to restore and maintain the maximum amount of the Nation's water at a quality suitable for repeated use." Abatement of pollution is implemented through grants and contracts to individuals, industries, local communities, municipalities, etc., in which a particular project may receive support of as much as 75 percent of the total investment.

Water Quality Impact Research Needs

The water requirements of our expanding population will continue to increase substantially in future years. Rangelands are of vital importance as a source of much of the water that is and will be needed for domestic, industrial, and agricultural use. To help meet these needs, specific information is urgently needed relative to: (1) the legal aspects and relative economic benefits of on-site versus off-site water use; (2) the relative benefits of practices which reduce sedimentation but also decrease total water yields; (3) the effects on runoff and water quality of converting brushlands to herbaceous cover; (4) the effects of converting woody riparian vegetation to herbaceous cover on water quality and yields, on food and habitat for aquatic life, and on stream bank stabilization; and (5) the effects of recreational use of range watersheds on the hydrologic cycle.

Improved Range Management Practices

With continuing research contributing to the existing organized body of knowledge known as Range Science, improved management practices will continue to evolve. Range Science is much younger than crop science and is more a synthesis of other disciplines. It has emerged from the biological sciences and from mathematics, physics, chemistry, and the social sciences. Other fields of study - such as meteorology, entomolgy, hydrology, animal science, forestry, agronomy, economics, etc. have and can contribute substantially to better range management principles. These disciplines must be encouraged to play a role in this development process. They can and should be coordinated through strengthened linkages fostered by increased educational and research activity.

Educational Needs

Since range management is a relatively new discipline, there must be recognition and appreciation for the need to provide continuing education, widely diversified, of trained rangemen. This continuing education should center on sound ecological principles applicable to range management needs, with emphasis on the Interrelationships of the climate-soil-plant-animal complex. Range management personnel, then, should be continually trained in these essential principals of proper range management.

The kind of educational foundation is important. It must provide the necessary preparation for further specialization in any of the several major rangeland uses. Decision-makers in the management of rangelands must of necessity work closely with specialists in other disciplines such as wildlife management, forestry, animal science, agronomy, hydrology, or recreation.

A broad-based environmental educational program for the Region VIII area could provide the mechanism to address these kinds of specific educational, technology transferral needs.

This delivery mechanism could be patterned after the existing educational framework of the Cooperative Extension Service. The Extension system is based on the enhancement of professionalism. Professionalism in Extension is manifested by a sense of responsibility that stimulates the indivdual to strive for greater technical competence and to perform, within the limits of one's competence, at a superior level. Recognizing that the improvement of one's competency is an individual responsibility, a well designed and executed educational effort must encourage and provide for the development of opportunities for such individual improvement by means of seminars, workshops, publications and other media, and technical assistance in the field.

In this respect, consideration for the establishment of a Regional Public Information and Pollution Control Technology Transfer Network within Region VIII is strongly recommended. (See Part II of this report)

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LOGGING AND FORESTRY

In our discussion of non-point source related problems stemming from current practices within the area of logging and forestry management and operations we will concentrate on the report "Forest Management in Wyoming." This report deals extensively with the wide range of problems occurring within the U.S. Forest Service Region 2 which includes the states of Colorado, Wyoming, and South Dakota. Similar problems occur within the other Region VIII EPA states and can be viewed accordingly.

Major contributing factors to non-point source pollution within the logging industry include (a) clearcutting, (b) road-building, (c) residue, and (d) nutrients.

Clearcutting

Clearcutting, the harvesting method that has been used almost exclusively in lodgepole pine, and frequently in Englemann spruce, is the overwhelming focal point of concern about forest management within Region VIII. In the Wyoming investigation, almost without exception, the size of clearcuts in Colorado, Wyoming, and South Dakota were protested. Forest personnel as well as loggers agreed that many cuts had been entirely too large and were opposed to extensive openings created by some of the older timber sales.

Another common criticism was the real, potential, and suspected damage that clearcuts were doing to watersheds, wildlife habitats, recreational opportunities and scenic values.

The report emphasized that clearcutting methods would have to be modified if the environment were to be protected. One of the major fears expressed was that clearcutting was causing increased spring peak runoffs resulting in serious streambank erosion, thus reducing the quality of water.

Strong evidence exists that streamflow response is proportional to change in forest cover. For example, 39% of the lodgepole pine timber was clearcut from a 7.4 acre watershed in Colorado that normally yielded 12 area-inches of runoff. As a result, annual streamflow was increased approximately 7.5 area inches from the area of timber cut, an amount equivalent to 3 area inches from the entire watershed. Although the Wyoming report noted "negligible" erosion and sediment production, whether this were entirely true would depend on one's definition of "negligible." It would seem that any increase in streamflow would cause an erosion and sediment production increase. A number of such occurances within any given forest area would most likely have adverse effects on water quality in the area.

On the other hand, the report concluded that "it is quite possible that spring snowmelt runoff from small tributary drainages that are a few hundred acres or less and are clearcut over substantial areas, could have been increased sufficiently to cause local scouring and streambank erosion."

Cutting Close to Streams and Ponds

Although cutting too close to ponds and streams was viewed more an aesthetic problem rather than a water quality problem, several examples of this practice were cited in the report. The report stated that the felling of trees per se does not affect water quality. On the other hand, it did emphasize that skidding of logs did result in increased sedimentation.

In several instances, the investigators encountered potential for damage to streamflow quality in the form of logging residues clogging stream channels. The example given was in Jules Bowl in the Shoshone National Forest. The report recommended research to determine the kinds and sizes of areas and proportions of watersheds that could be safely clearcut at one time without creating damages on streamflow quantity, quality, or timing and the nature and magnitude of on-site changes in nutrient content and stream eutrophication that may result from soil and vegetation disturbances.

Road Construction

Research and experience in many places have shown that none of man's activities in forests contribute more to poor water quality in streams than roads, especially roads that are located too close to streams, built on too steep a grade, and those inadequately drained. The report confirms that roads are the greatest man-caused source of stream sedimentation in the forests.

The possibility of disturbance of the ecological balance in forests increases with road use. The balance is extremely delicate in some areas, and failure to recognize the allowable limits of disturbance has led to serious resource management problems. Road construction is one of the most severe disturbances that man can impose upon the forest. Roads expose raw mineral soil to erosion and alter the contours of the landscape. Management practices that minimize the undesirable environmental effects of roads are essential.

Watershed

It has been charged that road planning and construction on Region VIII Forests have been faulty, causing accelerated soil erosion, increased sedimentation in stream channels, and damaged fisheries. Experience and research in a number of places - from Great Smoky Mountains of North Carolina, the Appalachians of West Virginia, the White Mountains of New Hampshire and through the Rocky Mountains of Arizona, Colorado, Idaho, and Montana to the Sierra Nevada of California and the Cascades of Oregon and Washington - confirm that roads are the main cause of reduced water quality in forested watersheds (Packer, 1967). Much of this same research also shows that well-designed roads located away from water courses and provided with proper drainage need not cause damage to the quality of streamflow. There is evidence that a high degree of quality control can be obtained in road construction. Perhaps the best examples in this respect are the Antelope Mountain and Enos Creek roads on the Teton and Shoshone National Forests, respectively. These roads were designed, located, and built with the greatest regard for watershed and esthetic considerations.

Observations strongly support research conclusions as to the importance of specific road design and construction criteria. In each of these Forests there are unstabilized road cuts and fills, poorly installed culverts, and sections of roads having improperly spaced drainage facilities. Of special importance are the many miles of temporary roads on which soil is being eroded because logging activities continued so far into the fall or winter that surface drainage facilities could not be installed in the frozen earth. These rather frequent occurrences of soil erosion and sediment movement from roads toward streams are reason for serious concern. Damage to watersheds and water quality from these sources has not yet been great, but there is urgent need to develop better quality control in roadbuilding and maintenance.

There are several instances of road construction on unstable areas, threatening serious watershed damage. A review of the conditions on five of these Wyoming areas illustrates several problems.

Leads Creek -- Part of the main haul road was built through soil derived from glacial silt, which is highly susceptible to accelerated sheet and gully erosion. Excessively wide stretches of this road coupled with inadequately spaced surface drainage and a few plugged culverts, have allowed sediment-laden runoff from the road to enter Leads Creek in several places.

Three Forks Creek -- The upper portion of the main haul road traversed extremely steep slopes. Here again, an excessively wide road was built, resulting in high vertical cut banks that are now collapsing, and overly steep fill slopes that are sloughing away.

Cabin Creek -- Portions of the main haul road were built across obviously unstable slopes ("slump topography") and potential landslip areas. As a result one entire section of road, several hundred feet long, has actually slipped down the hill into the drainage bottom, creating a new source of sediment during high water periods.

Poison Creek -- Portions of some of the temporary roads are on locations that do not allow good surface drainage. Overland flow down these road surfaces has concentrated to the point where large rills and small gullies have been eroded in the roadbed. Sediment from these eroding surfaces can be expected to degrade nearby streams.

Brooks Lake (Jules Bowl) -- Roads were constructed on relatively stable soils derived from variegated clay stone, shale, and sandstone, and from coarse glacial till. Some of the temporary roads were built at grades of more than 12% and some were excessively wide. Many of the fine soil fractions have already washed off these roads, leaving a rocky erosion pavement in places. Some poorly constructed cross-drains have broken through, permitting surface runoff to concentrate sufficiently to wash soil downslope. Fortunately, since most of the roads are far removed from Brooks Lake Creek, there is small probability that sediment will reach this live stream. Part of the Brooks Lake timber sale area is located on slump topography showing mass instability, expecially when the soil mantle becomes saturated. In several places large amounts of logging residue, some from road construction, were left in small tributary stream channels, thereby slowing the normal drainage of water out of small basins and permitting the soil mantle to become locally saturated continuously. There is already evidence of increased mass soil slumping as a result of this.

These mistakes in road location and construction are not isolated instances and they are cause for concern for several reasons. First, the knowledge necessary to prevent them was available but not used. Second, they cannot be dismissed on the grounds that "we are no longer doing it this way." Some of the cited roads were built during the past 5 years. There is still not enough quality control of road construction for watershed protection.

An associated problem with roads in forest and range areas is that in too many instances off-road vehicles have used them as"jumping-off" routes into other areas. This use creates "roads" where none were intended and can lead to many of the same problems as caused by roads actually planned.

EFFECT OF FOREST MANAGEMENT PRACTICES ON NUTRIENT LOSSES

Many questions concerning forest management practices revolve around nutrient losses resulting from timber cuts that tend to upset the balance of the forest ecosystem.

We must ask ourselves to what extent modern logging practices rob the land of needed nutrients. Will continued logging without regard for this aspect lead to loss of nutrients that are needed to assure future regrowth of forests?

Several studies have been conducted over the past decade. In a report prepared for the Hearings of the Subcommittee on Public Lands, Committee on Interior and Insular Affairs, United States Senate on the Management of Public Lands (Church Hearings), April-May, 1971, the U.S. Forest Service concluded: "On the basis of currently available information, we find no drastic or irreversible depletion of forest soil nutrient reserve caused by timber removal. Nutrient overflows are small compared to the total nutrient reserve in the soil.

"Centuries of experience in Japan and Germany show no site degradation from repeated even-aged cropping of forests, where proper management was used. Agricultural experience also indicates the ability of managed soils to maintain crop productivity and to be improved if depleted of nutrients and organic matter.

"Although not all timber types and soil conditions have been studied, about 15 Forest Service experimental watershed studies and perhaps 20 other studies of nutrient outflow are rapidly accumulating data for the evaluation of multidisciplinary research teams."

The report issued for the Church Hearings was based on studies conducted at Hubbard Experimental Forest, New Hampshire; White Mountain National Forest, New Hampshire; Fernow Experimental Forest, West Virginia; Coweeta Hydrologic Laboratory, North Carolina; H. J. Andrews Experimental Forest, Oregon; Alsea River Watershed, Oregon; Cedar River Watershed, Washington; Blackfoot-Clearwater Drainage, Montana; Flathead National Forest, Montana; and Truckee River, Nevada.

Blackfoot-Clearwater Drainage, Montana

Water quality and seasonal fluctuation of water quality were surveyed at 30 sites in the Blackfoot-Clearwater Drainage of Montana (Weisel and Newell, 1970). The researchers noted that, in comparison with other waters in the United States, the streams studied were relatively unaltered by man's activities and were of outstanding purity. The highest nitrate-Nitrogen level recorded was 0.16 ppm.

Flathead National Forest, Montana

The quality of surface runoff water from logged and unlogged units was measured by DeByle (1971), on the Miller Creek Block in the Flathead National Forest, Montana. On the logged units, slash was lopped in place and burned. Despite the drastic burning treatment, annual nutrient losses in surface runoff in pounds per acre were not large:

	Unlogged, Unburned	Logged and Burned
Potassium	3.40	2.70
Calcium	0.60	1.60
Magnesium	0.60	0.40
Sodium	3.10	1.70
Phosphorus	0.04	0.02
Total Dissolved Solids	24.00	21.00

The greatest loss by weight of any one element was 3.4 pounds per acre of potassium from the unlogged plot.

The Forest Service report cited above contained a reference to the fact that only very long-term research will show the complete nutrient regime in managed forest lands.

It is difficult to find quantitative information in ample amounts for Region VIII in terms of studies of nutrient losses related to forest management practices. There is no question that this is an area in need of greater study and more in-depth analysis by researchers.

FEDERAL LANDS - MISSOURI RIVER BASIN

National Forest System - The National Forest System in the basin is comprised of all or parts of 18 national forests, eight national grasslands, and two Land Utilization Project areas totaling 19.4 million acres. These lands are administered by the Forest Service of the Department of Agriculture.

Timber from the national forests is harvested under term timber sale contracts by private logging and milling enterprises. Rangelands are used by ranchers for livestock grazing under paid permits. Most of the grazing permits are 10-year term permits to assure continued stability to the agricultural economy dependent upon this resource.

The Forest Service in 1924 designated specific areas as wilderness areas within the national forests. The initial 1.6 million acres of the National Wilderness Preservation System created in 1964 are in nine national forests wildernesses, previously classified as Wilderness and Wild Areas. Another 900 thousand acres of the national forests, set aside in seven Primitive Areas, are being studied for possible inclusion in the Wilderness System. The wildernesses are an integral part of multiple use in the national forests. In management of these units, emphasis is placed on keeping and restoring the natural conditions. Mechanized equipment is not permitted, except in cases of emergency involving lives or property; trees are not cut; and roads and all developments except foot and horse trails are prohibited. Fishing, hunting, camping, hiking, and grazing of domestic livestock are permitted.

Public Domain--The Bureau of Land Management manages the remaining public domain lands and resources, the basic administrative units being the eleven districts within the basin.

Within the Missouri Basin there are 18.5 million acres of public domain, located principally in Montana, Wyoming, Colorado, and the Western Dakotas. The basic Federal management objective for these lands is to achieve their maximum use, consistent with conservation, and with development of the productive capacity of the renewable resources.

The traditional concept of the public lands as a grazing resource only is gradually being broadened. In the Missouri Basin these lands support 1,200,000 cattle and twice that number of sheep. Over 190,000 big game animals graze the lands, utilizing forage reserved for their use. Approximately 26,000,000 board feet of sawtimber are cut annually. There are an estimated 1,440,000 annual recreation visits to the public domain. This includes those by sportsmen who harvest some 17,000 antelope, 27,000 deer, 53,000 upland game birds, and substantial numbers of other game and fish. Mineral products are extracted in quantity, particularly oil and gas; 37.5 percent of the revenue derived is returned to the state of origin, 52,5 percent to the Federal Reclamation Fund, and 10.0 percent to the United States Treasury. Public land watersheds contribute importantly to main-stem flows, and their vast acreages are being recognized for their contributions to the "open space" philosophy.

Public domain lands are managed by a decentralized organization with major responsibility delegated to its field representatives. Framework policies expressed by Congress are carried out to stabilize the livestock industry; conserve soil and other natural resources; to utilize and protect timber, mineral, and other resources; encourage such multiple uses as recreation and fish and wildlife utilization; and to make the lands available for urban occupancy and industrial development. Land classification is underway on a basinwide scale to designate areas adapted to continued Federal retention and management, for use and preservation of their public values, and to identify those needed in special local government programs and those best suited for private ownership.

FOREST RESOURCES - MISSOURI RIVER BASIN

The forests of the Missouri Basin are concentrated largely in two major geographic areas: (1) in the Ozark Plateaus in the Lower Missouri Subbasin and adjacent areas in the southern portion of the basin; and (2) in the Rocky Mountains and Black Hills of the Upper Missouri, Yellowstone, Platte-Niobrara and Western Dakota subbasins.

The 22 million acres of forest in the western portion of the Missouri Basin comprise 73% of all its forest lands and represent 65% of the production from commercial forests. A large proportion of these forest lands is federally owned. In the western portion of the basin, trees seldom grow at less than 4,000 feet above sea level, except along river bottoms. A big proportion of the forests at low elevations consists of low-quality stands of juniper and ponderosa pine which are classed as noncommercial forests. The commercial forests are located at somewhat higher elevations and consist mostly of lodgepole pine, Douglas fir, Englemann spruce, and ponderosa pine. They occur along the eastern slopes of the Continental Divide and on a number of mountain ranges to the east. At still higher elevations there are additional noncommercial areas of rugged sites with scrubby trees--largely subalpine fir, white bark pine, and Englemann spruce.

FOREST REOUSRCES - UPPER COLORADO RIVER BASIN

Lumber for home construction is the major forest product of the Upper Colorado River Basin Region and most of it is exported to other parts of the country. The railroad, mining, electric-power, farm and ranch industries continue to be major users of lumber and wood products in the Region. New uses for timber are being developed and exploited by the wood manufacturing industries.

Statistical Highlights

Twenty-four million acres, or 33%, of the Region is forested, of which 9.4 million acres are classed as commercial (Table 60)

Of the commercial forest area 82% is in public ownership (primarily national forests), and is composed mainly of softwood sawtimber types.

Table 60. - Area of commercial forest land by type of ownership and subregion, Upper Colorado Region, 1965

Type of ownership	Subregion			
	Green River	Upper Main Stem	San Juan-Colorado	Region
	Thousand acres			
Federal:				
National forest	1,971	3,315	1,483	6,769
Bureau of Land Management	311	150	32	493
Indian	57	75	197	329
Other	-----	-----	2/	2/
Total	2,339	3,540	1,712	7,591
State and county	53	35	46	134
Farmer	408	790	204	1,402
Other private 1/	100	173	19	292
All ownership	2,900	4,538	1,981	9,419

1/ Forest industry has been combined with other private to avoid disclosure of holdings of an individual owner.
2/ Less than 0.5 thousand acres.

The inventory includes 57 billion board feet of sawtimber. The average sawtimber volume on commercial forest land is 6,034 board feet per acre.

Englemann spruce is the leading species with 33% of the growing stock volume and 43% of the sawtimber.

Current net annual growth amounts to less than 1% of inventory and averages 15 cubic feet per acre. Intensive management could increase the average net growth several times. Timber removals (mainly commercial harvests) in 1966 amounted to 53 million cubic feet. Saw logs accounted for 79% of the cubic volume of products, veneer logs 11%, pulpwood 1%, and miscellaneous products 9%. This represented only 0.36% of growing stock inventory as compared with a rate of 0.86% for the Rocky Mountain States.

Forest lands of the Upper Colorado Region have many values--recreation, forage for domestic livestock and wildlife, timber, and water. Use of forests for some of these values, particularly forage, has been heavy for many years. Recreation use has mounted extremely rapidly since World War II. Timber utilization has been relatively light, although it has continued to rise.

Projected Growth in Timber Harvests *

For the Region as a whole current (1965) annual removals of growing stock are about 38% of the current net annual growth. Annual growing stock removals are projected to equal growth by 1983, rising to 120% of growth by about 2012. Subsequently, although removals and growth both continue to rise, the difference becomes less and eventually (sometime after the end of the projection period) they should be about equal. Sawtimber removals are now (1965) about 72% of growth and projections indicate they will pass growth before 1970 and rise to 193% of growth in 2020. They probably will decline quite rapidly after 2020. Generally similar situations exist in each subregion although there are variations in extent and rapidity of change. Removals are currently (1965) less than growth in all subregions except in the case of sawtimber in the San Juan-Colorado where they are about in balance. (Upper Colorado Region Comprehensive Framework.Study).

There are a number of reasons that growing stock removals are projected at a higher level than growth over most of the projection period. The key is the situation with respect to National Forest timberlands. These lands, which comprise 72% of the Region's commercial area and 82% of the growing stock volume, support predominantly old growth timber. Trees in these stands are growing very slowly and many are dying from diseases and insects. Even many of the stands of poletimber size are more than 100 years old and are putting on very little growth because of overcrowding and stagnation. The objective of management is to cut over these stands fairly rapidly--if possible within at least 50 years--and convert the area to more vigorous young stands. There will, therefore, be a fairly heavy supply of timber available until the end of the conversion period. It is doubtful if regeneration on cutover stands and the growth response to cultural treatment in young stands will be rapid enough to bring growth up to the level of removals until a decade or so after the end of the projection period.

In contrast to projected increases for growth and removals, inventory will decrease--particularly sawtimber. Much of this reduction will result from the fairly rapid conversion of sawtimber stands to young growth. However, thinning and other management practices to promote better growth will be influential.

Timber Products

The total output of timber products for the Region is projected as rising from 47.8 million cubic feet in 1965 to 340 million in 2020--more than 7 times the 1965 output (Table 61). This projection is based on the present commercial forest acreage and will be reduced if this acreage decreases.

Projected increases in output for individual subregions are not expected to parallel the increase mentioned above for the Region (Table 61). The biggest increases are seen for the Upper Main Stem where 2020 output is 8 times that of 1965, and the Green River where it is 7.8 times. The San Juan-Colorado which presently is cutting a higher percentage of inventory than either of the other subregions, is projected to produce 5.5 times the 1965 output by 2020.

Substantial differences occur among products in projected trends. Sawlog output was projected to rise until about 2010 in all subregions and then start to decline. Veneer log output increases throughout the projection period but less rapidly in later years; the output in 2020 is slightly more than 9 times that of 1965. Pulpwood shows the greatest increase in all subregions, and for the Region as a whole 2020 production amounts to nearly 290 times the amount in 1965. Of the increase of 142 million cubic feet of pulpwood, 46% will come from the Upper Main Stem. Although output of other industrial wood in 2020 is projected at 5 times the amount in 1965, the increase comprises only 6% of the total increase for all timber products. The projection of plant by-products includes some provision for manufacture of particle board and/or other fiber products.

Table 61 .- Projected timber products output from all sources, for regional interpretation of OBE-ERS projections, by subregion, Upper Colorado Region, 1965, 1980, 2000 and 2020 1/

	Subregion			
Product and year	Green River	Upper Main Stem	San Juan-Colorado	Region
	- - - - - Thousand cubic feet - - - - -			
Saw logs:				
1965	11,507	13,068	13,299	37,874
1980	25,300	32,200	29,600	87,100
2000	37,100	51,700	43,700	132,500
2020	34,800	52,800	41,200	128,800
Veneer logs:				
1965	-------	3,241	1,764	5,005
1980	2,800	6,400	8,500	17,700
2000	5,700	14,200	12,000	31,900
2020	9,200	21,200	15,600	46,000
Pulpwood:				
Roundwood:				
1965	-------	12	-------	12
1980	14,800	21,800	2,300	38,900
2000	28,400	35,900	6,800	71,100
2020	38,200	45,800	12,700	96,700
Plant by-products:				
1965	-------	482	-------	482
1980	3,700	5,200	5,300	14,200
2000	8,200	13,100	11,100	32,400
2020	11,500	19,600	15,000	46,100
Total pulpwood:				
1965	-------	494	-------	494
1980	18,500	27,000	7,600	53,100
2000	36,600	49,000	17,900	103,500
2020	49,700	65,400	27,700	142,800
All other industrial wood products: 2/				
1965	1,347	2,375	754	4,476
1980	3,600	6,900	2,000	12,500
2000	5,000	10,400	2,500	17,900
2020	6,000	13,500	2,900	22,400
Total output:				
1965	12,854	19,178	15,817	47,849
1980	50,200	72,500	47,700	170,400
2000	84,400	125,300	76,100	285,800
2020	99,700	152,900	87,400	340,000

1/ All roundwood sources (all lands) plus pulpwood as a plant by-product.

2/ Includes: excelsior bolts, chemical wood, poles, piling, mine timbers, posts, box bolts, match stock and a miscellaneous assortment of items.

LOGGING AND FORESTRY MANAGEMENT TECHNOLOGY
A Review of Pollution Control Methods

Sediment Control

Erosion and the generation of sediment result from a combination of several factors. Sediment control is most effective when all factors are systematically accounted for in a control strategy. The individual control measures, together with points of control are as follows:

Harvest system selection: Harvest systems range from very selective cutting to clearcutting. With selective methods the forest is disturbed periodically, perhaps several times during the normal lifetime of the tree species. Selective logging methods are likely to generate low yields of sediment at frequent intervals. In contrast, the impact of clearcut is confined to one continuous period of 2-5 years. Intensive management during this period is necessary if sediment pollution is to be kept minimal. The clearcut system provides for a long period (the major years of growth) of time in which pollutional outputs usually are small. However, the clearcut system may not be the best vehicle for intensive timber production.

Logging system selection: Logging systems--tractor, high-lead, skyline, balloon, helicopter, or combinations--vary substantially in physical impact on the forest and in potential for erosion and sediment production. They also vary substantially in cost and in suitability for forest types and terrains.

Logging road construction: Logging roads are major sources of erosion and sediment. Minimization of pollution from roads can be gained by careful planning of the layout construction and use of roads, including the after-harvest use.

Control by reforestation: Stands of trees should be propagated in harvested areas, mismanaged areas, and areas devastated by disease, fire and other natural causes.

Effective reforestation is considered to be the most important remedial and control measure. The methods employed to propagate new stands of trees range from essentially unmanaged natural regeneration to hand planting of nursery stock.

Grazing control: Domestic animals can benefit the forest and help to minimize erosion. Improper or excessive grazing will promote erosion.

Engineering structures: Erosion control structures to manage water, prevent erosion or trap sediment can be built into the forest system.

Establishment of grass and legume stands: Logging-road banks, unused and abandoned road surfaces, fire lanes, and harvested areas may be seeded to grasses or other vegetative cover to stabilize soils. The grass cover is usually temporary, but may be a permanent part of the forest management system.

Control of nutrients: Nutrient elements are a natural part of forest ecosystems. Control of pollution from natural sources consists of erosion and runoff control. Added nutrients, from fertilization and fire retardants, are controlled by careful planning of applications to obtain maximum effect and to avoid direct contamination of surface water.

Control of pesticides: Several approaches to control pollution from pesticides can be employed. These are:

Rigorous management of aerial application to protect nontarget areas including bodies of water, and maximize effectiveness.

Application from the ground on specific targets, including direct injection into infected or weed trees.

Scheduling of applications for maximized effectiveness and minimum dispersal to nontarget areas.

Avoidance of highly persistent, bioaccumulated pesticides.

Minimum use of prophylactic applications.

Increased use of cultural and mechanical methods to control pests and weeds.

No spray, with complete dependence on natural prey-predator relationships in combination with cultural and mechanical control.

Thermal pollution: Control of thermal pollution requires policy planning followed by planned retention of forest areas needed to achieve thermal pollution goals.

Implementation of control methods: The practical worth of a control method hinges on effective implementation. Implementation requires development of policy and standards, adoption of regulations and enforcement procedures as necessary, definition of organizational/institutional functions, and selection/training of qualified implementation engineers at the field level.

Advanced Logging Methods

The application of advanced logging methods is taking the form of skyline cables, balloon, and helicopter logging. These methods represent distinct possibilities in lessening the amount of environmental disturbance related to conventional methods.

In the Rocky Mountain region, the higher elevation atmosphere tends to discourage the use of the helicopter or balloon methods. However, skyline cables are being utilized on Roaring Fork and in the San Juan National Forest. The method is being applied successfully and a rapid growth in skyline logging is anticipated.

Two skyline logging sites are located on the Roaring Fork in Colorado. One has been in operation for a short while;the other has been operating for about 18 months. The equipment used is a 600-foot cable system that hoists logs up steep slopes. Loggers cut 2 to 3 acre patches on the hillsides leaving mostly the young growth.

In addition to skyline logging, the Forest Service is requiring industry to do a better job of cleaning up debris left by logging. A tree that is cut and found to be rotted or unusable in some way can no longer be left in the forest but must be taken to a central landing point.

The San Juan National Forest is the largest and most productive of Colorado's forests. It contains the largest potential wilderness area-- the 440,000 acre Weminuche.

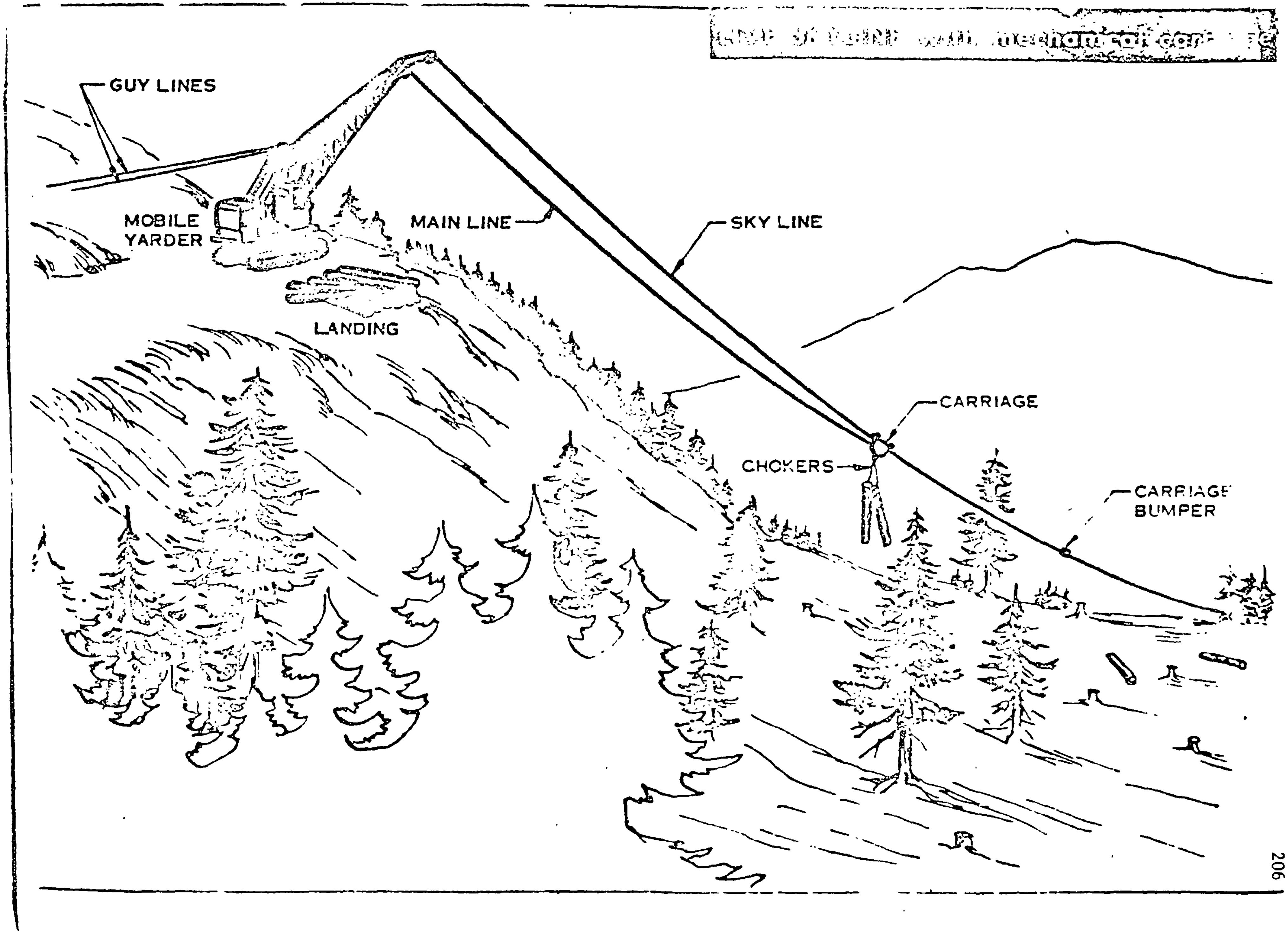
Its two million acres rivals the Alps for spectacular scenery. The forest produces nearly a fourth of all the timber produced in national forests in Colorado, parts of Wyoming, and South Dakota. Forest officials say it is their belief the 10% harvest increase ordered by the present Administration won't damage other resources or the sustained yield capability of the San Juan National Forest.

More Acres Required

However, problems can result from the lessening of full-scale clearcutting operations. More acres must be logged by partial cutting to get the same board-footage of timber as was available by clearcutting. In the San Juans, this could mean some areas now roadless must be brought into production.

Skyline, balloon, and helicopter logging are methods adaptable to remote areas, steep slopes, and unstable soils where road building creates excessive erosion from landslides and exposed cuts and fills. When operated skillfully, skyline cable logging does not produce skid trails because the entire log is lifted in transport. Francis Herman (1960) reported that skyline cable logging required only one-tenth the road construction needed for conventional logging methods such as tractor and high-lead systems. Skyline cable logging can be adapted for clearcutting as well as select cutting methods of harvesting.

FIGURE 37


GUY LINES
MOBILE YARDER
MAIN LINE
SKY LINE
LANDING
CARRIAGE
CHOKERS
CARRIAGE BUMPER

Research Needs

The following research needs were cited in a recent silvicultural pollution control study published by the Midwest Research Institute.

Forest monitoring for water quality: Improved pollution monitoring systems should be devised including sampling methodology, analysis techniques, instrumentation, and regional interpretation of the data.

Adaptation and use of available technology: A major effort should be made in each silvicultural region of the U.S. to demonstrate the applicability of current adapted technology during the timber harvest operation, under timber sale contract terms; and that improved, more accurate monitoring techniques be developed to achieve a more satisfactory basis for developing standards to relate the impact of individual timber sale operations to surface water quality.

Sediment control: A major applied research effort should be initiated followed by extensive demonstration and education programs to foster rational and practical procedures for reducing soil sediment by erosion from silvicultural activities, particularly during periods of harvest and reforestation.

Aerial logging: Emphasis should be put on systems for regional aerial logging to develop more cost effective ways to harvest timber now unavailable because of terrain, or to harvest areas where sediment by erosion would be difficult to control if standard haul roads and logging procedures were used.

Advanced reforestation methods: A multidisciplinary team should conduct an in-depth study of reforestation methods in order to conceptualize, and present for research study, systemized, preferably automated reforestation systems. Concepts such as planting seedlings from helicopters should be considered within the framework of a large nursery-reforestation complex designed to meet the needs of a large area.

Regional studies should be conducted to determine the differences in the costs of various types of forestry equipment and their effectiveness in minimizing pollution. These studies should examine the effectiveness in terms of the cost/unit of pollution control achieved.

Long-range regional impact of control measures: Pollution problems should be examined on a national basis, where applicable controls can be designed to meet pollution problems on a wide scale. When a problem is clearly regional in nature--because of forest types, soils, dominant ownership of commercial timber, regional economy, etc. -- then a regional solution should be developed.

Incentives for pollution control: Additional research should be directed toward identifying the types of incentives that would be most effective in minimizing various nonpoint pollution problems.

CONTROL TECHNOLOGY WITHIN REGION VIII

In reviewing existing management practices and current technology relative to forestry and logging operations in Region VIII, we draw the readers attention to the report "Forest Management in Wyoming - Timber Harvest and the Environment of the Teton, Bridger, Shoshone, and Boghorn National Forests, 1971." This report was prepared by a multidiscipline study team made up of six forest service scientists selected for their experience in both research and administrative aspects of managing and protecting National Forest resources. The report was prompted because of the high intensity of public concern in respect to clearcutting and general timber cutting practices.

What is significant is the many recommendations that generated as a result of the study team's intensive investigations. These recommendations have since been cited by foresters in Regions 1 and 4, as well as those in Region 2, where the study was made, as applicable in terms of meaningful guidelines to be studied and adopted. These three U.S. Forest regions (#1, #2, #4) take in the EPA Region VIII states and many of the Wyoming recommendations have been accepted by the Region VIII foresters.

The recommendations generally call for better use of existing knowledge and for additional research, improved resource inventories, more comprehensive planning, improved public communications and involvement, and, in general, more effective effort and better balances in timber-related management activities.

In reading over the recommendations one must keep in mind that there are a number of similarities within and between each of the forests in the Region VIII area, but there are also wide variations. Often, management situations vary markedly with such factors as land capability, environmental protection requirements, and forest stand conditions. These and other factors must be kept in mind when weighing the appropriateness of the land management decisions for each locality.

A review team evaluated each of the recommendations and responded by citing action already underway or to be taken. The following are representative of the responses. Only those judged relative to this report are reprinted here. Reading over the responses may help the reader gain an overview of some of the present management practices currently in operation throughout Region VIII.

Response to Recommendations

Recommendation. Timber sale plans should include silvicultural prescriptions by qualified silviculturists and specific instructions for timber harvest; long-term evaluation of the effects of the prescription should be mandatory.

We agree. The current standards call for preparation of silvicultural prescriptions that treat various items, including those noted in the recommendations. However, it is apparent that the standards are not being adequately met. We will take needed action to improve performance through training, more in-depth inspection and, where needed, assignment of personnel better qualified to accomplish the silvicultural work.

Evaluation of long-term effects of treatments specified in the prescriptions will be required.

Recommendation.

In Lodgepole Pine

> The Forests should continue to use clearcutting where it is a sound silvicultural harvesting method and in harmony with management objectives for the unit of land.
>
> Alternatives to clearcutting, such as seed-tree and shelterwood cutting and overstory removal, should be used where such methods are consistent with the ecological requirements and protection of the species or appropriate to other uses of the forest land.
>
> Thinning and sanitation salvage should be used independently or in combination with clearcutting where economically feasible.

We concur. Since clearcutting is an important tool in even-aged forest management and because it fits the silvical and ecological requirements of lodgepole pine, it will continue to be a method of cutting that species where such practice is in harmony with management objectives of the area.

Some additional research is needed on alternative silvicultural systems for lodgepole pine, such as the regeneration and the economic aspects of partial harvests, the management and control of dwarf mistletoe in partially cut stands, better harvesting practices to protect new or advanced reproduction and blowdown susceptibility of lodgepole sites.

Each ecological situation requires special consideration in determining appropriate silvicultural practices to be used. Opportunities exist for managing some lodgepole pine stands by silvicultural systems other than clearcutting. Some lodgepole pine stands have been open-grown, managed by design under other silvicultural systems. They were cut over in the "tie-hack" era to such an extent that subalpine fir, Engelmann spruce, or Douglas-fir have become well established as an understory. In such stands, it is often possible to remove the overstory lodgepole pine trees and develop the understory of other species as the next crop. Other stands were cut on a selection system to create better conditions in recreation areas or for special products such as corral poles. Also, in other situations there are opportunities to use seed-tree and shelterwood management systems. Prompt removal of residual trees following establishment of regeneration is usually essential to reduce the spread, to young reproduction, of dwarf mistletoe or other diseases which infect most old stands. Both Regions have directed the Forest Supervisors to evaluate their use of clearcutting as a method of harvesting and regenerating lodgepole pine, and to use alternative methods to clearcutting where such methods are consistent with management objectives and the ecological requirements of the species.

A system of using small clearcuts to serve as wildlife openings and provide diversity in the landscape, as well as yarding areas for selection or sanitation and salvage logging or commercial thinning in the surrounding area, has some application. Forest Supervisors are being directed to try various ways of combining clearcutting, selection cutting, sanitation cutting, or salvage and thinning.

Recommendation. The present limitation on clearcutting in the Engelmann spruce-subalpine fir type should be continued until satisfactory regeneration practices have been developed.

We agree. However, research needs to be strengthened to accelerate development of methods for quick regeneration of existing understocked clearcuts to provide for greater flexibility in management of the spruce stands in the future.

Recommendation. The Forests should consider using a light selection cutting or "pussyfoot logging" on low-yield sites.

We accept the recommendation. However, this does not infer that all of the low-yield sites will be harvested. Management on these sites will be based primarily on improving the stands for benefits other than continuous timber production.

Recommendation. The Experiment Stations should vigorously carry out research to classify and define plant habitats and their ecological potential for both lodgepole pine and Engelmann spruce-subalpine fir forest types in Wyoming.

Much practical knowledge exists. In addition, research has partially developed an ecosystem classification for much of the forested lands in western Wyoming. This study was centered largely in the Wind River Range, but is generally applicable to the majority of the lodgepole pine and Engelmann spruce-subalpine fir types throughout the State. We encourage additional ecological research by the Forest Service Experiment Station and others.

Recommendation. Forest Service Research and Administration should speed up action to develop systems for analyzing the true costs and benefits of forest management alternatives.

We agree that better systems for analyzing both the tangible and intangible costs, benefits, and adverse impacts or consequences of forest management alternatives would be extremely helpful in arriving at decisions. The developing field of model simulation and sensitivity analysis suggested in the report, as it can be applied, should help to make substantial progress. Research to develop models of Forest responses to management in economic, as well as biological terms, should be aggressively pursued.

Recommendation. Clearcut size limits must be determined by the resource values to be considered and by the specific characteristics of the harvest area.

We concur. Factors currently used to determine the size of cutting units include soil characteristics, forest stand conditions, land forms involving slope and aspect, esthetic, silvicultural, and wildlife habitat requirements, as well as access and logging capabilities. At the present time, the four Forests have a 35-acre maximum size limit on clearcuts for new sales.

Recommendation. More and better use should be made of the knowledge specialists in soils, hydrology, and related areas can furnish in planning timber management operations.

We will intensify our efforts to have the Forest Supervisors make better use of specialists, from all levels of the Forest Service, as well as from other sources. When the expertise desired is not available on the National Forest, we expect the Forest Supervisor to arrange for it through detail of qualified people, consultation, or other methods.

Recommendation. Timber sale contract requirements providing for protection of live stream channels from unnecessary disturbance and from clogging with logging residue should be strongly enforced.

We agree. Strong action will be taken to insure that the Forest Supervisors achieve contract compliance. Emphasis is being given to this in the training of sale officers and inspectors.

Recommendation. Research should determine (a) the kinds and sizes of areas and proportions of watersheds that can be safely clearcut at one time without creating damaging changes to streamflow, quantity, quality, or timing; and (b) the nature and magnitude of changes in onsite nutrient content and of eutrophication of streams that may result from soil and vegetation disturbances that attend timber harvesting.

We concur that additional information should be obtained on these subjects as well as other facets of wildland management. Information now available indicates that watershed values will not be adversely affected by clearcutting.

Recommendation. Transportation plans should indicate the purpose of every proposed road--whether permanent or temporary, the disposition of each temporary road, and the maximum level of road construction needed to attain management objectives.

The current transportation plan consists of a listing and mapping of facilities, needed for all forms of transportation, that are to be retained on a permanent basis and generally kept open to public use. It also shows the purpose for each listed road and the planned level of construction. Generally speaking, the level of construction has been based on limited information. In the future, we will insist that the Forest Supervisors base it on a thorough analysis of all available pertinent data.

We believe that it is not feasible to identify all temporary roads, their disposition and maximum level of construction in transportation plans. For those temporary roads constructed in connection with timber harvest, these elements will be shown in timber sale project plans and logging plans. However, since roads have such an effect on management and use of National Forest lands, a section will be added to the transportation and other applicable plans which will explain how temporary roads will be managed in keeping with the intent of this recommendation.

Recommendation. The transportation plan should be clear and logical, and presented in a form easily understandable to the public, and should specify drainages that will be exempt from any road construction or managed with temporary roads only.

We concur that transportation plans need to be readily understandable by the public and will take action to overcome present deficiencies.

Multiple use plans contain management decisions on how various areas of land will be managed, including areas from which road construction will be excluded. Transportation plans are based on these decisions. The place to look for decisions on drainages where roads will not be constructed or how temporary roads will be managed is in the multiple use plans. These plans are available for public inspection at the District Rangers' offices.

Recommendation. The temporary roads still open should be carefully evaluated; those classified as temporary should be closed and all others reconstructed as required for maintenance as part of the permanent road system.

We concur. Appropriate action will be taken.

Recommendation. In road layout and design, the relation between the road and the landscape should be clearly established so as to avoid a result suggesting single use.

We concur. The four Forest Supervisors currently require interdisciplinary review of road location and design prior to construction so as to assure a transportation system that will serve the needed uses and values of the area. This will be continued and strengthened, if needed.

Recommendation. The quality of design, location, and construction of roads, especially temporary ones, must be greatly improved to avoid unnecessary damage to soil and water.

We concur. The Forest Supervisors are now requiring and will continue to require interdisciplinary review of all permanent road locations and designs prior to construction. More intensive on-the-ground planning of and administration of temporary road construction will be required. In addition, we will have the Forest Supervisors give much greater emphasis to the supervision of both permanent and temporary road construction.

Recommendation. Existing specifications that temporary roads should be maintained for adequate drainage before winter should be scrupulously observed.

We concur and will review our instructions that cover this specific item. We will give this our personal attention to assure that the Forest Supervisors gain compliance from timber purchasers.

Recommendation. Much greater use should be made of geologists, hydrologists, and soil scientists in planning and constructing roads.

We concur and the Forest Supervisors will be instructed to proceed accordingly.

Recommendation. Forest Service Research, National Forest Administration, and the timber industry should jointly explore possibilities for using more of the wood left after logging, and for treating the remaining residue to facilitate natural and artificial regeneration and reduce the unfavorable visual impact.

We agree. A study to explore possibilities for using lodgepole pine logging residues is now underway in Wyoming. This is a cooperative study between National Forest administration, the Intermountain Forest and Range Experiment Station, the Forest Products Laboratory, and U.S. Plywood-Champion Papers Inc. Study components will include the following:

1. Characterization and inventory of logging residues.

2. Analysis of utilization and marketing opportunities for solid wood and reconstituted wood products derived from presently unutilized residues.

3. Design and test of systems for moving residues.

4. Regeneration problem appraisal in conjunction with ecological habitat typing.

5. Appraisal of logging and residue disposition on the environment, including social and nontimber biological impacts.

6. Analysis of the costs and benefits. This study should be followed by expanded research to provide a comprehensive answer to the Forest residue problem.

Action has continuously been underway to implement it. In 1970 the Forest Service adopted "Framework for the Future"--a set of objectives and policy guides developed and published to set forth the broad direction to be followed.

Within this context, a Forest Service "Environmental Program for the Future" is being developed. Development of goals for managing National Forest lands in Wyoming are a part of this Program. The process includes assembling more complete inventory information about land capabilities, social and economic needs, and people's desires; an interdisciplinary planning approach; formulating and evaluating land management alternatives; and selection of alternatives that will achieve optimum benefits for the American people. Throughout all planning stages the recommendations and viewpoints of the public will be solicited and included in the decision-making process.

<u>Recommendation. Resource inventories should be completed for all major resources.</u>

We recognize that a more adequate information base is needed to improve multiple use planning. People trained in a variety of skills are needed to accomplish this.

The two Regions employ a considerable number of different kinds of specialists. These specialists are accumulating resource and environmental data on areas where there is a priority need for information. This is a continuing job, since resource conditions are dynamic, and resource inventories will be developed as needed in accord with available funding. However, better inventory methods are needed to permit the frequent repeat inventories needed for flexible management, planning, and closely controlled execution.

<u>Recommendation. The Forests and Regions should strive toward a balance of resource skills in the Forest staff.</u>

We concur. This is a continuing Forest Service objective. There is presently a Servicewide effort to obtain a balanced program which involves both adequate financing and personnel. Studies are also underway to realign administrative units to provide a better balance in resource skills. Public interest and concern, expressed to elected representatives, is needed to support their efforts to obtain adequate funding and manpower for the quality forest management job which the public desires.

<u>Recommendation. More effective use should be made of existing information by (a) the forester, who should search the literature for usable ideas, and (b) the researcher, who should work more closely with the forester in putting new methods into practice.</u>

Action will be taken to insure that existing information and information currently being developed are used effectively.

<u>Recommendation. Periodic evaluation of the results of management activities should be an integral part of the land management job.</u>

We concur. Evaluation of past practices is one of the best ways to improve future courses of action. We will require documentation of events and subsequent evaluation on all projects which have significant impact on the land or resources. Compliance with this requirement will be emphasized through our internal inspection procedures. In addition, Forest Supervisors are expected to periodically present their evaluation of management activities to the public.

Recommendation. The Forest Service should strengthen the current research effort in Wyoming and should explore ways of using abilities outside the Service to develop needed information without delay.

The need for strengthening the Forest Service research program has been discussed elsewhere in this response. Cooperative programs and studies are in progress on the four Forests with groups such as the Wyoming Game and Fish Commission, University of Wyoming, and Smithsonian Institution. An expanded effort will be made to utilize any available talents outside of the Service.

Recommendation. No industrial harvest should be undertaken unless adequate funds and manpower are available to do a complete, professional job.

We agree with the intent of the recommendation. It is in accord with direction that quality will not be sacrificed for quantity.

Recommendation. Tenure and transfer policies should assure that quality land management is not itself sacrificed to provide land managers with the training and experience they need to achieve quality management.

We are unable at this time to identify instances where tenure of personnel, either short or long, contributed to resource problems associated with timber management. We believe forest officers are better qualified to carry out complex management responsibilities when exposed to a variety of situations to give them experience with a wide range of Forest Service activities and responsibilities. We will strive to place well-qualified people in land management positions and provide sufficient training and tenure to assure quality management.

Recommendation. Forest Service internal inspection procedures should be reviewed to determine why questionable practices were not detected before they provoked public criticism.

A careful analysis will be made of our inspection and controls system. Appropriate action will be taken to correct any deficiencies found.

Recommendation. The Forests and Regions should evaluate timber harvest areas that have drawn repeated public criticism and begin major rehabilitation programs where necessary to improve the visual image and protect other resource values.

We concur, subject to other resource considerations. Action to rehabilitate areas which have drawn criticism from the public has been underway in recent years. Such work will continue.

Recommendation. The Regions and Forests should strive for an underlying consistency in policy through good planning, but should preserve the flexibility needed to insure that management practices are appropriate to site conditions.

The principles expressed are sound. We believe that the Regions and the Forest Supervisors have made substantial progress in accomplishing the intent of the recommendation.

Comparison of current guidelines for timber harvesting methods, timber sale contract requirements, and road standards show that the differences are minor. We intend that practices appropriate for each management situation be applied regardless of Region or National Forest.

Recommendation. The Forest Service should seek statutory authority to modify contracts to protect environmental values.

We are advised that the Comptroller General has very recently ruled that environmental values, including intangible ones, can be considered in determining whether modification of a timber sale contract is advantageous to the Government. The Chief of the Forest Service is presently revising instructions covering modifications, to incorporate the intent of this ruling. When implemented, these instructions will likely permit solving the kinds of problems discussed in the report without the need for additional statutory authority.

Recommendation. The Forests should make every effort to involve the public in the planning process by (a) identifying appropriate land management alternatives through listening to people and giving them forest resource information and (b) assessing public opinion as to choice of alternatives.

We concur. Within the last several years, public involvement has played a more important part in developing management decisions for important land areas on each of the four National Forests. We pledge ourselves to continue and expand this effort.

Recommendation. The Forest Service should establish exploratory studies to determine the effects of logging residue management on water quality.

We concur. A principal objective of National Forest management is to protect water quality and to maintain and, where possible, improve productivity of the soil. More biological information about the many aspects of forest land management, related to nutrient cycling and sediment production, is needed. Though not enough is being done, the matter has not been and is not being ignored. A number of studies are completed and about 35 others relating to nutrient cycling in forest ecosystems are underway in 18 states. Most of the research is being done in the West. Commonly, the work is being done cooperatively by universities and Federal agencies, including the Forest Service. As previously noted, the cooperative logging residue treatment study being conducted on the Teton National Forest will provide additional information on nutrient cycling.

Observations in Wyoming by scientists employed in the Rocky Mountain and Intermountain Stations of the Forest Service support those reported by the study team - "...considering the smaller amount of residue and the generally heavy growth of forbs and grasses on Wyoming clearcuts, pollution by chemical nutrients does not appear to be a significant threat." However, in recognition of the relative vulnerability of thin soils on steep slopes to nutrient depletion following clearcutting and burning, clearcutting is being confined to sites with deeper soils and to slopes of about 40 percent or less.

Water quality is currently being monitored at a few locations on the Forests. Plans exist to extend this program as funds and personnel become available.

Recommendation. The Forests should secure timely meteorological information, and require that logging residues be burned during periods when burning is least likely to affect air quality adversely.

We will meet air quality standards. Three of the four Forests currently use meteorological information. Action will be taken to make it available to the Forest Supervisor of the Teton National Forest as well.

Recommendation. The Forests should eliminate the backlog of untreated residue as soon as possible.

We concur, and the Forest Supervisors are working toward this objective. However, there are some untreated areas where stands of young trees have become established. Where this is the case and stocking is satisfactory, it would be unwise to treat the residue for esthetic improvement when such activity would destroy the young trees and necessitate planting. The esthetic problem, in such cases, will be largely overcome as young trees emerge above the logging residue and green up the areas.

Recommendation. The Regions and Forests must better define resource management and environmental protection goals for the Forest and refine and update multiple use plans to include decisions that meet these goals.

This recommendation relates to the Forest Service mission of managing the National Forests to help meet people's present and future demands for goods and services. We agree with the intent of the recommendation.

Non-Timber Producing Alternatives

Multiple use activities and resources provided by our national forests can be optimized from carefully designed and executed forest cuttings · clearcutting. Examples of such improvements are covered in various sections above and are not reiterated here. Whether for increasing water yield, enhancing wildlife habitat, providing more pleasing and variable forest landscapes, improving browsing and grazing conditions or creating new recreational opportunities, all are influenced by and m· benefit from wisely planned cuttings. Any planned timber harvest whether by clearcutting or by other means, must be designed to fit into a well designed multiple use management plan.

Logging Residue Problems

Current general practice is to use large bulldozers to place the mass of logging debris remaining on the ground following logging of clearcut units into individual piles of long, continuous windrows to be burned when burning conditions are satisfactory. Depending on the degree to which the piling or windrowing of the material was done and the completeness of the burning operation, the subsequent appearance and condition of the area varies considerably. In some instances, it may be a tangle of unsightly, half-burned, charred logs, limbs, and tops. In other situations, it may be fairly clean, except for the conspicuous charred stumps in blackened spots or windrows.

The physical appearance of the area is only one consideration, however. Current practices of timber harvest and treatment of the logging residue cause: (1) wood that is technologically suitable for use being burned or left to decay; (2) possible environmental and ecological problems relating to nutrient cycling, regeneration, and erosion hazards; (3) increased fire hazards while debris remains on the ground; and (4) air pollution from the burning of residue.

A Study to Alleviate the Problem

Concern for these environmental and ecological problems of residue accumulation and for the utilization of more of the wood fiber was confined neither to the land managing agency nor to those criticizing timber harvesting practices. The timber industry itself was extremely interested in the possibility of solving some of the problems by making economic use of the residue. Leading in this direction was U.S. Plywood-Champion Papers, Inc., a major producer of lodgepole pine wood products in the Rocky Mountain area. Their concern culminated in a joint study with the U.S. Forest Service of potential economic use of lodgepole pine logging residues. Testing of harvesting methods and utilization practices that would accomplish a higher degree of utilization and would be compatible with ecological, environmental, and economic objectives of management of timber resources on public lands is a basic part of the study.

Scientists, technicians, and managers within the Forest Products Laboratory, the Intermountain Forest and Range Experiment Station, and the Intermountain Region of the Forest Service joined with professional personnel of U.S. Plywood-Champion Papers, Inc. for a study of complete tree and residue utilization of an overmature lodgepole pine forest within the Teton National Forest in Wyoming near the Continental Divide.

Study Objectives

The primary purpose of the study is to test the possibilities of utilization of logging residues. This will involve quantifying the nature and amounts of residues left on the site following conventional logging, how these residues can most efficiently be moved from the logging site, and if the conversion of residues into products is economically feasible. Studies of how this effects the cutting area will be closely related. Removal of logging residues, including the process used in such removal, will change the conditions for regeneration. It will radically reduce the need for slash disposal by burning. It will also have some effect on the protection or enhancement of esthetics, air quality, water quality, wildlife habitat, and other forest values and uses.

Studies have been initiated to provide answers to six basic questions:

1. What is the nature and amount of residues now left on a site following logging, including live and dead wood, standing and down trunk wood, and branches and needles?

2. What products can be manufactured from this material, by categories of mixes and residues?

3. How can these residues be moved most efficiently from the forest to the wood-using plant?

4. To what extent will regeneration problems be changed by removal of residue?

5. To what extent will the removal and utilization of residues, and the process used in such removal, protect or enhance forest values, including esthetics, air quality, water quality, and wildlife habitat? To what extent will residue removal alleviate the need for slash disposal by burning?

6. Is the conversion of residues into products economically feasible? Does this conversion as part of the total system have suitable cost-benefit ratio?

Some Preliminary Results

The problems of residue disposal and utilization associated with timber harvesting are not simple. They are generally linked with ecological, environmental, and economic factors pertaining to the management of the timber resource and to coordination complexities related to other resource uses and values. As such, identification and evaluation of a number of alternatives are essential; however, the alternatives do not lend themselves to easy differentiation. Many values are affected and, as this study illustrates, andwers to "what are the consequences?" and "what is the optimum solution?" of ten take a long time to assess.

This study will not solve all of the problems. Even though the methods used in the study may provide some of the answers, namely, land management alternatives and information on harvesting techniques, a major unresolved problem is one of adequate markets. The apparent gain in total fiber yield is a technological one; the economic feasibility of capturing it is another matter. Will consumers learn to accept more products processed from fiber as substitutes for the more scarce products made from solid woods? In the interest of forest conservation, will people be willing to use a slightly lower quality of paper for much of their paper needs?

The results of this study, while useful in comparable situations, cannot be reliably evaluated and applied to other situations. There are a multitude of forest land conditions, some quite different from the lodgepole pine areas of the Rocky Mountains, and different methods may be needed.

The timber harvest and data collection portion of this study was completed in October 1971. Additional observations and analyses of on-site effects of the overall chipping treatment are expected to continue for some time.

As yet, it is too early to give definitive answers to the many questions that the study was designed to answer. However, preliminary observations provide the following indications as to the efficiency and overall practicability of "near-complete" utilization in lodgepole pine timber harvest operations in the Rocky Mountains:

1. On the type of area treated in this study, it appears that the yield of wood fiber in timber harvest operations can be increased by at least one-third if logging residues can be utilized.

2. Performance of special equipment used in this study indicates their effectiveness and efficiency in "near-complete" utilization operations.

3. Costs of skidding whole trees to landings appear to be no greater than costs of skidding only the merchantable portions.

4. Visual evaluation of the areas where utilization was "near-complete" indicates that such utilization practices will tend to reduce some regeneration costs.

5. The scattered amount of material remaining on the ground following "near-complete" utilization appears to be insufficient to constitute a potential fire hazard or to require additional disposal.

6. Overall, the practice of "near-complete" utilization indicates significant environmental benefits in the way of protection of esthetic values, reduced air pollution (through elimination of residue burning), and perhaps a shorter period of time between harvest of one crop of trees and establishment of a new crop.

Until cost data are completed and dollar and non-dollar benefits are more accurately assessed, an accurate appraisal of the environmental benefits and the technical and economic feasibility of complete residue removal cannot be made. At the present stage of the study, however, complete removal appears to offer some important advantages over current timber harvest methods and practices.

U.S. FOREST SERVICE ENVIRONMENTAL POLICY

The National Environmental Policy Act of 1969 (Public Law 91-190) sets forth a policy of Congress "to create and maintain conditions under which man and nature can exist in productive harmony and fulfill the social, economic, and other requirements of present and future generations . . . ."

The Forest Service sees as its mission the need to meet present and future demands for goods and services from the Nation's forests and related resources. Briefly, the Forest Service recognizes three main responsibilities.

1. To develop, manage, and protect the National Forest System. These public lands include 187 million acres in 154 National Forests, 19 National Grasslands, and other areas located in 44 states and Puerto Rico. Resources on all of these units are managed directly by the Forest Service.

2. To conduct basic and applied research in forestry and related fields. This work is conducted at 80 locations throughout the United States, often in cooperation with university and other research agencies.

3. To cooperate in programs designed to improve the protection, management, and use of forest lands and resources in State and private ownership through technical and financial assistance to State forestry organizations and other cooperators.

In 1970, the Forest Service published a "Framework for the Future." This set of policy statements and guidleines indicated the broad direction to be followed by the Department of Agriculture. In that context, a Forest Service Environmental Program for the Future was developed. The program defined goals to improve environmental management and to increase the flow of goods and services and other benefits from forests and related lands. High quality in management practices and improved balance among the various Forest Service programs was emphasized.

In 1960, the Multiple Use-Sustained Yield Act (16 U.S.C. 528-531) officially made water, wildlife, recreation, range, and timber resources co-equal in management importance. Today, wild and scenic rivers, hiking routes, endangered species of wildlife and plant life, and the visual appearance of landscapes concern the resource manager as much as timber supplies and other "commodity" needs.

Some phases of the timber harvesting process are causing public concern and reaction in certain situations. For example, even-aged management requires at some stage a final harvest cut that sometimes includes clearcutting, a system which removes all the timber at one time. These concentrated harvest cuts on designated areas are one stage in a series of actions necessary to assure regeneration of a vigorous and healthy forest in certain timber types. Certain species and stand conditions may require this kind of silvicultural treatment if the forest is to be reestablished and remain productive. Some of the public object to the alleged "visual blemish" resulting from this method of timber harvesting. Others object to the road or transportation systems or to the possible impacts of certain methods of timber harvesting on wildlife.

Responding to the public demand for additional information about specific timber harvesting practices in identified areas, the Chief in 1970 ordered an internal nationwide review of timber management practices in the National Forest System. A multidiscipline team of staff experts published its findings in March 1971. The report, "National Forest Management in a Quality Environment--Timber Productivity," highlighted problem situations and developed a pattern for responsive actions.

The guidelines that resulted and the planned and ongoing Forest Service actions which respond to those guidelines are:

1. <u>Allowable harvest levels</u>

a. Allowable harvest on Federal forest lands should be reviewed and adjusted periodically to assure that the lands on which they are based are available and suitable for timber production under these guidelines.

b. Increases in allowable harvests based on intensified management practices such as reforestation, thinning, tree improvement and the like should be made only upon demonstration that such practices justify increased allowable harvests, and there is assurance that such practices are satisfactorily funded for continuation to completion.

If planned intensive measures are inadequately funded and thus cannot be accomplished on schedule, allowable harvests should be reduced accordingly.

2. <u>Harvesting limitations</u>

Clearcutting should not be used as a cutting method on Federal land areas where:

a. Soil, slope or other watershed conditions are fragile and subject to major injury.

b. There is no assurance that the area can be adequately restocked within five years after harvest.

c. Aesthetic values outweigh other considerations.

d. The method is preferred only because it will give the greatest dollar return or the greatest unit output.

3. <u>Clearcutting should be used only where</u>:

a. It is determined to be silviculturally essential to accomplish the relevant forest management objectives.

b. The size of clearcut blocks, patches or strips are kept at the minimum necessary to accomplish silvicultural and other multiple-use forest management objectives.

c. A miltidisciplinary review has first been made of the potential environmental, biological, aesthetic, engineering and economic impacts on each sale area.

d. Clearcut blocks, patches or strips are, in all cases, shaped and blended as much as possible with the natural terrain.

4. <u>Timber sale contracts</u>

Federal timber sale contracts should contain requirements to assure that all possible measures are taken to minimize or avoid adverse environmental impacts of timber harvesting, even if such measures result in lower net returns to the Treasury.

LOGGING AND FORESTRY
CONTROL TECHNOLOGY PRESENTLY EMPLOYED IN REGION VIII

The foregoing was a general overview of the various types of control technology presently existent and, in some measure, being utilized throughout the U.S. Forest Service system including the Region VIII states. More specifically we are able to provide some information on control measures presently being employed by the operators within the Region VIII area.

U.S. FOREST SERVICE REGION 2 (WYOMING, COLORADO SOUTH DAKOTA)

Erosion Contrcl Measures Being Emploved

Erosion control measures consist of constructing "water bars" and grass seeding on skid trails and temporary roads. Page 231 shows examples of erosion prevention and control measures required in all timber sale contracts.

Residue treatment activity, where located, how extensive, amount of treatment on annual basis, amount of residue backlogged (not treated) on an annual basis.

By residue treatment activity, we mean the logging and road construction slash created from timber harvesting operations. The treatment areas are located on all National Forests. Region 2 was unable to give any specific location on individual forests, but slash treatment is being done on most timber harvesting areas. Maximum utilization of material from the woods is a standard requirement. The reamining logging slash is treated by several different methods, such as (1) Dozer Bunch and Burn, (2) Hand Pile and Burn, (3) Prescribed Burn, (4) Lop and Scatter, and in some cases no treatment is necessary. How extensive is the treatment: Depends on several things--volume cut per acre, timber types etc. An estimate of the number of acres of logging slash treated and remaining for FY 1973 by forest follows in Table 62:

Table 62

National Forest	Acres treated FY 1973	Acres of carryover (backlog) from FY 1973
Arapahoe	260	70
Bighorn	800	400
Black Hills	21,700	400
Grand Mesa-Unc.-Gunnison	1,500	1,800
Medicine Bow	3,500	100
Nebraska	0	0

(continued)

National Forest	Acres Treated FY 1973	Acres of carryover (backlog) from FY 1973
Pike	Combined with San Isabel NF	
Rio Grande	300	100
Roosevelt	2,700	300
Routt	1,500	350
Pike-San Isabel	400	250
San Juan	5,000	300
Shoshone	300	100
White River	200	150
Total	38,160	4,320

Present forestry operations, harvesting underway in terms of location, size of cut, and duration.

Forestry operations or timber harvesting are being conducted in some manner on all 15 National Forests in the Region. For this report we will consider each National Forest as a "harvest area". Table 63 presents a "Summary of Operations." This is a summary of the approximate number of timber operators on each National Forest. This of course will vary from time to time and an individual operator could be operating on more than one timber sale at any given time.

In regard to "location, size of cut, and duration," we are able to provide the information by National Forest. The U.S. Forest Service was unable to break this information down any further. Reference is made to Table 64 "Timber Cut and Sold" record. This Fiscal Year information is broken down by forest and State for 1973. The length of a timber sale, of course, depends on many factors; but normally runs from 2 to 4 years.

Table 63 SUMMARY OF OPERATIONS - Timber Operator

Forest	Approximate Number of Timber Operators
Arapahoe	4
Bighorn	5
Black Hills	15
Grand Mesa-Unc.	8
Gunnison	4
Medicine Bow	7
Nebraska	1
Pike	2
Rio Grande	5
Roosevelt	2
Routt	6
San Isabel	3

Table 64. Number of Timber Sales as of July 1, 1973

Sale Classes Kind or Size	Wyoming	South Dakota	Colorado	Region 2
Convertible Prod				
to $300	316	132	1,240	1,689
$301 to $2,000	12	34	39	85
$2,001 to 2,000 M	12	5	31=	48
2,001 M to 5,000 M	5	3	13	21
5,001 M to 15,000 M	1	6	5	12
15,000 M and over		1		1
Total Convertible Products	346	181	1,328	1,856
Non-Convertible Products	164	27	3,217	3,620
Grand Totals	510	208	4,545	5,476

Table 64 (continued)

Forest	Approximate Number of Timber Operators
San Juan	9
Shoshone	5
White River	4

Table 65 Acres Cut Over by Timber Types
Yearly Average (FY 1968-1972)

Forest	Spruce Fir	Lodgepole Pine	Douglas Fir	Ponderosa Pine	Total
Arapahoe	500	1,000	-	-	1,500
Bighorn	360	1,500	50	-	1,910
Black Hills	145	-	-	23,400	23,545
Grand Mesa-Unc.	800	-	-	5,200	6,000
Gunnison	1,000	175	20	10	1,205
Medicine Bow	780	2,400	-	230	3,410
Nebraska	-	-	-	-	-
Pike	360	100	5	870	1,335
Rio Grande	2,300	50	250	130	2,730
Roosevelt	200	670	-	-	1,250
Routt	1,300	1,500	-	-	2,800
San Isabel	200	100	200	730	1,230
San Juan	4,400	-	1,000	10,000	15,400
Shoshone	180	1,200	40	-	1,420
White River	860	375	40	-	1,275
Total	13,385	9,070	1,605	40,950	65,010

Table 65 shows the yearly average (FY1968-1972) of acres cut over by timber types within specific forests.

Miles of road construction in each harvest area, type of road (temporary or permanent), type of surfacing, standard, grade, etc.

Following is a summary by forest of permanent type roads constructed by Timber Purchaser in FY 1973.

Table 66

Forest	Miles Permanent Reconstruction	Miles Permanent Construction	Total Miles
Arapahoe	3.1	0	3.1
Bighorn	0	0	0
Black Hills - S.D.	9.3	13.0	22.3
Wyo.	1.1	4.7	5.8
Grand Mesa-Unc.	0	0	0
Gunnsion	0	0.7	0.7
Medicine Bow	8.7	1.6	10.3
Nebraska	0	0	0
Pike	0	0	0
Rio Grande	7.0	20.6	27.6

Table 66 (continued)

Forest	Permanent Reconstruction	Permanent Construction	Total
Roosevelt	0	0	0
Routt	13.7	14.5	28.2
San Isabel	0	0	0
San Juan	53.1	12.1	65.2
Shoshone	0	0	0
White River	0	3.0	3.0
Total	96.0	70.2	166.2

There are no firm figures in the Division of Timber Management on the number of miles of temporary road constructed; however, based upon past history, approximately 3 miles of temporary road are constructed for every mile of permanent road constructed or reconstructed.

The temporary road surfacing is all natural surface. Permanent road surface is either natural or rock gravel surface. Approximately 70% of the permanent road constructed is rock gravel surfaced. A permanent road standard is based upon anticipated daily traffic 20 years hence, and therefore, varies greatly. Most roads now are being constructed for single lane traffic with a running surface of 14 feet. The maximum sustained grade is normally 8% and averages 5%.

Residue production, location and tons per acre.

The residue produced on National forests is primarily from timber harvesting operations. A survey made this past year gives a good indication of tons of residue produced per acre by size class and species. Following is a result of the survey.

Table 67 Tons of Residue Produced Per Acre

Size Class/Species	Ponderosa Pine	Lodgepole Pine	Spruce-Fir
Material Less than 1"			
Range - tons/acre	2.5 to 10.0	1.5 to 5.0	5.0 to 6.0
Average - tons/acre	6.0	3.0	5.5
Material 1" to 3"			
Range - tons/acre	2.5 to 11.0	3.0 to 24.0	3.0 to 7.5
Average - tons/acre	7.0	7.0	5.0
Material 3" & larger			
Range - tons/acre	1.5 to 18.0	5.0 to 39.0	32.5 to 85.0
Average - tons/acre	7.0	20.0	50.0
Total			
Range	7.0 to 28.0	17.0 to 51.0	45.0 to 98.0
Average	21.0	35.0	60.0

Table 68

Grand Mesa-Uncompahgre-Gunnison National Forests
Delta, Colorado

	Surfacing	Standard 2/	Erosion Control 3/	Slash	Species	MBF Vol.
1.	Native	SL-10	Seed 30 A. of landings and spur roads	Pile & burn 180 A.	ES TF	10,463 2,198
2.	Native	SL-12	Seed 15 A.	Pile & burn 109 A.	ES TF PP	10,607 1,193 2,700
3.	Gravel	SL-12	Seed 16 A. spur roads	Pile & chip 264 A.	PP	4,397
4.	-	-	-	-	Aspen	800
5.	-	-	-	Scatter on 30 A. spur roads	ES	3,860
6.	Gravel	SN-12	-	Treat 74.4 A.	PP-DF	8,800
7.	Gravel	SN-12	Seed 2.9 A. spur roads	Pile & burn 20 A.	PP	1,970
8.	-	-	-	-	PP	2,500
9.	Native	SL-14	Seed 20 A. spur roads	-	PP	8,603
10.	-	-	Waterbar 5 miles roads and trails	Pile & burn 3 A.	ES	350
11.	Native	SL-12	34 hours cat work	Pile & burn 30 A.	ES LP	2,000 150
12.	-	-	Seed 35 A.	Scatter on spur road 35 A.	ES	4,400
13.	Native	SL-12	121 waterbars	Pile & burn 20 A.	ES-TF Aspen	4,460 488
14.	-	-	53 waterbars, seed 6 A.	Pile & burn 20 A.	ES	995
15.	-	-	-	-	Aspen	1,400
16.	Native	SL-12	32 hours cat work	Pile & burn 16 A.	ES	1,200
17.	Native	U-2	16 hours cat work	Pile & burn 10 A.	ES TF	375 96

2/ SL-10 - Single lane with light traffic - 10 ft. wide
SN-12 - Single lane with normal traffic - 12 ft. wide.

3/ Actually each sale has a certain amount of waterbar work done on spur roads and in some cases on skid trails, although we do not have a record of the amount of such work to be done on all sales.

Slash Treatment

Most of the slash is treated by lopping and scattering or burning. Only a small portion of the lopping and scattering job is shown in the information above since most of it is not listed in the slash disposal plan for the timber sale, but is a contract item performed by the timber purchaser as a part of normal felling and bucking procedures. During the past year on a forest-wide basis, 97 acres of slash were piled and burned and 1510 acres were lopped and scattered. This left a backlog of approximately 240 acres of slash to be piled and/or burned.

Average residue production on timber sales by species is as follows:

ES-TF 50 tons per acre.
LP 48 tons per acre.
PP 20 tons per acre.

Table 69

	Location	Acres to be cut	Period of Sale		Miles of[1/] temp. road	Miles of perm. road
1.	T45N, R5W; T45N, R6W; T46N, R6W	709	6/28/65	9/30/74	14	3.3
2.	T49N, R13W; T48N, R13W	2870	6/28/65	12/31/73	23.3	4.3
3.	T48N, R14W	1660	4/23/71	3/31/74	12	7.4
4.	T49N, R15W; T49N, R 16W	80	6/29/73	12/31/74	-	-
5.	T44N, R1W	1155	6/29/71	6/30/74	12	-
6.	T49N, R14W; T50N, R14W	2265	9/18/64	9/30/74	16.4	12.5
7.	T43N, R13W	665	5/28/70	1/18/74	4	2.4
8.	T45N, R12W; T46N, R12W; T46N, R13W	1770	5/21/62	12/31/73	8.4	-
9.	T47N, R13W, T47N, R14W T48N, R14W	2334	11/20/59	6/22/74	30	11.4
10.	T51N, R3W; T51N, R2W	25	9/7/72	12/31/73	-	-
11.	T14S, R83W, 6th P.M.	236	1/18/71	12/31/73	5	.9
12.	T44N, R1E; T45N, R1E	2501	9/14/72	12/31/75	8	-
13.	T46N,& T47N, R11 & 12W	274	12/29/69	8/18/74	7	5.6
14.	T50N, R5W	362	12/12/72	12/31/74	6	-
15.	T49N, R6W	189	9/28/70	3/31/74	1	-
16.	T13S, R83W; 6th P.M.	216	10/20/69	3/31/74	3	.7
17.	T50N, R3W	75	9/26/73	9/30/74	1	3.0

1/ All temporary road has a native surface.

SAN JUAN NATIONAL FOREST, COLORADO

Location - Harvested timber throughout the National Forest occurs in the Ponderosa pine, Douglas fir, White fir and Spruce fir Zones. Approximately 5% is harvested with cable systems and the remainder is tractor logged. Sales areas are available at the Forest Headquarters.

The average annual cut over the past five years has been about 79,000 MBF per year.

The operating seasons are normally June 15 - October 31 in the Spruce fir Zones and all months except March and April in the Ponderosa pine Zones.

Road Construction

Road construction varies greatly with topography, logging systems, soils, timber types, and other factors. A broad guideline is one mile of temporary road per 1,000 MBF harvested. Permanent roads may or may not be in place for a particular sale area. Here again, a broad guideline would be one mile of permanent road per 2,000 MBF harvested. On the average, timber sale purchasers construct about 80 miles of permanent road per year. Almost all of the permanent roads are gravel surfaced. Temporary roads usually are not surfaced but may receive spot rocking, if needed. Standards and grades vary. Most of the permanent roads have a 12 foot running surface with intervisible turnouts, and are designed for 15 mile an hour traffic.

Permanent roads are designated as U-2 roads. These are single use roads of varying standards. In a timber sale area, these roads are constructed, then used and closed after the harvest is completed. They can be reopened and used again when timber needs to again be harvested in this area, probably another 10 years.

Erosion Control

All timber sale contracts require erosion control measures. They include drainage dips in temporary roads and skid trails and grass seeding in areas where drainage dips will not control accelerated erosion.

Slashburning

All of the timber sales now require that all slash, or residue, be manipulated so that it lies within two feet of the ground. A complete cleanup job in immediate foreground areas is done along permanent roads. This is usually accomplished by piling and burning. Some areas have a large amount of defective timber that is unmerchantable. This material is taken to open areas and piled and burned. All debris from permanent road construction is disposed of by piling and burning or burying.

Presently the yearly accumulation of a slash is treated currently or within two years after it has accumulated. There is a backlog of approximately 3,000 acres that will be treated for esthetic purposes when additional funding and manpower is available.

Residue Production

A study is presently underway, Nationwide, to determine this residue production in tons per acre. Estimates are that residue production is about two to three tons per acre.

U.S. FOREST SERVICE REGION 1 - (MONTANA, NORTH DAKOTA)

In U.S. Forest Service Region 1, the control of activities as they relate to timber harvesting is through the design of activity. The envorcement is through the contract for the various activities being performed. The design of projects is through a multi-discipline planning approach by specialists in their chosen field who work within the framework and policies guide. By using this approach, land capability determines the level of resource development and the intensity of management.

The "B" division of the timber sale contract provides the basis for assuring that the design criteria are attained. Where more specific instructions are deemed necessary, Division "C" clauses are made up to elaborate on the broad basic "B" division of the contract.

B6.6 Erosion Prevention and Control. Purchaser's Operations shall be conducted reasonably to minimize soil erosion. Equipment shall not be operated when ground conditions are such that excessive damage will result. The kinds and intensity of erosion control work done by Purchaser shall be adjusted to ground and weather conditions and the need for controlling runoff. Erosion control work shall be kept current immediately preceding expected seasonal periods of precipitation or runoff.

B6.61 Meadow Protection. Reasonable care shall be taken to avoid damage to the cover, soil, and water in meadows. Vehicular or skidding equipment shall not be used on meadows except where roads, landings and tractor roads are approved under B5.1 and B6.422. Unless other-wise agreed, trees felled into meadows shall be removed by endlining, and resulting logging slash shall be removed, where necessary to protect cover, soil and water.

B6.62 Temporary Roads. As necessary to attain stabilization of roadbed and fill sloped of Temporary Roads, Purchaser shall employ such measures as outsloping, drainage dips and water-spreading ditches.

After a Temporary Road has served Purchaser's purpose, Purchaser shall give notice to Forest Service and shall remove bridges and culverts, eliminate ditches, outslope roadbed, remove ruts and berms, effectively block the road to normal vehicular traffic where feasible under existing terrain conditions and build cross ditches and water bars as staked or otherwise marked on the ground by Forest Service. When bridges and culverts are removed, associated fills shall also be removed to the extent necessary to permit normal maximum flow of water.

B6.63 Landings. After landings have served Purchaser's purpose, Purchaser shall ditch or slope them to permit water to drain or spread. Unless agreed otherwise, cut and fill banks around landings shall be sloped to remove overhangs and otherwise minimize erosion.

B6.64 Skid Trails and Fire Lines. Purchaser shall construct cross ditches and water-spreading ditches on tractor roads and skid trails, where staked or otherwise marked on the ground by Forest Service. Forest Service shall designate cross ditching on Purchaser-built fire lines prior to or during construction. By agreement, Purchaser may use other comparable erosion control measures, such as backblading skid trails, in lieu of cross ditching.

B6.65 Current Operating Areas. Where logging or road construction is in progress but not completed, unless agreed otherwise, Purchaser shall, before operations cease annually, remove all temporary log culverts and construct temporary cross drains, drainage ditches, dips, berms, culverts or other facilities needed to control erosion.

Such protection shall be provided, prior to end of a Normal Operating Season, for all disturbed, unprotected ground which is not to be disturbed,further prior to end of operations each year, including roads and associated fills, tractors roads, skid trails and fire lines. When weather permits operations after Normal Operating Season, Purchaser shall keep such work on any additional disturbed areas as up-to-date as practicable.

B6.66 Erosion-Control Structure Maintenance. During the period of this contract, Purchaser shall provide maintenance of soil erosion control structures constructed by Purchaser until they become stabilized, but not for more than one year after their construction. Forest Service agrees to perform such structure maintenance under B4.225, if requested by Pruchaser, subject to agreement on rates. Purchaser shall not be responsible for repair of such structures damaged by other National Forest users whose activities are not a part of Purchaser's Operations.

Sediment Control

The control of sediment sources is primarily through the design of activities in the area. There are normally several different prescriptions on a given sale area depending on elevation, aspect, hydrology, slope, soil and ground cover. With the above condition and the silvicultural prescription the logging method and the necessary erosion abatement measures pertaining to logging, road construction, etc., are incorporated into the sale contract. These measures include seeding, barriers, ditching, and outsloping.

Yarding Control

Considering the physiographic items listed above along with the silvicultural prescription the method of yarding is determined. Yarding is an integral and inseparable part of the transportation planning. The yarding may be a cable or tractor ground lead system. It could also be a skyline or aerial system. More specifically, the yarding system will require either uphill or downhill yarding; specify whether the logs may touch the ground or be flown completely free of the ground. The size and number of spur roads and landings are also incorporated into the design of the yarding system.

Where compaction, scarification and erosion are a problem, yarding may be required only when the ground is frozen, or the yarding may proceed only if the soil moisture is less than a given percent. Another means of control is to specify the maximum ground pressure which can be exerted by the yarder. On very sensitive areas, skylines or aerial yarding systems may be required. The size, number, location and grade of skid trails are also specified where warranted.

Road Control

All of the major roads and portions of the secondary road system where additional control measures are needed, specify the design criteria and the construction specifications. Some of the items included in addition to the normal construction staking are complete disposal of road slash, layer compaction, mulching, hydro-seeding, sediment control for bridge and culvert installation, bin wall, rip-rap, rubble, and dustcoating.

Only a small percentage of roads are obliterated following harvest. These are minimal roads of low standard, which have only a single purpose of removing timber. An example of this is a temporary road which terminates at a landing in a clearcut. These type roads are not needed in a continuing basis for future management. Therefore, the topography is placed in as near a natural condition as possible so as to facilitate the natural overland flow of water. In the event the road is needed for future management, it would be built as a specified road with higher standards, included as part of the transportation system, and laid to rest following logging; meaning that use would be deferred for a period of 5, 10, or 15 years. This is accomplished by controlling traffic and making it as maintenance-free as possible by judicious outsloping, placement of water barriers and assuring that drainage facilities are functioning properly.

Reforestation Methods

The reforestation method for the area is determined prior to harvesting. Depending on the maturity of the stand, its condition, species composition, and the other related items like disease, size, steepness of slope, amount of residue, ground cover and habitat type the silvicultural treatment is prescribed, of which reforestation is a part. Should the prescription call for a regeneration harvest, the reforestation plan may call for natural regeneration, or natural regeneration aided by scarification, and/or the reduction of competitive vegetation. When planting is deemed necessary, the species planted is dictated by the habitat type and the planting stock is chosen from a seed source within the local habitat type zone.

In some areas reforestation is successfully accomplished by mechanical means of scarification, scalping and terracing. However, this method limits the area where equipment can work. Sensitive soils, steepness of slope and rock restrict the operable area even more. Where equipment cannot operate, fire is used. Under controlled conditions it returns nutrients to the soil, reduces competition until trees can compete, reduces the potential fire danger and prepares a seed bed.

Watershed Harvests

The drainage is mapped by a hydrologist and by means of measuring the annual precipitation, elevation and aspect, the water yield is calculated for the existing vegetation. From this the acres of harvesting by silvicultural prescriptions can be determined. As a general guide, streamflow increases are allowed to exceed 10 percent of the normal flow. Depending on the vegetative cover, geology and and soil in the area, the limit may be less. A recovery period is also calculated for the vegetation which restocks the harvested area.

Grazing Control

To control grazing on cut and fill slopes and other fragile areas, non-palatable vegetation is planted. If grazing is considered to be a general problem in the area, temporary control may be attained by drift fences, fencing off water holes, transporting water and salt to other adjacent areas, adjusting permits by season and number of animal unit months.

Chemicals

Where chemicals and the like are utilized, their use and application are carried out in strict conformance with the Federal Environmental Pesticide Control Act of 1972.

Water Quality Control

All cutting practices in the water influence zone are governed by the stream itself. This area is noted on both the sale area map and in the contract. The streams are also designated for protection on sale area maps. The prescription for the water influence zone is determined by a forester and fisheries biologist after considering the latitude, the direction of flow where harvesting will take place, the depth, width and temperature of the stream, the type of fish and aquatic life present along with the height and species composition of the timber stand and other associated vegetative streamside cover.

Other Controls

Other items which may be considered relevant to a non-point source pollution analysis is the initiation of new utilization standards. The object is to utilize more of the total green and dead wood fiber from designated trees. New mechanical means of spot sight preparation and brush disposal are being looked into for practicability. A key constraint is that they are limited to the more moderate, operable ground.

Not only are provisions made to keep bark out of the stream channels and ditches of a timber sale area, but also all foreign material which may be introduced whether it is green or dead.

U.S. FOREST SERVICE REGION 4 (UTAH-WESTERN WYOMING)

Control of Sediment Sources

Sediment sources are controlled on all disturbed areas by some form of erosion control work which might be revegetation or the construction of mechanical structures. Specific control measures for meadows are required which include the protection of the soil and grass cover. Vehicular or skidding equipment is not permitted in meadows, except where specific roads or landings are designed and approved.

Control by Harvest System Design

Varying types of harvest systems are utilized for each sale, dependent on the slope, the stability of the soil, and the type of silvicultural system involved. The harvest system is a requirement of the timber sale contract and is specifically stated on the sale area map for each cutting unit, such as tractor logging, cable logging, balloon or helicopter logging. The harvest system is integrally tied to the silvicultural prescription for each specific area.

Control by Skidding and Compaction

Skidding and compaction is controlled by the location and approval of skid trails and the harvest system utilized.

Improved Road Design and Construction

The Intermountain Area is improving the quality of road construction work associated with timber sale logging operations in the following manner:

a. Increasing efforts to decrease construction impacts by degrading horizontal and vertical alignment and reduced templates. This, in turn, reduces clearing width, size of cuts and fills, length of channel diversion into culverts, and visual impacts generally because of reduced overall disturbance.

b. Increasing emphasis on construction inspection. This is being accomplished in a variety of ways, such as district assignment of engineers, implementation of a construction imspection certification program, and direct assignment of engineers to supervise or inspect timber sale road construction.

c. Providing replacement of surfacing material depleted by the timber haul operations, as a result of the timber sale contract.

d. Exercising control over the extent and locations of temporary roads and enforcing closure and obliteration of such roads before leaving the sale area.

Reforestation System Selection

Basically this is determined by age, structure, composition, and health of the stand involved, and other silvical and regenerative requirements of the species at the point in question. For example, lodgepole pine with serotinous cones requires different treatment than those with nonserotinous cones, yet the characteristics may vary from one to the other in a short distance.

Unfortunately, current pressures, some valid and others strongly emotional, are coloring regeneration prescriptions so that the best treatment is not always utilized. The impact will be felt many years from now.

Treatment of Watersheds

The timber sale contract requires that live stream courses within each sale area be protected by keeping them clear of all logging debris. No logs can be skidded across live stream channels unless they are totally suspended by a cable system. Any crossing of a live stream must provide a structure which allows the unobstructed flow of water and such structures can only be placed at designated crossings.

Reforestation Without Burning

Here again, prescriptions are based on fuel volumes present, silvical and regenerative requirements of the species involved, and fire management needs. According to the Annual Slash Reports, many acres of slash in Utah receive only partial disposal.

Again, various pressures are coloring prescriptions. The most notable of these is the esthetic appeal. The degree of cleanup of forest fuels required to satisfy esthetic demands often creates biologically adverse conditions which delay regeneration and retard growth of new established seedlings. However, aesthetics are a valid use and shouldn't be ignored.

On the other hand, many stands, particularly in the lodgepole pine and spruce forests are so decadent, or so decimated by insect attacks that disposing of the volume of unutilizable material by any method is a problem. Some areas exist where use of roller choppers literally pave the forest floor with wood.

Broadcasting burning creates a condition where excellent survival and growth can be obtained from properly planted seedlings in the burned area.
This treatment has fallen into disfavor for esthetic reasons.

Grazing Control

Forest Service policy in this Region is to insure that every clearcut area is promptly regenerated (within five years) either naturally or by planting.
Once a decision is made to plant, every effort is made to eliminate the range use on the area that would destroy this investment.

Livestock damage may or may not be significant to tree survival when stocking is above an acceptable level. When stocking is below minimum, mortality by grazing is intolerable. Where stocking is more than adequate, grazing may be beneficial if it does not cause significant growth losses or mechanical damage which results in tree deformity. Therefore, the policy is that regenerated areas in need of protection within range allotments will be closed to grazing use.

Control of Bark Segments in Water

Actual control of bark segments in stream courses has not become a necessity, since the timber sale contracts prohibit felling trees in stream courses. If one does inadvertently fall in a stream course, it must be removed by endlining.

Obliteration of Roads Following Cuts

The present manual instructions, as well as all timber sale contracts, require the purchaser to "obliterate" which generally means to "put to bed" all temporary roads constructed in conjunction with the sale. Sections of roads existing at the time of the sale that are replaced with specified roads are also required to be obliterated by the purchaser as a part of that required road construction.
Those sections of roads which are not replaced by any of the required roads

will not be "obliterated" unless the operator requests to use the road as a temporary road. In that event, he would be required to do the obliteration work.

Control of Pesticides Application

About the only foreseen use of pesticides related to logging is for the suppression or prevention of bark beetles in slash. In the past, pesticides have been used to reduce spruce beetle infestation in spruce logging slash, and ips beetles in pine slash. Neither of these have been used to any extent in the past three years, although some ips control has been done. There are attempts to keep bettle populations at a low level through management practices, rather than through the use of pesticides.

Control of Fertilizer Application

None used in Utah or western Wyoming.

Control of Fire Retardents

None used in area in question related to logging.

Control of Thermal Pollution (Cuts Near Streams)

In the design of the timber sales, cutting along streams is either prohibited or carefully calculated to maintain or improve water temperatures for the maintenance of fish habitat. This control is accomplished prior to the sales award through careful layout with assistance from a fisheries biologist.

Skyline logging has been in use in this Region for over ten years. Cable or aerial (helicopter or balloon) logging is used in sales where minimal impact on the land is necessary, such as on steep slopes and/or fragile soils. Approximately 20 million board feet was harvested in the Region by cable systems in fiscal year 1972. It's anticipated this volume will increase as logging moves into the steeper ground, but probably will not exceed 25 million board feet per annum. Additional volumes will need to be harvested by helicopter or balloon. In fiscal year 1972, 6.3 million board feet was harvested by balloon. These projections are not firm and could vary considerably with intensive soil surveys and new equipment development.

There has been one balloon sale in the Region and three helicopter sales in areas which could not be harvested by conventional logging methods.

Actions Now Under Way to More Directly Recognize Environmental Problems

Steps are being taken now to improve National Forest administration. Some of those pertinent to timber management and related activities are:

1. A major effort is under way to develop a Servicewide multifunctional program-planning process--including public involvement. Many disciplines and points of view are being brought together, especially at the planning stage. The purpose is to overcome functional or single-interest approaches to resource management planning. The team approach should reduce the possibility of overlooking any significant ecological or environmental considerations.
2. An inter-disciplinary approach to planning and management will require more experts of many kinds. The Service now employs people representing more than 80 different professions. Even this range is not adequate for the "Environmental Decade" in either range or numbers. The Service is moving as rapidly as possible to round out the disciplines and increase the number of experts needed on the Forest Service team. From 1965 to 1970 the total number of permanent full-time employees rose only 6%; and the number of foresters dropped 3%. But, there were dramatic increases in the number of "environmental" professionals employed. For example, the number of landscape architects increased from 109 to 161; soil scientists from 84 to 124; geologists from 10 to 32; plant physiologists from 21 to 37; hydrologists from 4 to 74; fish and wildlife biologists from 14 to 107; and entomologists from 139 to 157. Similar changes are projected for the next 5-year period. In addition, other professions, such as those representing the social sciences, are becoming parts of planning teams and managerial groups.

(One of the major failings cited in the Bitterroot report was the lack of guidelines available in the area of silvicultural management practices. A recommendation was put forth for the necessity to train certified silviculturalists and subsequently a program was implemented at the University of

Idaho. Just this past year the first group of trained, certified silviculturists have been graduated. This program is looked upon as a major advance forward in fostering sound silviculture management practices.

3. Studies are under way to examine ways to reorganize National Forests to assure a multi-discipline team approach to resource management. Selected National Forests are now being restructured to test various organizational patterns designed to promote coordination in meeting environmental needs. For example, new staff groupings are being oriented toward planning, resource management, engineering, and administration rather than toward the traditional functional fields of timber management, recreation, fire control, and so on.

4. A start has been made to re-define the mission of timber management functions, to strengthen multiple-use aspects, and to reflect emerging concerns for environmental quality. This is expected to lead to departures from past concepts that tended to limit silviculture and other timber-related activities to the conventional aspects of timber production. Clearly, timber-management activities need to be "designed" to enhance multiple-use rather than to be "modified" for that purpose as in the past.

5. The Forest Service has engaged three Universities to help develop a National Forest transportation planning system and to train people to use it. This system will provide guidelines for determining road standards, as well as the optimum road network for forest-resource development and use. Many analytical tools have been developed and will be evaluated. Pilot testing of the system will be done as soon as possible.

CONCLUSIONS AND RECOMMENDATIONS

Summary of Managerial Practices and Research Needs

Over the years, research, equipment development, and experience have generated much capacity to handle forest residues. Both government and private forest managers are using present knowledge in varying ways to clean up or utilize residue, and most of their efforts are effective. More can be done. Some of what's being done can be altered to enhance the quality of total environment more effectively.

One attack is to reduce the amount of residues produced and to protect against losses to which they contribute. For example, improved fire protection would make it possible to "live with" debris left on land without the present risks of large and damaging fires.

Although the point of diminishing returns is not clearly established, studies have shown that increased fire protection is a prudent inventment. The most promising measures to reduce the incidence of large, damaging fires are to (1) strengthen initial attack forces, (2) establish fuelbreaks, (3) convert flammable forest types to less flammable species, and (4) prevent fires from starting. These measures reduce the need for disposing of natural debris by burning and decrease the need for treating man-caused debris. Progress in protection will require more emphasis on selected parts of the program where cost-benefit studies show the payoff to be substantial.

A second efficient course for handling woods waste is to use more of it.

Greater demand for raw wood and better prices have made it economically possible to take a far greater percentage of the wood material out of the forest than formerly. As the demand for wood grows, there have been many cases of relogging the forest two, three, and even more times to take out material not economical the first time. Some prelogging utilization of special products is also done. Less desirable timber trees plus tops, limbs, and pieces of logs are being used for pulp chips, fuelwood, mulch, posts and other products.

In addition, forest residues can be reduced through better utilization of logging debris and diseased and fire-killed timber. Steady progress has been made in the past. But to continue progress in some areas new markets will have to be developed, i.e., pinyon-juniper forests now cleared and burned to improve range in the Intermountain West might be partially used for attractive lathe-turned wood products.

Another great opportunity to reduce forest residue and improve utilization is through operations where all usable forest products on the land being worked are removed to market in a fully integrated operation.

Currently, opportunities for alternatives to burning residues are limited primarily to (1) chipping of debris in selected areas and (2) in some climatic zones lopping off and scattering slash and getting it near the ground where it will rot faster. Equipment is needed that will do a better and cheaper mastication of logging waste and that would keep it on the area but materially lessen the fire hazard. Such material would improve the soil and reduce erosion if left in place.

So far, burning is the most universal method used to dispose of forest residues. It is fairly economical. It frequently stops disease and kills pests. It reduces forest fuels and thereby minimizes the likelihood of destructive wildfires. Under many ecological conditions it promotes desirable forest regeneration. In some forests fire is necessary to get any regeneration at all. Combustion products are, however, cast into the atmosphere. Only recently has smoke from burning forest residue been recognized as an atmospheric pollutant. Even though its toxic qualities are unproved, forest managers and agencies are seeking methods and times of burning so that smoke disperses widely into the atmosphere.

Fire-control specialists are becoming more expert at applying fire of the intensity needed to reduce residue, to create ideal forest-regeneration conditions, and to conduct burns without harming soil nutrients or leading to soil erosion. Some residue burning is keyed to detract as little as possible from natural beauty and to minimize pollution from burning and the threat of wildfire. There is much to be gained from expanding these current pilot burning techniques to broader areas.

The following areas require emphasis in meeting the problem of pollution by forestry and logging operations.

1. Minimizing production of undesirable forest wastes

Forest residue caused by forest fires will be reduced by a strong action and research program to reduce the area burned. Action programs in the Department are directed to preventing as many fires as possible, discovering fires promptly, and taking fast aggressive action to control them at small size. Stronger ground and air forces are needed and will be applied as funds become available. Fuels need to be made less flammable with modification and breaks. Research is directed to new equipment and techniques to do these things better and more efficiently.

The Department of the Interior interest lies in keeping residues in forests under its jurisdiction to a minimum in regard to forest fires and for public recreation.

2. Improving utilization of forest residues

The Department of Agriculture's programs in forest areas are directed to more fully utilizing trees and other growth for useful purposes. Pulp operations are taking much smaller material than formerly. Prelogging and postlogging operations are taking out material formerly left in the forest that added to the fire hazard. New equipment and techniques are under development to increase this utilization. Further progress in this area will reduce residue accumulation and the need for burning. Progress continues in developing equipment and procedures for utilizing forest residues as mulch. This contributes to the control of wind and water erosion.

The Department of the Interior has no program in this area.

3. Treating or removing hazardous or excessive forest residues in the environment

The Department of Agriculture is developing improved techniques and planning additional research on procedures for doing a more efficient job of burning and at the same time reducing air pollution from smoke.

The problem of pollution from forest residues is being studied by the Department of the Interior to determine the effects on water quality.

4. Assisting local areas in developing guidelines and control programs to govern the disposal of forest residues

Cooperative forest programs of the Department of Agriculture in fire control and timber management assist local jurisdictions with slash burning. The cooperative management program assists local timber operators to better utilize their timber, which means less residue left in the woods. The USDA plans to continue its emphasis on assisting and encouraging local areas to adopt improved procedures for residue disposal or utilization as such procedures are developed.

The Department of the Interior has no program in this area.

5. Improvement of road construction control methods to lessen the environmentally harmful effects of roads

The quality of design, location, and construction of roads, especially temporary ones is steadily being improved as a result of the USDA's heightened awareness of this problem. Research efforts should continue in this respect and much greater use should be made of geologists, hydrologists and soil scientists in future planning and construction. Research should also continue with respect to advanced logging methods, i.e., balloon, skyline, and helicopter logging, and their feasibility in helping to reduce the pressure on road construction.

Educational Needs

Future land management decisions related to logging and forestry operations should be more firmly based on knowledge that allows for reasonable prediction of the outcome of management actions. A more unified approach to common problems and effective utilization of educational and technology transfer tools could serve to strengthen and improve management planning that would lessen the extent of non-point source pollution.

Good planning requires adequate information, well qualified personnel, ar[illegible] strong administrative support. Within this framework a more comprehensive st[illegible]ture for considering the capability, and vulnerability, of all resources can [illegible] enhanced.

Too often management errors result from ill-defined objectives. Adeq[illegible] consideration of total environmental values is often neglected.

The goal of better balance in forest resource management is attainab[illegible] requires effective participation of specialists in soils, hydrology, wil[illegible] landscape design, silviculture, engineering, and outdoor recreation. M[illegible] use plans require an interdesciplinary approach. Plans must be based [illegible] sociological, economic, and resource data, and to this end, planners [illegible]trators should increase their efforts to seek the counsel of other a[illegible] institutions, research groups, and interested citizen organization a[illegible]. A mechanism for the enhancement of this type of educational and inf[illegible] approach is needed. An environmental education network similar to [illegible] in the second part of this report could fulfill this mission.

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INDIVIDUAL HOME SEWAGE DISPOSAL

Individual home sewage disposal is the terminology currently being used on reports that deal with septic tanks, small aeration systems, evapotranspiration designs, etc. Simply using the words "septic tank" as a synonym for rural-domestic waste disposal is no longer valid due to the large number of alternative means of disposal that have appeared in recent years. In the early 1900's, there was a large amount of interest in developing better designs for "septic tanks" but since World War II there has been little additional research on the ways and means of disposing of sewage from a home not connected to a central system. The emphasis during this time was to connect all houses to central systems and as the population concentrated in large cities, this seemed feasible. A problem has resulted, however, in this strategy as will now be discussed.

Current Situation

As more and more of the United States' population moved into metropolitan areas, two things happened. First, the people became more affluent and second, they lost many of the amenities associated with a more rural life style. As a result, many urbanites purchased land in areas of less population density with pleasing natural surroundings and built a second home. In this way they were able to recapture some of their lost amenities and their affluence permitted them to "purchase" their needed privacy, recreation, pastoral setting, etc.

As the number of these second homes increased, the number of houses with individual disposal system increased and there was an increasing demand for equipment or designs for handling waste from the houses. This was due to two things. First, the homes were, and still are, usually built with large distances separating them (thus preventing a central system) and second, many of the houses were, and still are, built where the septic tank cannot be installed due to bed-rock near the surface or too tight or very loose soils. (For a detailed descriptionof the actual pollution problem due to the septic tanks, refer to Allen and Morrison, 1973.) Privacy and lower population densities demand large distances between houses and a location where ideal disposal is not possible. In the Rocky Mountain-Prairie Region obtaining desirable amenities usually means locating in the mountains.

To meet the increasing demand for individual home sewage disposal (since the septic tank is generally not acceptable in the mountains), many entrepreneurs entered the field each with an alternative that was, and in many cases still is, "better than all the others," to use an implied advertising phrase. Many of these units have been, and are still being sold. Many of the units are complicated, depend upon a continuous power source and source of waste, and require considerable maintenance.

As second (and rural) home owners began to purchase these units or install septic tanks, inadequate design and failures were numerous, resulting in contamination of surface and groundwaters. Much of this contaminated water was serving as fresh water supplies for either the home itself or someone either down slope or down stream.

These problems brought health and water pollution control personnel into action. However, the rules and regulations (or guidelines) under which they operated only included septic tanks and privies. The county and state regulators had no basis for correcting the problem. Little, if any, unbiased technical information was available on the many concepts being sold to "treat" individual home sewage.

The increasing need for individual home sewage disposal systems suddenly reversed a trend of many years. The lack of any research or development on individual home sewage disposal systems since World War II left everyone asking questions about these new units. Do they work?

All the available information at the time discussed only septic tanks and privies and since these alternatives are generally unacceptable in the mountain setting, few guidelines were available. No studies had been performed on these new concepts; no regulations at any level of government were available; no control was available.

As a result of the above described chain of events, the current situation is one of chaos in the control of individual home sewage disposal systems. For example, on July 24, 1972, a court decision threw out Colorado's existing regulations with respect to home sewage disposal saying that they were in desperate need of rewriting. The current state of technology makes it diffucult to write effective regulations that permit much flexibility. New, more comprehensive regulations have been written for Colorado and are now being implemented.

Magnitude of Problem

Data does not exist to describe the extent and magnitude of this problem specifically within the Rocky Mountain-Prairie Region. In 1967 the U.S. Public Health Service estimated that approximately 25% of the new homes were using individual home sewage disposal systems of some type. Today approximately 70% of the United States' population is served by a central system. Of the 30% that have individual systems, 15 to 17 million systems are septic tanks and cesspools and 5 to 10 million homes have privies or direct discharge into streams. The estimated number of individual aerobic systems in the United States is less than 50,000 (Ferraro, 1972).

In the past, individual systems were installed as a temporary measure until it was economically or politically feasible to construct a central system. This is still the case with homes being built beyond a central system, but still within eventual reach of a city or town. However, second homes are built with individual sewage disposal systems as a permanent installation and USDA predicts that by 1980 "about 180,000 city families a year will be buying second homes in the country." This is an 80% increase over the trend of today.

Looking at septic tanks and their reliability, Clayton (1972) presented findings that state for almost 6,000 septic tanks analyzed, there was a 92% survival rate. The data was collected on systems installed from 1952-1972. The areas where the data was collected (Virginia) has a conservative design criteria and a strict inspection program of new installations. The high survival rate indicates that if the septic system is designed and installed properly few problems will result. From this, it may be concluded that in the Prairie areas, if individual home sewage disposal systems are properly designed and installed there should be few pollution problems. Without more specific data no more can be stated. The MITRE report (Goldstein, et al., 1972), in fact, states that the use of more individual systems would result in a large savings to the U.S. in solving the water pollution problem. The reader is referred to the report for more details on the economics.

It should be noted at this point that many reports discuss the problems of home sewage disposal system failures and just the opposite conclusion to the above could be made with data from another report. This contradictory data is discussed in the technological discussion in Part II

The reasons it is concluded that individual disposal systems, if properly designed, installed and maintained, would operate successfully in the Priaire Region is the fact that there is often plenty of soil for leachfield placement. Due to a usual lack of soil in the Rocky Mountain area, the same conclusion may not be made. In the mountains, many systems have been installed over the years and problems abound due to a lack of proper treatment of wastewater. The wastewater passes through the fissures in the rock and receives little or no treatment in the process. (An Environmental Protection Agency (1970) study indicated that "the numerous individual subsurface disposal systems serving homes and businesses along the shores of Grand Lake, Shadow Mountain Lake, and Lake Granby was one of the major pollution problems in the area. The water quality in the lakes was being adversely affected.") It has been noted, however, that this has nothing to do with lack of soil and rock fissures--more a problem of proximity to the lake.

Another study (Millon, 1970) of fresh water wells at Red Feather Lakes, Colorado, indicated 62% fail to meet public health drinking water standards due to excessive coliforms. The problem again was attributed to the wastewater from surrounding spetic tanks reaching the freshwater wells untreated due to the lack of filtration.

The U.S. Geological Survey has an ongoing project in the mountainous part of Jefferson County, Colorado, in which the ground and surface water is being inspected. Hofstra (1973) reports that the 300-square mile area has been checked for bacteria and four chemical constituents by collecting about 800 samples, of ground water and a few stream and spring samples. About 80% of the homes in the area have individual wells and septic tanks. There are a few communities supplied with well fields; part of the area has piped surface water and only Evergreen, Hiwan Hills, Kettredge, and Kings Valley near Schaffers Crossing have sewage collection.

The basic data collected so far indicates an average specific conductance of groundwater of about 300 micromohs. The quality of virgin groundwater is very good. However, data show that 4 to 5 percent of the groundwater tested has nitrate nitrogen accumulations in excess of the 1962 U.S. Public Health drinking water standard of 10 milligrams N per liter. Also, 20% of the samples had total coliform bacteria counts above the Jefferson County Health Department standard of one colony per 100 milliliters and occasional samples contained fecal coliform colonies.

There are indications that about 50% of the groundwater tested has undergone some chemical degradation using nitrate, potassium, and chloride as indicators. Chemical degradation is most common in old communities with small lots.

Bacterial contamination is more common in shallow wells associated with alluvial sediments, but bacteria are found in every geologic setting.

Most wells are drilled to intersect fractures in metamorphic and granitic rocks beneath areas where the soil is often thin and highly permeable. Decomposed rock with abundant fractures commonly underlies the soil layers with fracturing decreasing with depth. The fracture aquifer has very low storage capacity, but is usually replenished by recharge of precipitation. Also, comsumptive use of water is small when septic tanks and leach fields are utilized.

A similar study currently underway by the Geology Department at Colorado State University has arrived at the same general conclusions as the USGS. This study, however, covers a larger geographic area.

Numerous other examples of problems in the mountains with individual disposal systesm can be found in the proceedings of a workshop on the subject held at Colorado State University (Ward, 1972). It is probably due to these problems with septic tanks in the mountains that has brought so many new systems onto the market. The vault has been proposed as the one fail-safe solution given that there is so little on these newer individual home sewage disposal systems. However, home-owners will go to great lengths not to use the vault to avoid paying the frequent pumping costs ($40/cleaning). This brings up another constraint of the solution, economics and social factors which marginal affluence bring into play.

In summary, and primarily based on Ward (1972), the problem of individual home sewage disposal in the Rocky Mountain-Prairie Region can be described as follows:

1. Inadequate designs and insufficient alternatives of individual home sewage disposal for mountainous areas are resulting in pollution of ground and surface waters in local situations.

2. Existing institutions have difficulty in regulating individual systems.

3. Land use controls could be made sufficiently strong, and second homes and individual disposal systems could be regulated or banned where they cannot be operated properly.

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INDIVIDUAL HOME SEWAGE DISPOSAL TECHNOLOGY

The major goal of individual home sewage disposal systems is to dispose of the waste water from the home in such a manner as not to cause a health hazard, nuisance, or water pollution. The technology available for the treatment and disposal of this waste water is quite varied; however, the septic tank, an anaerobic system, is the most commonly used (Bailey, et. al., 1969). In addition to the anaerobic systems, there are aerobic systems, special systems (coming from the space research), evapotranspiration systems and storage and haulaway. Each of these technologies will be discussed following a quantification of the wastewater characteristics.

Pelczar and Reid (1965) indicate that on the average, domestic sewage consists of 99.9% water (weight), 0.02 to 0.03 percent suspended solids, and other soluble organic and inorganic substances. Goldstein, et al (1972) notes, however, that sewage from individual homes is a complex commodity. It consists of all manner of liquids and solids that go down drains or that are flushed down toilets. The composition of sewage varies from day to day, from hour to hour and from house to house.

Laak (1971) indicates that the volume of the sewage can be broken down as follows:

Laundry	10%
Kitchen	10%
Bathtub/shower/handwash	40%
Toilets	40%

Similar data which may be more applicable to the Rocky Mountain-Prairie Region is currently being assembled at the University of Colorado under the direction of Dr. Ed Bennett.

With permanent residences the flow rates should be relatively stable permitting the design of an "adequate" home sewage disposal system. However, if the home is a second or seasonal home, the waste water flow rates are not stable and, therefore, present problems in designing an "adequate" system. Toby (1972) performed a survey of seasonal home use patterns and found that 6% of those surveyed used the home less than 30 days per year; 27% used their homes between 31 and 70 days per year; 19%,71-90 days; 20%, 91-120 days; and 28%, 121 days per year or more. The frequency and type of use can have a large influence on the design of a home sewage disposal system for a second home.

Anaerobic Treatment

Anaerobic treatment of individual home sewage revolves around the septic tank. Within the tank, anerobic biological processes (the breakdown of organic wastes takes place wit' bacteria which function in the absence of oxygen) results in the liquification of solid organic matter. Also as a result, volatile acids are produced from the liquified solids and dissolved organic solids. Methane, carbon dioxide, and small quantities of other gases are released during the anaerobic breakdown of the wastes. Small quantities of settled sludge accumulate under normal operating conditions and must be removed periodically. Storage for this sludge must be provided in the design of the anaerobic treatment system.

The septic tank itself consists simply of a container in which wastes are accumulated and digested under anaerobic conditions. Capacity and hydraulic design are the most important factors influencing septic tank performance. The capacity is important to all quiescent conditions and sufficient time for sedimentation. The capacity must be sufficient to dilute chemicals which are harmful to digestion and absorb surge flows from laundry and bathing without discharging digesting solids. Hydraulic design determines storage efficiency and the extent of short circuiting. This in turn determines the percentage of capacity that is effectively used (Bailey, et. al, 1969).

The septic tank itself is usually constructed of precast concrete and comes in many different configurations. Steel, brick, tile, plastic and other materials are also used. The sewage itself contains the bacteria which catalyze the anaerobic decomposition of the solids. A septic tank system has no moving parts and the only maintenance involves removal of the sludge. The design size determines frequency of sludge removal required for sludge accumulation depends upon number of people, types of waste, etc. No hard and fast rule can apply to all situations. The best practice is to regularly check the sludge accumulation (Bailey, et. al, 1969). For more specific details of septic tank design, refer to U.S. Department of H.E.W., Manual of Septic-Tank Practice, Hansen (1970), or to Salvato (1958).

A septic tank does not purify the sewage, eliminate odors, or destroy all solid matter. The most important function of septic treatment is the liquification, or solids breakdown, rather than BOD removal. Typical performance data for the septic tank will vary with the individual installation, but removals of 80 to 85 percent suspended solids and 90 to 95 percent settleable solids can be achieved under normal operating conditions (Engineering Science, 1970)

Bailey, et. al (1969) report, for the septic tank, BOD removal of 50%; COD, 48.4%; suspended solids, 73%; and volatile solids, 39.6%. They also report on a variation of the traditional septic tank system that contains two significant changes. The system requires that the wash waters be separated from the sanitary and kitchen wastes. The latter are handled in an upper compartment for a longer period of anaerobic digestion. This arrangement permits the sanitary wastes to receive more concentrated treatment while the bactericidal effects of some detergents and other chemicals are avoided. The wash waters are conducted to a lower chamber where they are mixed with the upper compartment effluent and, thus, undergo a somewhat shorter period of treatment. The final effluent of this septic tank variation is considered to be better than that of a normal septic tank and, consequently, can be used on poorer soils.

The major advantages of the anaerobic treatment systems are their simplicity and low maintenance costs. The reliability of the convential septic tank is reflected in its wide use and acceptance. The new system, to indicate its acceptability, has recently been approved by the Federal Housing Administration (Bailey, et. al, 1969).

Aerobic Treatment

There are now many types of aerobic treatment systems on the market for individual homes. Aerobic systems basically consist of a compartmented tank containing an aeration section and a settling section. The purpose of the aeration section is to increase oxidation while at the same time minimizing net production of sludge. In the settling section, gravity is used to separate solids from the effluent and then return it to the aeration tank. This is accomplished either by gravity or mechanical means. Engineering Science (1970) illustrate the basic features of an aeration unit. They refer to it as an "extended aeration" system.

Most aerobic systems are designed for continuous flow with a few operating on a batch basis to avoid flow surges in the aeration section. In the aeration section, the raw sewage is mixed with the oxygen in the air for relatively long periods of time. Since the system is aerobic, the bacteria in the sewage utilize the organic materials for growth which produces a flocculent bacterial sludge. This bacterial sludge rapidly absorbs nutrients from influent sewage. It is this bacterial matter that settles out in the settling chamber.

Engineering Science (1970) indicates that the effluent of an aerobic system is generally better than that of an anerobic system. Equipment manufacturers claim treatment comparable to municipal secondary treatment. This amounts to approximately 90% BOD reduction and 80% reduction of suspended solids. Data collected by several county health departments in Colorado shows that the units seldom perform in the field at advertised efficiencies.

The National Sanitation Foundation (1970) has established a standard for the performance of aerobic systems which demonstrates and measures what a plant can do under simulated on-lot conditions. This provides the public with unbiased data.

Russelmann (1972) notes that the Standard calls for an effluent quality having maximum limits for 5-day BOD and suspended solids. Two classifications are used, merely to indicate the performance level which may be expected. A Class I plant can produce an effluent BOD of 20 mg/liter at least 90% of the time. Also a Class I plant effluent must be relatively free of color, odor, oily film and foam. A Class II plant is one which can produce an effluent within 60 mg/liter BOD and 100 mg/liter suspended solids.

Thomas, et.al (1960) notes that a major advantage of the aerobic system is that its effluent, when compared to a septic tank effluent, is less likely to clog a soil absorption system. Winneberger, et. al (1960) list the disadvantages of the aerobic system as: (1) higher operating costs, (2) greater susceptibility to shock loadings of concentrated wastes and to harmful chemicals, and (3) variations in effluent quality due to such treatment upsets.

The following quote from Bailey, et.al (1970) describes very well the situation that exists in the Rocky Mountain-Prairie Region with respect to the marketing of individual aerobic treatment systems.

> "In the survey of individual treatment units as many manufacturers as possible were contacted. According to one manufacturer, the individual home treatment market has been in a constant state of flux. He reported that there had been twenty-five entries into the home waste treatment field since 1955 and that of these only fourteen were still in business. Eight of these fourteen had entered the market in the last three years. These figures indicate that there is a great interest in and a need for an individual treatment system to serve certain areas, but also that many of the treatment systems marketed have been unacceptable and probably have created a poor public opinion of the industry."

In addition to the above described common aerobic system there is another type of system called the biological filter. Here the sewage is distributed over filters which support biological growth on a solid media. This media is usually an impervious material, although coal, wood bark, and synthetic materials have been used. The design of the media bed is selected to optimize both the surface area for the biological film and the hydraulic characteristics of the filter. Also some provision is usually made for intermittent housing of the filter and for storage of sewage solids.

Effluent from a biological filter is usually dark in color but odorless. Coliform counts are high and occasional unloading of the biological growth causes additional suspended solids and odor problems. Engineering Science (1970) presents additional details regarding this small "trickling filter" concept.

Some of the aerobic systems, extended aeration or trickling filter, utilize chemical treatment to disinfect the effluent. Others also use sand filtration to treat effluents before surface disposal. For a comprehensive review of all aspects of aerobic treatment systems, refer to National Academy of Science (1958).

The following discussion of aerobic treatment systems taken from Bailey, et. al (1969) again very well summarizes the situation in Colorado, specifically, and the Rocky Mountain area in general, where surface discharge has been proposed as a way to avoid the high cost of drainfield construction in the rocky subsoil.

"High costs are a major problem with the aerobic treatment systems and discharging the effluent to surface drainage rather than to subsurface soil absorption system has been suggested as a means of cost reduction. Some of the treatment units do consistantly produce an effluent suitable for surface drainage. However, other units obviously have not met acceptable standards and in many areas surface disposal of aerobic effluent is not legally permitted. The reluctance of public officials to permit surface disposal is easily understood. Even for treatment units consistently producing a good effluent it takes only one malfunction to release contaminated water which could endanger the health of the community. Health officials do not have specific criteria at this time to evaluate the many different types of treatment units, their expected performance, or the maintenance problems that might be encountered; and rather than permit the development of a possible health hazard, a common reaction has been to prohibit all surface discharges from individual treatment units. Also, health officials realize that they could not adequately police the number of surface discharges that could occur. The quality of effluents discharged to storm drains, the most convenient disposal method, would be even more difficult to monitor.

Sludge disposal is also a problem with aerobic systems. When the extended aeration system was first proposed it was believed by many that all organic material would be eventually oxidized to gasious products and water. However, just as in the septic tank some organic materials resist digestion, as do nearly all the inorganic solids, so that there is a gradual build up of solids which must be removed to prevent the periodic discharge of slugs of sludge particles in the effluent. As with anaerobic systems the rate of accumulation depends on the system design and operation. Thus regular inspection is a necessity.

The further growth of the market for individual home aerobic systems thus seems dependent on the inclusion of adequate safeguards against unattended malfunctions through better instrumentation, better service contracts, and greater cooperation among the homeowners, the equipment manufacturers, and the public officials. The information supplied by the manufacturers indicates that they are attempting to achieve this goal. No completely satisfactory system has yet been proposed, but many advancements have been made and surface discharge is gaining acceptance in more areas as system improvements and safeguards are supplied.

Each treatment system has features which make it more suitable for certain applications and each situation will demand a careful examination of specific requirements before a particular treatment unit can be chosen."

Anaerobic versus Aerobic Systems

Goldstein, et. al (1972) note that based upon presently available technical data, it is not at all clear which type of system is inherently superior in removing suspended solids and reducing the oxygen demand of household wastes. Winneberger, et. al(1960) indicated that there was not significant difference between septic and aerobic tank performance as regards to removal of biologically or chemically oxygen demanding constituents of waste waters. The data is presented in Table 70.

Table 70 Winneberger, et. al (1960) Comparison of septic and aerobic tank performance.

Parameter	Aerobic Tank Effluent		Septic Tank Effluent	
	Mean	Std. Dev.	Mean	Std. Dev.
BOD mg/l	81.0	25.9	73.7	10.8
COD mg/l	143.5	39.1	152.0	29.2
SS mg/l	75.4	--	50.6	--

It was noted that the septic tank was significantly more stable in its performance--pulse loads were handled better in the septic tank.

Bernhart (1964) found results that were quite different. His field investigations indicated superior aerobic tank performance regards the removal of both oxygen demanding substances and suspended solids. He also stated that aerobic systems were more effective at reducing coliform bacteria.

Schad (1971) reports that BOD reductions of 75-90 percent and TSS reductions of 75-90 percent can be expected in aerobic systems, while reductions of 30-50 percent for both BOD and TSS can be expected in septic tanks.

Goldstein, et.al (1972) notes these divergent and opposing evaluations with regard to aerobic and anaerobic systems, even among highly respected and trained experts, and indicates that the validity and comparability of performance data may be strongly influenced by peculiarities of design, installation, and usage patterns of individual units. This type of observation is especially important for the Rocky Mountain-Prairie Region where many second homes operate under conditions that can hardly be classed as ideal from a waste water treatment point of view. From long stretches of no use to a sudden weekend of extensive use, the waste water treatment systems is expected to operate properly. Also the extreme temperatures of mountain winter homes adds additional constraints on efficient operation. However, it is the soil absorption system that is probably of major concern in mountainous areas.

Soil Absorption

Goldstein, et. al (1972) note that the soil absorption system which lies downstream of the septic or aerobic tank is the most fragile and most expensive part of the individual home waste treatment system. They also classify effluent disposal as occurring three ways: (1) down through the soil and possibly into groundwater, (2) laterally through the soil or groundwater aquifer, and (3) up by ponding in impervious soil until it erupts through the surface, or by diffusion and evaporation from soil or by being taken up into and evaporated by plants. Thus proper operation of a soil absorption system occurs when the water goes up, across, or down and leaves the immediate zone of the soil system with acceptable values of its physical, chemical, and biological characteristics such that when more effluent is added the soil will be able to adequately dispose of it.

Goldstein, et. al (1972) also note that the mechanisms by which the soil absorption system works are far from being completely understood even though there are currently many volumes on the subject. As a result the total picture is very complex and understood only in an elementary fashion.

A soil absorption system may be a long narrow trench, a wide shallow bed, a deep pit, or a combination. It is usually underground, but may be a mound above the surface. The tank effluent is piped to the absorption area where it passes through a perforated pipe or is dumped directly into the bed. The effluent seeps from the pipes into the soil across the soil-water interface. It is at this interface that a majority of the problems with seepage beds begins (Goldstein, et. al, 1972).

The clogging of soil absorption systems appears to be mainly due to the accumulation of suspended matter in the effluent, bacterial cells, and microbial activity products which eventually build up in the system to the point where pores in the soil are blocked. The rates of production of these clogging materials is critical to the life of the absorption system. Goldstein et. al (1972) notes that clogging occurs under both aerobic and anaerobic conditions but most sever clogging occurs when oxygen is absent or present in only very low concentrations. They include in their report a very good thirty page summary of the clogging mechanisms which will not be repeated here due to the length involved. McGauhey and Winneberber (1965) also present a discussion on preventing failures of soil absorption systems.

Given that soil systems if not designed, installed and maintained properly, can fail, there has been considerable interest generated in effluent disposal systems not dependent upon the soil.

Effluent Disposal Other Than Through Soil Absorption

One means of avoiding utilizing the soil for effluent disposal is to use the process of evapotranspiration. This is ordinarily accomplished by sealing a trench or a wide shallow area, backfilling with soil, and planting grass or shrubs to expediate the evaporation process. Bernhart (1973) and Engineering Science (1971) both present the details of this effluent disposal process. Engineering Science (1971) concluded that if a wastewater system used only evapotranspiration for volume reduction, the area required in the bed would range from a low of 890 square feet to a high of 10,371 square feet over the United States. Average rates of waste water production were assumed. They also noted that use of evapotranspiration will be effective only if the water table is at least 5 to 6 feet below the surface. Toxicity may become a problem if boron and TDS in the water supply are in excess of 1 and 2,000 mg/1. A combination of evapotranspiration and percolation is thought to offer the best approach to the disposal of wastewater emanating from a single household.

Other means to circumvent the soil absorption system for dispoasl are originating for the space program and research work on advanced municipal waste treatment practices. Solar distillation is the only advanced waste treatment process considered feasible at the current time for individual home sewage disposal. Engineering Science (1970) presents a discussion of the merits and economics of the system.

Hendel (1962) presents a discussion of the various processes of waste water recovery that have been considered for space travel. These include osmosis, electrodialysis, electrolysis, crystallization, sublimation, extraction, hydration, distillation, and closed ecological systems. However Engineering Science (1970) notes that from a cost standpoint, none of the space water recovery systems are practical in a household disposal scheme.

Closed toilet systems have been proposed as a means of eliminating discharges from this source. Several of these systems are commercially available, but Bailey, et. al (1969) reports the results of a survey which indicates that most people object to this type of system. They object to the initial expense and have a fear that unsanitary conditions would develop. Engineering Science (1970) presents a discussion of the various technologies utilized in these systems.

Along this same line, partial reuse of wastewater for toilet flushing has been proposed as a way to reduce waste water volume requiring disposal. Bailey, et. al (1969) report on many other ways to reduce volume of wastewater; however, this still does not eliminate the need for treatment and disposal.

Total evaporation is another alternative for disposal without a soil absorption system; however, it has also been shown, as was solar distillation, to be a high consumer of energy or required large land areas. Research work currently underway at Colorado State University is evaluating this concept for high elevations. The work, under the direction of John C. Ward in Civil Engineering, Colorado State University may yield results applicable to the mountainous areas of the Rocky Mountain-Prairie Region.

One last alternative to a soil absorption system is the simple storage and haulaway concept. Normally this involves installing a vault which must be pumped when it is full. The cost of pumping and haulaway is quite variable; however, Engineering Science (1970) notes a cost of $7.00 per 1000 gallons to haul fresh water to a California city in 1960. Taking this cost as a minimum baseline, it would cost a homeowner $84.00 monthly to transport 400 gallons per day of sewage flow. Of course on a second home this cost could be reduced, but still may be more than most people are willing to pay.

Summary

From the foregoing review of the current technology available for individual home sewage disposal, it is obvious no one way or technique can be recommended. There are many diverse opinions on the various technologies with additional technologies being added to the list. Dispite the problems with septic tanks and soil absorption previously reviewed, they have functioned for many years without significant failure in communities all over the U.S. This observation has led Goldstein, et. al (1972) to conclude that individual domestic waste treatment systems can indeed be designed for trouble-free operation and thus constitute a technically feasible alternative to central systems. The problem arises due to the fact that the design of an individual waste treatment system must necessarily include considerable art along with the somewhat vague scientific principles. The problem currently appears to have no solution and little effort is being devoted to obtaining one. It would appear that more research is needed in the area of developing sound scientific principles upon which the design could be based or there needs to be institutions to regulate individual home sewage disposal to the point where no systems would be installed unless there were a "good" chance that the system would operate properly.

In either case the extension effort for education of the public is essential, especially in the mountainous resort areas where the public is purchasing land and homes with little knowledge concerning the waste water disposal problem.

EPA believes that land use regulation is just as important as technological solutions, and, as a result, the current extension activities in rural land use planning may play as large a role in solving the problem as an extension effort in the technological area.

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LIVESTOCK WASTE DISPOSAL

The livestock industry in the Rocky Mountain-Prairie Region consists of various types of animals raised under different forms of farming operations ranging from a few sheep per acre to cattle feedlots with 150,000 head. The variability of livestock animals, type of operation, size of operation, and location makes it difficult to definitely state the exact magnitude of the waste disposal problem and its impact on the environment. However, by utilizing data on farm size and recent inventories on feedlots, dairies, swine operations, etc., it will be possible to make inferences concerning the existing and predicted situation for livestock waste disposal in the Rocky Mountain-Prairie Region.

Livestock Production

The Rocky Mountain-Prairie Region contains most types of livestock production with certain types being more prevalent than others. The region contained 13.3% of the nation's cattle on farms as of January 1, 1973, 4.7% of the nation's hogs on farms, 33.6% of the stock sheep as of 1971, 4.5% of the dairy cows as of 1970, and 3.1% of the hens and pullets of laying age as of 1971. Each of these categories of livestock will now be discussed in terms of their distribution within the region.

Cattle production occurs in all states in the Rocky Mountain-Prairie Region. The breakdown of total cattle on farms for the region is shown in Table 80 . From this table it can be seen that 28% of the cattle on farms in the region are located in South Dakota, 23% in North Dakota, 10% in Wyoming and 5% in Utah.

Since the magnitude of the livestock waste problem is related primarily to concentration of animals in production units (feedlots), simply looking at total numbers does not tell the entire story. Animals not in a feedlot are normally under pasture or range situations where their density is such that plant growth is not inhibited, but actually enhanced as the nutrients are recycled. Under these pasture or range conditions, no pollutional source is generally identifiable (Hamilton Standard, 1973). If over grazing does occur, a pollutional source in the form of sediments may occur, however.

The USDA (1973) reports on selected states where cattle are fed. The number of cattle on feed varies over the year and are reported by quarters. However, for purposes of this report, a semi-annual tabulation of cattle on feed (in feedlots) is presented in Table 72. The figures indicate that 11.9% of the fed cattle and calves in the 39 states concerned, were located in the Rocky Mountain-Prairie Region on January 1, 1972. The cattle in the first 4 states (North Dakota, South Dakota, Montana and Colorado) were located on a total of 11,401 feedlots of all sizes (total cattle for the states noted is 3,184,000). The breakdown as to number of feedlots within each size range and cattle marketed is given for the four states in Table 73 . No data was available for Wyoming and Utah.

The data in Table 73 indicate that for 1972, there were 335 feedlots in the four states with 1,000 head or more and they accounted for 77.2% of the total cattle on feed. In 1971 this figure was 73.5% in 374 lots. In 1972 in lots of 16,000 head or more, 34.2% of the fed cattle are accounted for. This percentage was located in 16 feedlots.

Table 71 Number of cattle on farms (thousands). (USDA, 1971, and USDA, 1973.)

	Jan. 1, 1969	Jan. 1, 1971	Jan. 1, 1973
North Dakota	2,025	2,190	2,435
South Dakota	4,366	4,498	4,496
Montana	2,984	3,104	3,197
Wyoming	1,447	1,461	1,565
Colorado	3,119	3,516	3,756
Utah	785	840	840
Total for Region	14,726	15,609	16,289
Total for U.S.	109,885	114,568	121,990

Table 72

Cattle and calves on feed in the Rocky Mountain-Prairie Region (thousands). (USDA, 1973.)

State	Jan. 1, 1971	July 1, 1971	Jan. 1, 1972	July 1, 1972
North Dakota	45	39	52	45
South Dakota	339	281	363	275
Montana	130	100	165	130
Colorado	888	879	983	1020
Wyoming	35	--	37	--
Utah	68	--	55	--
39 State Total	12,770		13,876	

Table 73

Number of cattle feedlots and fed cattle marketed by size of feedlot capacity. (USDA, 1973.)

State and Year	Under 1,000		1,000-1,999		2,000-3,999		4,000-7,999		8,000-15,999		16,000-31,999		32,000 & over		Total 1000 and over		Total all feed lots	
	Lots	Cattle Mktd.	Lots	Cattle Mktd.	Lots	Cattle Mktd.	Lots	Cattle Mktd.	Lots	Cattle Mktd.	Lots	Cattle Mktd.	Lots	Cattle Mktd.	Lots	Cattle Mktd.	Lots	Cattle Mktd.
1971	No.	1000 head	No.	1000 head	No.	1000 head	No.	1000 head	No.	1000 head	No.	1000 head	No.	1000 head	No.	1000 head	No.	1000 head
North Dakota	983	58	10	11	7*	11*									17	22	1,000	80
South Dakota	9049	480	33	46	13	28	5*	48*							51	122	9,100	602
Montana	387	35	46	18	22	50	18*	132*							86	200	473	235
Colorado	622	240	101	135	48	155	32	269	20	302	16	1050			217	1911	839	2,151
1972																		
North Dakota	1082	60	14	13	4*	12*									18	25	1,100	85
South Dakota	9046	454	39	31	8	15	4	16	3	45					54	107	9,100	561
Montana	317	26	36	31	17	33	14	86	5*	71*					72	221	389	247
Colorado	621	183	67	118	49	163	36	299	23	439	11	360	5	729	191	2108	812	2,291

* Lots and marketings from larger size groups are included to avoid disclosing individual operations.

In 1967 there were 1,127 cattle feedlots in Colorado with 850 having less than 500 head and 28 having greater than 5,000 head capacity (Loehr, 1972). In 1972, Colorado had 34 lots with more than 8,000 head and 621 with less than 1,000 head. As this trend toward larger lots continues, the percentage of cattle on larger lots will increase. With feedlots becoming fewer and larger, the situation can be likened to people moving to cities-- fewer cities but larger cities with large environmental problems. Likewise the large feedlots will present a large potential for environmental problems.

The above information on cattle production delineates the location of cattle production within the region. Of course within each state in the region there can be a further breakdown allowing the delineation of feedlot location with respect to the streams involved. This is beyond the scope of this report; however, data is available to break the location of feedlots down by region (river basin) for Colorado as a means of indicating how this could be done for other states.

The data used to do this breakdown for Colorado is taken mainly from "district" data. The districts do not follow river basin boundaries, but are fairly close except between the South Platte and Republican Basins (treated as one district) and the Arkansas River Basin. Some numbers attributed to being outside the Arkansas Valley are actually in the Valley. Within Colorado there were 3,516,000 head of cattle and calves on farms in 1971. Of this total 4% were located in the San Luis Valley, 17% in the Arkansas Valley, 19% in the Colorado River Basin, and 60% in the South Platte and Republican River Basins. The actual figures for 1968 and 1971 are presented in Table 72.

As for the distribution of cattle on feed, the vast majority (87%) in Colorado are located in the South Platte and Republican River Basins (eastern plains excluding the Arkansas Valley). The Western Slope contained 1% and the Arkansas Valley contained 12%. Table 73 contains the cattle and calves on feed by regions in Colorado.

Table 74

Cattle and calves on farms in Colorado by districts (roughly river basins), Jan. 1, 1968 and 1971 (Colorado Crop and Livestock Reporting Service, 1972).

	1968	1971
San Luis Valley	125,400	154,000
Arkansas Valley	493,700	597,000
Colorado River Basin	640,100	657,000
South Platte and Republican River Basins (Eastern Plains excluding Arkansas Valley)	1,800,800	2,108,000
State Total	3,060,000	3,516,000

Table 75

Cattle and calves on feed, Dec. 1971. (Colorado Crop and Livestock Reporting Service, 1972.)

Arkansas Valley	116,200
Western Slope	11,100
South Platte and Republican River Basins	831,700
Total	959,000

Turning to the hog situation in the Rocky Mountain-Prairie Region, it is noted that South Dakota contains 64% of the region's total of 2,895,000 in 1972. Table 76 contains the figures for all states in the region. North Dakota contains 13%, Colorado 11%, Montana 8%, Wyoming 2%, and Utah 1%. Hogs are generally raised in lots that may be called "feedlots"; however, the numbers are not as large as for cattle. Consequently there is little data on the number or size of hog "feedlots".

Looking specifically at Colorado (see Table 77) it is noted that as with cattle, most (64%) of the hogs are in the central and northern plains of the state. The San Luis Valley has 8%, the Arkansas Valley 17%, and the Colorado River Basin, 10%.

Both Tables 76 and 77 reflect the changing nature of number of hogs versus time. This is a reflection, to a large extent, of the fluctuating market conditions that prevail in the hog industry.

In 1971 the Rocky Mountain-Prairie Region contained 5,694,000 stock sheep of which 29% were in Wyoming, 18% in Montana, 17% in South Dakota, 17% in Utah, 13% in Colorado and 5% in North Dakota. The figures are presented in Table 78 Again sheep are fed in lots, but no data is readily available for the region as to number of lots or number of sheep on feed.

For Colorado the distribution of stock sheep numbers among the river basins is given in Table 79 . From this it can be seen that for 1971, 17% are in the San Luis Valley, 3% in the Arkansas Valley, 71% in the Colorado River Basin, and 9% in the South Platte and Republican River Basins. Table80 contains a breakdown of the sheep on feed in Colorado. The designation of regions was not clear in the reference of this table; therefore, the change of notation. It can be seen that as of 1972, most (84%) of the fed sheep in the state are in the northeastern portion, while 10% are in the Arkansas Valley, and 7% are on the western slope. This, more so than with cattle or hogs, indicates that the feeding in lots is done where the grain is located--on the irrigated plains of the state.

Table 76.

Number of hogs on farms (thousands). (USDA, 1971 and USDA, 1973).

	Jan. 1, 1969	Jan. 1, 1971	Dec. 1, 1972
North Dakota	321	425	368
South Dakota	1,860	2,009	1,860
Montana	177	221	240
Wyoming	29	38	55
Colorado	246	352	330
Utah	56	59	42
Total for Region	2,689	3,104	2,895
Total for United States	60,632	67,540	61,502

Table 77

Number of hogs on farms by district (River Basins) in Colorado Jan. 1, 1968 and Jan. 1, 1971. (Colorado Crop and Livestock Reporting Service, 1972.)

	1968	1971
San Luis Valley	13,500	29,200
Arkansas Valley	33,500	60,000
Colorado River Basin	24,000	36,800
South Platte and Republican River Basins	136,000	226,000
State Total	207,000	352,000

Table 78

Number of stock sheep on farms (thousands). (USDA, 1971).

State	Jan. 1, 1969	Jan. 1, 1971
North Dakota	309	291
South Dakota	1,052	990
Montana	1,130	1,042
Wyoming	1,766	1,644
Colorado	856	749
Utah	988	978
Total for Region	6,101	5,694
Total for United States	18,332	16,937

Table 79

Number of stock sheep on farms by district (river basin) in Colorado, Jan. 1, 1968 and Jan. 1, 1971. (Colorado Crop and Livestock Reporting Service, 1972.)

	1968	1971
San Luis Valley	152,000	130,000
Arkansas Valley	33,000	24,000
Colorado River Basin	614,000	528,000
South Platte and Republican River Basins	85,000	67,000
Total	884,000	749,000

Table 80

Number of sheep and lambs on feed for slaughter market by areas, Colorado, January 1, 1962, 1967, and 1972. (Colorado Crop and Livestock Reporting Service, 1972)

	1962	1967	1972
Arkansas Valley	112,000	101,000	46,000
Western Slope (Colorado and Rio Grande River Basins)	48,000	21,000	23,000
Northeastern Colorado	410,000	388,000	371,000
Total	570,000	510,000	440,000

This is especially clear with sheep since so many of the total numbers of stock sheep are located elsewhere in the state.

Also it should be noted that total numbers of sheep are declining. This reflects again the market situation. The demand is increasing for beef and pork, but not lamb.

Dairying in the Rocky Mountain-Prairie Region involved a total of 623,000 cows in 1970. No one state contains a large percentage of dairy cows since dairying is not a large agricultural industry in the region (see Table 81). North and South Dakota contain 26% and 32% of the region's dairy cows, respectively, primarily due to their location near the dairying center of the nation. The other states contain numbers somewhat proportional to their populations.

In Colorado the dairy cow distribution among areas of the state also follows population trends (see Table 82). The South Platte and Republican River Basins contain 72% of the state's dairy cows, the Colorado River Basin contains 16%, the Arkansas Valley 10%, and the San Luis Valley 2%. As with sheep, total dairy cow numbers are declining as are the total number of dairies. However, the average size of the dairy is increasing. A look at some national statistics will show this.

The trend of dairy herd size and number of cows in relation to number of herds is shown in Table 83 . This data indicates that herds with less than 30 cows will become relatively unimportant in 1980 representing only 12% of the herds and 4% of the cows. It can also be noted that in 1980, dairy farms with 50 or more cows will include more than 1/2 of the herds and 3/4 of the cows (Hoglund, 1973). These figures indicate general trends that can be expected in the Rocky Mountain-Prairie Region.

The location of dairies in the region, due to market considerations, can generally be expected to center around population concentrations. Since the region contains little dairy production for cheese, the above observation can be made.

Table 81

Number of cows and heifers 2 years old and over kept for milk. (thousands). (USDA,1971.)

State	Jan. 1, 1969	Jan. 1, 1970
North Dakota	168	163
South Dakota	214	200
Montana	49	47
Wyoming	20	19
Colorado	110	112
Utah	82	82
Total for Region	643	623
Total for United States	14,152	13,838

Table 82

Number of cows and heifers over 2 years old kept for milk by districts (river basins) in Colorado, Jan. 1, 1968 and Jan. 1, 1971. (Colorado Crop and Livestock Reporting Service, 1972)

	1968	1971
San Luis Valley	1,900	2,000
Arkansas Valley	10,600	9,500
Colorado River Basin	17,800	15,600
South Platte and Republican River Basins	78,700	73,900
Total	109,000	101,000

Table 83

Percentage distribution of Dairy herds and cows by size of herd, 1960, 1970, and 1980, U.S. (Hoglund, 1973)

Cows per Farm	Percent of Herds			Percent of Cows		
	1960	1970	1980	1960	1970	1980
10-29	76	54	12	58	33	4
30-49	17	30	36	24	30	21
50-99	5	13	36	12	25	34
Over 100	2	3	16	6	12	38
Totals	100	100	100	100	100	100

In 1971 the Rocky Mountain-Prairie Region contained 3.1% of the nation's hens and pullets of laying age. The distributions among states is shown in Table 84 . South Dakota contained 49% of the region's total in 1971 while all other states except Wyoming contained approximately 13% each. Wyoming contained 2%.

There is no breakdown of broiler production for the Rocky Mountain-Prairie Region since the industry is so small that to do so would disclose individual operations. The entire western U.S. contains 4.1% of the broiler industry with Washington, Oregon, and California containing 4.0%. This leaves 0.1% for the remaining western states.

With respect to turkeys, Montana and Wyoming contain too few to declare numbers. The remainder of the states contain 3.2% of the nation's production. In 1971, Utah contained 50% of the region's total number of turkeys, Colorado 34%, North Dakota 10% and South Dakota 6% (see Table 85).

The production figures that have been presented in the preceeding pages indicate the numbers of livestock involved and give some indication of the distribution of the animal waste problem in the Rocky Mountain-Prairie Region. Although livestock waste may present a sizeable non-point source of environmental degradation, there are other aspects of the situation which cannot be overlooked. The impact of livestock production on Colorado's agricultural industry is quite large. In 1964, the source of Colorado cash farm income in percentage of total was 50% for cattle and calves, 15% for other livestock and products, 5% for wheat, 22% for all other crops, and 8% in government payments. As with irrigation return flows, the livestock waste problem is made quite complex since it is tied so closely with the economy of many people in the region.

Waste Characteristics

Waste characteristics of livestock varies considerably depending upon the type of animal, facility used, and diet. However, for a given type of animal respectable ranges can be established. The Hamilton Standard (1973) report

Table 84

Hens and pullets of laying age on farms, Jan. 1, 1969 and Jan. 1, 1971 (thousands). (USDA, 1971)

	1969	1971
North Dakota	1,281	1,214
South Dakota	5,023	5,096
Montana	1,099	1,162
Wyoming	201	189
Colorado	1,529	1,606
Utah	1,276	1,188
Total for Region	10,409	10,455
Total for United States	316,177	335,079

Table 85

Number of turkeys on farms, Jan. 1, 1969 and Jan. 1, 1971 (thousands) (USDA, 1971)

	1969	1971
North Dakota	23	25
South Dakota	20	14
Montana	--	--
Wyoming	--	--
Colorado	69	83
Utah	92	120
Total for Region (4 States)	204	242
Total for United States	6,604	7,462

presents a comprehensive summary of livestock waste characteristics. Rather than repeat the voluminous waste characteristics here, the interested reader is referred to the Hamilton Standard (1973) report.

Due to size and numbers, cattle produce the largest volume of waste in the Rocky Mountain-Prairie Region. Because of this, cattle waste characteristics will be briefly reviewed with two tables.

Loehr and Agnew (1967) determined the waste production of a 900-pound steer as shown in Table 86 . They also compared the characteristics of beef cattle wastes to sewage sludge in order to relate the manure to a waste more familiar to sanitary engineers (see Table 87).

Pollution Potential

Pollution from a livestock feeding operation can be generally classified as either originating from the manure disposal operation or from runoff. Generally, a waste management system operator at the feeding operation to remove the wastes from the lot and provide for ultimate disposal. Also another waste management system collects the runoff from the lot and provides for ultimate disposal.

Over the years, the runoff problem has attracted the major concern as reflected in the specific nature of the regulations governing the situation. Quantification of the runoff problem is difficult since each feeding operation presents a considerably different pollution potential picture. As a result it is not possible to predict the general effects of feeding operations on the quality of a stream without performing a detailed field survey. Some detailed surveys have been reported and they give an indication as to what can happen.

Smith and Miner (1964) noted the slug effect that occurs on a stream's water quality from runoff after a storm passes over a cattle feedlot. The results of Smith and Miner's work is shown in Table 88 . They found the runoff to be high in ammonia, the stream consequently, was highly polluted with ammonia, and the ammonia associated with the runoff tended to be detectable before the

Table 86

Wnste charasteristics for a 900-pound steer (Loehr and Agnew, 1967).

Wet Manure per day in pounds	Dry Manure per day in pounds	Moisture content in %	BOD_5 in mg./kilo	COD in mg./kilo	Volatile solids, in lbs/steer/day	Coliform count/gram	Fecal coliform / Fecal strep
43 feces 17 urine 60	9	85	10,000 to 20,000 (one to two lb. per steer per day)	80,000 to 130,000 (9 lb. per steer per day)	7	230,000 (6 billion per steer per day)	less than .05

Table 87

Characteristics of beef cattle wastes and sewage sludge (Loehr and Agnew, 1967).

Source	Percentage of Dry Solids	COD/ Total Solids	COD/ Volatile Solids	5-Day BOD/ Total Solids	5-Day BOD/ Volatile Solids	COD/ 5-Day BOD	Percentage Volatility	pH
Beef Cattle Feedlot Wastes[a]	25-30	0.96	1.15	0.24	0.28	4.00	80-90	4.7-5.8
Topeka, Kans. Primary Sewage Sludge[b]	3-5	1.27	1.66	0.44	0.64	2.60	75	6.5-7.2

[a]Except where noted, the results are in milligrams/milligram.
[b]Except where noted, the results are in milligrams/liter.

Table 88

Fox Creek near Strong City, Kansas, November, 1962, Water Quality Parameters in Milligrams per Liter. (Smith and Miner, 1964.)

Time, in hours	DO	BOD_5	COD	Cl	NH_3
Average Dry Weather	8.4	.2	29	11	0.06
After Rainfall					
13	7.2	8	37	19	12.00
20	0.8	90	283	50	5.30
26	5.9	22	63	35	
46	6.8	5	40	31	0.44
69	4.2	7	43	26	0.02
117	6.2	3	22	25	0.08

other parameters. They also measured high bacterial counts in the feedlot runoff and noted a decrease in the ratio of fecal coliform to fecal streptococci when the feedlot runoff was present in the stream.

Miner, et. al (1966) have shown that the quantity of pollutants washed from a cattle feedlot during a rainstorm is a function of temperature, rainfall rate, and moisture content of the accumulated waste before rainfall. They also found that two weeks after cleaning, that feedlots reach their maximum pollutional potential.

Returning to the regulation of runoff and waste removal, it may be possible to get a handle on the magnitude of the pollution potential of livestock feeding operations. Since the greatest pollution potential revolves around the concentrated feeding operations, most regulations deal with the feedlot. Feedlots are generally required to register or be licensed by the state if their operation is above a given size. Most states either suggest or require that diversion structures be built around the feedlot so as to minimize runoff pollution. The water is generally diverted to a holding basin or pond from which it is later removed to a field. The design criteria for the ponds differs in different states. Some base the size on the 5-year 48-hour storm or a 10-year 24-hour storm while others utilize a 25-year 24-hour storm. Also, the ponds have to be pumped within a certain length of time after the storm; the exact time varies with the different states.

The actual disposal of the manure can be accomplished in several different ways and most states simply indicate in their regulations that the waste management system must be adequate. Being designed by a registered professional engineer satisfies this requirement in many states.

If it can be assumed that a feedlot that meets the above standards or regulations will not pollute or can be defined as such, then it will be possible to estimate the pollutional load of feedlots on the waters of a state by determining the number of lots not meeting regulations. Current estimates place this figure at approximately 10% for cattle. It has been estimated that perhaps 5 to 10% of the waste from a cattle feedlot actually enters surface and ground waters (Rademacher, 1970). Utilizing a 7.5% figure, the 10% of cattle with no waste management, and noting that in 1971 there were 830 feedlots in Colorado containing 959,000 head, it can be calculated that 215,775 tons of wet manure enter Colorado waters each day. This has a population equivalent of 72,625. To get these figures, it is assumed that all the cattle are characterized as in Table 95 and that the wastes from one steer equals that of 10 people (estimates range from three to sixteen). Referring back to Table 91 indicates that, again, the largest problem in Colorado is in the South Platte River Basin. Here the population equivalent is 62,278. Of course the above assumptions are ballpark figures at best, but to obtain more accurate estimates would require detailed field surveys. This is due to the large number of waste management systems utilized and the fact that little date is available to measure the effectiveness of the systems.

There are many procedures for livestock waste management and, obviously, some are better than others. However, nowhere in the literature is there an attempt made to quantify the effectiveness of waste management alternatives. The economics are compared, but not the "value" received for the cost. As a result it is not possible to indicate what effect the different waste management alternatives currently utilized are having upon the water quality in a state or river basin. Thus, it is assumed that if a feedlot has a runoff facility, its waste management program meets state regulations and no pollution occurs.

Butchbaker, et. al (1971) indicates an ordering of waste management systems according to pollution control and another ordering according to economics. The orderings are almost exactly opposite--the most economical is the worst as far as pollution control is concerned. Without knowing how effective one alternative is versus other alternatives, it is not possible to determine the optimum waste management system for given conditions and priorities.

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LIVESTOCK AND WASTE DISPOSAL TECHNOLOGY

The confinement of large numbers of animals for feeding purposes has produced one of the most complex and perplexing problems ever faced by engineers, planners, and developers not to mention the livestock feeder hemself. The problem revolves around solid waste disposal, water pollution and air pollution.

Considerable literature is available describing the characteristics of animal wastes and the alternatives available for its recycling, treatment, or disposal. Regarding waste characteristics there is a considerable range of values given. The data depends upon the literature one reads which in turn probably depends upon the type of feed, amount of bulk, and other items the animals are receiving. A brief review of the waste characteristics was presented in Part I of this report.

In this portion of the report, the types of control devices or remedial measures which can be used effectively to prevent the wastes from entering and polluting surface and ground waters are reviewed. In summary, the detention pond is the primary type of facility for cattle feedlots. For other types of feeding operations a variety of "lagoon" systems are used. Anaerobic lagoons, faculative lagoons, aerated lagoon, aerobic lagoons, the oxidation ditch, and holding pits are the major ones. Other technology receives a lot of attention, but is not that prominently applied. Economics dictates much of this (O'Brien and Filipi, 1969).

Johnson, et.al(1973) and David, et.al (1973) discuss in detail the economics associated with controlling runoff arising from feedlot operations. Johnson, et. al (1973) assume that beef feedlot operations with runoff problems will use a three component runoff control system to eliminate surface water pollution problems associated with production facilities. This system will generally consist of a diversion terrace, settling basin, and retention pond with associated pump-irrigation equipment. The economics of this situation results in a cost of $43.43 per head for runoff control on lots of 1,000 head or less in capacity, the comparable figure is $2.50. As a result of the figures, investment and cost economics will accure to large-size beef feedlot operations.

For the western U.S. the above technological solution is probably fairly accurate. The President's Water Pollution Control Advisory Board (1972) concluded that in areas of low rainfall control measures for feedlots can be reasonably simple to design and install when compared to controls required of municipal and industrial pollution sources. The Board indicated that this is possible through the use of techniques such as interceptor ditching, lagoons, land and terracing disposal.

Before presenting the available technology another topic needs mentioning. Beyond the characteristic of the waste itself, several studies have evaluated the quality of the runoff from a feedlot. Kreis, Scalf, and McNabb (1972) found that 50% of the rainfall events produced measurable runoff from the feedpens in a beef feedlot. A four to ten inch manure mantle on the feedpen surface was found to present runoff from 0.2 to 0.3 inch rainfalls depending on intensity and antecedent moisture conditions. The total runoff from the feedpens was equivalent to 39% of the total rainfall during the study period. Direct runoff from the feedpens contained pollutant concentrations in the form of oxygen demand, solids, and nutrients that were generally an order of magnitude greater than concentrations typical of untreated municipal sewage.

Swanson (1972) also reports on the characteristics of feedlot runoff. He indicates, among other conclusions, that runoff may not be expected from rainfall of 0.5 inch or less unless rainfall has occurred within the previous three days. He also concludes that feedlot runoff control facilities should be designed for periods of maximum and probably high intensity precipitation accompanied by minimum evaporation. Ordinarily, however, he indicates it should not be necessary to design such structures for the maximum possible precipitation. Design for storm return periods of 10 years should be adequate for most livestock runoff control facilities.

Feedlot Definition

In addition to the above brief comments on waste characterizations and economics, before discussing livestock waste disposal, the "feedlot" needs to be defined. Hamilton Standard (1973) indicates that animals are grown in both feedlot and non-feedlot situations. They define a feedlot as generally having two conditions: (1) a high concentration of animals held in a small area for extended periods of time for one of the following purposes:

a. Production of meat
b. Production of milk
c. Production of eggs
d. Production of breeding stock
e. Stabling for horseraces

and (2) the transporation of specially prepared feeds to the animals for consumption. Hamilton Standard (1973) also describes each animal industry and its particular feedlot situation. Their breakdown includes beef cattle, dairy cattle, swine, chickens (broilers and layers), sheep, turkeys, ducks, and horses. As noted in Part I, beef cattle are of most concern in the Rocky Mountain-Prairie Region; however, there is production of the other types of livestock in the Region.

Waste Management Technology

Livestock waste management can be divided into two basic categories: (1) management of the waste on the lot and (2) treatment or disposal of the waste or runoff from the lot. Hamilton Standard (1973) refers to this breakdown as in-process technology and end-of-process technology, respectively. Butchbaker, et.al, (1971) discuss waste management alternatives in terms of waste handling, waste treatment, and ultimate disposal. Shuyler, et. al (1973) discuss technology for beef feedlot waste managementin terms of site selection, runoff wastes, solid wastes, and liquid wastes with technical means of treatment and disposal of each waste listed. Loehr (1968) presents a technology review associated mainly with treatment and disposal. For this discussion the on-lot and off-lot breakdown will be used.

On-Lot Technology

On-lot waste management technology revolves around the design and operation of the feedlot and the effect these have on the environment. Hamilton Standard (1973) lists feed formulation and utilization, water utilization, bedding and litter utilization, site selection, pen design, housekeeping (cleaning and stockpiling of manure), and selection of method of production as factors which are directly concerned with what is happening on the feedlot itself and, consequently, indirectly effect the waste materials leaving the feedlot. Butchbaker, et. al (1971) indicate that the following factors affect the removal of waste from the surface of a feedlot:

1. moisture content
2. animal density
3. length of time from previous cleaning
4. amount of rainfall and intensity
5. slope of the feedlot surface
6. size of the pens
7. feedlot capacity
8. hauling requirements and ultimate disposal
9. temperature
10. evaporation rate
11. wind
12. solar radiation
13. soil type.

Butchbaker, et. al then describe in detail the technology currently available for solids removal and liquid waste removal. These basically revolve around scraping solid waste and flushing liquid wastes, respectively.

Off-Lot Technology

Off-lot technology is of major concern in this report since it is here that runoff control and manure treatment and/or disposal technology will be discussed. Hamilton Standard (1973) has prepared an excellent summary of this type of technology referred to as "end-of-process" technology in their report. This summary is shown in Table 89 . Level I under Status indicates that the technology currently available while level II refers to the best available technology economically achievable.

This general technology breakdown (applicable to all "feedlot" animals)

TABLE 89 - END-OF-PROCESS TECHNOLOGY CLASSIFICATION
(Hamilton Standard, 1973)

TECHNOLOGY	APPLICATION		FUNCTION			STATUS			TYPE OF PROCESS	
	Manure	Runoff	Containment	Complete Treatment	Partial Treatment	Level I	Level II	Experimental	Biological	Physical-Chemical
Land Utilization	X	X		X		X			X	
Compost and Sell	X			X		X			X	
Dehydration (Sell or Feed)	X			X		X (Sell)	X (Feed)			X
Conversion to Industrial Products	X			X				X		X
Aerobic SCP Production	X			X				X	X	
Aerobic Yeast Production	X			X				X	X	
Anaerobic SCP Production	X			X				X	X	
Feed Recycle	X			X				X		X
Oxidation Ditch (Spread or Feed)	X				X	X (Spread)	X (Feed)		X	
Activated Sludge	X				X		X		X	
Wastelage	X				X		X		X	
Anaerobic Fuel Gas	X				X			X	X	
Fly Larvae Production	X				X			X	X	
Biochemical Recycle	X				X			X	X	
Conversion to Oil	X				X			X		X
Gasification	X				X			X		X
Pyrolysis	X				X			X		X
Incineration	X				X			X		X
Hydrolysis	X				X			X		X
Chemical Extraction	X				X			X		X
Runoff Control		X	X			X				
BLWRS		X		X				X	X	
Lagoons for Treatment		X	X		X	X			X	
Evaporation		X	X		X	X				X
Trickling Filters		X			X			X	X	
Spray Runoff		X			X			X	X	
Rotating Biological Contactor		X			X			X	X	
Water Hyacinths		X			X			X	X	
Algae		X			X			X	X	

will serve as an outline for briefly describing the waste management technology. Hamilton Standard (1973) has more detailed descriptions while Butchbaker (1971) contain considerable detail on beef feedlot waste management alternatives. Other specific references mentioned earlier also describe the technology.

Land Utilization

This centuries-old practice simply involves returning the waste to the land. Of course the manner in which it is returned dictates the usefulness of the waste for crop growth or whether a site is simply being used as a disposal area (high rates of application). The waste can be spread in solid or liquid form either on or below the surface.

Spreading on the surface creates problems with odors, flies, and runoff. As a result subsurface injection is gaining in popularity. Smith and Gold (1972) describe their research at Colorado State University concerning subsurface injection of wastes. They inject at 3 to 6 inches and in the Rocky Mountain-Prairie Region with high evaporation rates, this insures rapid evaporation from the soil. This particular technology needs additional evaluation of environmental effects and then technology transfer will be necessary. Studies are currently underway to help determine some of the environmental affects, but very little technology transfer has occurred.

Land utilization (particularly surface spreading) is the most popular and economical means of ultimate disposal in the Rocky Mountain-Prairie Region.

Composting

Composting of animal wastes involves spreading the collected manure in windrows three to four feet high or deporting it in tubs or bins. The resulting humus can then be sold; however, there is a relatively limited market. As a result composting has limited use as a means for animal waste management.

Dehydration

The drying of animal wastes is a currently practiced technology which has a final product that is sold as fertilizer (primarily for gardens). The process is expensive and requires a market that can support the process. Recent attempts have been made to refeed the dried wastes; however, this is only experimental at the present time.

Conversion to Industrial Products

Manure has been processed (pyrolyzed) to create basic products in the manufacture of ceramic tile, a styrofoam like product, or brick. Pilot plants are currently testing the concept and looking for markets that will support the process. If these pilot studies are successful, the possibility of establishing plants to utilize manure from many separate feedlots becomes real. This, however, would require an extensive extension effort.

Aerobic Production of Single Cell Protein

Selected thermophilic bacteria are used to treat animal waste and produce a colony of proteinaceous single cell microorganisms. The process has reached the demonstration phase but has encountered difficulties. The process results in little or no pollutional discharge and produces a valuable product (protein).

Aerobic Production of Yeast

This process is in a preliminary laboratory stage of development which utilizes many stages for processing. If proven successful in the lab, much engineering refinement will be necessary to make the system practical.

Anaerobic Production of Single Cell Protein

Rather than using an aerobic process as before, this process uses anaerobic fermentation to create a proteinaceous feed ingredient. Methane is also produced. Development of the process is in the laboratory stage and still has several unanswered questions regarding the final product and the process.

Feed Recycle Process

The Feed Recycle Process is a proprietary process which separates nondigestible portions of the waste from the digestible protions by physical-chemical means. Protein recovery is 89%. The process is currently in a pilot plant phase.

Oxidation Ditch

Quoting from Hamilton Standard (1973), "The oxidation ditch is made up of two principle parts, a continuous open channel ditch, usually shaped like a race track, and an aeration rotor that circulates the ditch contents and supplies oxygen. The oxidation ditch is a modified form of the activated sludge process and may be classed as an extended aeration type of treatment."

This technology is commercially used with slotted floor animal confinement operations and has a relatively high rate of electrical power consumption. The system also needs regular maintenance and good management to operate effectively.

Activated Sludge

These processes are normally defined as bacterial digestion in an aerated tank. Most of the programs utilizing this technology are in a demonstration phase. Hamilton Standard (1973) contains a thorough review of these existing demonstration projects.

The processes are relatively complex, but have two advantages of greatly reducing land spreading and of being able to operate in winter. However, power and operating costs are high. Some forms of activated sludge treatment are ready for commercial development, thus the need for technology transfer.

Wastelage

This term describes the process of using 1/3 to 1/2 of the waste from a confined feeding operation, mixed with corn and corn silage, as a silage for feed. The concept is available for use, but FDA approval has not been received.

The manure and corn ingredients are ensiled for ten days prior to feeding. The process is relatively simple, but care is needed to maintain consistent wastelage quality. The application of this technology is limited to ruminants on hard surfaced or slotted floors.

Anaerobic Production of Fuel Gas

The production of synthetic natural gas (SNG) by anaerobic fermentation of animal wastes is currently in an advanced laboratory phase. Attempts to establish a demonstration plant have met with various economic constraints. It is hoped one will be available within a year to 18 months.

Large concentrations of animals will be necessary to justify the economics of a plant of this nature. Also, remaining sludge has to be disposed of.

Reduction with Fly Larvae

This process which utilized manure as a growth substrate for fly pupae which in turn are used as a high protein feed supplement is currently in an experimental stage. Laboratory tests are encouraging; however, the economics and actual feed utilization are untested. Also a residual waste exists.

Biochemical Recycle Process

This proprietary process, designed for flushed dairy waste, produces bedding materials, fertilizer, and water from the liquid manure. Due to the proprietory nature of the process, not much is actually known. A full-scale demonstration is now being developed.

Conversion to Oil

This concept has high operating costs and results in a low quality (and value) oil. As a result this experimental process does not look economically attractive at this time.

Gasification

Quoting Hamilton Standard (1973), "Manure is partially oxidized in the presence of steam to forma synthetic gas that can be used as an intermediate in ammonia production by conventional manufacturing plants. The ammonia plants would produce fertilizer. A thorough economic evaluation has not been made to date."

The process is in an early laboratory stage, has a moderate product value, has a high power requirement and requires a high concentration of animals.

Pyrolysis

Here the wastes are heated, in the absence of oxygen, to a high temperature. The products are gases (hydrogen, methane, water, carbon monoxide, and ethylene), liquor (oil) and an ash. The ash must be disposed of and air pollution is a problem. The product value is low and the process has been declared uneconomical. Current work is experimental.

Incineration

Due to problems that have plagued other waste incineration, animal waste incineration also appears to be not justified.

Hydrolysis and Chemical Treatment

This process carries the concept of refeeding beyond simply drying the wastes. Hydrolysis makes the treated wastes more digestible; however, it cannot currently compete economically with drying. Work on the process is experimental.

Chemical Extraction

Chemical extraction removes the undigested food from the wastes through a chemical process that is proprietary. The undigested food can then be recycled as feed. The process has been described by one expert as being neither chemically nor economically feasible. To be useful the waste would need to contain a large amount of undigested feed as opposed to large amounts of undigested roughage. This limits the process to animals with low roughage diets.

Runoff Control

Runoff control, due to the high pollution potential, is a critical technology. The variation of conditions from one feedlot to the next make it difficult to establish one form of runoff control for all feedlots. Hamilton Standard (1973) notes four reasons for this wide variation:

1. The runoff from feedlots is diffuse in nature and is difficult to treat with standard methods.

2. The waste flow is caused by unpredictable rainfall or snowmelt.

3. The wastes themselves are extremely variable in quality.

4. The raw wastes vary widely in characteristics.

Shuyler, et. al (1973) contains a complete description of runoff carried wastes.

The first stage of runoff control is collection and transportation of the wastes as they leave the pens. These transport systems may be either a channel which is designed to remove the solids and liquid or a channel which removes the liquid, but due to slope, allows the solids to be settled out.

The next stage usually consists of some form of a settling basin. Shuyler, et. al, (1973) present a commonly used design which consists of a shallow basin bounded on the down slope side by the retention pond dyke. Runoff drains from the pens and/or collection ditch through the settling basin, through a small culvert or standpipe with inlets at multiple levels, and into the storage pond.

From the storage ponds the runoff is disposed of most often by irrigation. This final step has been discussed under land utilization. Other systems of treatment and/or disposal include lagoons of all types, evaporation, etc. Miner (1971) presents a detailed description of the various lagoons used to treat runoff waste water.

Given that runoff control at a feedlot is a readily available technology, the implementation comes next. Within Colorado this data is required as a part of the county zoning, thus making it difficult to obtain. State permits are being developed, but are not a good source of data. Current data that is available at the state level (Pugsley, 1973), was compiled in 1972 and indicates that of the 900,000 head of cattle on feedlots that ship cattle to slaughter, 250,000 head had some form of runoff control and another 100,000 head has plans under consideration. It is estimated that another 100,000 head are now having plans considered. It is also estimated that another 150,000 head are in feedlots that were designed such that no runoff control is needed beyond what is part of the original construction. This leaves 300,000 head in Colorado without any runoff control facilities or any plans for them. It is this segment of the industry that an extension program could benefit.

Barriered Landscape Water Renovation Systems

The BLWRS is an experimental disposal system which utilizes a modified soil plot for treating and eventually disposing of the water through evaporation or percolation. The concept is experimental, but ready for demonstration. It can handle only sprayable wastes and is restricted by soil and climatic conditions.

Lagoons for Waste Treatment

Lagoons are a popular biological treatment of waste water and/or manure. Hamilton Standard (1973) notes that "They work well when properly designed and used, but they do not provide total treatment. Lagoon water is usually used for cropland irrigation, but it is sometimes given further treatment (e.g. chlorination) and discharged to a natural waterway.... Sludge must generally be removed every few years. Ambient temperature influences design and function. Economics often favor anaerobic rather than aerobic lagoons although odor control requires close attention."

Lagoons, as noted under runoff control, normally serve as a retention basin or storage pond prior to disposal on land. When used with runoff control, the slugs of wastewater tend to upset the balance needed for efficient treatment, thus the need for an ultimate disposal method. If lagoons are to be used for treatment, the waste water or runoff needs to be metered into the pond.

Evaporation

This process of ultimate disposal of the liquid waste (the solids must be disposed of in another manner) can be successful where the annual evaporation exceeds annual precipitation by a reasonable margin. Evaporation is normally an alternative to disposing of liquid wastes on land. The evaporation pond design must be large enough to handle the volume of wastes. This may require a large area.

The process is applicable to the Rocky Mountain-Prairie Region if it is not desirable to use the water to grow crops.

Trickling Filter

This old concept of treating municipal water has been tested in the laboratory on animal wastes. There have been no large scale demonstrations; therefore, the system is experimental from an animal waste treatment standpoint.

Spray Runoff

This experimental technology involves spraying waste water on a grass covered slope and collecting the runoff at the bottom. Microorganisms on the grass and soil act on the pollutants in the water. The process is used where spray irrigation is not practical and it is limited by weather and condition of wastewater--it must be sprayable. Data available on the demonstrations using this concept is limited and unconfirmed (Hamilton Standard, 1973).

Rotating Biological Contractor

Work on this experimental process has been discontinued due to relatively poor efficiencies and high cost. The concept involved using rotating discs with an aerobic film to treat the waste water.

Water Hyacinths

Water hyacints are placed in a series of lagoons downstream from an anaerobic lagoon to serve as partial treatment for the anaerobic lagoons effluent. The concept is in the early stages of development and is not currently being studied further.

Algae

As above, algae can be grown in a supernatant as a means of using photosynthetic reclamation of the animal wastes as a method of waste disposal. The harvested algae can be treated and then used as a feed additive. The effluent for the algae growing pond can be used to flush down the animal wastes. The closed loop operation poses some problems with salt buildup and the photosynthetic process depends upon the environment of the pond. Studies are currently underway on an experimental basis to solve some of the problems.

Management/Institutions

Control of feedlot waste normally involves the technology described above in conjunction with some form of management which may be voluntary or enforced through regulations established by various levels of government.

At the federal level, the Environmental Protection Agency has established a national permit system which requires feedlots above a specified size to apply for a permit. In order to obtain the permit the feedlot must demonstrate adequate control over its environmental factors. Not only does this involve application or implementation of technology, but also the assurance that proper management practices will be adhered to.

At the state level, more regulations are being established to control feedlot pollution. The state regulations are closely tied to local zoning laws which control land use and, thus, activities on the land.

Summary

The current development of laws and regulations controlling feedlot pollution is in a constant state of change. The result is an unstable situation within which feedlot operators find it difficult to operate. This uncertainty stems from two basic sources: (1) changing requirements of the regulations, and (2) not receiving complete and accurate information. It is with this second point that the Extension Service could render a vital role.

The technology transfer of feedlot pollution control techniques has occurred at meetings between EPA and large feedlot operators, but there has been little of this filtering down to the grass roots lands of the countryside. Here only rumors prevail. Also there is a need to provide "insight" into the technology so the feedlot operators know what they need and how it should be managed. Thus it appears that much more than simply a "technology transfer" conveyor is needed. This need is discussed in detail in Volume 2 of the report.

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CONCLUSIONS AND RECOMMENDATIONS

SUMMARY OF MANAGERIAL PRACTICES AND RESEARCH NEEDS

There are many possibilities for improved management and reclamation of animal wastes. Treatment and handling methods must be developed to conform with the avrious water-and-air-quality standards developed by the States and by the Federal Government.

Spreading manure on the land to reclaim nutrients is not now economically competitive with the application of mineral fertilizers. Three control approaches can be taken to minimize pollution from animal feeding operations--

(1) Increasing utilization and application of existing technology
(2) Enforcing regulations where improvement is technically feasible
(3) Developing more effective, complete, and economically feasible waste-management systems

The Department of Agriculture has developed information on specific animal-waste handling processes. Mich of this information has been applied on a limited basis and is potentially adaptable to wider use. The Department of Health, Education, and Welfare and the Department of the Interior also are studying animal-waste management. For example, the Department of the Interior is demonstrating the application of existing treatment and management techniques in both farm and concentrated feeding operations.

Industry also has developed information on specific waste handling techniques that are adaptable to animal-waste management. In addition, modified techniques from associated programs in municipal and industrial waste treatment should be adaptable to the liquid wastes from concentrated animal-feeding operations, for example, the activated sludge processes, chemical treatment for phosphate removal, and denitrification. Also, the numerous methods for handling and transporting domestic sludge and low water content sewage can be modified.

Under the Federal Water Pollution Control Act amendments of 1972, each State is obligated to develop standards for the quality of receiving waters. All the States have developed these water-quality standards and the Environmental Protection Agency has accepted almost all of them. Under both Federal and State standards, enforcement of effluent and receiving-water quality is handled primarily by the States with the Environmental Protection Agency providing additional resources when required

Efforts must be intensified to insure compliance with existing zoning regulations and to introduce more stringent zoning requirements to provide buffer zones around urban areas. These actions must be designed to protect both the public and the animal industry.

Animal waste managements must be integrated and coordinated with the total national pollution abatement plan (National Pollutant Discharge Elimination System). The importance of pollution control in the total management concept of the animal feeding industry must be recognized now and integrated into planning and operations. Long-range control demands more effective, complete, and economic waste management to meet pollution problems of the future. Intensified research and development is needed in all phases of animal-waste management, including characteristics of manures, removal from animal quarters, runoff, storage, transport, treatment, ultimate disposal, and economic evaluation to insure improvement of invironmental quality with minimum disruption of current production-efficienty levels.

The following areas are indicative of needed research and action programs for controlling animal wastes.

1. Minimizing pollution by improved use of existing technology as well as by developing new and improved animal-management methods and facility design.

The Department of Agriculture is performing research to identify the characteristics of animal wastes and the nature of pollution arising from livestock operations. Research has been initiated, with emphasis on cattle and poultry operations, to develop improved techniques and facility designs to handle and dispose of wastes in a manner that will reduce air and water pollution.

USDA action programs are directed toward (1) educational programs that recommend designs and management techniques that will alleviate pollution through use of current knowledge; (2) technical assistance within soil conservation districts and through extension specialists; and (3) loans to individuals and associations or groups of farmers who need to improve their facilities--improving animal-waste handling facilities would qualify. USDA envisages expansion in all types of activities and considers incentive payments particularly necessary in this area.

The Department of Health, Education, and Welfare is currently collaborating in a study being carried on by the State of New Jersey which includes consideration of the enforcement of criteria directed toward the better application of known technology. It is anticipated that the criteria and standards developed by the study will form the basis for enforceable regulations on a statewide basis.

The primary function of DHEW in this area will be to develop manuals, guides, and criteria for use and application by solid-waste program administrators in dealing with the off-farm problems of animal solid wastes, particularly in those situations where interfaces exist between large feedlots and urban environments. Technical assistance supported by organized training programs will be provided to interested control and health agencies.

The Department of the Interior has research and demonstration programs to develope improved techniques and facility designs to handle animal wastes in a manner that permits discharges that meet existing water-quality standards. In addition, it has a large program of research development and demonstration in the broad area of industrial pollution control and abatement. Under these programs, the Department is investigating various means for modifying the source, quantity, and quality characteristics and to develop means for prevention, control, and treatment of the animal wastes. USDI feels that existing legislation is adequate but that increased funds are necessary to implement the program.

2. Minimizing pollution by improved use of existing technology as well as by developing new and improved waste treatment and disposal methods

The Department of Agriculture's research program is directed toward methods of treating and disposing of animal wastes through a variety of techniques such as lagoons, oxidation ditches, and application to cropland. Additional research will be performed, including the investigation of other methods of disposal and of the capacity of cropland to accept animal wastes without damage to crops and land.

USDA action programs are generally in the form of educational and technical assistance provided directly to individual or groups of livestock producers in rural communities. Loan assistance for treatment and disposal systems is currently available for groups of farmers or associations. Cooperative and watershed organizations are expected to be utilized in the development of loan, grant, and research participation reimbursement programs for use in developing needed treatment and disposal systems.

The Environmental Protection Agency is supporting research on new methods of disposal of animal wastes on land, such as injection, composting studies to produce a product that can be disposed of more readily, lagooning, and incineration. While it is not anticipated that economically profitable methods will evolve in the near future, a substantive saving in costs of disposal may be possible.

The results of these and other research and studies will permit DHEW to establish standards of disposal and to set up a technical assistance program to State and local authorities to accelerate application of the standards. It is anticipated that demonstration grants (under the Solid Waste Act) and loan of personnel will be made in support of this program. The Department proposes keying this program to the need of large-scale producers such as feedlot operators and poultry producers.

The primary thrust of the program in the Department of the Interior is to utilize existing technology and develop new or improved treatment and disposal methods. The Department supplies direct technical aid to help resolve the water-pollution problems from feedlot operations and has a program of intramural and extramural research, development and demonstration of numerous unit processes and systems to minimize pollution from animal-feedlot operations. Section 6 (b) of the Water Quality Restoration Act of 1966 provides for grant support up to 70 percent of total project costs to institutions, industries, and individuals with a maximum support level of \$1,000,000. The existing extramural program involves the development and demonstration of improved techniques for controlling and treating liquid wastes from concentrated animal feeding operations. Included in this effort are lagoons, oxidation ditches, chemical treatment, activated sludge, biological dentrification, ultra filtration, and other concepts from the Advanced Waste Treatment program being adapted for application to animal-waste treatment.

3. <u>Minimizing pollution by improved use of existing technology as well as by developing new and improved methods for converting wastes to useful products</u>

The Department of Agriculture has conducted research on techniques and uses of animal wastes for profit or at least on offsetting disposal costs for several years. The conversion of poultry feathers into a protein feed is a classic example. Research for both on-farm and off-farm uses and processes is expected to continue. Action programs in this area of emphasis are primarily in the form of technical assistance in the construction of processing plants. As new developments arise, educational and technical assistance programs will probably be handled with work in other areas of emphasis.

Research in the development of useful products is being supported by the Department of Health, Education, and Welfare. Examples of research includ conversion of animal wastes to animal feed, soil conditioners, or fertilizer carriers, and extraction of protein for use as food supplement. The potential for reuse or recycling of these wastes is also studied. As indicated previously, the objective at this point is a profit. Demonstration grants will constitute the basic support mechanism of DHEW in the translation of the laboratory and pilot plant findings into full-scale operations. A technical assistance program to State and local agencies and private entrepreneurs will be established.

The Department of the Interior, in its efforts to dispose of treatment plant sludges, has as part of some of its projects the conversion of waste material into useful products or energy sources.

4. Minimizing pollution through (a) assisting in the establishment and enforcement of standards, and (b) providing criteria for land use planning

The Department of Agriculture research in this area is currently addressed toward land use planning, as a basis for developing criteria that are realistic in terms of the capability of the producer to meet them and in proper balance with other forms of pollution control. Research is needed to develop sound plans and implementation techniques for accomplishing protective zoning for agricultural production.

USDA action programs are currently very limited; they consist primarily of educational programs to help rural communities and rural areas develop plans and legislation for rural development and planning in which pollution control is one of the considerations. Expansion of this activity as well as a grant program for planning and implementation of standards and rural zoning is considered necessary. USDA has no authority for establishing or enforcing standards in this area.

The Environmental Protection Agency program is predicated on the fact that the basic responsibility for enforcement actions must reside with the State and, particularly, the local authorities. Support could probably be best developed through the mechanism of program support grants, but such grants are not authorized in the present Solid Waste Act. Eventually, the regulation and enforcement must be assumed by the local authorities as a part of their regularly constituted activities. Efforts in this direction are incorporated as a regular element in the EPA program in dealing with State and local authorities. Manpower needs would require an expanded cadre of trained personnel. Current training activities of the Solid Waste Program will help to meet this need. Pollution Control Programs must be based on reasonable and adequate criteria and standards which will evolve over the coming years.

The problems of land use planning have been given little consideration as they relate to installations producing animal wastes. Land use planners must be supplied with criteria which, if met, will permit the location of agricultural production centers in the vicinity of urban areas and the labor aupply. The development and use of the appropriate criteria as planned by EPA would provide the tool for progress and enlist the support and cooperation of the planners.

Water-quality standards adopted by all 50 States and approved by the U.S. Environmental Protection Agency include plans fos implementation for inter-state streams, lakes, and coastal waters. With few exceptions these standards deal effectively with municipal and industrial wastes and their effect on water quality. However, with regard to agricultural waste in general, many difficulties have been encountered in developing appropriate and workable standards. Additional technical information is needed on the characteristics of runoff and on the effectiveness of the numerous treatment concepts being considered to implement the existing standard requirements.

Educational Needs

Educational and technology transfer needs in relation to control of animal wastes are many and varied. Colorado State University and other land grant universities throughout Region VIII have, for many years, been engaged in animal wastes control research and related informational dissemination programs. However, due to the nature and extent of these problems and the hundreds of thousands of individual livestock producers involved, control technology dissemination in this field must remain vigorous and, ideally, should be intensified.

In view of the recently adopted National Pollution Discharge Elimination System (NPDES), these many thousands of individual operators who fall within the range of NPDES regulatory standards will require a great deal of new, and additional information concerning the ways and means for compliance. Much of this information should concern itself with the economics of compliance and, in many instances, the beneficial outcomes that can result.

An intra-state, and inter-state, informational and technology transfer delivery system such as that proposed by the Colorado Cooperative Extension Service in Part II of this report could help fulfill such a need.

PESTICIDES

Introduction

In 1828, Friedrich Wohler achieved the first synthesis of an organic compound; that is, he produced urea from ammonium cyanate. Hundreds of thousands of organic chemicals have since been synthesized: many with powerful physiological action.

The organic chemicals under discussion are insecticides, herbicides, fungicides, nematocides, rodenticides, growth regulators, defoliants, and miscellaneous industrial by-products that may impair quality of air, water, and soils. Proper use of many of these chemicals has made tremendous contributions to human convenience (controlling insects), human health (controlling disease-carrying pests), and human welfare (greatly augmenting needed food production).

Just as ordinary aspirin may be misused and cause human deaths each year, the kinds of chemicals aforementioned may be misused. Agricultural endeavor may suffer from unwise, inadvertent, or careless use of these organic chemicals.

Effects of Pesticide Utilization

Each year for nearly 20 years, thousands of pounds of persistent organochlorine pesticides have been applied to outdoor areas in many countries. These compounds may last for a very long time in the environment, and be carried by wind, water, and animals to places far distant from where they are used. As a result, most living organisms now contain organochlorine residues.

Any segment of the ecosystem - marshland, pond, forest, or field, often receives various amounts and kinds of pesticides at irregular intervals. The different animals absorb, detoxify, store, and excrete pesticides at different rates. Different degrees of magnification of pesticide residues by living organisms in an environment are the practical result of many interactions that are far more complex than just the magnification of chemical residues up the food chain. These magnifications may be millions of times from water to mud or only a few times from food to first consumer.

Direct mortality of wild animals as an aftermath of recommended pesticide treatments has been recorded in the literature of numerous countires. However, accidents and carelessness also accompany pesticide use on a percentage basis and are a part of the problem. More subtle effects on the size and species composition of populations are more difficult to perceive in time to effect remedies. The possibility of ecological effects being mediated through changes in physiology and behavior has received attention and has resulted in some disquieting findings. These include discovery of the role of organochlorines in stimulating the breakdown of hormones or in acting directly as estrogens, their involvement in embryonic and early post-embryonic toxicity, interferences with antibody formation, effects on behavior, and interactions with stress such as nutritional deficiencies or food deprivation. Delayed mortality long after dosage ceased has shown the serious effects of storage of organochlorines in wild fowl. DDT has been suggested as the indirect cause of failing reproduction and population decline of certain predatory birds due to a reduction of egg-shell thickness.

The impact of these new components of the environment has appeared in the form of death, reproductive impairment, disruption of species balance, and behavioral alteration, but the overall effects on the environment have not been determined.

Insecticides

Along with their many benefits to agriculture, insecticides can adversely affect agriculture in many ways. "Wastes in Relation to Agriculture" reports: The application of insecticides to protect cotton led to drift that destroyed the beneficial insect complex in citrus groves, necessitating the use of insecticides to control certain pests of citrus that were ordinarily controlled by beneficial insects.

-The use of malathion to control and eradicate a cereal, forage or forest insect pest has destroyed honey bees and other insects necessary for crop pollination.

-The application of persistent insecticides to potato lands has led to residues in sugarbeets grown in the same soil the following year, for which there are no tolerances.

-Residues may occur on agricultural commodities as a result of accidental contamination, inadvertent use, or even recommended use of pesticides. Losses from condemnation may be serious. Congress authorized an appropriation of $10 million to reimburse cranberry growers following confiscation of certain lots of cranberries found to contain illegal residues of a herbicide. This herbicide had been applied by some growers at the wrong time of the growing season in spite of warnings from recognized authorities. Dairymen whose milk was confiscated because of pesticide residues were compensated in the amount of $350,000.

-Fish in farm ponds have been killed because of the drainage of insecticide wastes from nearby lands into these ponds following heavy rains.

-Pesticides such as heptachlor and aldrin formerly were applied on rangelands to control grasshoppers, but their use was discontinued. Residues of these pesticides in meat of beef animals are not permitted. Such uses are no longer registered.

-The use of heptachlor in the past for the control of alfalfa weevil has led to soil contamination, and through translocation or external contamination of the hay during harvest has caused nonpermitted residues in milk of dairy cows consuming such hay. This use is no longer registered or recommended.

-The application of persistent insecticides, such as dieldrin for the eradication of the Japanese beetle, led to low-level but significant residues in livestock grazing in the eradication area.

-The careless disposition of insecticide and insecticide containers has caused injury to livestock through contamination of drinking water and feed.

Improper use of insecticides and so-called empty containers have caused injuries, and in a few cases even death, to farmers and farm labor applying the materials, and has created hazards to workers in the treated fields.

Herbicides

Use of selective herbicides has made a tremendous contribution to agricultural and forestry production. But these chemicals can be misused or used without proper precautions. The adverse effects arising from the use of these chemicals fall predominantly on agriculture and forestry.

Spray drift and vapors from aerial and ground applications of herbicides for the control of weeds and brush on non-agricultural lands, such as utility rights-of-way, roadsides, railroads, ditchbanks, and industrial and aquatic sites, often cause damage to nontarget crops--flowers, ornamentals, and trees. The volatile ester formulations of the phenoxy herbicides cause the greatest number of damage claims, but other herbicides also may cause damage.

Drift from aerial application of a herbicide on a crop such as rice may seriously damage a sensitive crop such as cotton, even miles away. In years past, there were serious incidents of this sort, but adherence to careful field application procedures has largely eliminated this source of damage. In addition, many States now control the application of herbicides by aircraft.

A herbicide may be carefully tested under certain environmental conditions for a specific crop and deemed to be completely safe; but under a changed environment, identical use on the same crop may cause serious damage. For example, prometryne was found to be completely safe for use as a selective herbicide on potato fields at many locations in the Northern States. However, in the San Joaquin Valley of California, residual effects caused serious damage to potatoes in the spring of 1966.

Herbicide wastes from sprayer-loading areas and storage areas, improper disposal of empty containers, and excess herbicides may damage nearby crops. Herbicide wastes may enter drainage and irrigation ditches and cause damage far removed from the source of contamination.

Fungicides, Rodenticides, Industrial Chemicals.

Occasional incidents occur wherein careless handling or misuse of these substances cause damage to agriculture or forestry, but adverse effects from these entities are much less than those experienced from insecticides and herbicides.

Seriousness of the Problem

The presence of residues in agricultural commodities, resulting from accidental contamination or inadvertent use of pesticides could constitute significant economic as well as health problems. Small quantities of potatoes, sugarbeet pulp, and soybean oil have been seized because of pesticide residues. Such events can adversely affect consumer acceptance and consumption of agricultural products once these incidents are brought to public attention.

The economic impact from the loss of honey bees and other beneficial insects, due to pesticides, has not been determined. In areas highly dependent on pollinating insects the losses could be substantial.

The economic losses incurred by damages from herbicide vapors and spray drift are unknown. However, the litigation and damage claims were sufficiently serious during the past 20 years to cause passage of laws and establishment of regulations in 45 states which authorize certain restrictions on the use of herbicides.

Damages to agriculture have occurred from use of pesticides. Whitten (1966) has provided a penetrating review of the evidence concerning adverse effects from using pesticides. Mistakes have been made. Decisions and recommendations have in the past proceeded from inadequate information. We must exercise every caution.

One must consider all the evidence relating to the use of these chemicals. Their assistance in man's eternal fight against insects, diseases, and weeds contributes immeasurably to the welfare of man. However, where misuse of agricultural chemicals occur, harmful effects upon fish, wildlife, and human beings result. As this chapter has indicated, there are numerous documented incidents where damages have occured. More recently, through enlightened management practices, damage to the environment is being lessened. This is to be commended and encouraged.

Pesticide Utilization in Region VIII

Within the Region VIII states, Colorado shows a marked increase in acreages treated with agricultural chemicals especially on weeds and grass in crops. In this catagory Colorado treated 593,279 acres in 1964 and in 1969 almost doubled the treated acreage to 973,747. Likewise in treatment of insects and disease in crops Colorado jumped from 363,074 acres in 1964 to 832,920 acres in 1969. By contrast North Dakota, South Dakota, Montana and Wyoming cut their treated acreage for insects and disease to about one-half during the same time period. However, these same states along with Utah increased treatment of acreage in weeds and brush for pasture by about 50% while Colorado shows a decline in this category of about 20%. (Table 90)

Nationally, North Dakota was the only Region VIII state that ranked among leaders in any specific category. This was in acreage treated for weed control in crops other than hay as reported by The Pesticide Review 1972.

Use of chlorinated hydrocarbons has declined in recent years in the Region VIII states. Other short term toxins are used or permitted for use by several agencies to control plant and insect pests.

Weed control personnel use 2-4-D (2-4-Dichlorophenoxyacetate acid) primarily to control weed growth on over 21 million acres within the Region.

Mosquito control districts use organic phosphates and pyrethrins to control insect larvae. Baytex, lethane, malathion, and pyrethrins are also utilized to control larvae and adult mosquitoes.

The U.S. Forest Service has ceased to spray the forests to control insect infestations, however, the Forest Service can, and does, spray for insect control under certain conditions. In Colorado, spraying is done on a localized basis and generally in cooperation with the State.

Data showing the quantities of pesticides utilized by all consumers within Region VIII, including private, industrial, and home consumption is difficult to come by.

Pesticides Statistics Region VIII - Fiscal Year 1972

Pesticides Consumed

Acreages treated with insecticides, herbicides, fungicides and other chemicals

Table 90

State	North Dakota	South Dakota	Utah	Montana	Wyoming	Colorado
Weeds and Grass in Crops-1969	6,817,702	3,129,915	109,007	2,903,493	183,418	973,747
-1964	6,814,780	3,325,021	110,367	3,898,445	112,502	593,279
Weeds and Brush in Pasture-1969	62,978	119,298	11,353	86,872	79,178	47,672
-1964	14,091	48,284	10,252	66,636	48,571	56,645
Insects and Disease in Crops-1969	587,486	527,336	129,532	322,754	59,268	832,920
-1964	950,673	861,564	125,288	927,174	135,244	363,074

Source: U.S. Agricultural Census, 1969.

DDT residues continued their general decline in Region VIII following the national trend. They were down more than 28% from 1970 to 1971 and amounted to less than one-fourth the disappearance during the peak of 1959.

Pesticides in Water - Region VIII

In June 1968, the Federal Water Quality Administration conducted the first spring survey of chlorinated hydrocarbon residues in surface waters of the conterminous United States. Dieldrin and DDT (and its congeners) were the residues most frequently detected. The maximum concentrations found never exceeded permissible FWQA limits in relation to human intake directly from a domestic water supply. However, they have often exceeded the environmental limit of o.050 ug/liter recommended by the Federal Committee on Water Criteria (Pesticide Monitoring Journal Vol. 4 No. 2, September 1970).

Region VIII States

Table 91 . Results of synoptic survey for pesticides in surface waters, June 1968.

Location	Concentration in µg/liter [1]						
	Dieldrin	Endrin	DDT	DDE	DDD	Lindane	BHC
MISSOURI BASIN REGION							
Missouri River							
St. Louis, Mo.	.010	—	—	—	—	—	-
Kansas City, Kans.	.009	—	—	—	—	—	—
Omaha, Nebr.	—	—	—	—	—	—	—
Yankton, S. Dak.	—	—	.053	—	—	—	—
Bismarck, N. Dak.	—	—	—	—	—	—	—
St. Joseph, Mo.	—	—	—	—	—	—	—
North Platte River							
Henry, Nebr.	—	—	—	—	—	—	—
Platte River							
Plattsmouth, Nebr.	.005	—	—	—	—	—	—
South Platte River							
Julesburg, Colo.	—	—	—	—	—	—	—
Yellowstone River							
Sidney, Mont.	—	—	—	—	—	—	—
Rainy River							
Baudette, Minn.	—	—	.037	—	—	—	—
Red River (North)							
Grand Forks, N.Dak.	—	—	—	—	—	—	.027
Emerson, Manitoba	—	—	—	—	—	—	—
Kansas River							
Lawrence, Kans.	—	—	.008	—	—	.003	—
Big Horn River							
Hardin, Mont.	—	—	—	—	—	—	—
South Central Region							
Rio Grande River							
Alamosa, Colo.	--	--	.029	--	--	--	--
Southwest Region							
Colorado River							
Loma, Colo.	--	--	--	--	--	--	--
Green River							
Dutch John, Utah	--	--	--	--	--	--	--

Table 92 . Pesticide occurrences by FWQA Region, 1964-68.

Pesticide	Missouri Basin*	Southwest **
Dieldrin	25	13
Endrin	13	5
DDT	18	10
DDE	6	5
DDD	10	4
Aldrin	0	1
Heptachlor	4	2
Heptachlor epoxide	6	2
Lindane	2	0
BHC	3	2
Chlordane	0	1
Total	87	45
No. of Samples	70	65

* Includes Colorado, Montana, North Dakota, and South Dakota

** Includes Colorado and Utah

Table 93 Top 10 Locations at which highest levels were observed each year 1964-1968. (Region VIII only).

Location	uG/1.	Location	uG/1.	Location	uG/1.	Location	uG/1.	Location	uG/1.
1964		1965		1966		1967		1968	
ENDRIN									
Big Horn Riv. Hardin, MT	0.026	Rio Grande R. Alamosa, CO	0.014	S. Platte R. Julesburg, CO	0.063				
Red Riv., No. Grand Forks, ND	0.023								
Yellowstone R. Sidney, MT	0.021								
DDT									
Red River Grand Forks ND	0.072	Rio Grande R. Alamosa, CO	0.149			Red River Grand Forks ND	0.054	Missouri R. Yankton, SD	0.053
		Red River Grand Forks ND	0.034					Rio Grande R. Alamosa, CO	0.029
		S. Platte R. Julesburg, CO	0.023						
DDE									
S. Platte R. Julesburg, CO	0.009	Yellowstone R. Sidney, MT	0.002						
BHC									
				S. Platte R. Julesburg, CO	0.022				

Organochlorine Insecticide Residues in Agricultural Soils of Colorado

An exploratory study of organochlorine chlorine's presence and persistance in soils of Colorado conducted by the Agricultural Experiment Station of Colorado State University in the summer of 1967 and analyzed in 1968. (Reported in EPA's Pesticides Monitoring Journal, Vol. 5, No. 3, December 1971.) DDT was detected in 27 of the 50 soils sampled and ranged in concentrations from 0.06 to 41.10 ppm. Aldrin and/or dieldrin residues were detected in 14 of 50 samples, ranging from less than 0.02 to 0.91 ppm. Heptachlor and/or its epoxide were found in 11 of the soils sampled at concentrations of less than 0.02 to 0.07 ppm. Gamma-chlordane was found in 8 of these 50 samples at concentrations of less than 0.02 to 0.05 ppm. Other materials detected in the 50 soil samples analyzed were: lindane, in 8 samples, dicofol in 7, endrin in 2, endosulfan in 1, tetradifon in 1, and toxaphene in 1. Residues of organochlorine insecticides were not detected in nine of the samples analyzed.

Although the study was somewhat exploratory in nature, the results may serve as an indication of the general occurance and persistance of organochlorine insecticides in agricultural soils of Colorado.

Residues of DDT were detected in all of the major agricultural areas of Colorado (54% of the soils sampled). Low levels of aldrin and/or dieldrin were detected in 28% of the samples studied. Heptachlor and its epoxide were found in 22% of the samples. The other insecticides all were found at lower frequencies.

These results indicate that significant amounts of DDT residues persist in the soils where they have been applied frequently. Overall, the residue levels of the organochlorine insecticides in the Colorado agricultural soils sampled generally were lower than those reported in other parts of the United States and Canada, the study reported.

Other Findings Relative to Region VIII

Tourangear (1969) reported eggs of ospreys on Flathead Lake, Montana contained up to 135 ppm of DDT.

Mussehl and Finley (1967) reported up to 280 ppm of DDT contained in fat tissue of blue grouse samples from Montana.

Pillmore and Finely (1963) citeup to 43 ppm of DDT in Montana and Colorado mule deer samples studied.

Jewell (1967) also reported DDT, Dieldrin and Endrin residues in fat tissues of Colorado deer samples studied in 1966.

Greenwood, et.al. (1967) studied samples of mule deer, white-tail deer, pronghorns, and elk in South Dakota and found 0.2 average DDT residue and traces of Dieldrin residues.

Pesticide and Herbicide Usage in Region VIII

Use of chlorinated hydrocarbons has declined in recent years in the Region VIII states. Other short-term toxins are used or permitted for use by several agencies to control plant and insect pests.

Weed control personnel use 2-4-D (2-4-Dichlorophenoxyacetic acid) predominantly to control weed growth on over 21 million acres in Region VIII.

Region VIII mosquito control districts have used organic phosphates and pyrethins to control insect larvae during 1972-73. Baytex (0,0-Dimethyl 0-(4-Methyl + h10)-m-folyl) phosphorothioate), Lethane - 384 (B-Butoxy-B^1-thiocyano diethyl ether), Malathion (0,0-Dimethyl phosphoro dithioate of diethylmercapto-succinate) and Pyrethrins were utilized to control mosquito larvae and adult mosquitoes.

The U.S. Forest Service has ceased to spray the forests to control insect infestations, however, the Forest Service can, under certain conditions, spray for insect control.

Individual use of herbicides and insecticides has not been assessed but is believed limited to organic phosphates and 2-4-D.

The U.S. Geological Survey (1970) reported no measured chlorinated hydrocarbons (.00 micrograms per liter) for the three forks of the Flathead River.

Gaufin (1972) believes that if chlorinated hydrocarbons are to be found within the aquatic ecosystem, the area of concentration and accumulation would be in bottom sediments and not in the water itself. According to Sonstellie (1972) certain drainages that were sprayed long ago have not shown complete recovery as evidenced by the present lack of certain Plecoptera (stone flies) which were previously to be found in the streams.

There is ample opinion that the use of chlorinated hydrocarbons should be totally banned from use. Organic phosphates used by mosquito control personnel and crop growers, in general, are reported to have only short-term toxic effects. Baytex is reported to hydrolize in a few weeks (Chemgro Corp. 1967). However, this pesticide is reported toxic to certain aquatic organisms of contrations of 5 ppm or less (Kemp, Abrams and Overbeck, 1971). Malathion has reported half life on the soil of 4 days (American Cyanamid Co., 1971). This pesticide has been reported toxic to Rainbow trout fry at concentrations of 1.0 ppm (Kemp, Abrams, and Overbeck, 1971). Diazinon (o,o-diethyl O-(2 isopropyl-4 methyl-6 pyrimdinyl) phosphorothioate), the pesticide most commonly used in orchards, is reported to have no residual effects (Giegy Chem. Corp., 1967). This chemical is reported toxic to Rainbow trout at concentrations of less than 0.2 ppm and toxic to certain zooplankton at concentrations of less than 1 ppb (Kemp, Abrams and Overbeck, 1971). While long term effects of these chemicals are not known, it is quite apparent that these chemicals must be applied properly and carefully to prevent contamination of water supplies. Aerial spraying, then, could contribute to pesticide residue occurances in certain drainage areas of Region VIII.

Residues in Fish in Region VIII

Pesticide data related to Region VIII states in terms of fish, wildlife, and estuaries were reported in the June 1971 Pesticides Monitoring Journal (EPA June 1971 Vol.5 No.1).

The fish monitoring program was conducted by the Bureau of Fish and Wildlife in 1967 and 1969. Included among the 50 nationwide monitoring stations were the states of Colorado, Montana, Utah, Wyoming, and North Dakota.

A total of 147 composite fish samples were drawn from the 50 stations in the fall of 1969. Most of the composites consisted of five fish. Results of the residue analysis are shown in Table 94 for those samples collected within the Region VIII states.

Table 94. Organochlorine insecticide residues in fish, fall 1969. Pesticide Monitoring Journal, 1971.

Station Number and Location	Collection Data: Species	No. of Fish	Average Length (Inches)	Average Wt. (Lb.)	Average Lipids (Percent)	Organochlorine Insecticides (PPM)[1]: DDE	TDE	DDT	DDT and Met.	Dieldrin	BHC*	Est. PCB's*
#32 Missouri River Garrison Dam, N. Dak.	Carp	2	15.2	1.6	7 05	.03	.02	.01	.06	.01	.01	<.10
	Goldeye	5	10 8	0.3	14.0	.03	.02	.02	.07	.01	.02	.18
	Walleye	4	17.6	1.4	5.03	.05	.03	.04	.12	.01	.01	.22
#33 Missouri River Great Falls, Mont.	Redhorse (sucker)	5	16.9	2.0	7.88	.03	.03	.02	.08	.01	.02	.25
	Goldeye	5	12.9	0.5	12.5	.29	.28	.34	.91	.02	.08	2.35
#35 Green River Vernal, Utah	Carp	5	11.0	0.9	2.50	.04	.08	.07	.19	.01	—	.83
	Flannelmouth sucker	3	19.2	2.6	8.97	.13	.28	.19	.60	.01	.02	2.14
	Black bullhead	3	5.4	0.2	1.51	.03	.02	.01	.06	.01	—	.15
#38 Utah Lake Provo, Utah	Carp	5	17.0	2.1	8.51	.10	.08	.04	.22	.02	.01	.29
	Black bullhead	5	9.8	0.5	6.15	.04	.05	.03	.12	.03	.01	.21
	White bass	5	10.2	0.5	2.87	.13	.09	.21	.43	.02	.01	1.04

The major conclusions drawn from this study are that DDT and dieldrin occurred in almost all fish samples examined. Residue levels of these insecticides remained high at some stations in 1969. Organochlorine insecticides were present in few samples and at generally lower levels than in previous years, according to the report.

<u>Residues in Wildlife</u>

Organochlorine residues occur in almost all birds analyzed in studies that have included samples from Region VIII states. Residues in western birds and fish have been studied extensively (Hunt, 1964; Keith and Hunt, 1966). Samples studied generally contained DDT, DDD, DDE, dieldrin, endrin, heptachlor, toxaphene, benzene hexachloride, and chlordane. Usually several kinds of pesticides are found in a single sample.

Eggs of cormorants nesting on interior lakes of North Dakota contained 11 ppm of organochlorine residues, primarily DDT and its metabolites but in-

Table 95 . Organochlorine insecticide residues in fish--mean values 1968 and 1969 samples. Pesticide Monitoring Journal, 1971.

Station Number and Location		DDT and Metabolites (PPM)[1]			Dieldrin (PPM)[1]		
		Fall 1969	Fall 1968[a]	Spring 1968[a]	Fall 1969	Fall 1968[a]	Spring 1968[a]
	MISSISSIPPI RIVER SYSTEM						
#23	Kanawha River	.43	1.32	.27	.02	.03	.01
#24	Ohio River	2.25	1.87	1.17	.05	.03	.03
#25	Cumberland River	.93	1.23	.44	.02	.03	.09
#26	Illinois River	1.88	.83	.46	.39	.31	.18
#27	Mississippi River (Iowa)	.24	.72	.44	.01	.03	.01
#28	Arkansas River (Ark.)	1.85	5.86	1.99	.05	.03	.21
#29	Arkansas River (Okla.)	.28	.38	.17	.02	.01	.04
#30	White River	1.35	5.89	2.31	.04	.05	.17
#31	Missouri River (Nebr.)	.69	.62	.44	.04	.12	.15
#32	Missouri River (N. Dak.)	.08	.19	.31	.01	.03	.01
#33	Missouri River (Mont.)	.50	.26	.06	.01	.03	.02
	HUDSON BAY DRAINAGE						
#34	Red River (North)	.44	1.35	.53	.01	.04	.20
	COLORADO RIVER SYSTEM						
#35	Green River	.28	.08	.27	.01	.00	.02
#36	Colorado River	.45	.11	.25	.01	.00	.02
	INTERIOR BASINS						
#37	Truckee River	.31	.60	.71	.01	.03	.02
#38	Utah Lake	.26	.14	.23	.02	.01	.03

cluding also about 0.2 ppm of dieldrin; some also contained traces of heptachlor epoxide (U.S. Bureau of Sport Fisheries and Wildlife).

Pheasants and sharp-tailed grouse of South Dakota have been analyzed for the presence of nine chlorinated hydrocarbon insecticides residues, DDT, DDD, DDE, endrin, lindane, heptachlor, heptachlor epoxide, aldrin, dieldrin. Eight of these residues were detected in the samples. Endrin was not found at levels above 0.05 ppm. Heptachlor and aldrin were found at low levels in a few of the birds. The combined levels of DDT, DDD, and DDE averaged 0.27 ppm in grouse and 0.37 ppm in pheasants. Lindane was not detected above 0.01 ppm in approximately 75% of the grouse and pheasants, and the remainder of the birds had residues below 0.2 ppm. Dieldrin was found in greater concentration in grouse (0.17 ppm versus 0.08 ppm), and heptachlor epoxide levels were higher in the pheasants (0.06 ppm versus 0.02 ppm).

The average amount of all chlorinated hydrocarbon insecticides found in the fat of grouse and pheasants in this study was 0.05 ppm.

Many surveys of insecticide residues in birds have been done in areas associated with either recent or heavy application of insecticides or in areas where it was suspected that the insecticides were damaging to the birds. The results of these studies would indicate higher levels than if the birds were randomly sampled from a large area. Mussehl and Finley (1967) analyzed the fat of 26 blue grouse (Dendragapus obscurua) collected from an area in western Montana which had been sprayed with 0.5 lb of DDT per acre. Levels of DDT and its metabolites in these birds ranged from 1.5 to 280 ppm. Grouse survival and productivity were not shown to be significantly affected by these residue levels.

Pesticides - Low Priority Problem

All indications currently are that pesticides contribute relatively little to non-point source pollution problems within the EPA Region VIII states compared with other sources. None of the states report any serious residue levels detectable in water sampling during the past two to three years.

Water quality monitoring data supplied by the U.S. Geological Survey also corroborates these conclusions.

One factor in the relatively low levels of pesticide residues in ground and surface waters has been the rather swift dissappearance of long-term, highly toxic DDT and DDT-related products. With the switch-over to less harmful, short-term organochlorine pesticides detectable residues have been decreasing accordingly.

Another contributing factor is that Region VIII states are relatively low consumers of pesticides generally. Total treated croplands rank low in comparison with such states as Texas, Illinois, Iowa, and Minnesota. Only North Dakota shows high acreage treatment for weed control in pastures at 6,817,000 acres for 1969 (Table 96)

A check of the Food and Drug Administration's Market Basket Sampling data also reveals very low, in fact almost non-existent, levels of pesticide residues in consumer food products tested in recent months within the six Region VIII states according to reports from the various State Departments of Health.

The general conclusions that might be drawn from the data examined relative to pesticide usage within Region VIII are that (a) Region VIII is a low-use region, (b) evidences of high pesticide residue levels are quire rare, most instances going back in years to the period prior to the banning of long-term, persistant chemicals, and (c) pesticides today rank relatively low as a contributor to non-point source pollution in the Rocky Mountain-Prairie States Region.

Table 96. --Pesticides used in crops and on livestock and poultry: Acreages treated and cost of treatment by States, United States, 1969 1/

State	Insect control					Nematode control		Fungus control		Weed control				Plant defoliation or regulation	
	Hay		Other crops		Livestock and poultry					Pasture		Other crops			
	Acres	Dollars	Acres	Dollars	Dollars	Acres	Dollars	Acres	Dollars	Acres	Dollars	Acres	Dollars	Acres	Dollars
Alabama	17,099	80,527	629,131	5,870,230	421,308	26,781	235,363	47,677	421,150	44,234	90,420	709,179	4,432,249	164,411	565,763
Alaska			342	4,264	1,372			1	100			1,970	8,454		
Arizona	42,160	363,911	510,149	11,624,808	167,210	21,571	295,836	35,934	247,580	12,613	66,991	324,637	2,598,941	202,612	1,088,895
Arkansas	18,671	51,746	1,588,954	8,570,162	435,231	27,987	185,890	41,949	305,528	84,379	157,851	2,675,415	16,502,920	601,089	1,822,732
California	379,961	2,497,600	3,082,420	63,116,309	1,235,875	245,604	4,737,385	577,025	11,797,236	56,841	153,189	2,241,846	18,530,175	630,463	3,661,758
Colorado	85,553	240,780	710,656	2,444,718	609,082	19,034	425,333	36,711	241,977	47,672	105,451	373,747	2,515,108	11,283	57,543
Connecticut	1,501	7,013	25,039	623,109	48,759	941	52,153	8,208	291,114	1,737	4,735	42,553	348,585	1,677	10,951
Delaware	653	3,601	49,387	440,899	25,437	1,013	17,083	7,578	82,465	360	1,408	187,795	721,762	3,345	10,097
Florida	11,742	40,459	1,257,452	23,476,181	680,637	51,488	1,213,890	819,445	13,679,300	68,166	188,650	476,006	4,080,045	19,746	183,505
Georgia	8,205	47,691	940,229	13,040,670	828,103	52,802	592,651	101,533	1,494,613	45,017	118,446	842,476	6,259,363	201,812	1,017,019
Hawaii	5	2,310	51,521	398,138	33,031	15,024	982,968	6,369	143,378	23,885	254,439	237,883	5,736,760	28,386	80,538
Idaho	52,180	187,080	381,281	2,930,122	359,152	9,442	159,063	74,252	496,693	55,209	147,698	937,727	3,475,413	56,732	223,543
Illinois	32,957	156,011	4,522,800	12,740,347	1,259,478	58,174	247,237	93,300	750,227	55,282	181,775	9,222,549	40,397,142	68,525	345,753
Indiana	52,717	201,308	1,290,044	3,904,045	670,055	18,878	149,383	59,257	670,728	33,431	116,921	4,330,896	18,388,110	31,755	180,113
Iowa	36,445	163,524	3,996,496	12,423,088	2,318,931	44,809	151,777	74,320	362,675	217,523	423,817	7,547,716	32,897,942	72,024	309,138
Kansas	34,702	113,034	1,417,715	3,833,706	1,162,565	12,789	55,739	49,979	254,920	454,472	746,660	2,524,429	8,622,263	31,104	95,328
Kentucky	44,226	187,864	230,399	2,032,918	673,891	4,815	38,762	9,366	115,842	36,690	93,846	589,217	2,772,047	28,975	429,159
Louisiana	22,403	78,730	1,059,424	8,148,346	399,161	16,041	160,027	33,418	212,642	117,424	204,338	1,543,539	10,204,037	204,634	715,708
Maine	990	4,314	157,185	1,335,760	77,667	901	6,616	74,933	801,129	840	4,631	124,408	501,187	65,047	304,907
Maryland	16,564	61,309	128,369	807,604	131,397	1,989	27,558	26,035	381,308	8,377	21,426	445,168	1,934,598	4,563	31,993
Massachusetts	1,171	5,751	34,575	888,698	52,852	953	51,199	12,400	295,552	736	2,087	35,252	436,207	3,287	35,325
Michigan	81,715	270,695	454,271	5,863,172	432,132	11,276	204,928	167,033	3,176,602	6,240	33,015	1,835,441	9,336,936	34,790	287,135
Minnesota	18,182	81,623	1,108,935	3,533,674	975,473	26,169	100,091	97,511	462,325	53,133	103,039	6,502,201	20,450,717	96,331	346,851
Mississippi	9,283	35,607	1,459,944	15,673,280	453,180	14,449	106,392	61,814	317,701	85,594	174,438	2,077,779	16,085,801	775,586	2,554,518
Missouri	39,094	138,323	1,199,368	4,070,535	1,135,728	17,930	95,911	42,760	445,067	125,829	377,013	3,241,383	15,852,375	113,832	443,802
Montana	56,000	114,667	98,517	175,776	394,150	1,379	19,242	168,237	197,488	86,872	175,534	2,303,493	2,719,735	18,571	40,561
Nebraska	35,852	124,294	2,363,660	6,483,571	1,388,491	48,614	293,145	50,751	163,683	387,004	673,122	3,512,414	10,443,489	34,190	87,745
Nevada	63,351	100,743	25,765	291,082	53,072	241	9,984	1,504	8,058	4,505	9,442	18,353	47,558	13,014	50,873
New Hampshire	554	1,381	7,272	168,962	22,040	14	494	4,340	140,110	271	717	12,094	77,570	1,249	13,359
New Jersey	4,937	19,932	120,773	2,510,461	86,433	3,889	155,154	50,015	1,056,548	587	3,072	159,007	1,055,216	5,000	61,755
New Mexico	31,534	130,050	215,956	1,411,480	187,846	9,825	89,335	11,401	74,737	56,510	92,543	205,556	728,869	8,596	34,427
New York	125,171	474,737	335,406	7,073,409	576,676	5,297	145,694	113,279	2,693,976	5,380	29,574	650,443	4,423,384	38,580	217,454
North Carolina	7,653	42,555	828,331	9,045,182	520,877	177,190	2,515,440	39,949	752,143	15,553	54,479	927,432	5,582,491	125,878	1,194,335
North Dakota	30,078	39,072	337,674	804,777	359,365	16,465	155,322	219,734	306,581	62,978	101,499	6,817,702	5,855,523	145,606	255,393
Ohio	140,586	492,340	854,556	3,437,622	544,019	15,391	113,879	79,734	1,093,549	19,812	75,103	2,716,659	10,356,605	22,270	140,629
Oklahoma	85,017	235,281	602,239	2,029,446	828,586	18,060	136,250	34,201	228,973	381,430	765,518	513,731	1,687,344	47,693	153,977
Oregon	36,358	137,427	223,197	3,734,313	230,030	17,853	509,889	111,523	1,458,299	116,729	187,668	1,099,834	4,263,988	31,911	200,290
Pennsylvania	145,490	486,033	217,126	3,050,381	558,245	4,311	74,832	70,901	1,563,474	10,132	31,567	723,545	3,290,747	24,730	195,493
Rhode Island	39	372	7,655	175,523	3,841	8	245	2,299	58,347	82	255	5,847	65,358	577	2,094
South Carolina	6,741	23,030	714,757	8,246,454	200,441	41,382	525,255	36,169	469,245	25,542	53,922	571,634	3,139,893	160,504	641,213
South Dakota	47,358	88,230	459,700	994,025	581,827	11,009	35,784	20,278	29,769	119,298	153,755	3,129,915	3,992,920	28,860	50,757
Tennessee	14,218	61,610	348,794	1,846,890	454,399	12,125	105,546	16,925	153,447	26,549	90,853	885,385	4,368,438	61,455	255,264
Texas	122,901	385,724	4,283,453	22,029,166	2,556,182	85,191	673,048	240,092	2,415,838	1,714,842	2,712,378	5,257,438	20,800,066	1,404,341	3,518,495
Utah	95,749	200,987	26,681	223,691	121,557	5,649	159,620	7,102	64,327	11,353	19,124	109,007	288,778	3,828	22,947
Vermont	7,480	26,589	11,099	153,418	81,311	389	2,797	3,750	117,465	722	4,052	39,441	234,550	2,120	14,084
Virginia	20,705	78,650	272,144	3,081,166	313,193	59,277	575,066	55,952	1,328,944	121,526	294,050	503,588	3,247,746	23,117	233,241
Washington	32,355	155,079	421,894	8,203,409	252,551	15,297	398,631	98,919	1,761,878	26,899	94,037	2,051,774	5,706,290	79,780	600,946
West Virginia	5,582	19,571	21,813	494,080	62,446	329	4,863	15,551	425,445	17,165	43,621	34,639	175,124	6,184	33,830
Wisconsin	18,564	81,805	769,906	3,438,076	1,032,047	12,945	57,773	69,928	772,067	40,696	87,968	1,955,864	9,258,390	38,143	155,599
Wyoming	35,760	85,736	16,112	63,874	212,726	4,103	132,076	6,396	20,732	79,178	148,508	183,418	654,530	2,764	8,339
Total	2,180,223	8,627,706	39,881,566	296,971,125	25,428,158	1,267,101	17,334,850	4,468,038	54,803,096	4,967,459	9,678,717	84,913,547	345,683,739	5,780,991	23,095,545

1/ The "1969 Census of Agriculture".

PESTICIDE CONTROL TECHNOLOGY

This chapter discusses methods that can be used to reduce the quantity of pesticides moving into the aquatic environment. There are several approaches: (1) reduce the movement of pesticides into water by controlling erosion and minimizing wind drift, (2) reduce the quantity of pesticides used by applying minimum amounts needed to control the pests or by substituting non-chemical methods of pest control, and (3) substitute biodegradable for persistent pesticides to the extent possible. A more detailed analysis of problems related to pesticides in the aquatic environment as well as a comprehensive review of control methods and alternatives may be found in the EPA Publication: Pesticides in the Aquatic Environment, April 1972.

Pathways and Control Methods

Agricultural pesticides enter the Region VIII's waterways by several means: (1) erosion, (2) runoff water, (3) escape of pesticides during application, (4) volatilization and redeposition of pesticides, and (5) accidents and incorrect container disposal. An obvious but fundamental means of reducing potential water pollution from pesticides is correct usage. It is essential that users follow recommended application techniques and not exceed prescribed dosages for specific pest problems. Methods of controlling pollution from various sources are discussed below.

Erosion

The major route of pesticides to the waterways is via erosion.

> Because of the tight binding characteristics of pesticide residues to soil particles, it is suggested that the general pollution of waters by pesticides occurs through the transport of soil particles to which the residues are attached.

Suspended plant particles or leachates from crop residue also carry pesticides to waterways. Since most pesticides adhere readily to soil, any cropping pattern or practice that is likely to cause erosion is also likely to foster entry of pesticide materials into lakes and streams. Limiting the use of pesticides on erosion-prone soil will reduce the pollution potential. Water and wind erosion control measures are also highly recommended.

Nonpersistent pesticides pose only short-term problems from erosion or runoff. Persistent pesticides are a more serious threat to waterways from water and wind erosion. However, the threat of polluting waterways is reduced by practices that minimize soil erosion.

Pesticide persistence depends primarily on the structure and properties of the compound, and to a lesser degree on location in or on the soil and soil particles. There is wide variation in persistence among different pesticides. For example, the highly toxic phosphate insecticides are relatively nonpersistent in soils. In contrast, some of the chlorinated hydrocarbon insecticides may persist 4 to 5 years under normal rates of application. The longer a pesticide reamins in the soil, the more likely it is to move from target sites to nontarget areas by water or wind erosion.

Runoff

Pesticides also enter waterways through surface runoff and groundwater supplies. As a group, pesticides have low solubility in water, but small amounts are transported in solution. Herbicides are generally more water soluble than insecticides, and a few are freely soluble. Frequently, a choice can be made between two chemicals of varying degrees of solubility. It is easier to prevent runoff of pesticides in arid regions, where crops are irrigated and application of water can be controlled.

Application Methods

The amount of pesticides entering lakes and streams is influenced by the method of application and the solubility and volatility of pesticides. Pesticides incorporated into the soil, rather than left on the surface of soil or plants, are less subject to movement by runoff waters and to evaporation.

Pesticides are applied in liquid form as a spray or in solid form as a dust or granule. Present methods of application are imperfect in that some of the pesticide reaches nontarget organisms. The major reasons are lateral displacement (i.e., wind drift) and volatilization of the water carrier and the pesticide. In each case, the pesticide material may enter open bodies of water directly, or after fallout and washout from nontarget areas.

Dusted and sprayed pesticides are subject to considerable drift. Drift is related to particle size, wind speed, climatological inversion, and height of pesticide emission. In certain circumstances, such as application on dense foliage, where the underside of the leaves must be treated, a certain amount of drift is needed to provide complete coverage. However, such drift may result in the movement of pesticides into neighboring fields and open bodies of water. Drifting can be reduced by spraying and dusting when wind and other weather conditions are suitable.

Research shows the potential of engineering techniques that will produce particles of more uniform sizes and thus reduce the number of small particles that are apt to drift. Various emulsifiers and oils can be added to the spray to increase droplet size and thereby reduce drift. The table on the following page shows the relationship between drift and particle size.

Of the various forms of pesticides used, granules drift the least. Their value in certain above-ground uses is limited, however, because they do not provide as complete physical coverage as a spray or dust.

Table 97. **Drift Pattern in Relation to Particle Size**

Particle Type	Drop Diameter	Drift[1/]	
	Microns	Meters	Feet
Aircraft spray:			
Coarse	400	2.6	8.5
Medium	150	6.7	22
Fine	100	15	48
Air carrier sprays	50	54	178
Fine sprays and dusts	20	338	1,109
Usual dusts and aerosols	10	1,352	4,436
Aerosols	2	33,795	110,880

1/ Distance a particle would be carried by a 4.8 km/h (3 mph) wind while falling 3 meters (10 feet).

Volatilization

For certain pesticides, volatilization can be a significant means of introducing pollutants into the environment. This applies to volatilization after application, as well as to evaporation between nozzle and ground during application. Small spray droplets result in high rates of evaporation of the water carrier. This leaves small particles of dry pesticides to drift into nontarget areas. Amine stearates and other additives can be used to decrease the evaporation and drift potential, thus reducing pollution from pesticides.

Container Disposal

Pesticides can enter the envrionment through careless or improper disposal of containers and unused materials. If these items are deposited or buried near waterways, the groundwater may become polluted. If they are burned, pollution may result through washout or fallout. Section 19 of the Federal Insecticide, Fungicide, and Rodenticide Act as amended in 1972 (Public Law 92-516) directs the Administrator of the Environmental Protection Agency to issue procedures and regulations governing the disposal of pesticide containers. Implementing regulations were published on May 23, 1973 (40 CRF, Part 165). Further dissemination of these regulations, and continuing education on the problems on incorrect disposal and on the dangers of accidental poisoning, can be expected to reduce pollution from these sources.

Livestock Pest Control

Insecticides used to control livestock pests are applied by various means, such as feed additives, backrubbers, sprays, pour-ons, liquid dips, or barn fumigations. Pesticide exposure to the environment is minimal with correct use. Barring dumping or accidental spillage, the potential for environmental pollution from this source is minimal.

Farm Woodlots

Pesticides are not used extensively on farm woodlots. Because of the relatively small size of tracts, aerial application is seldom used. Herbicides are perhaps the most frequently used pesticide on farm woodlots. They are selectively applied, frequently on stumps or at the base of trees. In the case of many pests, losses can be reduced through good farm woodlot management.

Control techniques are specific to each disease. Some examples are the timely removal of infected trees, pruning of infected parts, and elimination of alternate plant hosts in the case of rusts. Careful logging practices minimize mechanical injuries to trees. Injuries may serve as entry points for fungi.

Alternatives to Chemical Pesticide Use

Non-chemical methods of pest control can reduce the use of pesticides and thus their entry into the environment. However, for the foreseeable future, there will be a continuing need for pesticides in combination with these methods.

> Non-chemical methods of pest control, biological or cultural, will be used and recommended whenever such methods are economically feasible and effective for the control or elimination of pests. When non-chemical control methods are not tenable, integrated control systems utilizing both chemical and non-chemical techniques will be used and recommended in the interest of maximum effectiveness and safety.

Cultural Practices

A number of cultural practices can partly substitute for pesticides to prevent or reduce crop damage from insects, nematodes, weeds, and diseases. These practices include changes in methods of cultivating and harvesting crops that make the environment less hospitable to pests. Cultural practices are most successful if applied at a vulnerable stage in the pest's life cycle. Examples are the removal of crop debris to eliminate host sites, and adjustments in planting schedules to minimize pest influence on the crop. Tobacco stalks remaining after harvest support large numbers of tobacco hornworms, budworms, diseases, and several nematodes. Destruction or removal of the stalks immediately after harvest aids in controlling these pests.

Mechanical weed control is a generally accepted farm management practice. Such measures as row cultivation, proper seedbed preparation, and mowing of weeds on uncropped land reduce the production of weed seeds. Herbicides can then be applied at lower levels than under conservation tillage methods. Conservation tillage may increase certain disease and insect problems which could require increased use of the pesticides. A higher level of pesticide use under these conditions may not increase water pollution, however. A reduction in tillage means a reduction in soil erosion, a major source of pesticide movement and water pollution.

Biological Control

Natural enemies can be a major factor in controlling pests. A substantial number of devastating and extensive pest problems have been resolved by introducing or conserving natural pest enemies. Some examples are the control of Klamath weed in the Pacific Northwest, alligator weed in Florida, Comstock mealybug on apples in the Eastern United States, purple scale on citrus in Texas and Florida, citrophilus mealybug on citrus in California, alfalfa weevil in mid-Atlantic States, Rhodesgrass scale in Florida and Texas, European pine sawfly and Eurpoean wheat stem sawfly in the East, larch casebearer in the Northeast, and satin moth in New England and the Pacific Northwest. But, in general, the augmentation of natural populations of insect enemies with programmed releases of mass-reared specimens is still largely in the research stage.

The conservation of natural enemies is receiving considerable attention in the United States. This approach is currently fostered by a federally assisted program of 39 pest management projects in 29 states, and the program is expanding each year. Commodities involved include tobacco, cotton, alfalfa, field corn, grain sorghum, fresh market and processing corn, peppers, beans, potatoes, apples, citrus, and pears.

Boll weevils are controlled on several million hectares of cotton by means of cultural methods and fall insecticide applications, in order to dealy spraying in the spring. In this way, natural enemies of other insect pests will not be destroyed by early spraying for boll weevils.

At the present time, biological methods of controlling diseases, nematodes, and most weeds do not appear reliable.

Insect Sterilization

The use of sexual sterility is one of the most selective and environmentally acceptable methods of suppressing insect populations. Although the development of this approach has not received significant support from the private sector, it is operational in four instances: (1) the management of screwworm populations in the Southwestern United States and Northern Mexico, (2) protection of California citrus by release of sterila Mexican Fruit fly pupae in Northwestern Mexico, (3) the protection of 364,372 hectares (900,000 acres) of cotton in the San Joaquin Valley (California) from incipient populations of the pink bollworm, and (4) the suppression of pink bollworm on wild cotton in the Florida keys. The method was recently employed against the boll weevil in an areawide test in Mississippi, and holds potential when integrated with other techniques for eliminating this pest from the United States.

Insect Toxins and Pathogens

Over 363,636 kilograms of the toxin of Bacillus thuringiensis were marketed in 1972 in the United States for the control of caterpillars on lettuce, cole crops, tobacco, and ornamentals. With improved efficiency of the toxin and a reliable and adequate supply, the toxin could be marketed for wide use in controlling pests on cotton, forests, and other large-volume crops. A number of insect viruses are also being developed. For example, the Heliothis virus was recently registered for control of bollworms on cotton. However, the virus is not yet sufficiently persistent.

Insect Attractants

Various insect attractants have been developed to aid in insect control. International airports, harbors, and other ports of entry into the United States are ringed with light and other traps to attract various foreign species of insect pests. These devices are valuable in attracting alien insects, and have reduced the need for scheduled insecticide spraying for these pests. In orchards, sex attractants are being used in traps to determine pest levels and the need for pesticide application. In pilot tests, a sex attractant is being applied to the forest canopy in gelatine microcapsules in an attempt to prevent male gypsy moths from locating females. This same approach is being developed for the codling moth and other major moth species. Commercial use of these methods awaits further development.

Resistant Crop Varieties

Use of plant varieties that are resistant to diseases, insects, and nematodes is one means of solving pest problems in an economical and relatively desirable manner. Many crops could not be profitably grown in numerous locations except for the use of insect resistant varieties. These crops include alfalfa, corn, cotton, tobacco, small grains, clovers, and grasses. Soybeans, wheat, and sugar crops would not be commercially profitable in the United States except for the use of disease and nematode resistant varieties. The use of resistant varieties has been the only practical method found to suppress a large number of disease and insect pests of wheat, corn, barley, oats, grain sorghum, and rice. Many tolerant varieties of crops are available. Absolute resistance to pests is rare. However, even the modest resistance can greatly reduce the need for pesticides. Resistant varieties are not available and cannot be foreseen for all pests that attack major crops in the United States.

Crop Rotation

For centuries, farmers have used crop rotation to control pests. Rotations can be designed to partially reduce populations of a wide variety of diseases, insects, and nematodes. They are most effective in controlling pests on cultivated annual crops in areas of mixed agriculture.

A Review of Control Measures by States

Data was solicited from individual Region VIII states concerning present control practices and procedures. Each of the states responding indicated an anticipated increase in the use of pesticides although no specific figures were cited.

Wyoming

Expects an increase in pesticide consumption to continue. In relation to agricultural operations the following areas of the state were cited as heavy consumers of pesticides: Southeastern, Northwestern, and Central.

During 1973 pesticides were utilized in the following areas in mosquito control programs (non-emergency): Laramie, Lovell, Greybull, Glenrock, Cody, Cheyenne, Buffalo, Casper, Kemmerer, Newcastle, Powell, Sheridan, Worland, Cokeville.

Applications of pesticides directly to water in control of insects, trash fish, and aquatic plants occured at the Glendo Reservoir (Trash fish), Ocean Lake (Trash fish) and very possibly other unspecified areas.

Types of control measures and extent of utilization appears in the following figure:

Figure 33.

	Extensive	Moderate	Limited	Non-existent
Improved Management/Application Procedures		X		
Hot Air and/or Hot Water Treatments				X
Light Traps			X	
Use of Resistant Varieties of Crops			X	
Biological (parasites, predators, pathogens)			X	
Integrated Control (combinations of above)			X	
Pest Detection and Geographic Location			X	
Other (please describe)				

COLORADO

Colorado looks toward an increase in pesticide consumption. The following areas were cited as heavy users of pesticides in relation to agricultural operations:

Northeast - Weld, Larimer, Morgan, and Logan Counties
Arkansas Valley - Otero, Bent, and Prowers Counties
San Luis Valley - Del Norte, Alamosa, Costilla Counties
Tri-River Area - Mesa, Delta, and Montrose Counties

Colorado reports no emergency mosquito control programs during 1973 in which pesticides were used. However, there have been occasions where pesticides have been applied for the control of mosquito larvae within mosquito control districts. The years for these applications were not reported.

Some pesticide applications have been made in irrigation practices for the control of water weeds and, on occasion, pesticides are utilized by the State Fish and Game Department for the control of trash fish.

Types of control measures and extent of utilization presently employed are shown in the following figure:

Figure 34

	Extensive	Moderate	Limited	Non-existent
Improved Management/Application Procedures			X	
Hot Air and/or Hot Water Treatments				X
Light Traps			X	
Use of Resistant Varieties of Crops			X	
Biological (parasites, predators, pathogens)			X	
Integrated Control (combinations of above)			X	
Pest Detection and Geographic Location		X		

Other (please describe)

Use of attractant traps to trap males of codling moth in fruit areas.

NORTH DAKOTA

Reports an increased usage of herbicides and expects the trend to continue. Herbicides used extensively in wild oat control programs.

The greatest usage of pesticides is reported to be in the eastern regions of the state. Crops receiving pesticide controls are potatoes and vegetables in the Red River Valley.

There were no emergency mosquito control programs during 1973.

Pesticides are utilized for mosquito larvae control in the Fargo area of south eastern North Dakota, and in the northwest in the Williston area.

Types of control measures and extent of present utilization appear in the following figure:

Figure 35

	Extensive	Moderate	Limited	Non-existent
Improved Management/Application Procedures			✓	
Hot Air and/or Hot Water Treatments				✓
Light Traps			✓	
Use of Resistant Varieties of Crops			✓	
Biological (parasites, predators, pathogens)			✓	
Integrated Control (combinations of above)			✓	
Pest Detection and Geographic Location		✓		
Other (please describe)				

SOUTH DAKOTA

South Dakota reports no increase in the utilization of pesticides for the years 1970, 1971, and 1972. They do not anticipate any sizeable increase in use.

The heaviest use of pesticides is reported for the corn production area in the southeastern portion of the state.

There were no emergency mosquito control programs during 1973.

The State Fish and Game utilized pesticides in control of trash fish when necessary in all regions of the state.

Types of control measures and extent of present utilization is shown in the following figure:

Figure 36

	Extensive	Moderate	Limited	Non-existent
Improved Management/Application Procedures	✓			
Hot Air and/or Hot Water Treatments				
Light Traps				
Use of Resistant Varieties of Crops				
Biological (parasites, predators, pathogens)			✓	
Integrated Control (combinations of above)				
Pest Detection and Geographic Location				
Other (please describe)				

MONTANA

No report.

UTAH

Utah notes a slight increase in p esticide consumption generally and expects the trend to continue. Areas of greatest use are reported to be along the front range of the Wasatch Mountains, i.e. Box Elder, Weber, Davis, Salt Lake and Utah Counties as well as Millard County.

No significant emergency mosquito control programs were in effect for 1973. On a relatively minor scale emergency treatment applications can be listed for Moab, and Huntington, Utah.

There are several mosquito abatement districts which apply pesticides directly to water for the control of mosquitoes. The major use is reported for Box Elder, Weber, Davis, Salt Lake and Utah Counties.

Types of presently employed control measures and extent of utilization appear in the following figure:

Figure 37

	Extensive	Moderate	Limited	Non-existent
Improved Management/Application Procedures			x	
Hot Air and/or Hot Water Treatments				x
Light Traps			x very limited	
Use of Resistant Varieties of Crops		x		
Biological (parasites, predators, pathogens)			x	
Integrated Control (combinations of above)		x	x	
Pest Detection and Geographic Location		x	x	

Other (please describe)

Most of the organized mosquito abatement districts, including the Utah county program, are using pest management techniques . . such as water management, Gambusia, etc.

Some of the commercial fruit growers are using an integrated mite control program developed by the Experiment Station.

THE FEDERAL ENVIRONMENTAL PESTICIDE CONTROL ACT OF 1972

The Federal Environmental Pesticide Control Act (FEPCA) of 1972 became law on October 21, 1972, revising the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) of 1947.

Some sections of the new act became effective immediately, while others have deadlines for later enforcement, pending the establishment of regulations and development of Federal standards to guide States in implementing the legislation. All of the provisions of the new act must be in effect by October 1976.

Before registration may be granted for a pesticide product, the manufacturer is required to provide scientific evidence that the product, when used as directed, will (1) effectively control the pest(s) listed on the label, (2) not injure humans, crops, livestock, wildlife, or damage the total environment, and (3) not result in illegal residues in food or feed.

Background.--The FIFRA was administered by USDA until the authority was transferred to the EPA when it was established in December 1970. The administering Agency has authority to cancel a pesticide registration when the registered use of the product is in violation of the act or poses a serious hazard to humans or their environment. The registrant is entitled to appeal the cancellation notice through a process that can include public hearings and scientific advisory committees.

Suspension of a pesticide registration, unlike cancellation, halts interstate shipments immediately and is reserved for those products that present an imminent hazard.

The pesticide amendment to the Federal Food, Drug, and Cosmetic Act is a law closely related to the FIFRA and FEPCA. It provides protection to consumers from harmful pesticide residues in food. The amendment requires that, where necessary to protect the public health, a tolerance or legal limit be established for any residues that might remain in or on a harvested food or feed crop as a result of the application of a chemical for pest control. Tolerances are based on chemical and toxicological data showing that the residues are safe for consumption.

The authority to establish tolerance levels was transferred from the Food and Drug Administration (FDA) of the Department of Health, Education, and Welfare to EPA in December 1970. The enforcement of tolerances remains the responsibility of the FDA.

<u>Provisions of the New Law</u>.--Some of the provisions of the 1972 act are:

* The use of any registered pesticide in a manner inconsistent with labeling instructions is prohibited, effective immediately. Civil and criminal penalties for misuse of pesticides are provided.

* Knowing violations of the act by farmers or other private applicators can result in fines of up to $1,000 or 30 days imprisonment, or both, upon criminal conviction. Second and subsequent offenses are subject to civil fines of up to $1,000 as well.

* Any registrant, commercial applicator, wholesaler, dealer, retailer, or other distributor, who knowingly violates the law, is liable to a criminal fine of up to $25,000 or one year in prison, or both, and to civil penalties of up to $5,000 for each offense.

* Pesticides must be classified for general use or restricted use by October 1976.

* The States will certify pesticide applicators for use of restricted pesticides. The act allows 4 years for development of certification programs. Federal standards for certification must be set forth by October 1973, and the States must submit their certification programs based on these standards by 1975. The State programs must be approved within 1 year of submission.

* The Administrator of EPA may issue orders stopping the sale, use, or removal of any product when it appears that the product is in violation of the act or the registration has been suspended and finally cancelled. Products in violation of the act may also be seized.

* Pesticide manufacturing plants must be registered by October 1973.

* EPA is required to develop procedures and regulations for the storage and disposal of pesticide containers. They must accept, at convenient locations for disposal, pesticides which have had registrations suspended and then cancelled.

* The Agency is authorized to issue experimental use permits, conduct research on pesticides and alternatives, and monitor pesticide use and presence in the environment.

* The owners of certain pesticides whose registrations are suspended and finally cancelled are entitled to indemnification.

* States are authorized to issue limited registrations for pesticides intended for special local needs.

* States may impose more stringent regulations on pesticides than the Federal Government, except for packaging and labeling.

* The views of the Secretary of Agriculture are required to be solicited before the publishing of regulations under the act.

* Federal registration of all pesticide products, whether they are shipped in interstate or intrastate commerce, is required under the new act.

The reader is encouraged to consult the closest regional office of the EPA for further information and details on the provisions and regulations of the FIFRA, as amended by the FEPCA of 1972.

Recent EPA Actions.--Cancellation proceedings were initiated under the FIFRA against aldrin, DDT, dieldrin, and mirex. After extensive public hearings, nearly all remaining registered uses of DDT were cancelled in June 1972, the order to become effective December 31, 1972. This decision was based on potential future hazards to man and his environment.

The use of mirex against the imported fire ant in the southeastern United States has been limited, primarily because of the hazard to aquatic life.

Cancellation of the use of 2,4,5-T on food crops has been continued, pending the outcome of a public hearing on possible risk of injury resulting from its application.

In June 1972, cancellation of most of the major registered uses of aldrin and dieldrin on corn, fruit, and for seed treatments was continued pending the conclusions of a public hearing and a final decision by EPA on possible use restrictions.

Suspension and cancellation notices for mercury-bearing pesticides were issued. Used heavily by industry, mercury builds up in the food chain and persists in the environment.

All interstate shipments of pesticides registered for use in the control of predatory animals were halted. This action was taken following the discovery that their use was destroying valuable wildlife resources, including some endangered species.

Several statutes governing pesticides and environmental matters including FIFRA, as amended, and the administrative procedure provisions in Title 5 of the U.S. Code enable individuals or companies to avail themselves of judicial review assuring complete compliance with the provisions of FEPCA. As of the time of publication of this document, several legal actions involving recent EPA decisions are pending before the court.

EPA REQUIRES PESTICIDE FACILITIES TO REGISTER

The U.S. Environmental Protection Agency recently issued regulations requiring pesticide producing establishments for the first time to register with the Agency and submit annual reports on production, distribution, and sales.

The purpose of the regulations is to identify all pesticide producers and make available information necessary for effective enforcement of the Federal pesticides law.

Previous incidents, involving fish kills and other forms of environmental contamination, have demonstrated the need for prompt location of producers and prior knowledge of the types of chemicals each plant produces.

Pesticide producers in both interstate and intrastate commerce, foreign producers exporting to the U.S., and producers operating under an EPA experimental use permit will be required to register. This applies to producers involved in any aspect of the production process including manufacturing, processing, preparing, propagating, compounding, custom blending and repackaging, except under emergency conditions.

Persons producing pesticides currently registered with EPA have been mailed application forms by the Agency. Other producers can obtain the forms from EPA headquarters in Washington, D.C., or from the Agency's ten regional offices.

Applications for registration must be submitted to EPA's regional offices. All producers were urged to apply as soon as possible.

After receiving an application, EPA issues an establishment registration number to each pesticide producing plant. Within a designated time thereafter, the number must be displayed on each of the pesticide containers released for shipment by the plant.

Companies with more than one production site must file a single application from company headquarters. This form identifies each production establishment.

Thirty days after notification of registration by EPA, interstate and foreign producers must submit a report to the Agency on the types and amounts of pesticides currently being produced, the types and amounts produced last year, and last year's sales or distribution volumes. Forms for this report will be provided producers along with their notification of registration. In subsequent years, this report will be due from all producers, including intrastate producers, on February 1.

The pesticide establishment registration and reporting requirements are called for in Section 7 of the 1972 Amendments to the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) administered by EPA. Producers failing to comply with the requirements are subject to civil or criminal penalties under the Act.

CONCLUSIONS AND RECOMMENDATIONS

SUMMARY OF MANAGERIAL PRACTICES AND RESEARCH NEEDS

Improved knowledge of the fate of pesticides in the environment will be useful in resolving the controversies surrounding the use of these chemicals.

The extent to which a pesticide represents a significant pollutant is measured by the impact of the particular chemical on all components of the environment. An extensive effort is underway to determine the effects of specific pesticides on the environment, particularly with regard to man and beneficial organisms, algae, insects, fish, wildlife, etc. A systems approach is desirable because of the interactions between pesticides and other environmental contaminants and because there is movement of pesticides and their degradation products between soil, air, and water.

The nature and extent of pesticides in the environment is being determined by several monitoring programs of the EPA. These programs and results are published periodically in the Pesticide Monitoring Journal, published by EPA.

Federal agencies, universities, and industry also have been conducting research on the chemical changes that take place in organic pesticides in the environment and on the toxcity of the intermediate and end products. In some cases a metabolite has been shown to be significantly more toxic than the original pesticide. On the other hand, most end products are less toxic. A better understanding of the rate and manner of such degradation under different environmental conditions would provide a useful basis for determining the conditions under which specific chemical should be used.

There also are opportunities for reducing the quanitity of hazardous pesticides that are introduced into the environment.

The development of integrated contol programs involving the combined use of chemical, cultural, physical, and biological methods has progressed to the point where area pest-suppression programs appear feasible for several economically important insects. These programs have progressed through laboratory and limited field evaluations. In some cases, large-scale (thousands of acres) field applications of this technique are required. Further development of integrated control programs would greatly reduce the use of chemical pesticides.

Other opportunities to reduce the amount of hazardous pesticides introduced into the environment include application of chemicals only when required ; substitution of less dangerous, readily degraded materials; and such approaches as improved erosion control to prevent the movement of pesticides from land to water.

Probably significant amounts of pesticides are transported in air from their place of application as a result of drift during application and by volatilization following treatment. This movement may be the principal method of dispersion over wide areas. Continued research may result in development of the means to prevent its occurrence.

Research Needs

The following areas warrant major attention.

1. Evaluating the nature, extent, significance, and impact of pesticides in the ecosystem

In the Department of Agriculture, research is being directed toward the study of the biology, ecology, life history, physiology, morphology, taxonomy, nutrition, metabolism, habits, and behavior of target and non-target organisms. The effect of pesticides on field populations, including measurement of immediate mortality, long-term effects on reproduction and survival, and the effects of species composition and density are also encompassed in present research efforts.

Information gained from these studies assists in determining the nature, extent, significance, and impact of pesticides in the ecosystem.

USDA participates in the National Monitoring Program of the Environmental Protection Agency. Extensive long-range programs of soil monitoring are planned and limited parts of these programs are underway. Spot checking in suspected trouble spots will be continued. In addition, application of pesticides to forests and rangeland is monitored to determine the impact of these programs on the environment. These monitoring programs are a built-in part of the pest-control activities of the U.S. Agriculture Department.

USDA also conducts a pesticide-monitoring program in federally inspected meat-packing plants.

The Environmental Protection Agency has programs underway to--

Study medically and biochemically groups of people who are in contact with pesticides and other chemicals over a period of years to determine what effects chronic and acute exposure may have on the health of these people.

Maintain current information on the pesticide-use patterns in study areas to include changes in types of products, new compounds, and in amounts used and methods of application

Continue monitoring of pesticide residues and their products in human tissues of the general population

Continue assisting State health departments in the maintenance of epidemiological and biochemical competence in diagnosis of pesticde effects upon man.

Develop and improve methods for direct measurement of exposure of agricultural products, agricultural personnel, and other workers to pesticides, and an assessment of this exposure for potential toxicological problems.

Present investigations encompass programs of toxicology and chemistry of chlorinated hydrocarbons, organophosphate, insecticides, crabamates and herbicides, in order to ascertain the public health hazards associated with their use.

Pharmacologic studies are directed toward investigation of the physiological and biochemical mechanisms involved in the transportation, detoxification, and metabolism of pesticides. Particular emphasis is applied to the effects of low-level long-term exposure. Included will be studies of the mode of transport, binding factors, metabolism in human as well as experimental animals, correlation of blood and brain levels of pesticides to illness or other effects of pesticide ingestion.

Long-term chronic toxicity studies in animals with emphasis on teratogenic defects are underway. Relationship of the dosage that produces an effect in animals will be considered with respect to possible exposure of man.

The long-term goal of these studies is to find a more adequate way to measure hazards to public health rather than to observe gross symptoms such as death.

Chemical research on pesticide residues in foods emphasizes (1) establishing the chemical identity of the residue, including significant conversion products; (2) developing, improving, and validating methodology for measuring the amount of such residue; and (3) occasional checking on the validity of data submitted in petitions.

Biological research emphasizes (1) studying physiological effects and metabolism of pesticides in biological systems, including the metabolic fate of the compounds, their biochemical reactions, the nature of the metabolic pathways, and an evaluation of their effects in terms of toxic action; (2) performing toxicity studies of pesticides as a method for determing safe tolerance levels; and (3) developing data on the direct effect of pesticides on man.

Surveillance and monitoring programs are established and maintained to determine the extent, trends, and significance of pesticide contamination of the national food supply. In part, these programs support the National Pesticides Monitoring Program and are in collaboration with other agencies--Federal, State, and international--concerned with the use of pesticides and the effects of such use.

The U.S. Environmental Protection Agency has primary responsibility for investigation of the effects of pesticides, both acute and chronic, on fish and wildlife and their associated environments and also on water quality. It investigates the pathways traveled by pesticide residues from application to uptake to evaluate their possible behavioral and physiological effects on birds, mammals, fish, and shellfish, as well as the food chains of which they are a part, and water. In-house and grant-supported research and monitoring programs are conducted, using selected species as indicators for determining the degree of contamination and for devising safeguards that may be necessary. The Agency is coöperating with the Federal Committee on Pest Control in the National Pesticide Monitoring Program to the extent that its study of pesticide residues blankets continental United States and is concerned with fish, shellfish, wildlife, and water quality.

2. Reducing the amount of hazardous pesticides in the environment

The major emphasis of the Department of Agriculture pesticide programs is in this direction. These programs encompass--

A. Developing and using less hazardous alternate chemical controls.

B. Developing and using better methods of application that require less material or that place the needed toxic material more accurately. For example, pesticides are applied in forest only when meteorological conditions are right. Helicopters are used for applications near streams.

C. Developing and using nonpesticidal means such as (1) resistant crops, (2) parasites or predators, (3) self-destruction techniques (sterilization, breaking of diapause, etc.), (4) improved cultural practices and combinations of these and other procedures.

D. Developing and carrying out a comprehensive information and education program to encourage the safe use of pesticides for protection of the user, the consumer of food and fiber products, as well as for the protection of fish, wildlife, soil, air, and water from pesticide pollution.

Results to date indicate strongly that integrated control programs involving certain combinations of chemical control plus self-destruction techniques and improved cultural practices may, if applied to a wide area, drastically reduce the amount of chemicals required and eventually reduce the dependence on chemicals. These programs also provide attractive economical considerations.

There has been much publicity about the screw worm control program in the Southwest in which USDA participates. Plans are developing for extending the control area well south into Mexico. In this manner the length of the treated barrier will be considerably shortened with a consequent increase in control and a decrease in cost. A large-scale integrated control program is being established for the pink bollworm in the Southwest. The Department is considering large-scale field evaluations of other integrated programs for pest control. For example, a large-scale program to control the codling moth in apples appears to be feasible. The development and installation of such programs will be rather costly.

One approach to major integrated control programs could be the cooperative development of facilities and programs. USDA would cooperate with the particular agricultural segment involved, such as local growers association or a national organization that has close local affiliations. Under such a program the research and action agencies of the Department could develop the field program, train the necessary local people, and eventually turn the program over to the segment of the industry involved while continuing to provide necessary technical assistance. This is an example of how field evaluation of large-scale programs might be undertaken.

The Environmental Protection Agency has a primary policy to minimize the amount of pesticides sanctioned for use. Tolerances in foods are established at safe levels no higher than that required in the production of food even though a higher level may be safe.

The Department of the Interior is interested in minimizing the use of herbicides in irrigation-water conveyance systems. Programs include studies to determine the minimum amount of herbicides that can be applied in water conveyances to control noxious-vegetation growth. In addition, studies are being conducted to determine the persistence of herbicides and pesticdes following various rates of application.

3. Treating, controlling, or removing pesticides from soil, air, and receiving waters

The monitoring programs of the Department of Agriculture have indicated tha pesticde residues are present in soil, air, and water. The major portion of the Department programs have been devoted to monitoring of soil. This information coupled with information obtained during research aimed at more basic knowledge of pesticides aids in developing means of treating, controlling, or removing pesticides from the environment. To date limited progress has been made in treatment or removal of pesticide residues from air, soil, and water. Progress has been made in control materials for more persistent pesticides. As technology progresses and greater emphasis is placed on environmental quality, it is anticipated that the time will come when educational programs and significant technical and financial assistance are directed toward such work.

In-depth training schools are conducted for applicators, dealers, producers, professional leaders, and key consumer and user groups as a part of the USDA effort under this heading.

The Environmental Protection Agency's monitoring activities for pesticides in air may be considered as the necessary preliminary work for evaluating the impact of pesticide contamination of air on man's health. Available information is scanty and inadequate for this purpose. The scope and severity of the problem should be better defined before any action program is undertaken. Additional work is needed to define acute and long-term effects and the contribution of particulates and of other contaminants in air to the impact.

The Department of the Interior has major responsibility for the treatment, control, and removal of pesticides from the aquatic environment. The development of treatment methods for ameliorating and removing pesticides in water is extremely difficult. Several approaches are being actively pursued.

4. <u>Disposing of pesticide wastes, including used pesticide containers, in a manner least detrimental to the environment.</u>

Efforts are being made by the Department of Agriculture to obtain a valid estimate of the number and sizes of "empty" pesticide containers and the amount of pesticide wastes that exist. Present programs in this area of emphasis are modestly funded. The major program consists of contract research to determine the combustion temperatures and products of a series of representative pesticides. Another part of this contract deals with the design of a low-cost incinerator for the destruction of pesticides.

The planned USDA programs consist of additional work, probably by contract to develop similar information on other pesticides. Once a suitable design is developed for an incinerator and a demonstration model is constructed, tested, and proved, attention will be given to assisting in the construction and utilization of units at suitable locations.

The Department of Health, Education, and Welfare has responsibility for surveying methods currently used for the disposal of such wastes in the respective States. This preliminary information will aid definition of the scope of the problem and aid in the optimal location of future action programs.

The Department of the Interior has no program in this area.

5. Assisting State regulatory agencies in the establishment of uniform effective pesticide regulatory programs

The Department of Agriculture has assisted the Council of State Governments in developing uniform regulations in the form of a model law. This model law will be revised as needed. The Department will assist in this program.

USDA has cooperated with the State departments of agriculture in enforcing pesticide regulations. The Department does not enforce any State regulations but does participate in the exchange of information regarding enforcment activities within each State. Though the greatest effort may be completed, thses programs will continue

The Environmental Protection Agency promotes the adoption of uniform pesticide-residue legislation by the States; maintains an information system to the States whereby pesticide-residue tolerances, reports of seizures, prosecutions, and injunctions, and pesticide action-level guides, etc., are transmitted regularly to the States; transmits and maintains a Pesticide Analytical Manual for State regulatory analysis; answers inquiries from State officials concerning pesticde-residue problems; and on request offers technical assistance to the States in planning and developing State pesticide-residue programs. A partnership pesticide program with the States is now under consideration. This would permit the States to accept primary responsibility in the surveillance of pesticide residues at the grower level. Achieving full implementation of such a program will depend on FDA's obtaining authority to grant financial assistance to the States.

State and local chemists and other health personnel from throughout the country are trained in the lates techniques of chemical analysis and pesticides technology

On request, State laws pertaining to labeling and safe use of pesticides (protection of applicators, condition of equipment, delivery of desired amounts and concentrations, and education of applicators on hazards of compounds) are reviewed as part of the State Pesticide Projects and by the Training and Consultation Unit. This work is usally performed in connection with the State Health Department. In addition, a guideline law has been developed to serve as a uniform basis in evaluating State laws regulating professional applicators.

The Department of the Interior insures that proposed uses of new pesticide formulations will present the minimum hazard to fish and wildlife resources. The establishment of water-quality standards reflecting results of the research and development programs in this area are also of concern to the Department.

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FERTILIZERS

Agricultural Statistics - Region VIII

The Rocky Mountain-Prairie States Region (Colorado, Utah, North Dakota, South Dakota, Montana, Wyoming) represents a total land mass of 367,268,000 acres. According to the 1969 U.S. Agricultural Census, slightly more than 2/3, or approximately 67%, of this total land area is classified as land-in-farms (all owned or leased land other than forest Service or BLM managed. Includes cropland and grazing lands.) Operating farms within the Region total 166,981. This represents a decrease in operating farms of about 16% from the previous census of 1965 when a little more than 200,000 operating farms were reported. This decline is attributed to consolidation of some farming operations or the sale of farmland for industrial and residential development (Table 98)

During the five-year period 1965-1969, there was an 8,551,406 acre decline of total land in farms in the Region. However, the average farm size in the region increased from 1,161.6 acres to 1,647.4 acres.

Of the total farm acreage reported, 45,722,375 acres was in cropland with 7,496,420 acres classified as irrigated cropland. Over the years harvested cropland has declined steadily from an all time high reached in 1950. During the past three decades harvested cropland has declined nearly 50% within the region. This phenomenon can be attributed in part to the increased use of commercial fertilizer accounting for more productivity from less acreage.

The rapid expansion of fertilizer technology within the region has resulted, over the years, in higher crop yields per acre farmed as well as lower unit costs for food. This fact coupled with lower fertilizer costs has helped to improve the economic position of the farmer as well as increase farm productivity. At least 1/3 of the total crop yield in the region is attributable to the use of chemical fertilizers. However, there is suspicion that the increased use of fertilizers has resulted in an increase of adverse effects upon water quality especially in those areas where, through leaching and runoff, portions of the applied chemical fertilizers enter ground and surface water supplies.

Fertilizer Consumption Statistics

Total fertilizer consumption for the Region VIII states for FY 1972 was 1,347,890 tons (USDA Statistical Reporting Service, May 1973). This represents nearly a 14% increase over the total fertilizer consumption of 1,192,200 tons for the year 1969 (Table 99).

It is interesting to note that during the period 1963 - 1970 there has been no significant change in the number of harvested acres of cropland within Region VIII. However, fertilizer consumption during the same period has jumped from an average of 13 pounds per acre in 1963 to 35.5 poinds per acre in 1972. Fertilizer consumption during the period has nearly tripled. The six EPA Region VIII states combined show the lowest fertilizer application rates of any EPA Region in the contigious United States (Table 101)

Although no definitive studies have been conducted within the Region VIII states linking commercial fertilizers directly with contaminated water supplies, studies conducted elsewhere tend to incriminate nitrate from fertilizer as a contributor to water quality problems (Johnston et al., 1965; Doneen, 1968). A survey by Nettles in 1970 showed that 30% of the private wells tested in Chickasaw County, Iowa, contained enough nitrate-nitrogen or coliform bacteria to be labeled unsafe by U.S. Public Health standards. The report pointed an accusing finger at the residue of agricultural chemicals and suggested the need for setting standards in the use of agricultural chemicals to reduce environmental water pollution.

A similar survey conducted in 1967 by Keller and Smith that centered on analysis of 6,000 rural water supplies concluded there was some evidence of nitrogen infiltration from heavy annual application of nitrogen fertilizer. However, in this study, animal wastes were cited as a major source of contamination (see chapter on cattle feedlots). None of the reservoirs sampled showed increases in nitrate due to fertilization.

REGION VIII AGRICULTURAL STATISTICS 1969

Table 98

Farming
(by individual states)

State	North Dakota	South Dakota	Utah	Wyoming	Montana	Colorado
Total Land Area (acres)	44,335,000	48,611,000	52,541,000	62,212,000	93,158,000	66,411,000
Total Farmland (Acres)	43,117,831	45,584,164	11,312,951	35,[illegible]76,374	62,918,247	36,697,132
Land Not in Farms (Acres)	1,217,000	3,027,000	41,228,000	26,736,000	30,240,000	29,714,000
% Not in Farms	2.7	6.2	78.5	43.0	32.5	44.7
Total Number of Farms	46,381	45,726	13,045	8,838	24,951	27,950
Increase/Decrease 1964-1969	-2,455	-3,977	-2,714	-200	-2,069	-1,848
Average Farm Size (acres)	929.6	874.7	867.2	4,014.1	2,521.7	1,313.9
Increase/Decrease Total Acres in Farms 1964-1969	+400,471	+16,901	-2,915,513	-1,576,258	-2,915,513	-1,561,494
Total Croplands (acres)	29,458,878	19,837,884	1,945,000	2,788,000	16,109,000	10,773,000
Harvested Cropland (acres)	17,174,891	12,634,488	1,024,475	1,685,597	7,937,203	5,265,721
Irrigated Land (acres)	63,238	148,341	1,025,014	1,523,422	1,841,421	2,894,984

Region VIII Agricultural Statistics
(combined 6-state totals)

Land Area - 367,268,000 acres
Farmland - 235,106,699 acres
Not Farms - 132,162,000 acres
% Not Farms - 34.6%
Number of Farms - 166,981
Decrease 1964 to 1969 - 13,263 farms

Average Size - 1674.4 acres
Decrease in Acreage - 8,551,406 acres
Croplands - 80,871,762 acres
Harvested - 45,722,375 acres
Irrigated - 7,496,420 acres
Croplands as % of total area - 22%

Table 99 . Region VIII Fertilizer Consumption, FY 1969 vs. FY 1972. USDA Crop Reporting Board, Statistical Reporting Service, May 1973.

State	Total Tons Consumed	
	FY 1969	FY 1972
Colorado	251,200	309,551
Wyoming	77,300	79,821
Utah	87,700	109,429
Montana	171,600	203,000
North Dakota	344,700	341,595
South Dakota	259,700	304,494
Total Region VIII	1,192,200	1,347,890

Although the rate of increase nationally has been declining, four of the Region VIII states reported increased consumption for FY 1972 over FY 1971 (Montana, Utah, Wyoming, Colorado). Two reported decreased consumption during the same period (North Dakota, South Dakota).

Table 100 . Region VIII Harvested Acres and Pounds of Fertilizer per Harvested Acre, 1963-1970. Fertilizer Summary Data 1973, TVA National Fertilizer Development Center.

State	Harvested Crop Acreage		Fertilizer Lbs/Acre	
	1963	1970	1963	1970
Colorado	5,365,000	6,215,000	24	42
Wyoming	1,785,000	1,831,000	12	32
Montana	8,138,000	8,206,000	7	21
Utah	1,021,000	1,060,000	29	75
North Dakota	17,788,000	17,327,000	9	21
South Dakota	14,225,000	14,430,000	5	19
Total	48,522,000	49,069,000	14.3	35

Table 101

1970

Plant Nutrients Applied Per Harvested Acre
In the Continental United States

State	Applied Lbs/Acre	State	Applied Lbs/Acre
Alabama	270	Nebraska	83
Arizona	230	Nevada	23
Arkansas	66	New Hampshire	89
California	185	New Jersey	261
COLORADO	42	New Mexico	82
Connecticut	209	New York	103
Delaware	169	North Carolina	245
Florida	776	NORTH DAKOTA	21
Georgia	298	Ohio	154
Idaho	84	Oklahoma	73
Illinois	151	Oregon	109
Indiana	168	Pennsylvania	115
Iowa	136	Rhode Island	396
Kansas	70	South Carolina	210
Kentucky	163	SOUTH DAKOTA	19
Louisiana	123	Tennessee	134
Maine	222	Texas	108
Maryland	176	UTAH	75
Massachusetts	228	Vermont	71
Michigan	150	Virginia	186
Minnesota	83	Washington	95
Mississippi	114	West Virginia	69
Missouri	116	Wisconsin	95
MONTANA	21	WYOMING	32

Disposal of sewage and industrial wastes have been pinpointed in other studies as contributors to the nitrate problem (Navone, et al., 1963). This factor further complicates any attempt to positively identify farm fertilizers as the chief source of nitrate concentrations in surface and ground waters.

Natural Sources of Nitrogen

Presence of nitrate nitrogen in ground water is a natural phenomenon. Over 30 years ago, the U.S. Geological survey showed natural nitrate accumulation in certain areas to be quite abundant. In fact, nitrate accumulations were found in soils of geological formations in all of the 11 western states and many of the states entering into the Appalachia region. Studies in Colorado dating back to the turn of the century indicate tremendous accumulations of nitrate on the Colorado Plains before man ever appeared on the scene. For instance it is common knowledge that the Mancos shale formations along the western slope of Colorado are high in natural nitrates. There are also indications of high natural nitrate concentrations in the Arkansas River Basin. Gardner (1934) and Headden (1921) showed high concentrations of nitrate in Colorado soils in some areas long before the introduction of commercial fertilizers in the state.

Effects of Nutrient Losses

Little or no attention has been given to the problems of nutrient loss from agricultural fertilizers on a strictly regional basis for Region VIII. The Missouri River Basin Comprehensive Framework report makes little mention of the problems related to fertilizer utilization practices even though a considerable amount of the land area within the Basin is farmland.

According to the study, "...large volumes of ground water in North and South Dakota and parts of Montana and Colorado have dissolved solids generally exceeding 1,000 ppm, although there are also good quality waters found in these areas as well. While not meeting ideal standards, poor quality ground waters often are utilized for municipal, domestic, and other purposes, in lieu of alternative supplies that are much more costly to develop. The vast size of the basin and the range that exists in the parameters of water quality make it impractical to detail all available data concerning quality in ground waters of the Missouri Basin."

The Upper Colorado Region Comprehensive Framework study which includes parts of Colorado, Utah, and Wyoming has this to say about nutrient problems within the area:

"Dense populations of algae are present in some stream reaches, indicating that municipal and industrial effluents and irrigation return flows entering the streams are rich in nutrients. Nutrient data collected at Water Pollution Surveillance System Stations are presented in Table . It is difficult to appraise such data because of the many factors contributing to excessive plant production. Further, no specific limitations on nutrients were set as part of the water-quality criteria of the states. Investigation of eutrophication problems in areas outside of the Region has led to identification of limiting quantities of various forms of nitrogen and phosphorus, above which excessive fertility occurs. However, what may be critical in one instance may not be under different conditions elsewhere.

"Because the amount of phosphorus present in a form available for plant growth is constantly changing, the National Committee on Water Quality Criteria recommends controlling the total amount of phosphorus present in streams. As a guideline, the Committee recommends an upper limit of 0.1 mg/l for rivers with only 0.05 mg/l permitted where streams enter lakes or reservoirs. Data shown in the table indicate the presence of total phosphorus in amounts above these recommended maximums. In addition, the amounts of nitrogen (particularly NO_3 and NH_4) to total phosphorus should not be radically changed by the addition of materials.

"Quiescent reservoir waters are more susceptible to excessive plant growths than are rapidly flowing streams. Limited data collected at Lake Powell show average total phosphates ranging from 0.7 to 0.35 mg/l from 1964 to 1967. Annual averages appeared to be decreasing with time. Peak concentrations occur during winter months with lowest values present in spring and summer, reflecting consumption of nutrients by aquatic plants during the warmer months. Phosphate concentrations decrease going downstream in the reservoir, also indicating use by plants. Total organic nitrogen in Lake Powell averaged between 0.24 and 0.35 mg/l each year from 1964 to 1967.

"Water quality problems due to high levels of nutrients have been reported in Grand Lake, Shadow Mountain Reservoir and Lake Granby in the Upper Main Stem Subregion. Domestic wastewaters have been cited as the principal source of nutrient loads reaching the lakes.

"Nitrate concentrations in Flaming Gorge Reservoir in late 1964 reached 0.6 mg/l; summer lows were 0.2 mg/l. Phosphate averaged from 0.15 mg/l to 0.55 mg/l during 1964-1965. Oxygen deficiencies resulting from high algae concentrations were cited as a probable reason for a fish kill in Flaming Gorge Reservoir in late 1963. Otherwise, excessive production of water plants has not been reported as interfering with beneficial uses of the impoundments of the Upper Colorado Region."

Table 102 Nutrient Concentrations in Upper Colorado Region Streams

	Ammonia Nitrogen (mg/l as N)	Total Phosphorus (wet method mg/l as P)	Dissolved Phosphorus (wet method mg/l as P)	Total Soluble Phosphate (mg/l)
Green River at Dutch John, Utah				
Min.	-	0.01	0.01	0.00
Mean	-	0.02	0.01	0.003
Max.	-	0.09	0.02	0.20
No. of samples	-	23	26	103
Period of Record	-	'64-'68	'64-'68	'62-'64
Colorado River at Loma, Colorado				
Min.	0.00	0.01	0.01	0.00
Mean	1.36	0.20	0.02	0.34
Max.	9.50	1.00	0.15	5.00
No. of samples	164	28	25	163
Period of Record	'60-'66	'64-'68	'64-'68	'61-'67

Rainfall, Runoff, and Water Quality

There is no doubt that precipitation rates have a direct influence on fertilizer leaching and runoff. Nitrates are leached into the soil and eventually reach ground waters and other subsurface water supplies. Phosphates cling to soil particles and are generally transported via sediment into surface waters. Wadleigh (1968) reported that more than 50 million tons of primary nutrients are lost from U.S. agricultural and forested lands each year by virtue of sediment delivery.

In the Upper Colorado Region a broad range of climatic, and hence streamflow, conditions exist. Annual precipitation varies from over 60 inches in high-elevation headwater areas to less than six inches in desert areas of the southwestern portion of the Region, while temperatures vary inversely. (Figure 38)

In the Missouri River Basin Region annual precipitation varies from over 40 inches in parts of the Rocky Mountain and southeastern parts of the basin, to as low as 6 to 12 inches immediately east of the Rocky Mountains. Complicating the annual variations, there is a wide variation in the monthly pattern of precipitation throughout the Region. Figure 39 illustrates the average annual total precipitation in the Basin.

Land runoff and sediment transportation of nutrients play key roles in affecting water quality in most areas of the region. Barry Commoner (1968) estimated nitrogen fertilizer losses to be about 15% of total nitrogen fertilizer consumption. Taking 1971 as an example, total tonnage of fertilizer consumed within the Region VIII area amounted to 1,298,396 tons. Using Commoner's formula 195,000 tons of nitrogen fertilizer materials were lost to the environment as potential pollutants during the period. Commoner's formula is a valid one and generally accepted as applicable in all areas of the country.

Figure 38

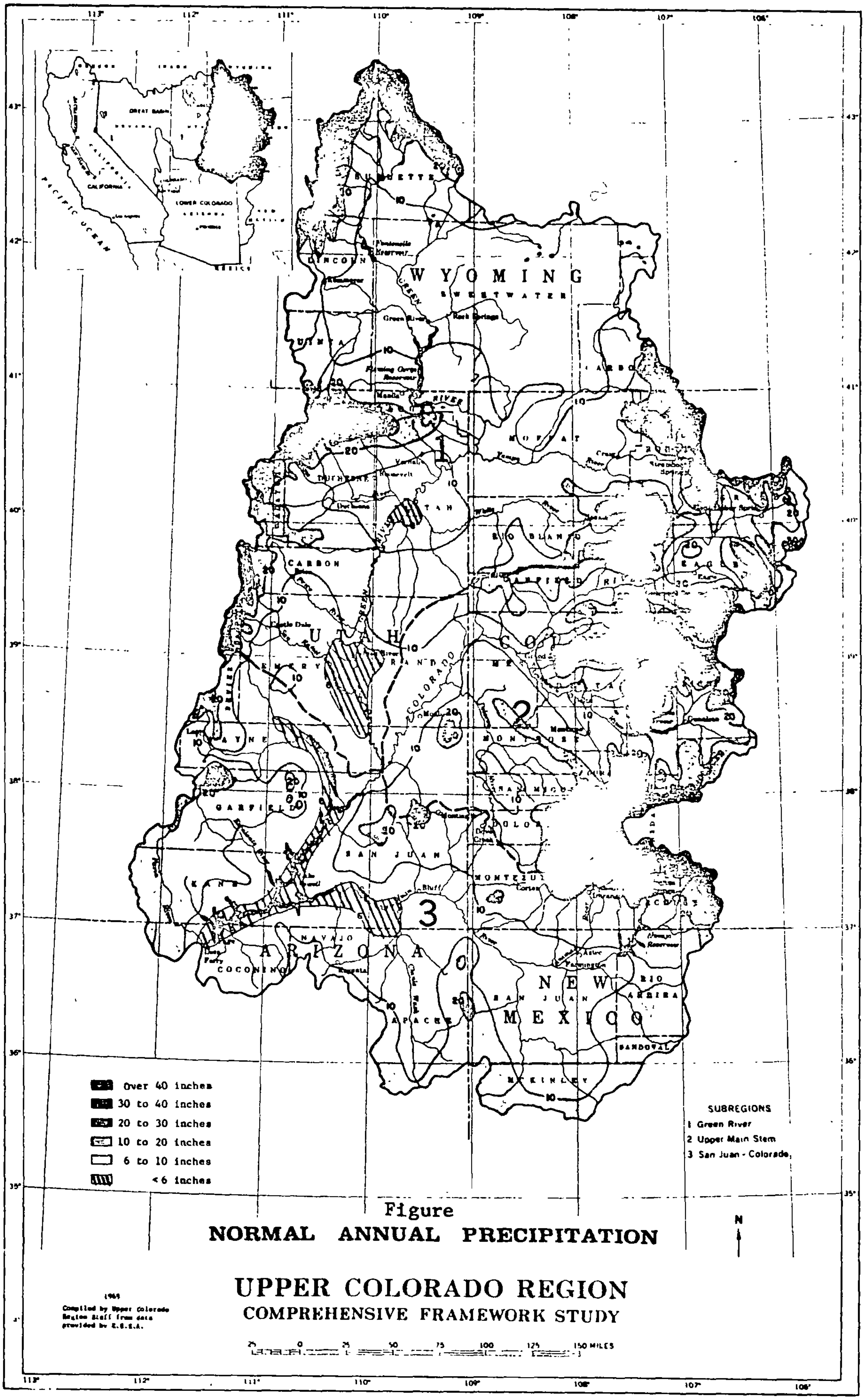
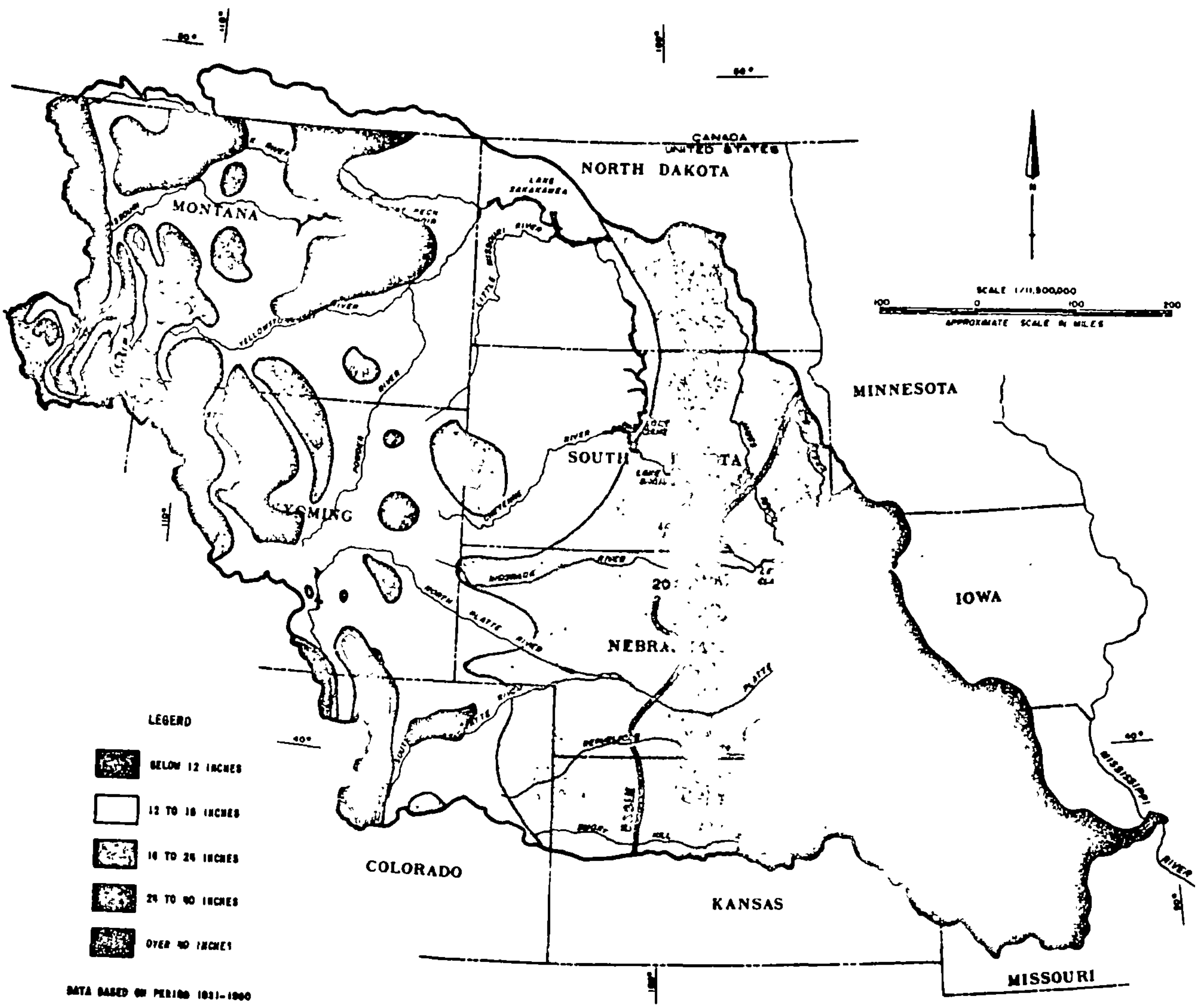

W Y O M I N G
U T A H
COLORADO
A R I Z O N A
N E W M E X I C O
Over 40 inches
30 to 40 inches
20 to 30 inches
10 to 20 inches
6 to 10 inches
< 6 inches
SUBREGIONS
1 Green River
2 Upper Main Stem
3 San Juan - Colorado
Figure
NORMAL ANNUAL PRECIPITATION
UPPER COLORADO REGION
COMPREHENSIVE FRAMEWORK STUDY
N
150 MILES

Figure 39 **AVERAGE ANNUAL TOTAL PRECIPITATION**



Missouri River Basin States

Impact of Chemical Fertilizers

The chemical composition of commercial fertilizers consists principally of nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O). These constituents are vital to good plant growth and high yield production. Present concerns on the impact of fertilizer on water quality within Region VIII focus upon nitrogen and phosphorus. The impact of potassium has thus far been minimal and no great concern over this nutrient as a potential pollution hazard has been expressed. All three nutrients are normal constituents of fertile soil.

Nitrogen

Of major concern is the possible entry of excessive amounts of nitrogen into surface and ground water supplies resulting in excessive nitrification of lakes and streams and contamination of public drinking water supplies.

Whether or not sufficient data exists to prove or disprove nitrogen and phosphorus from agricultural activity is causing any great alteration of surface and ground water supplies is a subject of continuing debate among many experts. According to Vietz (Bioscience Vol.21, No.10)..."although nitrate N from river water is of interest in relation to water quality standards, such analysis cannot be used alone to draw conclusions about fertilizer contribution of N, not even of nitrate to surface or subsurface drainage." On the other hand, Dr. Barry Commoner, in a 1968 address to the American Association of Agricultural Scientists in Dallas, cited an Illinois State Water Survey on the Missouri River that reported high nitrate levels and attributed them to farm use of fertilizers.

Phosphorus

Phosphorus is needed for plants to grow. It is a major component of the most widely used chemical fertilizer mixes and it is a major nutrient controlling the fertility of natural waters. Increases in phosphorus accumulations contribute to excessive growth of aquatic plants and blue-green algae with serious consequences as shown in studies by Sawyer (1947) and Verduin ('64, '67, '68, '69). The growth of algae and other aquatic plants is limited by phosphorus accumulations below 0.01 ppm, but concentrations of 0.05 ppm or higher may produce an excessive growth.

Phosphorus fertilizer is much less mobile in the soil since it is absorbed by soil particles. However, since phosphorus tends to be concentrated in the surface soil, it is susceptible to loss by erosion. Available evidence indicates that little fertilizer phosphorus leaks through the soil as inorganic phosphorus in solution but it can wash off as phosphorus absorbed on sediment. Thus, phosphorus additions to water bodies from farm lands are almost entirely associated with erosion. Phosphorus loss by this means is presently receiving considerable attention because of its influence upon the quality of our surface water supplies.

The hazard of phosphorus use on soils appears to pose fewer unanswered questions. Agricultural land, even woodland, contributes phosphorus to surface waters by erosion of soil, runoff of animal wastes, and leaching of phosphorus out of dead or burned vegetation. Phosphorus fertilizers can contribute to the enrichment of sediment, dung, and vegetation; but if phosphorus is needed to produce more vegetative cover and erosion is reduced, then phosphorus fertilization can reduce the amount of phosphorus carred on sediment. Water-soluble phosphates, such as superphosphate, are so quickly and tenaciously held to soil clays that there is little or no enrichment of the solution phase of the runoff. Lysimeter studies of leaching and analysis of tile effluents show that the losses and concentrations of phosphorus in the drainage are extremely low because of the soil's capacity to absorb phosphate (Taylor, 1967; Stanford et al., 1970). Leaching of phosphorus applied to organic soils may be greater because the phosphorus is less readily held and can move as soluble organic phosphate.

Biggar and Corey state, "Precipitation from the atmosphere (or by irrigation) is disposed of by 1) surface runoff; 2) ground water runoff (Interflow); 3) deep percolation; 4) storage; and 5) evaporation and transpiration. The first three of these can, and do, contribute to eutrophication by providing pathways fo nutrient movement to lakes and streams."

When nutrients percolate to the ground water, their movement to lakes and streams is dependent on ground water movement. Yet mixing of soil solutes with ground water and their subsequent movements are extremely complex and variable depending on the substrate and other factors. Biggar and Corey summarize: "Therefore, it is not safe to assume that nutrients derived from percolating waters will be diluted by the entire ground water mass prior to discharge into a lake."

Biggar and Corey state, "Runoff waters usually contain very little soluble inorganic nitrogen. In fact, the nitrate contents of runoff waters are usually lower than the average nitrate content of rain water. The first rain that falls sweeps most of the nitrate from the air and carries it into the soil."

"The relative concentrations of soluble phosphorus in surface runoff and soil percolates are the reverse of the nitrogen system. If phosphorus fertilizers were applied to the soil surface . . . the concentration of phosphorus in the runoff water might range up to a few tenths of a milligram per liter. In the water that percolates through the soil, the soluble phosphorus concentration is usually very low because the phosphorus precipitates in the subsoil. Therefore, most of the soluble phosphorus should reach the waterways via surface runoff."

"Nitrate is completely soluble in the soil solution and moves with it. Thus the soil percolates generally contain more nitrate than do surface waters. This nitrate eventually reaches the waterways unless the water emerges in a marsh, where it may be absorbed by the vegetation or reduced to gaseous nitrogen."

The movements of nitrates and phosphorus through the soil has been studied by numerous investigators, all in apparent agreement. Scalf, et al. (1968), found that the nitrate ion does not readily absorb but moves freely through aquifers, and there appears to be little denitrification occurring in saturated soils. Parizek, et al. (1967), found that phosphorus concentrations were reduced 99% during passage of sewage effluent through only one foot of soil.

Biggar and Corey cite Bertrand (1966) as having determined that in the great plains area, with an average of 20 inches of precipitation, about 18.8 inches are lost by evaporation and transpiration, 1 inch as surface runoff and 0.2 inches as percolate.

To calculate nutrient loss to surface runoff and ground waters is difficult at best. Lipman and Conybeare (1936) estimated nutrient loss in soils to erosion and leaching and found an average (and remarkably high) value of 52.0 pounds per acre per year of nitrogen and 12.17 pounds per acre per year of phosphorus lost to surface and ground waters. More recently Sawyer (1947) estimated the average loss of 6 pounds per acre per year of nitrogen and 0.62 pounds per acre per year of phosphorus to certain lakes in Wisconsin. Erickson and Ellis (1971) found that an average value for nitrogen and phosphorus losses from fertilized, non-irrigated farm lands of clay-loam soils to be about 10 and 0.1 pounds per acre per year, respectively. These farms applied about 140 poinds of fertilizer per acre per year. These investigators also estimated the amount of nitrogen fixed from the atmosphere to be 20 pounds per acre per year.

Irrigation greatly increases the amount of percolate and nutrient leeching.

Sylvester and Seabloom (1962) determined nutrient loss on irrigated lands in the Yakima Basin of Washington. Thirty-three pounds of nitrogen and 1.0 pound of phosphorus were estimated to be leached from an acre of irrigated, fertilized farm land to surface waters. These were the most conservative estimates.

Assuming all irrigated lands in the Rocky Mountain-Prairie states region to be fertilized, then estimates for nutrient inputs to surface waters can be calculated for the river basin drainages (Table 103).

Table 103

	North Dakota	South Dakota	Utah	Montana	Colorado
Fertilized Acres	7,855,000	3,473,000	297,000	3,019,000	1,518,000
Nitrogen Loss lb/yr	259,215,000	114,609,000	9,801,000	99,627,000	50,094,000
Phosphorus Loss lb/yr	7,855,000	3,473,000	297,000	3,019,000	1,518,000

Nitrates in Soils

Two recent reports (Ludwick, Ruess, and Giles, 1973) based on studies conducted by the CSU Experiment Station point strongly to the fact that considerable nitrogen is being carried over between cropping seasons in many fields. All districts samples averaged more than 100 pounds NO_3-N/A in the 3-foot sampled depth (Table 104). Fields in the Greeley District contained much higher levels than any of the other districts, averaging 290 pounds NO_3-N. Such a level is already excessive for sugarbeet production without the application of any additional nitrogen fertilizer.

High NO_3-N levels have likely resulted from a gradual accumulation over numerous years from applications of commercial nitrogen fertilizer and/or manure at rates somewhat above annual crop requirements. Considering the availability of feedlot manure in the Greeley district, it could be assumed that manuring has played a major role in this buildup. From the sugarbeet industry's standpoint, applications of excessive nitrogen are especially costly. Recent research data by the authors indicate that an accumulation of 100 pounds profile NO_3-N, in excess of that required by the crop for maximum root production, decreases actual percentage sucrose 0.85%

The relationshop of cropping history to NO_3-N levels is presented in Table 105. . Considering the relatively heavy fertilization of corn compared to pinto beans, it might be expected that NO_3-N levels would be much higher for those fields following corn. This, however, was not the case. Nitrate levels (distribution and total) are almost identical. Those fields following sugarbeets were considerably lower, averaging a total of 97 pounds per acre NO_3-N in the 3-foot depth compared to approximately 160 pounds per acre for the others. However, 97 pounds per acre NO_3-N carry-over still indicates available nitrogen levels were above optimum for the previous beet crop.

The purpose of sampling these fields by 1-foot increments was to evaluate the distribution of NO_3-N within the soil profile (0-3 ft.) and thereby determine the reliability of predicting profile nitrates based on analyzing only the surface 1-foot of soil. Overall, close to 50% of the NO_3-N was in the surface samples. The range encountered between factory districts was 42% for Eaton to 52% for Fort Morgan. The second and third foot depths contained progressively lesser amounts, with the exception of Ovid where the third foot averaged slightly higher in NO_3-N than the second. In all districts the third foot averaged somewhat over 20% of the NO_3-N, which in the case of the Greeley district represents 69 pounds per acre at this depth.

Good statistical relationships exist between the amount of NO_3-N contained in the 0-1 foot sampling depth compared to that in the 0-2 feet (r^2=0.89) and 0-3 feet (r^2=0.80) depths. This is partly due to the fact that the 0-1 foot measurement is also a component of the two deeper depths in the comparison and that close to 50% of the soil's NO_3-N is found in the surface foot.

Table 104
Soil nitrate nitrogen (NO_3-N) distribution in the 0-3 ft. depth prior to planting sugarbeets.

Factory district	Soil depth -- feet 0-1	1-2	2-3	Total
		lbs/A-ft.		lbs/A-3 ft.
Brighton (22)[1]	68	50	35	153
Eaton (26)	83	64	48	195
Ft. Morgan (82)	65	33	28	126
Greeley (22)	131	90	69	290
Kemp (50)	72	80[2]		152
Longmont (26)	90	52	45	187
Loveland (20)	62	42	30	134
Ovid (24)	59	29	31	119
Sterling (48)	66	37	28	138
All districts (320)	74	45	36	155

[1]No. of fields.
[2]Pounds in 1-3 ft. depth.

Table 105
Soil nitrate nitrogen (NO_3-N) distribution in 0-3 ft. depth following beans, corn, and sugarbeets.

Previous crop	0-1	1-2	2-3	Total
		lbs/A-ft.		lbs/A-3 ft.
Beans (65)[1]	76	47	37	160
Corn (147)	77	48	38	163
Sugarbeets (26)	51	26	20	97

[1]No. of fields.

Nevertheless, predictability is good and lends credence to the concept that NO_3-N analysis of surface samples gives fairly reliable information for formulating a nitrogen fertilizer recommendation. This is not to say that deep sampling should not be encouraged. Although overall relationships are good, there are individual fields which deviate greatly from the above discussed patterns (Table 106). In this study the prediction of NO_3-N content of the 3-foot soil depth, based on analyzing only the surface foot, was within 50 pounds of the true value for 82% of the fields and within 100 pounds for 97%. Prediction for 10 fields (3%) was in error by more than 100 pounds, and for nine of these it was an underestimate of the true soil content. An underestimate results from a NO_3-N accumulation in the lower soil depths not reflected by analysis of the surface foot. Such accumulations can significantly reduce sugar content and post nitrate pollution hazards.

A contributing factor to excessive use of fertilizers could quite possibly be that modern equipment makes it easier to spread and easier to haul large quantities. This observation was made in an interview with Dr. John Reuss, Associate Professor of Agronomy, CSU.

Dr. Reuss discussed a recent comparative analysis of residual nitrates in field plots in Colorado that were to go into sugarbeet production. These plots were selected by random sample method and were not biased by controlled selection methods (Table 107).

The high ratings possibly resulted from residual nitrates due to previous heavy applications of manure. Where plots were located near feedlots this seemed to be the pattern. Common practice seems to be to get rid of the manure and consequently very heavy applications are made in nearby fields. The addition, subsequently, of commercial fertilizer applications tends to compound the situation.

Table 106
Deviation of predicted nitrate nitrogen (NO_3-N) based on analysis of 0-1 ft. from that found by analysis of the entire 0-3 ft. depth.[1]

Deviation NO_3-N, lbs/A	No. of fields	Percent of fields	Cumulative deviation, percent
0-25	178	55.6	55.6
25-50	85	26.6	82.2
50-75	34	10.6	92.8
75-100	13	4.1	96.9
100-125	5	1.6	98.5
125-150	4	1.2	99.7
150-175	1	0.3	100.0

[1] $Y_{(0\text{-}3\ ft.)} = 3.77 + 1.91X_{(0\text{-}1\ ft.)}$

Table 107

Comparative Summary of Field Plots - 1973
Colorado

Site No.	Cooperator	Location	Factory District	lbs NO_3 - N 0-5	Profile	Ft.
1	Pratt	Burlington	Kemp	597.6	622.1	6'
9	Agron. Farm	Ft. Collins	Loveland	332.1	367.0	6'
2	Brooks	Eaton	Eaton	258.5	293.4	7'
3	Leffler	Eaton	Eaton	238.7	262.4	7'
8	Amen	Longmont	Longmont	241.6	254.2	6'
6	Peterson	Lucrene	Greeley	169.2	203.4	7'
14	Worley	Holyoke	Sterling	153.7	174.9	7'
15	Crosentino	Ft. Lupton	Brighton	91.1	93.3	6'
7	Alberts	Ft. Lupton	Brighton	82.8	83.2	6'
10	Dunn	Kersey	Greeley	50.7	74.4	7'
13	Poitz	Yuma	Ft. Morgan	31.0	33.2	7'
5	Peppler	Longmont	Longmont	26.0	33.9	6'
4	Morita	Pierce	Eaton	19.9	19.9	5'
11	Bishop	Burlington	Kemp	16.7	16.7	5'
12	Penny	Burlington	Kemp	7.0	7.0	5'

Until a relatively few years ago, commercial fertilizer application in Colorado was below recommended rates. However, after educational efforts were initiated to inform farmers of this situation, more fertilizer was applied. Many began over-applying fertilizers, however.

Nitrogen pollution potential increases greatly as the application rate of nitrogen exceeds the true crop need for near maximum yield. At rates of N needed to produce near maximum yield measured pollution is relatively low. Many good field trial results showing yield data are available. The Kern Sugar beet and Kern Potatoes figures (California Agriculture Extension Service publication Soil and Water Summer 1973 - No. 18) illustrate this point. These figures were drawn from data developed by a group from the Agricultural Extension and Experimental Station investigations of nitrogen losses below crops by means of suction probes placed in a below-the-root system of potatoes and sugarbeets (Figures 40 & 41)

Figure 40

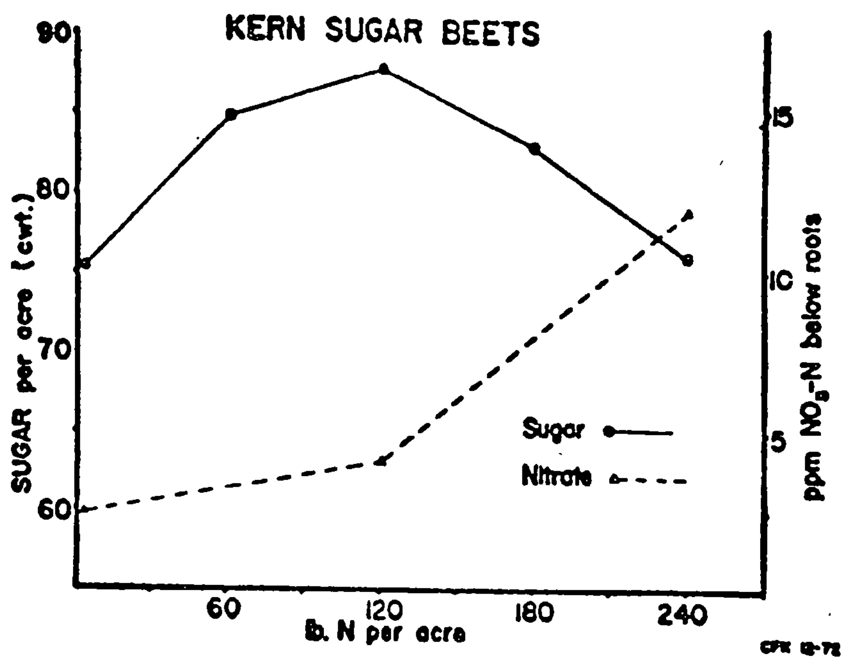
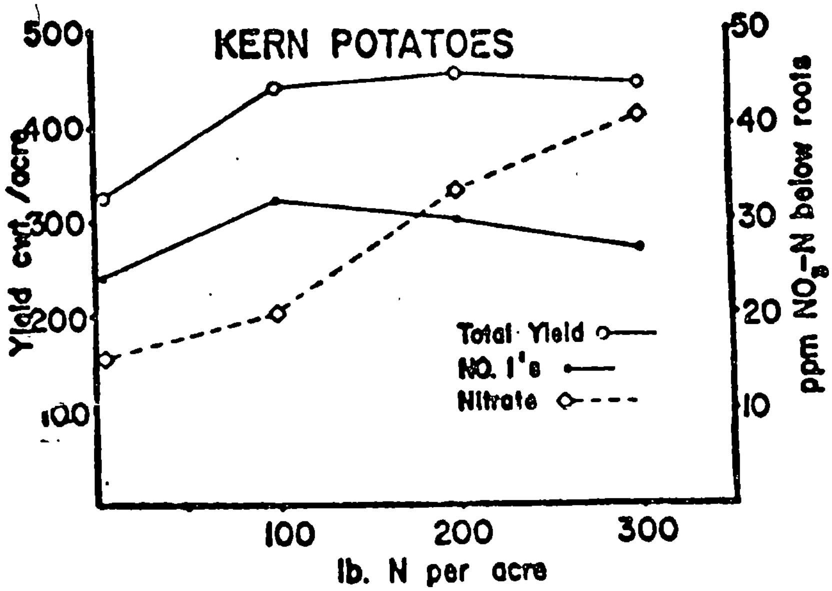


Figure 4.12



Very few data, though, are available where actual pollution potential has been measured. Hopefully, if the above nitrogen-yield-pollution potential relationship holds, fertilization guidelines as presently used will protect water quality of drainage waters moving to underground water supplies.

Influence of Suppliers

There is considerable concern among Region VIII agronomists as to the degree of influence exercised by suppliers of commercial fertilizers over the user. It has been noted that many farm soil samples are collected by the suppliers' representatives and presented for analysis to selected labs. Labs dependent upon the repeated business of the fertilizer manufacturer are suspected in some instances to have provided analysis recommending fertilizer use rates in excess of what is actually needed.

Another factor is that soil analysis labs are not required to be registered. There is no certification process regulating the labs and hence little control over the quality of the analysis being made.

Water Supply Impact on Fertilizer Consumption

In 1965 a study conducted by R. L. Anderson and L. M. Hartman at Colorado State University focused on changes in crop selection, yields, water application, and fertilizer application practices as induced by increased water supply resulting from the completion of the Colorado Big Thompson Project. Heavier fertilizer applications on crops became general in the area during the period when supplemental water was introduced on the farms surveyed (150 farms made up the sample).

It is hazardous to say what proportion of increased fertilization was due to supplemental water and what proportion was due to changing practices which were general throughout the area.

Changes in Fertilizer Use

Item	Before C-BT	After C-BT	Change
Farms using (%)	42	91	49
Average Acres fertilized	53.1	88.5	35.4
Fertilizer applied per acre available N and P_2O_5)			
Sugarbeets (lbs/acre)	78.4	144.2	65.8
Corn (lbs/acre)	43.8	85.5	41.7
Dry beans (lbs/acre)	33.0	61.5	28.5
Alfalfa (lbs/acre)	55.2	73.6	18.4
Barley (lbs/acre)	37.8	39.4	1.6
Wheat (lbs/acre)	--	71.5	71.5

The farmers surveyed made substantial changes in fertilizer use during the period of adjustment of more irrigation water. Before the Project 42% of the farmers were using some fertilizer; by the early 1960's, 91% were using fertilizer. Average acres fertilized increased from 53 acres per farm to 88.5 acres.

Notable changes occured in fertilizer practices on a number of specific crops. Less than 10% of the farmers raising barley and alfalfa were using commercial fertilizers early in the 1950's, but 30% were using it during the 1959-1961 period.

Table 108
Use of fertilizer before and after C-BT water on survey farms, NCWCD, Colorado, 1951-1953 and 1959-1961.

	Farms using fertilizer								Farms not using fertilizer	
	Before C-BT water				After C-BT water					
	no.	percent	Avg. crop acres	Avg. no. crops	no.	percent	Avg. crop acres	Avg. no. crops	no.	percent
Area I	9	31	38.9	1.4	26	90	111.8	2.5	3	10
Area II	26	53	55.1	1.6	46	94	89.0	2.4	3	6
Area III	22	50	58.4	1.9	42	95	81.6	2.4	2	5
Area IV	6	21	46.3	1.5	23	82	73.8	1.6	5	18
TOTAL	63	42	53.1	1.7	137	91	88.5	2.3	13	9

Table 109
Fertilization practices on 150 survey farms before and after C-BT water, NCWCD, Colorado, 1951-1953 and 1959-1961.

	Percent of farms fertilizing		Average acres fertilized		Available nitrogen per acre		Available phosphate per acre		Average fertilizer per acre	
Crop	Before	After	Before	After	Before	After	Before	After	Before	After
	percent		acres		pounds					
Barley	9	30	39.9	35.1	7.1	24.7	30.7	14.7	37.8	39.4
Alfalfa	6	31	22.2	32.4	...	13.8	55.2	59.8	55.2	73.6
Corn	19	69	31.5	46.4	28.0	53.7	15.8	32.5	43.8	86.2
Beans	*	21	10.0	34.2	33.0	26.3	...	35.2	33.0	61.5
Sugar-beets	46	79	34.0	35.7	22.4	50.3	55.9	92.1	78.3	142.4
Wheat	...	28	...	47.0	...	33.4	...	38.1	...	71.5
Pasture		25	...	51.6	...	68.8	...	42.2		111.0
Oats	9	15	30.0	13.7	42.9	26.6	61.8	62.4	104.7	89.0
Potatoes	25	60	15.0	18.3	60.5	72.5	30.0	136.8	90.5	209.3
Peas		13	...	40.0	...	66.0	...	22.5		88.5
Onions	100	100	10.0	18.5	66.0	57.6	92.0	107.8	158.0	165.4

*One farm.

The number of farmers fertilizing corn increased to 69% from the previous 19%. The proportion of the farmers fertilizing sugarbeets increased from 46% to 79% between the two periods.

Farmers fertilized 3.6 times as many acres during the 1959-1961 period than before the C-BT water was available. In addition to fertilizing more acres, the farmers interviewed were using heavier applications of fertilizer per acre.

Average nitrogen applications rose from 7 pounds per acre to 24 pounds on barley, from 28 to 53 pounds on corn, and from 22 to 50 pounds on sugar-beets.

Impact on Air and Water

It is almost impossible to pinpoint with any degree of accuracy the impact on air or water of commercial fertilizer applications in any of the Region VIII states. Since a variety of crops are produced (Table 109), fertilizer mixes in various combinations are applied depending upon crop, soil conditions, availability of water, and the experience and knowledge of the farmer. In Colorado alone, more than 200 combinations of mixes are purchased and applied annually ranging from grade 0-35-0-20 to 34-3-7 (Table 110).

How much of these materials and/or fertilizer components end up in water supplies, soil residuals, or are lost through sediment runoffs or other means to the environment has never been fully determined nor is it likely to be in the very near future.

One could speculate that where corn and sugarbeets are the predominant crop in Colorado (Northeast and East Central regions) that higher risks of fertilizer pollution exists. But one would have to look very closely at irrigation rates, sediment runoff problems, soils types and so on to support with any vigor this hypothesis.

As Viets points out (Fertilizer Technology and Use, 1971) "only N and P are receiving much attention as being of pollution significance. Although other elements contained in fertilizers have occasionally been low enough in water to limit activity of photosynthetic organisms, the cases are rare. Micronutrients added in fertilizers may be toxic if they get into water, but only two, Mo and B, have sufficient mobility in soil to have much significance.

In relation to N and P, 129 cores representing non-irrigated fields in native grass, cultivated non-irrigated fields, irrigated fields in alfalfa, and corrals were obtained from mortheastern Colorado during the period of April 26 through the week of August 8, 1966 (Stewart, Viets, Hutchinson, Kemper, Clark, Fairborn, and Strauch, 1967).

This study found that usually small accumulations were contained in

Table 110

COLORADO FERTILIZER SALES BY GRADES AND MATERIALS

Compiled by the Feed and Fertilizer Section, Colorado Department of Agriculture, Denver, Colorado, from tonnage reports submitted by manufacturers.

GRADE	TONS			GRADE	TONS		
	7-1-71 12-31-71	1-1-72 6-30-72	7-1-71 6-30-72		7-1-71 12-31-71	1-1-72 6-30-72	7-1-71 6-30-72
0-35-0-20	29	4	33	9-6-3	65	188	253
1-0-0	19	31	50	9-18-9		30	30
1-1-1	32	1,763	1,795	9-27-9		14	14
1-11-0	1	9	10	9-30-0	26		26
3-18-0		92	92	9-46-15		2	2
3-18-18		4	4	10-4-4		24	24
4-0-0		161	161	10-4-6		11	11
4-8-8	1	2	3	10-4-7		25	25
4-10-10	5	26	31	10-5-5	14	143	157
4-12-12	1	5	6	10-6-4	142	740	882
4-13-11	35	22	57	10-7-4	3	12	15
4-13-17		1	1	10-8-7		4	4
5-1-1		2	2	10-10-5	6	120	126
5-9-7	1		1	10-10-10	18	15	33
5-10-5	1		1	10-12-6	2	5	7
5-10-10		14	14	10-12-8	1		1
5-10-15	3	6	9	10-16-8	6	2	8
5-15-0	4		4	10-20-20	7	9	16
5-15-5	1	2	3	10-30-10	50	21	71
5-15-10	56	47	103	10-33-0	54	62	116
5-15-15		30	30	10-34-0	2,767	7,682	10,449
5-20-10		5	5	10-50-0	61		61
5-35-7	62	204	266	10-52-17		8	8
5-35-10		2	2	11-2-2		9	9
6-4-0		350	350	11-4-7	30		30
6-6-6		3	3	11-5-6	325	289	614
6-6-8	1	1	2	11-8-8		24	24
6-9-5	3	4	7	11-15-20	1	1	2
6-10-4	1,307	131	1,438	11-27-0		45	45
6-10-6		1	1	11-37-0	84	1,134	1,218
6-10-8		9	9	11-48-0		75	75
6-12-6	2		2	12-0-0	291	337	628
6-18-6		1	1	12-4-4	19	67	86
6-24-24		2	2	12-4-8		73	73
7-6-19		2	2	12-6-6	3	9	12
7-9-5	1	1	2	12-8-4	5	1	6
7-21-7	436	928	1,364	12-10-0		48	48
7-28-14	1	1	2	12-10-4		7	7
8-0-0	351	1,008	1,359	12-12-4	3	45	48
8-8-8	16	19	35	12-12-12		134	134
8-12-4	3	10	13	12-16-4		11	11
8-14-6	1		1	12-16-14	6		6
8-24-8	100	553	653	12-24-12	46	609	655
8-25-5	161	59	220	12-31-14	1	1	2
8-32-4		5	5	13-13-13		7	7

Table 110 (Continued)

GRADE	TONS 7-1-71 12-31-71	1-1-72 6-30-72	7-1-71 6-30-72
13-34-10	7	54	61
13-52-0		283	283
14-0-0		25	25
14-3-3	3	9	12
14-4-6		1	1
14-14-14	7		7
14-26-0		46	46
14-28-7	9	70	79
15-0-0	2	159	161
15-5-0		23	23
15-5-5	2	67	69
15-6-4	5	30	35
15-7-3		11	11
15-10-5	3	97	100
15-10-8		8	8
15-15-15	13	15	28
15-18-0	40		40
15-20-0		185	185
15-22-0		70	70
15-25-10		3	3
15-30-0		8	8
15-30-15		117	117
15-39-9		43	43
15-42-6	5	6	11
16-4-8		27	27
16-8-4	1	1	2
16-8-8	5	74	79
16-8-10		4	4
16-10-4	219		219
16-10-5	7		7
16-11-3		2	2
16-11-13	6		6
16-16-8	207	66	273
16-20-0	246	4,400	4,646
16-20-4		10	10
16-20-6	306	110	416
16-21-5	9	36	45
16-48-0	1,478	1,922	3,400
17-0-0	38	3	41
17-3-4		5	5
17-5-5	1	17	18
17-10-5		10	10
17-11-15		2	2
17-12-4	11	59	70
17-43-0		53	53
18-3-3	7	22	29
18-3-5	3	2	5
18-4-4		12	12
18-4-5	2	34	36
18-8-10		23	23
18-10-3		80	80
18-10-5		15	15
18-10-7		2	2
18-18-0	2	145	147
18-20-4		20	20
18-24-6	28	91	119
18-24-8		8	8
18-24-16		2	2
18-25-0		160	160
18-36-6		56	56
18-46-0	11,772	48,776	60,548
20-0-0	16	1	17
20-3-3	2	1	3
20-4-8	3	25	28
20-5-5	502	1,073	1,575
20-6-6	40	141	181
20-10-5	623	1,697	2,320
20-10-10	29	18	47
20-20-10	85	272	357
20-20-20	3	4	7
20-30-10	4	11	15
21-4-4	16	114	130
21-6-0	5		5
21-6-11	6	6	12
22-4-4	49	277	326
22-5-5	269	688	957
22-6-3		2	2
22-7-14		76	76
22-10-10	10	28	38
22-12-4		22	22
22-20-10	1		1
23-7-7		8	8
23-18-6	1	1	2
23-19-17	8	24	32
24-5-3	5	3	8
24-8-0	56		56
24-8-12		2	2
24-12-0		5	5
25-5-3	174	530	704
25-5-5	22	37	59
25-5-20	2	1	3
25-7-7	6		6
25-10-5	2		2
25-10-10	1	6	7
25-15-10	18		18
25-25-0		16	16
27-6-5	1	7	8
27-14-0	106	158	264
30-0-0	3	18	21
30-3-10	11	12	23
30-5-3	10	5	15
30-10-0	87	646	733
30-10-10		7	7
30-15-0		5	5

Table 110 (Continued)

GRADE	TONS		
	7-1-71 12-31-71	1-1-72 6-30-72	7-1-71 6-30-72
32-0-8 ---	2	1	3
32-5-3 ---	9	4	13
34-3-7 ---		10	10
Miscellaneous	469	697	1,166
TOTAL MIXED	23,870	81,801	105,671

Table 111

MATERIALS	TONS		
	7-1-71 12-31-71	1-1-72 6-30-72	7-1-71 6-30-72
Anhydrous Ammonia -------------	21,180	32,762	53,942
Aqua Ammonia ------------------	157	2,928	3,085
Ammonium Nitrate --------------	10,670	21,639	32,309
Ammonium Sulfate --------------	3,754	29,279	33,033
Nitrogen Solutions ------------	12,639	13,979	26,618
Urea & Urea Forms -------------	775	2,946	3,721
Superphosphates ---------------	202	8,052	8,254
Diammonium Phosphate ----------	167		167
Ammonium Phosphate ------------	167		167
Phosphoric Acid ---------------	7	6	13
Nitrogen Phosphates -----------	122		122
Triple Superphosphates --------	3,884	4,725	8,609
Muriate of Potash -------------	1,637	7,825	9,462
Sulphate of Potash ------------	570	2,576	3,146
Sulphate of Potash-Magnesia ---	359	939	1,298
Gypsum ------------------------	16	21	37
Sulfur ------------------------	279	1,472	1,751
Zinc Sulphate -----------------	844	1,459	2,303
Iron Sulphate -----------------	46	103	149
Manganese Sulphate ------------		306	306
Sewage Sludge -----------------	155	352	507
Calcium Nitrate ---------------	66	2,815	2,881
Calcium Sulphate --------------	1,576		1,576
Ammonium Thiosulphate ---------		1,568	1,568
Bone Meal ---------------------		16	16
Blood Meal --------------------		5	5
Miscellaneous Materials -------	945	1,493	2,438
TOTAL STRAIGHT MATERIALS ------	60,217	137,266	197,483
GRAND TOTAL MIXED FERTILIZERS AND MATERIALS --------------	84,087	219,067	303,154

non-irrigated fields indicating some leaching of nitrate. This even though rainfall averages only about 15 inches per year. The native grass fields did not show, as a rule, nitrate accumulation in the profile. Significant quantities of nitrates were found in most cores taken from irrigated fields being cropped with row crops or cereal grains. On the other hand, cores obtained from irrigated alfalfa fields generally contained none (less than 0.5 ppm) or insignificant amounts of nitrate.

(The same report made reference to the increased consumption of fertilizers. "Use of commercial fertilizers, mainly on irrigated lands, has been steadily increasing. In Colorado as a whole, commercial fertilizer nitrogen sales on an elemental basis have increased almost five-fold in the last decade -- from 7,041 tons in 1965 to 38,682 tons in 1964. In six counties in Northeastern Colorado, constituting about half the area studied, commercial fertilizer nitrogen use in five years almost doubled from 9,216 tons in 1959 to 17,009 tons in 1964. There is no evidence of general excessive use.") Figure 42 shows where core samples were taken.

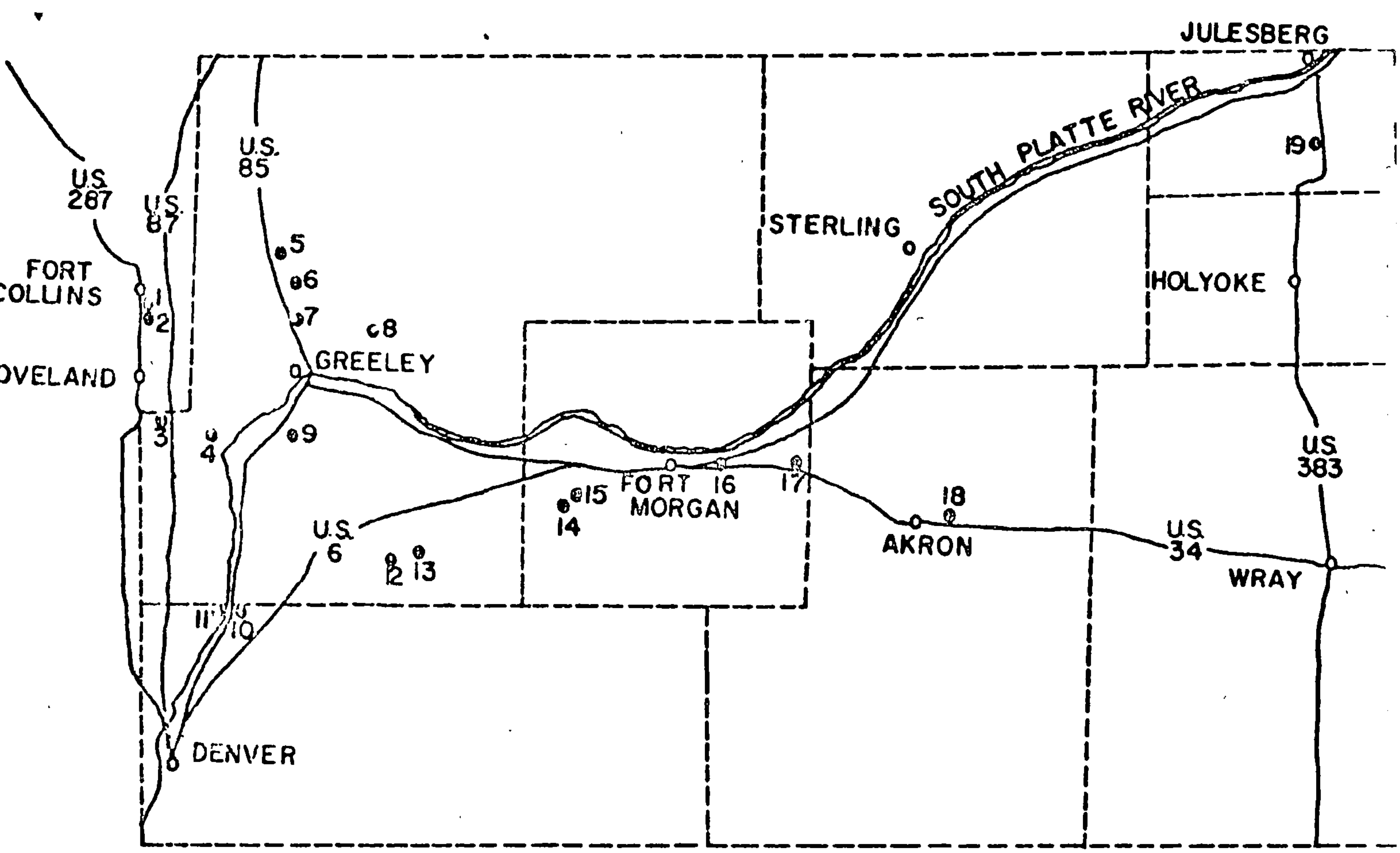


Figure 42--Northeastern Colorado, showing the locations (Nos. 1 to 19) where cores were taken.

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FERTILIZER CONTROL TECHNOLOGY

Currently Recommended Technology and Managerial Practices for Reducing Pollution from the Use of Fertilizers

Alternatives available for controlling pollution and for reducing environmental destruction caused by fertilizer use are not plentiful. Those that are available relate closely to plant physiological aspects in crop production and improvement in fertilizers application. They include slow-release fertilizers, timing of fertilizer application, levels of fertilizer use related to crop requirements, and improved methods of application.

Slow-Release Fertilizer

There is growing interest in the utilization of slow-release fertilizers as a means of minimizing some of the adverse effects on the environmental quality resulting from repeated applications of commercial fertilizers, especially nitrogen fertilizer. The feasibility of this approach has been demonstrated through laboratory, greenhouse and experimental studies.

Slow-release fertilizers are developed primarily to increase the efficiency of nutrients used by plants. In terms of plant physiology and crop quality, efficiency can be defined as nutrient recovery and economics of use. Allison (1966) reported that only 50-60 percent of nitrogen fertilizer applied to soil is recovered by crop plants, according to the results of long-term field and lysimeter studies. While reported values for crop uptake of fertilizer phosphorus and potassium during a single season generally vary between 5-25 and 40-70 percent, respectively, factors contributing to these incomplete recoveries are a result of rapid dissolution of the applied fertilizer, and thereby, release of the nutrient at high concentration. From the viewpoint of plant physiology, slow-release fertilizers ideally should supply nutrient to the soil solution at a rate and a concentration which allow the growing plant to maintain maximum expression of its genetic capability. Thus, the development of fertilizer having slow release of nutrients will enable more complete utilization of nutrients by plants.

Several advantages, from the viewpoint of improving fertilizer nutrient recovery by crop plants, are cited for slow-release fertilizers. They are (a) reduction of nutrient loss through leaching and runoff, (b) reduction of chemical and biological reactions in soil which cause fertilizer nutrient to remain in unavailable form to plant, and (c) reduction of rapid nitrification and nitrogen loss through ammonia volatilization and denitrification (Hauck and Koshino, 1971). Clearly, if plant use of nutrient can be improved by accurate control of nutrient supply, then control of release is desirable.

Most of slow-release fertilizers are designed to delay or reduce the rate of nutrient delivery to the soil solution. There are four types of slow-release materials: (1) water-soluble materials containing plant-available forms of nutrients where dissolution is controlled by a physical barrier, e.g. by a coating; (2) materials of limited water solubility which during their chemical and/or microbial decomposition release nutrients in plant-available form, e.g. the ureaforms; (3) materials of limited water solubility and plant-available forms, e.g. metal ammonium phosphate; and (4) soluble or relatively water-soluble materials which gradually decompose, thereby releasing their nutrients, e.g. guanylurea salts. The rates of release for all types of materials can be further modified through use of chemical additives, such as nitrification inhibitors, which affect microbial activity.

Many experiments, both laboratory and greenhouse, have demonstrated that nitrification inhibitors, under certain conditions, can reduce nitrogen loss and increase crop yields. This has also been demonstrated in field experiments.

Alexander (1965) listed many inhibitors and summarized the literature on their use. Turner and Goring (1966) examined the value of N-SERVE in relation to N fertilization of cotton, sweet corn, spinach, sugarbeets, sugar cane, and rice. They also provided information on formulation, storage, and application of fertilizers amended with nitrification inhibitor. They concluded that yield and nitrogen content of several crops could be increased by the use of nitrification inhibitor. Chemical inhibitors to delay oxidation of ammonia to nitrates and nitrites was suggested by Black (1968). In general, the inhibitors appeared to be more effective at temperatures below 21°C and much less effective at temperatures up to 32°C. Studies by Huber and associates (1969) in Idaho and Janssen and Wiese (1969) in Nebraska support these conclusions.

Slow-release fertilizers are still receiving research emphasis. They are generally experimental fertilizers from which fertilizing agents are released slowly over a period of time. They are not produced as fertilizers on a commercial scale. A product patented by the Archer Daniels Midland Co. (license now held by Sierra Chemical Co.) is the only coated nitrogen fertilizer know to be produced commercially. However, the use of this fertilizer has been limited to nonfarm use such as ornamentals and in turf grass formulation. Sulfur-coated urea currently is the slow-release nitrogen product of this type being tested most extensively. Some interest in the coated phosphorus, potassium, and mixed fertilizers has been also developed. Products tested include those coated with sulfur studies by Mamaril (1964); urea-formaldehyde by Smith (1964); asphalt by Hall and Baker (1967); and calcium carbonate, calcium sulicate, Portland cement, or rock phosphate by Raupach (1968). No difficulty is expected in the development of coated, mixed fertilizers except for mixes high in ammonium nitrate content and particles with highly irregular contours.

Few studies have been reported for the use of slow-release fertilizer materials in vegetable production. Usually, intensive vegetable production requires that large amounts of fertilizer be applied to insure adequate levels of nutrient at all growth stages. However, vegetable crops have been used as test crops. For example, Heilman and associates (1966) reported cabbage for evaluating resin-coated ammonium nitrate; Dilz and Steggerda (1962) indicated spinach for testing oxamide.

There is growing interest in finding efficient and economical slow-release nutrient sources for use in forests, forest nurseries, fruit trees, and other tree crops. White (1965) showed that soluble salts encapsulated in polyethylene can safely be placed in direct contact with pine and spruce seedling roots. Usage of such capsules makes possible slow-release fertilizer for periods 1 to 6 years, depending on the physical and chemical characteristics of the capsule.

Dahnke and associates (1963) reported that in the greenhouse experiment, more nitrogen fertilizer was recovered by corn forage from "coated" than from "uncoated" ammonium sulfate, but yield from both materials were similar. However, one application of sulfur-coated urea produced as much grain as three applications of uncoated urea. Lunt (1968) also reported that under leaching conditions the use of sulfur-coated urea obtained substantially higher yields and more nitrogen was taken up than from uncoated urea.

Slow-release fertilizers, mainly nitrogen, have been on the market for some time in the U.S. Slow-release fertilizers are used almost entirely on ornamentals and in turf-grass formulation. They are produced in small amounts commercially, but are only a very small fraction of an estimated 3.3 million tons of soluble fertilizer produced for nonfarm use. Approximately 50,000 tons of ureaform are produced on the market yearly. Small amounts of Isobutylidene Diurea (IBDU) have been included in fertilizer for use on golf greens for 6 years in the U.S. and this fertilizer material is now produced commercially as a slow-release fertilizer for use on home lawns. The potential for increased use of slow-release materials for nonfarm purposes is expected. However, the practicability and economy of large-scale use on U.S. farms are still in question.

Current costs of slow-release fertilizers can be considered high. Estimated cost of producing the fertilizer is 25 to 50 percent higher per unit of slow-release fertilizers than the uncoated version. However, the real costs of slow-release fertilizers cannot be obtained solely from production costs. They must be obtained by considering factors such as improved crop quality, labor savings, and convience of using, among others. These factors are much more difficult to evaluate in an economic sense although the amount of literature about slow-release fertilizers is growing, little information is available on the large-scale use of such fertilizers in practical agriculture due to high cost of production, hence none has been able to show that the benefits would equal the added cost. Thus, it is too early to evaluate slow-release fertilizers on the basis of a cost-benefit ratio at present stage of development of slow-release fertilizers. But, this may well change in the years ahead. Breakthroughs in mass production of slow-release fertilizers can be anticipated that will both lower their production cost and improve their effectiveness through changes in the technology of fertilizer production. Effects of changes in technology of fertilizer production will bring users to the point where adequate returns can be demonstrated in wider segments of U.S. agriculture to offset the additional production cost. This likelihood is exaggerated when one considers that modern farming will eventually become more sophisticated and that labor cost will continue to increase.

Timing of Application

Recent research indicated that leaching nitrates below the rooting zones of plants can and does occur in soil. It also points out that leaching nitrates below the rooting zone of plants may be more prevalent on sandy soils under irrigation than on heavier textured soils during summer when evapotranspiration is greater than precipitation. In late fall (or under fallow) and early spring when soils are not frozen, movement of nitrates downward within the soil profile occurs, and some may eventually reach underground water supplies and hence contribute potential pollution. Therefore, better knowledge about fertilizer distributions to crops at different times during the year would be useful to minimize losses of nitrogen and moderate potential pollution. To achieve this end, nitrogen should be kept to a minimum during the colder months of the year or in the absence of a crop, and fertilizer nitrogen should be added in amounts which allow for, but do not greatly exceed, the amounts needed for efficient crop production. Our present advanced technology can be utilized to make more effective utilization of fertilizer in crop production. Thus, timing and placement of fertilizers must be adjusted to maximize efficiency of utilization of crops, on the one hand, and to minimize potential pollution by leaching and erosion, on the other hand.

In general, farmers want to handle a minimum of fertilizer at or near planting time, hence, part of the seasonal requirement of low mobility nutrients may be applied prior to plowing or soil preparation. Fertilization is one job that can be partially completed before spring planting for many crops and soils. This will lead to an important saving in time and labor.

Since nitrogen fertilizer in the nitrate form moves freely in the soil, it requires more careful management to assure an available supply throughout the entire growing season. As nitrogen fertilizer is the first limiting nutrient and the required rate is greatest for many of our important crops, timing and placement must be adjusted so as to achieve a maximum efficiency of utilization of fertilizer by the crop.

A study of leaching losses of nitrogen made by Brown (1965) concluded that leaching losses increase with increasing rates of nitrogen application. As farmers continue to increase the use of nitrogen fertilizers, the question arises as to the comparative value of fall, spring and summer fertilization of corn with nitrogen and the associated environmental danger. The pollution potential from nitrogen fertilization must be carefully considered, since it is subject to loss through several mechanisms. If the nitrogen is in the nitrate form considerable leaching may result. In addition, wet conditions cause appreciable nitrogen loss through denitrification.

A study of the movement of nitrate nitrogen in soil profiles made by Olsen and associates (1969) indicated that more leaching of nitrate nitrogen occured between fall and spring than during the growing season and more under fallow than cropped conditions.

In reviewing the timing of fertilizer applications, Viets (1971) reported that fall application of ammonial fertilizers should be avoided until the soil has cooled below 45°F at the 4-inch depth in order to slow the nitrification rate. Nitrogen fertilizer application in the fall should be avoided in view of the potential pollution hazard.

Voss (1972) reported research on the timing of fertilizer applications in Iowa and Illinois. He concluded that: (1) time of nitrogen applications does not appear critical in most of Iowa; (2) areas with wet soils in the spring may show an advantage for preplant or sidedress applications according to Illinois data. He recommended that choice of time and method of nitrogen fertilizer application and materials should be a management decision within a producer's corn production system. Available labor for each individual related to size of operation, crop sequence, tillage practices, soils, pest problems, average and expected weather conditions, etc., should be taken into consideration and the practices of fertilization fit into his crop production system.

Morris and Jackson (1959), Doll (1962), Laughlin (1963), and Welch and associates (1966) have reported lower yields of crops other than corn, when nitrogen fertilizer was applied in the fall than when it was applied in the spring.

Generally, both phosphorus and potassium can be applied preplant in the fall or whenever soil conditions permit, providing erosion losses are avoided by soil incorporation or use of crop residues and cover crops. Some caution is advised for potassium on deep sandy soils where leaching of potassium may occur.

A large part of phosphorus and potassium and frequently some nitrogen fertilizers are usually applied just prior to tilling or plowing the soil for the crop to be grown. This operation may be started shortly before planting or as much as 6 months prior in the case of plowing the land in the fall. These applications are frequently supplemented with small amounts of fertilizers placed in or near the row at the time of planting in order to furnish a source of readily available nutrients for the young seedlings during the early part of the season.

On coarse-textured soils in Minnesota, Dr. J. M. MacGregor (1973) indicated the advantage of timing the nitrogen fertilizer applications to when the crop has a demand for it as shown in Table 112.

Table 112. Advantage of Timing N Applications.

Total N applied Lb/A	Dates	Lb N/A per application	Corn yield bu/A
0		--	43
100	applied at planting (5/11)	100	92
100	applied at planting (5/11, 6/11, 7/11, 8/11)	25	154
200	5/11 - at planting	200	158
200	5/11, 5/26, 6/11, 6/26, 7/11, 7/26, 8/11 and 8/26	25	192

More intensive management of our pasture programs will have a positive influence on fertilizer consumption. Fertilization can be an economical way to increase grouping rates and thereby increase herd size. Most pasture plants need nitrogen, phosphorus, and potassium. Grasses are big users of nitrogen and yields will be low if this nutrient is inadequate. A study of better pasture with fertilization by Schaller and Voss (1970) indicated that the best time to apply nitrogen fertilizers on pastures is influenced mainly by the growth pattern of the grass, and to a lesser degree, by the need for pasture and convenience of application. They pointed out the following findings of the study: (1) for cool season grasses, namely, blue grass and tall grasses, adequate nitrogen must be available during two periods of best growth, from May to about mid-July and from mid-July through August, for top grass yields; (2) when you increase grass production by fertilization, you must be prepared to use the forage about the time it is produced; (3) the best time to make a single nitrogen application at a moderate rate would be early spring before major growth starts, but fertilizer could be lost if the snow melts rapidly and runoff occurs; (4) single application also can be made in early August or late fall before the ground freezes (early August application will boost fall growth and provide some carryover to spring, however, late fall application will boost growth the following spring); and (5) for a "high rate-split application program," the first application of 80 pounds of nitrogen on blue grasses or 120 pounds on tall grass should be made in early August so as to stimulate fall growth and boost grass vigor for a fast start the following spring. The second application should be made about early June.

Most studies indicate that with certain precautions phosphorus and potassium can be applied in the fall with very little, if any, loss of nutrients.

Improved Methods of Application

Methods of fertilizer placement, processes in nutrient uptake by plants, effects of placement on soil and on soil-plant relations, effects of temperature on nutrient uptake, and placement in relation to root distribution and moisture should be reviewed carefully to improve effective use of chemical fertilizers. Thus the technological improvement of fertilizer application will improve utilization of fertilizer and thereby minimize pollution potential.

In an analysis of new trends in fertilizing corn, Barber (1969) asserted that application methods of fertilizer for corn should be re-evaluated due to radical changes in corn fertilization. The following points were raised in his study. In the northern Corn Belt, where farmers are applying 150-200 lbs. N/acre per year for corn, the fertilizer can be applied any time between late fall and a month after planting. Nitrogen fertilizer should be applied 6-10 inches deep to avoid loss.

The biggest changes have occured in the application of phosphorus fertilizer. In one study 50 lb P_2O_5/acre with application 2 inches to the side and below the seed gave a 10-bushel increase. The same amount broadcast and plowed under gave a 14-bushel increase. The increased yield occured because the phosphorus in the row was only available during the first 4 weeks, while most of the plant's need for phosphorus occurs in the remainder of the growing season. Only low rates of application, such as 10-50 lb. P_2O_5/acre, should be applied near the row at planting time.

Theoretically, phosphorus fertilizers should not be applied very far in advance of seeding the crop. Since soluble phosphorus changes to less-available forms in the soil, the effectiveness declines with time between application and the time the crop needs it.

Regarding the methods of application for potassium fertilizer, it can be applied as a band or broadcast with about equal efficiency. It may be broadcast in fall, winter, or spring and can be applied once every two years but it should be applied as a plowdown instead of disked into the surface.

Fertilizer nitorgen and crop rotation in relation to movement of nitrate nitrogen through soil profiles were studied by Olsen and associates (1970). Results indicate: (1) total amount of NO_3-N in the soil profiles was directly related to the rate of nitrogen application and to the frequency of corn in rotation; (2) more leaching of NO_3-N generally occured between fall and spring samplings than during the growing season: and (3) the most effective methods indicated for limiting the amounts of NO_3-N passing through the soil profile to the water table include: (a) limiting rates of nitrogen fertilizer to approximately that required by the crop, (b) reducing the acreage and frequency of corn or other crops that receive fertilizer nitrogen in the rotation, and (c) maintaining a crop cover on the land as much of the time as is feasible.

Anhydrous ammonia and ammonia solution are agronomically equivalent to other nitrogen fertilizer sources but must be applied according to the following rules formulated by Pionke and Walsh (1968) in order to minimize chances of crop damage and ammonia loss.

1. Anhydrous ammonia and ammonia solution must be applied below soil surface to minimize physical loss of ammonia. Apply anhydrous ammonia at least 6 inches deep under most conditions and at least 8 to 10 inches deep in dry loam, silt loam or clay loam soil. Apply ammonia solution 2 to 4 inches deep. Do not, under any conditions, apply either anhydrous ammonia or ammonia solution to dry sandy soil.

2. Do not apply anhydrous ammonia or ammonia solution to stony or wet, heavy-textured soil or soil with unbroken corn stalk residue at the surface. Such conditions prevent proper closure of the application slit and allow substantial ammonia loss. With sidedress applications under these conditions, plant damage almost always occurs.

3. To avoid leaching loss, do not make a preplant application of

nitrogen fertilizer to sandy or sandy loam soil in fall or spring. To avoid denitrification loss, do not apply nitrogen fertilizer on poorly-drained or periodically flooded soil in fall.

Limit fall application of anhydrous ammonia and ammonia solution to moderately well-drained to well-drained loam, silt loam or clay loam soil at temperatures below 50 degrees. In a normal year, soil reaches this temperature after late October in southern South Dakota and all of Wyoming and in mid-October in northern South Dakota, North Dakota, and Montana.

4. In spring, incorrect preplant application of anhydrous ammonia may later damage germinating plants. To minimize this hazard, apply it 5 inches below the planting depth of the seed.

5. All except extremely dry soil can be tilled 1 to 2 days after anhydrous ammonia or ammonia solution application without substantial ammonia loss.

6. When anhydrous ammonia or ammonia solution is applied in spring, plant at right angles to the direction of fertilizer application.

Research work has shown the advantage of plowing down both phosphorus and potash for crops to minimize environmental pollution when water runoff occurs. Research work on a soil low in phosphorus and very low to low in potassium is shown below in Table 113.

Table 113. Methods of application of phosphorus and potassium for corn.

Fertilizer applied lb/A		Method of application	Corn yield bu/A
P_2O_5	K_2O		
0	0	---	55
60	0	disked in	53
		plowed down	55
60	80	disked in	103
		plowed down	113

Research in North Dakota has shown that row or starter fertilizer often produced very profitable responses even though fair amounts have been broadcast and plowed down.

Stewart and associates (1968) observed that little nitrate was present under alfalfa fields and grasslands to depths of 20 feet. Where the water table is within this depth, some nitrate may even be removed from the water table.

Erosion losses of nitrogen are mostly associated with the selective removal of organic nitrogen compounds in the erosion debris. Therefore, to minimize losses of nitrogen and reduce potential water pollution, erosion control practices should be included in soil management. According to Amemiya (1970), practices for erosion control are designed to do one or more of the following: (1) reduce runoff velocity, (2) dissipate raindrop impact forces, (3) reduce quantity of runoff, and (4) manipulate soils to enhance the resistance to erosion. The important relationship between soil erosion and tillage methods has been reported by many investigators.

The importance of fertilizers and a sod-based rotation in reducing erosion losses from clay pan soils in Missouri was observed by Whitaker (1961). He found that erosion from corn in a sod-based rotation was only 60% of that from continuous corn.

Sod crops and crop residues left on soil surfaces during non-cropping seasons can also reduce erosion as will minimum tillage.

Timmons and fellow researchers (1968) conducted a definitive study on the loss of crop nutrients through runoff in Minnesota. They found that the loss of both total nitrogen and total phosphorus was much greater on southern Minnesota land in cultivated fallow or continuous corn than land in a three-year rotation containing a hay crop. Their data illustrates widely accepted fact that the high loss of nutrients in solution in runoff from alfalfa was in the corn-oats-alfalfa rotation. They also found that this high nutrient loss occurred in the spring runoff of snowmelt water that leaches nitrogen and phosphorus from the frozen alfalfa plants. This discovery suggests that concentration of soluble nutrients, particularly phosphorus, may be high in spring runoff from land in grass or legumes, even though soil losses are minimal. Holt and associates (1970) discussed this possibility in detail.

A study on loss of phosphorus by erosion of a Hartsells fine sandy loam on two- to four-percent slopes in Alabama was reported by Ensminger (1952). He found that unfertilized plots in a crop-cotton rotation lost 43 pounds

Table 114. Total nutrient content of runoff and sediment from five systems on plots 23.9 miles long on Barnes loam with 6% slope, during 1966 and 1967.

Cropping Treatments	Total N		Total P	
	Runoff	Sediment	Runoff	Sediment
	Kg/ha per year			
Fallow	2.27	62.6	0.06	0.34
Corn - continuous	0.35	12.7	0.07	0.11
Corn - rotation	0.81	4.1	0.07	0.04
Oats - rotation	0.22	5.2	0.01	0.03
Alfalfa - rotation	3.33	0.2	0.22	0.00
Rotation average	1.46	3.1	0.10	0.02

Source: Timmons et al., 1968.

of phosphorus, while nine plots fertilized with phosphorus from various materials over the 16-year study period had an average loss of 172 pounds. He further observed that in a similar rotation with winter legumes following cotton, phosphorus losses for comparable treatments were 25 and 147 pounds.

Brage and associates (1951) reported that a long rotation of root crops, grain and 1 to 3 years in hay increased the amounts of carbon and nitrogen in the soil, but did not increase yields.

Levels of Fertilizers Used Related to Crop Requirements

There is general feeling that chemical fertilizers can be applied so that potential pollution is no problem, provided erosion can be controlled.

To minimize movement of nutrients by runoff water, fertilizer must be incorporated into the soil during or soon after application. Adjustment of application rates to plant needs may be required to prevent unused fertilizer from being leached into groundwater and tiles. Nitrogen fertilizer recommendations suggested by Fenster and associates (1969) are based on the nitrogen requirement of a crop for maximum efficient production, efficiency of utilization of nitrogen fertilizers used, and nitrogen-supplying capability of the soil via release of nitrogen from the organic nitrogen pool. A number of recent research projects are attempting to determine what constitutes an acceptable application rate for fertilizer that will both sustain crop production and minimize environmental pollution. Therefore, the environmental quality factor will have to be brought into the formulation of responsible recommendations.

Many studies have been done in obtaining valuable information helpful in assessing the amount of nitrogen fertilizer required in a particular situation. A new and promising approach to this problem has been suggested by Stanford and associates (1965) and Stanford (1966). They pointed out that in the case of crops like sugarcane, potatoes, or malting barley where surplus nitrogen reduces quality, it should be the minimum requirement for maximum production of a product of acceptable quality. They found that overapplication of nitrogen fertilizer to sugarcane in Hawaii caused sugar losses.

A study done in Missouri by Smith (1968) recommended that application rates be limited to maximum yield requirements. This would be approximately 100 pounds of nitrogen per acre, unless nitrates were being leached into groundwater supplies.

Stout and Burau (1967) reported that when irrigation waters from surface wells containing nitrates are used, cropland management recommendations can be developed to include the amounts of nitrogen which will be supplied with the irrigation waters.

One of the nitrogen recommendations suggested by Fenster and associates (1969) is based on the efficiency of utilization of nitrogen fertilizer used. Cook (1969) suggested that use efficiency of nitrogen, which averaged less than 50%, must be increased in the years ahead through reduction in loss of nitrogen by leaching. He also indicates that promising research was underway in the following areas: (1) the control of ammonia oxidation and other reactions in soils, (2) the decomposition of urea, (3) higher analysis and more readily available compounds of phosphorus reacted with ammonia, (4) pelleting of fertilizers to control solubility rates and with the seed for immediate utilization, and (5) agronomic control by plant analysis with subsequent and immediate application of fertilizer if needed by aerial top-dressings or perhaps in irrigation waters. It should be noted that different soils, climates, and cropping systems would have to be given individual research attention.

According to Iowa crop rotation data, one year of a good alfalfa stand has provided enough nitrogen for first-year corn to maintain a five-year average of 120 bushels per acre. Some other data suggests that a good alfalfa stand of more than one year may provide up to 130 pounds equivalent of nitrogen fertilizer to first-year corn. Nitrogen fertilizer response data for continuous corn systems, conducted on experimental farms in and next to Iowa, show the effect of weather and soils. These data furnish a basis for checking and adjusting current nitrogen application rate suggestions and for understanding factors affecting response of corn to nitrogen fertilizer.

Suggested fertilizer needs for present crop production practices made by Duncan (1970) are shown in Table 115. The range in the suggested rates takes into account soil differences and, to a lesser extent, anticipated yields. These levels of nutrients from commercial fertilizers, manure, crop residues, etc. should be adequate for most farms on all except very low fertility soils. Increasing these nutrient levels will not necessarily increase crop yields

Table 115. Suggested Nutrient Levels for Minimizing Pollution, Pounds/Acre.

Crop	N	P_2O_5	K_2O
Corn for Grain	120-160	40-80	10-80
Soybeans	0	20-50	0-40
Oats	20-60	10-40	0-20
Alfalfa Hay	0	40-80	40-110
Tall Grass	20-160	10-40	10-40

Source: Voss, 1971.

and may create additional pollution potential. Recent research at midwestern universities reveals that fertilizer rates for different crops on silt loam soils indicated in Table 115 do not pose a significant pollution potential for groundwater, nor an enrichment problem in surface waters when they are properly used.

A rule of thumb for application rates on continuous corn to produce profitable yields and still be environmentally safe, would be one pound of nitrogen fertilizer for each bushel of yield potential or productivity on specific soils. Barnes (1972) presented evidence to support this approach.

To determine fertilizer application rates, it is important to know that all three elements, nitrogen, phosphorus, and potassium, are in the right proportions. A proper balance between the amount of available nitrogen, phosphorus, and potassium is needed for best plant growth. Fertilizers that contain the right mixture of elements can be bought to fit soil needs. Soil tests can be used to indicate what fertilizers are needed. However, soil tests do not include methods or timing of fertilizer application. Neither does it indicate the form of a nutrient that may be most desirable to apply. This information must be obtained with field studies in addition to correlation studies to determine critical levels of nutrients.

On most soils in the central part of the U.S., the level of available phosphorus, as measured by soil tests, gradually rises under such a system, particularly if the initial level is low. When soil tests are high, rates of fertilizer should be cut back so that proper levels are maintained. Low rates are generally used when capital is limited, and the aim is to obtain maximum returns per dollar spent for fertilizer.

Schaller and Voss (1970) conducted research on better pastures with fertilization. Regar'ing rates of nitrogen application, their suggestions range from 60 to 240 pounds of nitrogen per acre, depending on factors such as the need for forage, grass variety, the thickness of sand, kind of grazing management, and moisture supply. They concluded that (1) 60 to 120 pounds of nitrogen fertilizer per acre is considered a moderate rate and should be applied as a single application; (2) additional nitrogen up to double the above rate can be used, but as a split application: (3) the higher fertilization rates should be considered if you need forage, are practicing some type of rotation grazing, and if the moisture supply looks favorable; and (4) applying high annual rates of nitrogen in at least two applications is safer, allows better use of the nitrogen fertilizer and more total yield for the year.

Suggested annual phosphorus and potassium application rates for Kentucky bluegrass and the tallgrasses are based on soil test levels. If a soil test is not available, use the very low or low test values at least the first year of application. Then test your soil and adjust accordingly. In any case, soil should be tested every three to four years. You may find phosphorus and potassium levels will increase after a few years of fertilization, and the annual rates can then be reduced. Rates for the tall grasses are 10 to 20 pounds per acre higher than bluegrass because the tallgrasses yield more.

Suggested annual application rates for phosphorus and potassium for legume-grass pastures are shown in Table 122. Phosphorus rates are the same for legume-grass pastures as for tallgrasses. But the potassium rates are ten pounds higher at each soil test level for the legume grasses. This is because legume grasses require more potassium than tallgrasses.

The economic phase is concerned with how to minimize the unit cost of the crop produced by the proper selection of nutrients that are needed by the crop on the specific soil on which it is to be grown. Cate and Vettori (1968) reported that many of the commercial farmers around the world invest about 10 to 15 percent of their gross income in fertilizer and lime. Either applying a nutrient not needed or omitting a nutrient that is needed results in increasing the unit cost of the crop produced. Cate (1969) indicated that the optimum rate of fertilizer application would be that which results in the minimum unit cost of the product. When the price of the product is high and the demand is great, then the rate of application may be extended beyond that giving the minimum unit cost.

CONCLUSIONS AND RECOMMENDATIONS

SUMMARY OF MANAGERIAL PRACTICES AND RESEARCH NEEDS

Programs are required that maximize fertilization benefits and minimize environmental pollution, particularly in localities where nutrient contamination may be excessive.

Control of excess nutrients arising from fertilizer application rests ultimately on a better understanding of the movement and ultimate fate of these materials. Data obtained from monitoring nutrient concentrations in distinctive and important agricultural areas and forests could be used to assess the relative importance of the fertilizer contribution to the nutrient problem. Clarification of nutrient transportation and deposition mechanisms may furnish new leads to control.

Additional information on the potential danger of excess nitrogen accumulation in food plants, water, soil, and air would provide an assessment of the emphasis that should be placed in each area. Better knowledge of the fate of liquid-ammonia applications along with nitrogen contamination of the environment resulting from fertilizer distribution at different times during the year also would be useful.

Existing technology can be utilized to make more effective use of fertilizer in crop production. The improvement and application of information on predicting nutrient content and availability in soils to determine the need for supplemental fertilizer application and on crop and fertilization management programs that minimize the release of nutrients to receiving waters could result in meaningful reductions in nutrient contamination of the environment.

There are also opportunities to treat or remove plant nutrients from surface or subsurface water. Progress has been made in developing techniques for removing trace elements from sewage and industrial wastes. The diffuse sources of nutrients from agricultural operations makes the application of these techniques more difficult, but there are situations where water treatment or removal may be appropriate, for example, in irrigation return flows.

Improved knowledge of the effect of nutrients on the growth of algae and noxious water plants could lead to control through maintaining nutrient content of the water below growth-promoting levels. Methods might be developed for rendering nutrients unavailable for plant growth in receiving waters. Means might be developed for preventing the release of nitrogen and phosphorus from sediments. Biological and chemical control of algae and other water weeds may be feasible under some conditions. Microorganisms (plant disease), insects, snails, higher animals, and herbicides might be used to prevent excessive growth of water plants.

In recognizing that control of water plants may not always be feasible, opportunities for their utilization as food or feed or other useful products should be pursued. Even if successful methods are developed for eliminating nutrients from receiving waters, present concentrations and attendant plant growth will persist for considerable periods of time. This is further justification for efforts in this area.

The following areas merit principal attention in combatting the excess nutrients problem.

1. <u>Behavior and fate of applied nitrogen, phosphorus, and other nutrients</u>

In the Department of Agriculture, most of the research on the behavior and fate of applied nutrients has been directed toward determining the most effective use of fertilizer applications. Studies have included experiments on (a) yield response of crops to increasing rates of fertilization; (b) correlations of yield response or nutrient uptake with soil analyses as a basis for developing reliable soil testing methods to aid in predicting optimum fertilization levels; (c) time and frequency of fertilizer application to define means of obtaining the most efficient use of applied nutrients; and (d) determining sources of nutrients most appropriate for different soil areas, crops and management systems. Associated laboratory investigations have revealed some of the fundamental relations between chemical properties of soils and behavior of applied nutrients under different climatic situations.

One of the least understood aspects of nitrogen fertilizer behavior concerns the part of applied nitrogen that is lost to the atmosphere in gaseous forms, e.g., as elemental nitrogen gas or gaseous oxides of nitrogen. The extent to which gaseous losses occur under field conditions, owing to chemical or biological mechanisms operating in the soil, and the significance of such losses in alleviating nitrogen pollution of ground water are unknown. Clarification of this problem may provide avenues for (a) improving fertilizer-use efficiency and (b) controlling or manipulating gaseous losses to minimize opportunities for ground-water contamination.

The Environmental Protection Agency has directed efforts to determine the impact plant nutrients have on drinking water supply and public health. Information and technology are being generated by--

(a) Epidemiological studies of water quality and disease
(b) Studies of the behavior and control of contaminants in surface waters
(c) Investigation of health parameters applicable to reclaimed waste waters

Another study involving surveillance of drinking-water quality includes many quality constituents that are contributed by agricultural pollution.

Because of the deleterious effects of nutrients on water quality, the Department of the Interior has an extensive in-house and extramural program to determine the fate, behavior, and availability of the numerous forms of nutrients in receiving waters. The Department also has extensive programs to determine the effects on food-chain productivity, which in turn affects fish productivity, and on the fate of nutrients resulting from irrigation practices.

2. <u>Minimizing runoff and percolation of nutrients by using them more effectively</u>

Existing authorizations are adequate for the Department of Agriculture to conduct research and action programs in this area. Information on nutrient runoff in relation to soil type, slope, crop management, and storm characteristics has been derived from small-plot field installations. More recently, larger scale watershed studies have begun to include measurements of nutrient losses as an incidental part of the more detailed studies of soil and water movements occurring within the watershed. Information on downward percolation of nutrients, particularly nitrate nitrogen, is being obtained from vertical profile samplings under fertilized fields and feedlots.

With increasing use of fertilizers, the opportunities for nutrient losses and the probability that such losses will occur also increase. More information is needed about the behavior of nutrients in soils under high fertilization for action effective in minimizing losses with various systems of farm and forest management involving different levels of fertilizer use.

The Department of the Interior has programs in irrigation practices, concerned with their effect on uptake or runoff of plant nutrients.

3. <u>Controlling, treating or removing excess plant nutrients from surface or subsurface drainage to maintain the desired quality of receiving waters</u>

Research and action programs in the Department of Agriculture largely have involved development and establishment of systems for controlling entry of contaminated waters into lakes and other bodies of water, e.g., terracing, diversion ditches, grass waterways, and ponds. Existing authority has been adequate for these programs.

In the future, increasing emphasis may be given to developing means of reducing the nutrient concentration in drainage water before its release into the receiving body. Use of the nutrient-absorption properties of soil itself or of synthetic ion exchangers has undergone extensive research. Long-term projections might even envision application of desalinization methods involving low-cost power. USDA envisions that additional authorization would be required for providing financial assistance to put into action some of the schemes for nutrient removal or water treatment that might evolve from concerted research efforts in this area.

The Environmental Protection Agency in its activity to assure the Nation safe drinking water standards maintains a continuing surveillance of drinking-water quality. Many of the quality constituents are contributed by agricultural pollution, including plant nutreints. Closely associated with this effort is research and development activity to determine the behavior and means of controlling contaminants in surface waters.

Because of its mandate to insure the quality of receiving waters, the Department of the Interior has extensive programs to minimize and remove significant amounts of nutrients released to these streams, rivers, etc. Advantage is being taken of the large program in preventing and abating nutrient contributions from municipal and other industrial sources for application to problems associated with irrigation.

4. Effects of nutrients on algae and noxious water plants

The limited current efforts in research by the Department of Agriculture in this area are directed toward determining nutrient requirements of these organisms. The Department anticipates that expanded research on algae would be coordinated with studies on the nutrient composition of water in relation to sources of such nutrients. Involved, for example, is the question of the limiting or critical phosphorus concentrations for algal growth and the role of sediment-borne phosphorus in supplying this element. Action and research phases relating to control of algal growth would be concerned with (a) suppressing algal growth in water potentially capable of supporting noxious levels and (b) keeping nutrient concentration below the levels considered to be critical for growth.

The Department of the Interior is concerned with the deleterious effect of algal growths and aquatic weeds on water quality as well as in the operation of water-resource developments. In order to determine and develop realistic water-quality standards for nutrient concentrations in receiving waters, it is necessary that the Department determine the temporal quality-quantity relationships of the nutrient-algae regime. Accordingly, a large part of the in-house program and a significant part of the extramural research is included in this area.

5. Use of harvested algae and other water plants

One method that has been suggested for lowering the nutrient content of water involves growing algae to consume nutrients, followed by harvesting the algae or other water plants. Such an approach is worthy of further study, provided economic means of utilizing the harvested product can be devised. Some research is underway in the Department of Agriculture on using algae as an animal feed supplement. Further research is needed to evaluate the intrinsic value of algae in animal nutrition in relation to their biochemical components and to determine in feeding trials their value as a supplement to low-protein feeds. Harvesting and processing methods for algae also will require research and development.

The Department of the Interior considers the extraction of algae from the water cycle as one of many water-treatment methods for nutrient removal. In-house and extramural projects are directed toward developing process systems to effectively implement this concept. As in other treatment processes, the solid residue, in this case the algae, must be either digested or converted to useful products. Research in this area indicates the latter approach could be economically justified.

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LAND DISPOSAL: SLUDGE AND MUNICIPAL SEWAGE

Rapid population increases in the Rocky Mountain-Prairie Region combined with an increasing rise in living standards results in a very large increasing rate of waste generation. This fact, combined with the "no pollutant discharge" concept of the seventies is causing many local civic servants and wastewater treatment managers to consider land disposal as a viable alternative. The July, 1973 edition of the Water Pollution Control Federation Journal contained a special feature on this renewed interest in land disposal presenting both pros and cons.

As for utilization of land for wastewater disposal, the concept is quite old, dating back well over 100 years. In the Rocky Mountain-Prairie Region the concept has been employed in several communities for a number of years. Hutchins (1939) reported on 113 communities in the western U.S. which were using sewage for irrigation purposes in 1935. Most of these communities were in California and Texas. Those listed in the Rocky Mountain-Prairie Region were Greeley, Colorado; Anaconda, Helena, and While Sulphur Springs, Montana; Brigham, Richfield, Salt Lake City, and St. George, Utah; and Cheyenne, Wyoming. Rapid City, South Dakota; Denver, Colorado; and Ogden, Utah were irrigating with sewage diverted from public stream channels.

Thomas (1973) in reviewing Hutchins (1939) and Hutchins (1972) statistics notes that most of the localities listed by Hutchins in 1935 also appear in the 1972 survey. This situation indicates that a substantial number of southwestern communities have practiced irrigation of crops with wastewater continuously for more than 37 years (Thomas, 1973).

Magnitude of Land Disposal

A more recent statistical review by Jenkins (1970) shows that the total number of wastewater treatment systems applying effluent to land is increasing in the U.S. In 1940 there were 304 systems applying wastewater to land while in 1972 there were 571 systems. The population served increased from 0.9 million to 6.6 million.

Looking specifically at the Rocky Mountain-Prairie Region, Table116 presents Jenkins' results. This indicates that Colorado and Wyoming currently contain the majority of land disposal of wastewater.

Table 116 . Municipalities Using Land Application and Population Served by States, Rocky Mountain-Prairie Region, 1968 (Jenkins, 1970).

State	Number	Population Served
Colorado	10	165,250
Montana	4	2,550
North Dakota	5	3,325
South Dakota	--	--
Utah	1	100
Wyoming	5	15,895

Thomas (1973) notes that the data reported in the surveys may be surfeit since the method of reporting differs from survey to survey. Also a discrepancy appears to exist in Utah since there is only one system listed while in 1935 there were 5. If Hutchins' (1972) data is accurate in stating that a substantial number of communities have operated on land disposal for 37 years, some systems were apparently overlooked by Jenkins. Thomas (1973) indicates this is the case.

A very recent survey of land application of wastewater effluents in the Rocky Mountain-Prairie Region by Dean (1973) is very enlightening. Dean was primarily interested in sites utilizing spray irrigation or overland flow or ridge and furrow irrigation. The survey included six industrial and 37 municipal sites. The breakdown of the total number of sites per state is given in Table 117 with the systems categorized as operating, under construction, planned, or seriously being considered.

Table 117. Rocky Mountain-Prairie Region Sites (Dean, 1973).

State	Operating	Under Construction	Plans & Specs	Serious Consideration	Total
Colorado	10	2	8	3	23
Utah	4	2	--	--	6
Montana	2	2	1	2	7
Wyoming	1	1	1	1	4
North Dakota	1	--	--	1	2
South Dakota	1	--	--	--	1
Total	19	7	10	7	43

This 1973 data indicates some of those listed by Jenkins (1970) in his 1968 survey have discontinued operations. Tables 118 and 119 contain Dean's (1973) description of land use of the sites and year each site was placed, or planned to be, in operation, respectively.

Table 118 . Distribution of Sites by Land Use. (Dean, 1973)

Golf	14	Landscaping	5
Crops		Pasture	4
Hay and Grass	6	Forest	1
Alfalfa	2	Undecided	4
Natural Vegetation	7		

Table 119. . Years Sites Placed in Service (Dean, 1973).

Date	No. of Sites	Date	No. of Sites
1951	1	1970	2
1958	1	1971	1
1959	1	1972	2
1960	1	1973	7
1964	2	1974	10
1967	1	Future	12
1969	2		

Dean (1973) noted from his survey that the most common (18 responses) reason given for choosing land application of secondary effluents was that the water was already owned by the user and that it was suitable for a secondary use such as golf course irrigation. The second most common (15 responses) reason was to avoid direct discharge to a stream. Of the 43 sites surveyed, five reported some problem with odors. Algae became a problem in some lakes on golf courses.

The average area of a disposal site in the Rocky Mountain-Prairie Region where the effluent is used for irrigation was listed by Dean (1973) as: (1) Golf - 107 acres, (2) Crop/Pasture - 92 acres, (3) Recreational area - 516 acres, and (4) other - 30 acres. Ten of the areas had a sandy loam soil type, six had a sandy soil, four a loam, three a clayey loam, and one a clay soil. The others were not known. A solid set irrigation system below ground was by far the most popular irrigation system (25 areas). Three areas used an above ground solid set system; three had a portable system; two had a movable boom; and two had overland flow. The irrigation rates were quite variable.

With respect to sludge disposal, Jenkins' (1970) statistics presents some interesting results. For the U.S., sludge drying beds were reported for 6,046 plants or about half the total 12,565 plants. Nearly 4,500 plants reported not having dewatering or other organized drying methods. The breakdown for the Rocky Mountain-Prairie Region is shown in Table 120 . Of the 1,177 plants processing sludge, 634 or 54% have no sludge dewatering or other organized drying methods. The statistics do not say what these plants do with their sludge.

Table 120 . Summary of Sludge Processing by States for the Rocky Mountain-Prairie Region, 1968 (Jenkins, 1970).

States	Sludge Processing - No. of plants with--								
	Septic Tanks	Imhoff Tanks	Stage Digestion	Separate Digestion	Sludge Beds	Lagoons	Mech. Dewatering	Misc.	None
Colorado	13	19	14	42	73	1	1	7	124
Montana	9	5	9	9	19	2	2	--	101
North Dakota	9	20	1	1	14	--	--	2	195
South Dakota	--	43	5	13	48	5	4	4	127
Utah	11	7	15	23	39	1	3	1	22
Wyoming	9	6	2	7	11	--	11	3	65
Totals	51	100	46	95	204	9	21	17	634

The editors of Wastes Engineering (1962) performed a survey of consulting engineers and State Pollution Control Agencies and found that disposal of liquid digested sewage sludge to open land is very common among smaller waste treatment plants. Burd (1968) states that liquid sludge disposal will continue to be popular at small plants because it offers many advantages. MacLaren (1961) considered land disposal of liquid sewage sludge to be applicable to all plants serving less than 50,000 persons. From this it is possible to assume that most of the smaller plants in the Rocky Mountain-Prairie Region currently use land for ultimate disposal of sewage sludge. This is definitely the case for Northeastern Colorado (Schuyler, 1973).

For the larger municipalities or urban areas, the resources available offer additional opportunities for disposal of sludge. Denver burned its sludge until air pollution problems prevented this. Denver is now returning their sludge to the land. Colorado Springs puts some of their wastewater on parks and golf courses. Bauer (1961) presented engineering design data and operating results of the effluent reuse at the Air Force Academy.

Beyond the Rocky Mountain-Prairie Region, two studies are gaining renewed interest in light of the current thought about using land for sewage disposal. These are the Chicago work with on-land disposal of sewage sludge and the Muskegan County, Michigan work with using wastewater to irrigate land. Dalton and Murphy (1973) discuss the Chicago work while Egeland (1973) reviews the Michigan efforts. Each of these projects has earned favorable comments and criticism.

This (based on existing information) very briefly describes the on-land disposal of municipal sludge and wastewater operations in the Rocky Mountain-Prairie Region. An excellent description of how wastewater sludge is utilized on land is presented by the Water Pollution Control Federation (1971). Rather than repeat the description here, the reader is referred to this publication.

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ON-LAND DISPOSAL TECHNOLOGY: SLUDGE AND MUNICIPAL SEWAGE

On-land disposal of municipal sewage or sludge can occur on the surface, in the upper few inches of the soil, or it can be "buried". Sewage disposal, as surveyed by Dean (1973), almost always occurs on the surface either through spray irrigation or overland flow or ridge and furrow irrigation. Septic tank systems of land disposal are below the surface. Sludge disposal is currently associated with all the above techniques, with no one technology having been proven better than the others. Here, as with sewage effluent disposal on land, a debate rages as to which is the better technology. The technologies will be briefly reviewed here and the debate left to the references (Egeland, 1973; Thomas, 1973; Davis, 1973; and Dalton and Murphy, 1973). For additional references, Law (1968) presents an annotated bibliography on agricultural utilization of sewage effluent and sludge; Whetstone (1965) has an annotated bibliography on reuse of effluents; and Ramsey, et. al (1972) presents selected references on soil systems for municipal effluents.

Wastewater Effluent Disposal

On-land disposal of wastewater effluents normally involves some form of pretreatment. This pretreatment can take many forms as was noted by Dean (1973). In his survey of on-land effluent disposal in the Rocky Mountain-Prairie Region he found eleven different types of pretreatment. These are listed in Table 121 .

The actual on-land disposal can also occur in many ways. "Land disposal" historically has meant disposal; however, today the emphasis seems to be on treatment and/or reuse. As a result the process of applying wastewater effluents to land has been given many new (and confusing) names. Thomas (1973) recognizes this problem and proposes three catetories of on land disposal:

1. Infiltration - a type of system usually designed to prevent surface runoff. It is characterized by high loading rates (up to 90 m/yr) and up to 99% of the wastewater being added to the groundwater is recharge.

2. Crop irrigation - a type of system which may or may not control surface runoff. It is characterized by low loading rates (15 to 215 m/yr), loss of water by evapotranspiration, and also recharge to the groundwater.

Table 121 . Effluent Pretreatment for On Land Disposal Sites in the Rocky Mountain-Prairie Region.

NUMBER OF SITES	PRETREATMENT
5	Activated sludge with polishing pond and chlorination
1	Activated sludge with filters and chlorination
1	Activated sludge with tertiary treatment and chlorination
5	Extended aeration with polishing pond and aeration
3	Extended aeration and chlorination
10	2 cell aerated lagoon with chlorination
3	2 cell aerated lagoon with polishing pond and chlorination
3	Trickling filter with polishing pond and chlorination
1	Trickling filter with chlorination
5	Screening only (industrial)
1	Septic tank with chlorination
5	To be determined

In general, the two forms of water utilization are comparable in magnitude.

3. Spray-runoff - a type of system which is designed to return 50% or more of the applied wastewater as direct surface runoff. It is characterized by intermediate loading rates (2 to 7 m/yr), variable evapotranspiration losses, and site locations which have impermeable soils.

In using categories such as this, Thomas (1973) notes that such systems as recharge basins, septic tank absorption fields, spray disposal, and ridge and furrow basins can be grouped under the infiltration category; spray irrigation, flood irrigation, and living filter systems are crop irrigation schemes; and all overland flow systems can be grouped in the spray-runoff category. He also notes that the septic tank/soil absorption systems apply more wastewater to the land than any other method. This subject is discussed elsewhere in the report.

Thomas (1973) ranks on land disposal of industrial wastewater as the second largest applicator. Blosser and Caron (1965), Philipp (1971) and Parsons (1968) are cited as three examples of successful industrial applications of paper mill wastewater to land. It is also noted that there are approximately 300 operating industrial systems in the United States today. Rose, et. al (1971) laments the fact that given all this experience and expertise, there exists no compendium on land treatment of industrial wastewater. They foresee the need to utilize this experience in preparing a report which could delineate procedures for evaluating engineering factors, limitations on use of land treatment, operational capabilities, and costs. Also they note that while much experience has been gained in the design of land treatment systems, little information exists of the effects on soil properties, animal and plant life, and groundwater. Thomas (1973) makes the following comment relative to the existing situation with industrial wastewater:

> "There is considerable information available about designing systems to achieve desired objectives at specific sites, but the scattered bits of information have not been assembled into compendiums for generalized use."

Land treatment of municipal wastewater effluents has many of the same problems mentioned above for industrial effluents. Thomas (1973) reviews many of the existing applications of municipal effluents on land. Two recent projects have begun to answer some of the questions relative to possible effects. The work by Pennsylvania State University at University Park (Parizek, 1967) has been looking at effluent application rates which promote plant growth while minimizing nitrates in the groundwater. Work at Muskegon, Michigan, likewise illustrated how groundwater buildup of nitrates could be controlled with proper crop production. During the winter the wastewater is stored (Muskegon County Board, 1970, and Bauer Engineering, 1971). Other studies such as those by Merrill, et. al (1967) and Bouwer, et.al (1972) are also contributing to an understanding of the effects of on-land disposal of effluents.

Dean (1973), after presenting the results of his survey, presents some points for consideration which tie in quite well with the above described situation. He notes:

> "Proper effluent application rates are site specific as to soil type, topography and annual precipitation. Numerical guidelines can either be too conservative or too liberal for a specific site and also run the risk of becoming an unquestioned design parameter whose use can lead to inadequate design."

and that,

> "Design review and approval by a team of qualified soils engineer, hydrologist, geologist and agronomist could be required to insure proper design."

given the existing state-of-the-art for on-land treatment/disposal of effluents, these points do warrant careful consideration.

Sludge Disposal

Sludge is a concentrated form of the wastes carried to a wastewater treatment plant. Whereas on-land effluent disposal involves applying all the wastes and water to the land, sludge disposal on land involves only the wastes. The cleaned water is returned directly to the stream. These wastes (sludge) have varying characteristics and concentrations depending upon where they are removed from the wastewater treatment process. Some treatment plants remove the sludge (primary sludge) from the process and dispose of it without further treatment. However, most plants promote separate anaerobic sludge digestion in one or two stages. There may or may not be ~~any~~ prior thickening. In the past the sludge was air dried following digestion and either buried or spread on land. More recently there has been a trend toward sludge thickening or concentration followed by burial, heat drying or incineration (Water Pollution Control Federation, 1971). However, environmental, energy and economic problems (up to 40% of the cost of a primary treatment plant may be for sludge handling) have forced many treatment plants to seek alternative methods to recycle and utilize sludge.

Total recycle of sewage sludge and other organic wastes by spreading on land has received renewed attention in recent years (Anon, 1967; Anon, 1971; Dalton and Murphy, 1973; Dalton, Stein and Lynam, 1968; Ewing and Dick, 1970; Hinesley, 1971; Hinesley, Braids, and Molina, 1971; Hinesley and Sosewitz, 1969; Law, 1968; Lunt, 1959; Nusbaum and Cook, 1960). The projects conducted by San Diego (Nusbaum and Cook, 1960) and Chicago (Dalton and Murphy, 1973) offer excellent examples of how sewage sludges can be used beneficially. The Chicago project has encountered considerable public resistance due to odor problems and was stopped recently by revocation of permits (This information is based on an article authored by Casey Bukro which appeared in the Chicago Tribune on June 24, 1973.) The particular situation points out the need for solving the engineering problems associated with on-land disposal prior to or at least concurrent with demonstration of the utilization of sludge in a recycle program. Further, psycological and political problems are often encountered when sludges are transported to communities outside of or at some distance from the generating community. A preferable solution would be to devise techniques for on-land disposal of sludges which are ecologically acceptable, economical, minimize energy consumption, and utilize as much of the material as possible within the community served by the treatment operation.

The proportionate costs of solids handling and disposal with reference to the total cost of wastewater treatment has been well documented in the sanitary engineering literature (Levin, 1968). Dalton et al. (1968) reported that the cost of solids disposal in Chicago was 46% of the annual operating and maintenance budget. City officials at Boulder, Colorado, (Smith, et al. 1973) estimate this cost at approximately 30% of the budget; however, the present cost for disposal is approximately $50 per dry ton.

Potentially large savings resulting from land application of wastewater sludges have been reported in the literature. Burd (1968), in an extensive review of sludge treatment and disposal costs, reported that costs (1968) for a land disposal system used for soil conditioning were $15/dry ton, while those for landfilling dewatered sludge average $25/dry ton, or 67% more. The cost of sludge disposal is unique for each particular treatment plant system, with factors such as type of system, site location, transport distance, local land costs and operating costs all affecting total costs. Although the case for land disposal becomes more convincing with increasing population served and transport distance to the disposal site, Riddell and Cormack (1966) concluded that on-land disposal was also justified for smaller communities. Troemper (1968) reported that the net cost of digested sludge disposal at the Springfield (Illinois) Sanitary District was in the range of $2.50 per ton of dry solids. It is also interesting to note that cost crop yields were enhanced for solids loading rates ranging from 36 to 206 dry tons per acre per year.

The actual sludge utilization procedures vary considerably. Composting (the mixing of sludge with other solid wastes in an aerobic situation) has been studied recently and proposed as a means of decomposing organic solid wastes to a stable humus-like material. The Water Pollution Control Federation (1971) states that the objectives of all processes are the same: (a) to provide optimum particle size, pore space, moisture, and other conditions conducive to aerobic decomposition; (b) to mix, reaerate, readjust moisture, and gradually reduce particle size of the sludge during active composting; and (c) to cure or mature the product to prevent nuisances and health problems. They also classify composting systems into three types:

1. Open windrow, pile, or bin composting with turning;
2. Composting in ventilated cells with intermittent disturbance; and
3. Composting in mechanical units with continuous mixing and positive aeration.

Direct application of sludge to land may occur with dry or wet sludge. The sludge, when applied on land, serves more as a soil conditioner than as a fertilizer, although there is anywhere from 2.06 to 5.96 percent nitrogen in sludge. In general, sludge is considered to have the same fertilizer value as manure (Water Pollution Control Federation, 1971).

Dry application of sludge has been the major means of on-land disposal in the past. Following drying, the sludge is removed and utilized in a great variety of ways. At Pueblo, Colorado, sludge cake with 25% solids is sold at $6.00/cu.yd. It is shredded and loaded on customer's trucks. Demand exceeds supply (Anon, 1965). Other areas bag the dried sludge and sell it as a soil conditioner. Others simply pile it on the land or spread it near the treatment plant.

Recently the direct application of wet or liquid sludge is gaining in acceptance. The main reasons for this are elimination of expensive drying beds, lower cost of sludge handling, and avoidance of many odor problems (Water Pollution Control Federation, 1971). The previously mentioned San Diego and Chicago operations operate with wet sludge.

The actual procedures for spreading liquid sludge on land include spraying and spreading with trucks. There are problems with surface spreading, however. Surface spreading of organic wastes can result in a serious deterioration in the quality of runoff waters (Bernard, et al., 1971; EPA, 1971). Further, surface application near populated areas often results in problems of aesthetics and various forms of nuisance pollution, such as odors and flies. Because of these problems, future use of surface spreading appears to be limited to situations where conditions can be carefully controlled.

To avoid many of the problems associated with surface spreading and to gain more control over the disposal operation, subsurface injection of sludge has been gaining in popularity. The City of Boulder, Colorado, is now utilizing the concept of subsurface injection and indications are that the system shows great promise. The comparative economics for a 100,000 population disposal capacity indicate an approximate 30% reduction in solids handling costs when compared to the present disposal system. Additionally, many of the aesthetic and environmental problems associated with the present system could be eliminated, a natural resource would be conserved, the potential soil conditioning value could be significant, and the amount of energy required for sewage treatment could be reduced.

The actual procedures and equipment for subsurface injection vary considerably. Several firms manufacture subsurface injectors for disposing of liquid manure. Tests with several of these machines have not given satisfactory results except at low rates of application because of difficulties in covering the material. These injectors are, without exception, mounted on portable tanks. This configuration limits the operative efficiency because of the time required to fill the tank and move to the disposal site. In addition, mobility problems often restrict operation of these systems to nearly ideal conditions.

Reed (1972) developed subsurface disposal machines referred to as Plow-Furrow-Cover and Sub-Sod-Injection. The Plow-Furrow-Cover equipment consists of single 16" mounted moldboard plow and a transport tank. Material is deposited in the furrow immediately in front of the plow and is thereby covered as the plow opens the next furrow. The disadvantages of this method are:

1. It is not always desirable or possible to plow when it is necessary to dispose of wastes.

2. In loose soils, material seeps into the open furrow causing traction problems.

3. A transport tank is towed by the tractor to supply manure to the machine. This limits the efficiency of the system and could result in problems due to poor mobility of the tank.

Kolega et al.(1971) used the Plow-Furrow-Cover method to dispose of septic tank pumpings. Fedlman and Hore (1971) increased the disposal capacity of the P-F-C method through use of a larger plow and tanks which spread material on the ground ahead of the plow. Reddell et al. (1971 and 1972) utilized deep plowing (30-36 inches deep), trenching, and disc plowing in variations of the P-F-C techniques. Similar techniques have been described by other authors (Anon, 1973; Dodson and Stone, 1962; Law, 1960). However, in some instances, the sludges used were chemically and/or mechanically dewatered to approximately 20% solids and placed in trenches. This type of disposal should be classified as landfill since the sludge is not incorporated in the soil and it remains as placed for many years without further decomposition (Babbitt, 1958), The Sub-Sod-Injector consists of two plow shares welded together to form a wide sweep. This machine works well in heavy soil where the turf will flow around the large injection tube and fall into its original position. In loose soil or light sod, soil does not flow around the large tube leaving an open trench and exposing waste material to the air. Machines are manufactured which are similar to the SSI, but use two or more small injector sweeps. Bartlett and Marriott (1971) described the development of a sweep injector similar to several commercially available models. In all of these machines, waste materials are deposited directly behind the shank of the injector which increases the possibility of leaving material exposed on the soil surface and does not provide thorough mixing of injected material with soil.

A very important aspect of on-land disposal relates to the hygienic factors. Bacteria originating from application of organic wastes are generally filtered out by the soil through a depth of approximately 2-5 feet (McCoy, 1969; Murphy et al., 1973; Robeck, 1972; and Wengel and Kolaga, 1972). Law (1968) concluded that sewage sludge could be used on agricultural land provided adequate controls were exercised to prevent bacterial contamination of crops. Rudolphs et al., (1950) described conditions under which raw fruits and vegetables grown in infected soils can become contaminated with pathogenic bacteria. Survival of viruses in soils has apparently received less study. Meyer et al., (1971) reported that certain treatments reduced infectivity of specific types of animal viruses. Robeck (1972) reported that polio virus was removed by on-land disposal techniques.

The need to control runoff waters from land receiving surface application of manure has been discussed by several authors (Barker, 1972; Bernard, et al., 1971; Cropsey and VanVolk, 1972; and Sewell, 1972). In addition, surface applications often result in various forms of nuisance pollution (odors, flies, etc.) and public relations problems. Most of these problems can be eliminated by subsurface injection or deep burial (Babbitt, 1958; Bartlett and Marriott, 1971; Feldman and Hore, 1971; Manges, et al., 1972; Reddell, et al., 1971; Smith and

Gold, 1972; and Smith, et al., 1973), however, other problems discussed later may result from deep plowing.

Applications of organic wastes on land can accentuate the salinity of soil, runoff, and deep percolating waters. Salinity has been discussed by Viets (1971) from the standpoint of feedlots. Bartlett and Marriott (1971) reported significant increases in salt concentrations at depth up to 4 feet for manure application rates up to 75 tons per acre per year. Similar results have been reported elsewhere (Manges, et al.,1972; Mathers and Stewart, 1971; Travis, et al., 1971; and Wells, et al., 1970).

These reports also indicate that yield of agricultural crops decreases with increasing salinity. However, Manges, et al. (1972) reported that pre-irrigating corn planted on manure treated plots improved germination. Reddell et al. (1972) found that yields increased one year after heavy applications of manure were deep plowed. Deep plowing may be useful in controlling salinity of surface soils; however, it may also increase groundwater contamination and result in mummification.

The most serious problem resulting from heavy applications of organic wastes to the land may be nitrate pollution. Wengel and Kolega (1972) reported that applications of poultry manure in excess of 30 tons of dry matter per acre produced unacceptable concentrations of nitrate in the groundwater. Silage corn produced on test plots receiving heavy applications was found to contain nitrate levels which could be toxic to ruminent animals. Bartlett and Marriott (1971) also reported high levels of nitrates in grasses produced on heavily loaded test plots. Reddell et al., (1972) reported excessive nitrate levels in forage sorghum the first year after application of manure; however, nitrate levels were acceptable the second year. Nitrate pollution from feedlots, fertilizer applications, and sewage sludge disposal have also been described in other literature (Hinesley, et al., 1971; Law, 1968; Stewart, et al., 1967; and Viets, 1971).

Swanson et al. (1973) reported that beef feedlot runoff effluent could be applied to various perennial forage crops at rates up to 90 inches per year without detrimental salt or nutrient accumulations in the soil. Chemical analysis of the crops revealed no undesirable build-up of toxic elements. Nienaber et al. (1972) reported that a minimum of one-half acre of disposal area per acre of feedlot was required for disposal of runoff with impairing crop growth. Booram et al. (1973) concluded that the buildup of nitrogen and phosphorus would limit permissable anaerobic lagoon effluent application rates. Salt and/or heavy metal buildup was not a problem due to the normally high rainfall on the test site.

Uptake of toxic elements by plants from soils treated with organic wastes may increase with either increasing application rates and/or increasing concentration of the toxic elements in the waste material (Anon, 1973; Davies, 1972; and Spotswood and Raymer, 1973). In fact, Murphy et al.(1973) reported a decrease in concentration of five heavy metals in drainage water after application of wastewater solids. This decrease was attributed to an increase in the soil pH caused by application of wastewater solids and resulting vegetative growth.

The application of large quantities of sludge to land may cause changes in soil tilth and structure which indirectly affect the quantity and quality of deep percolation water. These changes in the soil may produce the following effects:

1. Alteration of the water infiltration rate and water holding capacity of the soil.
2. Alteration of the rate of movement of soil water in response to evaporation potential as described by Corey and Kemper (1968).

Changes in quality of deep percolation water due to the application of sludge may result from the following:

1. Transport of contaminants from the sludge itself.
2. Changes in the mobility of fertilizer chemicals.
3. Changes in the capacity of the water to act as a solvent.

In cases where land and/or transportation costs are excessive and heavy applications of sludge are necessary, control of deep percolating waters will be required. Some means of treating the material to control contaminants and to stabilize the various salts would be desirable; however, the development of a suitable treatment does not appear feasible at present.

A subsurface (tile) drainage system would be effective for controlling deep percolation water. The water collected by the drainage system would be only a small portion of the total quantity of liquid applied to the soil and could be evaporated or recycled. Troemper (1968) discussed the use of a subsurface drainage system in an on-land sewage sludge disposal system. The expense of installing a drainage system would be justified provided the land area required and/or transportation costs for disposal of a given quantity of sludge could be sufficiently reduced.

Current research at Colorado State University has resulted in the development of a subsurface injector for sewage sludge which eliminates many of the problems previously discussed (Smith, et al., 1973 and Smith and Gold, 1972). The unique feature of the machine is that material is discharged uniformly and at shallow depths under the wings of wide sweeps while the tilling action of the sweeps mixes it with soil. Experience gained in current CSU sewage disposal research has indicated that this procedure is desirable for the following reasons:

1. Thorough mixing produces a large interface area between the material and soil. Because of the capillary attraction of the soil, water moves into the soil and the injected material dries rapidly. The soil then dries, primarily by movement of water to the soil surface. This decreases the possibility of groundwater contamination and permits injections at greater frequency.

2. The material is maintained in an aerobic environment thus eliminating the possibility of mummification.

3. Less tractor drawbar power is required to pull the injector through the soil thereby reducing disposal costs.

The injectors can be operated at depths ranging from 3 inches to 10 inches. Sewage sludge having 5% solids is fully covered at an operating depth of 3 to 5 inches with 200 gpm discharge and ground speed within the range from ½ to 1 mph (22,000 to 22,000 gal/acre). The maximum total loading of sludge achieved to date is 280,000 gal/acre of 45 dry tons/acre of 3.8% solid material in nine applications over a two month period. The maximum rate of injection achieved to date in a single application was 86,000 gal/acre of liquid (1.8% solids) hog manure. All treated plots show improved crop growth compared to control plots.

The experimental machine has been used with sewage sludge having a solids content up to 10%. However, 5-6% solids is considered optimum because of difficulties in pumping thicker material through the machine and because lower solids contents significantly increase the volume of liquid that must be handled.

The most significant result achieved to date is the fact that an injector can be used to achieve high loading rates at low costs. Sludge from the Fort Collins, Colorado No. 2 plant was injected at the CSU Agronomy Farm on a continuous basis from August 15 to December 1, 1972. The soil at the disposal site is 40% clay and the total disposal area included approximately one-half acre. This site was adequate for the entire output of the treatment plant (15,000 gal./wk.). No environmental nuisances were noted at the test site.

The optimum rate of application per pass depends upon the soil type, the particular machine, depth of injection and average weather conditions. It should be noted that the optimum application rate must be considered on the basis of a continuing operation over a period of time. Deep and/or heavy injections dry slowly and may result in a lower total application rate.

On the basis of results obtained thus far, a conservative estimate of the disposal capacity of most soils would be in excess of two acre-feet per year. This represents an average of one injection every 17 days and a loading rate of approximately 130 dry tons per acre of 5% solid material. While this application rate is greater than that which will permit good crop growth except for some grasses, the cost of disposal should be considerably less because of lower land costs and lower sludge distribution costs. In addition, it is possible that a recycle benefit could be obtained by stripping injected soils for use as top soil, fertilizer or as a conditioner for other soils.

A pre-production prototype injector has been designed cooperatively by CSU and International Harvester Co. This machine is currently being operated by the Hampton-Roads Sanitation District near Williamsburg, Va, to dispose of municipal sewage sludge. Sludge is pumped at 400-500 gpm through rigid irrigation pipe to a 660 foot, 4 1/8" ID flexible hose which is pulled by the injector. A 90 hp (International Model 996) hydrostatic drive tractor provides adequate power to pull the injector and hose. The hydrostatic drive permits use of full engine power at any operating speed and thus the tractor is ideally suited to this operation. Normal operating speed of the injector is between 3/4 to 1 mph and the application rate is approximately 29,000 gallons per acre per pass.

Machines similar to the IH prototype are now being tested at Boulder and Fort Collins, Colorado. The Boulder machine is approximately the same size as the IH prototype and the Fort Collins machine is smaller, having a capacity of approximately 300 gpm at 1 mph forward speed. The latter machine will be used by the City of Fort Collins for sludge disposal and by CSU for continued research at the CSU Agronomy Farm. Tentative plans call for the installation of two additional machines in Texas and New Hampshire.

The injection machine currently being used at Williamsburg, Virginia and Boulder, Colorado, cover a width of approximately 8 feet. Depending upon forward speed, these machines can inject at rates up to 1000 gpm. With a forward speed of less than 1 mph, approximately 500 gpm is required. Correct sizing and selection of the equipment will permit this system to be utilized by virtually any disposal operation or cooperative of sewage treatment plants. By proper positioning of the hose, approximately 40 acres can be injected at a given location.

Disposal sites for the injector can be prepared in advance and/or reserved for use during wet and cold weather. The injector system has relatively light draft force requirements and can be operated in moderately wet conditions by equipping the propelling vehicle with floatation tires or wide tracks. For more severe weather conditions, land can be thoroughly dried by repeated tillage operations and then covered with plastic, sawdust, straw or similar mulch. The objective is to dry the soil thoroughly, keep it dry, and thus prevent freezing. Prepared areas are suitable for at least one wet or cold weather injection pass. Obviously, the maximum possible rate of injection per pass should be used to minimize the required land area.

A sodded or grassy area could also be reserved for utilization during extremely wet conditions. The injector can be used in sod without serious disturbance of the surface. Generally, sod flows around the shank of the sweep and falls into its original position. For this type of operation, the injector should be equipped with wide sweeps, and the number of sweeps should be reduced because of the increased draft force. However, these modifications can be made quickly and with minimal expense on the current machine.

Several states are now considering or have pending legislation which will prohibit spreading of waste materials on frozen ground. The intent of this legislation is to prevent pollution of streams caused by melting and runoff of winter precipitation prior to the time the ground thaws. Because of this delay, the total quantity of material spread in a given drainage area determines the pollution potential rather than the actual application rate in tons per acre.

Elimination of on-land disposal during cold weather plus the need to provide for emergencies will require that most operating disposal systems include adequate storage facilities. Systems for storing organic wastes and the necessary management procedures are reasonably well defined (Agricultural Engineers Digest, 1966) and will require no further developmental work. Odor control is not usually a problem if material is retained in a covered pit except when agitating or emptying the contents. Since the primary use of storage will be during cold weather, the odor problem should be further reduced. However, control of pH, odor counteractants and masking agents, or various cultures could be used for odor control if needed.

Summary

As noted earlier, much controversy surrounds the technology of on-land disposal of both sewage effluent and sludge. Also much uncertainty exists relative to the effects of the practices upon the environment, human health, etc. However, much research and demonstration of practices and techniques are now underway. As the results of this work become available it is imperative that the information is distributed to the individuals in charge of wastewater treatment. This will necessarily involve an extension program which is in tune with the current controversies and is able to utilize the research results to answer the many questions now being asked.

Also as new factors of on-land disposal come into focus (such as the energy situation), an active and efficient extension program would serve to identify problems and guide research activities toward obtaining solutions.

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THE IMPACT OF OIL SHALE DEVELOPMENT

With the impact of the energy crisis a relatively recent shift in national priorities has occured. In his State of the Union message of January, 1974, the President emphasized that this nation could no longer rely on foreign oil suppliers to fulfill the bulk of this country's domestic fuel needs. Instead, he called for an acceleration of the development of existing energy resources and a step-up of research and exploration to discover new ones within our own borders. Included among these existing resources for immediate development are the vast oil shale deposits of northwestern Colorado, southwestern Wyoming, and northeastern Utah. Undoubtedly, this raises deep concern for additional potential non-point sources of pollution within the Region VIII states.

Present estimates place the potential yield of oil shale resources somewhere near 26 trillion barrels of oil. Projections are that it will require at least 20 to 25 years to harvest this abundant supply. To accomplish this, vast amounts of men, machinery, and natural resources will be utilized. Existing towns are projected to quadruple in size, new towns are being proposed, extensive transportation networks must be planned and developed, thousands of units of new housing will have to be built, new recreational areas will have to be created, and support services of all types must be established. What all this means is that, with the anticipated intense land use that is to occur, the problems of non-point source pollution that inevitably accompany these kinds of activities will most assuredly be compounded.

At this juncture no one can positively forecast what kinds of non-point pollution problems are likely to occur or their intensity. Hopefully, the kinds of development that takes place will take cognizence of the potential pollution dangers inherent in these kinds of activities and will plan accordingly. Here might be an ideal situation for technology transfer agents to be involved in the planning from the outset. Certainly, programs should be inaugurated as early as possible to offset any possibility of overlooking crucial considerations that must be taken during initial planning phases if non-point source pollution problems are to be kept to a minimum in the Region.

These huge tracts of shale land estimated to hold twice as much recoverable oil as the Arab-dominated mid-East, cover 11 million acres in the three-state Region.

The area is called the Green River formation. It has 7,000 foot mountain plateaus in the eastern part which generally get enough rainfall and snow runoff to support thousands of cattle and sheep herds. Further west the land drops off and becomes more desert-like, with a few irrigated farms straddling the streams.

Only about 35 families live in the 1,300 square miles atop the rich oil shale, many of them on century-old cattle spreads dotting the open space. There are no real urban areas. Vegetation is scattered. The temperature of the dry air reaches 100 degrees or more in the summertime, and as low as 40 below in the winter. But, is considered by many to be exceptionally rich in environmental resources.

The region had no electricity until the late 1930's and there were no paved roads until the '40's and '50's. This is the same area where a 5,000 acre tract brought a bid of $210 million for oil shale mining rights. Additional tracts in the tri-state area are to be leased the coming months.

Several years ago, when the government offered oil shale leases in the region, the offer had to be cancelled because bids barely exceeded a half million dollars. The energy crisis and the Arab oil embargo, however, have changed all this.

Environmental Problems

Federal officials have cautioned that the billions of barrels of oil locked within the Green River formation probably can't be mined quick enough to relieve the present crisis. In a 3,200 page environmental impact statement, the Department of Interior says that just the start-up of such a proto-type proposal could alter large sections of the region for 100 years or more. According to the statement, air and water quality could suffer, wildlife may be killed or chased away, the land might be scarred forever by strip mining and the human population will probably quadruple overnight.

One of the major concerns will be what to do with the shale once the oil is extracted. The debris expands as it is processed and there would be more "shale" at the end than there was in the beginning. What impact this would make in terms of non-point source pollution is strictly conjecture at this point.

In addition to the area to be mined directly, the government estimates an additional 5,000 to 10,000 acres will be needed to provide for utility corridors, roads, and urban expansion. The transformation of these lands from their present natural state to other uses is bound to contribute to the intensity of non-point source pollution in the region.

The Department of Interior has also projected a need for as much as 189,000 acre feet of water a year for mining operations and processing. This high water use could further increase the problems of salinity in the waters flowing to Arizona and California, the report indicates.

What remains to be seen is whether or not careful planning and emerging technology can serve to minimize the pollution potential. Emphasis will have to be placed on a sophisticated program of technology transfer and control methodology dissemination via a well-financed delivery system. In this context, then, a "new frontier" emerges--the challenge of applying enlightened management practices to all aspects of shale oil development and related activity. A unique opportunity looms to demonstrate that this new energy resource can be mined with minimum disruption to the natural environment. The challenge is mind-boggling and the costs will be astronomical. But, nevertheless, the challenge is there.

ENVIRONMENTAL QUALITY CONTROL--RELATED TO ENERGY RESOURCE DEVELOPMENT

The responsibility for various aspects of environmental regulation within the Region VIII shale oil states has traditionally been vested in a number of separate state agencies: health, air pollution, water, public utilities. Three of the four states have moved toward coordination of such activities, either through staff or line organizations as follows:

Colorado:	Coordinator of Environmental Problems established in 1971, though it was not funded after the first year (Colo. Rev. Stat. §132-1-9) (1963) (1971 Supp.)
Montana:	An Environmental Quality Council, with the strongest legislation to support it, is mandated by the Environmental Policy Act (Rev. Codes of Montant, §69-6501) (1947) (1971 Supp.)
Wyoming:	A Department of Environmental Quality with responsibility for air, water, land reclamation and solid waste disposal established by the Environmental Quality Act (Syom. Stat. §35.501.1 to 35.502.56) (1957) (1973 cum supp.)

In Utah, studies toward a Department of Environmental Control (HB 35), and a Committee to study resource depletion and future energy sources was deferred in Committee.

In addition to this environmental quality legislation, legislation regarding strip mining and reclamation was put before several legislatures. Where the previous enactments on this subject were less restrictive than older laws of the eastern states, there was significant tightening up and new enactments in the western states recently. Some actions of special interest are:

Montana: Establishes bond with permit application, as level of \$200 - @2,500 per acre and requires annual renewal of permit. Sets forth many specific legislative regulations and requires written consent of proposed work from surface owner. Surface owner has action for contamination, diminution or interruption of water supply due to mining operation (Rev. Codes of Montana §50-1034 to 1057) (1947) 1973 Supp.)

Wyoming: No permit may be granted without written consent to surface owner and bond to cover damages. Other provisions to protect surface owner (Wyom. Stat. §35.502.20 to 502.41) (1957) (1973 Supp.)

Colorado legislation in 1973 relieved mining operators of reclamation responsibility under certain conditions (§92-36-1, et. seq.). A relatively weak Mined Land Reclamation Act in Utah (SB 12) failed to pass. Additional legislation in Montana requiring strip mining operators to return reclaimed land to persons giving easement (to retain agricultural uses) failed to pass (SB 382). A bill to require reclamation only on public lands was deferred in Committee in Montana (SB 387).

PLANNING CONCERNS

In addition to the planning aspects related to environmental quality or land use, specific energy-focused planning groups have been set up in several of the states:

Colorado: An Energy Task Force was set up by the Governor in Spring, 1973. It is reported to have about 50 members, with government and industry well represented.

Montana: An Energy Advisory Council has been established, under the leadership of the Governor, & SJU 24.

In Utah, SJ Res. 21, creating a committee to conduct a study of all energy resources was deferred in Committee.

In Colorado, HB 1414 establishing an Energy Commission failed to pass as did SB 205 to establish a Long Range Coordinator. An energy coordinator has been recently appointed by the Governor, however.

Also concerned directly with energy planning was a proposed termination or moratorium on strip mining that failed to pass in Montana (HB 391 and 492) and a severance tax increase in that state which did pass (HB 509). An attempt to increase this tax in Wyoming failed (HB 152).

In reviewing a summary of the above state actions, it should be noted that socio-cultural impacts, except for taxation, have not been specifically addressed. Although all states in the region region except Colorado experienced a net outmigration of population in the period 1960-1970, the migration implications, the cultural changes and the "boom and bust" potential of energy resource development are not specifically addressed as yet.