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Methods of Preventing, Detecting and Dealing With Surface Spills of Contaminants Which May Degrade Underground Water Sources For Public Water Systems

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METHODS OF PREVENTING, DETECTING AND DEALING WITH SURFACE SPILLS OF CONTAMINANTS WHICH MAY DEGRADE UNDERGROUND WATER SOURCES FOR PUBLIC WATER SYSTEMS

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PREFACE

In recent decades ground water pumped from wells has begun to play a more significant role in water supply. More than one half of the Nation's population is now depending on ground water for its drinking water supply. The widespread availability of ground water and general consistent temperature and chemical quality have let to the present day expansion of waterwell systems in the Nation.

Management and protection of the ground water resources are of the upmost importance. Pollution of surface water supplies generally is readily detected and often can be corrected, whereas pollution of ground water is often not detected until a considerable part of an aquifer system has been adversely affected.

Accidental spills of contaminants (including, but not limited to, liquid wastes, toxic fluids, and hydrocarbons) occur in every region. If allowed to stand, these spills are accompanied by the risk that the contaminant can penetrate the soils and rocks in the vicinity of the spill and contaminate ground water quality with subsequent degradation of a water supply. Spills can occur at industrial sites, storage and distribution areas along highway and railroad rights of way, along pipelines and at airports during storing, handling, processing, or transporting contaminants.

The purpose of this study is to prepare GUIDELINES and TECHNICAL DOCUMENTS that can be utilized by industry, Federal, State, and local governmental agencies to assist in eliminating or minimizing the efforts of spills of contaminants that might adversely affect underground water which supplies, or can reasonable be expected to supply, any public water system.

Finally, this report and guidance fulfill that mandate contained in the Safe Drinking Water Act (P.L. 93-523) Section 1442(a)(6) requiring that the Administrator of the Environmental Protection Agency " ... carry out a study of methods of preventing, detecting, and dealing with surface spills of contaminants which may degrade underground water sources for public water systems."

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SECTION 1

INTRODUCTION

Accidental land spills of hazardous materials including some hydrocarbons occur regularly in every region of the United States. The causes are varied and include tank car accidents, train derailments, pipeline ruptures, bulk and underground storage leaks. Regulations have been established to protect the nation's streams, lakes, ocean waters and air from man-induced contamination. However, the same degree of concern has been lacking when spills have affected the quality of ground water. Local contamination of the ground-water resources resulting from spills is a significant problem and has only recently received attention by State, Federal and industrial authorities.

Approximately 48 percent of the United States population depends on ground water for drinking purposes. Of the total population, 29 percent obtains water through public ground-water supplies and 19 percent through rural cluster well systems and individual domestic wells.

In 1970, the total quantity of water withdrawn for public supplies was estimated as 27 billion gallons per day (102 million cubic meters per day). Included in this quantity was water for domestic use, water for commercial and industrial use, water lost in the distribution systems and water supplied for carrying out public services such as firefighting, street washing, etc. Of the total, ground water supplied approximately 34 percent and was the major source of water to over 59 million persons served by public water supplies. Water utilities, supplied by surface-water sources, furnish almost twice the volume of water, but are relatively few in number compared to the number of utilities using ground water resources.

The U.S. Environmental Protection Agency has been given the responsibility for studying the methods of preventing, detecting and dealing with surface spills of contaminants which may degrade underground water sources for public

water systems. Therefore, the objectives of this study were to:

- develop procedural guidelines for preventing, reporting, evaluating, investigating and abating various types, sources and materials of land spills which could threaten underground public supplies;
- document, review and analyze the major and consequential incidents of such contamination;
- evaluate the regulatory controls as to the degree that they protect ground-water resources from contamination by land spills;
- outline the on-scene technical and economic advantages of implementing various preventive, control, investigative and remedial strategies and measures.

This report presents the results of the following tasks as condensed from the scope of work:

Task 1 - Identify major and consequential land spills that have contaminated underground water which supplies, or can reasonably be expected to supply, any public water system.

Task 2 - Identify the materials that may cause damage to underground water sources.

Task 3 - Evaluate the on-scene removal or mitigating actions taken in spills identified in Task 1.

Task 4 - Evaluate current Federal, state and local regulations for applicability to protect underground water sources from spills.

Task 5 - Develop criteria to determine areas which are not susceptible to contamination of underground drinking water sources from land spills.

Task 6 - Develop a guidance document to provide industry and government agencies the information needed to prevent underground water contamination if and when a land spill occurs.

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

The following are conclusions based on the results of this study:

- Spills and leaks of oil and hazardous materials on and below the land surface are numerous and threaten the quality of U.S. ground-water resources.
- Petroleum products, in transport or storage, are the most frequently spilled or leaked. Failure of underground tanks,such as those used by service stations,is the most frequent cause of these incidents.
- The practices of effective inventory control, monitoring, corrosion protection and other spill prevention techniques were found to be used less frequently than needed for adequate protection of ground-water resources throughout the U.S.
- More research is needed regarding attenuation, leachability, sorption and other factors affecting the migration of hazardous substances in soil/water systems.
- Little emphasis has been placed on ground-water protection during land spill clean-up activities and, in most cases, concern about ground water occurs after the ground water has been contaminated.
- Research and technology for the containment and detoxification of oil and hazardous materials in soil/water systems is needed.
- Existing Federal and state programs address many of the sources of potential contamination, but they do not provide comprehensive protection of ground-water resources.
- Most state laws give broad authority to protect all waters of the state, including ground water. Such language, plus deficiencies in budget and staffing, force state and local agencies to act on cases of ground-water contamination only after the fact.

- Because clean-up of contaminated ground-water is rarely economically or technically feasible, action by the states has been toward condemning the affected water supply.
- Individuals, private organizations and public agencies seldom have the resources and technical capability to structure and prove their case of ground-water contamination when suing a major corporation responsible for the spill that caused the contamination.
- There is insufficient documentation on spill incidents that have contaminated ground water to determine whether or not effective actions were taken at the time.
- Data are lacking concerning the susceptibility of aquifers to contamination from land spills.

From the foregoing conclusions, the following recommendations are offered:

- The most effective way to protect ground water from spills is to control and monitor the potential source of the spill so that if one occurs, effective action can be taken immediately.
- New and existing potential sources of contamination should be evaluated on a case-by-case basis.
- A comprehensive Federal program for ground-water spill management should be developed.
- State laws should provide the authority to protect ground water from spills as well as other sources of contamination.
- The Federal EPA should fund more projects to improve detection, abatement and prevention techniques to reduce the occurrence of ground-water contamination from spills.
- State and Federal spill coordinators should have effective reporting and documentation procedures for spills that may affect ground water.
- Research and development programs should be implemented on soil attenuation of spilled materials, leachability and other factors that determine oil or other hazardous material migration in a variety of soil/water systems.
- Geohydrological investigations should be done to determine the susceptibility or non-susceptibility of major underground drinking water

sources to potential contamination.

- The Federal Spill Prevention Control and Countermeasure (SPCC) plan should be revised to include facilities with less than 159,000 liters (42,000 gallons) underground storage, such as service stations.

SECTION 3

DISCUSSION OF RESULTS

TASK 1 - INVENTORY OF LAND SPILLS

The objective of this task was to identify major and consequential land spills that have contaminated underground water which supplies, or can reasonably be expected to supply, any public water system. The land spills of prime interest to this effort were those of oil or any hazardous substance that occurred accidentally as opposed to deliberate disposal.

Reports of over 4,600 land spill incidents were collected after a computer search at EPA Oil and Special Materials Control Division, visiting 5 EPA Regional Offices (I, II, III, IV and VIII), 20 states and contacting 7 others. Of these reports, 168 had sufficient information to ascertain that they had affected or were threatening to affect ground water. Tables listing information about the 168 spill incidents appear in Appendix A of this report. The data are summarized as follows:

- Type - hydrocarbon 135 80%
  chemical 33 20%

- Major Sources - service station related 47 28%
  storage above ground 40 24%
  storage below ground 12 7%
  pipelines 17 10%

- Distribution -

CA	18	MA	2	NJ	1	RI	1
CT	2	MI	5	NY	24	TX	15
ID	4	MN	19	NC	2	VA	9
IL	9	MO	6	OH	12	WA	3
MD	4	NH	2	PA	28	WI	2

• Causes -	Leaks	81	48%
	Spills	71	42%
	Unknown	16	10%

During the retrieval of this information, it became obvious that very few states or the Federal EPA had adequate documentation on land spills relating to their contamination of ground water. Hydrogeological data were lacking from most reports. Federal spill coordinators were not required to address the problem of ground-water protection and most states had inadequate laws and regulations governing the protection of ground water from spills of contaminants. Some of the states with regulations of this type could not afford a full-time hydrogeologist with their limited budgets.

It is suggested that the data form, devised for use in Task 3 of this program, be used as an example of the type of information required for a spill incident to adequately evaluate the spill's effect on ground water.

TASK 2 - IDENTIFICATION OF POTENTIAL CONTAMINANTS OF UNDERGROUND WATER SOURCES FROM LAND SPILLS

The objective of Task 2 was to identify and categorize those substances which may cause ground-water contamination when introduced into a ground-water environment. Over 900 chemicals have been compiled from the Coast Guard hazardous chemical list and the EPA hazardous substances and priority pollutants lists. These chemicals have been categorized in seventeen functional groups and appear in Appendix B, together with toxicity and solubility ratings. The toxicity and solubility information will help guide one's actions when confronted with a spill and will provide industry and government agencies the sense of urgency needed to prevent ground-water contamination.

Solubility information was gathered from the CRC Handbook of Chemistry and Physics, 52nd Edition, 1971-1972 and from EPA's Office of Hazardous Materials Technical Assistance Data Base System (OHMTADS) computer dialog system.

The Handbook of Chemistry and Physics rates the chemicals qualitatively from insoluble to infinitely soluble using six degrees of solubility. This scale was used directly with the following numerical range scale to

simplify it. Numerical ranges for the solubility ratings were determined by comparison with those substances which were rated both quantitatively and qualitatively in the reference sources. These numerical ranges were then used to determine the qualitative rating for those chemicals which had only quantitative values.

Range, ppm (gm/100 cc)	Solubility Rating
$\leq$ 10.0 ($\leq$ 0.001)	0 = insoluble
10.0 - 10,000 (0.001 - 1)	1 = slightly soluble
10,000-1,000,000 (1-100)	2 = soluble
1,000,000-5,000,000 (100-500)	3 = very soluble
$\geq$ 5,000,000 ($\geq$500)	4 = infinitely soluble
	5 = decomposes

No solubility value for a substance indicates that solubility data were not found.

Toxicity data were obtained from Sax's Dangerous Properties of Industrial Materials. An explanation of the rating system used is given in Appendix B. A qualitative scale ranging from 0 = No toxicity to 3 = Severe toxicity, was used to characterize the toxicology of the various chemicals. The letter "U" indicates toxicity data were not available or detailed in the referenced text. However, "U" followed by a number indicates an estimate from the text, by the author, of the compound's toxicity based on the data available. The major toxicity ratings were further categorized in the Sax text according to the following: acute local (epidermal exposure); acute systemic (inhalation, ingestion or absorption through skin); chronic local; and chronic systemic. Since we are concerned with contamination of potential underground drinking water sources and keeping the rating system simple, the most severe toxicological rating for ingestion has been used.

While these ratings are based on acute oral toxicity levels for pure chemicals, the true hazard of these substances as components entering soil ecosystems and eventually reaching ground water may differ entirely from their apparent toxicities. This can be caused by varying degrees of attenuation of materials traveling through soil systems, degree of aerobic and anaerobic biological degradation, chemical reactions, solubility, synergistic reactions with existing materials as well as flow, dilution effects, and

mixing capabilities of the ground water system. However, such extensive and complete data exist on only a few materials such as PCBs, pesticides and specific heavy metals which have posed imminent health and environmental hazards. Much more work is needed to characterize the remaining materials in such detail.

The solubility and toxicity ratings used and explained in this report are to give a fundamental and rapid idea of the nature of a material being handled in a spill incident. Further information is needed for a detailed evaluation of the severity and imminence of the environmental hazard posed in such an incident. This includes such details as flammability, explosiveness, potential for air pollution, chemical, physical, biological and detailed toxicological properties, the nature of hydrogeological system, and recommended procedures for safe handling and clean-up.

TASK 3 - EVALUATION OF CURRENT SPILL CLEAN-UP TECHNIQUES

Oil and other hazardous materials play a vital role in the economic structure of the nation. However, in the course of production, transportation, storage and processing of the materials, numerous unintentional spills occur. Reported spills range in size from a few ounces to several million gallons. The damage to a ground-water regime results from inadequate response, containment and recovery. Emphasis should be placed on the handling of spills during and immediately after they have taken place. It has been found for example, that in many tank truck accidents, liquids spilled on roadways have been flushed from the road surface to contaminate adjacent soil covering a shallow aquifer so that traffic will flow better. The threat to life, property and the environment as a result of oils or hazardous material spills dictates that corrective action be immediate and effective. The technology for handling such occurrences is advancing rapidly as a result of the experience gained and documented in recent years. However, when hazardous fluids enter the sub-surface as a result of undetected spills or underground leaks, the problem takes on broader ramifications. In this situation, time and cost of remedial measures are increased. Each situation is site specific and depends upon the local geologic and hydrologic conditions.

This section is designed to evaluate current practices in the areas of response and clean-up of oil and hazardous material spills throughout the U.S. The following is a discussion of specific areas of response and clean-up with an evaluation and recommendation for each.

- Reporting and Documenting of Spill Incidents

Standardized methods for reporting and documenting spill incidents affecting ground water are not practiced in most areas of the U.S. A few states such as Pennsylvania, California, Minnesota and New York have adequate reporting and response programs. The report form used by Versar to inventory and evaluate the spill incidents is presented in Appendix C. This form can be utilized by state or local spill response teams for reporting and evaluating the immediate and future action needed to mitigate the effects of the spill on a soil-water system.

- Monitoring

The monitoring required and practiced for the detection of leaks is proportional to the quantity of a product handled. Regular checking of pipelines and tanks is accomplished by monitoring, periodic inspection and periodic pressure testing. Emphasis has been on the hazards involved and on economics. If the leak is so small or so located that it constitutes no hazard (as defined by the Office of Pipeline Safety), and the costs of repairing the leaks are greater than the loss incurred by the leakage, no attempt will be made to detect, locate or repair the leak. In small installations such as the household fuel storage tank, gasoline station tank and local collection or distribution, monitoring is usually not practiced. Local governments which regulate such operations do so by ordinances and codes specifying the materials and methods of installation. Commonly, monitoring for such leaks is initiated only after an owner discovers his water well is contaminated. Another example is when an operator determines that the product is leaving the tank faster than he is using it.

Monitoring procedures have been developed and implemented by interstate carriers, but also can be applied to any underground tank or pipeline. These procedures are under the control of the Office of Pipeline Safety.

To assure that interstate carrier monitoring and pipeline operations are being done satisfactorily, the Office of Pipeline Safety requires a report for any leakage in excess of 8,000 liters (ca. 2,100 gal) of a commodity from the initiation of the leak to the time of cessation. Unfortunately, many cases of ground-water contamination result from leaks of less than 8,000 liters.

- Underground transportation and storage evaluation

In the United States, underground storage and transmission of a wide variety of fuels and chemicals are practiced for a variety of commercial, industrial and individual uses. Industrial use is predominantly for fuels, but a wide range of other chemicals is also stored in tanks. The largest use of underground tanks and pipes is in the petroleum industry. Their use has expanded with the industry to the point where pipelines are now the major mode of transportation for liquids and gases within the continental United States. The present and increasing emphasis on the aesthetic value of burying utilities and other commercial or industrial structures has increased the number of underground tanks and pipes. Because pipelines are economical, there is an increasing trend toward developing methods for pipelining slurried solids such as coal or ores. Pipes and tanks are subject to failures from a wide variety of causes and the subsequent leakage then becomes a source of contamination to local ground waters.

This section describes the nature and occurrence of tank and pipeline leakage problems in the United States and summarizes the practices which have been found effective in the control and abatement of ground-water pollution. Emphasis in this section is on petroleum products because they constitute the majority of materials stored or transmitted underground. Leakage of petroleum and petroleum products from underground pipelines and tanks is much more pervasive than generally realized. This is particularly true for small installations such as home fuel oil tanks and gasoline stations, where installation, inspection and maintenance standards are low. In Pennsylvania, where standardized investigative procedures have been adopted, some 150 instances of ground-water pollution were reported in a single year from gasoline stations.

Commercial businesses and individual homeowners use underground storage almost exclusively for fuel. The most numerous underground storage tanks are

those used by gasoline stations and for fuel oil at residences. These small tanks are usually coated with a protective paint or corrosion resistant material, but they are frequently subject to corrosion-induced leakage. The primary problem associated with such tanks is the fact that their installation and use are not usually well regulated. If any regulation exists concerning such tanks, in most cases it is a local regulation requiring that tank construction and installation be satisfactory, but it is rare that any follow-up or periodic checks are required to determine whether or not leaks have developed. Because such tanks are small and comparatively inexpensive, cathodic protection is not required even when the tanks are buried in clay soils, which are known to promote galvanic action.

The only pipelines for which any program of leak prevention and any requirements for decontamination exist are the transportation pipelines, and these are not all covered. All interstate transportation pipelines and some intrastate pipelines are regulated; on collection and distribution pipelines there is no regulation other than that of the initial installation. The purpose and intent of the regulations which exist are for preventing the escape of combustible, explosive or toxic chemicals. Prevention of ground water pollution has not been a consideration. Because interstate pipelines are a major means of transportation, they are regulated by Federal government agencies in the Department of Transportation. Since leaks of petroleum products can produce a fire or explosion hazard, these regulated pipelines are required to report leaks and spills for these hazards only.

Examination of spill data indicates that the major cause of leakage is corrosive substances which attack the lines both externally and internally. The second greatest cause can be found by aggregating those causes related to pipeline component, equipment, personnel failure or malfunction. The third cause is line rupture as the result of accidents caused by earth-moving equipment. The remaining few causes include vandalism, severe weather, lightning, floods, earthquakes and forest fires.

Most of the research and development on methods for controlling and abating the contamination of ground water by leakage from tanks and pipelines in the sub-surface has been concerned with reducing fire, explosion and toxicity hazards. Although it would appear that this work is not often

aimed toward abating pollution of ground water, it has been applicable when judiciously applied. In pipelines, containment is accomplished by use of automatic shutoff valves inserted in the pipe at intervals. These valves are designed to close off any section of pipe where a significant drop in line pressure occurs. This method, like containment devices for tanks, tends to limit the spread and the volume of the leak and thereby permit easier clean-up. At the present time, this form of protection is required on interstate pipelines, but not on most small collection and distribution systems.

The abatement methods currently used are soil removal, biodegradation, pumping and ditching. If a leak is discovered and is accessible soon after it occurs, the method widely used for preventing ground-water contamination is removal of the contaminated soil. After the soil has been removed, the problem has been how to dispose of it. The most suitable method for handling biodegradable materials, such as oil, and many agricultural chemicals such as ammonia, is to spread the contaminated soil in a thin layer, 20 centimeters or less in thickness, and permit the natural aerobic soil bacteria to degrade it. This is usually accomplished within six months. If the liquid is not biodegradable, the soil must be removed to an appropriate industrial waste treatment plant and processed as an industrial waste.

Earth removal can be an extensive operation requiring more than simply digging a hole with a bulldozer and hauling the soil away in a truck. In at least one case in an urban area, such earth removal involved the demolishing of buildings and excavation of an area of approximately the size of a city block.

In cases where the pollutant has reached the water table but has not yet moved a significant distance from the leakage site, a removal well is most widely used. This method works best for water-soluble chemicals and for materials that float on the water table. With respect to soluble chemicals, the effect of pumping will be to reverse the normal direction of water movement away from the site of the leak. The drawdown cone that the well produces will trap the product. In the case of oil, two pumping locations are often used - a deep pump inlet to maintain the drawdown cone and a skimming pump with its inlet floating on the surface to remove the oil.

If the pollutant has moved far enough downgradient that recapture by use of a drawdown cone is infeasible, a ditch placed across a shallow contaminated plume is widely used to capture the contaminant.

When the water table is far below the surface of the ground, a row of pumping wells is usually required. Placed across the contaminated plume, their drawdown cones will merge, producing a trench in the water table. The contaminant cannot escape from the depression and with time will gradually be removed by the wells. After the contaminated water is removed, it can be processed as an industrial wastewater before disposal. Another method currently under research is that of sub-surface biodegradation. Many chemicals such as ammonia and petroleum products are biodegradable by aerobic bacteria, but below the surface air transfer is slow and the aerobic bacteria tend to consume the oxygen. At the present time research is being conducted to identify anaerobic bacteria which would also be capable of such biodegradation. Further research is needed in the areas of detection and abatement of spills affecting ground water. In addition, response teams equipped with the best available technologies should be deployed in those areas where ground water is relied on for water supplies. This could be done at both the Federal and industrial levels.

TASK 4 - EVALUATION OF CURRENT FEDERAL, STATE AND LOCAL GROUND-WATER PROTECTION REGULATIONS

The objective of this task was to evaluate the applicability of current Federal, state and local regulations to protect underground water sources from spills. Government regulations provide the legal framework through which official agencies operate to protect the integrity of ground water resources.

A literature search revealed an excellent source of information on the adequacy of Federal legislation with regard to the protection of ground water. This document is entitled, "The Report to Congress - Waste Disposal Practices and their Effects on Ground Water," January 1977, by the Office of Water Supply and the Office of Solid Waste Management Programs, EPA. Section XVI, Existing Federal Legislation, of this report, discusses the following Federal

laws and their applicability to ground water protection:

- Refuse Act
- Water Pollution Control Act of 1948
- Public Law 92-500
  - Section 208
  - Section 304(e)
  - Section 402
- Solid Waste Disposal Act of 1965
  - Amendments of 1970
- National Environmental Policy Act (NEPA) of 1969 (PL 91-190)
- Safe Drinking Water Act of 1974 (PL 93-523)
- Atomic Energy Act of 1954, as amended (Reorganization Plan No. 3)

The following observations were made regarding the adequacy of existing (at that time) Federal legislative programs within EPA's authority for protection of ground water:

1. PL 92-500 primarily focuses on navigable waters rather than ground water or "public waters," meaning both navigable and ground waters.

2. Section 208 of PL 92-500, at least on paper, provides strong language for ground water protection. However, no mechanism exists for EPA to insure the implementation of ground water protection plans developed pursuant to the 208 process.

3. The coverage under NPDES (Section 402 of PL 92-500) is extremely limited as regards ground water protection both because of the language in Section 402 and the narrow definition of "pollutant" in Section 502.

4. Under PL 93-523, the Safe Drinking Water Act, several definition problems have led to interpretations which limit the coverage of the Act. Some of the major polluting activities may not be subject to the requirements of PL 93-523.

5. The Solid Waste Disposal Act has not proved an effective vehicle to protect ground water. It has expired.

6. NEPA, through the EIS process, is a significant vehicle for reviewing and evaluating the ground-water impact of Federal actions.

7. Radioactive wastes present a significant potential contamination threat to ground water. Federal authorities appear adequate for protection of public health; however, implementation has not always been adequate. Limitation by Federal legislation of releases of radioactive contaminants to ground water from other than those emanating from "source, special and by-product materials" may be inadequate. No known limits exist on medical radionuclides given to patients and then excreted into local sewage systems.

8. The Federal power over sub-surface waters is less clear than over surface waters and its exercise may raise Federal-state constitutional questions.

The more recent Public Law 94-580, Resource Conservation and Recovery Act of 1976, also provides EPA with teeth to protect ground water from spills of hazardous materials. However, as in PL 92-500, no mechanism exists for EPA to insure the implementation of ground-water protection plans developed pursuant to PL 94-580.

The efforts on this task consisted of contacting, in person or by telephone, the various state personnel cognizant of their state's laws and regulations regarding the protection of ground water. In addition, the literature search revealed a study[1] performed by the National Water Well Association for the EPA during 1976. This document points out that statutes and regulations which protect ground water reflect the difficult and complex nature of ground-water pollution control. They cite the following ten "control points" as follows:

1. Surface water standards
2. Land use regulations
3. Control of waste disposal sites
4. Management of water levels and pumping rates

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[1] A Manual of Laws, Regulations, and Institutions for Control of Ground Water Pollution, NTIS PB-257 808, June 1976.

5. Control of well construction and operation
6. Air quality standards
7. Control of land spreading of potential pollutants
8. Control of storage areas
9. Control of mining and quarrying
10. Control of transportation and handling of fluids

All the above "control points" can effect the protection of ground water, but most are not primarily designed to do so. Also, most "control points" pertain to intentional activities. This program was concerned with provisions for accidental activities such as spills, underground tank leakage, etc.

Table 1 summarizes the results of the state-by-state survey to determine state laws and/or regulations that protect ground water. The provisions referred to in Table 1, and explained below, were established by Versar, Inc., as those that impart effectiveness to a ground-water protection regulation. Only three states, Alaska, California and Wyoming, have ground-water protection laws that contain all provisions. Florida, Georgia, Hawaii, Massachusetts, Nevada, New Jersey and Pennsylvania ground-water protection regulations contain almost all of these provisions. It is, therefore, concluded that only about 20 percent of the states have adequate ground-water protection regulations.

Ground-Water Protection Provisions in Table 1

1. Any person owning or having control over oil or hazardous materials that is spilled such that there is a substantial likelihood it will enter underground public waters shall:
   (a) Immediately stop the spilling;
   (b) Immediately collect and remove the spilled oil or hazardous material unless not feasible, in which case the person shall take all practicable actions to contain, treat, and disperse the same in a manner acceptable to the state in coordination with the U.S. Environmental Protection Agency and in accordance with Annex X of the National Contingency Plan;
   (c) Immediately proceed to correct the cause of the spill;

TABLE 1. STATE LAWS PERTAINING TO GROUND-WATER PROTECTION

STATE	TITLE, PERTINENT SECTIONS	PROVISIONS
Alabama	N/A	N/A
Alaska	Alaska Oil Discharge Pollution and Control Act	1→6
Arizona	Arizona Oil Spill Contingency Plan Section A	1d, 2, 4, 5
Arkansas	Water & Air Pollution Control Act	1(a→d) 2, 3, 4
California	Porter-Cologne Act	1→6
Colorado	Colorado Water Quality Control Act Part 6	1d
Connecticut	Water Pollution Laws	1(a→e), 2, 3
Delaware	Delaware Environmental Protection Act Section 6028	1d
Florida	Florida Statutes 403 CH 17 Fla. Rules of Administrative Procedure, Section 3, 4	1(a→e), 2, 4, 5, 6
Georgia	Georgia Water Quality Control Act	1(a→e), 2, 3, 4, 5
Hawaii	Department of Health Regulations Chapter 37-A	1(a→e), 2, 3, 4, 5
Idaho	Water Quality Standards and Wastewater Treatment Requirements Section X G	1a, b, d
Illinois	Illinois Pollution Control Board Rules And Regulations, Chapter 6 Public Water Supplies, 313-C	1a, b, c, d, e 2, 3, 6

(continued)

TABLE 1. (continued)

STATE	TITLE, PERTINENT SECTIONS	PROVISIONS
Indiana	Indiana Board of Health Regulations	1(a→e), 2, 4, 6
Iowa	Iowa House File 490	1(a→e), 2, 3, 5
Kansas	Kansas State Board of Health Regulations 28-16-27. Pollution Spills and By-Passes	1d, e
Kentucky	Water Quality Regulations	1(a→e), 2, 3, 4
Louisiana	Department of Conservation Memorandum	1(a→e), 2, 4
Maine	Oil Conveyance Law, MRSA Title 38, Chap. 3, Oil Discharge Prevention & Pollution Controls	1(a→e), 2, 3, 5, 6 (oil only)
Maryland	Maryland Natural Resources Law For Hazardous Substance	1(a→e), 2, 3, 5
Massachusetts	General Laws of Massachusetts	1(a→d), 2, 3, 4, 5, 6
Michigan	Michigan Spills Contingency Plan	1(a→e), 2
Minnesota	Laws Relating to the Minnesota Pollution Control Agency, Chapter 116, Section 116.061	1a, b, c, d
Mississippi	Mississippi Code Of 1972, Section 49, 17.1 - 17.31	1(a→d), 2, 3, 5
Missouri	Rules of Department of Natural Resources Division 20 - Clean Water Commission Chapter 5 - Hazardous Materials 10 CSR 20-5.010	1a, d, 2
Montana	N/A	N/A

(continued)

TABLE 1. (continued)

STATE	TITLE, PERTINENT SECTIONS	PROVISIONS
Nebraska	Ground-water Standards	1(a→e), 2, 4
Nevada	State of Nevada Water Pollution Controls	1(a→e), 2, 3, 4, 5
New Hampshire	New Hampshire Revised Statutes Chapter 146-A	1(a→d), 2, 3, 4
New Jersey	Spill Contingency & Control Act	1(a→e), 2, 3, 4, 5
New Mexico	Amended Water Quality Control Commission Regulations 1-203 Notification of Discharge	1a, b, d
New York	Policies and Procedures Manual Title 1800 - Emergency Operations New York State Department of Environmental Conservation (Memorandum)	1d, 4 6
North Carolina	N/A	N/A
North Dakota	Spill Contingency Plan	1(a→e), 2, 3, 4
Ohio	Ohio Water Pollution Controls	2
Oklahoma	Oklahoma Statute 52	1(a→d), 2, 3
Oregon	Oregon Department of Environmental Quality, Oil Spill Contingency Plan Subdivision 7, 47-105 Notice, Control and Clean-up of Oil Spills Required	1a, b, c, d, e, 2, 3
Pennsylvania	Title 25 Rules and Regulations Part I. Department of Environmental Resources Subpart C Protection of Natural Resources Article II. Water Resources 101.2	1(a→d), 2, 3, 4, 5

(continued)

TABLE 1. (continued)

STATE	TITLE, PERTINENT SECTIONS	PROVISIONS
Rhode Island	General Laws of Rhode Island	1(a→c), 4
South Carolina	Federal Water Pollution Control Act. PL-92-500	1(a→e), 2, 3, 4
South Dakota	South Dakota Water Pollution Standards	1a, b, d, e, 3
Tennessee	Tennessee Code Annotated	1(a→d), 2, 3
Texas	State of Texas Oil and Hazardous Pollution Contingency Plan Section VI	1d, 2, 3, 4
Utah	State of Utah Oil and Hazardous Spills Directory	1a, b, d
Vermont	Vermont Statutes Annotated, Chapter 47 Section 12	1(a→d), 2, 3, 4
Virginia	State Water Control Law Article 8	3
Washington	Laws and Oil Spill Emergency Procedures	1a, b, d, 3
West Virginia	Code of West Virginia Chap. 20, Article 5A	1(a→e), 2, 3, 4
Wisconsin	Wisconsin Proposed Bill 880	1a, b, c, d
Wyoming	Wyoming Water Quality Rules and Regulations Chapter IV	1→6

(d) Immediately notify the state of the type, quantity and location of the spill, corrective and clean-up actions taken and proposed to be taken; and

(e) Within short duration following a spill, submit a complete written report to the state describing all aspects of the spill and steps taken to prevent a recurrence.

2. Clean-up of oil or hazardous material spills shall proceed in a timely and diligent manner until official notice is obtained from the state that satisfactory clean-up has been achieved.

3. State compliance with state abatement requirements does not relieve the owner or person responsible from liabilities, damages or penalties resulting from spill and clean-up of such oil or hazardous materials.

4. Notification of the state does not relieve the owner or responsible person from the liabilities of the mandatory reporting requirements to the U.S. Environmental Protection Agency.

5. State clean-up fund for mystery spill.

6. State underground pipeline and storage tank corrosion requirements.

TASK 5 - DEVELOPMENT OF GROUND-WATER CONTAMINATION SUSCEPTIBILITY CRITERIA

This section presents the criteria to determine areas which are susceptible or non-susceptible to contamination of underground drinking water sources from land spills. The criteria take into account the interaction of geology, hydrology, physiography and frequency and type of spill. The susceptibility of an aquifer to contamination from a leak or spill is determined by the hydrogeological factors of the area, and the amount, distribution and type of pollutants within the hydrologic province.

The hydrogeology of a given area determines the occurrence and movement of ground water and therefore determines what happens to a contaminant that may enter the ground-water regime.

Generally, a contaminant will percolate downward through a zone of aeration to a saturated zone and then laterally to points of discharge. The natural direction and rate of migration are dependent upon the geology,

although artificial controls can alter the rate and direction.

Surface and sub-surface conditions which have created large catchments for underground water can just as easily create catchments for contaminants. Contaminants can enter an aquifer by percolation through the zone of aeration, by infiltration and migration in the zone of saturation, or by direct injection.

The important hydrogeologic factors in determining aquifer susceptibility to contamination are given below:

- Distance to Point of Water Use

The chance of significant ground-water contamination decreases as the distance between the source of contamination and a point of ground-water use increases. Some reasons include:

a. Dilution tends to increase with distance;
b. Sorption is more complete with increased distance;
c. Time of contaminant exposure to soil increases with distance, resulting in an opportunity for more complete decay or degradation; and
d. Sometimes the water table gradient decreases with distance, and therefore, the velocity of flow decreases with the distance from the contamination site.

- Depth to Water Table

The water table is a determinable but fluctuating boundary between the unsaturated zone and the underlying zone of saturation. The thickness and nature of the unsaturated zone are important considerations in the management of spills affecting ground water. In most places, loose granular materials occupy at least part of the unsaturated zone, and contaminants tend to be stationary except when leached or carried downward by precipitation or by seepage. The great reliance on the unsaturated zone for natural contamination control stems chiefly from the biological and chemical degradation and the sorption of contaminants.

- Water Table Gradient

The direction of flow and flow rate of ground water are important con-

siderations in evaluating the possibilities of contamination at a specific site. Measurements of water levels in wells and the preparation of a water table map are major steps in solving or avoiding the more serious contamination problems. If a water table map is not available or the cost of making one is not justified, a hypothetical water table map may be constructed to visualize the general gradient of the water table and thus the general direction of water movement. Of course, it is important to know whether a contaminant is moving toward or away from a water supply.

- Permeability - Sorption

Because there is a tendency for many contaminants to be retained on earth materials by chemical and physical sorption, an evaluation of the permeability-sorptive capacity of the site should be made. Determining the presence of cracks, fractures and other openings is important because they can provide easy access for a contaminant to the saturated zone of an aquifer.

Spill Site Evaluation

In conducting the Surface Impoundment Assessment program, the Office of Drinking Water has developed a rating system for rapid evaluation of the hydrogeological parameters discussed in the previous section. This rating system determines the aquifer sensitivity of an area where at a minimum cost a surface impoundment is located. It can be used to determine quickly the probability of ground-water contamination potential caused by an accidental spill.

The system examines contamination potential in the upper ground-water system which usually is a water-table aquifer. In a few areas of the country, the first aquifer to be encountered may be an artesian aquifer in which case this rating would also apply. Five basic factors are scored in this system:

(1) the hydrogeology of the unsaturated zone above the aquifer (thickness of unsaturated zone, permeability and general attenuating characteristics of the material, whether consolidated or unconsolidated);

(2) the aquifer transmissivity;

(3) the ground-water quality;

(4) the physical and chemical character of the spilled material such as toxicity, concentration, volume, etc.

(5) the potential for contamination of existing ground and surface water supplies by considering distance and direction of contaminated ground-water movement.

When conducting this assessment, the following steps are taken:

Step 1. Rating the Unsaturated Zone

The hydrogeologic properties of the material underlying the spill site in the unsaturated zone above the aquifer are rated to determine the potential for contaminants to reach the water table. The permeability and sorption characteristics of the earth materials (either consolidated or unconsolidated) may decrease the rate of waste movement and attenuate the waste concentrations to a certain degree. Finer grained unconsolidated material and impermeable consolidated rock inhibit the movement of fluids to the ground water. Additionally, the finer grained earth materials (clays) tend to retard the waste movement by attenuation mechanisms (ion exchange, adsorption and absorption), depending upon waste type and the chemical milieu of the underlying unsaturated zone. The thickness of the unsaturated zone also affects the attenuating capability of the spill site by providing greater contact time of the spilled material with the earth materials and by providing the opportunity for other processes (oxidation, precipitation, biological degradation and filtration) to help attenuate the spilled material.

Although it is acknowledged that contaminated ground water is subject to varying degrees of attenuation as it flows through the aquifer, this rating system focuses primarily on the potential for ground-water pollution. This occurs when contaminants reach the ground water. For this reason, the hydrogeologic factors being rated in this step are those of the material above the aquifer in the unsaturated zone.

Step 2. Rating the Ground-Water Availability

In determining the ground-water pollution potential of the spill site, the overall aquifer property of transmissivity, is important. Transmissivity

is the ability of the aquifer to transmit ground water and is related to the hydraulic conductivity and saturated thickness of the aquifer.

Step 3. Rating the Ground-Water Quality

Ground-water quality is a determinant of the ultimate usefulness of the ground water. Consideration of ground-water quality is intended to indicate the background water quality of the aquifer. Ground water presently used for drinking water or having fewer than 500 mg/l total dissolved solids (TDS) is rated highest, and water of more than 10,000 mg/l TDS is rated the lowest quality.

Step 4. Rating of the Physical and Chemical Character of the Spilled Material

The rating of the potential health hazard of the spilled material to drinking water supplies involves the physical and chemical character including toxicity and the volume of the spill. The rating of the toxicity of the spilled material will be characterized according to the waste characteristics identified in the SIC code.

Step 5. Scoring of the Site's Ground-Water Contamination Potential

Upon completion of the first four steps rating the hydrogeologic factors, the aquifer, and the potential waste character, a final score will be determined for that spill site indicating its overall relative ground-water contamination potential.

Step 6. Determination of the Potential Health Hazard to Present Drinking Water Supplies

In order to allow further prioritization of the spill sites by their potential threat to drinking water sources, the distance to present underground and surface drinking water supplies will be rated in conjunction with the determination of the direction of movement of the waste plume (i.e., towards or away from the water supply).

Step 7. Rating the Degree of Confidence

This step allows the spill investigator to indicate his/her confidence in the data used to arrive at the Step 1 through 6 scores. High confidence is given to site specific data sources, and low confidence is given to assumptions based on general knowledge.

Step 8. Miscellaneous Identifiers

This step allows the evaluator to identify special conditions that would not be evident from the numerical scores. For example, the letter A can be added to the score to indicate that the spill site is in an alluvial valley.

Step 9. Recording of Final Score

In this step the evaluator will record the values determined in Step 6 through 8, along with those recorded in Step 5. Upon completion of this step all values for Steps 1-8 will have been recorded and the rating of the ground-water contamination potential will be completed.

The following table shows the general ranges for ground-water contamination and incumbent risks or probability of aquifer contamination. This table can be used as a general guide to determine the degree and urgency of action needed in response to a spill according to the probability of aquifer contamination.

To explain this system in detail, the "Manual for Evaluating Contamination Potential of Surface Impoundments" (EPA 570/9-78-003) is reprinted in Appendix E in the "Guidance Document."

It must be emphasized that the use of the above system is intended as only a standardized methodology for recording the hydrogeologic parameters at a spill site and obtaining a first approximation of the potential for ground-water contamination. The rating system should be utilized to get a quick overview of the spill's threat to ground water and the degree and quickness of the response to the spill required.

To assist in the hydrogeological evaluation of pollution hazards, the following information should also be made available.

- direction and amount of surface runoff
- amount of evaporation and transpiration
- natural and extent of artificial controls exerted on the aquifer, i.e., pumping wells, recharge and discharge areas
- soil attenuation properties

GENERALIZED SPILL SITE RATINGS

Probability of Aquifer Contamination	Step 1 Unsaturated Zone	Step 2 Ground-water Availability	Step 3 Ground-water Quality	Step 4 Contaminant Hazard Potential	Step 5 Ground-water Contamination Potential (1) + (2) + (3) + (4)	Step 6 Potential Endangerment
Very High	9	6	5	9	24-29	9
High	7	5	4	7	18-23	7
Medium	5	4	3	5	12-17	5
Low	3	3	2	3	6-11	3
Very Low	1	2	1	1	1-5	0

The retrieval of such information can be made from existing hydrogeological surveys, pumping test analysis, borehole logging information, geophysical surveys, rainfall and evapotranspiration details and river flow records. Given this information, the hydrogeologist should be able to determine ground-water movement and flow patterns, with the aim of assessing whether or not a given aquifer system affords adequate protection against sources of contamination.

After the determination of aquifer sensitivity is completed, a second stage of susceptibility evaluation is required. This involves an evaluation of the sources of contamination in the vicinity.

The following are some major factors to be considered:

- Type of contaminants
- Volume in the surrounding area
- Storage types
- Transportation amounts, type and routes
- Preventive techniques used in the area

Figure 1 illustrates the concentration of underground transportation of petroleum products by pipeline in the Gulf Coast area. Pipeline transportation and storage facilities with an overlay of the critical ground-water sensitivity areas can provide a comprehensive planning mechanism for the protection of an area's ground-water resource.

TASK 6 - DEVELOPMENT OF A GUIDANCE DOCUMENT

A separate guidance document entitled "Protection of Ground-Water Resources from the Effect of Accidental Spills of Hydrocarbon and Other Hazardous Substances," was developed.

The purpose of the document is to assist state, regional and industrial personnel by providing guidance on spill prevention and clean-up methods as they relate to ground-water contamination. The document is divided into several sections, each with a specific purpose. The Table of Contents of this document appears as Table 2.

The following is a general description of each of these sections:

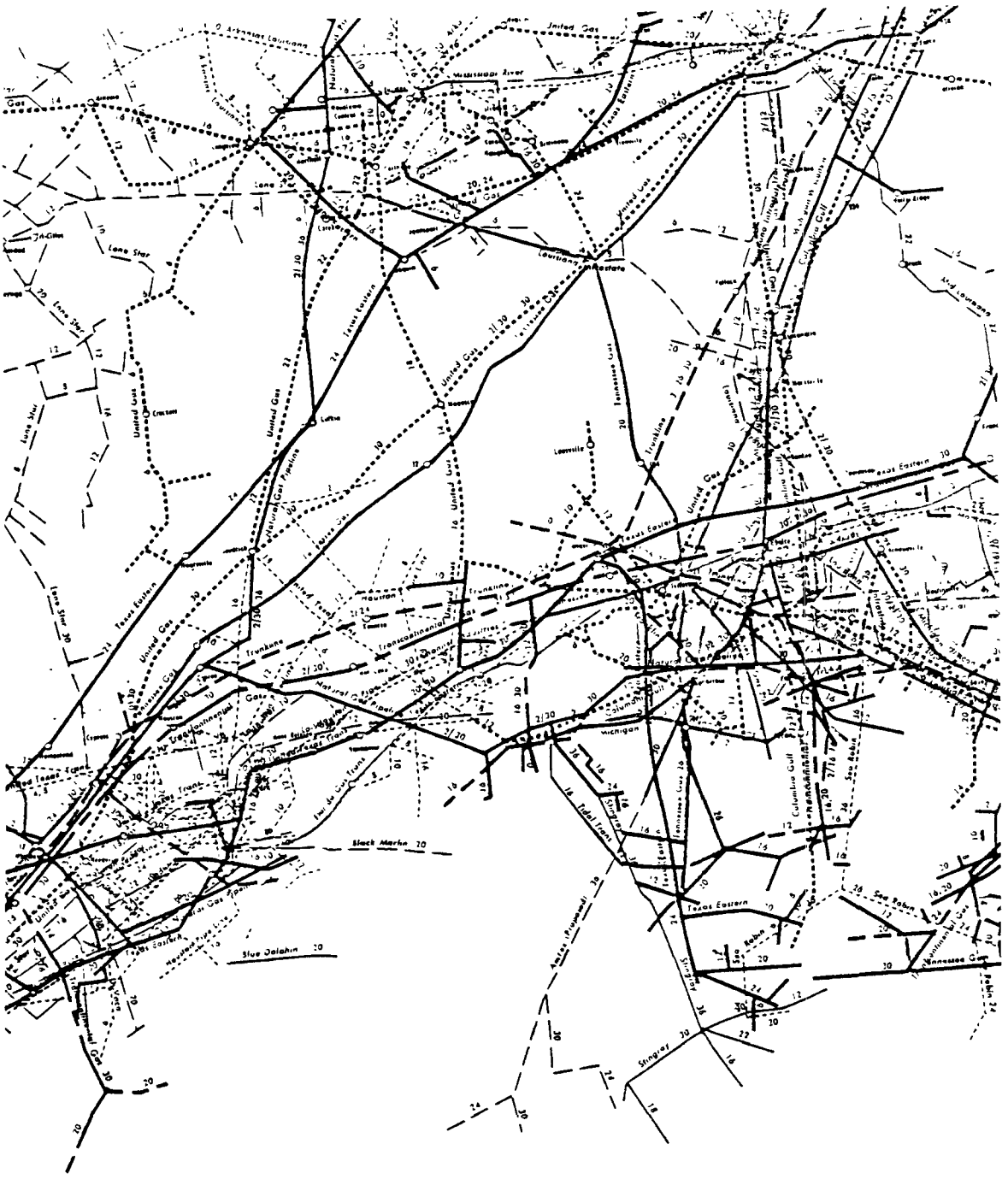

Figure 1. Section of an illustration showing pipelines along the Gulf Coast area.

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- Hydrogeological Information - This section describes ground water and those hydrogeological factors which are important for the assessment and evaluation of a spill.

- Spill Damage Assessment Techniques - The information in this section describes the basic state-of-the-art in sub-surface spill damage assessment.

- Land Spill Prevention and Control Techniques - This section describes several prevention and control techniques used to minimize ground-water contamination.

- Bibliography - This section contains those references used in the preparation of this document and others for the reader's further specific investigation or knowledge in the areas of spill abatement and prevention.

- Appendices - The appendices contain details regarding the following areas:

  A - Description of U.S. aquifer systems
  B - State laws applicable to ground-water contamination
  C - State and Federal spill response telephone numbers
  D - State geologist to call for specific hydrogeological information in each state.

SECTION 4

BIBLIOGRAPHY

1. "Analytical Instrumentation". W. L. Budde and D. Craig Shew. Presented to the Office of Research and Development, EPA, ADP Workshop, Bethany, West Virginia, October 2-4, 1974.

2. "Application of Ground Water Flow Theory to a Sub-surface Oil Spill". Holzer. Ground Water, Vol. 14, No. 3, 1976.

3. "Applied Hydrology". Ray K. Linsley, Jr., Max A. Kohler and Joseph L. H. Paulhus. McGraw-Hill, New York, 1949.

4. "Aspects of Aquifer Management". Leslie G. McMillion and Diane Olsson. The Cross Section, Vol. 18, No. 3, March 1972.

5. "Bacterial Degradation of Motor Oil". J. D. Walker, R. R. Colwell and L. Petrakis. Journal of the Water Pollution Control Federation 47(8): 2058-2066.

6. "Biodegradation of High-Octane Gasoline in Ground Water". Raymond, Jamison and Hadson. Development in Industrial Microbiology, Vol. 16, 1975.

7. "Control of Hazardous Material Spills". Proceedings of 1973-78 National Conference on Control of Hazardous Material Spills.

8. "Corrosion Control for Buried Service Station Tanks". Paper #52, John Fitzgerald. Presented at the International Corrosion Forum devoted exclusively to the Protection and Performance of Materials, April 14-18, 1975, Toronto, Ontario, Canada.

9. "Elements of Applied Hydrology". Don Johnstone and William P. Cross. Ronald Press Co., New York, 1949.

10. "Feasibility of Plastic Foam Plugs for Sealing Leaking Chemical Containers". R. C. Mitchell et al, U.S. Environmental Protection Agency, R2-73-251, May 1973.

11. "Gasoline in Ground Water". McKee, Laverty, Hertel. JWPCF, Vol. 44, No. 2, 1972.

12. "General Principles of Artificial Ground-Water Recharge". O.E. Meinzer. Econ. Geol. 41:191-201, 1946.

13. "Ground Water". C. F. Tolman. McGraw-Hill, New York, 1937.

14. "Ground Water Hydrology". David Keith Todd. John Wiley & Sons, Inc., New York, 1959.

15. "Ground Water Monitoring to Verify Water Quality Objectives". Leslie G. McMillion. Presented to Conference on Land Disposal of Wastewaters, East Lansing, Michigan, December 6-7, 1972.

16. "Ground Water Pollution in the South Central States". Marion R. Scalf, Jack W. Keeley and C. J. LaFevers. EPA-R2-73-268, June 1973.

17. "Ground Water Problems Associated with Well Drilling Additives". D. Craig Shew and Jack W. Keeley. Presented to EPA's Office of Toxic Substances Conference on Environmental Aspects of Chemical Use in Well Drilling Operations, Houston, Texas, May 20-22, 1975.

18. "Ground Water Reclamation by Selective Pumping". Leslie G. McMillion. Transactions of Society of Mining Engineers, AIME, Vol. 250, March 1971.

19. "Guidelines for Interception of Ground Water Contamination near Buildings". Department of Environmental Conservation, New York.

20. "Hydrology". C. O. Wisler and E. F. Brater. John Wiley & Sons, New York, 1949.

21. "Hydrology". Edited by Oscar E. Meinzer under auspices of National Research Council. Dover Publications, Inc., New York, 1949.

22. "Nutrient, Bacterial, and Virus Control as Related to Ground Water Contamination". Sub-surface Environmental Branch, Robert S. Kerr Environmental Research Laboratory, National Environmental Research Center, EPA. Prepared for Region IV, EPA, Atlanta, Georgia. December 1974.

23. "Occurrence of Ground Water in the United States, with a Discussion of Principles". O. E.Meinzer. U.S. Geological Survey, W.S.P. 489, 1923.

24. "Oil Pollution Prevention, Non-Transportation Related Onshore and Offshore Facilities". Federal Register, Vol. 38, No. 237, p. 34164-34170.

25. "Outline of Ground Water Hydrology". O.E. Meinzer. U.S. Geological Survey W.S.P. 494, 1923.

26. "Outline of Methods for Estimating Ground Water Supplies". O. E. Meinzer. U.S. Geological Survey, W.S.P. 638-C, 1932.

27. "Polluted Ground Water". David Keith Todd, Daniel E. Orren McNulty. Water Information Center, Inc., New York, 1976.

28. "Practical Handbook of Water Supply". Frank Dixey. Murby, London, 1931.

29. "Present Status of our Knowledge Regarding the Hydraulics of Ground Water". O. E. Meinzer and L. K. Wenzel. Econ. Geol. 35:915-941, 1940.

30. "Proceedings of the Second National Ground Water Quality Symposium". National Water Well Association and Robert S. Kerr Environmental Research Laboratory, NERC, EPA. Symposium held in Denver, Colorado, September 25-27, 1974.

31. "Regulatory and Legal Aspects of Aquifer Management". Leslie G. McMillion and Diane L. Olsson. Presented to American Institute of Chemical Engineers, February 22, 1972.

32. "Sampling Equipment for Ground Water Investigations". Leslie G. McMillion and Jack W. Keeley. Ground Water, Vol. 6, No. 2, March-April 1968.

33. "Significance and Nature of the Cone of Depression in Ground Water Bodies". C.V. Theis. Econ. Geol. 33:889-902, 1938.

34. "Sub-surface Biological Activity in Relation to Ground Water Pollution". James F. McNabb and William J. Dunlap. Proceedings of the Second National Ground Water Quality Symposium. Paper presented to Symposium in Denver, Colorado, September 25-27, 1974.

35. "Technology for Managing Spills on Land and Water". D. B. Dahm and R. J. Pilie. Environmental Science and Technology, Vol. 8, No. 13, 1974.

36. "The Migration of Petroleum Products in Soil and Ground Water - Principles and Countermeasures". American Petroleum Institute, Publication No. 4149, 1972.

37. "The National Ground Water Quality Symposium". Environmental Protection Agency and National Water Well Association 16060 GRB 08/71.

38. "The Role of Geosciences in Ground Water Development and Protection". Jay H. Lehr and Jack W. Keeley. Presented to Geosciences and Man Committee, International Union of Geological Sciences, Bad Hamburg, Germany, July 1974.

39. "The Theory of Ground Water Motion". M. K. Hubbert. Jour. Geol. 48: 785-944. Nov-Dec 1940 (Jan. 1941).

40. "Underground Leakage of Flammable and Combustible Liquids". 1972. NFPA No. 329, National Fire Protection Association.

APPENDIX A

LAND SPILL INVENTORY DATA

STATE: CALIFORNIA

SPILL ID #	LOCATION	CONTAMINANT & VOLUME	SOURCE	CAUSE	EFFECT
CA-1	Concord Contra Costa Co.	Gasoline & diesel fuel Unknown	Bulk storage facility	Unknown	Extensive groundwater contamination and surface water contamination.
CA-2	Porta Costa Contra Costa Co.	Petroleum prod's Unknown	Bulk storage and transfer lines	Leakage	Heavy soil, groundwater and small stream contamination.
CA-3	Orinda Village	Gasoline 1,700 gal.	Service station line	Leakage	Groundwater contamination affecting municipal water supply.
CA-4	San Jose Santa Clara Co.	Hazardous chemicals Unknown	Chemical waste processor	Leakage & Spillage	Possible groundwater contamination and surface water contamination.
CA-5	San Jose Santa Clara Co.	Pesticides Unknown	Pesticide processing facility	Leakage, spillages, intentional discharge	Possible contamination of groundwater.
CA-6	Sonoma Sonoma Co.	Gasoline Unknown	Bulk storage facility	Filler line failure	Contamination of two domestic wells.
CA-7	Selby Contra Costa Co.	Sulfuric acid and lead, zinc Unknown	Chemical processing facility	Poor waste discharge control	Severe soil and groundwater contamination and surface water contamination.
CA-8	Petaluma	Gasoline 3,500 gal.	Service station	Valve failure	Contamination of domestic well and commercial sump system.
CA-9	Emeryville Alameda Co.	Chromium Unknown	Electroplating process facility	Poor waste discharge control	Groundwater contamination.
CA-10	Alturus	Diesel fuel 500 gal.	R.R. engine	Spillage	Soil contamination possible groundwater contamination.
CA-11	Los Molinos	Gasoline	Truck	Spillage	Soil, possible groundwater contaminated.

STATE: CALIFORNIA

SPILL ID #	LOCATION	CONTAMINANT & VOLUME	SOURCE	CAUSE	EFFECT
CA-12	Corning	Diesel fuel 2,400 gal.	Train	Derailment accident	Soil contamination.
CA-13	Visalia	PCP and other hazardous chem's. Unknown	Chemical dip tank	Leakage	Groundwater and soil contamination.
CA-14	Sacramento	Gasoline 9,000 gal.	Bulk storage facility	Valve failure - faulty construc.	Groundwater contamination of immediate area.
CA-15	Riverside Orange Co.	Fuel oil 17,000 gal.	Bulk storage facility	Leakage	Soil contamination.
CA-16	Orange Orange Co.	Gasoline 378,000 gal.	Bulk storage facility	Valve failure	Soil contamination and groundwater contamination.
CA-17	L.A. - Glendale	Gasoline Unknown	Unknown	Unknown	Groundwater contamination threat to city water supply.
CA-18	Oroville	PCP Unknown	Wood Processing plant	Poor waste discharge control	Extensive groundwater contamination and multiple commercial and domestic wells.

STATE: CONNECTICUT

SPILL ID #	LOCATION	CONTAMINANT & VOLUME	SOURCE	CAUSE	EFFECT
CT-1	Plainfield Windham Co.	Organohalides Volume Unknown	Industrial Site	Spillage	1 Public Well and 1 Industrial Well Contaminated
CT-2	Plainville	Organohalides Volume Unknown	Industrial Site	Poor Waste Discharge control	1 Public Well Contaminated

STATE: IDAHO

SPILL ID #	LOCATION	CONTAMINANT & VOLUME	SOURCE	CAUSE	EFFECT
ID-1	COEUR D'ALENE KOOTENAI CO.	PETROLEUM PRODUCT (GASOLINE SUSPECTED) VOLUME UNKNOWN	UNKNOWN SUSPECTED BURIED STORAGE TANK	UNKNOWN SUSPECTED LEAK	1 PUBLIC WELL CONTAMINATED
ID-2	MURRAY SHOSHONE CO.	#2 DIESEL FUEL 169,312 GAL.	PIPELINE	RUPTURE (PRESSURE)	GROUND WATER CONTAMINATED NO WELLS AFFECTED
ID-3	MOUNTAIN HOME	GASOLINE 35,070 GAL.	PIPELINE	LEAK (PYROLYSIS)	GROUND WATER CONTAMINATED NO WELLS AFFECTED
ID-4	BUHL TWIN FALLS CO.	#2 DIESEL FUEL 97,692 GAL.	PIPELINE	RUPTURED BY CATAPILLAR	GROUND WATER CONTAMINED NO WELLS AFFECTED

STATE: ILLINOIS

SPILL ID #	LOCATION	CONTAMINANT & VOLUME	SOURCE	CAUSE	EFFECT
IL-1	CHARLESTON COLES COUNTY	CYANIDE VOLUME UNKNOWN	TRAIN	DERAILMENT	
IL-2	ASHMORE COLES COUNTY	NITRIC ACID VOLUME UNKNOWN	TRAIN	DERAILMENT	
IL-3	MATTOON	CYANIDE VOLUME UNKNOWN	TRAIN	DERAILMENT	
IL-4	ROODHOUSE GREENE COUNTY	DIESEL FUEL VOLUME UNKNOWN	UNKNOWN	UNKNOWN	2 DOMESTIC WELLS CONTAMINATED
IL-5	MAPLETON	ACRYLONITRILE VOLUME UNKNOWN	TRAIN	DERAILMENT	3-6 DOMESTIC WELLS CONTAMINATED
IL-6	WINNEBAGO	VARIOUS WASTE CHEMICALS VOLUME UNKNOWN	STORAGE	IMPROPER DISPOSAL	1 DOMESTIC WELL CONTAMINATED
IL-7	SPRINGFIELD SANGAMON COUNTY	GASOLINE VOLUME UNKNOWN			FUMES IN HOMES
IL-8	RANTOUL CHAMPAIGN COUNTY	PENTACHLORO-PHENOL VOLUME UNKNOWN			
IL-9	DES PLAINES COOK COUNTY	GASOLINE VOLUME UNKNOWN	STORAGE TANK	LEAKAGE	FUMES IN BASEMENT OF HOUSE

STATE: MARYLAND

SPILL ID #	LOCATION	CONTAMINANT & VOLUME	SOURCE	CAUSE	EFFECT
MD-1	PHOENIX MILITARY RESERVATION, BALTIMORE, Co.	FUEL OIL VOLUME UNKNOWN	UNPROVEN POSSIBLE BURIED STORAGE TANK	UNPROVEN POSSIBLE LEAK	1 DOMESTIC WELL CONTAMINATED
MD-2	MD. JOB CORPS CTR. WOODSTOCK BALTIMORE Co.	FUEL OIL VOLUME UNKNOWN	UNPROVEN SUSPECTED BURIED STORAGE TANK	UNPROVEN SUSPECTED LEAK & REFUELING SPILLS	2 INSTITUTIONAL WELLS CONTAMINATED
MD-3	BRYAN'S ROAD CHARLES CO.	GASOLINE, VOLUME UNKNOWN (2,200 GAL RECOVERED FROM TELEPHONE VAULT)	SERVICE STATION STORAGE TANK	UNPROVEN SUSPECTED LEAK & REFUELING SPILL	BURIED TELEPHONE VAULT CONTAMINATED
MD-4	FREDERICK FREDERICK CO.	FUEL OIL 4,000 GAL.	BURIED STORAGE TANK	LEAK CAUSED BY WALL WHICH COLLAPSED DURING HEAVY RAIN	SURFACE STREAM CONTAMINATED

STATE: MASSACHUSETTS

SPILL ID #	LOCATION	CONTAMINANT & VOLUME	SOURCE	CAUSE	EFFECT
MA-1	Dedham	#2 Fuel Oil Volume Unknown 20,000 Gal. Recovered	Buried Storage Tank at Industrial Site	Leak	Surface Stream Contaminated From Ground Water Seepage
MA-2	Burlington	Gasoline 1000-5000 Gal.	Pipeline	Rupture	2 Public Wells Shut down to Avoid Contamination

STATE: MICHIGAN

SPILL ID #	LOCATION	CONTAMINANT & VOLUME	SOURCE	CAUSE	EFFECT
MI-1	CLIO	GASOLINE VOLUME UNKNOWN	PIPELINE	LEAKAGE	CITY WATER SUPPLY CONTAMINATED
MI-2	NILES BERRIEN COUNTY	GASOLINE 300,000 GAL.			POSSIBLE DOMESTIC WELL CONTAMINATION
MI-3	MUSKEGON	PETROLEUM 2,431 GAL.	PIPELINE AND STORAGE	SEEPAGE	SEVERAL DOMESTIC WELLS CONTAMINATED
MI-4	CARSON CITY MONTCALM COUNTY	PETROLEUM VOLUME UNKNOWN	REFINERY	UNKNOWN	SEVERAL DOMESTIC WELLS CONTAMINATED POSSIBLE MUNICIPAL
MI-5	OS CODA	TRICHBROETHYLENE VOLUME UNKNOWN			1 DOMESTIC WELL CONTAMINATED

STATE: MINNESOTA

SPILL ID #	LOCATION	CONTAMINANT & VOLUME	SOURCE	CAUSE	EFFECT
MIN-1	Coon Rapids	Petroleum 5,090 gal	Service station storage tank	Leakage	Soil and ground water contaminated 80% recovered.
MIN-2	Eyota	Fuel Oil #2 7,000 gal	Commercial storage tank	Drain left open when filling	Probable ground water contamination in immediate area.
MIN-3	Newport	Gasoline Unknown	Pipeline	Leakage	Explosive fumes in basements and in sewage lift station.
MIN-4	Waseca	Gasoline 9,848 gal	Service station storage tank	Rupture	Ground water and sewer line contaminated.
MIN-5	Albert Lea	Gasoline 500 gal	Service station storage tank	Leakage	Potential ground water contamination.
MIN-6	Graceville	Gasoline Unknown	Service station storage tank	Rupture	Station well contaminated. Station building destroyed in explosion. Fumes in homes.
MIN-7	Clements Redwood County.	Gasoline Unknown	County vehicle maintenance facility	Refueling spills	Domestic well contaminated. Fumes in basement.
MIN-8	Hector	Gasoline 15,000 gal.	Bulk Storage Facility	Leakage	Soil and ground water contaminated.
MIN-9	Elk River	Fuel oil #2 Unknown	Power plant storage	Leakage	Soil and ground water contaminated.
MIN-10	Stillwater	Gasoline and fuel oil Unknown	Service station and domestic fuel lines	Leakage	Ground water contaminated.

STATE: MINNESOTA

SPILL ID #	LOCATION	CONTAMINANT & VOLUME	SOURCE	CAUSE	EFFECT
MIN-11	Cosmos	Gasoline Unknown	Service station storage	Leakage	Ground water contamination. City sewer, public basements contaminated.
MIN-12	Two Harbors	Gasoline 2,400 gal	Tank truck	Truck accident	Explosive vapors in woods and house trailer. Possible ground water and domestic well contaminated.
MIN-13	Browerville	Gasoline Unknown	Service station storage	Leakage	Soil saturated. Fumes in adjacent home.
MIN-14	Mankats Blue Earth County	Gasoline 6,000 gal	Pipeline	Equipment rupturing line	Soil contamination.
MIN-15	Winona	PCB Unknown	Scrap yard	Poor waste discharge control	City wells contaminated.
MIN-16	Sauk Rapids	Gasoline 1,000 gal	Service station lines	Line or valve failure	Ground water contaminated.
MIN-17	Backus Cass County	Gasoline 6,800 gal.	Bulk storage tanks	Rupture	Several domestic wells contaminated.
MIN-18	Austin Mower Co.	Gasoline 2,500 gal	Service station lines	Leakage	Fumes in home. Possible sewer contamination.
MIN-19	Clearwater Co.	Crude oil 92,000 gal	Pipeline	Rupture	Ground water contamination.

STATE: MISSOURI

SPILL ID #	LOCATION	CONTAMINANT & VOLUME	SOURCE	CAUSE	EFFECT
MO-1	BARRY CO.	NITRATE VOLUME UNKNOWN	UNPROVEN NITROGEN-FERTILIZER PIPELINE SUSPECTED	UNPROVEN SUSPECTED LEAK	LARGE SPRING, FARM WELLS AND POND CONTAMINATED, PHYSIOLOGICAL DAMAGE TO LIVESTOCK PERSISTENT PROBLEM.
MO-2	UNION FRANKLIN COUNTY	MONOCHLOROBENZENE 135,000 LBS.	TRAIN	DERAILMENT	1 DOMESTIC WELL CONTAMINATED
MO-3	WENTZVILLE ST. CHARLES CO.	GASOLINE VOLUME UNKNOWN	SERVICE STATION STORAGE TANK	LEAKAGE	FUMES ACCUMULATED IN BASEMENT OF HOUSE AND EXPLOSION RESULTED
MO-4	BOLIVAR POLK CO.	GASOLINE VOLUME UNKNOWN	SERVICE STATION STORAGE TANK	LEAKAGE	BURIED TELEPHONE CONDUIT CONTAMINATED, FUMES IN BASEMENTS OF BUILDINGS OVER 6 BLOCK AREA.
MO-5	AVA DOUGLAS CO.	PENTACHLOROPHENOL VOLUME UNKNOWN	WOOD-TREATMENT PLANT	POOR HOUSEKEEPING	CONTAMINATED GROUNDWATER LEACHED INTO STREAM (PRAIRIE CREEK)
MO-6	WEST ALTON ST. CHARLES CO.	GASOLINE VOLUME UNKNOWN	UNKNOWN POSSIBLE PIPELINE	UNKNOWN	FUMES IN BASEMENTS AFTER FLOOD

STATE: NEW HAMPSHIRE

SPILL ID #	LOCATION	CONTAMINANT & VOLUME	SOURCE	CAUSE	EFFECT
NH-1	Lebanon	PVC & Dioctylphthalate 400 Gal.	Truck	Traffic Accident	2 Domestic Wells Contaminated
NH-2	Manchester Hillsborough Co.	#4 Fuel Oil Volume Unknown 250,00 Gal Recovered	Storage Tank at Factory	Leak	Contaminated Ground Water and Seeped into Surface Drainage Ditch

STATE: NEW JERSEY

SPILL ID #	LOCATION	CONTAMINANT & VOLUME	SOURCE	CAUSE	EFFECT
NJ-1	SOUTH ORANGE	GASOLINE VOLUME UNKNOWN	UNKNOWN	UNKNOWN	8 DOMESTIC WELLS CONTAMINATED

STATE: NEW YORK

SPILL ID #	LOCATION	CONTAMINANT & VOLUME	SOURCE	CAUSE	EFFECT
NY-1	MECHANICSTOWN, WELLKILL ORANGE COUNTY	GASOLINE VOLUME UNKNOWN	UNKNOWN POSSIBLE STORAGE FACILITIES (TANK FARMS)	UNKNOWN POSSIBLE LEAKAGE	2 DOMESTIC WELLS CONTAMINATED WELL CONTAMINATION TO A DENSELY POPULATED AREA IS POSSIBLE
NY-2	SMITHTOWN SUFFOLK COUNTY	HEATING OIL 300 GAL.	PIPELINE	RUPTURE	GROUNDWATER CONTAMINATED POTENTIAL WELL CONTAMINATION
NY-3	WARREN HERKIMER COUNTY	GASOLINE	SERVICE STATION UNDERGROUND STORAGE	LEAKAGE	SEVERAL DOMESTIC WELL CONTAMINATED
NY-4	WESTHAMPTON AIRPORT SUFFOLK COUNTY	JP-4 (JET FUEL) 90,000 GAL.	STORAGE FACILITY (TANK FARM)	SPILL	PUBLIC WATER SUPPLY CONTAMINATED
NY-5	BALSTON	PETROLEUM VOLUME UNKNOWN	SERVICE STATION UNDERGROUND STORAGE	LEAKAGE	PUBLIC WATER SUPPLY CONTAMINATED
NY-6	CUYLER CORTLAND COUNTY	GASOLINE VOLUME UNKNOWN	UNKNOWN	UNKNOWN	1 DOMESTIC WELL CONTAMINATED
NY-7	ROCHESTER MONROE COUNTY	GASOLINE 1,478 GAL.	SERVICE STATION PUMP	VANDALISM TO PUMPS	GROUND WATER CONTAMINATED, NO WELL CONTAMINATION
NY-8	ALBANY COUNTY AIRPORT	JET A FUEL 750 - 1,000 GAL.	STORAGE TANK BULK STORAGE	OVERFILLING	SATURATED SOIL
NY-9	EDINBURG	GASOLINE VOLUME UNKNOWN	SERVICE STATION UNDERGROUND STORAGE	LEAKAGE	1 DOMESTIC WELL CONTAMINATED
NY-10	MERRICK NASSAU COUNTY	GASOLINE 8,000 GAL.	SERVICE STATION UNDERGROUND STORAGE	LEAKAGE	POTENTIAL GROUND WATER THREAT

STATE: NEW YORK

SPILL ID #	LOCATION	CONTAMINANT & VOLUME	SOURCE	CAUSE	EFFECT
NY-11	GENESEE	GASOLINE	SERVICE STATION UNDERGROUND STORAGE	LEAKAGE	1 DOMESTIC WELL CONTAMINATED
NY-12	SPRINGWATER LIVINGSTON COUNTY	GASOLINE 300 GAL.	SERVICE STATION UNDERGROUND STORAGE	LEAKAGE	SATURATED GROUND CAUSING FUME PROBLEMS
NY-13	AVOCA ALBANY CO.	FERRIC CHLORIDE ACID 4,000 GAL.	TRUCK TANKER	LEAKAGE	GROUNDWATER CONTAMINATION, NO WELL AFFECTED, COHACTON RIVER THREAT
NY-14	PORT JEFFERSON SUFFOLK COUNTY	#3 OIL 2,000 GAL.	STORAGE TANK OVERFLOW	OVERFLOW WHILE FILLING	SEEPAGE INTO GROUND
NY-15	WATKINS GLEN SCHUYLER COUNTY	GASOLINE 1,000 GAL.	SERVICE STATION UNDERGROUND STORAGE	LEAKAGE	GROUNDWATER CONTAMINATION, NO WELL CONTAMINATED
NY-16	POUGHKEEPSIE DUTCHESS COUNTY	GASOLINE 1,200 GAL.	SERVICE STATION UNDERGROUND STORAGE	LEAKAGE	POSSIBLE GROUNDWATER CONTAMINATION
NY-17	HENRIETTA MONROE COUNTY	GASOLINE VOLUME UNKNOWN	SERVICE STATION UNDERGROUND STORAGE	LEAKAGE	GROUNDWATER CONTAMINATION, NO WELL CONTAMINATION
NY-18	TUPPER LAKE FRANKLIN COUNTY	#2 OIL VOLUME UNKNOWN	UNDERGROUND STORAGE FOR STORE	LEAKAGE	ENTERS BASEMENT W/HIGH WATER TABLE
NY-19	OVID SENECA COUNTY	GASOLINE VOLUME UNKNOWN	SERVICE STATION UNDERGROUND STORAGE	LEAKAGE	ENTERS BASEMENT OF SERVICE STATION
NY-20	HANNIBAL OSWEGO COUNTY	GASOLINE VOLUME UNKNOWN	SERVICE STATION UNDERGROUND STORAGE	LEAKAGE	1 DOMESTIC WELL CONTAMINATED

STATE: NEW YORK

SPILL ID #	LOCATION	CONTAMINANT & VOLUME	SOURCE	CAUSE	EFFECT
NY-21	ASTORIA	#2 FUEL OIL 200,000 GAL.	STORAGE TANK	LEAKAGE	GROUND WATER CONTAMINATION, NO WELL CONTAMINATION
NY-22	ROCHESTER, BARGE CANAL MONROE COUNTY	UNKNOWN CHEMICALS 1,500 GAL.	STORAGE BARRELS	LEAKAGE	SATURATED GROUND, POSSIBLE EXPLOSION AND GROUNDWATER CONTAMINATION
NY-23	ROCHESTER MONROE COUNTY	ACETONE 20,000-22,000 GAL.	TRAIN CARGO	DERAILMENT	GROUNDWATER CONTAMINATION, NO WELL CONTAMINATED
NY-24	HARRIMAN STATE PARK (SULLIVAN COUNTY)	JP-1 SPILL	JET 727	CRASH	GROUND SATURATED, POSSIBLE GROUNDWATER CONTAMINATION

STATE: NORTH CAROLINA

SPILL ID #	LOCATION	CONTAMINANT & VOLUME	SOURCE	CAUSE	EFFECT
NC-1	KERNERSVILLE FORSYTH CO.	HYDROCARBON 30,000 GALLONS	CHEMICAL WASTE PROCESSING PLANT	VANDALISM	GROUND WATER CONTAMINATION
NC-2	FARMVILLE	MISC. CHEMICALS 211,099 LBS. 14,295 GALLONS	FERTILIZER & PESTICIDE WAREHOUSE	FIRE	GROUND WATER CONTAMINATION

STATE: OHIO

SPILL ID #	LOCATION	CONTAMINANT & VOLUME	SOURCE	CAUSE	EFFECT
OH-1	NEW GUILFORD COSHOCTON COUNTY	GASOLINE VOLUME UNKNOWN			WATER SUPPLY FOR SEVERAL RESIDENTS
OH-2	WOOSTER WAYNE COUNTY	GASOLINE VOLUME UNKNOWN			6 DOMESTIC WELLS CONTAMINATED
OH-3	NORTH PERRY LAKE COUNTY	FUEL OIL #1 VOLUME UNKNOWN	STORAGE TANK	LEAKAGE	COMMERCIAL WELL CONTAMINATED
OH-4	NEW CONCORD	FUEL OIL VOLUME UNKNOWN	STORAGE TANK	LEAKAGE	1 DOMESTIC WELL CONTAMINATED
OH-5	WRIGHT-PATTERSON AIR FORCE BASE	JET FUEL 8,319 GAL	STORAGE	FAILURE TO CLOSE VALVE	GROUNDWATER CONTAMINATED IN THE AREA
OH-6	TAYLOR ESTATES FRANKLIN COUNTY	SEWAGE VOLUME UNKNOWN	SEWAGE LINE	LEAKAGE	BACTERIAL CONTAMINATION TO PUBLIC WATER SUPPLY
OH-7	RUBYVILLE SCIOTO COUNTY	GASOLINE VOLUME UNKNOWN	UNDERGROUND STORAGE TANK	RUPTURE	SEVERAL DOMESTIC WELLS CONTAMINATED
OH-8	RICHLAND TOWNSHIP BELMONT COUNTY	CHLORODANE VOLUME UNKNOWN	HOME BASEMENT	INJECTION FROM TERMITE CONTROL	1 DOMESTIC WELL CONTAMINATED
OH-9	GIBISONVILLE	GASOLINE VOLUME UNKNOWN			1 DOMESTIC WELL CONTAMINATED
OH-10	HEATH	HYDROCARBON 2,000,000 GAL.	REFINERY		SEVERAL DOMESTIC WELLS CONTAMINATED

STATE: OHIO

SPILL ID #	LOCATION	CONTAMINANT & VOLUME	SOURCE	CAUSE	EFFECT
OH-11	DUBLIN	LAQUER AND PAINT THINNER VOLUME UNKNOWN	UNKNOWN	UNKNOWN SURFACE SPILL SUSPECTED	1 DOMESTIC WELL AT A VETERNARY CLINIC
OH-12	DUNDEE TUSEARALVAS COUNTY	ETHYL ACETATE AND BENZENE	UNDERGROUND STORAGE TANK	LEAKAGE	1 DOMESTIC WELL CONTAMINATED

STATE: PENNSYLVANIA

SPILL ID #	LOCATION	CONTAMINANT & VOLUME	SOURCE	CAUSE	EFFECT
PA-1	RIVERSIDE NORTHUMBERLAND CO.	ACETONE 102,000 GAL.	CHEMICAL PLANT STORAGE TANK	LEAK	ACCUMULATED IN SUNKEN ELEVATOR SHAFT
PA-2	CARROLL TWP YORK CO.	1,1,1 TRICHLOROETHANE VOLUME UNKNOWN	SEPTIC-DISPOSAL COMPANY STORAGE AREA	IMPROPER STORAGE (POOR HOUSEKEEPING)	2 DOMESTIC WELLS CONTAMINATED
PA-3	HENDERSON TWP HUNTINGTON CO.	GASOLINE VOLUME UNKNOWN	SERVICE STATION STORAGE TANK	LEAK	1 DOMESTIC WELL CONTAMINATED
PA-4	SOUTH WHITEHALL TWP LEHIGH CO.	GASOLINE VOLUME UNKNOWN	SERVICE STATION STORAGE TANK SUCTION LINE	LINE FAILURE	1 COMMERCIAL WELL CONTAMINATED
PA-5	WARICK TWP LANCASTER CO.	GASOLINE VOLUME UNKNOWN	PRIVATE STORAGE TANK	LEAK	1 DOMESTIC WELL CONTAMINATED
PA-6	MANCHESTER TWP YORK CO.	GASOLINE	UNPROVEN SUSPECTED GARAGE	UNPROVEN SUSPECTED SPILLAGE	1 DOMESTIC WELL CONTAMINATED
PA-7	MT. POCONO MONROE CO.	GASOLINE 8,000 GAL.	POWER COMPANY STORAGE TANK	PUNCTURE	4 DOMESTIC WELLS CONTAMINATED
PA-8	DERRY TWP MIFFLIN CO.	FUEL OIL VOLUME UNKNOWN	UNPROVEN SUSPECTED STORAGE TANK AT SERVICE STATION	SUSPECTED LEAK	1 COMMERCIAL (HOLIDAY INN) WELL CONTAMINATED
PA-9	KRALLTOWN ELEM. SCHOOL, WASHINGTON TWP, YORK CO.	FUEL OIL VOLUME UNKNOWN	LINE FROM STORAGE TANK	LINE FAILURE	1 PUBLIC (SCHOOL) WELL CONTAMINATED
PA-10	EAST HANOVER TWP LEBANON CO.	PETROLEUM PRODUCT VOLUME UNKNOWN	UNPROVEN SUSPECTED PRIVATE STORAGE TANK	SUSPECTED LEAK	2 DOMESTIC WELLS CONTAMINATED
PA-11	SPRING TWP CENTRE CO.	KEROSENE 250 GAL.	ELEVATED STORAGE TANK	TANK SUPPORT COLLAPSED	3 DOMESTIC WELLS CONTAMINATED

STATE: PENNSYLVANIA

SPILL ID #	LOCATION	CONTAMINANT & VOLUME	SOURCE	CAUSE	EFFECT
PA-12	BRIAR CREEK TWP COLUMBIA CO.	GASOLINE VOLUME UNKNOWN	STORAGE TANK AT "COUNTRY STORE"	LEAK	1 DOMESTIC WELL CONTAMINATED
PA-13	MIDDLE PAXTON TWP DAUPHIN CO.	GASOLINE 1500 GAL.	SERVICE STATION STORAGE TANK	LEAK	1 DOMESTIC WELL CONTAMINATED
PA-14	MONROE TWP SNYDER CO.	KEROSENE 200 GAL.	ELEVATED STORAGE TANK	TANK SUPPORT COLLAPSED	1 SEMI-PUBLIC (MOBILE HOME PARK) WELL CONTAMINED
PA-15	EQUINOX BUCKINGHAM TWP WAYNE CO.	FUEL OIL VOLUME UNKNOWN	STORAGE TANK AT GROCERY STORE	RUPTURE (30 YRS. PRIOR TO REPORTED CONTAMINATION)	2 DOMESTIC WELLS CONTAMINATED
PA-16	CARLISLE ARMY BARRACKS CUMBERLAND CO.	FUEL OIL 500 GAL.	STORAGE TANK	LEAK FROM FAULTY FITTING	SPRING CONTAMINATED
PA-17	CRESSON TWP CAMBRIA CO.	GASOLINE 2600 GAL.	SERVICE STATION STORAGE TANK	LEAK	SPRING CONTAMINATED (WHICH FEEDS SURFACE WATER-SUPPLY RESERVIOR)
PA-18	COLLEGE TWP CENTRE CO.	GASOLINE VOLUME UNKNOWN	SERVICE STATION STORAGE TANK	LEAK	1 DOMESTIC WELL CONTAMINATED
PA-19	COLLEGE TWP CENTRE CO.	GASOLINE 1000 GAL. OVER 40-DAY PERIOD	VALVE/LINE FROM SERVICE STATION STORAGE TANK	VALVE/LINE FAILURE	CREEK CONTAMINATED
PA-20	AYR TWP FULTON CO.	PETROLEUM PRODUCT VOLUME UNKNOWN	DISTRIBUTING TERMINAL	UNPROVEN SUSPECTED LEAK OR SPILL	1 DOMESTIC WELL CONTAMINATED
PA-21	BELLWOOD BLAIR CO.	GASOLINE 2500 GAL.	SERVICE STATION STORAGE TANK	LEAK	FUMES ACCUMULATED IN BASEMENTS OF 3 BUILDINGS
PA-22	NIANTIC DOUGLAS TWP MONTGOMERY CO.	GASOLINE VOLUME UNKNOWN	UNPROVEN SUSPECTED STORAGE TANK AT STORE	UNPROVEN SUSPECTED LEAK	3 DOMESTIC WELLS CONTAMINATED

STATE: PENNSYLVANIA

SPILL ID #	LOCATION	CONTAMINANT & VOLUME	SOURCE	CAUSE	EFFECT
PA-23	NORTH MIDDLETON TWP CUMBERLAND CO.	KEROSENE 3000 GAL.	BURIED STORAGE TANK	LEAK	1 DOMESTIC WELL CONTAMINATED (SPILL OCCURRED 1 YR. PRIOR TO CONTAMINATION AND HAD BEEN "CLEANED-UP").
PA-24	WHITEHALL TWP LEHIGH CO.	GASOLINE 756 GAL.	PIPELINE	PUNCTURED BY DRILLING RIG	PUBLIC AND PRIVATE WELLS IN AREA PROTECTED BY RAPID ACTION BY STATE TO ENSURE ABATEMENT.
PA-25	DRUMS BUTLER TWP LUZERNE CO.	FUEL OIL VOLUME UNKNOWN	BURIED STORAGE TANK LINE AT SCHOOL	LINE FAILURE	7 DOMESTIC WELLS CONTAMINATED
PA-26	CHAMBERSBURG FRANKLIN CO.	GASOLINE 3500 GAL.	BURIED STORAGE TANK AT PENN. DOT HWY SHOP	LEAK	FUMES ACCUMULATED IN BASEMENT OF HOUSE AND CAUSED DESTRUCTIVE EXPLOSION
PA-27	AMBLER WHITE MARSH TWP MONTGOMERY CO.	GASOLINE 135,000 GAL.	PIPELINE	LEAK	2 PUBLIC WELLS CONTAMINATED ENHANCED BIODEGRADATION USED SUCCESSFULLY TO CLEANSE GROUND WATER
PA-28	MECHANICSBURG MONROE TWP CUMBERLAND CO.	GASOLINE			COMPREHENSIVE REPORT BEING SENT

STATE: RHODE ISLAND

SPILL ID #	LOCATION	CONTAMINANT & VOLUME	SOURCE	CAUSE	EFFECT
RI-1	Greenville	Gasoline 50,000 Gal.	Service Station Storage Tank	Leak	Stream and abandoned domestic wells contaminated

STATE: TEXAS

SPILL ID #	LOCATION	CONTAMINANT & VOLUME	SOURCE	CAUSE	EFFECT
TX-1	Leon Valley Bexar Co.	Gasoline Volume Unknown	Line From Service Station Storage Tank	Line Failure	6 Domestic wells and 1 Public Well Contaminated
TX-2	Leon Valley Bexar Co.	Gasoline Volume Unknown	Pumps at Automotive Research Facility	Leakage from Pumps & Improper Discharge onto Surface	1 Industrial Well Contaminated
TX-3	Odessa Ector Co.	Sewage (E.Coli Bacteria, Nitrate, Ammonia, & High TDS)	Sanitary Sewer Line	Leakage	5 Domestic Wells Contaminated
TX-4	Cedar Park Williamson Co.	Gasoline Volume Unknown Reportedly 50 gal.	Service Station Storage Tank	Unproven, suspected Loss During Installation of tank	3 Domestic Wells Contaminated
TX-5	Childress Childress Co.	Gasoline Volume Unknown	Unproven, Suspected Service Station Storage Tank	Unproven, suspected Leak	6 Domestic Wells Contaminated
TX-6	Marble Falls Burnett Co.	Gasoline Volume Unknown	Unproven, Suspected service Station Storage Tank	Unproven, suspected leak	Surface Stream Contaminated from Ground-Water Seepage
TX-7	Johnson City Blanco Co.	Gasoline Reportedly 400 gal.	Service Station Storage Tank	Leak	1 Domestic Well Contaminated
TX-8	San Angelo Tom Green Co.	Gasoline Volume Unknown	Unproven, suspected Bulk Plants or Service Station	Unproven, suspected Leak	2 Domestic Wells Contaminated
TX-9	San Angelo Tom Green Co.	Gasoline Volume Unknown	Unproven, suspected line from Storage tank at City Shop	Unproven, Suspected Line Failure	3 Domestic & 1 County-owned Wells Contaminated
TX-10	Hutto Williamson Co.	Diesel Fuel est. 40-75 gal.	Farm Storage Tank	Leakage	1 Domestic Well Contaminated
TX-11	Valera Coleman Co.	Gasoline Volume Unknown	Unproven, suspected service station storage tank	Unproven, suspected Leak	3 Domestic Wells and 3 Commercial Wells Contaminated

STATE: TEXAS

SPILL ID #	LOCATION	CONTAMINANT & VOLUME	SOURCE	CAUSE	EFFECT
TX-12	Waco McLennan Co.	Gasoline 1300 Gal.	Line From Service Station Storage Tank	Line Failure	1 Domestic Well Contaminated
TX-13	La Gloria Starr Co.	Gasoline Volume Unknown	Unknown, Suspected Storage Tank	Unknown, Suspected Leak	1 Domestic Well Contaminated
TX-14	Bowie Montague Co.	Gasoline Volume Unknown	Unproven, Suspected Pipeline	Unproven, suspected leak	1 Industrial Well Contaminated
TX-15	San Angelo Tom Green Co.	Gasoline 5000 Gal.	Buried Storage-Tank Pump at Service Station	Leak due to Crack in Pump	8 Domestic and 2 Irrigation Wells Contaminated

STATE: VIRGINIA

SPILL ID #	LOCATION	CONTAMINANT & VOLUME	SOURCE	CAUSE	EFFECT
VA-1	ARLINGTON ARLINGTON CO.	GASOLINE 2,000 GALLONS	DELIVERY TRUCK	GAS PUMPED INTO OLD FILL PIPE WITH NO TANK UNDER IT	GROUNDWATER THREATENED
VA-2	TROUTVILLE BOTETOURT CO.	PETROLEUM PRODUCT	UNKNOWN	UNKNOWN	STRONG GASOLINE ODER IN WELL
VA-3	HUNT	GASOLINE SMALL AMOUNT	GASOLINE TRUCK	LEAK	SOIL CONTAMINATION
VA-4	MATHEWS	GASOLINE	UNDERGROUND STORAGE TANK	LEAK	GASOLINE FUMES
VA-5	CUMBERLAND CUMBERLAND CO.	HYDROCARBON	FUEL OIL TANK	SEEPAGE	2 SCHOOL WELLS CONTAMINATED
VA-6	ROCKBRIDGE CO.	GASOLINE 11-27 GALLONS	FEED PIPE TO GAS PUMP	LEAK	SCHOOL WELL CONTAMINATED
VA-7	RICHMOND CHESTERFIELD CO.	#2 FUEL OIL	FUEL OIL TANK	LEAKAGE	1 DOMESTIC WELL AFFECTED
VA-8	BLACKSBURG MONTGOMERY CO.	GASOLINE SPILL <16 GALLONS	FUELING OPERATION	SPILL	CONTAMINATION OF SOIL AND 2 DOMESTIC WELLS
VA-9	WINCHESTER FREDRICK CO.	PETROLEUM LUBE OIL	UNKNOWN	LEAKAGE	1 DOMESTIC WELL CONTAMINATED

STATE: WASHINGTON

SPILL ID #	LOCATION	CONTAMINANT & VOLUME	SOURCE	CAUSE	EFFECT
WA-1	Medical Lake Spokane Co.	Gasoline 14,700 Gal.	Pipeline	Ruptured By Backhoe	1 Domestic Well Contaminated
WA-2	Wiley City Yakima Co.	Gasoline 505 Gal.	Tanker Truck	Refueling Spill (Faulty Transfer hose coupling)	1 Domestic Well Contaminated
WA-3	Lynden	Gasoline 6600 Gal.	Tanker Truck	Traffic Accident	Ground Water Contaminated, No Wells affected due to Rapid Clean-up

STATE: WISCONSIN

SPILL ID #	LOCATION	CONTAMINANT & VOLUME	SOURCE	CAUSE	EFFECT
WS-1	LAKE BEULAH WALWORTH CO.	PHENOL 9,000 GAL.	TRAIN	DERAILMENT	11 DOMESTIC WELLS CONTAMINATED
WS-2	JEFFERSON CO.	CRUDE OIL 6,500 BARRELS (273,000 GAL.)	PIPELINE	RUPTURE	NO WELLS OR STREAMS AFFECTED DUE TO CONTAMINANT AND CLEAN-UP.

APPENDIX B

LIST OF 918 HAZARDOUS SUBSTANCES AND THEIR SOLUBILITY AND TOXICITY RATINGS

TOXICOLOGY[1]

TOXICITY DEFINED

Toxicity is the ability of a chemical molecule or compund to produce injury once it reaches a susceptible site in or on the body. Toxicity hazard is the probability that injury may be caused by the manner in which the substance is used.

Acute

This term will be used in the medical sense to mean "of short duration." As applied to materials which are inhaled or absorbed through the skin, it refers to a single exposure of a duration measured in seconds, minutes or hours. As applied to materials which are ingested, it refers generally to a single quantity or dose.

Chronic

This term will be used in contrast to "acute" and means "of long duration." As applied to materials which are inhaled or absorbed through the skin, it refers to prolonged or repeated exposures of a duration measured in days, months or years. As applied to materials which are ingested, it refers to repeated doses over a period of days, months, or years. The term "chronic" will not refer to severity of symptoms but will carry the implication of exposures or doses which would be relatively harmless unless extended or repeated over long periods of time (days, months or years). In this book the term "chronic" includes exposures which might also be called "subacute," i.e., somewhere between "acute" and "chronic."

Local

This term refers to the site of action of an agent and means that the action takes place at the point or area of contact. The site may be skin, mucous membrances of the eyes, nose, mouth, throat, or anywhere along the respiratory or gastrointestinal system. Absorption does not necessarily occur.

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[1] Dangerous Properties of Industrial Materials N.I. Sax.

Systemic

This term refers to a site of action other than the point of contact and presupposes that absorption has taken place. It is possible, however, for toxic agents to be absorbed through a channel (skin, lungs or intestinal canal) and produce later manifestations on one of these channels which are not a result of the original direct contact. Thus it is possible for some agents to produce harmful effects on a single organ or tissue as a result of both "local" and "systemic" actions.

Absorption

A material is said to have been absorbed only when it has gained entry into the blood stream and consequently may be carried to all parts of the body. Absorption requires that a substance pass through the skin, a mucous membrane, or the air sacs (alveoli) of the lungs. It may also be produced by means of a needle (subcutaneous, intravenous, etc.) but this is not of importance in industrial toxicology.

TOXICITY RATINGS

An explanation of the toxicity ratings is given in the following paragraphs:

U = Unknown--

This designation is given to substances which fall into one of the following categories:

(a) No toxicity information could be found in the literature and none was known to the authors.

(b) Limited information based on anaimal experiments was available but in the opinion of the authors this information could not be applied to human exposures. In some cases this information is mentioned so that the reader may know that some experimental work has been done.

(c) Published toxicity data were felt by the authors to be of questionable validity.

0 = No toxicity--

This designation is given to materials which fall into one of the following categories:

(a) Materials which cause no harm under any conditions of use.

(b) Materials which produce toxic effects on humans only under the most unusual conditions or by overwhelming dosage.

1 = Slight toxicity--

(a) Acute Local. Materials which on single exposures lasting seconds, minutes or hours cause only slight effects on the skin or mucous membranes regardless of the extent of the exposure.

(b) Acute Systemic. Materials which can be absorbed into the body by inhalation, ingestion or through the skin and which produce only slight effects following single exposures lasting seconds, minutes, or hours, or following ingestion of a single dose, regardless of the quantity absorbed or the extent of exposure.

(c) Chronic Local. Materials which on continuous or repeated exposures extending over periods of days, months, or years cause only slight harm to the skin or mucous membranes. The extent of exposure may be great or small.

(d) Chronic Systemic. Materials which can be absorbed into the body by inhalation, ingestion or through the skin and which produce only slight effects following continuous or repeated exposures extending over days, months, or years. The extent of the exposure may be great or small.

In general, those substances classified as having "slight toxicity" produce changes in the human body which are readily reversible and which will disappear following termination of exposure, either with or without medical treatment.

2 = Moderate toxicity--

(a) Acute Local. Materials which on single exposure lasting seconds, minutes or hours cause moderate effects on the skin or mucous membranes. These effects may be the result of intense exposure for a matter of seconds or moderate exposure for a matter of hours.

(b) Acute Systemic. Materials which can be absorbed into the body by inhalation, ingestion or through the skin and which produce moderate effects following single exposures lasting seconds, minutes or hours, or following ingestion of a single dose.

(c) Chronic Local. Materials which on continuous or repeated exposures extending over periods of days, months or years cause moderate harm to the skin or mucous membranes.

(d) Chronic Systemic. Materials which can be absorbed into the body by inhalation, ingestion or through the skin and which produce moderate effects following continuous or repeated exposures extending over periods of days, months or years.

Those substances classified as having "moderate toxicity" may produce irreversible as well as reversible changes in the human body. These changes are not of such severity as to threaten life or produce serious permanent physical impairment.

3 = Severe toxicity--

(a) Acute Local. Materials which on single exposures lasting seconds or minutes cause injury to skin or mucous membranes of sufficient severity to threaten life or to cause permanent physical impairment or disfigurement.

(b) Acute Systemic. Materials which can be absorbed into the body by inhalation, ingestion or through the skin and which can cause injury of sufficient severity to threaten life following a single exposure lasting seconds, minutes or hours, or following ingestion of a single dose.

(c) Chronic Local. Materials which on continuous or repeated exposures extending over periods of days, months or years can cause injury to skin or mucous membranes of sufficient severity to threaten life or to cause permanent impairment, disfigurement or irreversible change.

(d) Chronic Systemic. Materials which can be absorbed into the body by inhalation, ingestion or through the skin and which can cause death or serious physical impairment following continuous or repeated exposures to small amounts extending over periods of days, months or years.

I. Metals and Inorganics (265)	Solubility	Toxicity
aluminum chloride	2 *	3
aluminum fluoride	0	3
aluminum nitrate	2	2
aluminum sulfate	2	3
ammonia, anhydrous		3
ammonium bicarbonate	2	U food additive
ammonium bifluoride		3
ammonium carbonate	2	1
ammonium chloride	2	1
ammonium dichromate	2	3
ammonium fluoride	2	3
ammonium hydroxide (28% aqueous)	2	3
ammonium iodide	3	2
ammonium molybdate	d	2
ammonium nitrate - carbonate mix	3	1
ammonium nitrate - phosphate mix		1
ammonium nitrate - sulfate mix		1
ammonium oxalate	2	3
ammonium pentaborate	2	2
ammonium perchlorate	2	2
ammonium persulfate		1
ammonium phosphate		U
ammonium silicofluoride		3
ammonium sulfamate	3	1
ammonium sulfate	2	1
ammonium sulfide	3	3
ammonium sulfite	2	2

* with violence

	Solubility	Toxicity
boric acid	1	2
boron trichloride		3
boron tribromide	d	3
bromine	2	3
bromine pentafluoride	d	3
bromine trifluoride	d *	3
cadmium	0	3
cadmium bromide	2	3
cadmium chloride	3	3
cadmium fluoborate		3
cadmium nitrate	3	3
cadmium oxide	0	3
cadmium sulfate	2	3
calcium	d	1
calcium arsenate	1	3
calcium carbide	d	2
calcium chlorate	2	2
calcium chloride	2	1
calcium chromate	2	3
calcium cyanide	d	3
calcium fluoride	1	3
calcium hydroxide	2	1
calcium hypochlorite	2	3
calcium nitrate	3	2
calcium oxide	d	1
calcium peroxide	1	1
calcium phosphate	2	U food additive
calcium phosphide	d	3
carbon dioxide	1	1

* with violence

	Solubility	Toxicity
carbon disulfide	1	3
carbon monoxide	1	3
carbon tetrachloride	0	3
chlorine	2	3
chlorine trifluoride	d	3
chlorosulfonic acid	d	3
chromic anhydride	2	3
chromium	0	0
chromyl chloride		3
cobaltous chloride	2	1
cobaltous nitrate	3	2
cobaltous sulfate	2	1
copper	0	2
cupric arsenite	0	3
cupric bromide	1	2
cupric chloride	d	2
cupric fluoborate		3
cupric nitrate		2
cupric oxalate	1	3
cupric sulfate	d	3
cuprous cyanide	0	3
cuprous iodide	0	2
cyanide	0	3
cyanogen	2	3
cyanogen bromide	2	3
cyanogen chloride	1	3
decaborane		3

	Solubility	Toxicity
difluorophosphoric acid, anhydrous		3
ferric ammonium oxalate		3
ferric chloride	2	1
ferric nitrate	2	2
ferric sulfate	1	1
ferrous ammonium sulfate	2	1
ferrous chloride	2	1
ferrous fluoborate		3
ferrous oxalate	3	3
ferrous sulfate	1	1
fluorine	d	3
fluosilicic acid	2	3
fluosulfonic acid	2	3
gallic acid	1	U
hydrochloric acid	2	3
hydrofluoric acid	4	3
hydrogen, liquid	2	1
hydrogen bromide	3	3
hydrogen cyanide	4	3
hydrogen peroxide	4	3
hydrogen sulfide	2	3
hydroxyl amine sulfate	2	3
lead	0	3
lead arsenate	1	3
lead fluoborate	d	3
lead fluoride	1	3

	Solubility	Toxicity
lead iodide		3
lead nitrate	2	3
lead thiocyanate	0	3
litharge		3
lithium	d	2
lithium aluminum hydride	d	3
lithium hydride	d	3
magnesium	0	2
magnesium perchlorate	2	2
mercuric ammonium chloride		3
mercuric chloride	0	3
mercuric cyanide	2	3
mercuric iodide	1	3
mercuric nitrate	d	3
mercuric oxide	0	3
mercuric sulfide	0	3
mercurous chloride	2	3
mercurous nitrate	3	3
mercury	0	3
molybdic trioxide	1	1
nickel	0	2
nickel ammonium sulfate	2	2
nickel bromide	3	2
nickel carbonyl	1	3
nickel chloride	2	2
nickel cyanide	0	3
nickel fluoborate		3
nickel nitrate	3	2
nickel sulfate	2	2
nitric acid	4	3

	Solubility	Toxicity
nitric oxide	2	3
nitrogen, liquid		0
nitrogen tetroxide		3
nitrosyl chloride	d	3
nitrous oxide	1	3
oleum		3
oxygen, liquid		0
pentaborane	d	3
perchloric acid	4	3
phosgene	0	3
phosphoric acid	d	2
phosphorous, red	1	1
phosphorous, white	0	3
phosphorous oxychloride	d	3
phosphorous pentasulfide	0	3
phosphorous tribromide	d	3
phosphorous trichloride	d	3
polyphosphoric acid		2
potassium	d	3
potassium arsenate	2	3
potassium binoxalate		3
potassium chlorate	2	2
potassium chromate	2	3
potassium cyanide	2	3
potassium dichromate	2	3
potassium hydroxide	3	3
potassium iodide	3	2
potassium oxalate		3
potassium permanganate	2	3

	Solubility	Toxicity
potassium peroxide		3
selenium	0	2
selenium dioxide	2	2
selenium trioxide	3	2
silicon tetrachloride	d	3
silver	0	1
silver carbonate	1	1
silver fluoride	3	3
silver iodate	1	1
silver nitrate	3	2
silver oxide	1	1
silver sulfate	1	1
sodium	d	3
sodium amide	d	3
sodium arsenate	3	3
sodium arsenite	3	3
sodium azide	2	3
sodium bisulfite	2	2
sodium borate	2	3
sodium borohydride	2	3
sodium chlorate	2	2
sodium chromate	2	3
sodium cyanide	2	3
sodium dichromate	3	3
sodium ferrocyanide	2	1
sodium fluoride	2	3
sodium hydride	d	3
sodium hydrosulfide solution	3	3

	Solubility	Toxicity
sodium hydroxide	2	3
sodium hypochlorite	3	2
sodium nitrate	2	2
sodium oxalate	2	3
sodium phosphate	1	U
sodium silicate	2	1
sodium silicofluoride		3
sodium sulfide	3	3
sodium sulfite	2	2
sodium thiocyanate	3	3
sulfur, liquid	0	1
sulfur dioxide	2	3
sulfuric acid	4	3
sulfuric acid, spent	4	3
sulfur monochloride	d	3
sulfuryl chloride	d	3
thallium	0	3
thiophosgene	0	U
thorium nitrate	3	2
titanium tetrachloride	2	3
trichlorosilane	d	2
uranyl nitrate		3
uranyl sulfate	2	3
vanadium oxytrichloride	2	3
vanadium pentoxide	1	2
vanadyl sulfate	3	2
zinc	0	0
zinc ammonium chloride		1

	Solubility	Toxicity
zinc arsenate	0	3
zinc borate	2	2
zinc bromide	3	2
zinc chloride	3	1
zinc chromate		3
zinc fluoborate		3
zinc nitrate	3	2
zinc phosphide	d	3
zinc silicofluoride		3
zinc sulfate	2	1
zirconium nitrate	3	2
zirconium oxychloride	2	1
zirconium sulfate		3

II. Aliphatic Hydrocarbons (145)	Solubility	Toxicity
A. Unsubstituted (48)		
acetylene	1	2
anthracene	0	3
butadiene inhibited		2
butane	2	2
butylene	0	2
camphene	0	U
carene	0	
cyclohexane	0	2
cyclopentane	0	2
cyclopropane	2	2
1-decene	0	2
dextrose solution		U
dicyclopentadiene		
diisobutylene		2
dipentene		U-3
1-dodecene	0	U
ethane	0	2
ethylene	0	2
heptane	0	2
1-heptene	0	1
hexane	0	1
1-hexene	0	2
isobutane		1
isobutylene	0	U

	Solubility	Toxicity
isohexane		1
isopentane	0	1
isoprene	0	2
maleic anhydride		3
methane	2	1
methyl acetylene-propadiene mixture		U
methyl cyclopentane	0	U
neohexane	0	U
nonane	0	2
1-nonene		
octane		2
1-octene		3
pentane	1	1
1-pentene	0	2
polybutene		
polypropylene		U food additive
propane	2	1
propylene	3	2
propylene-butylene polymer		
sulfolane		
1-tetradecene	0	U
tetrahydrofuran		3
1-tridecene	0	
1-undecene	0	U

B. Halogenated (54)	Solubility	Toxicity
allyl bromide	0	3
allyl chloride	0	3
allyl trichlorosilane		3
amyl chloride (N-)	0	U
amyl trichlorosilane (N-)		3
butyl trichlorosilane		3
chloro dibromo-methane	0	3
chloroform	1	3
cyclohexanyltrichlorosilane		3
dichlorobromomethane	0	3
dichlorobutene		U-2
dichlorodifluoromethane	2	1
1,2-dichloroethane	1	
1,2-dichloroethylene	1	2
dichloromethane	1	3
1,2-dichloropropane	1	3
1,3-dichloropropane	0	3
dichloropropene	0	3
1,1-difluoroethane		2
dimethyldichlorosilane		3
epichlorohydrin	0	3
ethyl aluminum dichloride		
ethyl aluminum sesquichloride		
ethyl chloride	1	2
ethylene chloride	1	3
ethylene dibromide	1	3

	Solubility	Toxicity
ethylene dichloride	1	3
ethyltrichlorosilane	d	3
hexachlorobutadiene	0	
hexachlorocyclopentadiene		2
hexachloroethane	0	2
methallyl chloride		2
methoxychlor	1	1
methyl bromide	1	3
methyl chloride	1	3
methyl dichlorosilane		3
methyl phosphonothioic dichloride anhydrous		3
methyl trichlorosilane		3
monochlorodifluoromethane		2
perchloromethyl mercaptan		3
tetrachloroethane	1	3
tetrachloroethylene	0	3
tetrachloromethane	0	3
tetrafluoroethylene inhibited		U
tribromomethane	1	2
1,1,1-trichloroethane	0	2
1,1,2-trichloroethane	1	2
trichloroethylene	1	3
trichlorofluoromethane	1	1
trifluorochloroethylene		1
trimethylchlorosilane		3
vinyl fluoride inhibited		U
vinylidene chloride inhibited	0	2
vinyltrichlorosilane		3

C. Substituted (other) (43)	Solubility	Toxicity
diethyl carbonate		2
diethyl zinc	d	
dimethyl hexane dihydroperoxide		2
dimethyl polysiloxane		1
dimethyl sulfate		3
dimethyl sulfide	0	U-3
dimethyl sulfoxide	2	2
dimethyl zinc	d	
ethylene oxide	2	3
ethylidenenorborene		
ethyl mercaptan	1	2
ethyl nitrite	d	2
ethyl phosphonothioic dichloride, anhydrous		3
ethyl phosphorodichloride		3
ethyl silicate		3
glycidyl methacrylate		3
hexadecylinmethylammonium chloride		
isopropyl mercaptan	1	3
isopropyl percarbonate		U
lauroyl peroxide		3
lauryl mercaptan	0	3
malathion		2
methylcyclopentadienylmanganese bicarbonyl		U
methyl mercaptan	1	3
methyl parathion		3
nickel acetate		2
nitroethane	1	2
nitromethane	2	3

	Solubility	Toxicity
2-nitropropane	1	2
propylene oxide	4	2
propylene tetramer		2
N-propyl mercaptan	1	3
sodium alkyl sulfates		
sodium cacodylate		3
sodium hexadecyl sulfate		
sucrose	2	0
tetraethyl dithiopyrophosphate		3
tetraethyl lead	0	3
tetraethyl pyrophosphate		3
tetramethyl lead	0	3
triethylaluminum	4*	3
triisobutyl aluminum		3
zinc dialkyldithiophosphate		

*with violence

III. Alcohols (56)	Solubility	Toxicity
allyl alcohol	2	3
amyl alcohol (N-)		2
benzyl alcohol	2	1
1,4-butanediol	4	2
1,4-butenediol	2	U
butyl alcohol (N-)	2	2
butyl alcohol (sec-)	3	2
butyl alcohol (tert-)	4	2
1,4-butynediol	3	3
catechol	2	3
B chloroethyl alcohol		3
chlorohydrin		U-3
collodion		1
cyanoethyl alcohol		U-3
decyl alcohol	0	U-1
diacetone alcohol	2	2
diethylene glycol	2	2
diisobutyl carbinol	2	U-1
dipropylene glycol	4	2
dodecanol	0	U-1
ethoxylated dodecanol		
ethoxylated penadecanol		
ethoxylated tetradecanol		
ethoxylated tridecanol		
ethoxy triglycol		2
ethyl alcohol	4	1
ethyl butanol		2
ethylene glycol	2	2

	Solubility	Toxicity
ethyl hexanol, (2-)	0	1
furfuryl alcohol	2	U-2
glycerine	2	1
heptanol	1	2
hexanol	1	1
hexylene glycol	2	2
isoamyl alcohol		2
isobutyl alcohol	2	3
isodecyl alcohol	0	U
isooctyl alcohol	0	
isopropyl alcohol	1	2
linear alcohols (12-15 carbons)	2	
methyl alcohol	2	3
methyl amyl alcohol		3
octanol	0	
pentadecanol		
pentaerythritol	2	U
poypropylene glycol		
propyl alcohol (N-)	4	
propylene glycol	4	2
sorbitol	3	U Food Additive
tallow fatty alcohol		U
tetradecanol	0	U
tetraethylene glycol		2
tridecanol	0	U-1
triethylene glycol	4	2
tripropylene glycol		2
undecanol	0	U

IV. Aldehydes	Solubility	Toxicity
acetaldehyde	4	3
benzaldehyde	1	3
butyraldehyde (N-)	2	3
butyraldehyde (iso-)	2	3
crotonaldehyde	2	3
decaldehyde		3
ethylhexaldehyde		3
2-ethyl-3 propylacrolein		3
formaldehyde solution	2	3
furfural	2	3
glutaraldehyde solution	4	3
glyoxal, 40 (solution)	3	3
hexaldehyde (N-)		3
isodecaldehyde		3
isooctaldehyde		3
isovaleraldehyde	1	3
methyl formal		3
paraformaldehyde	3	3
propinaldehyde	2	3
valeraldehyde	1	3

V. Ketones (19)	Solubility	Toxicity
acetone	4	2
acetone cyanohydrin		3
acetophenone	0	U-1
acetylacetone	3	2
amyl methyl ketone (N-)		U
benzophenone	0	U
chloroacetophenone		2
cyclohexanone	2	U-2
cyclohexanone peroxide		U-2
di-n-butyl ketone		
diisobutyl ketone	0	1
isophorone	0	3
mesityl oxide	2	3
methyl-n-butyl ketone		3
methyethyl ketone	3	1
methyl isobutyl ketone	1	3
methyl isopropenyl ketone (inhibited)		
methyl vinyl ketone		
B-propiolacetone		3

VI. Organic Acids (27)	Solubility	Toxicity
acetic acid	4	3
acetyl peroxide solution		2
acrylic acid	4	3
adipic acid	1	U-1
butyric acid (N-)	1	1
cacodylic acid	3	3
caprolactam (solution)		
citric acid	3	0
cyanoacetic acid	2	3
di-(2-ethylhexyl) phosphoric acid		U-2
ethylene diamine tetraacetic acid (EDTA)		1
formic acid	4	3
fumaric acid	1	1
isobutyric acid	3	2
isophthalic acid	1	1
lactic acid	3	2
maleic acid	3	3
monochloroacetic acid		2
oleic acid	0	1
oxalic acid	2	3
peracetic acid		3
propionic acid	4	1
pyrogallic acid	4	3
salicilic acid	3	2
sodium methanearsenate		3
stearic acid	0	1
tannic acid	2	2

VII. Esters (65)	Solubility	Toxicity
acetic anhydride	2	3
acetyl bromide	d	3
acetyl chloride	d	3
allyl chloroformate		3
ammonium acetate	2	
ammonium citrate		
ammonium formate	3	U-3
ammonium gluconate		
ammonium lactate	4	
ammoniumlauryl sulfate	2	
ammonium nitrate urea solution	2	1
ammonium oleate	2	
ammonium stearate		
ammonium tartrate		
amyl acetate (N-)	1	U-3
antimony potassium tartrate		3
calcium resinate		U
cadmium acetate	3	3
chloracetyl chloride		
cobaltous acetate	2	1
cupric acetate	1	3
cupric acetoarsenite		3
2,4-dichlorophenoxyacetic acid esters	0	2
dioctyl adipate		U-1
dioctyl sodium sulfosuccinate		1
dodecyl sulfate, magnesium salt		

	Solubility	Toxicity
dodecy sulfate, sodium salt		
dodecyl trichlorosilane		U-3
ethyl acetate	2	2
ethyl acetoacetate		2
ethyl acrylate	1	3
ethyl butyrate	1	U food additive
ethyl chloroacetate	0	3
ethyl chloroformate	d	3
ethyl chlorosilane		3
ethyl formate	2	2
ethylene glycol diacetate		U-2
2-ethylhexyl acrylate (inhibited)		U-1
ethyl lactate	4	U
ethyl methylacrylate	1	U-2
ferric ammonium citrate		U
ferric glycerophosphate	2	
glycidyl methacrylate		
2-hydroxyethyl acrylate (inhibited)		
hydroxylpropyl acrylate		
hydroxylpropyl methacrylate		
isobutyl acetate	1	2
isodecyl acrylate (inhibited)		
isopropyl acetate	2	2
lead acetate	2	3
lead tetraacetate		3
mercuric acetate		3

	Solubility	Toxicity
methyl acetate	3	2
methyl acrylate		3
methyl amylacetate		2
methyl chloroformate		3
methyl methacrylate		1
potassium oleiate		1
propionic anhydride	d	U-1
N-propyl acetate		2
silver acetate	2	1
sodium oleiate		1
uranyl acetate	2	3
vinyl acetate	1	1
zinc acetate	2	1

VIII. Ethers (26)	Solubility	Toxicity
bis-2-chloroethoxy methane		
bis-chloromethyl ether		3
bis-2-chloroethyl ether		3
bis-2-chloroisopropyl ether		U
2-chloroethyl vinyl ether		2
cresyl glycidyl ether		
di-n-butyl ether		1
diethylene glycol dimethyl ether		
diethylene glycol monobutyl ether	4	2
diethylene glycol monobutyl ether acetate	2	3
diethylene glycol monoethyl ether	4	3
diethylene glycol monomethyl ether	4	3
dimethyl ether	2	2
1,4-dioxane	0	3
ethylene glycol diethyl ether		U-2
ethylene glycol dimethyl ether	2	U-2
ethylene glycol monobutyl ether	2	2
ethylene glycol monobutyl ether acetate		2
ethylene glycol monoethyl ether	4	2
ethylene glycol monoethyl ether acetate	2	2
ethylene glycol monomethyl ether		2
ethyl ether	1	2
isopropyl ether	1	2
polypropylene glycol methyl ether		1
propylene glycol methyl ether		1
vinyl methyl ether (inhibited)		U

IX. Monocyclic Aromatics (excluding phenols, cresols, phthalates) (47)

	Solubility	Toxicity
alkylbenzene sulfonic acids		
ammonium benzoate	2	
benzene	1	2
benzene isopropyl hydroperoxide		U-2
benzene phosphorus dichloride		2
benzene phosphorus trichloride		2
benzoic acid		1
benzoyl chloride		2
benzyl chloroformate		2
benzyl dimethyl octa-decyl ammonium chloride		
benzyl trimethyl ammonium chloride	3	U
bromobenzene	0	1
calcium dodecylbenzene sulfate		
p-chloroaminobenzene		
4 chloroaminotoluene		
chlorobenzene	0	2
n-decyl benzene		U
dibenzoyl peroxide		2
4,4-dichloro-alpha-trichloromethyl-benzhydrol		
1,2-dichlorobenzene	0	2
di-p-chlorobenzoyl peroxide		U
diethylbenzene		U-2
2,4-diisocyanotoluene		3
diisopropylbenzene hydroperoxide		U-2
2,4-dinitrotoluene	0	3
2,6-dinitrotoluene		

	Solubility	Toxicity
dodecylbenzene		U-2
ethylbenzene	0	2
hexachlorobenzene	0	1
isopropyl benzene (cumene)	0	3
isopropylamine dodecylbenzenesulfonate		
isopropymethyl benzene (cymene)	0	
methyl styrene (alpha)		2
nitro benzene	1	3
styrene	0	2
sodium alkylbenzenesulfonates		
tetra decyl benzene		
toluene	0	2
p-toluenesulfonic acid		U-2
o-toluidene		3
1,2,4-trichlorobenzene	0	U-2
triethanolaminedodecylbenzenesulfonate		
triethyl benzene		U-3
vinyl toluene		U-2
m-xylene	0	1
o-xylene	0	1
p-xylene	0	1

X. Phenols, Cresols and Xylenol (33)	Solubility	Toxicity
bisphenol A		3
bisphenol A diglycidyl ether		3
4-bromophenyl phenyl ether		
p-tert-butyl phenol	1	3
carbolic oil		3
p-chloro-m-cresol	0	3
2-chlorophenol	1	3
4-chlorophenyl phenyl ether		
creosote, coal tar		3
dibutyl phenol		3
2,4-dichlorophenoxyacetic acid		2
2,4-dichloro phenol	1	3
diethyl-p-nitrophenyl monothiophosphate		3
2,4-dimethyl phenol	1	3
4,6-dinitro-o-cresol	1	3
2,4-dinitrophenol	1	3
diphenyl dichlorosilane	d	3
diphenyl ether		
diphenylmethyldiisocyanate		3
ethoxylated nonylphenol		3
ethylphenyldichlorosilane		3
hydroquinone	2	3
2-nitrophenol	1	3
4-nitrophenol	1	3
nonyl phenol		3
pentachlorophenol	1	3
phenol	2	3
phenyl dichloro arsine liquid		3

	Solubility	Toxicity
polymethylene polyphenyl isocyanate		3
2,4,6-trichlorophenol	1	3
2,4,5-trichlorophenoxy acetic acid		
tricresyl phosphate	0	3
xylenol	1	3

XI. Phthalate Esters (12)	Solubility	Toxicity
bis (2-ethylhexyl)-phthalate		
butyl benzylphthalate	0	U
captan		0
di-n-amyl phthalate		U-2
di-n-butyl phthalate	1	
diethyl phthalate	2	2
diheptyl phthalate		
diisodecyl phthalate		2
dimethyl phthalate	1	2
dimethyl terephthalate		
di-n-octyl phthalate	1	
phthalic anhydride		1

XII. Polycyclic Aromatic Hydrocarbons (25)	Solubility	Toxicity
acenaphthene	0	U
acenaphthylene	0	
anthracene	0	3
benzo(a)anthracene	1	
benzo(b)fluoranthene	0	
benzo(k)fluoranthene	0	
benzo (g,h,i) perylene	0	
benzo(a)pyrene	0	U
chrysene	0	
cupric napthenate		2
coumaphos		1
decahydronapthalene		
dibenzo(a,h)anthracene	0	
ethoxydihydropyran		U-2
fluoranthene	0	U-2
fluorene	0	U
indeno (1,2,3-cd)pyrene	0	
naphtha: coal tar		3
naphtha: solvent		3
naphtha-stoddard solvent		2
naphtha: VM + P (75% naphtha)		3
naphthalene	0	2
naphthenic acid		U-2
phenanthrene	0	1
pyrene	0	3

XIII. Nitrosamines and other Nitrogen-Containing Compounds (73)

	Solubility	Toxicity
acrylonitrile	2	3
aniline	2	3
anisoyl chloride		3
benzidine	1	3
brucine	1	3
carbaryl		2
cupriethylenediamine		
cyclohexylamine	2	3
diazinon		2
2,3,5,6-dibenzo pyridine		
di-n-butylamine		3
3,4-dichloro benzidine		
diethanolamine	3	1
diethylamine	3	3
diethylenetriamine	4	3
diisopropanolamine		
diisopropylamine	1	3
dimethyl acetamide		U-2
dimethylamine	3	2
dimethyl formamide	4	3
1,1-dimethyl hydrazine	3	3
dimethyl nitrosamine	2	U-3
2,4-dinitroaniline	0	3
M-dinitrobenzene		3
diphenylamine	0	3
1,2-diphenylhydrazine		

	Solubility	Toxicity
diphenylnitrosamine		
di-n-propylamine		U-3
di-n-propylnitrosamine	1	
ethylamine		3
ethylenediamine	3	2
hexamethylenediamine		2
hexamethyleneimine		3
hexamethylenetetramine		2
hydrazine	3	3
isobutylamine		3
isobutyronitrile		U-3
isopropylamine	4	3
maleic hydrazide	1	U
methyl amine	3	
N-methylanaline		3
methyl ethyl pyridine		2
methyl hydrazine	2	3
1-methyl pyrrolidine		U
monoethanolamine		2
monoisopropanol amine		U
morphaline		2
nabam		2
1-naphthyl amine		3
nicotine	2	3
nicotine sulfate		3
nitraline		

	Solubility	Toxicity
nitrilotriacetates		
nitrilotriacetic acid		
2-nitroaniline	1	
4-nitroanaline	0	
phenylhydrazine hydrochloride	3	3
piperazene	2	1
potassium dichloro-s-triazinetrione		
propyleneimine (inhibited)		2
pyridine	4	2
quinoline	2	3
sodium dichloro-s-triazinetrione		
tetraethylenepentamine		U
thiram		2
trichloro-s-triazinetrione		
triethanolamine	4	1
triethyl amine	2	3
triethylene tetramine	2	3
trimethyl amine	3	U
tris-aziridinyl-phosphine oxide		3
urea	3	0
urea peroxide		2

XIV. PCBs and Related Compounds (7)	Solubility	Toxicity
PCB-1016 (Aroclor 1016)	0	3
PCB-1221 (Aroclor 1221)	0	3
PCB-1232 (Aroclor 1232)	0	3
PCB-1248 (Aroclor 1248)	0	3
PCB-1254 (Aroclor 1254)	0	3
PCB-1260 (Aroclor 1260)	0	3
2-chloronaphthalene	0	3

Pesticides (25)	Solubility	Toxicity
olein	2	3
drin	0	3
HC (alpha)	0	3
HC (beta)	0	3
BHC (Lindane) (gamma)	0	3
BHC (delta)	0	3
lordane	0	3
D		2
E		
T	0	3
meton		3
,3-dichlorobenzene		2
,4-dichlorobenzene		2
dieldrin	0	3
-endosulfan (alpha)		
-endosulfan sulfate (beta)		
endosulfan sulfate		
endrin		3
endrin aldehyde		
heptachlor	0	3
heptachlor epoxide		
isophorone	2	3
parathion		3
TCDD (2,3,7,8-tetrachlorodibenzo-p-dioxin)		
toxaphene	0	3

XVI. Petroleum and Other Fuel Related Compounds (60)	Solubility	Toxicity
gas oil: cracked	0	U
gasoline: automotive (4.23 g Pb/gal)	0	1
gasoline: aviation (4.86 g Pb/gal)	0	1
gasoline: casinghead	0	1
gasoline: polymer	0	
gasoline straight run	0	
gasoline blending stocks: alkylates	0	
gasoline blending stocks: reformates	0	
boiler compound - liquid	0	3
jet fuel: JP-1 (kerosene)	0	2
jet fuel JP-3	0	2
jet fuel JP-4	0	2
jet fuel JP-5 (kerosene, heavy)	0	2
kerosene	0	2
liquid natural gas	0	
liquid petroleum gas	0	U
tallow (mixture of hydrocarbons)	0	1
motor fuel anti-knock compounds	0	3
octyl epoxy tallate	0	
oil: clarified	0	
oil: crude	0	2
oil: diesel	0	2
oil fuel: no. 1 (kerosene)	0	2
oil fuel: no. 1-D	0	
oil fuel: no. 2	0	
oil fuel: no. 2-D	0	
oil fuel: no. 4	0	U

	Solubility	Toxicity
oil fuel: no. 5	0	U
oil fuel: no. 6	0	U
oil, misc: absorption	0	
oil, misc: coal tar	0	3
oil, misc: croton	0	3
oil, misc: linseed	0	1
oil, misc: lubricating	0	1
oil, misc: mineral	0	0
oil, misc: mineral seal	0	U-2
oil, misc: motor	0	
oil, misc. neatsfoot	0	U
oil, misc: penetrating	0	
oil, misc: range	0	
oil, misc: resin	0	
oil, misc: road	0	
oil, misc: rosin	0	U
oil, misc: sperm	0	U-1
oil, misc: spindle	0	1
oil, misc: spray	0	
oil, misc: tall	0	1
oil, misc: tanners	0	
oil, misc: transformer	0	U
oil, misc: turbine	0	
petroleum naphtha	0	2
petrolatum (vaseline)	0	U

	Solubility	Toxicity
turpentine	0	3
wax: carnauba	0	0
wax paraffin	0	0
asphalt	0	U-2
asphalt blending stocks: roofers flux		U-2
asphalt blending stocks: straight run residue		U-2
charcoal		0
ethylhexyl tallate	0	

XVII. Edible Organic Compounds (13)	Solubility	Toxicity
corn syrup		0
oil, edible: castor	0	0
oil, edible: coconut	0	0
oil, edible: cottonseed	0	0
oil, edible: fish	0	0
oil, edible: lard	0	0
oil, edible: olive	0	0
oil, edible: palm	0	0
oil, edible: peanut	0	0
oil, edible: safflower	0	0
oil, edible: soya bean	0	0
oil, edible: tucum	0	0
oil, edible: vegetable	0	0

APPENDIX C

SPILL INCIDENT REPORTING FORM

SPILL INCIDENT

EPA Region _____ Spill ID _____

State _____

Hazardous Chemical (specific) _____

Petroleum (specific) _____

Location (specific) _____

_____

Date _____

Source of Spill _____

Cause of Spill _____

Quantity or Volume Spilled _____

Degree of Contamination _____

Response to Spill State _____ Time lapse (days) between spill and response _____

Federal _____

Other _____

Clean-up or Abatement Activity Yes _____ No _____

If yes, what type _____

_____

_____

Monitoring Wells Yes ____ No ____

If yes, what type and how many _____

_____

_____

Recovery Techniques

Type and degree of success _____

_____

_____

Amount of Contaminant Recovered _____

Other Data Related to Abatement Activity _____

_____

_____

_____

NUMBER AND TYPES OF WELLS AFFECTED

Public _____ Domestic _____ Commercial _____

Industrial _____ Irrigation _____ Other _____

Distance from Spills to Wells _____

Construction Characteristics _____

_____

_____

Stream Affected Yes _____ No _____ Name _____

Degree of Contamination _____

Topography _____

Soil Type _____

Vegetation _____

Average Annual Rainfall _____ Immediate Rainfall _____

HYDROGEOLOGY

AQUIFER TYPE

I. Granular _____
II. Carbonate _____
III. Fractural Rock _____
IV. Combination I & II _____
V. Combination I & III _____
VI. Combination II & III _____

AQUIFER CONDITIONS

Confined Artesian _____
Unconfined Water Table _____
Combination _____
Ground Water Region _____

Geologic Formation _____

Lithology _____

Structure _____

Trend of Fracture traces, linaments, faults _____
Depth to Bedrock _____ Depth to Water Table _____
Ground-Water Gradient (Direction and Magnitude) _____

REMARKS _____

REFERENCES _____

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