UNITED STATES DEPARTMENT OF AGRICULTURE
Rural Electrification Administration

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SUBJECT: **Design Guide for Oil Spill Prevention and Control at Substations**

TO: All Electric Borrowers

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PURPOSE: This bulletin provides guidance and assistance in protecting the environment against accidental oil spills. This publication aids the electric borrower in interpreting Federal regulations and developing the necessary documents and oil retention systems to meet these regulations.

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Date

REA BULLETIN 1724E-302

DESIGN GUIDE FOR OIL SPILL PREVENTION AND CONTROL AT SUBSTATIONS

ELECTRIC STAFF DIVISION

RURAL ELECTRIFICATION ADMINISTRATION

U.S. DEPARTMENT OF AGRICULTURE

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ABBREVIATIONS

CFR	Code of Federal Regulations
EPA	Environmental Protection Agency
FOA	Forced Oil & Air (Transformer)
IEEE	Institute of Electrical & Electronic Engineers
OA	Oil & Air (Transformer)
OCB	Oil Circuit Breaker
PVC	Polyvinylchloride
REA	Rural Electrification Administration
SPCC	Spill Prevention Control & Countermeasure Plan

CHAPTER I
INTRODUCTION

1. SCOPE OF BULLETIN: This bulletin covers oil spill prevention and control due to accidental discharges of oil from power facilities and electrical equipment containing oil. Topics include: (1) applicability of Oil Pollution Prevention Regulations (40 CFR, Part 112) published by the Environmental Protection Agency (EPA) to electrical facilities and equipment; (2) preparation and implementation of an oil Spill Prevention Control and Countermeasure (SPCC) plan for those facilities which, due to their proximity to navigable waters and amount of oil contained, are required by EPA regulations to have an operational SPCC plan; (3) properties of oil commonly used or stored in electrical facilities and equipment; (4) techniques, procedures, and methods for oil spill prevention, its containment, removal, and disposal; and (5) an example of a typical SPCC plan.

1.1 Purpose of Bulletin: This bulletin is intended only as a guide to enable REA electric borrowers to meet the requirements of the EPA regulations. Each borrower, however, is responsible for assuring compliance with the regulations.

1.2 EPA Regulations: In 1973, the EPA published regulations for the prevention of water pollution due to oil spills from oil storage facilities. The regulations are identified as Title 40, Code of Federal Regulations, Part 112, (40 CFR, Part 112), "Oil Pollution Prevention for Non-Transportation Related Onshore and Offshore Facilities," and became effective on January 10, 1974.

These regulations require that an engineering assessment be made of each power facility to determine the potential for oil discharge and the resulting impact. This assessment is to be based on considerations of the volume of oil and the location of the facility relative to waters which may be affected. If a potential exists, the regulations require the preparation and implementation of a SPCC plan for all new and old facilities which could reasonably be expected to discharge oil into the navigable waters and ground water of the United States or adjoining shorelines.

1.3 Scope of an SPCC Plan: The SPCC plan should address both oil spill prevention and the measures to be employed in the event of a spill to control and contain the oil discharge. The plan should include provisions to insure that: (a) employees are adequately trained to reduce the possibility of oil spills;
(b) periodic inspection and review of operation procedures for facilities and equipment to cover oil spill considerations;
(c) when appropriate, pollution prevention equipment be installed and maintained; (d) suitable secondary containment be provided to contain any oil that may be spilled; and, (e) proper oil disposal procedures are available and are followed.

1.4 <u>Need for an Effective SPCC Plan</u>: Besides the necessity of compliance with EPA or state pollution regulations, any sizable oil spill from power facilities may carry serious consequences to the utility even though it may not be in close proximity to navigable waters. Damage suits, legal fees, penalties, and cleanup expenses may arise from oil releases onto neighboring properties and have a costly impact on the utility. Adverse publicity from a spill migrating from the facility's property may possibly impair the utility's ability to obtain future zoning or other permits, and detract from the utility's goals of maintaining goodwill to its neighbors and protection of the environment.

CHAPTER II
GENERAL INFORMATION CONCERNING SPCC PLANS

2. FACILITIES AFFECTED BY EPA REGULATIONS: Before an adequate spill prevention plan is prepared and a containment system is devised, the engineer must first be thoroughly aware of the requirements included in the EPA regulations. This and the next two sections should be consulted for an indepth discussion of the EPA requirements and how they apply to power facilities.

Regulation 40 CFR, Part 112, applies to all non-transportation related facilities engaged in drilling, producing, gathering, storing, processing, transferring, distributing, or consuming oil products. To exclude facilities containing and using small quantities of oil, such as those used by homeowners, these regulations only apply if the facility meets the following conditions:

a. Facilities with above-ground storage capacities greater than 660 gallons in a single container or 1320 gallons in aggregate storage, <u>or</u>

b. Facilities with a total storage capacity greater than 42,000 gallons of buried oil storage, <u>or</u>

c. Facilities which, due to their location, could reasonably be expected to discharge oil into or upon the navigable waters of the United States or its adjoining shorelines.

2.1 <u>Persons Responsible for SPCC Plans</u>: Individual SPCC plans should be prepared by the owner/operator of each facility which meets the above criteria. An SPCC plan should also be prepared for each mobile or portable oil storage facility, and must be general enough to be applicable for any location to which this unit may be moved.

The owner/operator has the responsibility of determining whether each facility could "reasonably be expected" to discharge oil into navigable waters or upon adjoining shorelines. If a facility is far removed from navigable waters, the probability of discharge into navigable waters may be very remote. Among the factors the owner/operator should consider in making such a determination are:

a. Prior spill history.

b. Location (proximity to navigable waters).

c. Potential size of discharge.

d. Soil and terrain conditions.

e. Frequency and amount of rainfall.

2.2 Navigable Waters: The term "navigable waters" is defined to include all of the following:

a. Waters that are navigable including adjacent territorial seas.

b. The entire river system extending upstream to its uppermost tributaries.

c. Lakes and ponds utilized by interstate travelers for recreational or other purposes.

d. Intrastate lakes, rivers, and streams from which fish or shellfish are taken and sold in interstate commerce.

e. Stream beds and river beds which may normally be dry and only contain water during heavy rain periods.

f. All wetlands.

This broad interpretation of "navigable waters" basically means that an SPCC plan must be prepared and maintained for any facility which may lead to the discharge of oil into any form of waters within the United States.

2.3 Completion of SPCC Plan: SPCC plans are to be prepared and fully implemented before new facilities become operational. This implementation includes any construction or plant modifications, changes in operational maintenance or administration, or the training of personnel which are prescribed in the plan. If the operator cannot comply with this time requirement due to the nonavailability of qualified personnel or equipment, a written request for an extension of time must be sent to the EPA Regional Administrator (See Appendix A for a complete listing of regional offices).

A request for extension must include the following information:

a. A complete copy of the SPCC plan.

b. An explanation of the cause of any such delay and the specific aspects of the SPCC plan affected by the delay.

c. A discussion of actions being taken to minimize delay.

d. A proposed time schedule for implementation of corrective actions.

2.4 Certification of SPCC Plan: Each SPCC plan must be reviewed, certified, and dated by a registered Professional Engineer. The engineer must state and attest that he is familiar with the provisions of 40 CFR, Part 112, that he has examined the facility in question, and that the plan has been prepared in accordance with good engineering practices.

2.5 **<u>Safekeeping of SPCC Plan</u>:** A copy of the SPCC plan must be maintained at the facility for which the plan was prepared and be available for EPA on-site inspection during normal working hours. It should be noted that the EPA will not evaluate SPCC plans for adequacy and/or completeness, but only as to whether the plan exists. However, if the facility experiences spill problems, the plan may be critically reviewed by EPA, and by the appropriate state and local agencies to determine its adequacy. Based on this review, the EPA may require that the plan be amended to include additional preventive measures.

2.6 **<u>Amendments to the SPCC Plan</u>:** The owner/operator is required to amend the plan when any of the following events occur:

a. When required by the EPA after a review of the plan, submitted because of an oil spill.

b. Whenever there is a change in facility design, construction, operation, or maintenance which considerably affects the potential for an oil spill.

c. Whenever a review by the owner/operator indicates that a more effective control and prevention technology will significantly reduce the likelihood of an oil spill. This review occurs at least once every 3 years.

2.6.1 The owner/operator must submit the SPCC plan with any amendments to the EPA and to the appropriate state agencies for their review whenever a facility experiences: (1) a single spill of 1,000 gallons or more, or (2) any two oil spills within a 12-month period.

2.6.2 Within 60 days of the occurrence of either of the above situations, the owner/operator must submit to the EPA Regional Administrator and to the appropriate State agency on water pollution control the following information:

a. Name of facility.

b. Name of the owner/operator of the facility.

c. Location of the facility.

d. Date of initial facility operation.

e. Storage capacity of facility (equipment).

f. Description of the facility, including maps of the site, oil flow path, and topographical maps.

g. A complete copy of the SPCC plan with any amendments.

h. The cause of the spill, including a failure analysis of the system.

i. The corrective actions and/or countermeasures taken.

j. Additional preventive measures taken or contemplated to minimize the possibility of recurrence.

k. Other information as the EPA Regional Administrator may require.

2.6.3 EPA will review the information and any recommendations made by State agencies and may require the operator to amend the SPCC plan. If the EPA proposes any amendments to the plan, the operator will be notified either by certified mail or by personal delivery specifying the required changes. The amendment required becomes effective 30 days after notice, unless the operator appeals. The operator must implement the amendment as soon as possible, but no later than 6 months after the amendment becomes part of the plan. Within 30 days from receipt of the notice, the operator may submit written information and arguments to appeal any proposed amendment requirements. After considering all material presented, the EPA will either notify the operator that an amendment is required or rescind the previous notice.

All SPCC plan amendments, except those proposed by an EPA Regional Administrator, must be certified by a registered Professional Engineer.

The owner/operator of facilities which violate the requirements of the EPA regulations relating to the preparation, implementation, or amending of SPCC plans is liable for a civil penalty of not more than $5,000 for each day that such violation continues. The EPA Regional Administrator may assess or waive the civil penalties at his discretion. The penalty will not be assessed until the owner/operator has been given notice and an opportunity for a hearing.

CHAPTER III
ELECTRICAL FACILITY APPLICABILITY

3.0 ELECTRICAL FACILITY APPLICABILITY: EPA regulations (40 CFR, Part 112) were originally written and intended to prevent and control the discharge of oil from facilities directly involved with drilling, gathering, refining, storing, and consuming oil products for heating, cooling, and manufacturing purposes. EPA has included under the storage portions of these regulations electrical apparatus which contain oil for electrical insulating purposes.

Electrical faults in this power equipment can produce arcing and excessive temperatures that may vaporize insulating oil, creating excessive pressure that may rupture the electrical equipment tanks. In addition, operator errors, sabotage, or faulty equipment may also be responsible for oil release which may enter waterways.

3.1 Factors Influencing the Extent of Damage of an Oil Spill: The initial cause of an oil release or fire in electrical apparatus may not always be avoidable, but the extent of damage and the consequences for such an incident can be minimized or prevented by adequate planning in prevention and control.

The risk of an oil spill caused by an electric equipment failure is dependent on many factors, including:

a. Engineering and operating practices (i.e., electrical fault protection, loading practices, switching operations, testing, and maintenance).

b. Quantities of oil contained within apparatus.

c. Station layout (i.e., spatial arrangement, proximity to property lines, streams and other bodies of water).

d. Station topography and site preparation (i.e., slope, soil conditions, ground cover).

e. Rate of flow of discharged oil.

Each outdoor facility must be evaluated to select the safeguards commensurate with the risk of a potential oil spill.

Containment facilities or systems may be selected such as drains, swales, stone filled pits (which may or may not be lined with impervious material), weirs or oil separators, spill diversion ponds, all in combination with the utility's SPCC plan.

The following list shows typical volumes of oil contained in electrical equipment at rated voltage levels:

TRANSFORMERS			
	Voltage	kVA	Approximate Gallons of Oil
Single Phase OA	34.5/15 kV	2,500	640
		3,333	867
	69.15 kV	833	575
		2,500	880
		5,000	1,175
Three Phase OA (Without LTC)	34.5/15 kV	7,500	1,310
	69/15 kV	1,500	1,110
		5,000	1,535
		10,000	1,900
Three Phase FOA	138/15 kV	20,000	5,336
		40,000	8,946
	161/69 kV	100,000	5,750
	230/23.8 kV	650,000	41,000
	345/15 kV	400,000	20,013
	345/69 kV	168,000	21,700
Three Phase (Auto) FOA	161/69 kV	83,000	9,650
	230/69 kV	100,000	11,700
	230/115 kV	165,000	18,000
	230/115 kV	200,000	22,475

VOLTAGE REGULATORS			
	Voltage	kVA	Approximate Gallons of Oil
Single Phase	2.5 kV	167	100
	7.6 kV	167	75
	14.4 kV	144	116
	19.2 kV	333	190

OIL CIRCUIT BREAKERS		
	Voltage	Approximate Gallons of Oil
Single 3ø Tank	14.4 kV	170
	34.5 kV	218
	69 kV	569
	138 kV	2,530
Three 1ø Tanks	121 kV	2,650
	145 kV	2,715
	169 kV	4,050
	242 kV	7,150
	362 kV	10,000

MISCELLANEOUS EQUIPMENT			
Item	Size	Voltage	Approximate Gallons of Oil
Recloser (3ø)	560 amp	14.4 kV	50
Capacitors (not subject to "Oil Pollution Prevention Regulation" but subject to "Toxic Substance Control Act").			

Table 3-1

3.2 __Oil Capacities of Equipment__: In order to determine which size and type of electrical facilities require an SPCC plan, it is necessary to know the oil capacities of each piece of electrical equipment at the facility.

3.2.1 Based on the quantities of oil stipulated in the regulations (i.e. 660 gallons in a single container, or 1,320 gallons aggregate storage), the following electrical facilities will probably require the preparation of an SPCC plan.

a. Power Plants

b. Substations

c. Switching Stations

d. Mobile Substations

e. Large Customer Installations (appx. 750 kVA & greater)

f. Test Facilities

g. Pipe Type Cables

h. Equipment Storage and Maintenance Facilities

First the engineer should consider whether the quantities of oil contained in the station exceed the quantities of oil specified in the regulations. Second, if there is no likelihood of the oil reaching navigable waters during an oil spill or rupture, no SPCC plan is required.

3.2.2 It should be noted that SPCC plans should be prepared for each piece of portable equipment and mobile substations. These plans should be general enough that these plans may be used at any and all substation or facility locations.

3.3 **__Probability of an Oil Spill__**: The probability of any type of oil spill is greatly influenced by the frequency and amount of oil which is routinely handled and transferred. Fuel oil storage and transfer facilities have a higher incidence of spills and failures than electrical power facilities. Power facilities have very low turnover rates of oil due to the fact that this oil is not consumed but is used as an insulating and cooling medium.

Electrical facility failures and spills may occur due to equipment failure, vandalism, sabotage, accidents, or negligence. The task force on oil spill prevention of the IEEE Substation Environmental Committee in January 1978, published the results of two questionnaires on oil spills in electrical facilities.

HISTORY OF OIL SPILLS		
Original IEEE Questionnaire Responses		
	1965 thru 1974	1975 thru 1976
1. How many oil discharges did you have?	16+ (5/yr.)	33
2. How many oil discharges left substation property?	7	7
3. How many oil discharges reached surface waterways?	7	6
4. How many oil discharges reportedly reached ground water?	3	3
5. How large were the discharges from transformers? (with 660 gal./tank)		
A. 10-100 gallons	18+ (5/yr.)	11
B. 101-1000 gallons	20	18
C. 1001-2500 gallons	6	2
D. 2501-5000 gallons	4	1
E. Larger - How much?	3	1
6. How large were the discharges from oil circuit breakers? (with 660 gal./tank)		
A. 10-100 gallons	6	--
B. 101-1000 gallons	5	--
C. 1001-2500 gallons	1	--
D. Larger - How much?	--	--

SUMMARY OF SUPPLEMENTAL QUESTIONNAIRE RESPONSES			
		1965-1974	1975-1976
1. What was the average number of pieces of equipment in service (with 660 gal./tank).			
Transformers		26,223+	28,031+
Oil Circuit Breakers (OCB)		10,702+	11,804+
(The best approximation readily available)	Total:	36,925+	39,835+
2. How many of the oil spills you reported were caused by:			
Failure	Trans.	23	19
	OCB	10	2
Sabotage	Trans.	14	23
	OCB	--	--
Accident or	Trans.	6	5
Negligence	OCB	1	--
Leaks	Trans.	4+ (5/yr.)	5+ (5/yr.)
	OCB	1	--

Table 3-2

The first questionnaire collected data on utility oil spill history and determined to what extent oil containment was used in these facilities. The second questionnaire was used to obtain additional backup information which was used in determining probability of failure. Table 3-2 shows responses of 28 utilities who answered both questionnaires.

Using these figures, we can calculate the percentage of spills per number of pieces of equipment in service.

1965-1974	1975-1976
$\frac{110}{36,925} \times 100\% = 0.3\%$	$\frac{33}{39,835} \times 100\% = .08\%$

This information shows that during the 10-year period, 1965 through 1974, these companies averaged less than one discharge for each 330 pieces of equipment in service. Over the 2-year period, 1975 through 1976, these companies had less than one discharge for each 1200 pieces of equipment in service.

It is also interesting to note that of the spills reported, about 6 percent left the property and entered waterways during the period from 1965 to 1974, and about 14 percent during the period 1975 through 1976.

Caution should be taken when drawing conclusions from this data since the actual sampling of utilities is small, and not all oil discharges may be recorded. The study also does not furnish data on the proximity and number of the facilities to surface water sources. In addition, the probability of spill occurrence is a function of length and type of service which the equipment is subjected. As existing and future equipment is subjected to higher short circuit forces, the probability of failure may substantially increase.

CHAPTER IV
GUIDELINES FOR PREPARATION AND IMPLEMENTATION OF AN SPCC PLAN

4.0 GENERAL: Detailed guidelines for the preparation and implementation of an SPCC plan are given in Section 112.7 of 40 CFR, Part 112. The plan, in general, should be carefully thought out, prepared in accordance with good engineering practices, and should follow Section 112.7. The overall objective of this engineering analysis study should be directed towards spill prevention by identifying facility weaknesses, and then designing and planning these facilities to prevent and/or greatly reduce the occurrence and effects of spills.

4.1 Major Sections of an SPCC Plan: Following a detailed engineering review of the existing proposed facility, an SPCC plan should be developed which contains at least the following three major sections:

a. Description of the facility including topographical maps.

b. Identification of sources of potential spills.

c. Engineering description of the corrective actions to be taken to prevent failures and, if a failure occurs, to contain the flow of oil before it reaches navigable waters or shorelines.

4.2 Contents of an SPCC Plan: The best method of presentation is that of a narrative engineering report with supporting maps and drawings. The description of the facility should be related to the plot plan of the facility including details of drainage patterns and locations of waters which may be affected by oil discharges.

The engineer should then identify the significant potential spillage areas and, based on prudent engineering judgment, eliminate small or insignificant sources of potential spills. This engineering judgment should carefully weigh the probability of the equipment spill occurrence and the magnitude of the probable spill size. This may result in the exclusion of such devices as current transformers, coupling capacitor potential devices, potential transformers, small station service transformers, small reactors, etc.

After defining the course of potential spills, the predicted maximum quantity and rate of spillage should be estimated, and using the topographical maps and available soil data, a prediction should be made as to the direction and the rate of flow.

Finally, the engineer must determine if and what form of preventive measure for each source of spillage should be provided or adequately show that spill prevention at the facility is not practical and discuss the necessary cleanup procedures. The solutions for the preventive type SPCC plan may vary widely, depending on the size, type, and general proximity of the facility to surface waters and type of terrain and soil. The solutions may range from diking, culverting, ditching, retention ponds, and curbing, to various types of collecting systems.

4.4 Substitution of an SPCC Spill Contingency Plan for Required Prevention Measures: Whenever an oil spill contingency plan is substituted for the required prevention measures, the owner of the facility must be able to demonstrate in writing and with drawings that Part 112 requirements are impractical and/or that there is no likelihood of the oil reaching navigable waters. "Impractical," as interpreted by EPA, means that measures are unsuitable for practical use at that facility and not merely uneconomical. In other words, it is not the owner's preference as to which type of plan to develop, but rather it is totally dependent on whether adequate means are available for that particular facility. If it is determined that no prevention system is available, the cleanup type plan must discuss detailed cleanup procedures to include containment and removal. This latter method will not relieve the owner of the facility from liability costs, cleanup costs, and fines as a result of a spill. In fact, these costs may in many cases amount to many hundreds of times those costs associated with providing a protective system initially.

CHAPTER V
REA RECOMMENDATIONS

5.0 GENERAL: As discussed in the preceding chapters, EPA by law does not approve or scrutinize SPCC plans and facility designs at the time of facility installation but may require that the plans be amended and modified after a spill. The modifications may take the form of changes in cleanup procedures and/or the installation of an oil retention system.

EPA regulations leave considerable leeway for individual interpretation concerning engineering alternatives that are best for a particular installation. REA has developed guidelines which are intended to assist the user in determining the necessity of an SPCC plan and, if required, to what degree of engineering complexity.

This determination should be based on the geographical location of the facility and on the quantity of oil contained at the facility. Since there is a direct relationship between the quantity of oil contained in the equipment at a facility and the voltage of that equipment, voltage of a facility is a convenient method of formulating REA recommendations.

5.1 <u>Recommendations</u>: REA recommends that the SPCC plan should consider some method of oil retention at any power facility which has a total oil storage of 1,320 gallons or more and meets any one of the following characteristics:

a. All electrical facilities 230 kV and above. (This does not mean that lower voltage facilities containing a large number of pieces of equipment or large capacity equipment need not be considered).

b. All facilities which due to their locality could discharge oil into rivers, wetlands, streams, and creeks.

c. Any facility which has the possibility of discharging oil into the ground water.

d. Any electrical facility located in environmentally sensitive areas such as those established by EPA or other state agencies.

e. Any facility located in urban, suburban, or rural areas where adverse publicity could be detrimental in obtaining future zoning, building permits, etc,

When determining the size and type of oil retention system to be used at a particular site, the cost of the system should be directly related to the risk of damage to the surrounding locale. The distance from the water to the facility has not been defined since that will depend on slope of ground, type of soil, amount of oil (i.e., equipment size), etc.

It is required by 40 CFR, Part 112, that if pits, tanks, or ponds are used, that they be sized to hold 100 percent of the oil contained in the largest single piece of equipment plus a reasonable allowance for precipitation, and not on the total capacity of the facility. Berms and equipment pits should be provided with a means to drain rain water from the enclosures without possible loss of oil. This may be done by imbiber beads, sump pumps, or any other acceptable means.

5.1.2 Use of Cleanup Procedures in Lieu of Oil Retention Systems: If the engineer reviewing the facility determines that there is no likelihood of oil reaching water sources, then it is the engineer's responsibility to adequately show this in the SPCC plan and then include a step-by-step discussion of the cleanup procedures that will be used in the event of a spill. The borrower should be aware that there are possible serious consequences associated in developing an SPCC plan around cleanup rather than prevention. A cleanup SPCC plan does not relieve the owner of financial responsibilities associated with the spill. These financial costs will include a maximum fine of $5,000 and all costs associated with the oil cleanup and civil lawsuit damages. EPA has determined that oil cleanup costs vary from $10 to $100 per gallon (as of 1979) of recovered oil and civil costs up to several million dollars.

5.2 Summary: Reemphasizing general requirements of EPA, an SPCC plan for a particular facility needs only to include a description of the oil spill prevention, or if the requirements for spill prevention are demonstrated to be impractical, a description of cleanup procedures. REA recommends that both be discussed whenever possible in order that a plan of action may be available in the event of a system failure.

CHAPTER VI
CHEMICAL AND PHYSICAL PROPERTIES OF OIL

6. PROPERTIES OF OIL: Table 6-1 lists some of the chemical and physical properties of a representative sampling of various types of petroleum products which may be found in a power facility and briefly relates how these properties affect spill behavior.

6.1 Chemical Changes to Oil: Spilled oil interacts with the environment in several characteristic ways, some of which can be predicted from a knowledge of the oil composition and properties.

Spilled oil undergoes chemical changes such as oxidation. Oxidation under the influence of the ultra-violet rays of sunlight can eliminate a very thin oil slick. However, oxidation is a mixed blessing in that the hydrocarbons contained in oil may oxidize to oxygen-containing compounds which are more toxic than the oil.

6.2 Biological Changes to Oil: The biological change process which oil undergoes involves the bacterial decomposition of oil. This metabolic decomposition of oil is the single most important natural cleanup operation.

Both of these processes are active when insulating and fuel oil are spilled. The importance of each is dependent on the type of oil and the environmental and temperature conditions under which the spill occurs.

6.3 Natural and Environmental Conditions Influencing the Damage from Oil Spills: In addition to the amount of oil spilled, environmental conditions present at the time of an oil spill can greatly influence the amount of damage which results. Calm water, a light breeze, and warm temperatures may favor rapid cleanup operations by fast evaporation rates and minimal mixing between the oil and the water. On the other hand, rough water conditions hamper cleanup operations by the thorough mixing of oil and water, forming an emulsion which impedes oil removal and allows oil to penetrate to greater depths.

A variety of natural processes occurs when oil is spilled on water, which collectively will result in the weathering or aging of the oil. They include spreading, evaporation, dissolution, emulsification, chemical reaction, and biological degradation. These processes tend to disperse the oil and eventually lead to its dissipation or removal from the environment.

6.3.1 Spreading Process: By far, the most important of these is the spreading of the oil to a thin film, for without this happening first, many of the other dispersive processes would not occur or would only happen at greatly reduced rates. Paradoxically, it is this same tendency to spread rapidly that may cause the oil spill to "get away" from cleanup personnel.

Table 6-1: Some Properties of Petroleum Products Which Affect Spill Behavior

Property	Description	Average Crude Oil	Gasoline	Products Diesel	#2	Fuel Oils #5	#6	Lube Oil	Insulating Oil	Relationship of Property to Spill
Viscosity (Centistoke at 100°F)	Resistance to flow	Can range from low to high	Low	Low (1.4-3.0)	Low (2)	High (75)	High (75)	Mod-high	Mod (60)	Low viscosity materials spread easily over surface.
Surface Tension	Resistance to spread over another liquid	High	Low	High	High	High	High	High	Mod (46)	Low surface tension materials spread more rapidly.
Volatility	Tendency to evaporate	Low - (some components)	High	Low	Low	Very Low	Very Low	Very Low	Low	High volatility favors evaporation; if combined with low flash point, presents explosion hazards.
Relative Solubility	Tendency for all or part of a spill to dissolve in water	Very low	Very Low	Very Low	Very Low	Very Low	Very Low	Emulsilies	Low	Most petroleum products have some readily soluble components (including additives) that may be toxic to aquatic organisms.
Density (specific gravity)	Mass per unit vol. Tendency to sink in water	Med-high (0.85-0.95)	Low (.73)	Low (.85)	Low (.82)	Mod (.86)	High (.96)	Mod (.85)	Mod (.89)	Materials heavier than water (sp. Gr = 1.0) generally will sink. Materials near 0.9-1.0 sp. Gr may tend to "float" under the surface.
Emulsibility	Tendency to form stable suspension with water	Low-high	Very Low	Low	Low	High	High	High	Low	High emulsibility spreads oil throughout water column; extends possible contamination range.
Pour Point	Lowest temp. at which oil will pour	Low	Low	Low 20°F	Low 20°F	Low	High 60°F	Low 10° F	High 67°F	As pour point is approached, spill spread rate decreases.
Flash Point	Temp. at which ignition occurs	Mod.	Very Low (-40°F)	Mod.	Mod. (100)	High (130)	High (150)	Very high (350)	Very high (300)	Low flash point combined with high volatility in confined area creates explosion hazard.

Two important driving forces that cause oil to spread on water are gravity and surface tension. The fact that oil is lighter (less dense) than water brings the force of gravity into action. Oil is a complex mixture of many varying compounds each of which may have a different density. On the average, insulating oil will have an overall density which is about 90 percent of the density of water.

To understand the role of gravity in the spreading process, it is instructive to consider floating oil confined by some type of barrier such as an oil drum constructed from a plastic with a density identical to that of oil (shown by Figure 6-1.)

This full barrel will have the density of oil which means that 90 percent of its volume will be below the water's surface, and 10 percent above. The floating oil extends a height (h) above the surface of the water. At any point in the oil surface at the level of the water surface, there is a pressure (p) which is due to the weight of the oil above the water surface.

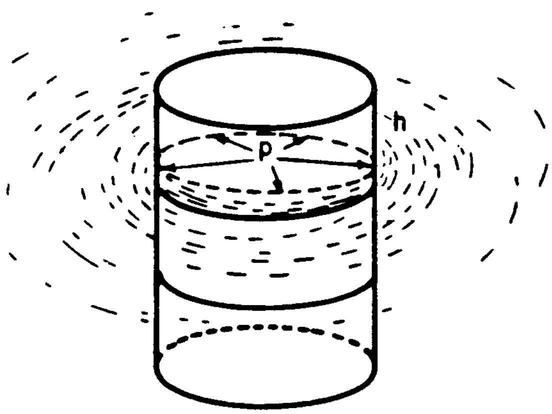


Figure 6-1: A Hypothetical Floating Barrel of Oil

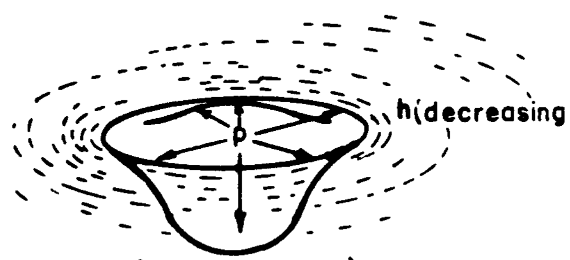


Figure 6-2: Oil Spreading

Now imagine that the plastic is rapidly disintegrated by the water and the drum is no longer there to confine the barrel of oil. The uniform pressure just above the surface of the water becomes an unopposed force toward the sides of the (missing) drum, and the oil will "spill out" over the surface of the water, as indicated by Figure 6-2. Since weight is removed as the oil above the surface spills away, the oil below the surface floats higher in the water causing more "spillage" to the sides. Consider also that the height above the water continues to decrease and the sideways force due to the gravitationally induced pressure decreases with (h). The initial value of (h) and hence, the initial gravitational spilling force depends on the volume of oil spilled. Thus, large spills spread more rapidly, and decrease with time.

It is important to consider the kinds of forces that oppose spreading forces because spreading will cease when the driving and opposing forces are balanced. In the early phase of a large spill, the major opposing force is simply the natural tendency of the oil to remain at rest, its inertia. However, as the gravitational driving force decreases with the decreasing thickness of the floating oil, the opposition due to the oil's viscosity and its drag when sliding becomes important. The initial two phases are known as gravity inertial spreading and gravity viscous spreading.

When the slick from oil has thinned to about .08 cm (.03 in.), the gravitational spreading force ceases to be a major factor and surface tension effects, which were negligible before, become the dominant driving force.

The concept of surface tension can be explained in terms of the forces between the molecules of a liquid. A molecule in the interior of a sample of liquid experiences attractive forces from the other molecules that surround it. A molecule on the surface of the liquid experience an unbalanced force due to attractions with molecules to the sides and below it and the nonexistent or very weak interactions that it has with the vapor molecules above the liquid surface. Thus, surface molecules experience a net force that pulls them towards the interior. If the amount of surface area is somehow increased (a bubble grows, a flat surface curves, etc.), work must be done to bring molecules from the interior to the surface. The opposition that must be overcome to create additional surface is called the surface tension. Wherever there is an interface such as between water and air, oil and air, or oil and water, there will be a surface tension characteristic of the interface.

It would be quite advantageous to be able to make accurate predictions concerning spreading rates during this final or surface tension-viscous phase of spreading because all (unchecked) spills will eventually spread by this mechanism. Small spills, which are far more frequent, will spread solely because of surface tension. Unfortunately, it is almost impossible to make valid predictions for many situations because the spreading coefficient will vary with time.

The evaporation and dissolution of the lighter components of the oil will change as properties such as surface tension, density, and viscosity change with time.

The ambient temperature is important in the surface tension phase of spreading but has only a small effect during gravity-forced spreading. For example, at arctic sea water temperatures near 20°F, the spreading coefficient is approximately zero, and the oil will not spread to a thin film. Also, the rate of evaporation and dissolution will increase as the temperature increases.

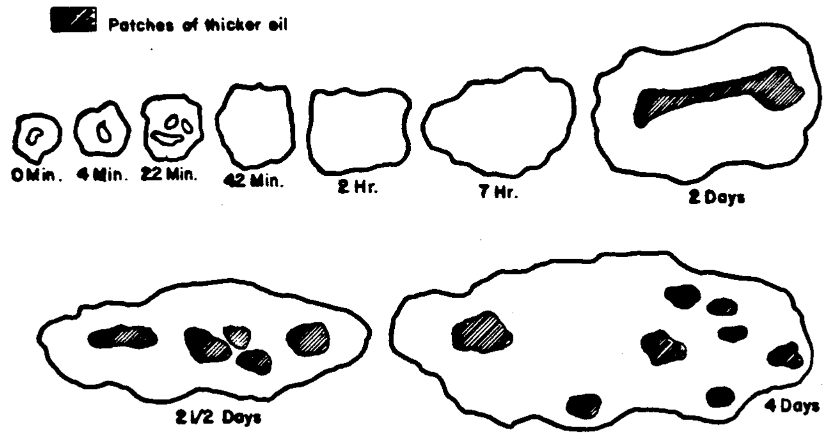


Figure 6-3: Development of an Oil Slick

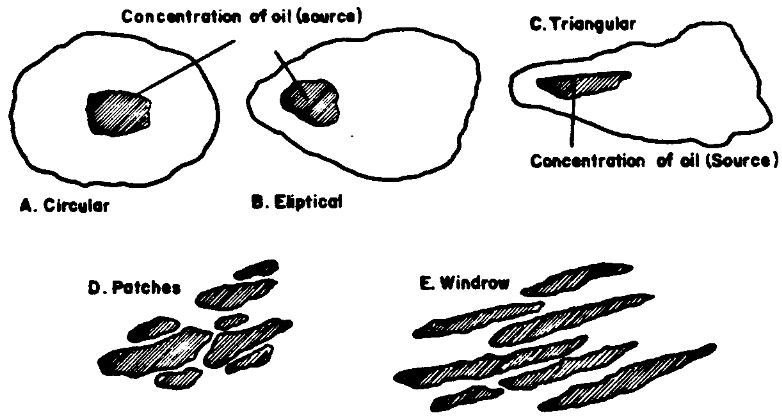


Figure 6-4: Typical Spill Distribution Patterns. A: Quiet Water - Unrestrained Spill. B: Mild Current or Wind. C: Strong Current or Wind. D: Light Oil - Moderate Wave Action. E: Swift Current - Wave Action.

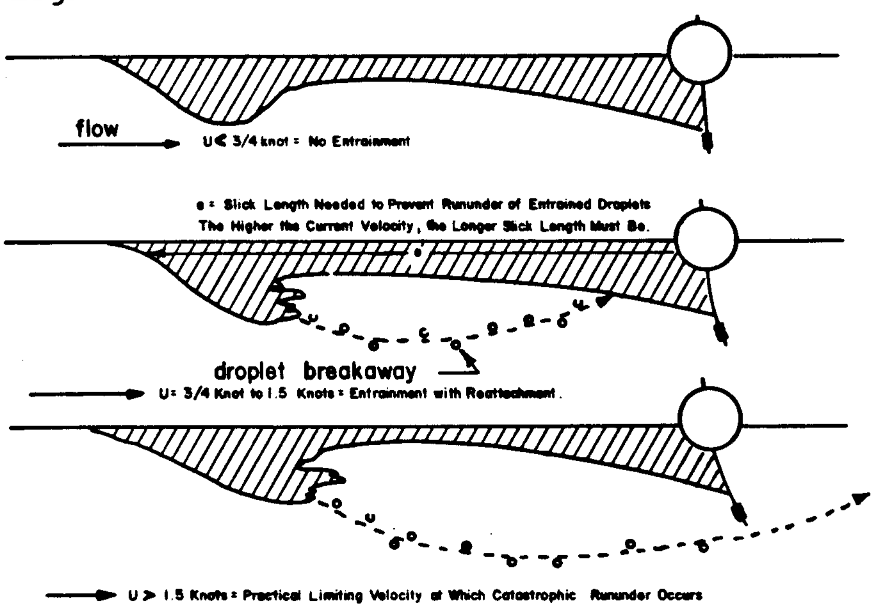


Figure 6-5: Entrainment Failure

The evaporation of the lighter oil products, with time, will usually lead to slicks which are nonhomogeneous and have thick and thin regions, as shown by Figure 6-3.

The preceding discussion of the spreading process occurring in calm water is an idealization since wind, waves, and water currents are not considered. Currents and wind will displace the entire growing slick from its original location, to include some modification of the shape of the slick (see Figure 6-4, A, B, and C; whereas, wave motion coupled with currents will break up a slick into patches and windrows (parts D and E of Figure 6-4).

A useful rule of thumb is that the center of a slick will migrate with any current at the speed of that current and will also drift in the wind direction at about 3 percent of the wind speed. Laboratory measurements indicate that the drift may actually vary from 2.5 to 4 percent of the wind speed.

6.3.2 **__Agitation and Disposal of Oil Slicks:__** The agitation of oil slicks due to the breaking waves in rough water and the action of surf can be effective in supplying the energy to form the small droplets of stable emulsions and then disperse them. Such oil particles ranging in size from 0.0002 in. to 0.1 in. have been found in the water as far as 150 miles from the original spill.

There is also data indicating that aerosols of oil droplets in air can be formed by the action of wind and waves in producing spray.

6.4 **__Use of Booms in Controlling the Spread of Oil__:** When deployed for oil containment in streams or channels, booms will form a U shape open to the current so that the oil will collect at the bottom of the U. The force of the moving current tends to confine the oil at the bottom of the U, placing the deepest part of the floating oil there. A vertical cross section would show the oil mass to be wedge-shaped with its thinner leading edge toward the open mouth of the U of the boom. The boom needs to float sufficiently high above the water to prevent the oil from splashing over the top of the boom with normal wave action. Booms also need to extend deep enough into the water to hold the oil at nominal currents.

A useful analog to remember is that the average insulating oil will have a density similar to the density of ice which is about 90 percent of water's density. Thus, a pool of oil, like an iceberg, is 90 percent below the water surface. If the boom draft below the water surface is 1/2 ft., the current pushing the oil against the bottom of the U cannot exceed 1.78 ft./sec. (about 1 knot) without the oil running under the bottom of the barrier, a phenomenon called "drawdown".

Booms require a greater draft to contain oil in currents greater than 1 knot. However, at about .75 knots a phenomenon occurs and a "headwave" develops on the underside of the leading edge of the wedge of oil (Figure 6-5b and 6-5c). At currents between .75 and 1.5 knots, droplets are entrained (broken off) from the turbulent backside of the headwave. If the slick is long enough, the majority of these droplets will rise and rejoin the oil pool (Figure 6-5b). At currents greater than 1.5 knots, the majority of the drops escape by running under the barrier (Figure 6-5c), and increasing a boom's draft will <u>not</u> prevent this type of slow leakage. A towed boom experiences essentially the same forces as a stationary boom in a current at towing speeds greater than 1.5 knots, droplet entrainment with rununder occurs. In fact, if a boom is towed against a current, the sum of current velocity and towing velocity cannot exceed 1.5 knots without rununder occurring.

CHAPTER VII
OIL SPILL PREVENTION TECHNIQUES

7.0 OIL RETENTION SYSTEMS: Once a need for an oil spill prevention system is determined, the engineer must weigh the advantages and disadvantages that each oil retention system may have at the facility in question. The oil retention system chosen should balance the cost and sophistication of the system to the risk of the damage to the surrounding locale. The risks will depend on such items as soil, terrain, relative closeness to waterways, location to property owners, and potential size of discharge. Each of the systems that are described below should be considered based on their relative merits to the facility under consideration. One system will not always be the best choice for all situations and circumstances.

7.1 Yard Surfacing and Underlying Soil: Four to six inches of rock gravel surfacing are normally required in all electrical facility yards. This design feature benefits the operation and maintenance of the facility by providing proper site drainage, reducing step and touch potentials during short circuit faults, eliminating weed growth, improving yard working conditions, and enhancing station aesthetics. In addition to these advantages, the gravel will aid in fire control and in reducing potential oil spill cleanup costs and penalties which may arise from the Federal and State environmental laws and regulations.

Yard surfacing should not be designed to be the only method of oil containment within the substation, but it should be considered as a backup in limiting the flow of oil in the event that the primary system is not adequate.

Soil underlying power facilities usually consists of a nonhomogeneous mass which varies in composition, porosity, and physical properties with depth. The soil's drainage characteristics are of primary concern in the design of an oil containment facility and is termed permeability. The permeability coefficient, "k", is a measure of the capacity of the soil to conduct or pass water under a unit hydraulic gradient. Coarse grained soils are more pervious and have corresponding higher permeability coefficients than fine grained soils. Using the coefficient of permeability, "k", and knowing the hydraulic gradient(s), the flow volume, "V", discharged through the soil's cross-sectional area, ft^2, during time, "t", may be estimated by $V = kSAt$.

Soils and their permeability characteristics vary widely as indicated below:

Permeability Coefficient (cm/sec)	Degree of Permeability	Type of Soil
Over 10^{-1}	High	Stone, gravel and coarse to medium grain sand.
10^{-1} to 10^{-3}	Medium	Medium grain to uniform, fine sand.
10^{-3} to 10^{-5}	Low	Uniform, fine to silty sand and sandy clay.

7.2 Pit Liners and Sealers: Pits with liners or sealers may be used as part of an oil containment system capable of retaining any discharged oil on-site for an extended period of time. Any collection or containment pit should be constructed with materials having medium to high permeability (above 10^{-3} cm/sec) and be sealed in order to prevent migration of spilled oil into underlying soil layers and ground water. These surfaces may be sealed and/or lined with any of the following materials.

a. Plastic or rubber - Plastic or rubber liners may be purchased in various sizes and thickness. Consideration should be given in the selection of a liner that is not subject to mechanical injury which may occur due to construction, installation, equipment, chemical attacks on surrounding media, and oil products.

b. Bentonite (Clay) - Clay and Bentonite may also be used to seal electrical facility yards and containment pits. These materials can be placed directly in four to six-inch layers or may be mixed with the existing subsoil to obtain a soil permeability of less than 10^{-3} cm/sec.

c. Spray on Fiberglass - Spray on fiberglass is one of the most expensive pit liners available, but in some cases the costs may be justifiable in areas which are environmentally sensitive. This material offers very good mechanical strength properties and provides excellent oil retention.

d. Reinforced concrete - Four to six inches of reinforced concrete may also be used as a pit liner. The advantage of this material is that it is readily available at the site at the time of initial construction of the facility. The disadvantages of this material are that initial preparation is more extensive and materials are not as easily workable as some of the other materials.

If materials other than those listed above are used for an oil containment liner, careful consideration should be given in <u>not</u> selecting materials which may dissolve or become soft with prolonged contact with oil, such as asphalt.

The final selection of pit liners or sealers should be based on cost, strength, and durability.

7.3 <u>Substation Ditching</u>: One of the simplest methods of providing total substation oil spill control is the construction of a ditch entirely around the outside periphery of the station. The ditch should be of adequate size as to contain all surface run-off due to rain and insulating oil. These ditches may be periodically drained by the use of valves (Figure 7-1). Here again, the method discussed in the previous section should be utilized in determining the allowance for precipitation.

a. <u>Advantages</u>
- o Economical

b. <u>Disadvantages</u>
- o Periods of heavy rain may not provide adequate containment.
- o Standing pools of water may breed insects.
- o May not be feasible in porous soil areas.

7.4 <u>Collecting Pond with Trap</u>: This system consists of a collection pit surrounding the protected equipment, drains connecting the collection pits to an open containment pit, and an oil trap which is sometimes referred to as a skimming unit and the discharge drain. This system is shown in Figure 7-2.

The collection pit surrounding the equipment is filled with rocks and designed only deep enough to extinguish burning oil. The bottom of this pit is sloped for good drainage to the drain pipe leading to an open containment pit. This latter pit is sized to handle all the oil of the largest piece of equipment in the station. A cross section of the system is shown schematically in Figure 7-3. The trap shown in Figures 7-4 and 7-5 is designed to contain the total capacity of oil on top of the water.

To maintain a dry system in the collecting units, the invert of the intake pipe to the containment pit should be at least the maximum elevation of the oil level. In areas of the country subject to freezing temperatures, the trap (skimmer) should be encased in concrete, or other such means available, to eliminate heaving due to ice action.

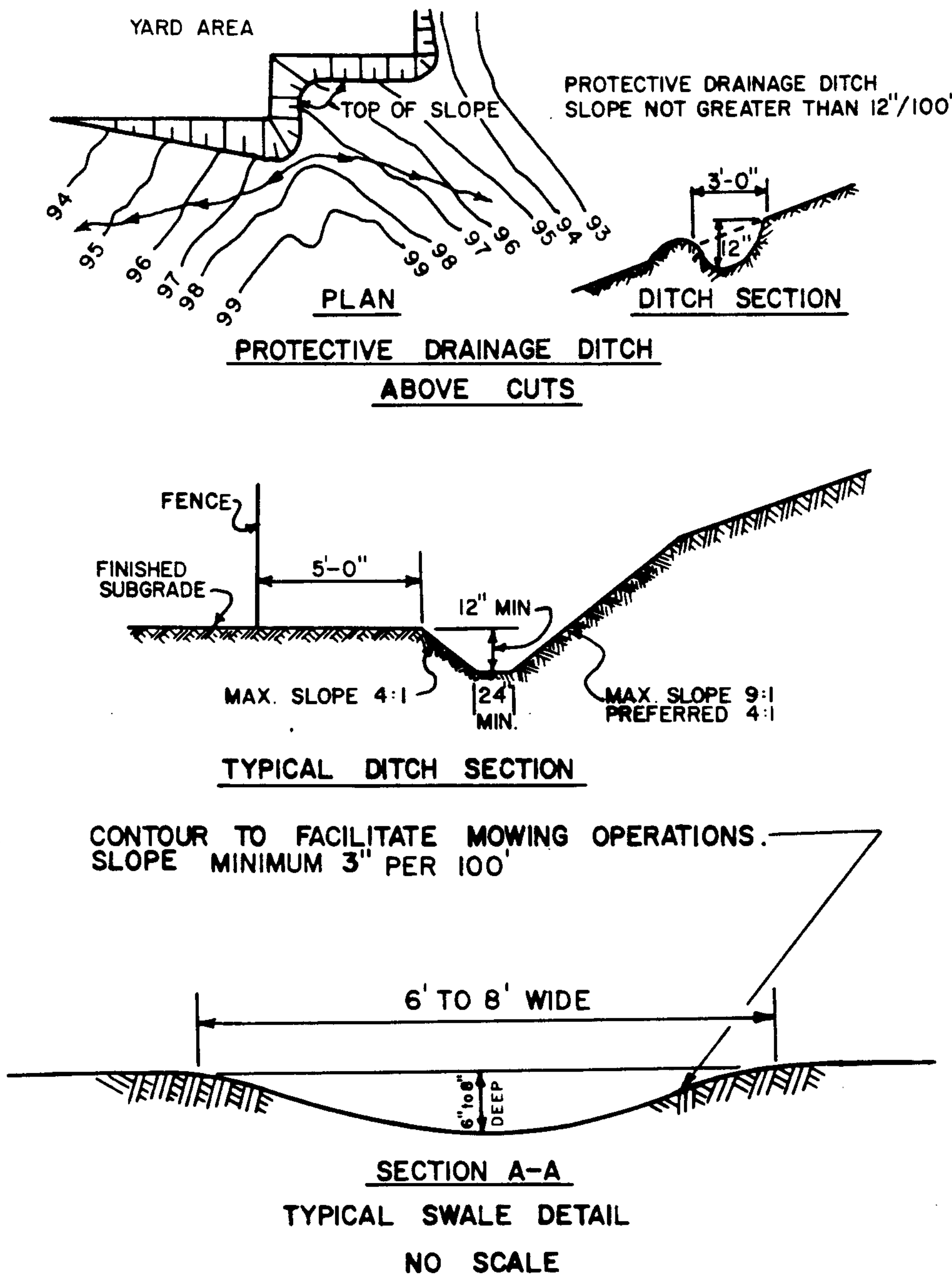


Figure 7-1: Methods of Ditch Construction

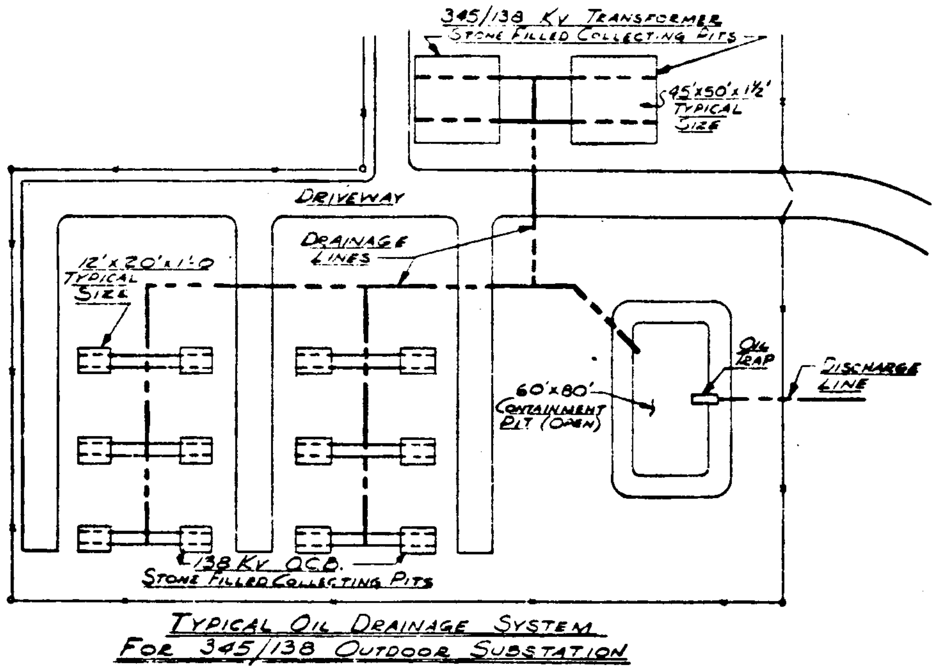


Figure 7-2: Typical Oil Drainage System for 345/138 kV Outdoor Substation

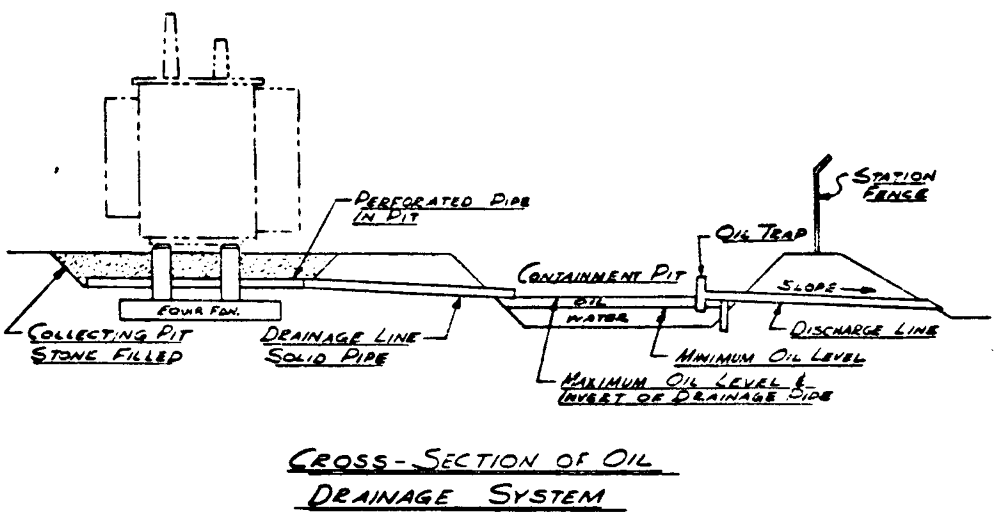


Figure 7-3: Cross Section of Oil Drainage System

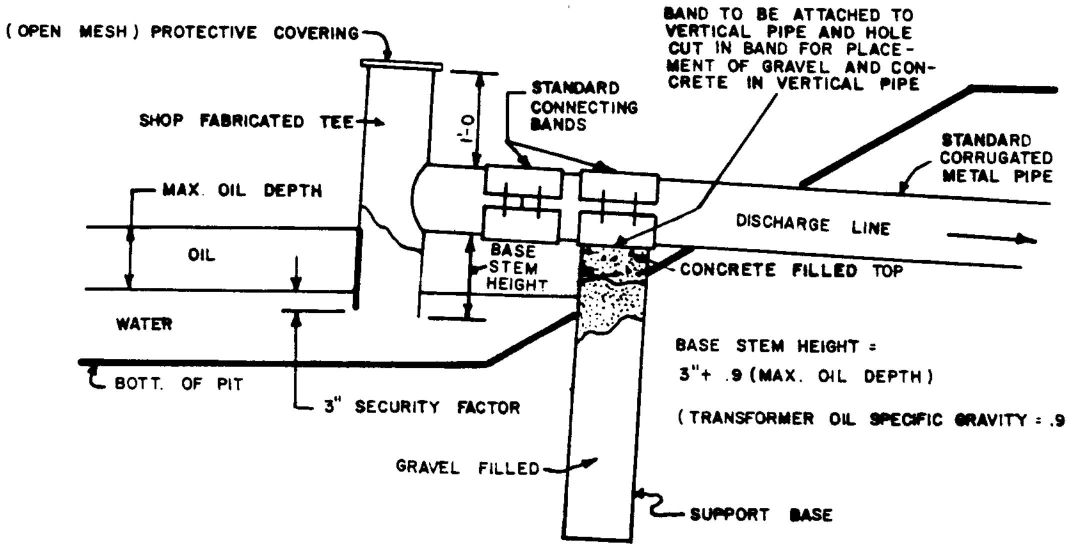


Figure 7-4: Oil Trap or Skimming Unit

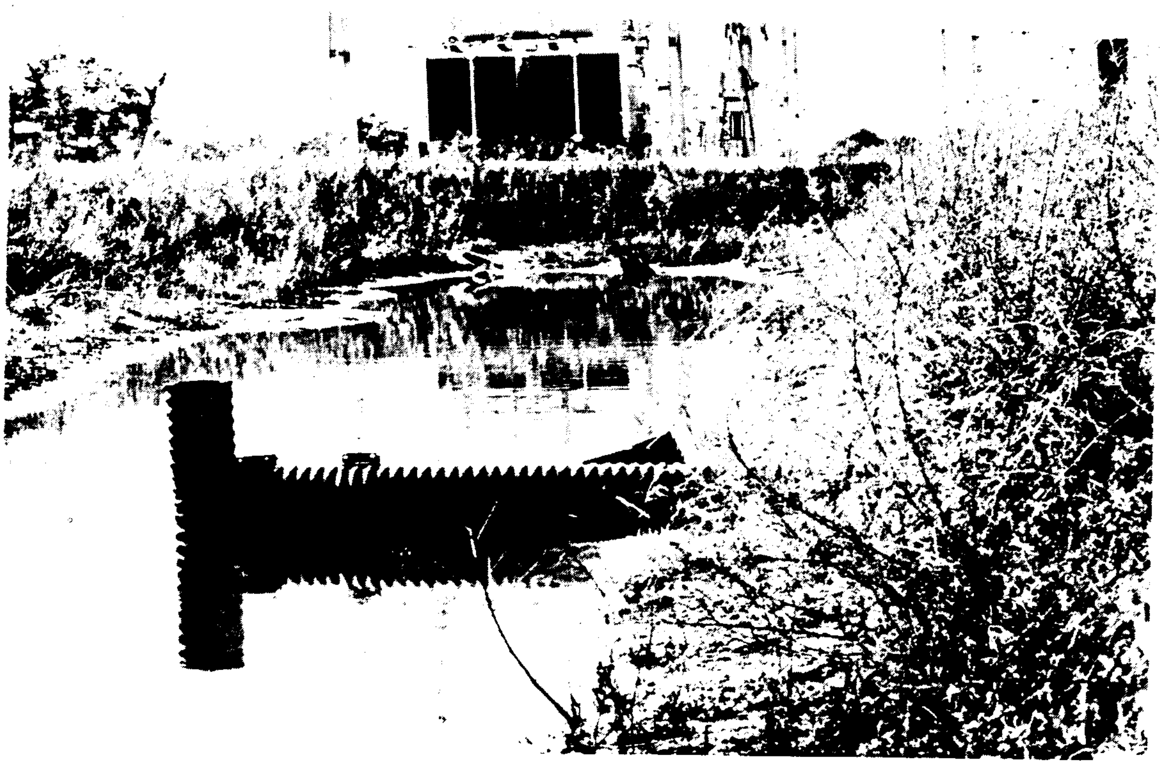


Figure 7-5: Oil Trap in Containment Pit

An alternate method of constructing an oil trap is shown in Figure 7-6. The trap in this method is fabricated with 3 to 4 inch PVC pipe. Galvanized pipe is not recommended for use for subsurface work due to corrosion and subsequent loss of the pipe.

a. Advantages
   - o Relatively inexpensive
   - o Easily maintained
   - o Provides additional substation drainage
   - o Reliable

b. Disadvantages
   - o More substation area required
   - o Unsightly, possible hazard to personnel and equipment movement
   - o May have possible insect breeding problems

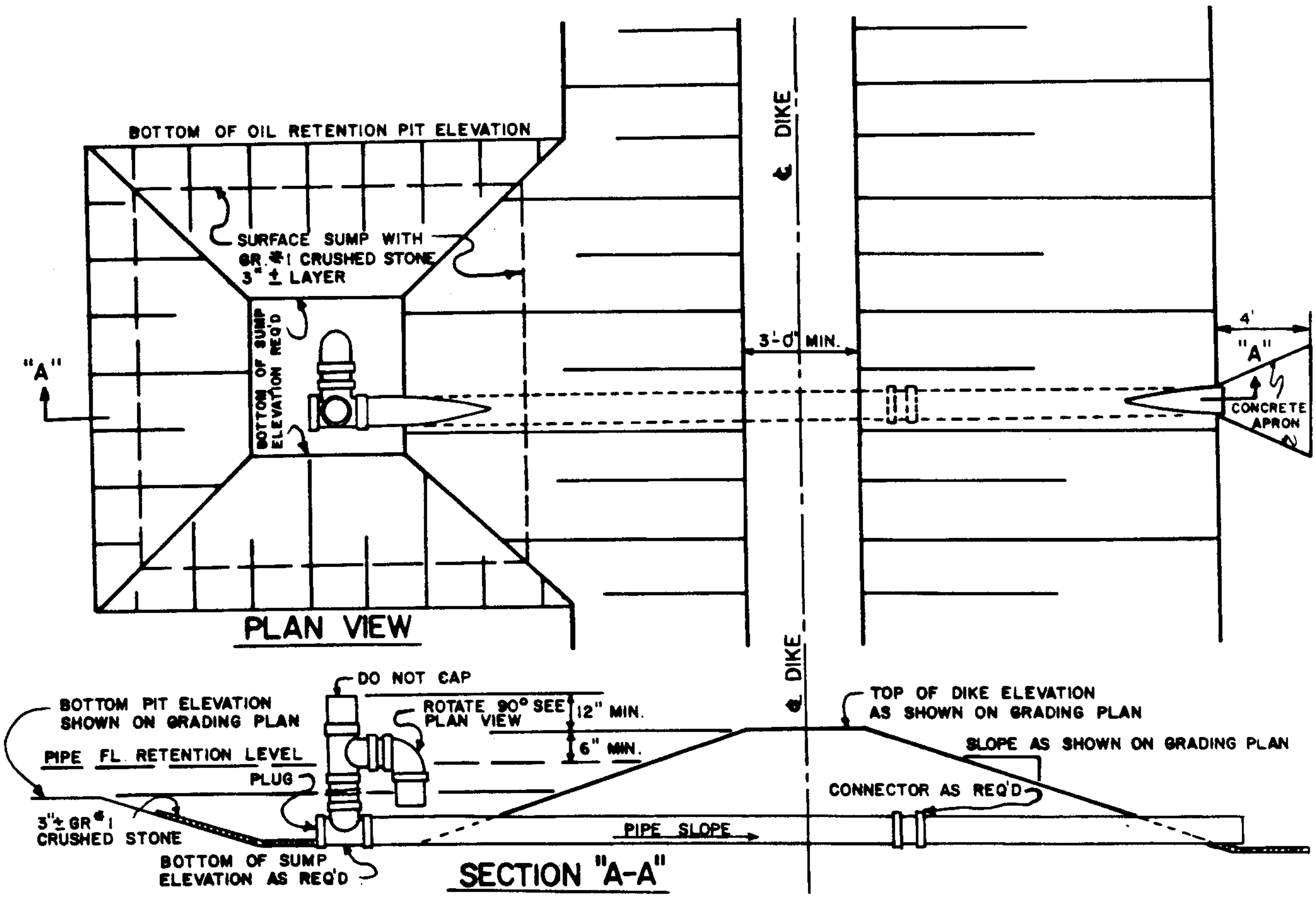


Figure 7-6: Oil Trap Construction Using Galvanized or PVC Pipe

7.5 Imbiber Beads: Imbiber beads are a patented oil absorbent in the form of spheres, the size of a pinpoint. The beads will absorb oil and swell to approximately 27 times their original size. This swelling property has been utilized to form a valve which passes water, but when oil enters, the bead swells, thereby stopping the flow. These beads can be purchased in a premanufactured 3-1/2 inch diameter valve or a 6 inch cartridge type (see Figures 7-7 and 7-8), or in loose form and placed in a gravity drain catch basin (Figure 7-9). Cartridge valves are easier to install than in the loose form but require periodic replacement (normally semiannually to annually) due to picking up of yard oil and rusting and subsequent failure of the bead container. It is important in designing these drainage units that the silt be removed before the water passes into the bead bed. The most effective means is a sand filter of the same particle size as the beads. If this sand filter clogs, it can be scraped off and replaced which is cheaper than changing the beads. In cold weather areas, some type of freeze protection such as heat tape or the use of a closed cell soft foam may be needed to prevent freeze fracture.

The beads may be used to drain water from any containment system. Figures 7-10 and 7-11 are intended to show details of some facility water collection outlets and how imbiber bead valves may be applied to these installations.

a. Advantages
   - Reliable operation
   - Low maintenance

b. Disadvantages
   - Expensive

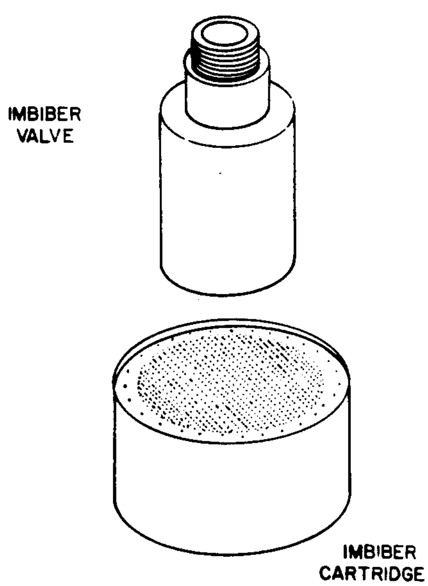


Figure 7-7: Imbiber Bead Valves and Cartridges

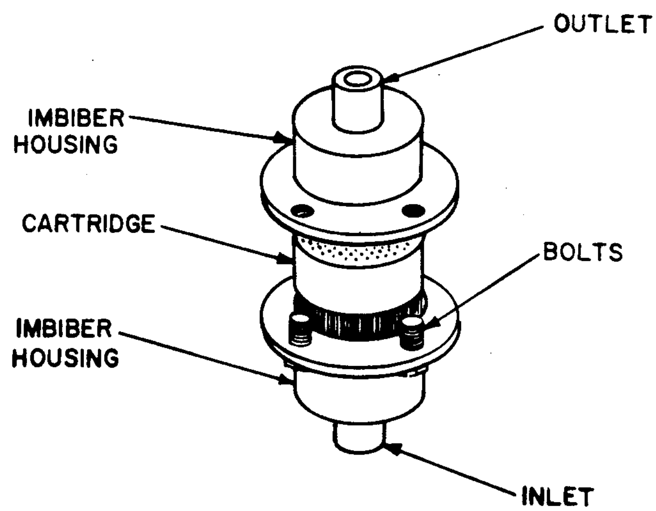


Figure 7-8: Installation of Imbiber Bead Cartridges

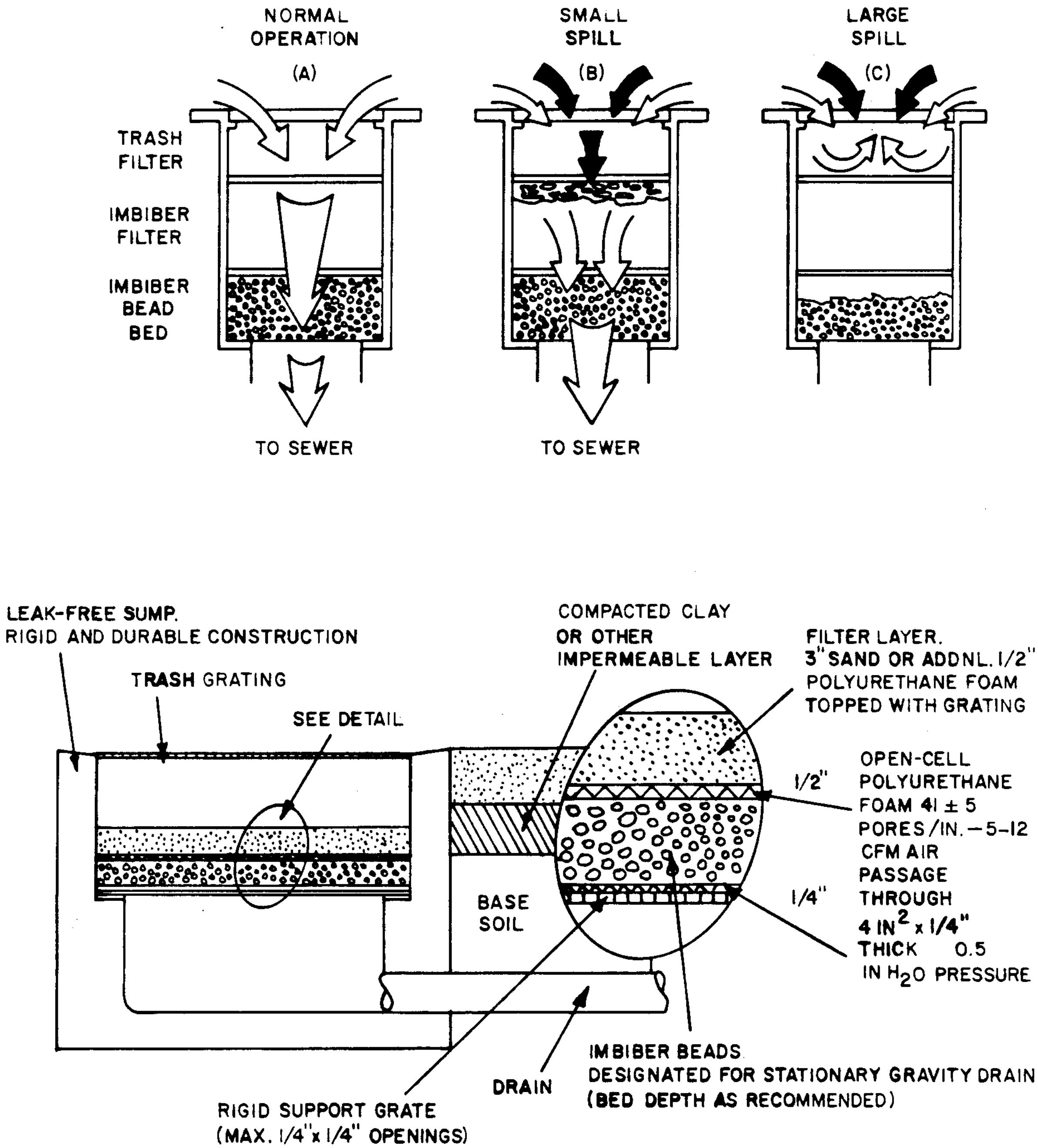
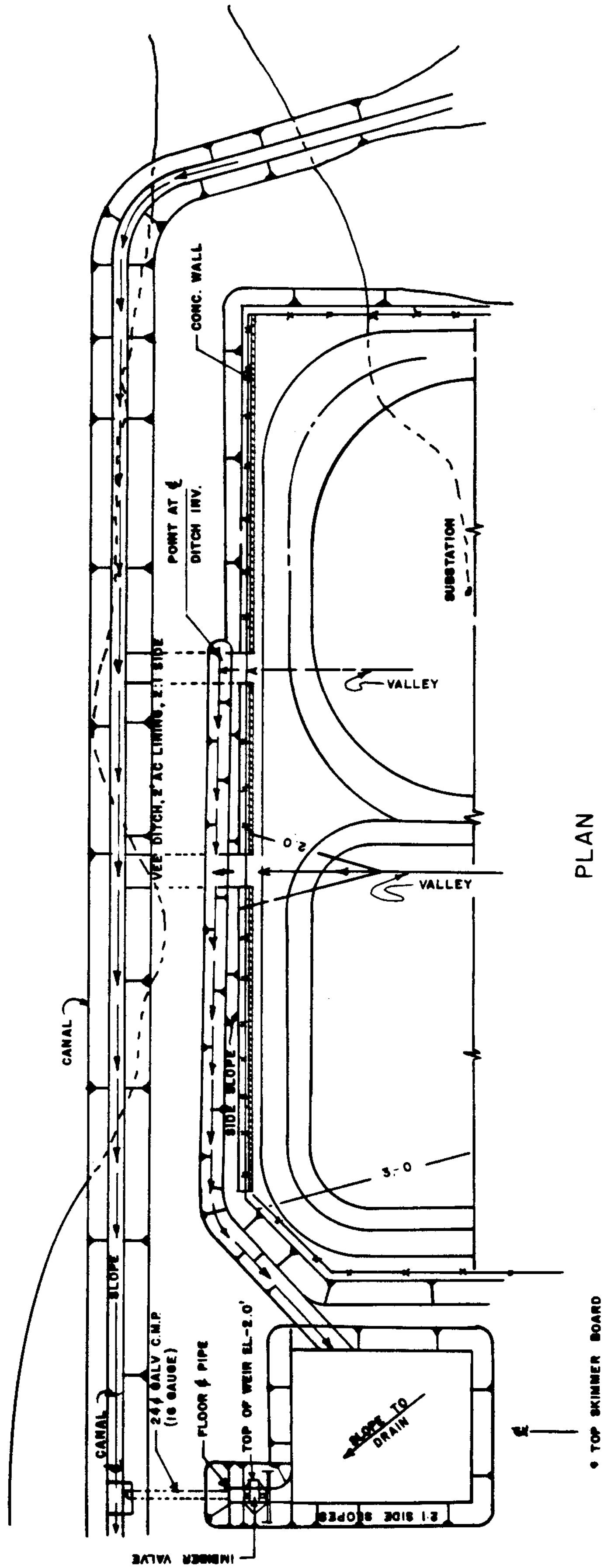


Figure 7-9: Installation of Imbiber Beads in Gravity Drain

Figure 7-10: Typical Drainage of Substation Using Imbiber Bead Collection Ponds



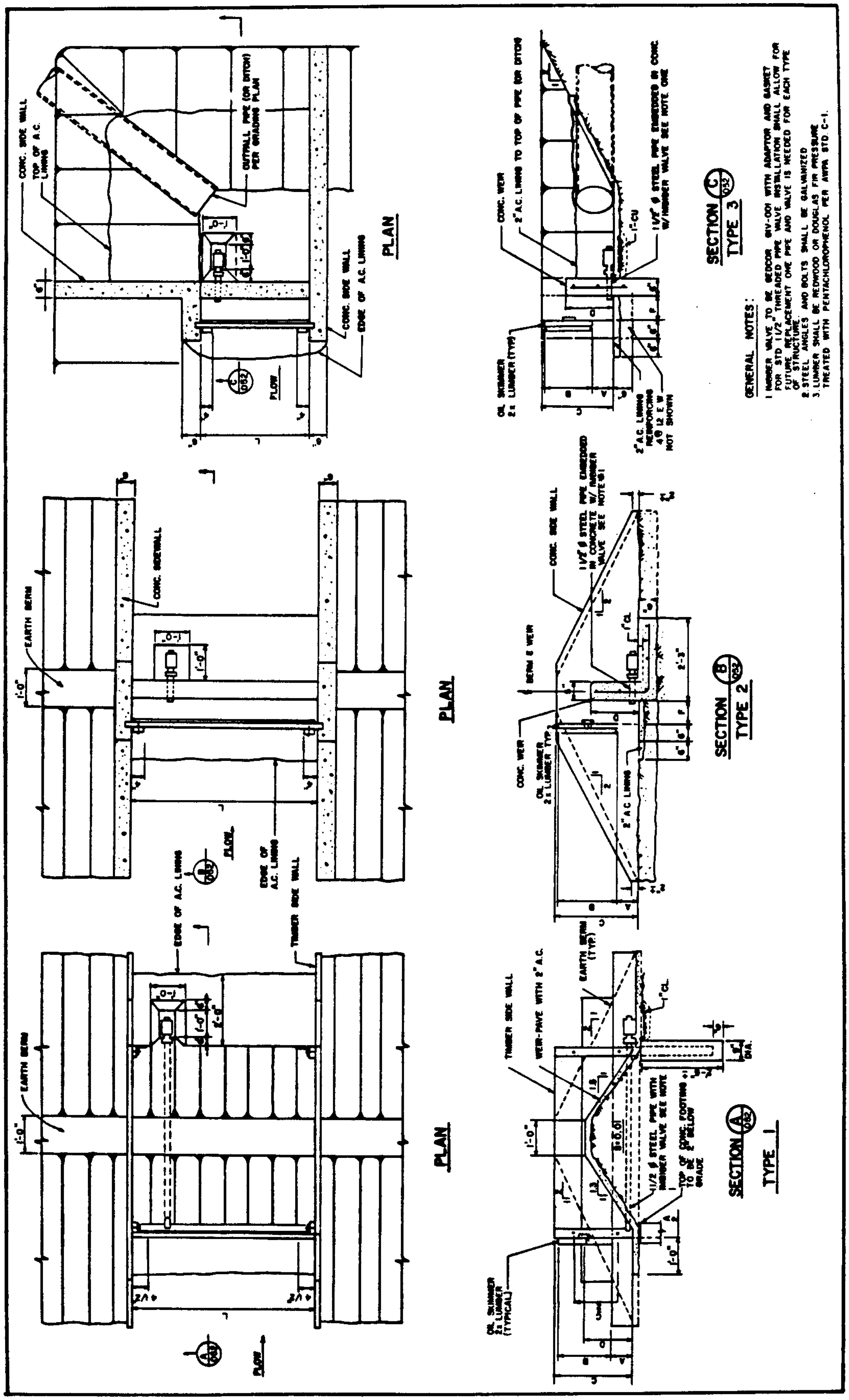


Figure 7-11: Outlets from Collection Pond

7.6 <u>Oil Separator Tank</u>: This system is feasible only when there is sufficient gradient for gravity discharge from the underground tank. The oil and water are collected from the equipment area and are discharged into an oil separator tank. The principle upon which this system operates is that oil is lighter than water and floats above it.

The oil separator tank should be designed to contain all of the oil in the largest single piece of equipment should a major rupture occur (see Figures 7-12 and 7-13). These tanks may be formed and poured in place or a precast septic tank may be purchased and slightly modified. This system allows the water to continuously pass through but retains the oil. The oil retained in the tank must be pumped into a tank truck and disposed. The oil separator tank principle may also be applied to above-grade diked basins if freezing temperatures are not prevalent.

To avoid improper operation of this system, it is necessary that the water level not be allowed to drop below the bottom of the discharge pipe inlet in the tank. All oil separator discharge pipes should be vented in order to maintain atmospheric pressure in the tank, thereby preventing any possible siphon effects.

Modification to the above-grade separator system may be considered if regular inspection is performed. It could consist of a transformer area that is lined and diked with impervious material. A short section of four inch pipe passing through the dike with a shut-off valve which may either be: (a) left open for continuous drainage and closed in an emergency when alarms or inspection indicates, or (b) closed and opened as necessary to drain the collected water at periodic inspections.

a. <u>Advantages</u>
   - Reliable
   - Easily maintained

b. <u>Disadvantages</u>
   - Relatively expensive
   - Requires periodic maintenance
   - Discharge pipe outlet may be inoperative during freezing temperatures

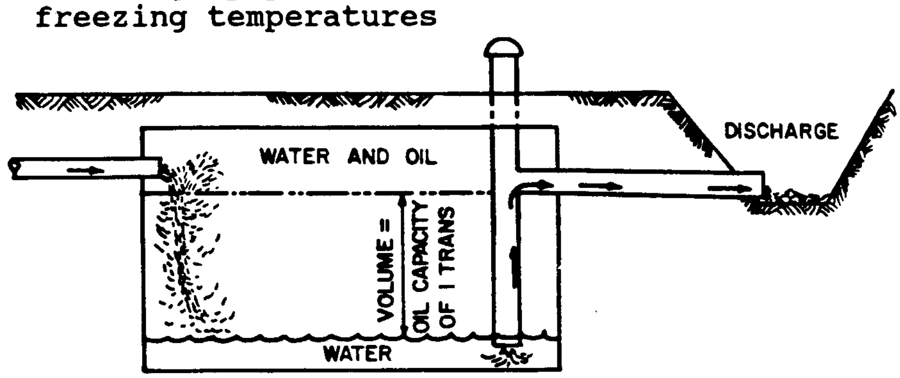


Figure 7-12: Typical Construction of Oil Separator Tank

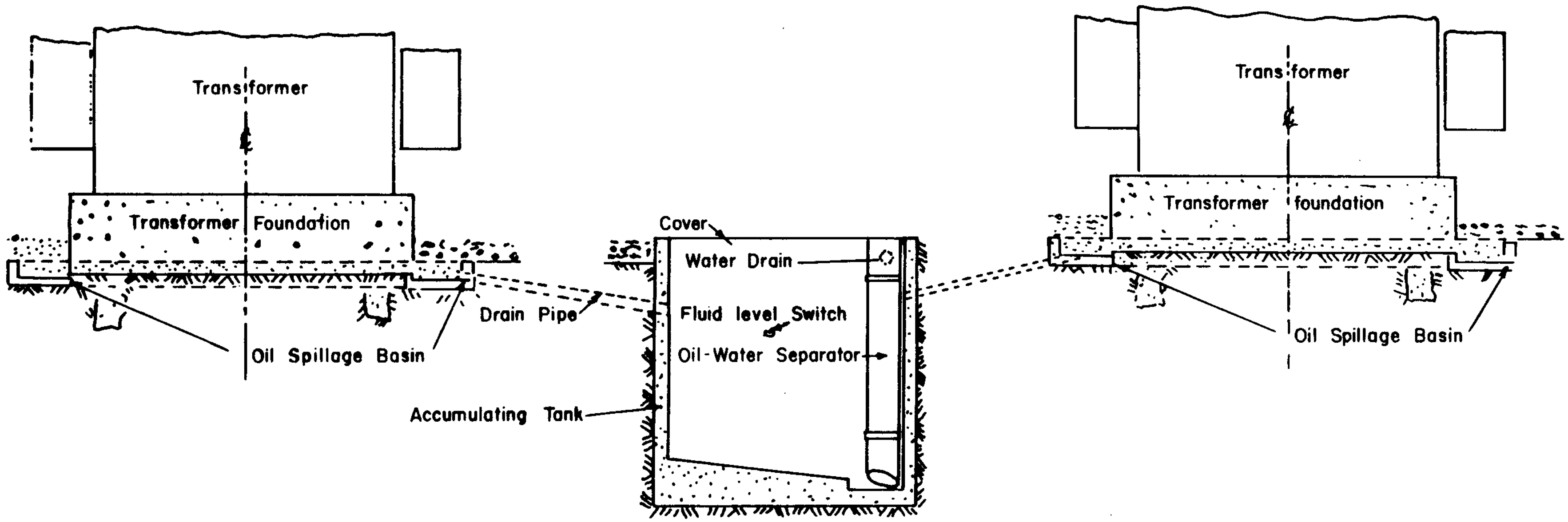


Figure 7-13: Transformer - Accumulating Tank Combination

7.7 Oil Stop Valve: The previously described oil separator tank system can be slightly modified by the use of "oil stop valves" to greatly improve the system's reliability.

The valve's only moving part, a ballasted float, has a specific gravity between that of oil and water. When oil spill conditions occur, the float loses buoyancy, sinking in the higher level of oil until it seats itself on the orifice to the discharge outlet.

As the spill conditions are corrected, the float rises and water is allowed to pass through the orifice. If the oily water includes neutral buoyancy material (such as suspended particles) which might interfere with the seating of the float, screening may be installed (see Figure 7-14).

a. Advantages
   - o Smaller catch basins are required since oil can be maintained on property
   - o Relatively inexpensive
   - o Direct acting

b. Disadvantages
   - o Possible clogging
   - o Periodic inspections required

7.8 Equipment Pits: This method of oil retention is less costly than other systems and provides a permanent means of oil containment. The size of the pit surrounding each piece of equipment must be sufficient to contain the spilled oil in the air voids between the aggregate of gravel fill or stone. A gravel gradation with a nominal size of 3/4 inch to 2 inch which results in a void volume between 40 and 45 percent of the pit volume should be used. A more accurate value of the void volume may be obtained from the stone supplier or by estimating the specific gravity of the solid and density of the material and using the formula:

$$\text{Void Volume (porosity), \%} = 1 - \left(\frac{\delta}{62.4 G_{SP}}\right) 100$$

where G_{SP} = specific gravity of the solids (varies from 2.6 to 2.8)

δ = dry density of gravel fill, pounds per cubic foot (varies from 80-110)

For some limestones and sandstones, the G_{SP} and δ values may be lower. The theoretical maximum amount of oil that can be contained in 1 cubic foot or yard of stone is given by the following formula:

$$\text{Oil, Volume, gallons} = \frac{\text{void volume, \%}}{100 \times .1337 \text{ cu. ft.}}$$

where 1 gallon = .1337 cu. ft.

In the case of the 3/4 inch gravel, the estimated volume of gravel needed for a 40 percent void volume of stone to contain the oil from a 1,000 gallon transformer is:

$$\frac{40}{100 \times .1337} = 3.0 \text{ gallons/cu. ft}$$

and

$$\frac{1000 \text{ gallons}}{3.0} = 334 \text{ cu. ft. of gravel fill}$$

This indicates that approximately 12.4 cubic yards of gravel fill is required in order to properly contain the entire volume of oil contained in a 1,000 gallon transformer.

If the pits are not to be automatically drained of rain water (see "Oil Containment Pits"), then an additional allowance must be made for precipitation. The additional space required will depend on the precipitation for that area and the frequency at which the facility is periodically inspected. It is generally recommended that the pits have sufficient space to contain the amount of rainfall for this period plus a 20 percent safety margin. Appendix B should be consulted in determining the normal precipitation for any particular area.

For instance, if the above Galveston, Texas, transformer facility is to be inspected monthly, and if the overall dimensions of the pit and transformer foundation are not to exceed 12 by 10 feet, then the additional precipitation allowance can be calculated as follows:

Max. Monthly Precipitation (Appendix B, Page F-5) = 5.6 in.

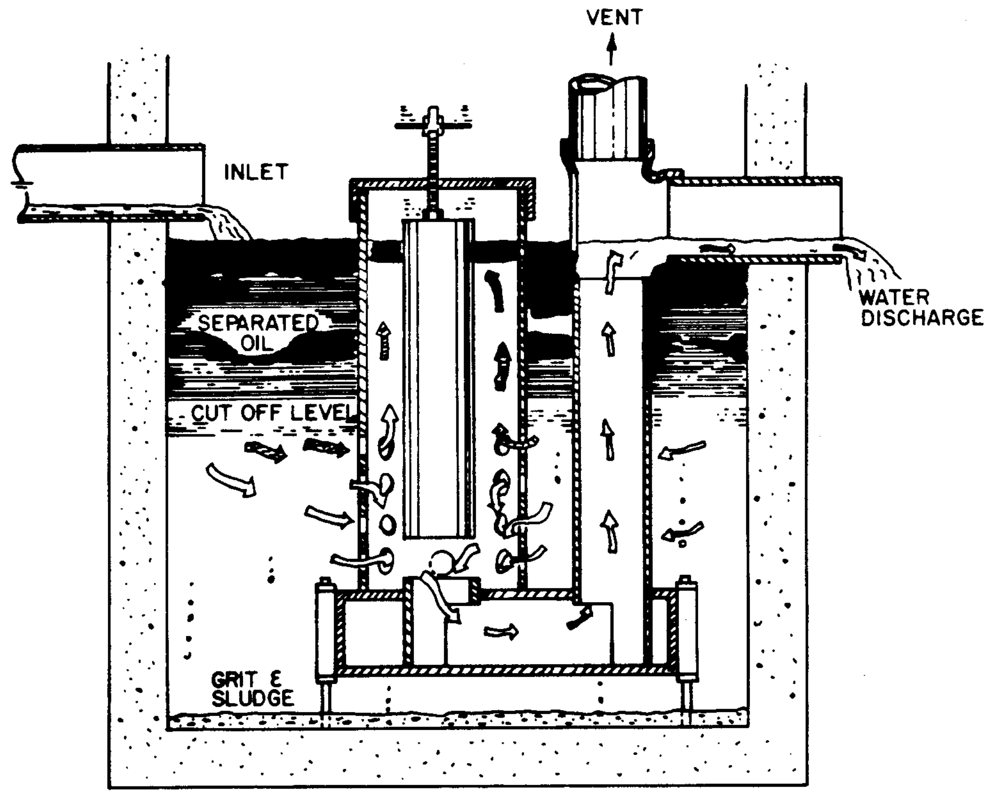
Volume of precipitation = 144 x 120 x 5.6 = 96,768 cu. in.

Vol. of precipitation plus heavy rain allowance = 96,768 x 1.20
= 116,121 cu. in.
= 67.2 cu. ft.

The volume of stone needed to contain 67.2 cubic feet of water assuming 40 percent void volume is:

$$\frac{67.2}{.4} = 168 \text{ cu. ft.} = 6.2 \text{ cu. yd. of stone}$$

OIL STOP VALVE



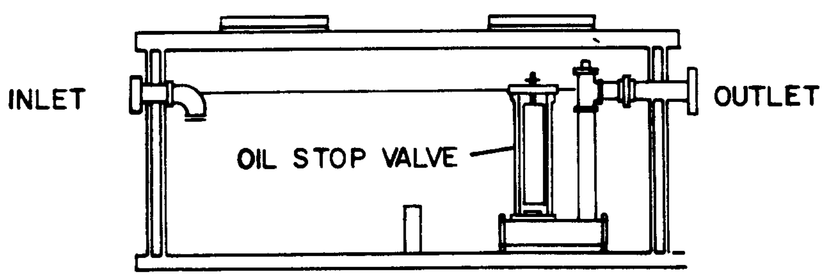


Figure 7-14: Oil Stop Valve Installation

Therefore, the approximate volume of stone needed to contain 1,000 gallons of transformer oil in a manual drain pit is 18.6 cu. yards (12.4 + 6.2).

The area directly surrounding the pit must be graded to slope away from the pit to avoid filling the pit with water in times of rain.

7.9 <u>Oil Containment Pits</u>: The most reliable but most expensive methods of preventing and insuring that oil will be contained on the substation property is to place all major substation equipment on or in containment pits. These pits will confine the spilled oil to relatively small areas which in most cases will greatly reduce the cleanup costs. Figure 7-15 illustrates one method of pit construction which allows the equipment to be installed partially below ground. The sump pump can be manually operated during periods of heavy rain or automatically operated. If automatic operation is preferred, special precautions must be included to insure that oil is not pumped from the pits. This can be accomplished with either an oil sensing probe (see Figures 7-16, 7-17 and 7-18), or by having all major equipment provided with oil limit switches (an option available from equipment suppliers). These limit switches are located just below the minimum top oil line in the equipment and will open when the oil level drops below this point.

Above grade pits and/or berms as shown in Figures 7-19 and 7-20, have maintenance disadvantages but can be constructed relatively easily after the equipment is in place at new and existing electrical facilities. These pits may be emptied manually by gate valves or pumps depending on the facility terrain and layout, or automatically implemented by the use of equipment oil limit switches and dc operated valves or sump pumps. The dc valve operation (Figure 7-21) allows surface water to normally run from the pit and closes when the oil level drops within the protected device.

Another method of pit construction is shown in Figures 7-22, 7-23, 7-24, and 7-25. This method allows the electrical equipment to be at the same elevation as the other adjacent equipment. This retention system is more costly than the above system since the foundations are larger, but allows access to the equipment even after the spill has occurred. The pit in this installation must be sized to contain the total amount of equipment oil in the voids between the stones (as discussed under the "equipment pits" section). This system should also be provided with a sump pump similar to the previously described system.

a. Advantages
- Limits possible damage to adjacent equipment
- Minimizes cleanup costs
- Requires minimum amount of land
- Below grade pits provide noise abatement

b. Disadvantages
- Expensive
- Requires periodic maintenance
- Requires energy to operate
- May require higher adjacent conductor supporting structure to maintain electrical vertical clearances

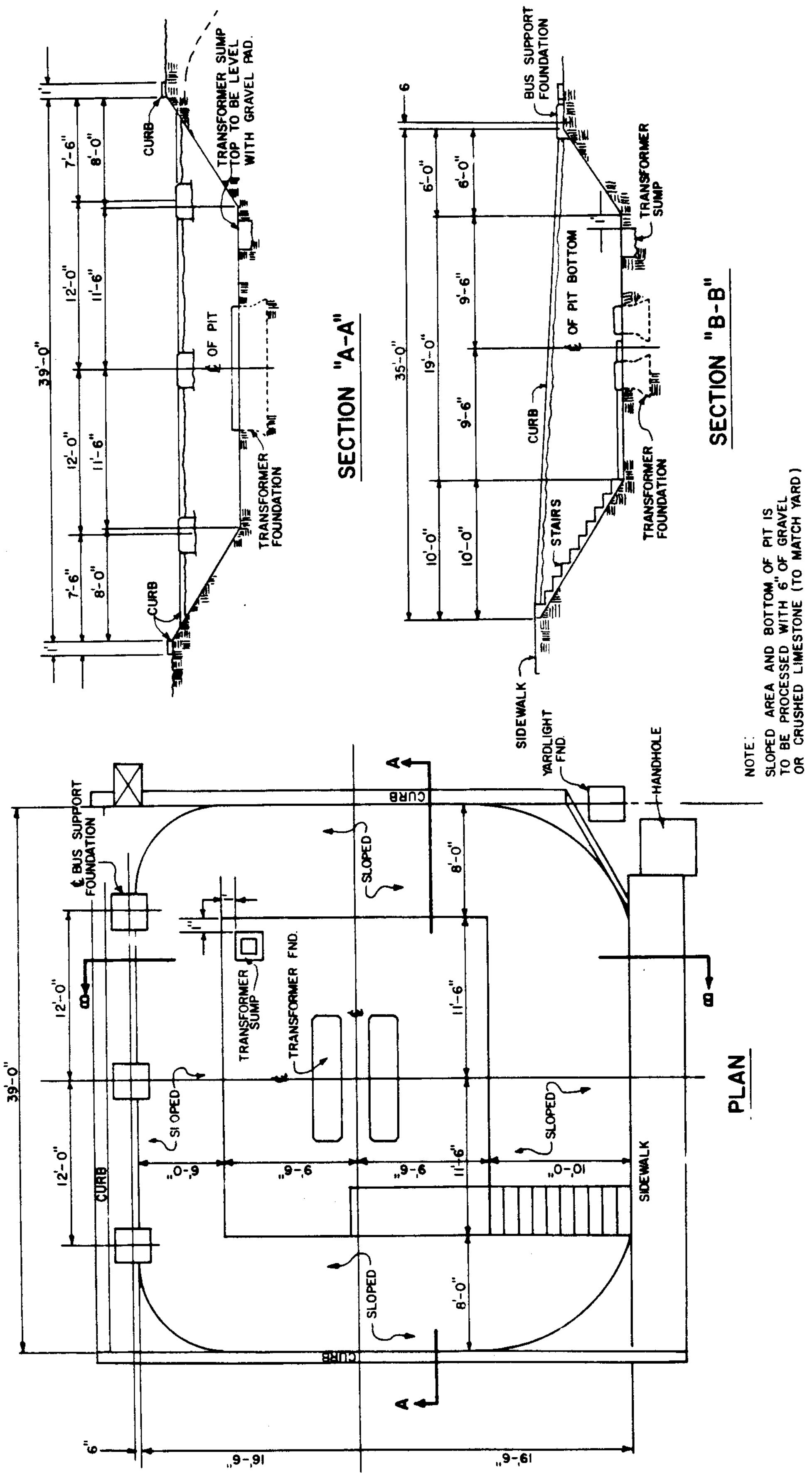


Figure 7-15: Below Grade Pit Construction

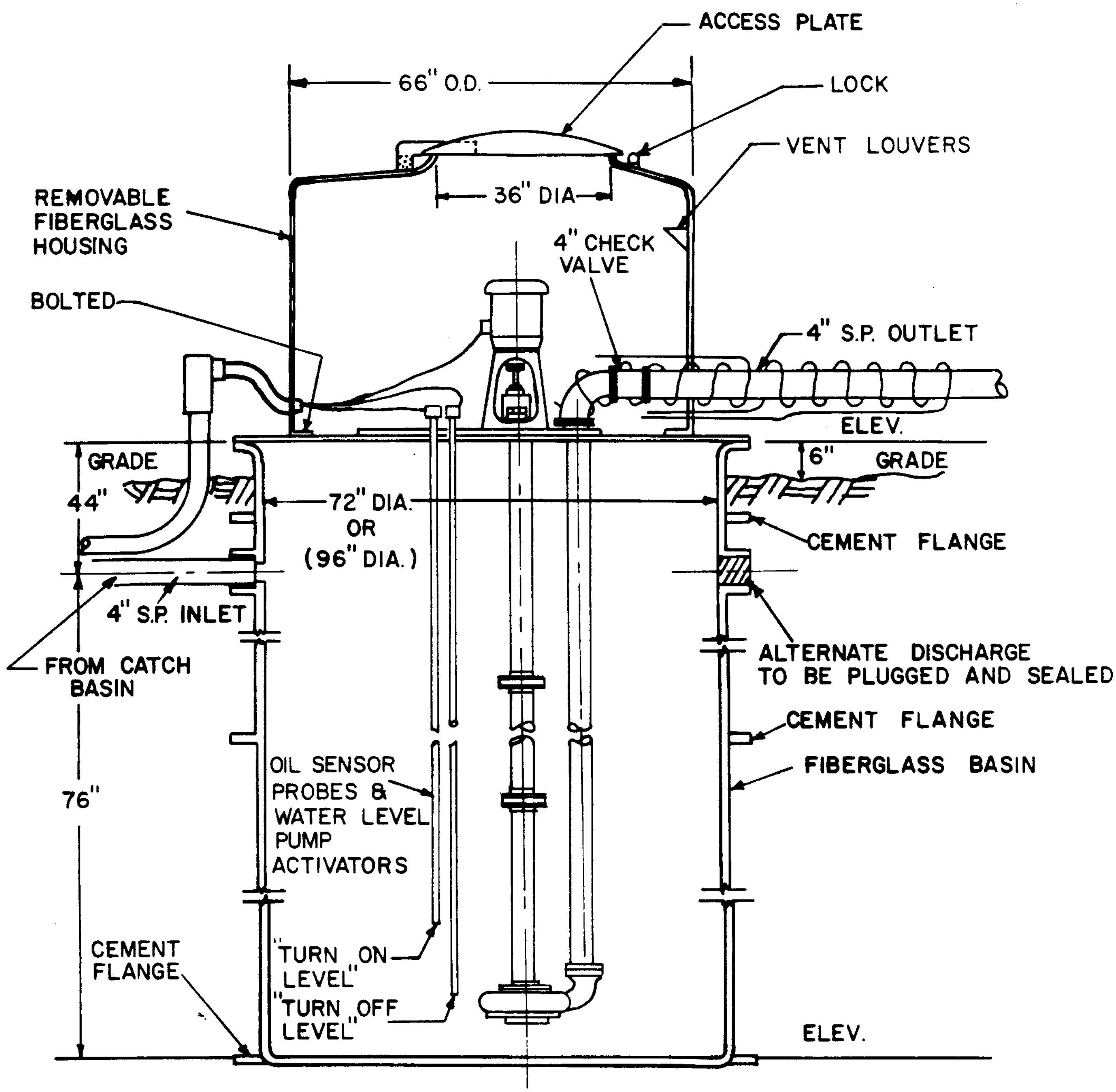


Figure 7-16: Above Grade Sump Pump Discharge

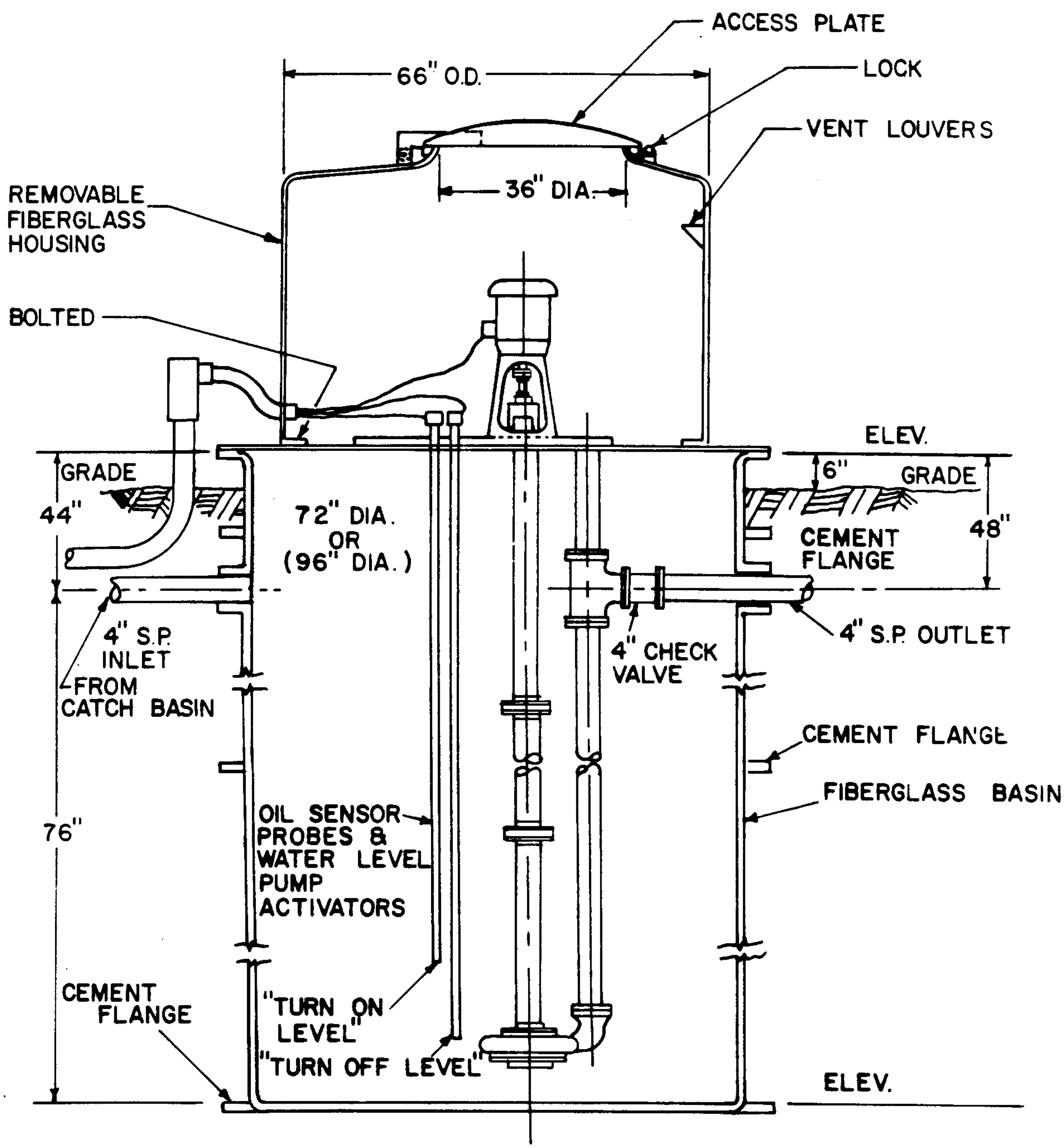


Figure 7-17: Below Grade Sump Pump Discharge

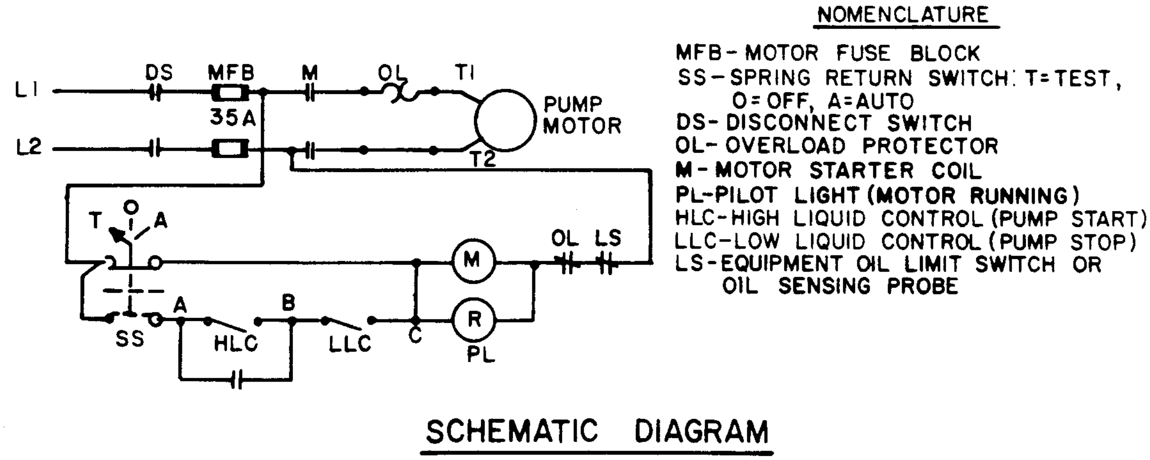


Figure 7-18: Schematic Diagram of Sump Pump Control Using Equipment Oil Limit Switch or Oil Sensing Probe

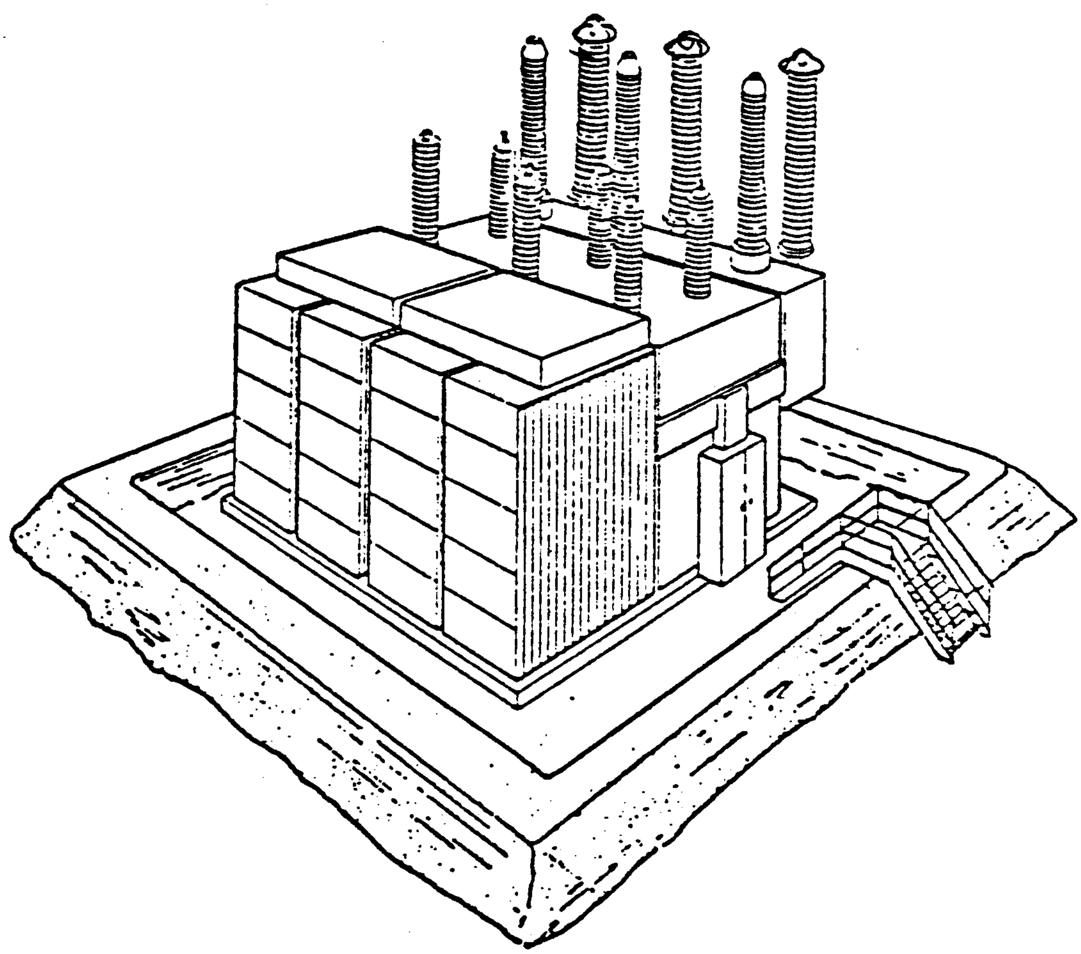


Figure 7-19: Transformer Dike

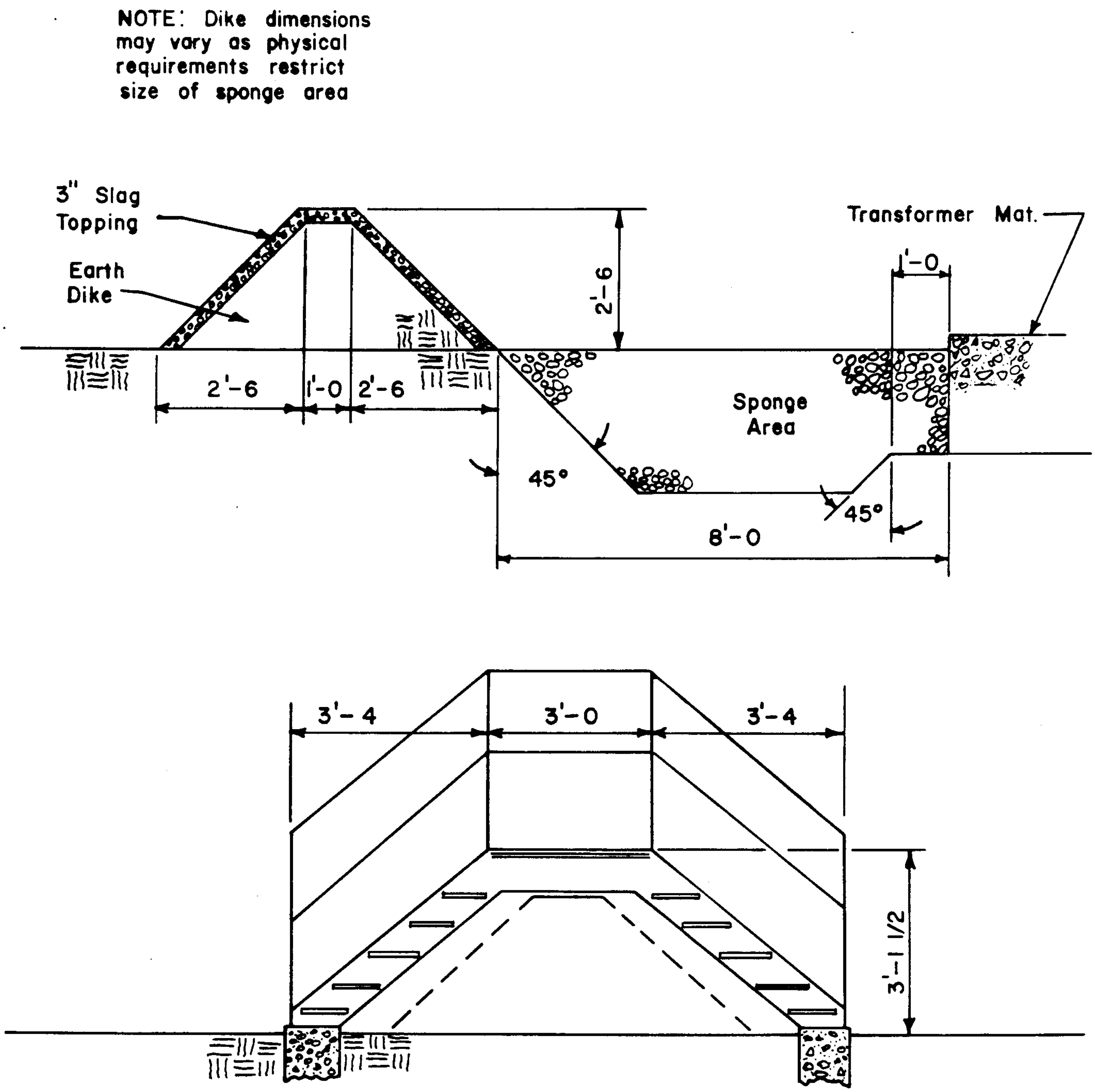


Figure 7-20: Dike, Sponge Area, and Stile Details

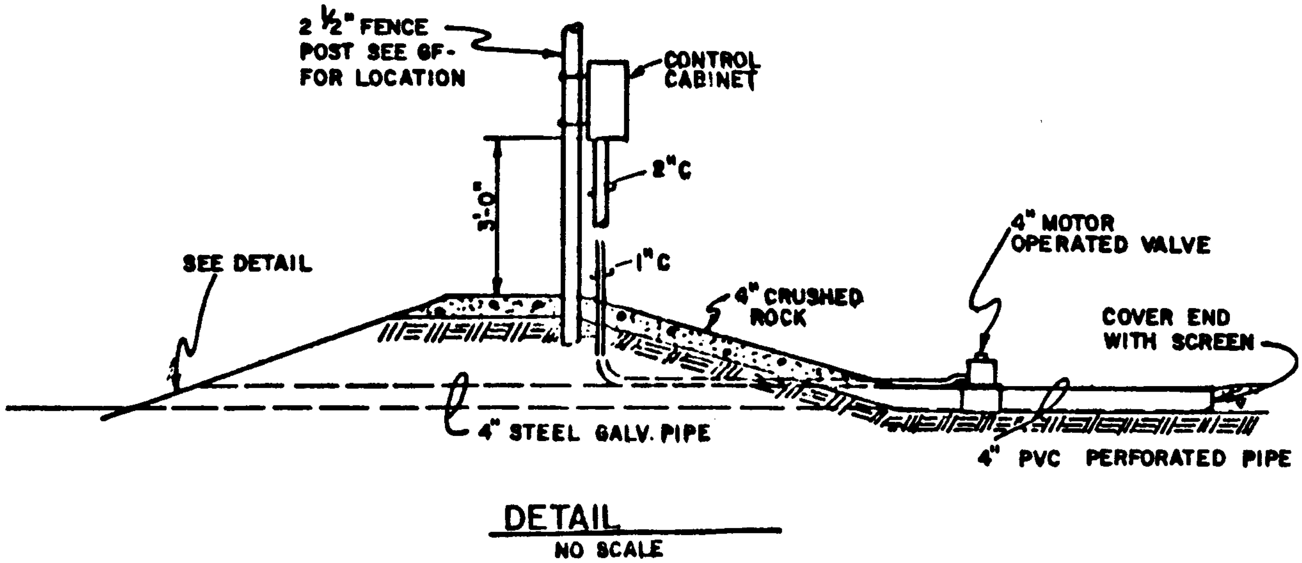


Figure 7-21: Typical Berm Discharge Using Oil Sensing Probe

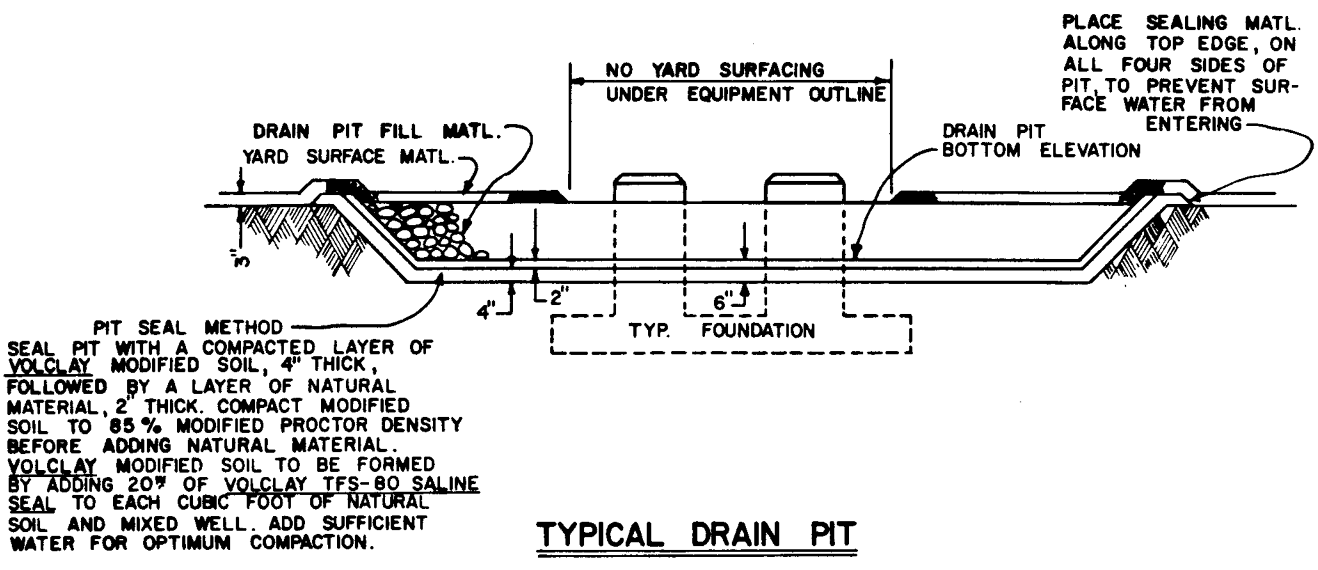


Figure 7-22: Typical Drain Pit

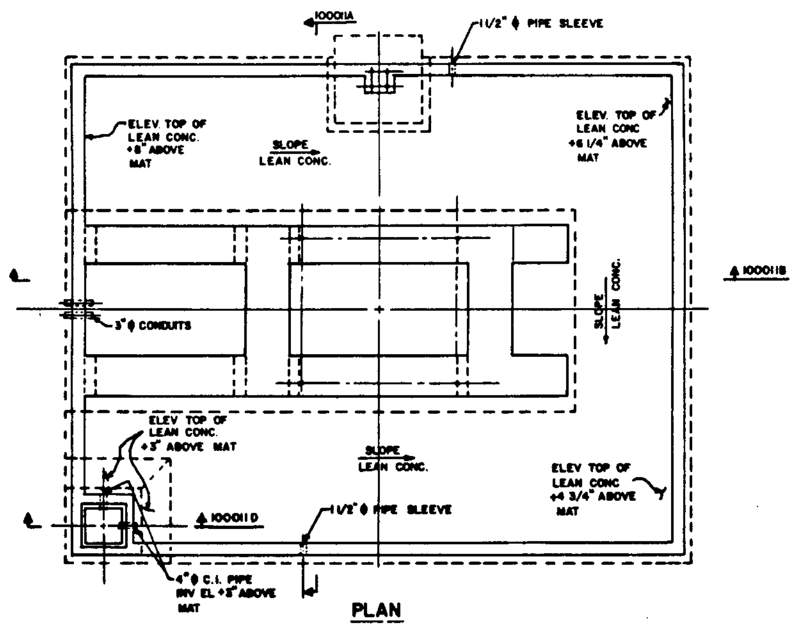


Figure 7-23: Plan View of Equipment Pit

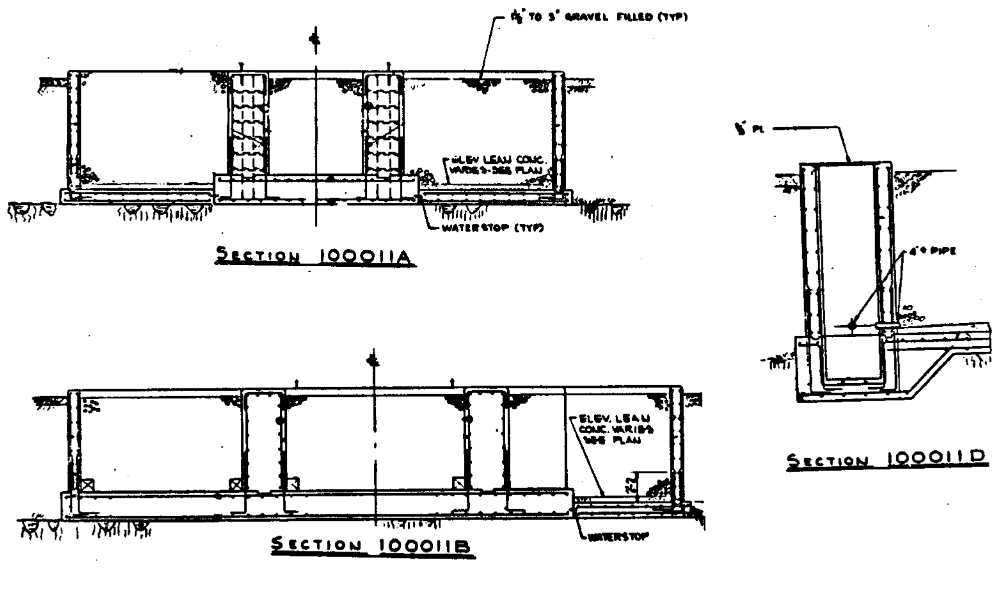


Figure 7-24: Details of Equipment Pit

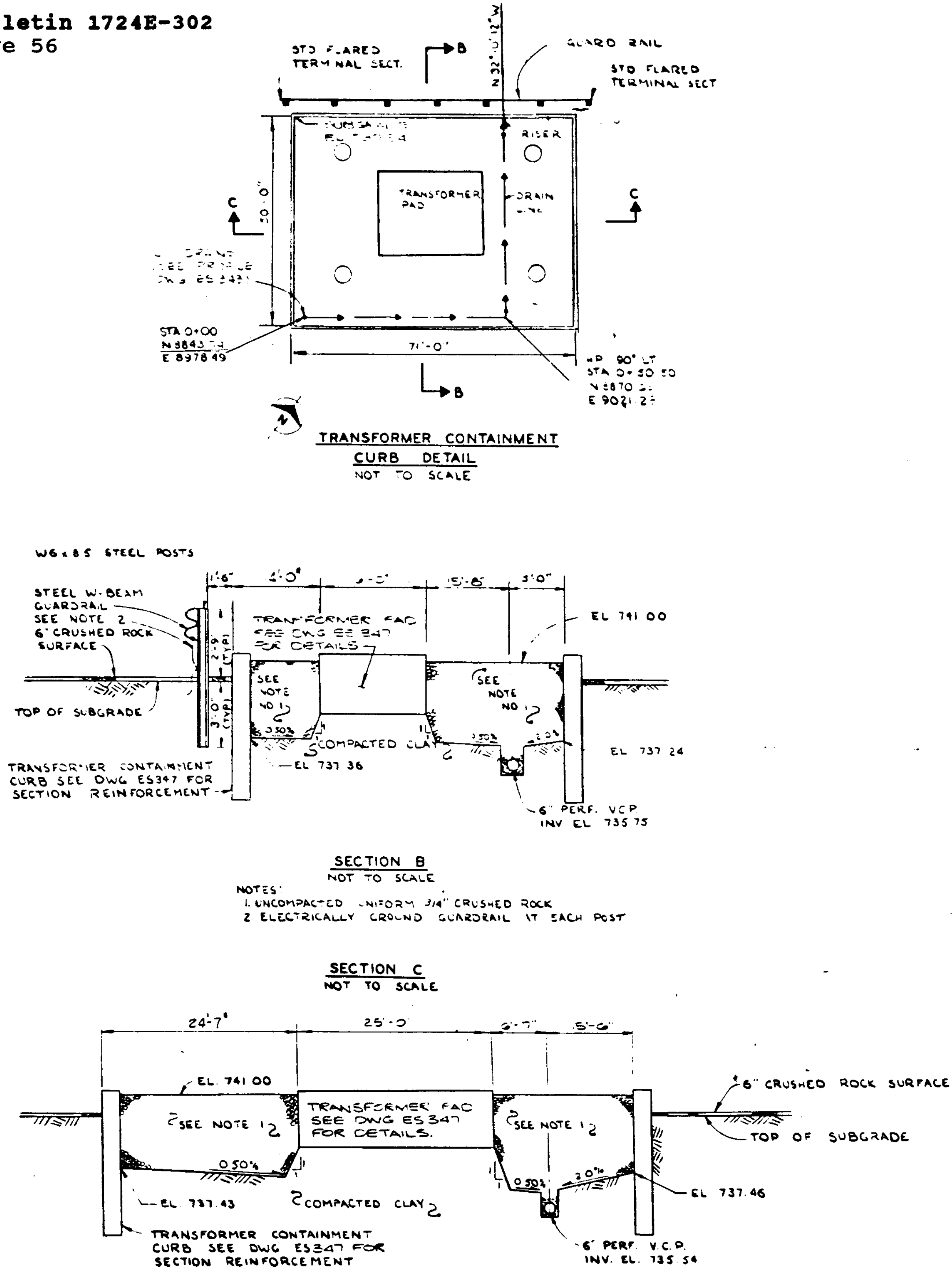


Figure 7-25: Typical Drain Pit

CHAPTER VIII
OIL CONTAINMENT

8.0 GENERAL: Containment is perhaps the most important act in the removal of an oil spill, as it is used to prevent the spread of the oil, and thus minimizes environmental damage. Successful containment is highly dependent upon response time which in turn is dependent upon many variables. Some are "permanent" variables: geographic features which limit access to a spill, equipment design and availability limitations, and personnel capability. Other factors affecting response time will change with each spill: time of notification, size of spill, physical and chemical properties of the spilled oil, and climatic conditions at the time of the spill.

When designing a containment system for a given area, the exposure to spills needs to be considered first, followed by the "permanent" variables (above). This review should narrow the choice of equipment to that best suited to meet a particular area's limitations. To a certain extent, personnel capability can be improved, and the other spill variables can be anticipated through training in spill drills at various times of the year.

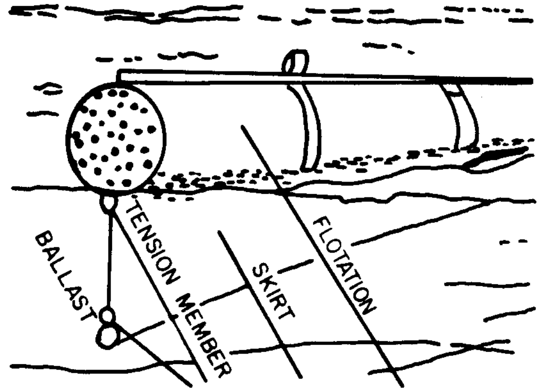
This section deals with the principal methods or systems used to contain a spill on inland or coastal waters.

8.1 Booms: An oil boom is a man-made unit placed on water to serve as a barrier to the movement of oil across a designated plane. There are many different types, shapes and sizes of booms now being used and research continues to improve their use and performance. A boom basically traps floatables at the surface while at the same time permitting the flow of water under the debris-formed dam. These five components, shown in Figure 8-1, should be considered when selecting a boom that is used for oil spill containment or to direct flow:

- Float
- Skirt
- Tension member
- Ballast or weighting member
- Coupling

Figure 8-1:

The Main Components of a Boom



8.1.1 **__Floats__:** The principle component of all booms is a floatation device which keeps the unit afloat and in many instances acts as a barrier in conjunction with the skirt. Floats vary in size and shape depending on use and need. Some circular floats are as small as 3 inches in diameter and range upward to more than 3 feet in diameter. Booms are manufactured with detachable floats, air inflatable floats, or inseam floats.

The type and shape of the float are major factors in the selection of a boom, as they will determine whether the boom can or cannot be stored on a reel. Some floats will cause a storage problem due to bulk and/or the need to accordian the floats because of their rigidity. Another problem with some floats is their erratic behavior when deployed and towed at moderate speeds. The type and shape of float will also determine the ease in transport and recovery.

Floats that are porous will absorb a medium to light weight oil, making the cleaning of the boom after use more difficult. These types of floats can be protected with a vinyl cover and/or sealed by a paint or other compound that can be cleaned much more readily.

For noninflatable floats, polyethylene form is generally used as the float material.

Air or gas-inflated float booms are more durable, but more expensive than the plastic float types. The inflated type float provides maximum buoyancy and, when collapsed, is more easily handled and stored.

Although carbon dioxide gas from pressurized cylinders can be used for inflation, a more common method is the use of compressed air, requiring engine-driven compressors. Disadvantages of inflatable floatation range from possible escape of gas or air from leaks, ruptures, and/or possible poor heat seals.

Other types of boom floatation have been used but are generally associated with local improvisation and ingenuity. For example, logs have been joined together with cables to form a barrier. Booms can also be built from sealed metal drums joined to plywood sheets using steel cables. These booms tend to be very awkward to handle and deploy, thus they are not generally recommended except during emergencies.

8.1.2 **__Skirts__:** The primary purpose of a skirt is to serve as a dam or barrier with the float during containment. The skirt often extends above the water becoming part of the float section thereby sealing the section between floats. Skirt characteristics which should be considered when selecting a boom are:

a. Fabric: Some booms have a plastic skirt, some a rubberized or neoprene covered laminated material most use a vinyl-coated nylon or polyester fabric. This light fabric will permit a more collapsible skirt, while a heavy fabric will tend to stiffen the vertical plane. Usually the heavier the fabric, the more ballast or weighting material that can be added. The fabric should always be cleaned and rinsed after each use. Storage of the boom usually requires it to be folded between floats. This bending and unbending requires a flexible material to prevent damage to the boom.

b. Depth: The skirt acts as a fin when being towed and as a barrier when placed in position. Therefore, specifying the depth of the skirt of that part which is to be submerged is an important decision to make in selecting a boom. If the boom is to be towed great distances and at moderate speeds, then a shallow skirt is more desirable. A longer or deeper skirt will contain a greater amount of floatables. However, deeper skirts will have more pressure exerted on them by currents or tides and therefore will be more difficult to deploy and control. A skirt of less than 6 inches is considered impractical except for special uses.

c. Tensile Strength: The horizontal tensile strength of the skirt (the ability to withstand pulling pressure) is limited so care should be exercised not to exceed this strength unless the boom is reinforced with additional tensile strength members.

d. Flexibility: A collapsible or flexible skirt fill permit the boom to seal off a spill in very shallow waters and across a sloping beach or shoreline. A rigid or vertical skirt will lie down and permit the spill to escape.

8.1.3 __The Tension Member__: This member determines the deployable length of a boom. The function of this member is to evenly distribute the horizontal load that may be imposed on it from currents and wind conditions. Dacron straps, steel cables, and chains are those materials more commonly used as tensile members (see Figure 8-2).

8.1.4 __The Ballast Member__: Most oil booms have a ballast or weighting member along the bottom edge of the skirt. When a boom is deployed, the ballast keeps the skirt in a more vertical position, permitting it to act as the required barrier. A more vertical skirt is also more easily towed and positioned. An unweighted skirt will readily plane in very low currents. Ballast weight will vary depending upon water currents where the boom is used and upon how the boom is used. The deeper the skirt and the higher the current, the more ballast that is needed.

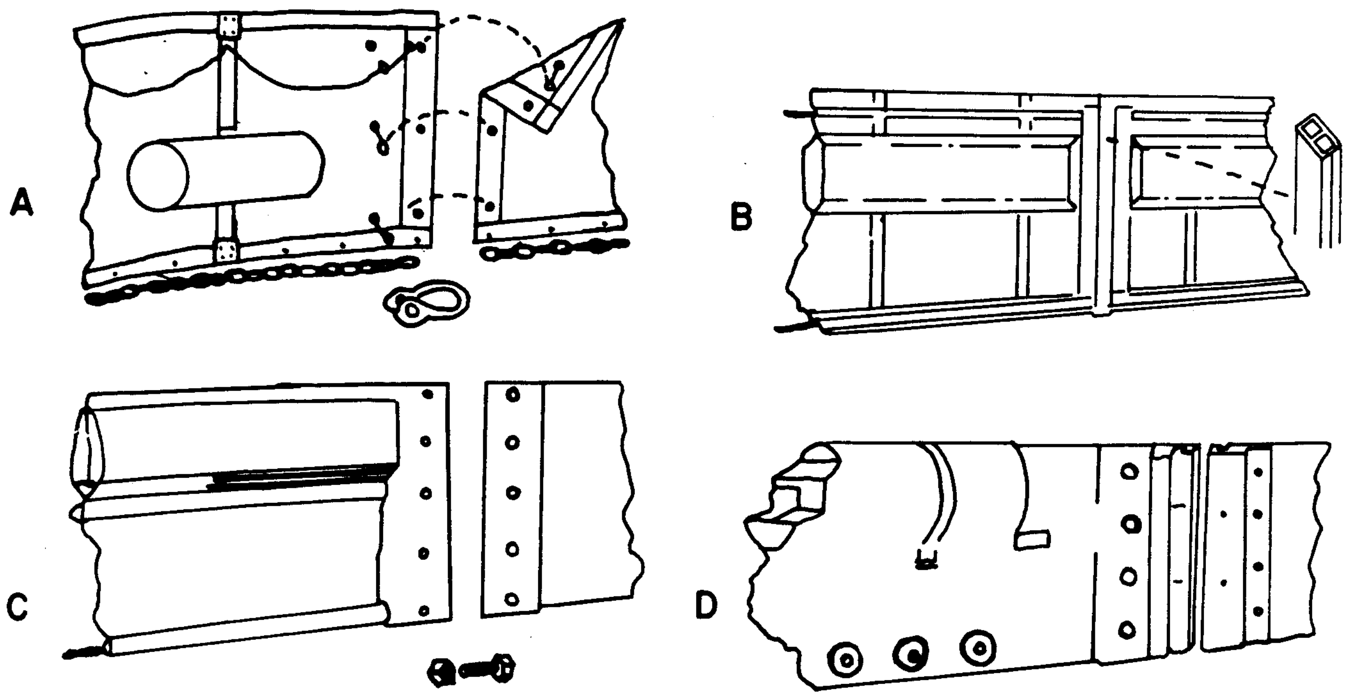


Figure 8-2: Boom Tension Members: A) Bottom Chain, B) Inseam Cable, C) Dacron Straps, D) External Cable

Ballast need not be a completely fixed part of the boom, but can be attached in several ways. On some booms, ballast can be added to grommets in the skirt or to the chain or cable at the base of the skirt. In some cases, the chain or cable serves the dual purpose of ballast as well as tension member and as such, it must be free for the full length of the section. Ballast should be attached to the boom with minimum looseness to prevent wear and tear of the skirt material or holding straps during handling.

8.1.5 __Couplings__**:** Usually booms can be selected in 50, 100, and 200 foot sections. Some air inflatable booms can be purchased in sections up to 1600 feet.

When shorter sections are purchased, the coupling for those sections should be considered. A coupling that can quickly and effectively unite two boom sections could be one of the most important factors in determining response time. Nonfitting couplings, or those requiring off-site adjustments, can and will cause delays, possible leaks at the union and in certain cases even rejection of the entire section (see Figure 8-3).

Unfortunately, there is no standard boom coupling. Some manufacturers have standardized specific boom sizes and couplings so that a deployed boom may contain sections manufactured by several companies.

Nearly all couplings are rigid, extending from near the top of the float to the base of the skirt. A coupling will cause the union section to be rigid. As a result a collapsible skirt with a coupling is not effective in waters shallower than the skirt length. Proper care of the coupling unit is essential as a bent or corroded bolt section may require that the section be discarded.

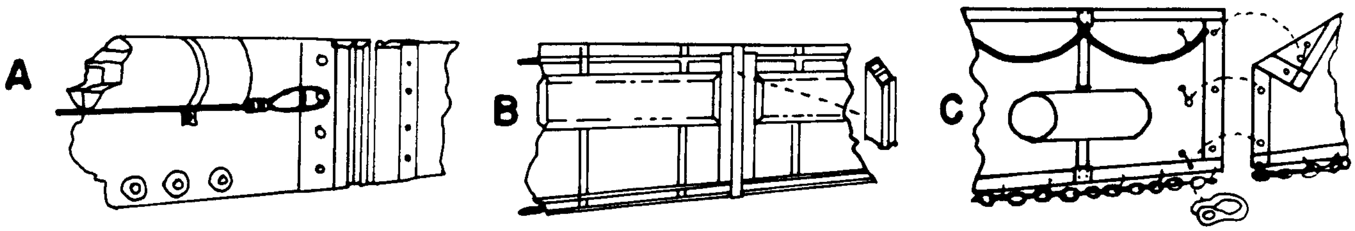


Figure 8-3: Boom Couplings: A) Metal Interlock (Slickbar), B) PVC Joint, C) Bolted Overlap

The five principle components of a boom have been reviewed but these other factors should be considered when selecting a boom design.

8.1.6.1 Length: Boom manufacturers usually carry a limited number of standard sections requiring the purchaser to specify not only the type but also the section lengths. Lengths other than standard are usually more costly. Standard lengths vary between manufacturers but are mostly in the 40, 50, and 100 foot range.

8.1.6.2 Factors Affecting Deployment: Deploying a boom on perfectly still water (say on an enclosed swimming pool) is simple. However, the actual deployment of booms to serve as barriers to floating oil is more complex due to many natural variables. Some of these variables include: water pollution, current, wind, physical and chemical properties of the oil, water and air temperatures, water depth, accessibility to the spill site, source and magnitude of the spill and finally, the type, size, and length of boom available.

8.1.6.3 Current: Floating oil will move in the same general direction and at nearly the same speed as the carrying body of water unless there are offsetting forces such as wind and/or deflecting objects in the path of the current. Any barrier, such as a boom, placed directly across the flow will be exposed to maximum forces on the skirt (that part below the surface). This load can be great enough to sever the tensile members. The current load may also exceed the vertical load applied by the ballast of the boom, resulting in "planing" of the skirt which will release any trapped oil. See Figure 8-4.

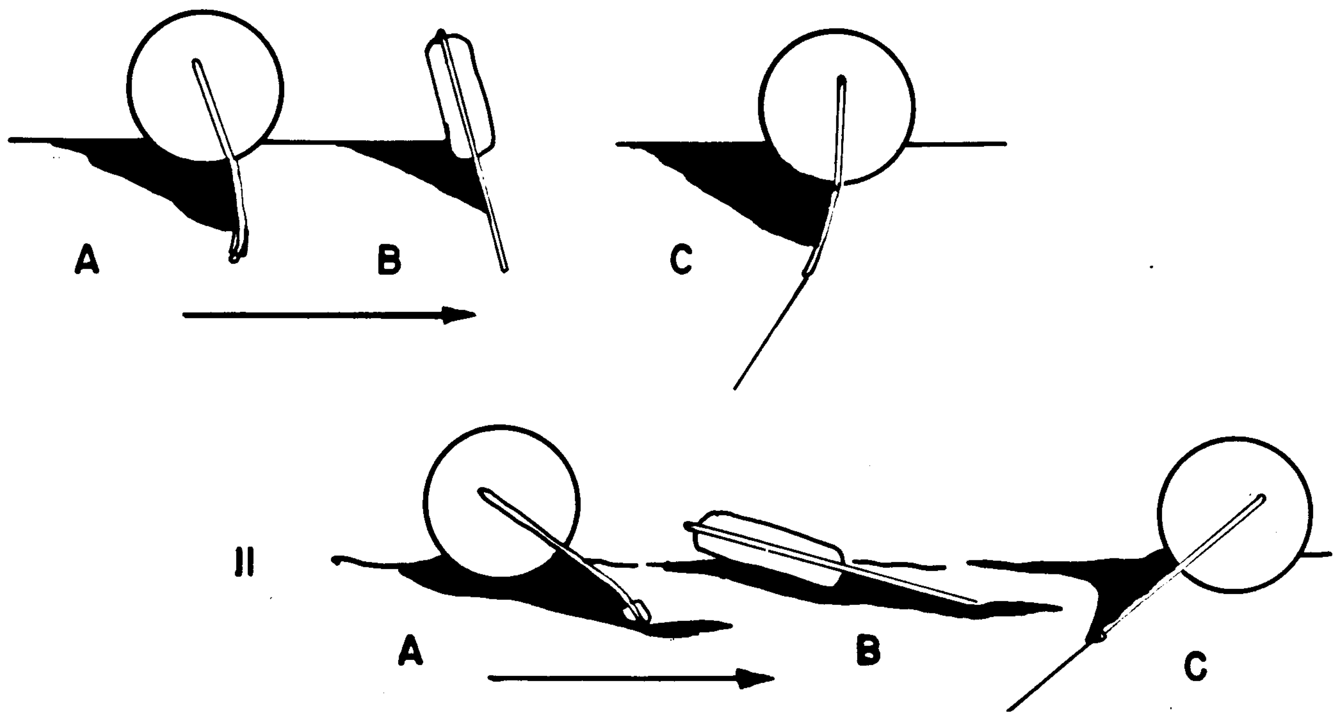


Figure 8-4: Boom "Planing" in Current. I. In Low Current Situation, Oil is Held by Each Boom Type, A) Weighted Flexible Skirt, B) Rigid Skirt, and C) Bottom Tension. II. In a High Current, the Flexible Skirt, A) Experiences Partial Failure, the Rigid Skirt, B) is Planing with Current, with Almost Total Failure, While the Bottom-Tension C) is Still Holding Most of the Oil. (NOTE: This does not consider escape by entrainment. See below).

The current forces against a deployed boom can be calculated by the following formula:

$$F = .92 D_W V^2{}_W$$

where:

F = Forces, #/lin. ft.
Dw = Depth of skirt, vertical feet into water
Vw = Velocity of water, ft./sec.

In using this formula be sure to consider the following:

- o True depth of skirt. If the current forces are great enough to cause some planing, the true vertical depth will be less than the actual length of the skirt.

- o Average water velocity. Measure the water velocity at several points near the surface and at the bottom of skirt depth and then average. These velocities can vary markedly.

Note: Winds will also affect the direction and rate of movement for oil floating on water; both forces must be considered when deploying a boom. See the variable "Wind".

Spills in high current waters present difficult control problems requiring specialized directional boom equipment which needs to direct the oil to the more quiet waters near shore where it may be more easily removed. This directional boom must be long enough to reach well out into the river, which increases the load on the boom, requiring great tensile strength. It is likely that some of the oil will escape the first boom making deployment of a second boom in a downstream location necessary.

Many times the currents along the banks will be deflected by submerged objects resulting in eddy currents. This may even move water near the bank in an opposite direction to the flow in the center of the stream or channel. This reverse flow will naturally influence the trapping capability of a deployed boom.

8.1.6.4 Wind: The forces exerted by wind play a major role in oil spill containment. Factors which affect wind-moved oil on water include water current, the physical properties of the oil, and the spill size. Generally, wind will move most oil over water at a rate of 3 percent of the wind velocity, i.e., with a 33 mile per hour wind and no current, the floating oil can be expected to move with the wind at a speed of approximately 1 mile per hour. This may not seem much, but it amounts to 880 feet in 10 minutes. Thus, wind-driven oil requires a prompt response with a quickly deployable boom. Figure 8-5 shows some of the possible effects that wind may have on the movement of oil.

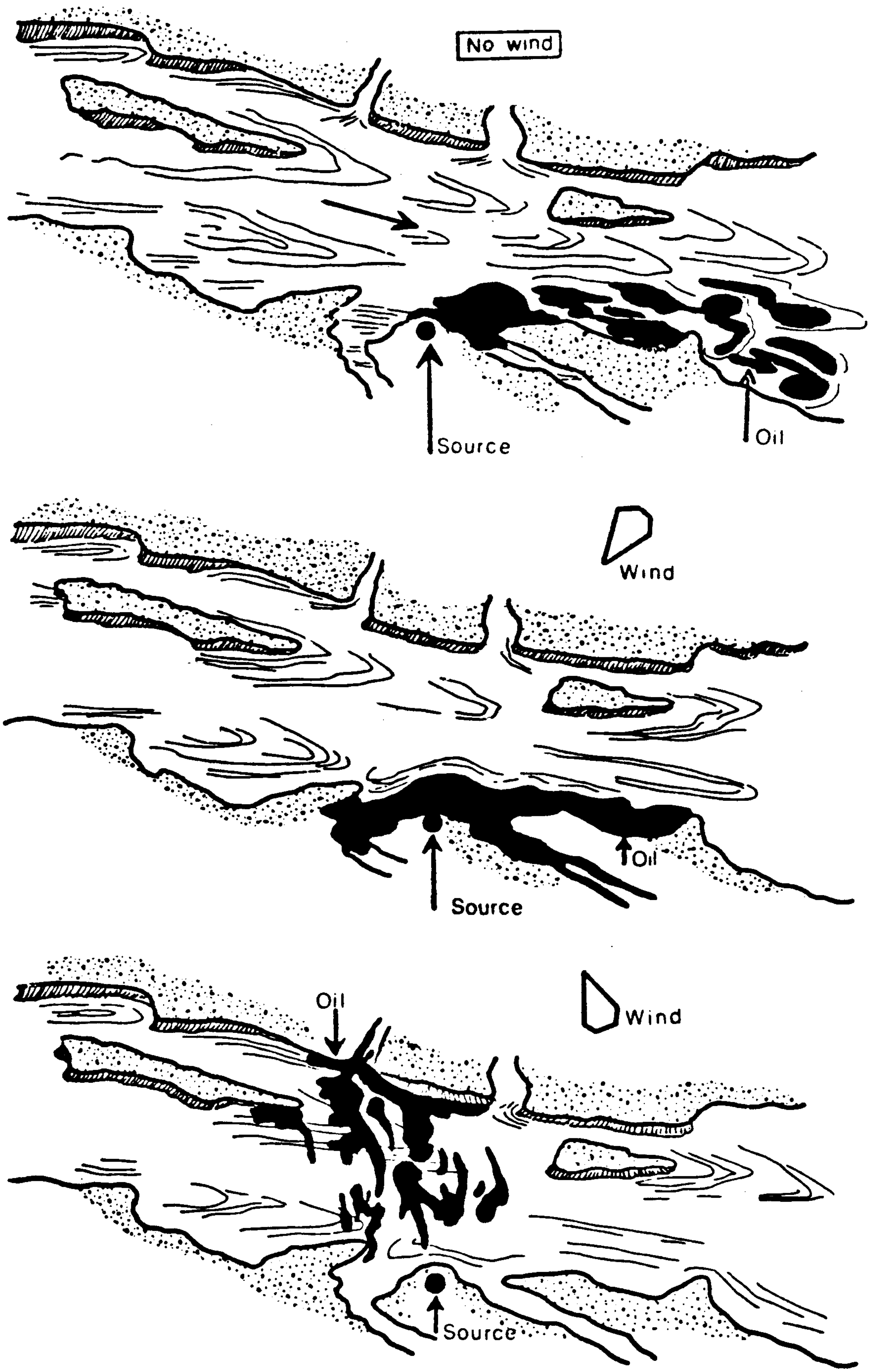
Wind will also exert a substantial force against the float or sail portion of a deployed boom. These forces should be considered when selecting a boom for deployment. They can be calculated as follows:

$$F^W = .00339 V^{W2} H$$

where:

F^W = Force exerted against float, #/lin. ft.
V^W = Wind Velocity, knots
H = Height of float above water, ft.

Winds create waves and chop which greatly affect the efficiency of oil booms. Most booms used in coastal areas will contour well to waves where the length to height ratio is about 8:1. Boom performance will deteriorate as this ratio lessens. Rollover of rigid booms and submergence are common experiences when deploying a boom in windy and choppy waters.


No wind
Source
Oil
Wind
Oil
Source
Oil
Wind
Source

When wind and current are working together, the total load on a deployed boom will be the sum of the two forces. Tangential forces can be compensated for by applying the proper factor depending upon the angles involved.

A floating barrier deployed across a moving body of water to trap floating oil experiences a well-known behavior--submerged escape. A skirted boom acts much like a dam and assumes a natural catenary configuration. Floating oil will then accumulate at the turbulent base of the catenary. If the current is at or below 0.7 knots, oil will begin appearing downstream and eventually all of the trapped oil may escape.

A deployed barrier or dam interferes with the flow of surface waters down to the depth of the boom skirt. To escape this trap, the surface water must increase its velocity and travel under the skirt. As the velocity of the surface water increases in its downward plunge, the floating oil travels with this water under the boom. The greater the stream or tidal current, the more turbulence occurs and the more trapped oil will escape. Currents which do not exceed 0.7 knots usually do not cause oil loss under the boom. This is probably because the downward forces are not great enough to affect the gravitational differences between the water and lighter oil.

In streams, rivers, or channels with current velocities of 2 knots or more, spilled oil will usually accumulate in the more quiet bends of the water channels or along the more shallow and less rapid waters near the banks. This greatly aids the cleanup insofar as selecting where to deploy a boom to best trap the floating and moving oil. See Figure 8-6.

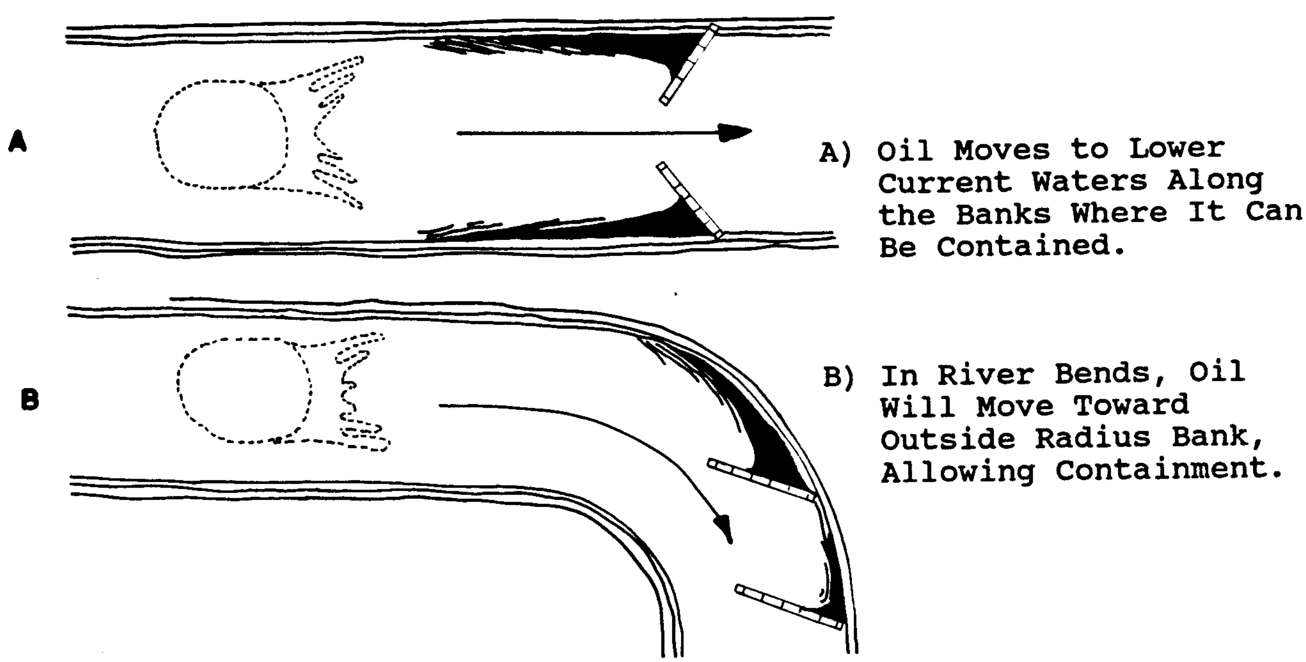


Figure 8-6: Action of Spilled Oil in Fast Current Rivers

A wind-moved oil spill will finger disperse more readily than a current-moved spill. The wind will tend to push only the surface of the oil spill and not the entire mass while a current will carry the entire spill along with it. Where differing oil thickness exists, the difference between the surface tension of the water and the oil then plays a significant role in the amount of fingering.

Wind can be a valuable tool to the cleanup contractor if used properly. Its force on floating oil is usually positive with reasonably predictable results. Using a boom to guide or direct the wind or current-moved oil to a pickup center is most effective, quick, and inexpensive. However, cross-wind or cross-current deployment of boom or wind will subject a boom to maximum load forces and risk partial to total failure. On the negative side, winds can change direction and speed quickly, drastically adding to the problem of boom selection and deployment.

8.1.6.5 Water Depth: Either a rigid or collapsible skirt boom may be deployed in water that is deeper than the depth of the skirt at all times with allowance being made for tidal differences. However, if one end of a boom needs to be onshore, near shore or where the skirt will be exposed during low tide, then a boom with a collapsible skirt should be used if available. Such a skirt will collapse on the slope of the beach, maintaining a barrier at the water's edge. A rigid skirt will fall flat and permit the trapped oil to escape unless a trench is dug into the beach or bank deep enough to bury part of the boom and keep the oil from escaping. See Figure 8-7.

Deep water can cause problems in anchoring a deployed boom. Properly securing a boom deployed in deep water (more than 40 feet) requires the use of large anchors, with long lengths of rope. These extra requirements increase equipment needs and response time. See Figure 8-8.

8.1.6.6 Accessibility and Response Time: The ideal oil spill incident for the cleanup contractor is the one reacted soon enough to contain the source and prevent spreading. This, of course, requires prompt notification and response. Not many incidents fall into this category.

Usually the call for service is delayed because of darkness, inclement weather or dependence upon practices "as usual". A 30 mile per hour wind can move the spill a distance of 1 mile in 1 hour. Delays in response often are the single most serious cause for any impact an oil spill may have on the environment.

During free movement on water, oil may find its way into the more inaccessible areas, where cleanup is more difficult. Controlling the oil with booms during its movement can prevent this by directing the spill to better recovery areas.

A pipe type cable break will present a major problem as this source is not easily accessible and the spill will continue until the pumping has been stopped and the line has lost its oil, This type of spill can occur anywhere along a cable right-of-way and not be noted until a pressure drop is evident or the actual spill has been reported. Pipe type cable spills can be entirely land-locked, near lakes, creeks or rivers or in the bays and estuaries of a coastal region. A diversity of boom types, lengths, and sizes is needed to cope with these possibilities. Boom selection for this purpose will depend upon exposure.

8.1.6.7 Boom Application: There are two primary methods of developing a boom: stationary, with the boom anchored or held in place; and moving, with the boom moved over the water's surface by vessels, or in certain cases, by wind forces.

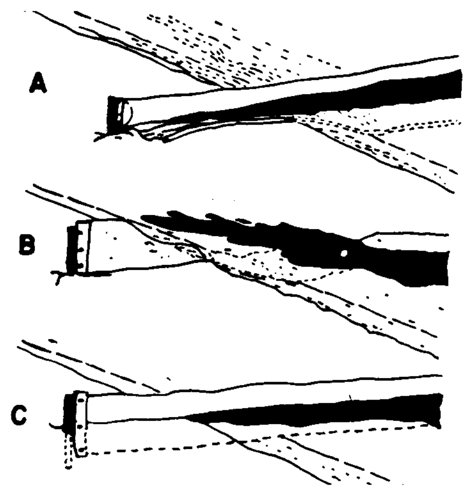


Figure 8-7: Flexible vs. Rigid Skirts. A) A flexible boom skirt will collapse on the beach slope, trapping the spill. B) A rigid-skirt boom will fall over, allowing the oil to escape. C) When a rigid-skirt boom is put into a trench, it can remain vertical and trap the spill.

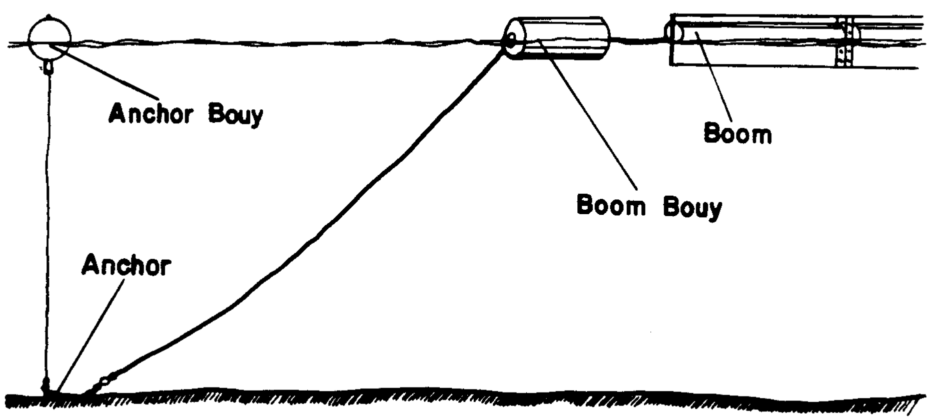


Figure 8-8: Anchoring a Boom in Deep Water. (Not to scale) The length of the line from the boom buoy to the anchor should be at least five times the depth of the water.

The vast majority of spill situations will call for a stationary boom deployment. In certain situations, a moving deployment can provide quicker and easier recovery of spilled oil. However, moving deployment generally requires much more experience in boom and boat handling than stationary deployment. Also, it can more easily end in the loss of trapped oil if diligence and care are not taken during all phases of the operation.

In stationary deployment wind and current act to destroy the effectiveness of the boom. As noted earlier, high winds or currents of 0.7 knots or more will carry oil under a conventional boom. With low current and/or wind velocities, boom deployment directly across (perpendicular to) the flow will contain the spill.

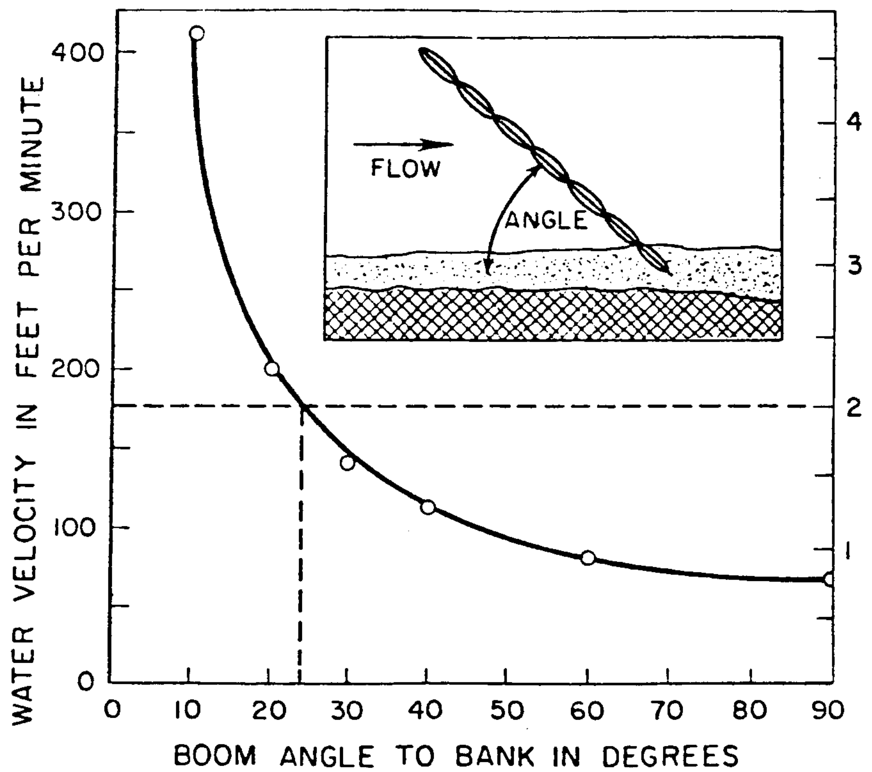


Figure 8-9: Suggested Boom-to-Shoreline Angles for Different Current Velocities. A) With a current of about 0.85 mph, the angle can be 60½. B) A current of 1.5 mph requires a 30½ angle. C) A current of 2.75 mph can be handled with a 15½ angle. When stream current velocity exceeds 3 mph, seek out bends or other places where the current naturally slows down to a more reasonable speed.

To cope with those situations involving water velocities above the magic 0.7 knots, booms can be deployed at an angle to the flow. This type of deployment will reduce the force against the boom, and direct the oil along the side of the boom to a collection point, usually the shoreline but often a floating skimming device.

The smaller the angle between the collection point and the boom, the greater the current toleration. See Figure 8-9.

When a boom is used as a directional device, anchoring along the length of the boom should be avoided whenever possible. Figure 8-10 illustrates some of the problems that can arise in such a situation.

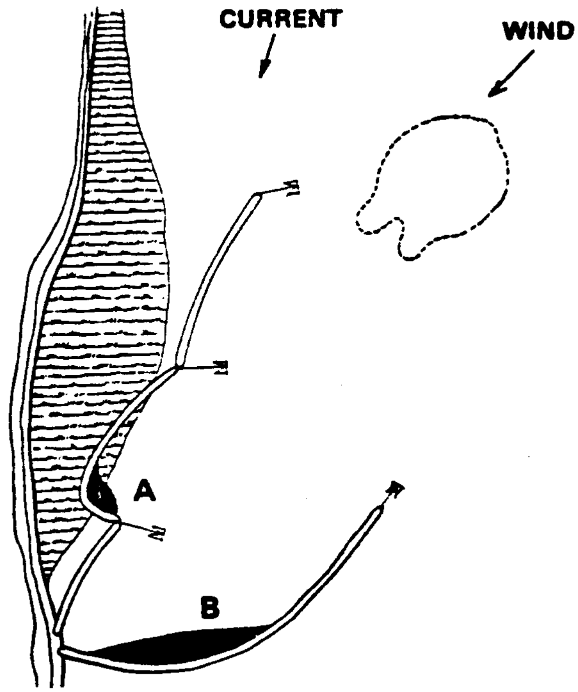


Figure 8-10: Possible Problems Caused by Improper Boom Anchoring. A) If a deflection boom is allowed to form a deep catenary configuration between anchoring points, some of the oil will remain trapped in these pockets.
B) If a containment boom is allowed to form a catenary, the oil will collect in the catenary, rather than move to the shore. In either case, recovery of the oil is much more difficult.

8.1.6.8 Moving Deployment: When the body of water is wide enough or the oil is moving near the center of a stream, moving deployment of a boom directly across the path of the spill can be used to contain it (See Figure 8-11). The boom should be controlled at each end by a vessel which can easily maneuver in the particular waters. The boom should then be allowed to form a deep catenary configuration to trap the oil at the base of the catenary. As the oil reaches the boom, the entire trap and vessels should move downstream (downwind) at near the speed of the current (wind) holding the spilled oil within the catenary arc. Care should be taken not to pull one end against a current as this will cause the skirt of the boom to plane, releasing the trapped oil.

At an opportune time and place, one end of the boom can be moved ahead, carefully maneuvered toward the shoreline and tied. Meanwhile, the other end can be moved somewhat upstream (upwind) from the tied-down end. The oil then is allowed to slide downstream (downwind) along the side of the boom to where it will concentrate and can be removed. A successful operation of this type needs practice and expert boat maneuvering.

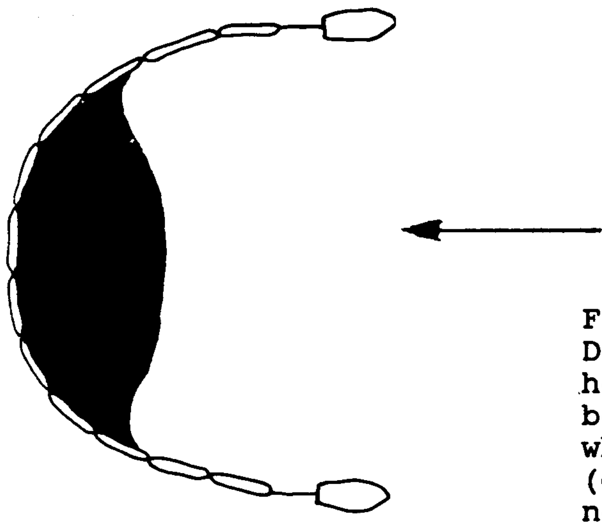


Figure 8-11: Moving Deployment. A boom is held in a catenary between two boats, which move downwind (down current) at or near the speed of the wind (current).

8.1.7 Special Situations: Debris often accompanies floating oil, particularly in streams and rivers, but to some extent in all water courses. This debris can cause removal problems by clogging most recovery devices and/or by absorbing the oil. Large pieces or great amounts of debris can pile up behind a boom, raising the skirt enough to allow the trapped oil to escape, damaging the boom or even breaking it.

When containing a spill in a high debris location, special precautions have to be taken. Double, or even triple booming may be necessary. Alternately, a debris "fence" could be deployed upstream of the containment boom, with a crew stationed to clean off the debris is it piles up.

Since the deployment of a boom is controlled primarily by the direction and speed of current and/or winds, rapidly changing winds or currents (such as ebb and flood tides) will create difficulties in keeping the spilled oil contained.

Knowledge of the behavior of the changing currents and winds peculiar to a specific area is paramount in determining how and where to deploy containment booms. This knowledge can be gained from local experts acquired by trial runs and maintained with periodic drills. To ensure containment, more than one length of boom will need to be deployed. Figure 8-12 illustrates one method to use or consider in such a situation.

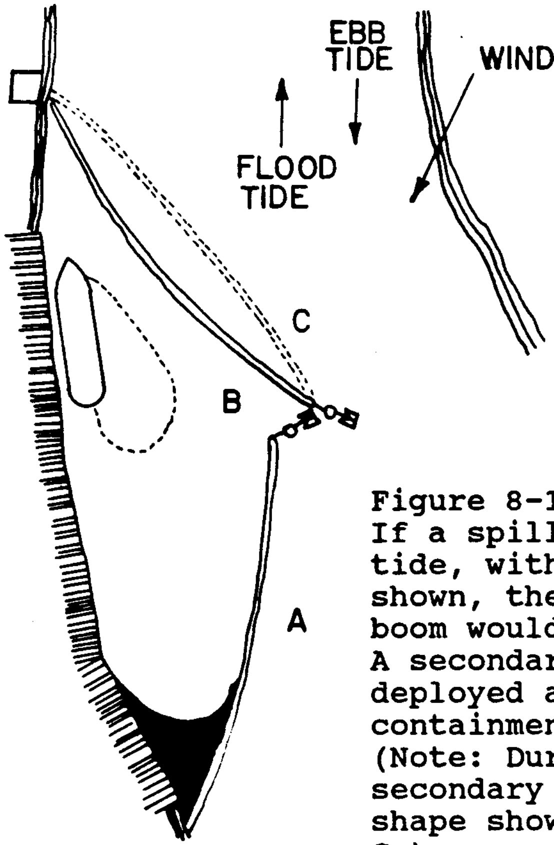
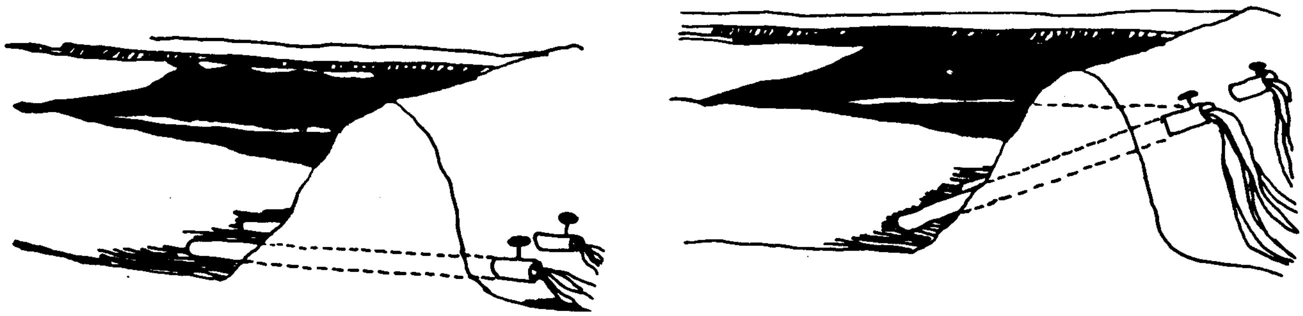


Figure 8-12: Changing Currents. If a spill occurs during ebb tide, with a prevailing wind as shown, the primary containment boom would be deployed at A. A secondary boom would be deployed at B to maintain containment during flood tide. (Note: During flood tide the secondary boom would assume the shape shown by dotted line at C.)

8.2 **<u>Containment Dams</u>:** Although the deployment of floating booms is by far the most used oil spill containment method, there are some locations and situations where other types of containment will be more effective, and easier or cheaper to accomplish. Streams, creeks, and other small drainage channels (usually in inland areas) are often too narrow, too fast moving, and/or too steep-sided for proper boom deployment. For spills on these types of waterways, containment dams constructed from either earth or absorbent materials, offer a good choice for trapping the oil.

8.2.1 Earthen Dams: An earthen dam can be constructed quickly across a dry creek bed using a bulldozer, dragline, or backhoe. If necessary, the dam can be constructed by a crew of men with shovels, but this method is not recommended except in extreme emergencies. In any event, lead time (the amount of time before the spill is expected to get to the containment site) is critical. When selecting a dam site, it is necessary to choose a location far enough downstream to be able to finish the dam before the oil arrives.

In constructing the dam, place two or more drain pipes or culverts near the base positioned in the direction of the stream flow. These pipes need to be longer than the width of the dam at its base, and should have a diameter large enough to allow passage of the water without causing it to back up higher than the dam. Multiple drain pipes are used to control the water flow. By plugging one or more of the drain pipes, the water can be maintained at the proper level to keep the oil afloat, yet trapped behind the dam. Installing the pipes on a slant can also help control the water level (See Figures 8-13 and 8-14).



Figures 8-13 and 8-14: Earthen Dams, Cross Sections. Left: Multiple pipes near the bottom with valves to control the flow and retained depth of the water. Right: Pipes installed on an incline to control water depth. The top of the incline determines the height of the retained water and oil.

Once drain pipes are in place, the remainder of the dam can be built up to the desired height, being sure to keep the earthen material well compacted during construction. The final height should be just enough to trap the oil. The width across the top will depend upon the need for crossing the dam by equipment and personnel.

8.2.2 Straw or Absorbent Dams: Occasions will arise when floating booms or earth dams are not practical for containing a floating spill on a shallow and relatively narrow creek or stream bed. In this situation a straw or absorbent dam can be constructed.

This type of dam can be constructed readily in shallow running water from materials usually available in any community. Across a deeper body of water, hanging the barrier to a cable suspended across the stream will accomplish the containment. In the latter case, weights will be needed to keep the base of the barrier from planing downstream, releasing the absorbent and oil. (See Fig. 8-15).

An absorbent barrier is constructed by first stretching a wire fence across the stream and anchoring it firmly at each bank. The wire may be chicken, hog-type, or chainlink, but it should be dense enough to prevent straw or other sorbent materials from washing through it easily. The wire fence can be kept vertical by driving steel support posts or pipes into the stream bed at 8 to 10 foot intervals. Once the fence is erected, straw can be scattered across the upstream side to a depth of 4 to 6 inches extending upstream some 10 to 15 feet, depending upon the size of the spill.

Absorbents other than straw may be used; however, make sure that sufficient material is used to ensure some absorbent depth at the dam. Whereas straw readily gives a desired depth, some other absorbents tend to float permanently and additional material is needed to achieve the proper absorbent depth at the barrier.

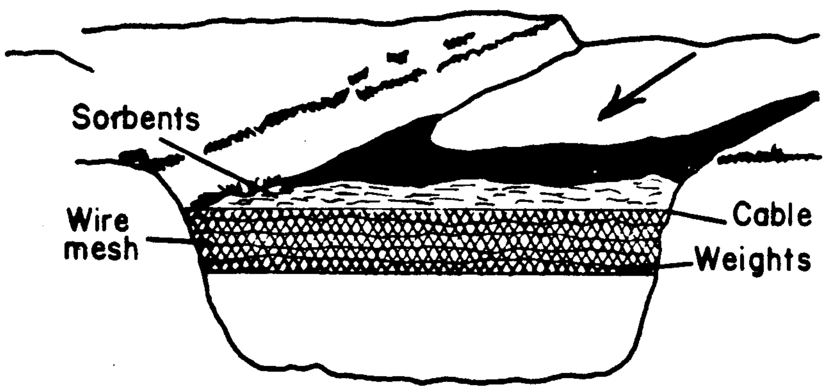


Figure 8-15: Cross Section of a Sorbent Fence. Weights on the bottom of the wire mesh keep it from planing and releasing the absorbent and oil.

The effectiveness of this type of barrier depends on the amount of water in the stream and its velocity, size of the spill, and physical characteristics of the oil. Runoff from a large rain may well cause dam failure. Under normal conditions, a sorbent dam should withstand water velocities of up to 2 to 2-1/2 feet per second.

The type of oil spilled will determine how much absorbent material will be needed. The lighter the oil, the more absorbent needed. Therefore, second and even third absorbent dams may be necessary to recover all the spilled oil.

8.3 **<u>Collecting Agents</u>:** Under favorable conditions, certain oil spills can temporarily be contained by the use of chemicals. When applied to the surface, these chemicals will retard the spreading oil and may even concentrate the spill. Winds, waves, and currents may hamper the use of these collecting agents and therefore must be considered when contemplating the use of collecting agents. One product is known as "Oil Herder" and is available from ASI, Inc., Compton, California. The other is available from Exxon Chemical in Houston, Texas, and is known as "OC-5".

These agents can be applied at a rate of 2 gallons per linear mile of spill perimeter. They can be reapplied if needed every

6 hours, subject to a maximum of three applications in any 24 hour period.

The Navy recommends spreading the agent very thin, on the order of 1 fluid ounce per acre. The agents can be applied with an oiler can for small applications and ordinary 3 to 5 gallon conventional garden-type pressure sprayers for larger areas and dosages. The nozzle should be adjusted for a fine stream and not a spray. For best results the agent should be applied to the oil-free water just next to the spill and then around the entire periphery of that portion of the spill needing control. To reduce the diameter of a small spill, apply the agent around its perimeter.

The aforementioned collecting agents will work favorably on any petroleum or vegetable oil that has not been altered by chemical treatment or by the addition of soaps or detergents. The quicker the application, the better the results as the effectiveness of the agent diminishes with weathering and oil-in-water emulsification of the spilled oil. The effectiveness of the agent is maximum in still waters. However, it is still useable in medium wind-and-water chop. Debris will impede its effectiveness, as will temperatures of 38°F or less. Trial tests should be made by all potential users of collecting agents.

CHAPTER IX
OIL REMOVAL

9. REMOVAL OF OIL: Once an oil spill on water has been contained by any of the means described in the "containment" section above, it must then be removed utilizing the most effective method (one which incurs the lowest cost and least harm to the ecology of the area).

Like containment, removal of an oil spill from the surface of the water can be a complex task requiring a variety of methods. Mechanical units such as skimmers or vacuum trucks may be used. In some spills, the use of absorbent materials to soak up the oil may suffice. Even nature can play a role through the process of bacterial degradation. Under special conditions, chemicals may be used to disperse the spill in the water column. Finally, the oil spill may be removed by burning it off or by spreading heavier-than-water granules on it and sinking the oil to the bottom. (NOTE: U.S. regulations prohibit the use of sinking agents.)

9.1 Vacuum Units: Using a vacuum unit is one of the most acceptable methods for removing a contained oil spill, unless the spilled hydrocarbon is too viscous to be sucked into the unit. A vacuum unit on a truck bed combines the spill removal and transportation functions, saving several steps that would otherwise need to be taken without such a unit. This contributes to lower cost of cleanup by using vacuum trucks.

Although the vacuum truck is one of the most commonly used tools in the oil spill cleanup business, it does have some disadvantages that should be considered.

a. It is a large, expensive, mechanically complicated unit.

b. The size and weight preclude accessibility to many oil spill areas.

c. Proper maintenance is mandatory and is expensive if the truck is not used regularly.

A small, skid-mounted vacuum unit may serve well in an area where small oil spills predominate. This kind of unit can be mounted on a trailer for transporting it to a spill site. A skid-mounted unit can be towed along a beach by a tractor. Such a unit usually can be designed for the needs of an area and built by the nearest tank or welding shop.

Vacuum units are most effective when a spill has been contained in thick pockets of relatively pure oil. Because of the high per-hour cost of operating vacuum units, their use will not be the most cost effective method of removing small, or widely dispersed, thin layer oil spills. Additionally, large amounts of debris can clog hoses and pumps. In this case, prescreening of the debris is required (See Figure 9-1).

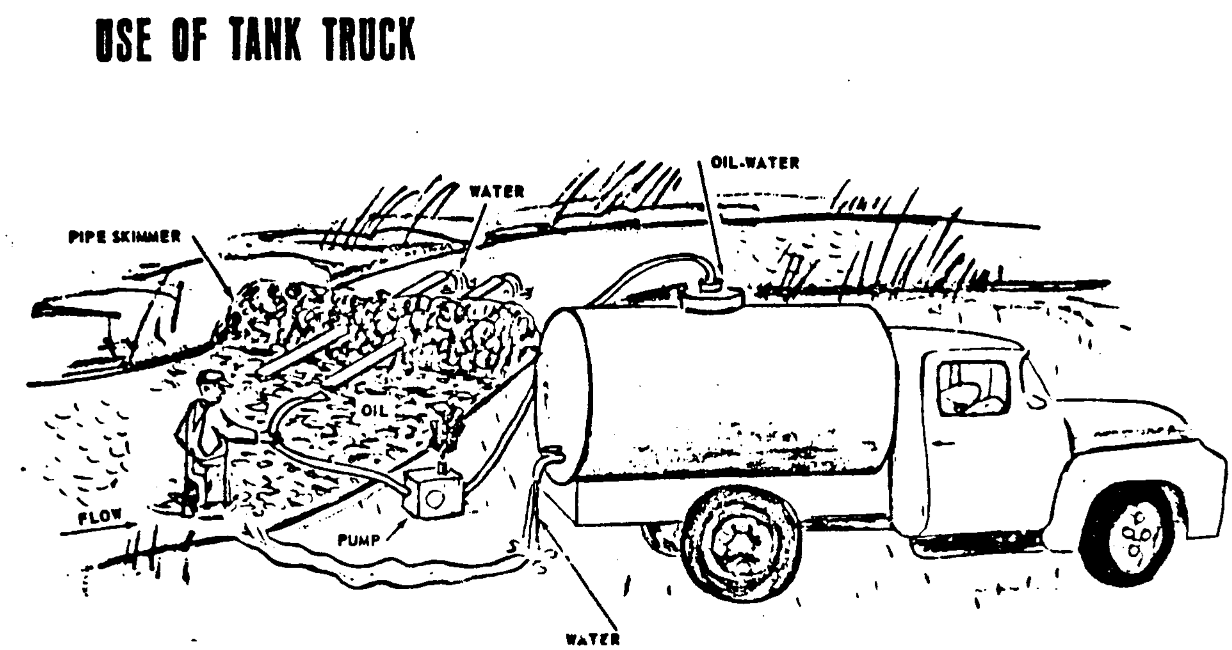


Figure 9-1: Impounded oil may be removed from a stream by pumping into a tank truck. The oil-water mixture is pumped into the top of the tank and after separation of oil and water, the water may be returned to the stream by opening a valve at the bottom of the tank. Sufficient settling time should be allowed to permit a fairly complete separation.

9.2 <u>Skimmers</u>: Many mechanical devices have been developed to receive and physically remove spilled oil from the surface of a water body. These devices are called skimmers. They vary in shape, size, purpose, and cost. Skimmers may be simple homemade units made from scrap parts and costing little, to sophisticated, complex units priced at several hundred thousand dollars each.

The two basic types of skimmers used today are:

a. Suction units
b. Oleophilic units.

Although suction units vary greatly in design and purpose, they all require some sort of suction device to remove the entrapped or contained oil. The above basic units may be subdivided into these five different categories:

- Enlarged suction head
- Floating weir
- Oil-water trap
- Dynamic inclined plane
- Cyclone operation

Oleophilic units all use a material to which floating oil will adhere. The oil is removed from the material by various systems. Several types of oleophilic materials and removal systems are used in this skimmer category, which may be subdivided into the following:

- Belts
- Drums
- Disks
- Ropes

Unfortunately, there is little versatility in skimmer design and purpose, and as such, there is a fairly rigid set of conditions under which skimmers will operate properly. All have varying difficulty with wave action. Some are extremely sensitive to air intake and the subsequent loss of suction and most cannot be used in debris laden waters.

Generally, an oil skimmer should meet the following criteria:

- Be quickly deployable during worse than average climatic conditions
- Be able to handle small solids and debris without damage
- Use self-priming and/or diaphragm type pumps
- Be rugged and dependable for continued operation with minimum of maintenance
- Be able to operate in shallow waters (10-20 in.)
- Be as portable as possible

9.2.1 Suction Types

9.2.1.1 Enlarged suction head skimmers: Enlarging the head attached to the end of a suction hose increases horizontally the area over which suction is exerted. Such a head floats on the water with the suction opening at the oil-water interface. See Figure 9-2 for three different types of such heads.

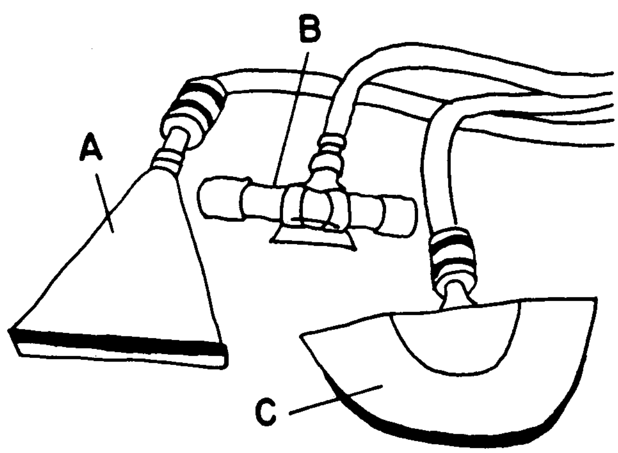


Figure 9-2: Three Types of Enlarged Suction Heads.
A) Duck-bill B) Pipe Extension C) Flexible

A flexible head is more versatile than a rigid type as it will contour itself to small wave action, maintaining its effectiveness. The capacity of a unit will depend upon the size of the head, size of the suction hose, and pump capacity. A delicate blending of all three factors is needed for effective results.

These units will operate in shallow water, but they are subject to being clogged by debris. They also can draw air which will impede operations unless self-priming pumps or vacuum units are used. Care should be taken when deploying the units in choppy or debris laden waters. These are relatively low-cost skimming units.

9.2.1.2 Floating weir skimmers: Floating weir skimmers are mechanical devices that float on water and permit oncoming oil to pass over its adjustable weir plate onto an area where the oil is confined and then sucked or pumped off. The units are widely used and are available in a variety of shapes, sizes, and capacities. Figure 9-3 illustrates the weir skimmer action.

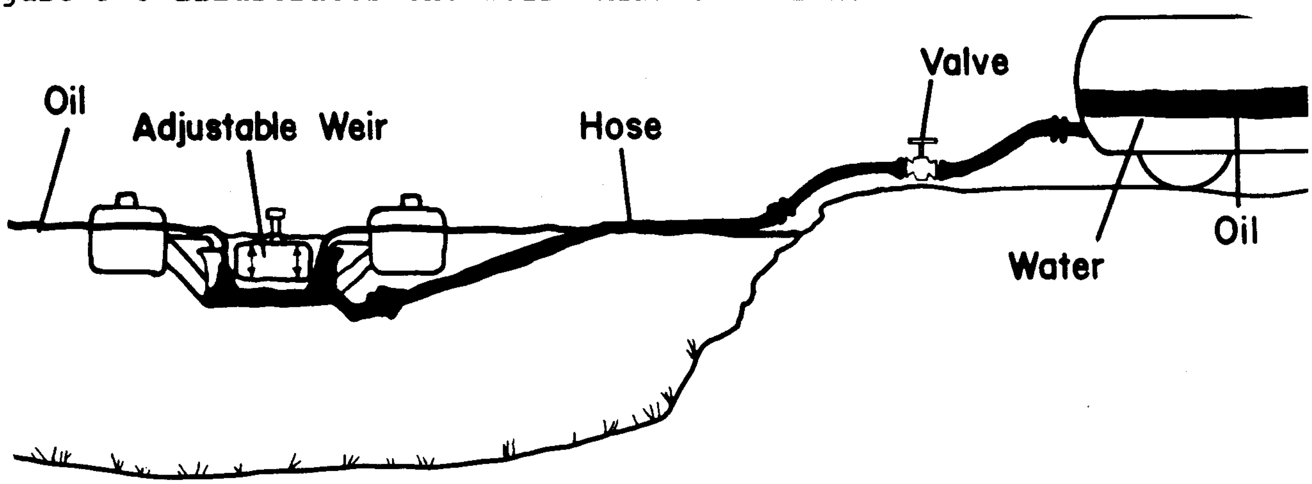


Figure 9-3: Weir Skimmer Operation

These units, like the suction head skimmer, are portable and can be quickly deployed. The cost of such units is supportable when compared to that of the large units requiring service crews and craft. They can be located in the center or near center of a contained spill or maneuvered about in the contained area by ropes handled by two men.

The capacities of floating weir skimmers are dependent upon the sump size of the weir, size of suction hose, and capacity of the pump. The units are very effective in medium to light gravity oil spills where the water is quiet and debris-free. The units are generally light in weight and buoyant, which makes them susceptible to failure in medium choppy water. They can be clogged quickly in debris laden waters and will usually require personnel to adjust the weir or unclog the screen.

A weir skimmer requires practice and experience for the most effective use. Weir adjustments, relocation, and cleaning of debris usually require constant attention from the crew, all of which adds to the cost of this operation. The use of such units should be limited to those times when other types of spill removal are not justified.

9.2.2 Oleophilic types: These all operate on the principle that oil rather than water will adhere to the oleophilic part of the unit which is immersed in the oil. As the part is mechanically removed from the spill, the adhering oil is either wiped, scraped, or squeezed off into recovery tanks. Metal and plastic surfaces are used for the oleophilic parts. These skimmer types come in various forms and shapes.

Any piece of rope dragged through an oil spill will absorb some oil. The larger the rope or the greater the surface area exposed to the spilled oil, the greater the removal. Also the more oleophilic the rope material, the more oil and less water will be removed.

One manufacturer has applied this principle and markets a rope type skimmer. This unit is widely used and is available with assorted sizes and lengths of rope. The rope consists of a basic tension core to which is interwoven additional oleophilic material to enlarge the overall diameter and increase manyfold the surface area that is exposed to a spill. These ropes are available in sizes (outside diameter) from 4 inches to 36 inches and can be provided in any predesigned length.

The rope is deployed into an oil spill as a continuous loop, moored at one end around an anchored, floating tail pulley. The oil adheres to the rope and is removed by a wringer as it passes through a power machine located at the opposite end of the rope extension. The power units that propel and wring the rope are available in a variety of sizes and can be driven by gasoline, electric, diesel, or pneumatic engines.

This type of skimmer is effective and versatile. It recovers little free water, will operate in light or viscous oils, and is not too troubled by debris. The units are operable in shallow or deep waters, wherever the trail pulley can be stationed. Portability allows for reasonable response within a limited area. The principle disadvantages are rope maintenance and relocation costs. The units range in cost from near $3,000 to $100,000, depending upon size and length of the rope and size of the power unit. Care has to be taken to prevent recontamination from dripping oil as the rope approaches the unit. Other absorbent materials on the water, dock, or ground around the power unit may be needed for this protection.

9.3 <u>Sorbents</u>: "Sorbent" is the name given to those products or materials which are oleophilic and hydrophobic. That is, they have a high capacity for adsorbing or absorbing an oil product, and they tend to repel water. In usable form, sorbents must float on water long enough to adequately absorb the oil and then be removed. These sorbents can be classified as either: (1) mineral products, (2) natural (organic or agricultural) products, or (3) manufactured (synthetic) products.

They are used widely to clean up small terrestrial or marine spills and for completing the cleanup of a large spill. Their use is generally more costly than conventional mechanical procedures except for small, or thin-layer oil spills. Sorbents usually have to be spread and recovered by hand, thus limiting the area that can be adequately cleaned by this process. Selection of absorbing materials for storage and use will be influenced by the local exposure to oil spills and the type of hydrocarbon that might be spilled. The following may assist in this selection.

9.3.1 Mineral Products: Several commercially available minerals have a high affinity for oil, including volcanic ash, diatomacious earth, vermiculite, perlite, and some chalks. For oil spill cleanup work these materials need to be ground into a very fine-grain form. This leaves much of the material as dust which is one of its greatest disadvantages. The materials do absorb certain oils to acceptable ratios - three to six times their weight - but are very expensive and thus are not commonly used for oil-on-water cleanup. Also, the oil spill recovery process may be complicated because these materials may:

- o be too fine-grain to permit removal by conventional means such as nets, sieves, etc.
- o be abrasive to mechanical pumps
- o require specialized equipment to spread and recover
- o not burn, eliminating burning as a disposal process

9.3.2 Natural or Agricultural Products: Many agricultural products are available for use in absorbing an oil spill from water. Most leaflike plants contain some natural oils, giving them a greater affinity for oil than water. When dry, they are lightweight enough to float on water. All of these products will become water wet in time and sink, carrying the oil with them. Straws with hollow stems will float for longer periods than grass or hay. These sorbents are plentiful in agricultural communities and usually are available within a short distance.

Agricultural products are relatively inexpensive but are bulky. If needed in sizable quantities, they will require large protected storage areas. A rain-wet straw or hay loses a great deal of its affinity for oil, is more difficult to spread, and will sink more readily. The method of packaging or baling is important. Baling wire will quickly rust out in humid climates rendering the bale useless for transport. Plastic baling line for storage of hay or straw is preferable.

Spreading an agricultural product on the water or along a beach can be a costly and time-consuming operation unless a mechanical spreader can be used. Such mechanical units usually are available in agricultural communities. They are also used by highway construction contractors.

Some of the natural products that have been tested and used as oil spill sorbents are:

- Rice straw
- Oat straw
- Wheat straw
- Flax straw
- Johnson grass (hay)
- Coastal Bermuda (hay)
- Buffel grass (hay)
- Bagasse (sugar cane)
- Red top cane
- Cottonseed hulls
- Corn cobs (ground or unground)
- Peat Moss
- Sawdust

Sawdust quickly becomes water-wet, reducing its oil absorbing capacity and it tends to sink quite readily. Sawdust is also easily churned at the beach by breakers and dispersed in the water column, adding to the problem. On the beach, sawdust readily mixes with the sand during raking, making it impossible to remove.

Peat moss is expensive for oil spill cleanup work. Like cottonseed hulls and corn cobs, it will readily become water-wet and sink. These products can be used on land and on beach but their cost may preclude their use.

Bagasse and red top cane are regional products. Bagasse has a high affinity to oil but will readily become water-wet and sink. Red top cane, like bagasse, quickly becomes water-wet and sinks. Also it has a relatively, low oil sorption capability.

Grass or hay makes a good sorbent. It is generally available as feed for livestock, but since it is a feed, it costs more than straw. This is principally a leafy material which has a high oil absorbing capacity. However, it can and will become water-wet in time and sink with the oil. Its use in shoreside or beach operations can be justified. It can be removed from the water by use of fine screens and easily raked into piles on a beach.

Straws are the most common and widely used natural absorbing materials. The straws can be either oat, wheat, rice, or flax. These are centrally available to most communities. They are the most absorbing of the agricultural products. Straw will float for longer period because of their hollow or fibrous stems. Straw is the least expensive of the natural products and if baled properly can be stored for many years. Tests have shown that straws have a 30 percent greater oil absorbing capacity than hays, 40 percent more than canes, and 100 percent more than cottonseed hulls. Straws have been known to absorb between 8 and 30 times their weight of oil.

9.3.3 Synthetic Products: Synthetic products are widely used and are available from manufacturers under various trade names. They are manufactured from high molecular weight polymers such as polypropylene, which has high absorbing capacities. Polyurethane, for example, theoretically can absorb 90 percent of its volume and under ideal conditions 100 times its own weight of oil.

Synthetic products are marketed in various forms: (1) as a relatively fine-grain, loose, and sugary textured material, (2) as a medium coarse material with particles the size of a dime or less, (3) as pads 1/4 inch to 1/2 inch thick and approximately 14 inches square, (4) as particulate baled in pieces the size of a fist, (5) in rolled sheets 3 feet wide and 200 feet long, (6) in various pillow-shaped forms, (7) as absorbing booms, (8) as a mop similar to a household mop, (9) as a tangled mass of thin strips, and (10) in liquid components for on-site generation of an absorbing foam which can be chopped and spread by hand or by mechanical means. Other marketed forms will undoubtedly be developed as the need arises.

9.3.4 When and How to Use Sorbents: The use of sorbents for oil spill cleanup work varies among the areas of the country. Some cleanup contractors limit their stockpile to synthetics while others include the agricultural products - principally straw. One experienced and diversified contractor is known to have said, "Until something is found to be better than straw, something that is as cheap and universally acceptable, most cleanup contractors will continue to use straw as the principal sorbent."

The following characteristics of sorbents will influence their selection and use:

a. All sorbents are bulky; storage of sizeable quantities requires larger, covered storage facilities. Straws or agricultural products are the bulkiest and require special storage to prevent rodents from nesting and ruining the sorbent.

b. In heavy oil exposure areas, stockpiling of sorbents is a must. Having to wait on delivery of sorbents may be the difference between a minor and major disaster.

c. Absorbing products are available in various shapes and sizes. The straws or agricultural products come in bales, spread by a mechanical mulcher. The synthetics are available in many forms, from sugary granules in bulk to blanket sheets. They are usually spread by hand, but mechanical spreading is available for those products made available in a particulate form.

d. On a per pound basis, straws are much cheaper than the synthetics. Ability to absorb and price must be considered when selecting synthetic sorbents for storage and immediate availability.

e. All sorbents used for oil spill cleanup should be recovered and disposed of through standard procedures (See following subsection, "Disposal"). The small-grained, loose type sorbents are very difficult to remove from water, adding delay and cost to the operation.

9.3.5 Application of Straw: Baled straw is a mass of stalks which have been reduced to this state by a thorough tumbling in the threshing process. It is normally used for stock bedding because of its toughness and absorbency. In tests, straws (oat, wheat, and rice) have been found to collect a large proportion of their ultimate total of oil in the first few minutes after contact with the oil. Fifty-gram samples of the three straws deployed over a medium gravity crude (Sp. Gr. 0.795) for 5 minutes revealed an average removal of 207 ml. of oil and 8 ml. of water. A 15 hour test with the same oil averaged recovery of only 245 ml. of oil and 37 ml. of water. Therefore, try not to leave straw on water for prolonged periods as its effectiveness is greatly diminished after the first few minutes. As time on water increases, the risk that the oil soaked straw will sink also increases.

Straw, because of its low cost and capability of being mechanically spread over large areas, is most effective on land, beaches, or shorelines. Land and beaches contaminated with a viscous oil that has not penetrated the sand or rocks can be cleansed readily and cheaply using straw. Straw is also effective along stretches of shoreline where oil on water is about to reach the shore. Straw should be spread plentifully as it serves a dual role - it absorbs the oncoming oil and prevents or reduces the amount of oil that reaches the beach itself. Under these circumstances, the amount of straw spread, time on water, and removal should be carefully controlled.

Straw also will make a very effective dam either in baled form across shallow water or in dispersed form behind a wire fence in deeper water (See Figures 9-4 and 9-5).

Straw spread over water will consist of many small pieces of stalk. These small pieces will find their way into places difficult to reach for removal. Therefore, try not to use straw as an oil sorbent near an open rocky shoreline where the straw cannot readily be removed.

Straw on open waters is difficult to retrieve. Special recovery sieves are needed and even then, all of it will not be recovered. Open water spreading of straw should be avoided unless the spill is small, contained, and mechanical means are not available to remove the oil.

Spreading the straw on an oil spill on water precludes the pumpability of the oil, rendering mechanical removal devices useless. Therefore, do not spread straw on an oil spill which can be removed more effectively by pumps or vacuum units.

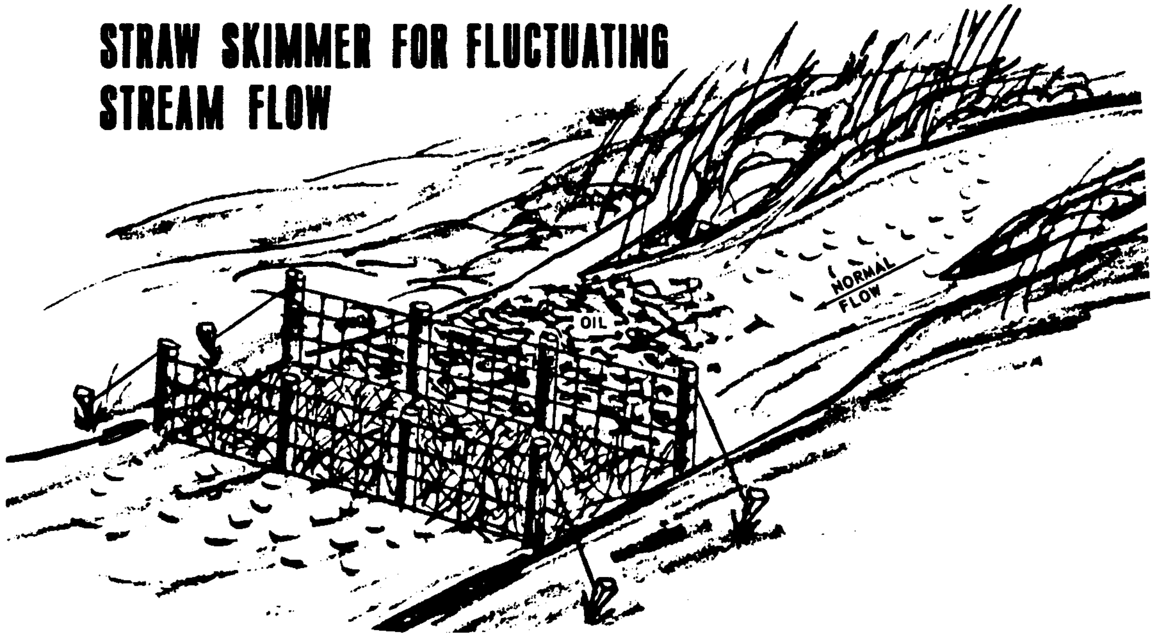


Figure 9-4: Stretch Wire Fence Across Stream and Anchor Securely. Straw is placed on upstream side of fence. This type of installation should be used in a location where the stream banks are of sufficient height and movement of water is relatively slow.

STRAW SKIMMING INSTALLATION

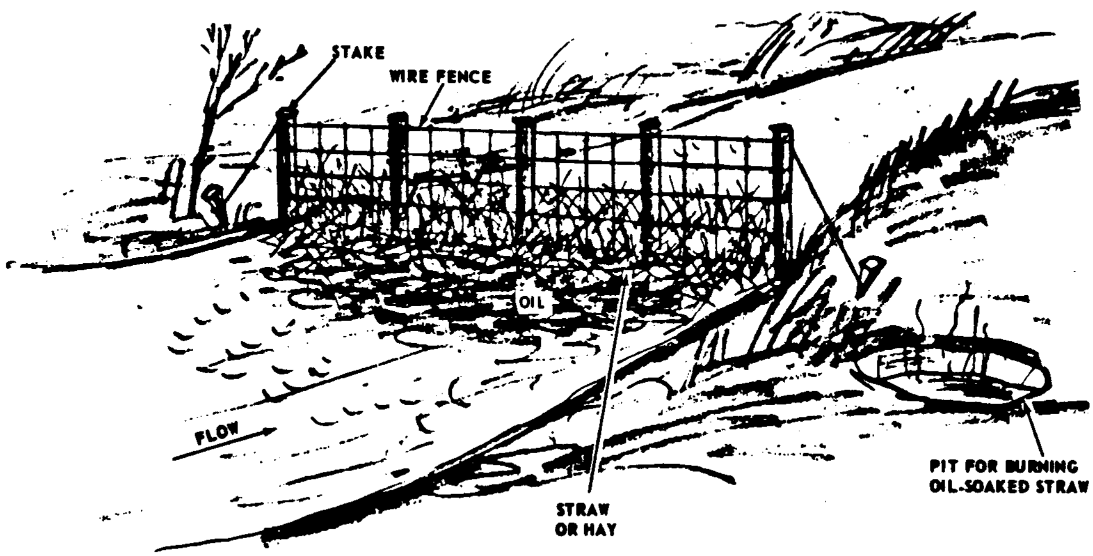


Figure 9-5: The Ordinary Straw Skimmer may not be Used Effectively in a Stream Having a Constantly Changing Flow Direction. When this type of skimmer is Installed in a body of water which is subject to fluctuating flow movement, the straw must be held in place by wire fence on both sides of the straw.

9.3.6 Using Synthetics: Synthetic sorbents play an important role in absorbing oil. Besides being used by oil spill cleanup contractors, they are widely used to absorb oils from the floors of factories, machine shops, electrical oil filter equipment, etc. All oil spill cleanup contractors stock large supplies because synthetic sorbents serve a vital need. These products are more expensive than straws but work well in certain situations where the straws should not be used. Like the straws, synthetic sorbents should not be used where mechanical (pump or vacuum) removal of the spill is possible.

Synthetic sorbents can be divided into five categories:

9.3.6.1 Fine to Medium Grain: In this form, the product is difficult if not impossible to remove from water. It should not be used for absorbing oil from water. Fine grain sorbents are best used to clean up oil from terrain and to absorb oil out of oil-soaked lawns. The fine grain particles should not be used on beaches as raking will only mix the oil-soaked sorbent with the sand, adding to the removal problem. This type of product should be stocked in those isolated areas that are exposed to oil spills that may trespass private lawns, golf courses, etc.

9.3.6.2 Course Grain (Particulate): This versatile sorbent can be deployed by hand or machine. The pieces are large enough to be easily removed by rakes or sieves from beaches, water or terrestrial areas. Because of its relatively high cost, its use should be limited to the cleanup of small spills that other sorbents or mechanical units cannot remove more rapidly and at less expense. Using particulate in open rocky areas is not advisable as the pieces are not connected and therefore could be difficult to remove.

9.3.6.3 Pads: These types of sorbents are marketed in cartons or bundles weighing 15 to 25 pounds and containing 100 to 110 pads, each approximately 14 inches square and between 1/4 to 1/2 inch thick. These pads are the most commonly used of all the synthetic products. Some have grommets in one corner so that they can be connected for isolating in a specific area and for quicker removal. The pads must be manually deployed, and usually are recovered by hand. They are commonly used to clean up small spills or to polish the cleanup of larger spills. These pads can be used effectively for absorbing oil out of rocky crevices and hard to reach places. They become entirely impregnated with oil when spread on a thick layer of medium to light gravity oils. When the spilled oil is thin (such as infiltrating oil), only one face of the pad and its perimeter get oil-wet, requiring manual turnover. Pads are not effective in sorbing a viscous material from the water or a beach.

Some types of pads are fibrous, which permits wringing out the oil and reusing the pad. Although this option is available, it is not commonly used because the labor cost of wringing the pad exceeds the initial cost of the pad. However, if a temporary shortage should exist, then wringing could be justified.

9.3.6.4 Rolls: The 200 foot rolls have a more limited use but offer some advantages. Since the absorbing material is in a rolled form, it is more concentrated thus requiring less storage space for equal poundage. Rolls can be used on a beach by spreading out the entire 200 feet at the water's edge to receive an oncoming light gravity oil (diesel fuel, insulating oil, etc.) spill. This is one case where using absorbing rolls is preferable to using straws. Absorbing rolls can also be used as footpaths for personnel and wheelbarrows or as blankets for temporary storage of oil-soaked material to prevent dripping oil from recontaminating clean areas of beaches, docks, etc. Pieces can be cut from the rolls when sections larger than the 14 inch by 14 inch pads are needed. Storing some rolls of sorbents in areas of high oil spill exposure may well be worthwhile.

9.3.6.5 Other Forms: Synthetic absorbing material is also marketed as pillows, booms, and as a mass of thin strips, much like strips of cellophane. The pillows resemble a house pillow and are covered by burlap or other porous material of various shapes. Some pillows are grommeted for joining for easier use and recovery. Sorbent pillows can be used to plug leaking boom sections, to absorb oil in rocky areas, and to make a boom by tying together a number of pillows.

Absorbing booms are available, manufactured much like the pillows but longer, in 20 to 25 foot sections. They do not have a skirt or tension member and should only be used to absorb thin, light gravity oil films along a relatively short distance. Absorbing booms are relatively expensive and cannot be reused, so their use can be justified only for isolated and special incidents. This type of sorbent would work best across a slow moving narrow body of water with a widespread thin film of high gravity oil.

Synthetic sorbents are also available in thin strips of vitreous material which can be tangled to form a loose mass or paralleled and tied to a pole to form a mop, much like a household mop. The tangled mass can be thrown into a viscous spill, allowed to absorb the oil, then be removed manually or by a specially designed mechanical apparatus. This method of removal is effective on viscous oil at shoreline locations where a considerable amount of debris is present. However, before employing this method, compare its cost with the cost of first removing the debris and then the oil by other means. When the tangled mass type is used, it is usually discarded after recovery since the labor cost of squeezing the oil from the base, loosening the fibers, and redeploying will exceed the cost of a new unit.

The mop types are used manually for removing a spill from difficult to reach places such as crevices, rocky areas, between floating craft, under confined piers, or dock facilities.

9.4 **<u>Biological Degradation</u>:** The waters of the United States contain many species of microorganisms which increase in abundance as you move from the colder waters to warmer waters. These micro-organisms consume hydrocarbons (oil) as an energy source. The natural micro-organism process of consuming and thereby removing oil from water is well recognized and is the reason given for the disappearance of much oil spilled in the waters throughout the world. However, the use of the process as a practical method of removing oil from inland or coastal waters is questionable.

Detergents and dispersants can be used to break up an oil spill into smaller oil droplets, permitting more rapid decomposition of the oil by microbial action. The ecological effects of this use are debated among competent marine biologists. Some of these biologists advocate the use of chemicals to disperse the oil in waterways, while others are opposed to the use of either detergents or dispersants under any circumstances, claiming the oil and chemicals form a more toxic mixture.

The natural micro-organism process alone does remove some oil spilled on the waters, but it <u>should not</u> be expected to materially assist the overall spill cleanup problem other than as a bonus in the cleanup of any residual oil.

9.5 **<u>Combustion</u>:** This method of oil-on-water removal is effective where the conditions permit. Combustion is the most inexpensive way to remove oil, but it is also the most hazardous. Many factors need to be considered when contemplating the burning oil floating on water, including the following:

9.5.1 Ignition: It is nearly impossible to ignite a thin layer of low gravity oil floating on a large body of cold water because of conductive heat losses into the water. If oil is lighted, steam is generated which chokes off oxygen and smothers the flame. Burning is not a complete process, therefore other methods are required to remove the residual oil.

Several manufacturers are demonstrating so-called "wicking" agents which act much like a wax candle. When spread on oil and set afire, heat from the burning wick reduces the viscosity of the surrounding oil which is then drawn into the burning area. The wicks insulate the water from much of the heat combustion. These "wicking" agents are bead-like and some can be recovered and reused. The cost of the "wicking" agent, the equipment to spread and recover it after burning, and the cost of cleaning and restorage must be considered in estimating the overall cost of cleaning up an oil spill by the combustion process.

Generally, the longer the spilled oil remains on the water, the more difficult it is to ignite and burn, primarily because the volatile components (which are most easily burned) evaporate quickly. This method of removing spilled oil from water offers some limited use, but in general is not operationally practicable.

9.5.2 Smoke: Permits from air pollution agencies are required to burn oil off water because the poor combustion causes heavy smoke. If a contained oil spill is kept burning, the burning will consume the containing equipment, unless earthen or fireproof devices are used. This special equipment will greatly increase the associated cost of containment. Burning of oil spills in or near public or private structures should never be considered.

9.5.3 Wind and Wave Action: Wind and wave action has a cooling effect through convection and adds greatly to the loss of heat.

9.6 **Sinking Agents:** This is a process of removing an oil slick from the surface of water by simply spreading a hydrophobic material over the oil which becomes coated with oil then sinks in the water. A number of materials are available for this purpose, the principal one being sand. Some companies market a specially treated material to be used as a sinking agent.

The process itself is not generally accepted as there are some unresolved problems associated with physically sinking the oil. The mechanism of sinking and the depth to which the oil-coated material will sink are not fully known yet. These factors vary with the properties of the oil, water, and the material used, as well as prevailing climatic conditions. The oil retentive quality of the material used can also vary with time and changes in climatic conditions. This may then result in release of the attached oil permitting it to resurface. An effective oil sinking agent would be one that would sink the oil permanently to a specific depth to permit total decomposition of the oil through the process of biodegradation.

The toxic effects of the method must be considered. Wildlife regulatory agencies are opposed to the use of sinking agents because this method transfers oil from the surface of the water to a depth where it may be even more harmful to the ecology of the area. The use of this method would also be relatively ineffective and too costly to use on a thin oil slick.

A great deal of research undoubtedly will continue on the use of sinking agents. In the meantime, this method of eliminating an oil spill is not permitted in U.S. waters.

CHAPTER X
OIL SPILLS ON LAND

10. MIGRATION OF PETROLEUM PRODUCTS IN SOIL AND GROUND WATER: Petroleum oil spills on land are of concern for the electric industry since the greatest majority of facilities do not spill oil directly into waterways but rather will migrate oil into ground water sources. The actual impact of land spills will vary widely and will depend on such factors as volume of spill, type of soil, nature of ground water system, and the weather. It is thus nearly impossible to outline procedures that are universally applicable for all circumstances. The mechanisms of migration are complex, but where sufficient geological data are available, it is possible to predict whether a given amount of oil is likely to reach a water table or to estimate the depth to which it is likely to migrate in the soil. When a large amount of oil is involved, skilled geological and hydrological personnel may be helpful in determining problem areas.

In order to have a better understanding of the potential hazard of oil on water supplies and/or ground water, a discussion of soil characteristics and water hydrology is required.

To anticipate effectively the behavior of oil spilled on soil requires detailed knowledge both of the local geology and ground water conditions and of the principles described here. The geology of most areas of the U.S. has been mapped quite thoroughly and ground water conditions, where they are important, are well understood. Leading sources of such information include:

- United States Geological Survey, Ground Water Division (Offices in most major cities and State capitals).
- State water resource agencies (described by various titles).
- State Geological Surveys, (Usually in the State capital, but often associated with a State university).
- University geology departments.
- City water departments.

10.1 <u>Rocks and Soil</u>: Most rocks and soils are composed of small fragments or grains such as sand. The irregular shape of these grains, when they are pressed together, creates small openings or voids. A quantitative measure of the total column of the voids is the "porosity" of the rock or soil. It is within these "pores" that fluid may be contained. If the pores are interconnected, the rock is "permeable"; that is, a fluid can pass through it. "Permeability" is a quantitative measure of this property. Materials such as clay, silt, and shale are called "impermeable" because they have extremely small pores, are poorly interconnected, and fluids cannot pass readily through them.

The more common rocks and soils are sedimentary. Usually they occur in distinct layers or beds as a result of successive deposition of different types of rock material. Such bedding is commonly exposed in road cuts. The beds may be horizontal, but more often will slope or "dip" in some direction. This dip, in addition to the varying porosities and permeabilities of the different layers, does much to govern the movement of fluids underground.

One particular rock, limestone, is especially soluble in water. Limestone that is near the surface sometimes develops large openings and fissures that range from less than an inch to many feet across. The more spectacular examples include great caverns such as Mammoth Cave in Kentucky and Carlsbad Caverns in New Mexico. The rock in such caverns clearly has extremely high porosity and permeability. In other instances, limestone may have very low porosity and permeability.

Crystalline rocks, such as granite, marble, and quartzite, usually are not porous. Frequently, however, such rocks are cracked or fractured to some depth, and a certain amount of fluid may exist in and move through these openings.

10.2 **Ground Water:** In most parts of the U.S., free water exists at some depth in the ground. In many areas enough is present to provide a major part of the water supply for towns and cities, as well as rural areas. In areas where ground water is used extensively, products spilled on the ground may create risk of contamination.

The source of most ground water is precipitation over land, where water is absorbed by porous soils and rocks at the surface. Other important sources are rivers and streams that may lose water into the subsurface. Details of a hypothetical total ground water system are shown in Figure 10-1.

Moisture is present to some degree in practically all soils. Starting at the surface, moisture generally increases with depth in a zone of partial saturation called the "vadoe zone." The depth at which water completely fills the pores in the soil defines the beginning of the "zone of saturation." The upper surface of this zone is the "water table," and the water in the zone is "ground water."

The position of the water table is revealed by the level to which water rises in wells. The water table usually is an undulating surface that conforms in a general way to the topography of the land. It fluctuates seasonally, rising during rainy seasons and falling during dry periods. Immediately above the water table is the "capillary zone." This zone may vary in thickness from less than an inch in coarse, permeable soil to 15 inches or more in very fine grained, low permeability soil or rock. Water in the capillary zone will not flow since it is held by capillary forces that are stronger than gravity. The capillary zone is important because the nature and thickness of this zone determines the spreading characteristics of oil that reaches the water table.

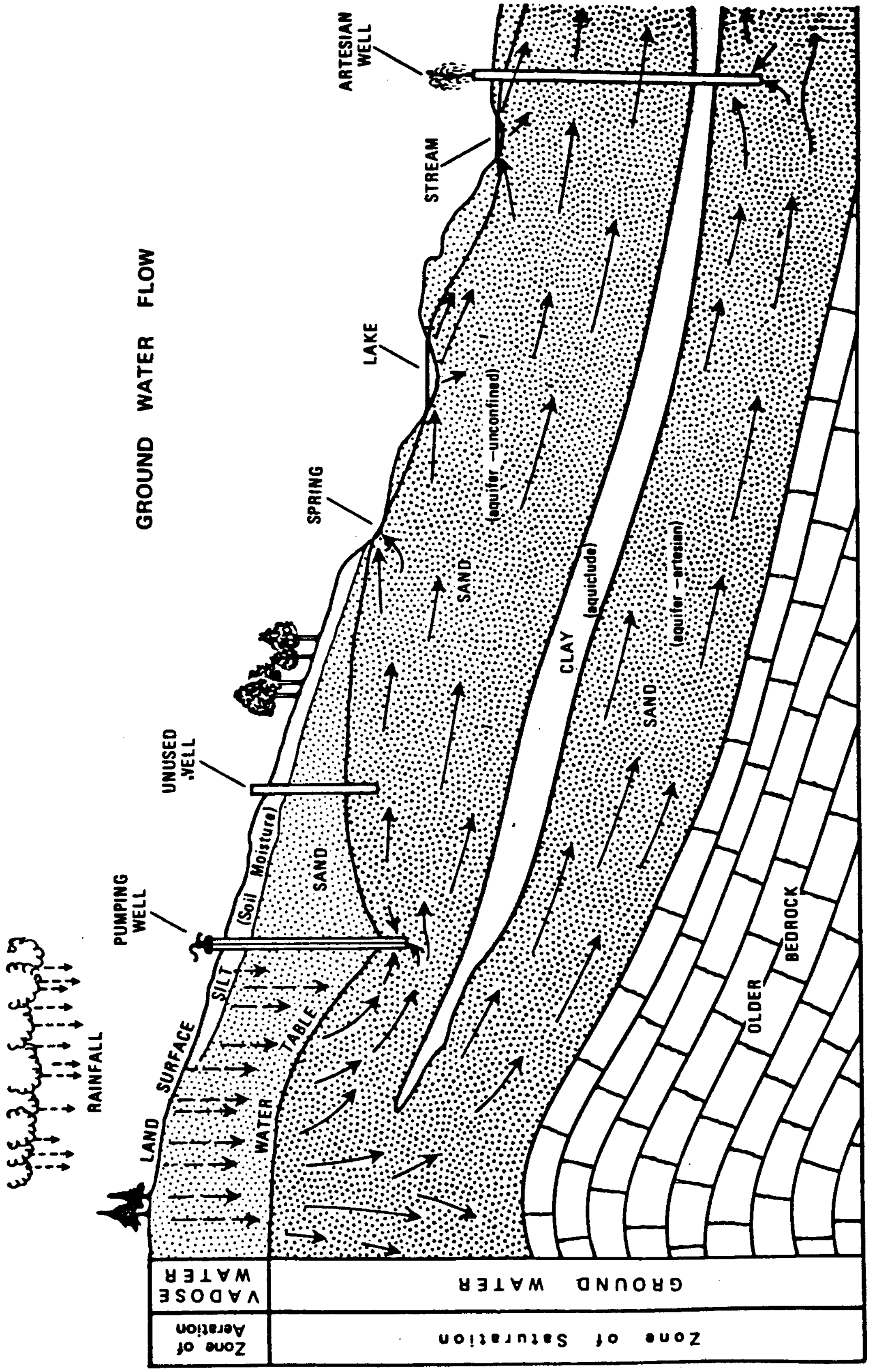


Figure 10-1: Hypothetical Ground Water System

Most layers of rock or soil in a ground water system can be classified as either "aquifers" or "aquicludes." An aquifer is a layer of rock that is sufficiently permeable to transmit water in usable quantities to a well or spring. An aquiclude, on the other hand, is sufficiently impermeable to bar the passage of water. An aquifer where the water table is not separated from the surface by an aquiclude is an "unconfined" aquifer, and ground water associated with it is free to move by gravitational forces. An aquifer that is overlain by an aquiclude is a "confined" or "artesian" aquifer. Artesian water normally is not free to move by gravitational forces, but is under sufficient pressure to rise above the top of the aquifer in a well or spring. The height to which artesian water rises at such a discharge point is a measure of the pressure head created by the weight of the water in areas of the aquifer at higher elevation.

In certain unique situations a body of ground water may be hydrostatic in that, essentially, it does not move. In most cases, however, ground water is constantly in motion. Water in an unconfined reservoir is under atmospheric pressure and moves laterally under the influence of gravity towards a point of discharge such as a well or spring. The direction of flow as a rule will roughly parallel the land surface. Water in an artesian aquifer is under a pressure related to the highest elevation of the aquifer and will move toward the point of lowest pressure. This point may be a well or, more commonly, an area where the overlying aquiclude is locally superimpermeable and permits slow upward leakage into higher beds. So long as the system remains "artesian," the rate of leakage cannot exceed the rate at which new water is entering the aquifer at a higher elevation.

Certain cities and industrial areas draw many millions of gallons daily from ground water reservoirs. The sites and relative production rates of the wells may be such as to disrupt normal flow patterns significantly. Complete reversal of direction in limited areas is not uncommon. In such areas, fortunately, considerable data are usually available for use in solving ground water problems. In complex situations, the direction of flow is determined by drawing maps based on pressure data from wells in the area.

The rate of movement of ground water is usually overestimated by most people who think of it in terms of a surface stream. A more realistic comparison is the flow in a large lake where water moves imperceptibly toward a single outlet. Measured rates of ground water movement vary markedly, from many feet per day to a few feet per year. The range is so great that the data are of little use in terms of specific locations. The water in a typical sand aquifer might move from several inches to 4 or 5 feet per day. The rate in a limestone or gravel aquifer could be much higher. The rate of flow depends mainly on the permeability of the aquifer and the hydraulic gradient or slope of the water table. To measure the flow rate of ground water directly is extremely difficult and is seldom used in practice . Such data, when required, usually are calculated by hydrologists using permeability and pressure data from wells and cores of the aquifer or from actual pump tests.

10.3 **<u>Behavior of Spilled Oil in Soil</u>:** An accidental spill of oil or its products may occur suddenly or it may occur slowly over a long period. The physical behavior of the spilled material is the same in each case, varying only in time and extent. A slow leak over an extended period is not detected until oil appears at some point where it is not wanted. By then the problem of controlling the spill may be very difficult and expensive.

Spilled oil commonly migrates along artificial fills, such as pipeline trenches, foundation fills, and utility conduits, in a manner somewhat related to its behavior in natural soils. Such excavations often are backfilled with material more permeable than that removed. These excavations consequently offer a migration route of minimum resistance, and any fluid will tend to move along them more rapidly than through natural soils.

Oil spilled on undisturbed ground will tend simply to move downward, under the force of gravity, while spreading laterally to some degree. The rate of movement depends on the viscosity of the oil and permeability of the soil. If the spill area is essentially round, the general shape of the area of passage is a cone, modified by the nature of the soil layers the oil passes through (Figure 10-2). The downward movement eventually will be interrupted by one of three events: the oil will be exhausted to immobility, it will encounter an impermeable bed, or it will reach the water table.

10.3.1 Exhaustion to Immobility: As the oil moves downward through the soil, a small amount attaches itself to each particle of soil contacted and remains behind the main body of oil. Where the spill is small relative to the surface area available for contact in the zone of migration, the body of oil is exhausted on the way down until the degree to which it saturates the soil reaches a relatively low point called the "immobile" or "residual" saturation. At this point, the oil essentially stops moving. If the condition develops before the oil reaches the water table, the danger of further contamination is greatly reduced. Subsequent rainfall percolating through the soil will carry minor additional amounts of residual oil and dissolved components downward. This situation, however, creates less risk of significant pollution than if the main body of oil reaches the water table.

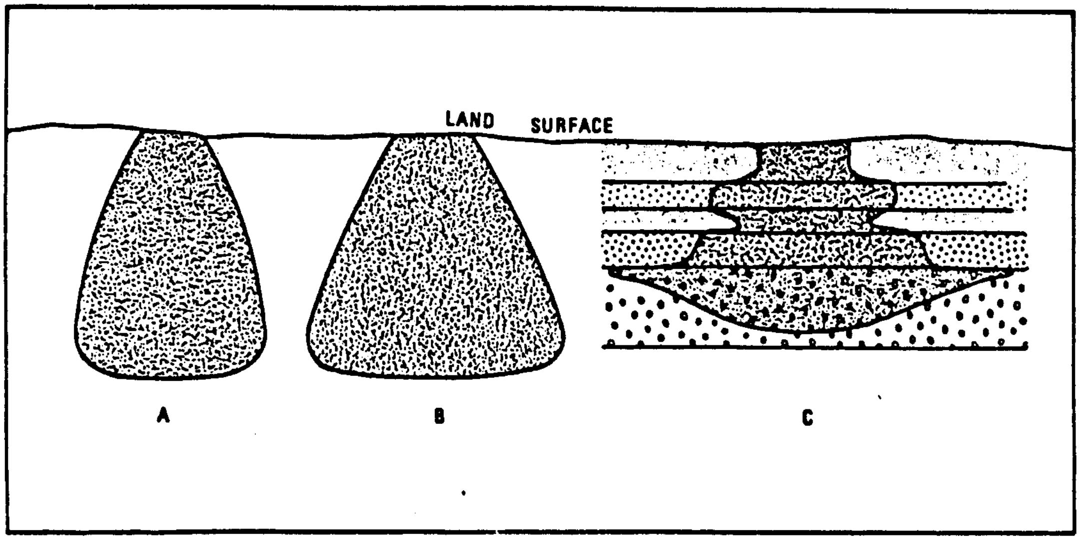


Figure 10-2: Generalized Shapes of Spreading Cones at Immobile Saturation

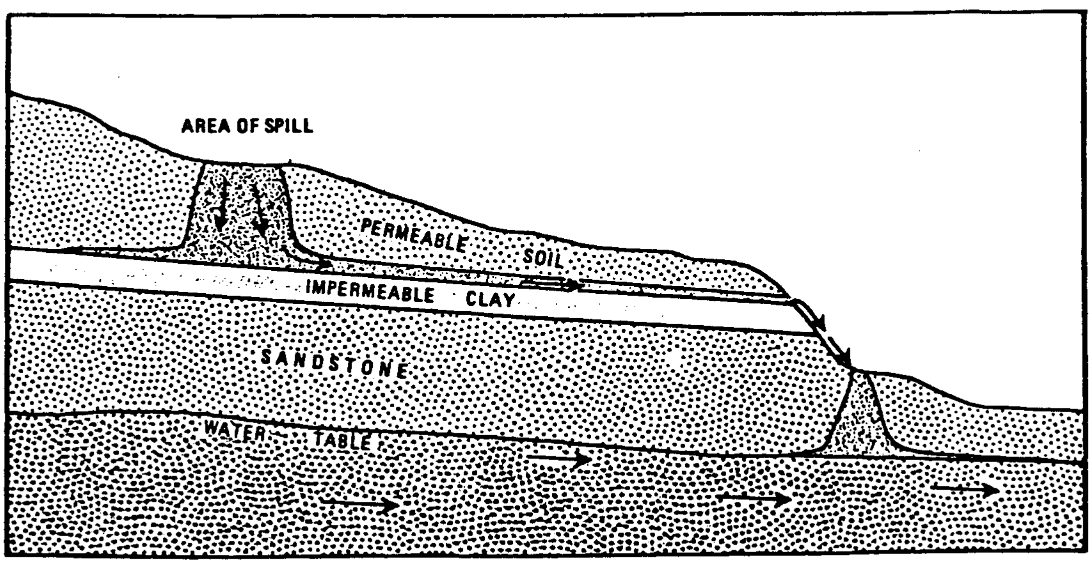


Figure 10-3: Demonstrates Possible Migration to Outcrop, Followed by Second Cycle of Ground Water Contamination

At the time of a spill, precise and detailed data on the nature of the soil and oil are rarely available. Should they be available, however, the volume of soil required to immobilize the spill can be calculated using the following (saturation) equation:

$$\frac{8.4 \times V}{P \times Sr} = \text{Cubic yards of soil required to attain immobile saturation.}$$

Where: V = volume of oil in gallons

P = porosity of soil

Sr = residual saturation = .1 for light oils

If the depth of the water table is known, the saturation equation can be used to estimate the likelihood that the spilled oil will reach it. To do so, calculate the volume of soil that lies under the surface area of the spill to the depth of the water table. Make little or no allowance for the lateral spread of oil underground. The result will conservatively understate the volume of soil actually available to absorb the oil. If the result, in cubic yards, is less than the value obtained from the saturation equation, a risk exists that fluid oil will reach the water table.

10.3.2 Movement to Impermeable Bed: As the body of spilled oil moves downward, its course is affected by the variations in permeability of the various soil layers through which it passes. Should the oil encounter an impermeable layer, it will spread laterally until it reaches immobile saturation or until it comes to the surface where the layer outcrops. Should the latter occur and enough oil is still in motion, a second cycle of soil contamination will begin (Figure 10-3). These events can occur only if no effective water table exists above the impermeable bed. The condition is most common in an arid region or during a dry season and exists as a rule only within several feet of the surface.

10.3.3 Movement to Ground Water: The movement of oil downward to contact the water table usually is the most hazardous possible result of a spill on land. The degree of risk depends on the nature of the ground water system and the extent to which it is used.

In the capillary zone, immediately above the water table, the water content begins to increase reaching 100 percent at the water table. In very fine grained sediments the capillary zone may be 15 to 18 inches thick; in coarse grained material, 1 to 3 inches is common. As the descending body of oil reaches the top of the capillary zone, the oil begins to spread over the water table. It spreads in a layer roughly the thickness of the capillary zone and elongated in the direction of the water's movement. The oil continues to move forming a pancake-shaped layer until it reaches immobile saturation or returns to the surface at a discharge point (Figure 10-4). The ultimate extent of the oil pancake can be calculated, but doing so under field conditions involves so many assumptions and estimates that the result can easily be inaccurate by more than 100 percent. In practice, such calculations must be treated with great discretion. The actual transport of oil in moving ground water is governed by complicated mechanisms for which exact explanations are neither possible nor necessary. A few basic facts suffice for practical understanding. Most oils do not mix with water, but simply float on its surface. However, some refined products contain components that are soluble or will diffuse in water to the point where they become offensive and make the water unfit for domestic use. As a rule, the lighter the product, the greater its content of soluble or diffusible components. These general principles are illustrated in Figure 10-5.

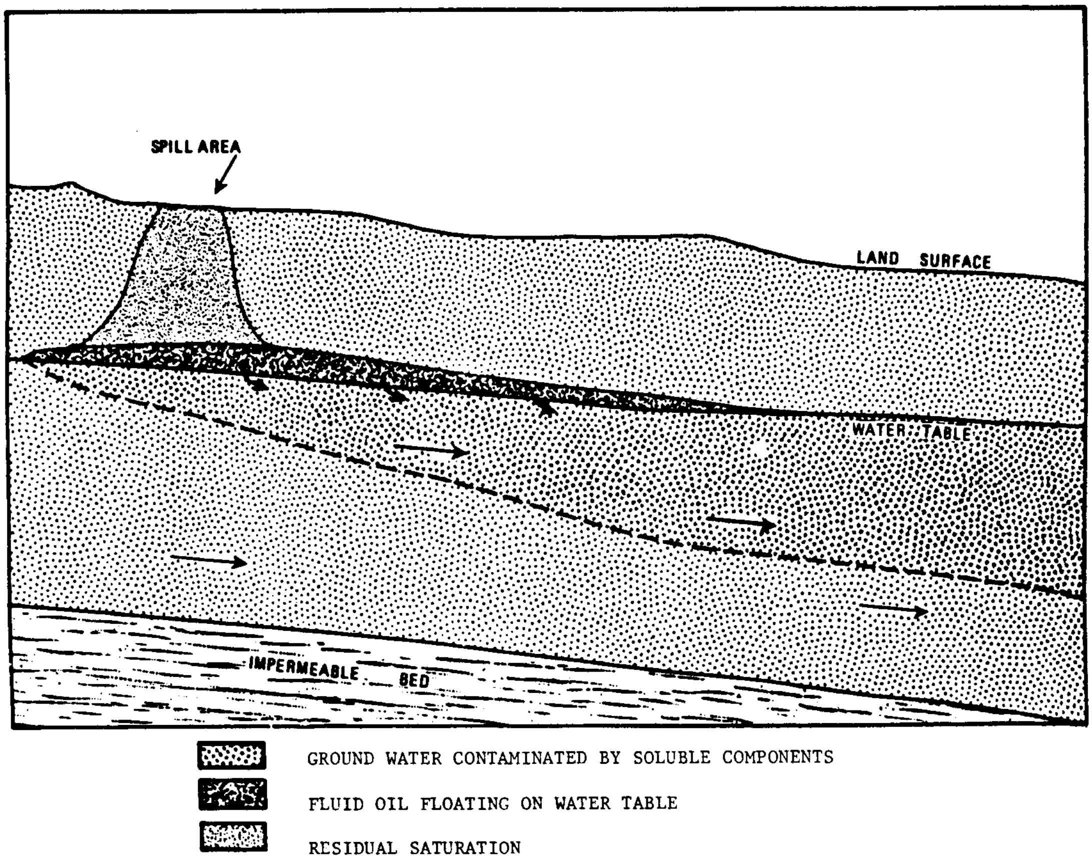


Figure 10-4

Most of the oil that reaches a water table will be suspended or will float at or near the surface of the water. The oil will tend to move with the water, but it will be absorbed continually by soil particles that it contacts. Thus the volume of oil being transported will shrink eventually to zero. If the water table drops, the oil will follow and some of it will be absorbed by the soil it passes through. When the water table rises, oil previously absorbed by the soil will be picked up and then will continue to move laterally with the ground water (Figure 10-5).

Ground water is recharged most commonly by rainfall that infiltrates the soil and percolates downward to the water. Where this water passes through the cone of residual oil, or through the pancake of oil of the water table, it will pick up soluble components of the oil and carry them into the ground water system. Experiments have shown that some of these dissolved components may be absorbed by some types of soil through which the ground water passes. Later, when weaker solutions of the dissolved components enter the same part of the soil formation, they may redissolve the absorbed components. The net result of these processes is that oil dissolved in ground water will tend to travel at a lower velocity than the water and thus to persist longer in a given area.

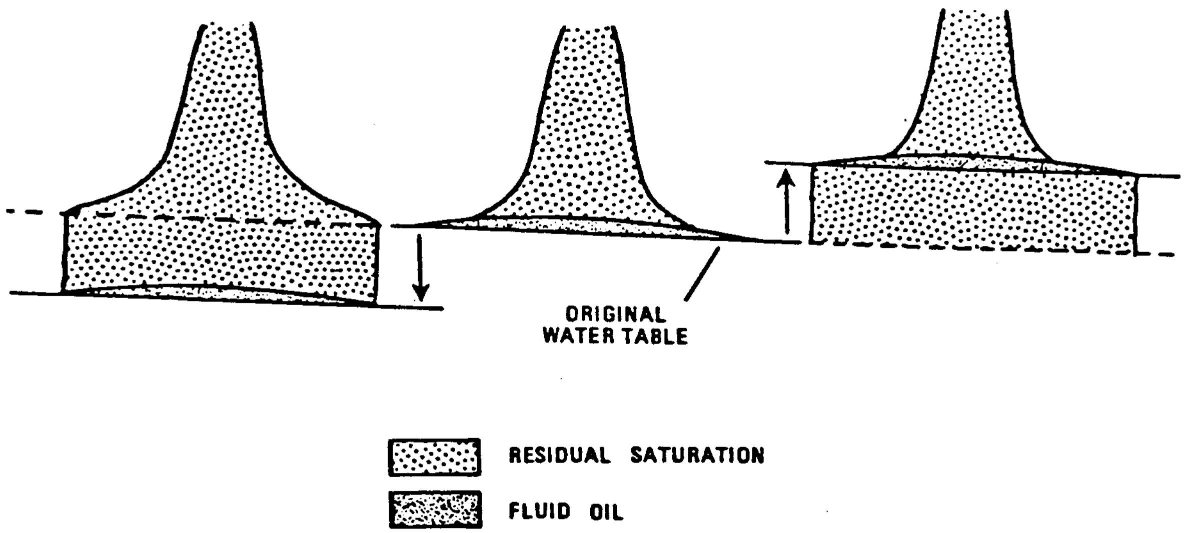


Figure 10-5: Contaminating Effect on Soil Caused by Vertical Movement of Oil on Fluctuating Water Table

10.4 <u>Land Spill Control and Recovery</u>: There are two steps to be taken following an oil spill on land: immediate measures, which are to be implemented after the spill to minimize seepage; and restorative measures, which are concerned with recovery of oil after seepage has occurred. The methods described in this section can be used at an early stage for either step. More complicated and exotic methods may sometimes be required.

Immediate measures apply to spills that are detected soon after they occur. Oil spreads into the soil fastest immediately after the spill and the rate diminishes rapidly with time. To have maximum effect, therefore, measures to recover fluid oil at the surface must be taken as soon as possible. Oil may seep into clay soils quite slowly, allowing several hours or even days for surface recovery.

A sandy, gravelly soil, on the other hand, may absorb the oil in a few minutes (see soils section in Chapter 7). The main limitation to surface recovery will be the time required to mobilize suitable equipment and supplies.

If conditions favor an attempt at surface recovery, three basic techniques should be considered: containment, surface spreading, and absorption. The selection will depend on the volume of the spill, the topography, and the nature of the soil and ground water system.

If the volume of spilled oil is known or can be estimated, the depth to which the oil will penetrate before reaching immobile saturation can be calculated. The calculation will be reasonably accurate only where soils are more or less homogeneous. Still, if the depth to the water table is known it is easy to estimate roughly whether the oil is likely to initially migrate into ground water. If the risk exists and if time permits, excavation of the contaminated soil should be considered. Excavated soil can then be cleansed or removed to a disposal site. If excavation is impractical or impossible, plans should be made to recover the oil while it is still localized in the subsurface, using the best available methods.

Seepage often has been discovered during construction projects when oil or oil-contaminated water has flowed into an excavation. This illustrates two key principles: (1) a seepage problem is not necessarily preceded by a surface spill, and (2) oil will migrate under gravitational forces and with moving ground water. The second point is the basis of the most widely used methods of removing oil from the soil or from an aquifer. These methods embrace three distinct procedures: removal of oil while it is still moving through the soil, but before it has reached the water table; removal of oil floating as a "pancake" on the ground water; and removal of water contaminated with soluble fractions of the oil.

Effective cleanup of a significant spill on land requires equipment and machinery designed for moving earth, drilling, and pumping. Makeshift devices and methods should be used as a rule only temporarily and as a last resort. Speed is vital and every effort should be made to mobilize suitable equipment as soon as possible.

Rarely do conditions favor the recovery of moving oil after it has penetrated the surface, and before it has reached the water table. If the oil has penetrated only a few feet, and if high capacity earth movers are available, it may be possible to remove the contaminated soil.

Migrating oil will spread laterally over a layer of clay or other impermeable material. If such a layer lies near the surface, the oil might be recovered in ditches, using techniques similar to those for recovery from the water table (see Chapter 9 on oil removal for details). Since such an impermeable layer will protect underlying ground water, the consequences of forgoing a recovery attempt and allowing the oil to spread to immobile saturation should be considered.

10.5 **Ground Water Removal:** The primary method of recovering oil from the water table is by creating local depressions and withdrawal points in the water table. Regional water flow is thus interrupted by these depressions and all movement of oil and water within the depression cone is toward the withdrawal points (Figure 10-6). Oil floating on the water table within the depression is prevented from migrating further by removing it from the surface of the ground water. The depression is commonly created by sinking wells and pumping water from them. The same result can be achieved with ditches, provided that they can be dug to a depth below the ground water table.

This second method involves constructing a ditch across the entire front of the migrating body of oil and below the top of the water table. As the oil floats across the ditch it is skimmed off the surface of the water (Figure 10-7). While this method is much less efficient than lowering the water table, it also produces much less fluid to be handled at the surface and is less costly. Under certain conditions, usually with a small spill, the method might be preferable. Its effectiveness depends on proper location of the ditch across the downstream end of the spill.

Because of the need for rapid action, the steps taken immediately after an oil spill on land generally precede any real assessment of the extent of the contamination. If ground water seems likely to be affected, however, such data will be required. Thorough investigation increases the effectiveness of subsequent cleanup operations. The main purpose of the investigation is to determine the number, type, and optimum locations of recovery points.

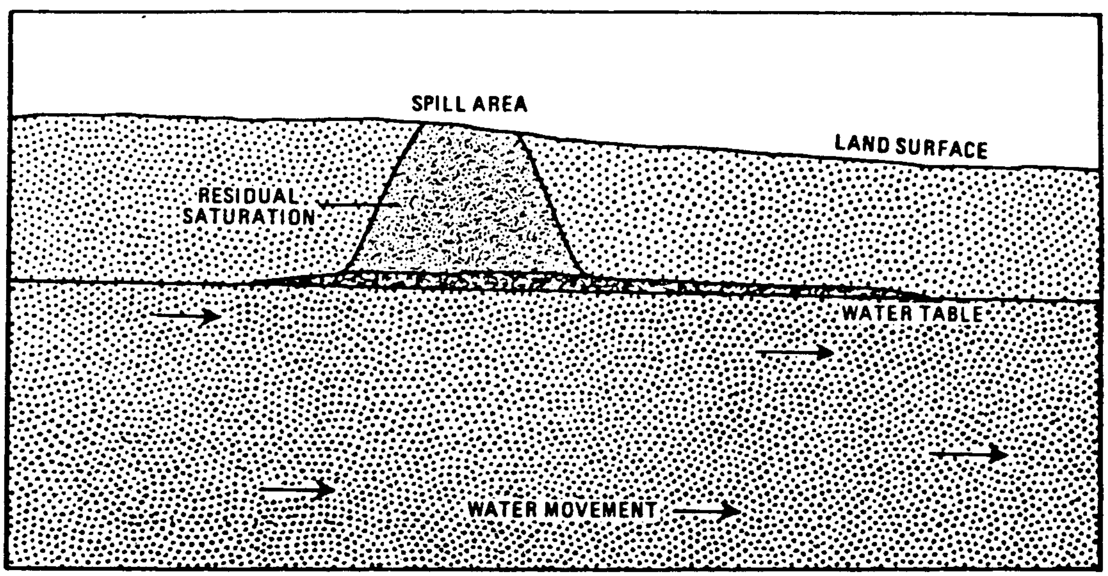


Figure 10-6A: Fluid Oil Floating on Water Table and Showing Elongation of "Pancake" in Direction of Water Movement

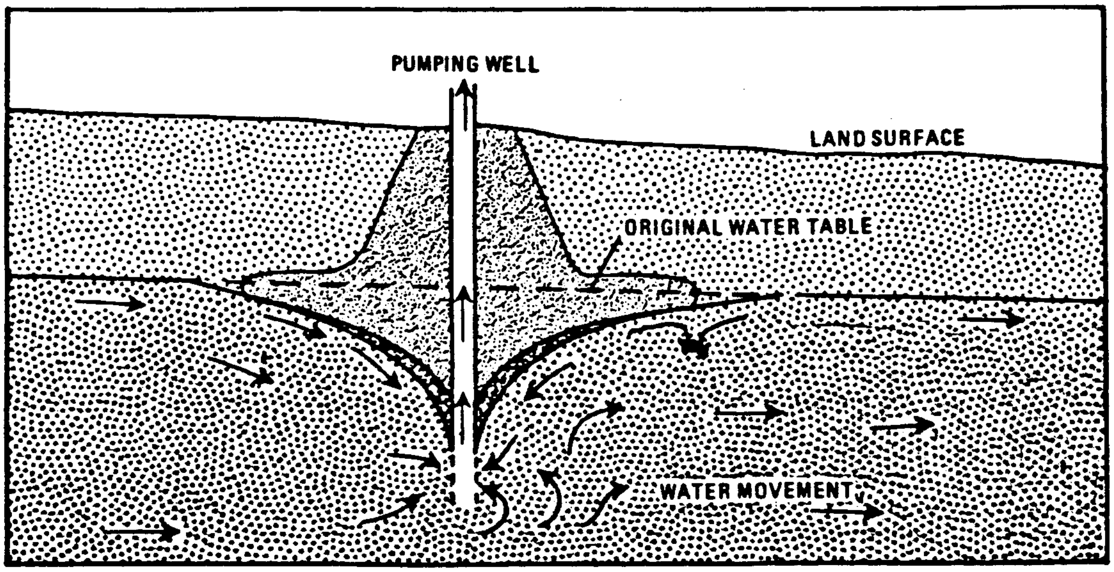


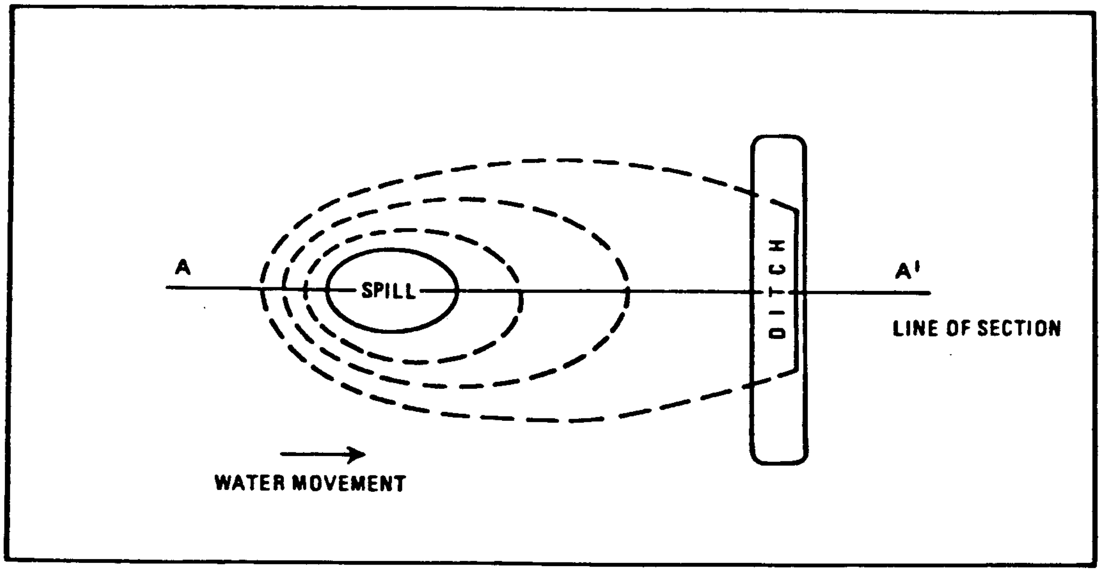
Figure 10-6B: Oil on Water Table is Trapped in Cone of Depression Created by Drawdown of Pumping Well.

The investigation normally is made by means of inspection holes and ditches (as described below). Inspection holes must extend several feet below the water table and should be designed to permit easy sampling and measuring of water levels. Grease, oil, or gasoline from machinery must be kept out of the holes to avoid erroneous data.

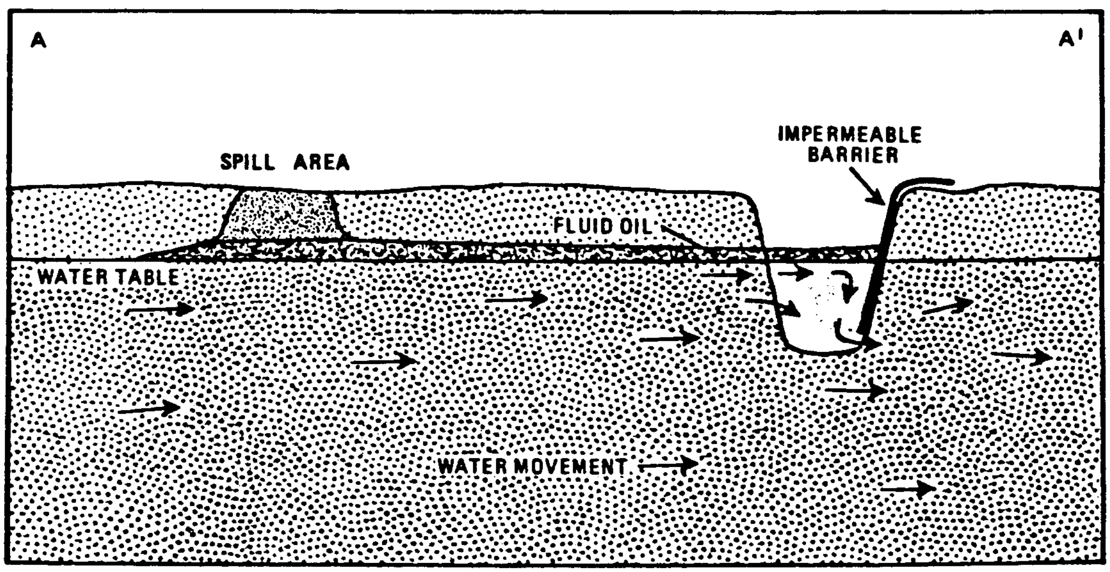
The best locations for inspection holes most often will be just beyond the surface limit of the spill. Where a hole is found to be contaminated, another must be drilled farther out. Contaminated inspection wells, however, can double as recovery points. Once a series of inspection wells has isolated the contaminated area, the wells must be monitored periodically for later spread of the contaminant. The holes may also be useful in evaluating the development of the depression created in the water table by the recovery wells.

Ditches are an efficient method of removing oil if the water table is sufficiently shallow. Ditches deeper than 6 to 8 feet are usually impractical, but the limitation is imposed by the ditching equipment available and the extent to which the soil will support the walls of the ditch without caving. Ditches in unconsolidated soils must have gently sloping sides and a large amount of soil must be removed relative to the depth of the ditch.

If the ditch is to be used as a withdrawal point to lower the water table, it should be at least 3 or 4 feet below the water table, and pumping capacity should be great enough to keep the water drawdown to the bottom of the ditch. Width is important only in that the ditch must be wide enough to accommodate the necessary pumps or other removal devices.



PLAN VIEW



CROSS SECTION

Figure 10-7: Oil Moving with Shallow Ground Water Intercepted by Ditch Constructed Across Migration Path

If the ditch is to be a collection point for skimming, its downstream wall should be lined with an impermeable material such as polyethylene film (Figure 10-8), which will block floating oil but permit water to pass below. Skimming must be continuous or collected oil will tend to move to the ends of the ditch and pass around the barrier.

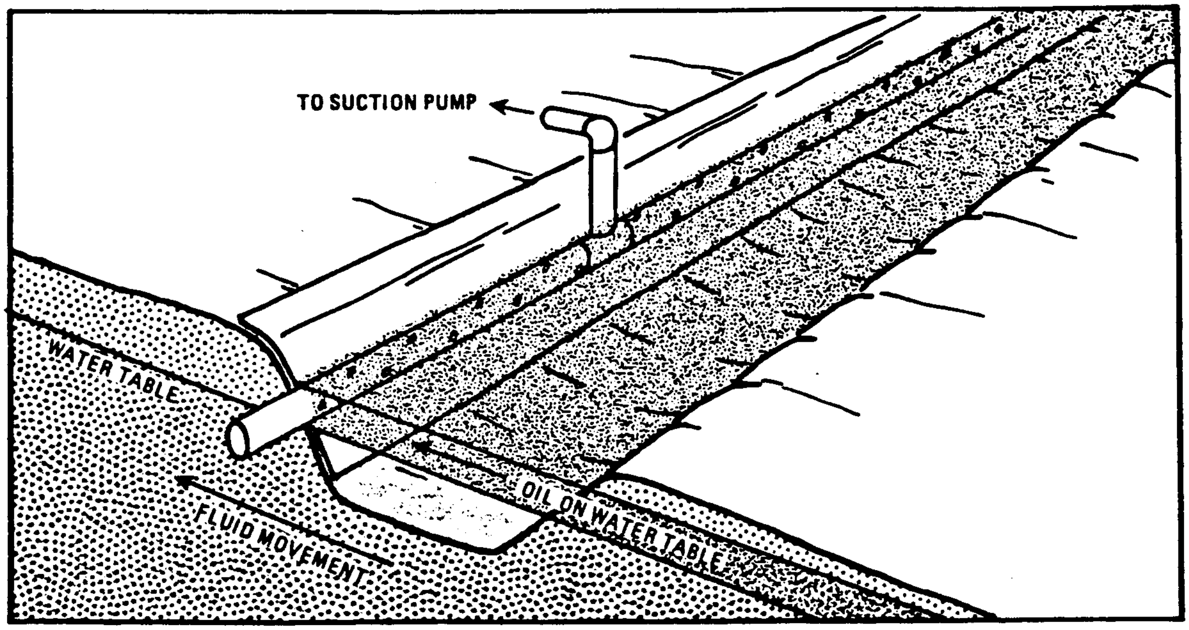


Figure 10-8: System for Skimming Water Surface in Ditches or Wells

Ditches need not be left open. One approach is to lay a string of perforated culvert pipe in the bottom and backfill the ditch with very porous material such as broken rock or gravel. Fluid enters the pipe through the perforations and can be removed through an opening left in the backfill for the purpose. Sometimes an intercepting ditch can be filled with straw to absorb the oil. The straw can be replaced periodically as it becomes saturated.

Fluid should be recovered from wells by the use of pumps. In the initial emergency, any kind of pump may be used, such as a boat-bailing pump or a hand operated water well pump. As soon as possible, however, a standard well pump should normally be installed. Discharge capacities range from a few to about 100 gallons per minute, depending on pump size, casing diameter, and depth. Most such pumps require 5 or 6 inch casing. Submersible pumps, though highly efficient, should be used with caution since some types burn out quickly if operated dry. For depths to about 25 feet, gasoline powered suction pumps are suitable for extended use and are widely available.

High speed, rotary pumps should be avoided when pumping combinations of oil and water. They tend to encourage formation of oil water emulsions which complicate separation at the surface.

The effects of well pumping from different depths are shown in

Figures 10-9A and B. The contaminated soil is relatively permeable, and the oil has migrated to the water table and spread there as a pancake. In Figure 10-9A, Well A does not extend into the pancake and pumping will recover a small and insignificant amount of the oil that is migrating to the water table. Well B extends into the pancake and will produce oil from it initially, but the flow will fall quickly to a very low rate. The pancake is too thin to permit effective direct recovery. Well C extends into the water table. It will produce water at first, but soon will begin to recover the floating oil as the fluid at the top of the water table is drawn down to the pump (Figure 10-9B).

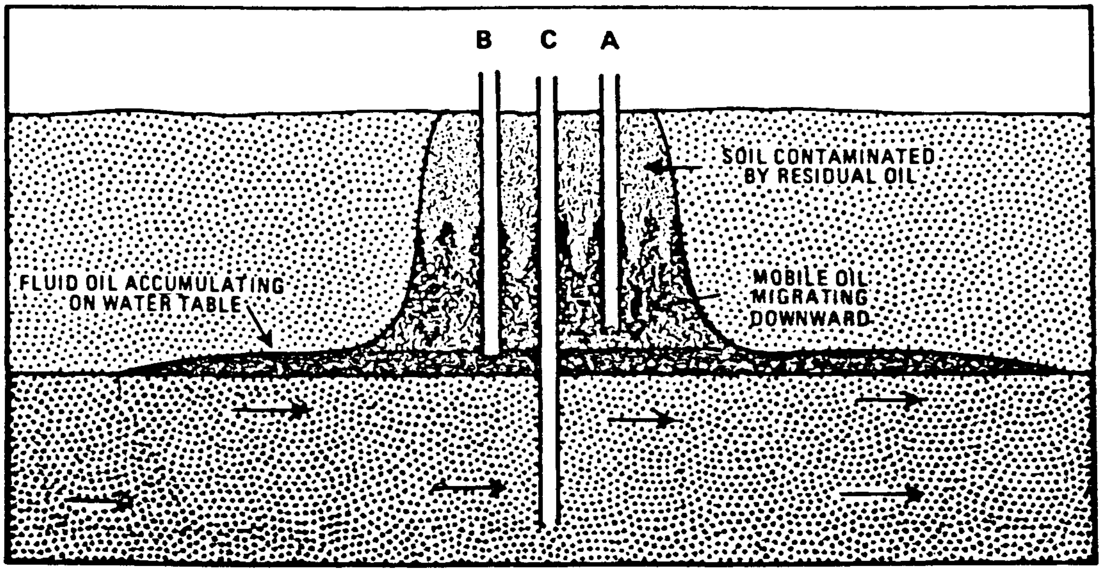


Figure 10-9A: Typical Conditions During Latter Stage of Migration of Oil to Water Table

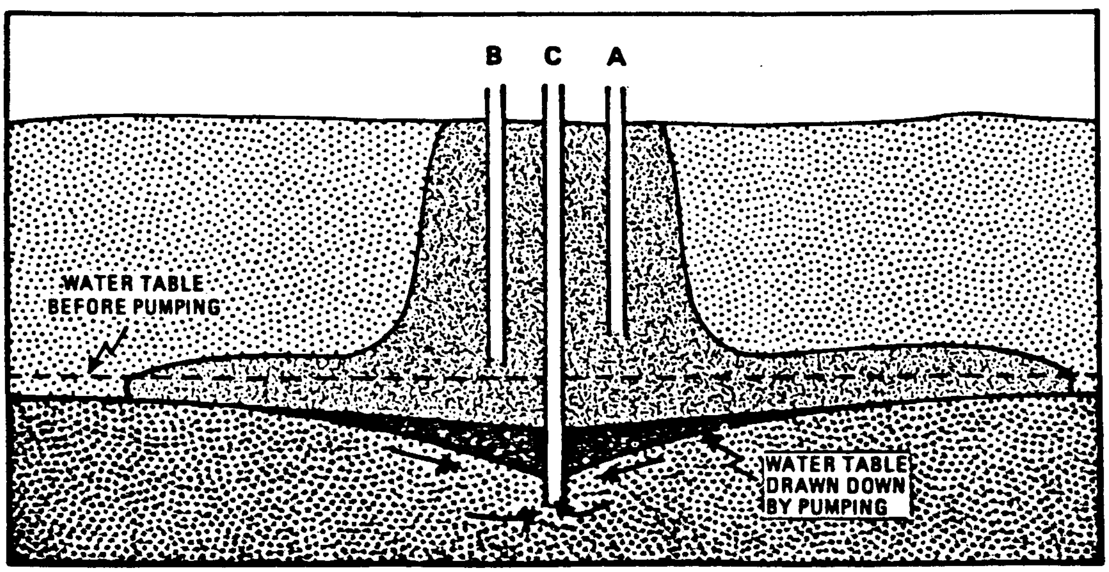


Figure 10-9B: Effect on Water Table of Pumping from Well C

The water table is lowered at the withdrawal point of Well C because water is removed faster than the soil's permeability allows it to be replenished. Both water and oil from the pancake are then drawn toward Well C by the pressure differential. Water must be pumped from Well C fast enough to create a depression cone that extends beyond the oil pancake and is deep enough to reverse the natural gradient of the water table. The oil will thus be prevented from flowing with ground water away from the withdrawal point. With large spills, several wells may be required to depress the water table adequately over the necessary area.

Since permeability varies infinitely, no quantitative standards exist that apply to the depression-forming process in all areas. Figure 10-10 shows the development of an actual depression cone (Figure 10-10A) in an aquifer test near Saratoga Springs, N.Y. Precise selected data from the test are shown in Figure 10-10B. The aquifer was 75 feet thick and consisted of fine to coarse, silty sand of moderately high permeability. It can be seen that the cone develops rapidly at first, then spreads with decreasing speed.

When enough data are available on an aquifer, the behavior of the depression cone some distance from the producing well can be calculated quite accurately. Within 100 to 200 feet of the well, however, local heterogeneities in the aquifer make such calculations unreliable. A standard procedure is to sink two or three monitor wells in one or more straight lines away from the production well. By observing fluid levels in these wells, the exact time and amount of drawdown can be determined. From these data the further expansion of the depression cone can be predicted. Withdrawal rates should be adjusted, ideally, to maintain a cone large enough only to contain the oil. Creation of an unnecessarily large cone results in production of a large volume of uncontaminated water from beyond the area of the spill.

The average depression cone actually is much shallower than is suggested by Figure 10-10B (in which horizontal distances are in feet and vertical distances in inches). If the water table is horizontal, a shallow depression normally will suffice to confine the floating oil. If the water table is inclined, which it usually is, the cone must be deep enough to reverse the resulting gradient. The point at which the reveal occurs is the water table "divide". If the oil is to be contained effectively, the divide must lie beyond the contaminated area (Figure 10-11).

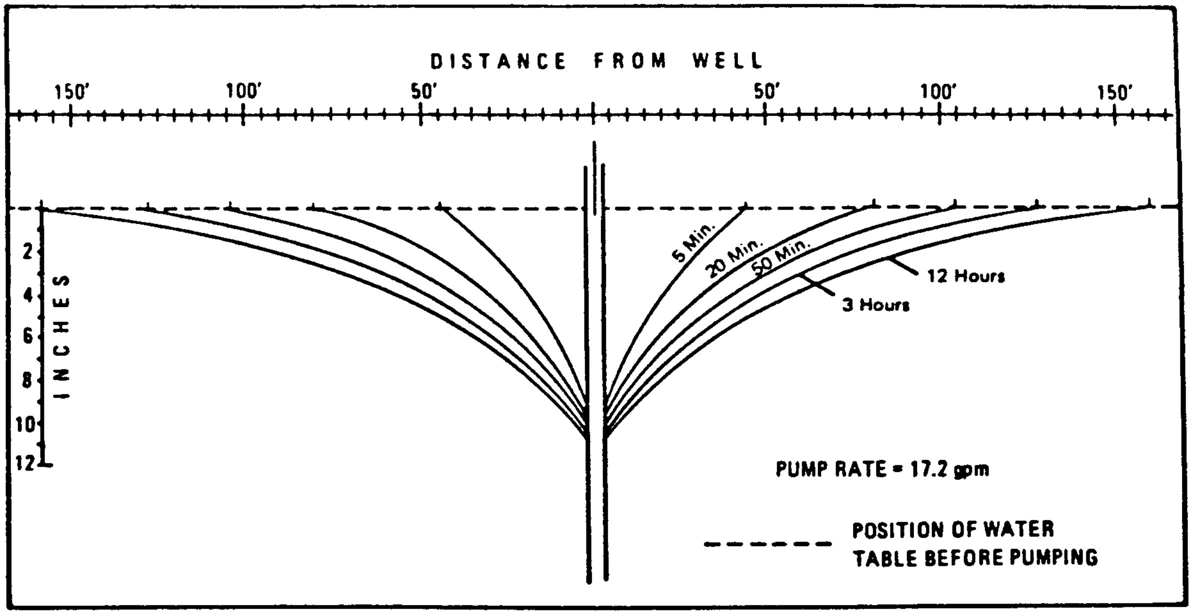


Figure 10-10A: Diagrammatic Illustration of Development of a Cone of Depression Based on an Actual Aquifer Test. Scale is Approximate. For Precise Data Plot, See Figure 10-10B.

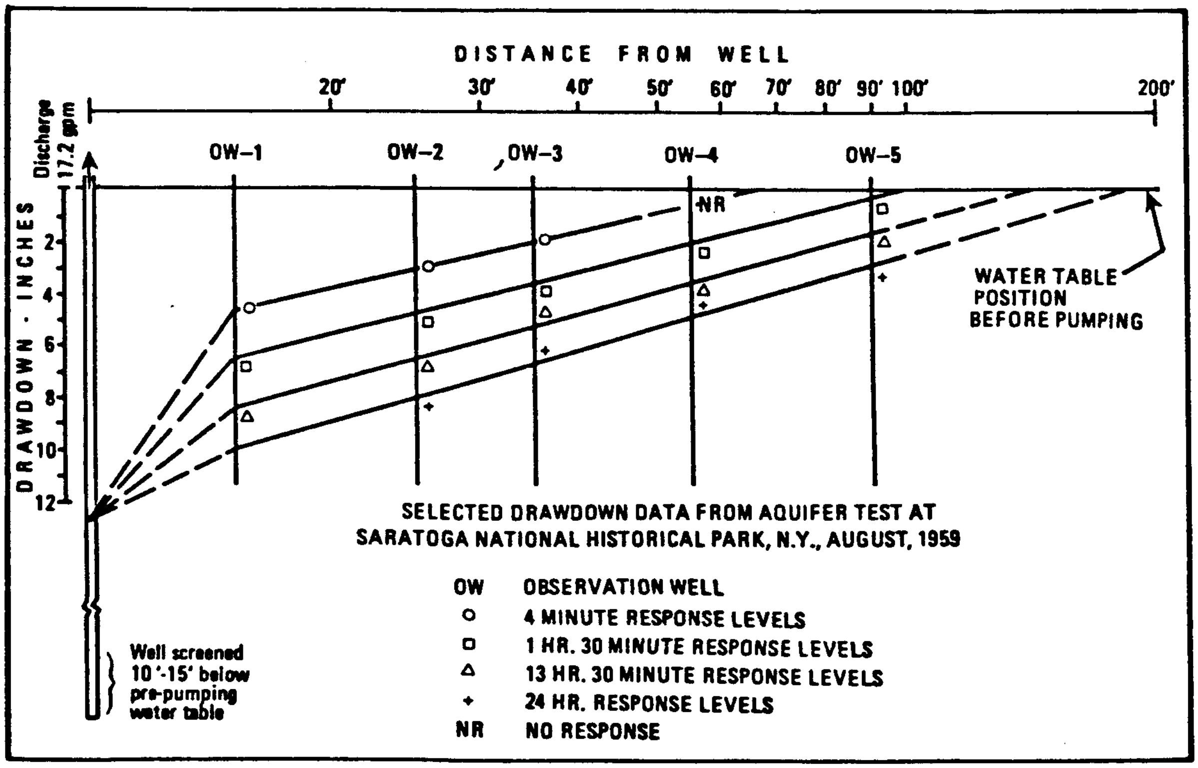


Figure 10-10B: Selected Drawdown Data for an Aquifer Test

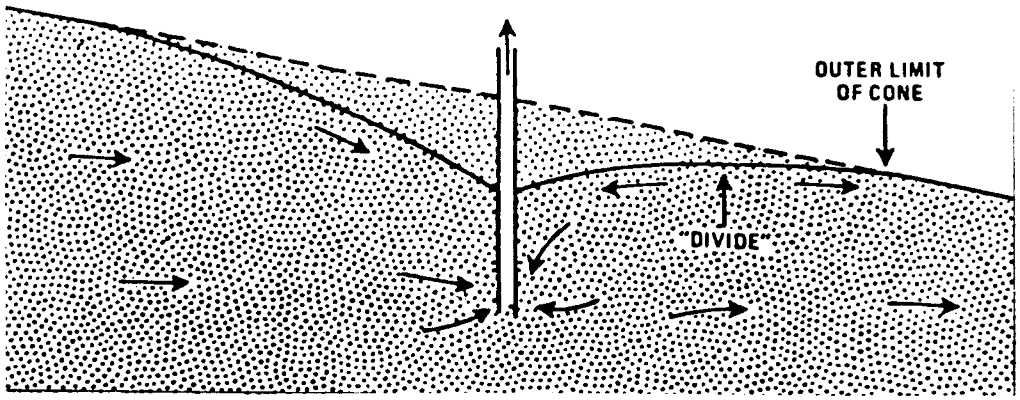


Figure 10-11: Drawdown Configuration of Well Pumping From Inclined Water Table. Fluid at the surface of the water table between the divide and outer limit of cone will not be trapped, but will move down gradient with the water.

The data of Figure 10-10 may not be precisely applicable to any other area. However, the data demonstrates that in a good aquifer a depression cone of considerable extent can probably be created in a matter of minutes or hours. This is enough time in most cases to install a recovery system before the oil can be carried out of reach by moving ground water. The importance of the drawdown in relation to the gradient must also be kept in mind. The complexities described here and others not covered indicate the advisability of securing professional counsel.

Although a depression cone can be maintained by pumping from far below the surface of the water table, floating oil will not be recovered unless the surface is drawn down to the withdrawal point. It is thus more effective to use two pumps instead of one. The larger pump is used to maintain the depression, while the smaller is arranged to pump the oil from the surface of the water (Figure 10-12). This method tends also to minimize the volume of fluid that must be separated at the surface.

Depending on the seriousness of the spill, pumping may be required for weeks or months. Ideally, pumping should be continued through several fluctuations of the water table and abandoned only after the contamination has been reduced to an acceptable level.

Recovery wells must be operated until the aquifer is no longer threatened by oil leached from the soil by percolating surface water. It may be possible to speed the leaching process by irrigating or flooding the soil above the contaminated zone, thus vastly increasing the volume of percolating water. Another approach that has been suggested is "miscible drive" by a harmless, water-insoluble oil, such as a purely paraffinic hydrocarbon.

This material, being miscible with the contaminant, would dissolve and extract it more quickly and completely than water. Left behind in the soil would be a harmless residue of the extracting oil to be consumed by natural processes. Should such exotic processes be indicated, they should be planned carefully by qualified people and be acceptable to EPA and local pollution control authorities.

Water produced from an oil contaminated reservoir may contain both fluid and dissolved petroleum products. They must be removed before the water is allowed to return to the ground water. Oily fluids can be removed from the water by a gravity separator as discussed in Chapter 7.

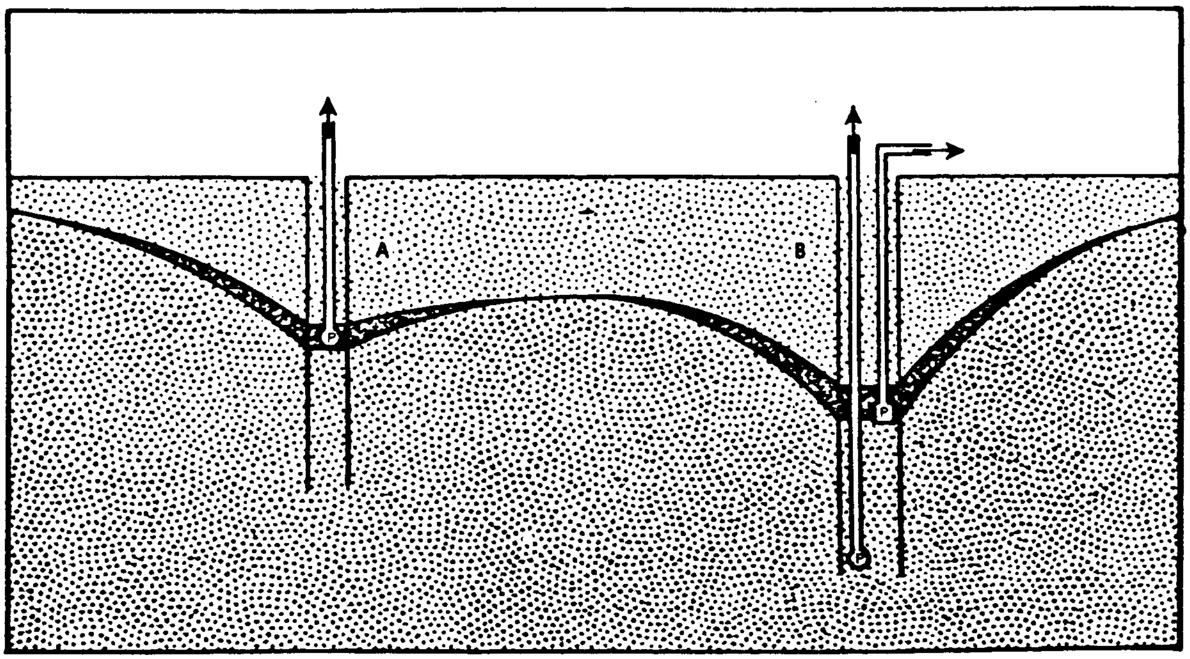


Figure 10-12: Well A is Maintaining Depression and Recovering Oil in Single Operation by Drawing Fluid Surface Down to Pump Level. Well B is maintaining depression by pumping clean water from below water table. Floating oil is recovered by suction pump at fluid surface.

10.6 **Soil Washing:** In suitable conditions, much oil can be recovered from loose, excavated soil by water washing with a high pressure hose. The soil can be placed on the edge of a pit and washed into the pit with a fire hose. The oil floats to the surface of the resulting pond and can be skimmed off.

This procedure might also be used "on-site." The contaminated soil would be excavated to form a pit, which then would be lined with an impermeable material such as plastic sheeting or clay. The soil could be washed back into the pit and the oil skimmed off. This approach would reduce trucking costs greatly.

CHAPTER XI
OIL DISPOSAL

11. RECLAMATION: Once an oil spill has been contained and harvested, the next step in completing the job is the disposal of the harvested material in a satisfactory and approved manner. This can be accomplished by using one or a combination of four basic disposal methods:

- o Transport to oil reclamation centers
- o Burning on site or at preselected burning pits, incinerators, or generating stations
- o Burial on site or at approved distant sites
- o Landfarming at approved sites

Prior to determining which method of waste disposal should be used, local and state authorities should be consulted as to possible restrictions and special sites that may be available. In addition, any insulating oil which is to be disposed of should be tested for PCB concentration levels and should be disposed of accordingly (see EPA regulations 40 CFR, Part 761, for further details of PCB disposal).

11.1 <u>Burning</u>: In addition to state regulations, local governments have adopted regulations concerning open pit burning and incineration. Therefore, thorough knowledge of the local and state laws is a prerequisite to consideration of burning a recovered oil spill, whether debris-laden or not. In any event, permits must be obtained where required.

When possible, burning a recovered oil spill with accompanying debris near the site of cleanup is preferable to using distant sites because the recovered oil may be more volatile during the early stages and will burn more efficiently, with less ash or residue. Transportation costs and the risk of further damage to the environment will also be reduced from possible spillage along the route. Such onsite burning should be done sufficiently distant from any area that may be used for human, animal or feed occupancy. Burning should be done only when and where prevailing winds will carry the smoke over the least inhabited area.

Burning any accumulation of oil or oily debris should be monitored at all times by personnel experienced in the behavior of open fires. Proper equipment should be at the burn sites to control the burn and extinguish it if necessary. Local municipal or volunteer fire departments can provide the experienced personnel and equipment.

Open pit burning of free and relatively clean oil will normally leave very little residue; however, a debris-laden oil will not burn with such efficiency, leaving a significant amount of unburned trash along with some ash. This can be buried readily if a pit has been provided. Therefore, when oily debris is to be burned, a pit deep enough to hold the residue should be dug at a suitable location where burial can be accomplished by simply backfilling the hole.

11.2 <u>Incineration</u>: Incineration is the least polluting method of burning. It is, however, the most costly, not readily available, and requires preparation of the material into a form which can be fed into the incinerator. The cost of incineration, including transport to the incinerator, can be equal or greater than all other costs of a cleanup operation. Therefore, before employing this system of disposal, carefully consider the alternatives. However, existing regulations may leave no other alternative. Some type of acceptable incineration is available in major metropolitan areas, but not usually in the rest of the nation. For these remote areas, incineration would require long transport of the waste to such a site.

Incinerators vary in size and shape and will only receive material in a certain form. Therefore, if incineration is to be used, the material will have to be prepared in the right form for incineration. Trash grinding machines which may be necessary may not be available.

11.3 <u>Generating Station Disposal</u>: An alternative to formal incineration, which is far less costly, is the burning of this oil laden soil, debris, and absorbent material in coal generating station boilers. This material should be spread over the coal pile in thin layers to insure complete combustion. Care should be exercised, as discussed previously, to insure that the size and shape of the materials being disposed of will not interfere with the operation of the conveyor system and pulverizers. This system of disposal should work particularly well in areas where lignite coal is the primary energy source.

11.4 <u>Burial</u>: Burial of recovered oil, debris laden or not, should not be done indiscriminately. In most states, burial must be at an approved site. Sanitary landfills, industrial disposal sites, and/or fly ash disposal sites will usually be able to handle small amounts of oil wastes. For burying large volumes of oil material, a special site may have to be selected, approved and constructed (which usually means great expense). In obtaining the use of specified burial sites, a number of factors must be considered.

For any burial site considered, oily waste disposal must be compatible with surrounding land uses. Residential, recreational, or industrial sites nearby may preclude the use of an otherwise ideal site. On the other hand, it might be less difficult to find an approved site near such areas. The use of prime agricultural or potential residential land cannot be automatically discounted since it may be the only site that is finally approved.

A most important factor in narrowing site choices is the suitability of the land for oily waste burial. The site's characteristics <u>must not allow</u> the buried oil to become a source of ground or surface water pollution (see Chapter 10). Soil conditions, subsurface hydrology, geologic structure, and surface topography all must be considered in deciding upon the suitability of a site.

Soil conditions will determine the potential migration--upward, downward, or laterally--of the buried oil. A loose, unconsolidated sand or gravel bed in a potential site area would not be suitable, especially in high rainfall areas. Oil can migrate in any direction in this type of soil. A loosely packed backfill can permit upward percolation and surface exposure. Heavy rainfall would accentuate the rise to the surface. Oil in earthen pits has been known to migrate upwards by either capillary action or by a rise in water level. This oil can contaminate the surface area of the pit, and, to a lesser degree, the soil a good distance from the pit. This could well condemn the use of that portion of land for many years to come.

Obviously, selection of a suitable site for burial of oily wastes requires specialized knowledge, which is best obtained from engineers and scientists familiar with a particular area.

Once the suitability of potential sites has been determined, another factor will affect whether the site selected is in a rural, agricultural or a higher density area - landowner, public and/or governmental agency opposition to the use of the site for oily waste burial. Selection and approval of a burial site ultimately may be made after a series of compromises among the various opposing interests.

11.5 **<u>Land Spreading (Land Farming)</u>:** This is the term given to disposal of oil or oily debris by mixing it with soil to promote aerobic degradation. Land farming is the most sophisticated method of disposing of oily waste or debris. Many variables must be carefully reviewed before undertaking a land farm operation.

Site selection is the first prerequisite. The larger the volume of oil for disposal or the greater the oil concentration, the more land area will be needed. Depth of suitable soil plays a role. The deeper the farming, the less surface area is required.

The type of oily waste or oily debris, along with the physical and chemical properties of the oil need to be known to determine the soil's suitability and compatibility with the oil. Major errors or oversights here could result in causing damage instead of alleviating a problem.

Once compatibility of the oily debris and soil has been established by local experts, preparing the soil and stockpiling the waste for burial can proceed. This requires proper and adequate equipment as well as experienced operators.

Preparing the soil is not an easy task. It is recommended that brush and rocks 6 inches or more in diameter be removed as they inhibit proper soil/oil mixing. The site should be leveled to a 1 or 2 percent grade. The soil should be scarified 1 to 2 inches in a cold climate, or 3 to 4 inches in warmer climates. It may be necessary to add soil nutrients to support the growth of hydrocarbon-consuming microbes.

The oily waste of debris must be prepared and stockpiled near the land farm site. It is recommended that it be spread over the scarified soil to a thickness of no more than 5 inches. Rototillers, harrows, discs, etc., can be used to mix the oily debris and soil to depths of 4 to 5 inches. Tilling the mixed elements can then follow using normal agricultural procedures. It may be necessary to periodically remix the soil and debris to aereate the material and induce biodegradation. Some sites have been known to require plowing every 2 to 4 months. Once no oil is visible after remixing, the process can be considered complete and successful. Revegetation can then follow.

Land farming may indeed be the answer for disposal of certain oily wastes and debris. It should not be undertaken without guidance from those experienced in the process, approval from regulatory agencies (State or Federal), and finally, with the aid of a specialist knowledgeable of the local soils and conditions.

CHAPTER XII
SPCC HYPOTHETICAL EXAMPLE

12. Hypothetical Example: The following SPCC plan was created as an illustration for instructional purposes. The oil retention method and cleanup procedures used in this plan should not be construed as the best or only method available but are intended to illustrate the engineering decisions which must be made for each and every electrical facility.

Note, that even though oil retention and cleanup procedures are both included in this plan, the EPA regulations only require that a plan discuss either preventive techniques utilized or cleanup procedures to be used at a particular installation. The inclusion of both methods in this plan provides a better understanding of the alternatives available.

SPILL PREVENTION CONTROL AND COUNTERMEASURE PLAN

FOR

LEE'S LANDING SUBSTATION

PREPARED BY:
Substation Design Section
Penn West Cooperative,
Bangor, Pennsylvania 54321

CERTIFICATION

I hereby certify that I have examined the facility, and being familiar with the provisions of 40 CFR, Part 112, attest that this spill prevention control and countermeasure plan has been prepared in accordance with good engineering practices.

____
Printed name of registered professional engineer

____
Signature of registered professional engineer

Date __________ Registration No. _________________ State ______

____
Approval of cooperative manager to implement plan

REVISIONS

DATE __________ Reason ___________________ Signature ___________

DEFINITIONS

<u>SPILL EVENT</u> - A discharge of oil into or upon navigable waters or adjoining shorelines in a quantity sufficient to cause an oil slick or sheen on the surface of the water.

<u>OIL</u> - Oil of any kind or in any form including, but not limited to, petroleum products, fuel oil, sludge, oil refuse, or oil mixed with water.

<u>DISCHARGE</u> - Includes, but is not limited to, spilling, leaking, pumping, pouring, omitting, emptying, or dumping.

<u>NAVIGABLE WATERS</u> - For practical purposes, these include every stream or waterway in the United States.

I. Introduction

Regulations issued by the U. S. Environmental Protection Agency which became effective January 10, 1974, require that owners or operators of nontransportation related facilities engaged in drilling, producing, gathering, storing, processing, refining, transferring, distributing, or consuming oil or oil products which could reasonably be expected to discharge oil in harmful quantities into or upon the navigable waters of the United States or adjoining shorelines, shall prepare a spill prevention control and countermeasure plan.

The regulation requirements and guidelines for preparation of SPCC plans are set forth in EPA Regulation 40 CFR 112, "Oil Pollution Prevention, Nontransportation Related Onshore and Offshore Facilities," and have been followed in the preparation of this document.

II. General

Penn West Cooperative owns and operates electric transmission and/or distribution systems in four counties in the State of Pennsylvania. Operation of these systems within the realm of technological and economic feasibility requires the use of relatively large autotransformers, power transformers, regulators, and oil circuit breakers that are filled with highly refined, contamination-free oil for the purpose of providing insulation between electrically energized internal parts. The insulating oil in each of these devices is vital to its continued performance as an essential link in our electrical system. For this reason, precautions are being taken to assure that insulating oil is maintained at the proper level in each of these devices.

Past operating history of oil-filled electrical devices, both on our system and industry wide, indicates that the probability of an oil spill of such a magnitude or of a close enough proximity as to cause damage to U.S. waters or shores is extremely remote. In fact, a recent IEEE study of the seriousness of the oil spill problem at electrical substations concludes that the probability of an oil discharge is less than one discharge for each 1,200 pieces of equipment in service or .08 percent.

This remote probability of an oil leak from electrical facilities is the result of equipment-design and operation-maintenance procedures and the frequent routine inspections of all substation equipment by personnel to detect oil leaks before they become significant. Continual loss of oil in one of these devices (approximately 10 percent) results in an electrical failure of the device. This failure would be detected almost instantaneously by the resulting loss of electric service. Response to this loss of service would be the immediate dispatch of maintenance personnel to the substation, who would then perform all tasks necessary to contain and clean up any possible spill in accordance with the procedure outlined in this SPCC plan.

III. <u>Policy</u>

An accidental oil release from electrical apparatus may carry serious consequences to our cooperative even though it may not be in the proximity of navigable waters. Damage suits, legal fees and cleanup expenses arising from oil releases onto neighboring properties could have a costly impact not only financially but also in our ability to obtain zoning and other permits. Our cooperative is firmly committed to maintaining goodwill to our customers and in protecting the environment.

Each outdoor substation and switching station will be evaluated by qualified and responsible engineers to select the safeguards which are commensurate with the risk of potential oil releases. The facility's design has included several devices or systems which include ditches, swales, berms, containment pits (which may or may not be lined with impervious materials), weirs or oil separators, and spill diversion and retention ponds.

The method of retention selected will be dependent on many factors to include:

1. Engineering and operating practices (i.e., electrical fault protection, loading practices, switching operations, test and maintenance program).

2. Quantities of oil within apparatus.

3. Station layout (i.e., special arrangement, proximity to property lines, streams and other bodies of water).

4. Station topography and site preparation (i.e., slope, soil conditions, groundwater level, ground cover).

IV. Operating History

Penn West Cooperative has experienced three oil spill events from substation transformers and oil circuit breakers in the past 25 years. One spill occurred as a result of vandalism, one as a result of a transformer failure, and another spill occurred during the filling operation of an oil circuit breaker.

On October 3, 1980, approximately 1,000 gallons of transformer insulating oil was discharged from a hole blown into a transformer cooling fin at the Bunter Substation. This hole was a result of a 30 caliber rifle shot from an unknown source which led to approximately 75 gallons entering nearby Tinkers Creek. Virtually all of the oil was recovered at the substation site and one-half mile below the point of the oil entrance into the creek by the use of vacuum trucks and absorbent materials. The recovered oil was transported to a nearby generating station for disposal by mixing with boiler fuel.

The second transformer spill occurred on August 13, 1981, at Woodbine Substation when a 10 MVA power transformer containing 2,100 gallons of oil had an electrical failure. The failure caused 3 oil pipe couplings to open when the pressure relief system failed to operate. Approximately 1,600 gallons of transil oil was discharged into the adjacent stone and cable trench conduit system inside the station yard. Most of the oil was recovered by tank trucks from the cable trench conduit system, and the remainder of the oil was removed by digging up and disposing of oil-soaked stone and earth.

The latest substation oil spill occurred on May 3, 1985, during the construction of the Clinton Substation. During the filling of the 69 kV oil circuit breakers, one of the filling lines broke as a result of negligence on the part of the construction contractor. Approximately 20 gallons of insulating oil were discharged into the breaker containment pit with virtually all the oil being reclaimed.

Penn West Cooperative
Lee's Landing Substation, SPCC Plan

The following specific SPCC plan for Lee's Landing 69/115 kV Substation is a supplement to the general SPCC plan applicable to all Penn West Substations.

Substation Location

The substation is located in Chan County, Pine Creek Township, along State Road 23, and approximately one quarter mile east of the intersection of State Road 23 and U.S. 276. The substation is set on predominantly hilly ground and is located approximately 200 feet from the Machodoc River.

Drawings LD-1 and LD-2 show the location of the substation in relation to the river and the substation drainage pattern.

History of Leaks and Spills

Since the construction of the Lee's Landing Substation in 1973, there have been no oil spill problems.

Detection of Spills

Any appreciable loss of oil will result in an electrical failure of that piece of equipment. Electrical failure would result in customer calls being made to the Penn West trouble dispatcher (215-555-6712) which is manned 24 hours a day. Maintenance personnel would be immediately dispatched to the station to determine the cause of failure and take corrective steps, including the control of any oil spill which may have occurred.

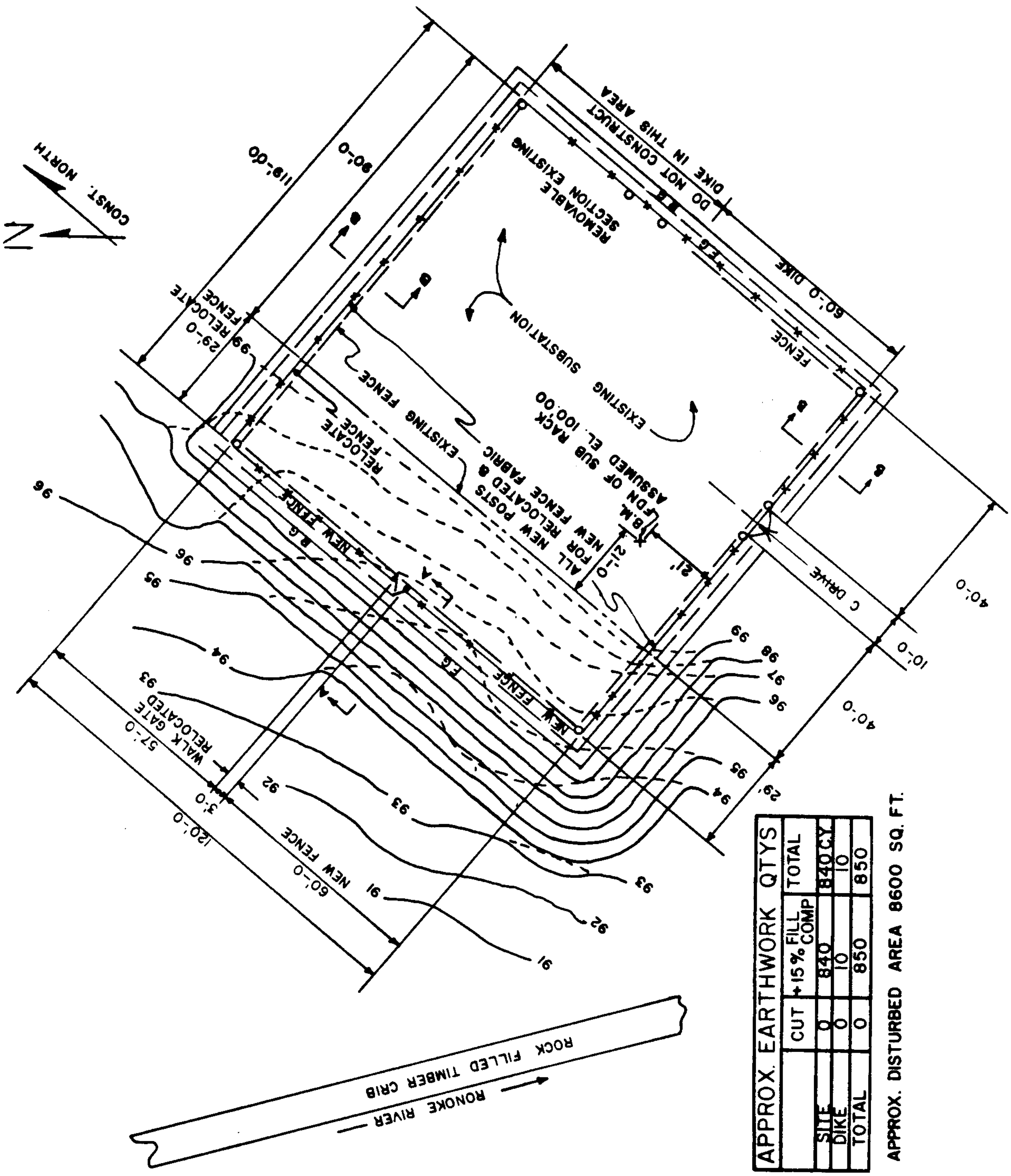
Small and slow leaks would be detected and corrected during routine station and maintenance inspections which are conducted at least monthly.

Access Control

In order to prevent unauthorized access, the entire substation facility is surrounded by a 7-foot high chain link fence topped with 3 strands of barbed wire. All gates are securely locked. The fence and gates are conspicuously marked with posted signs as a warning to intruders that they are trespassing on private property where dangerous high-voltage equipment is located. Operating handles will be removed from all valves located on oil-filled equipment as a precaution against unauthorized operation. Photoelectric controlled lighting is installed for night security as well as for maintenance and operational purposes.

Potential Equipment Failure

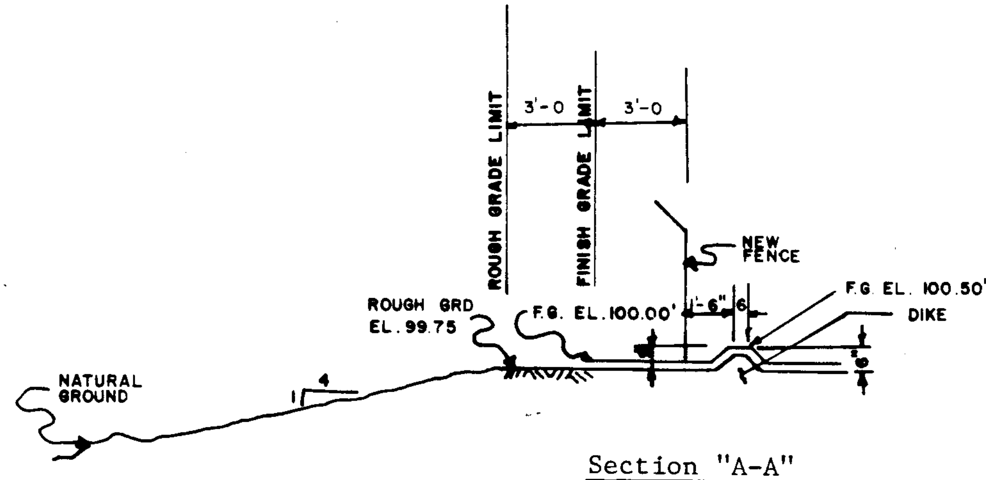
See Drawing No. LD-3 for number and relative position of oil-filled equipment.



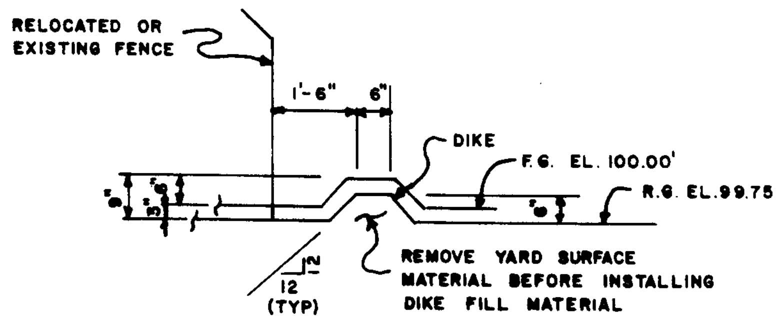
APPROX. EARTHWORK QTYS			
	CUT	+15% FILL COMP	TOTAL
SITE	0	840	840 C.Y.
DIKE	0	10	10
TOTAL	0	850	850

APPROX. DISTURBED AREA 8600 SQ. FT.

DRAWING LD-1



Section "A-A"



Section "B-B"

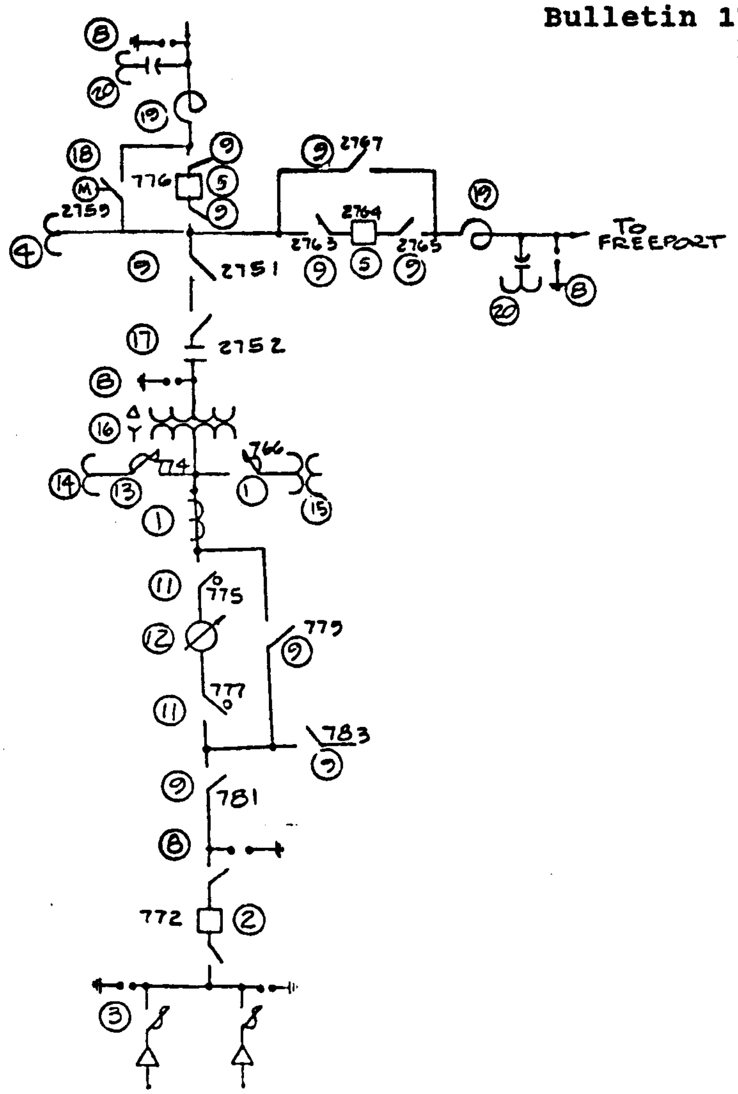
LEGEND

PROPOSED CONTOUR LINE ___________

EXISTING CONTOUR LINE _ _ _ _ _ _

(Elev. based on 1975 survey data.)

DRAWING LD-2



NO.	DESCRIPTION
1	3 CURRENT TRANSFORMERS 400:5
2	15 kV OIL CIRCUIT BREAKERS
3	FUSE
4	2 POTENTIAL TRANSFORMERS 120:1
5	OCB POWER CIRCUIT BREAKER/DISC. DEVICE
6	3 ø 75 kVA STA. SERV. TRANSFORMER
7	FUSE 10 A
8	LIGHTNING ARRESTER
9	3 PST GOAB SWITCH
10	3 PT'S 60:1
11	1 PST HOOK STICK SWITCH
12	3-1 ø VolTAGE REGULATORS (333 kVA)
13	FUSE
14	1 PT 60:1
15	15 kVA STA. SERV. TRANSFORMER
16	3-1 ø 3333 kVA POWER TRANSFORMER
17	CIRCUIT SWITCHER
18	MOTOR-OPERATED AIR BREAK SWITCH
19	IN-LINE WAVE TRAP
20	CCPT

DRAWING LD-3

Equipment	Type of Failure	Total Qty. of Oil	Direction
3-10 Power Transformers	Tank Rupture	1700 gal. ea.	NW
Oil Circuit Breaker #2764	Tank Rupture	590 gal.	W
Oil Circuit Breaker #776	Tank Rupture	590 gal.	W
3-10 Voltage Regulators	Tank Rupture	190 gal. ea.	W
Oil Circuit Breaker #772	Tank Rupture	170 gal.	W
Total		7020 gal.	

The maximum volume of oil that is likely to be lost during a spill or leak event is generally assumed to be the storage capacity of the largest piece of equipment located on the property (or 1700 gallons). The probalility of multi-equipment failures is very remote and the expenses incurred in designing for such catastrophic failures are not justified at this station.

Substation Containment

The method of containment selected for Lee's Landing Substation was predominantly based on the relative location of the substation to the Machodoc River and the topographical drainage of the site.

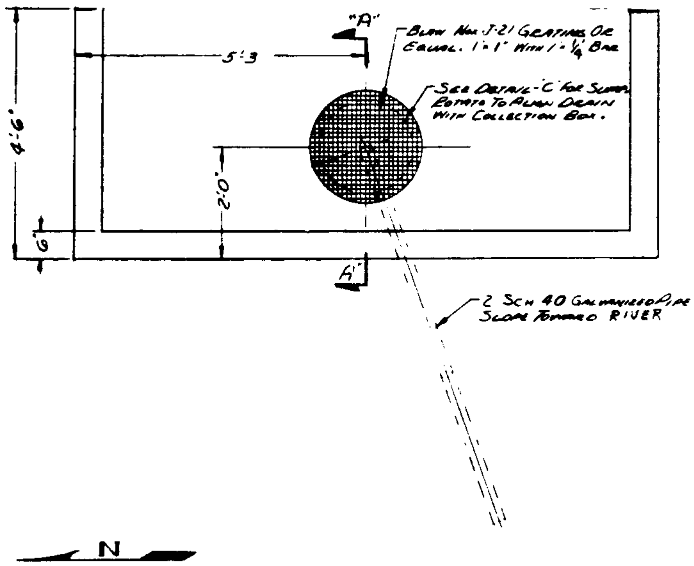
Due to the relative porous subsoil in this area, the top 6 inches of the berm and the substation yard are made up of a mixture of bentonite clay (coefficient of permeability $K\text{-}10^{-6}$ cm/sec) and the existing soil. This mixture will prevent any spilled insulating oil from leaking into the water table and the Machodoc River.

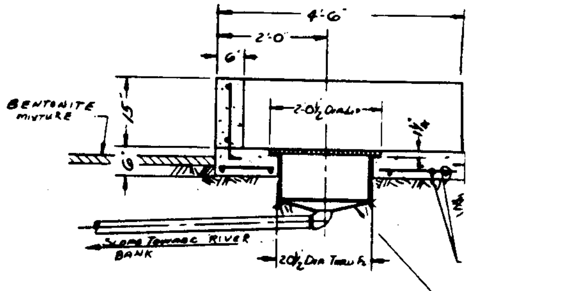
Berm construction was also chosen due to the added advantage of being able to contain the oil in temporary oil holding tanks and mobile substations which may, on some occasions, be located at the site during scheduled or unscheduled maintenance.

Due to the site's topography, rain water will drain to the west corner of the substation where it will be discharged through a 2 inch sand filter and a 7 inch bed of imbiber beads (see Drawing LD-4). Any oil which may be present in the water will be absorbed into the beads and in the event of a large spill, the beads will swell and contain the oil within the substation property.

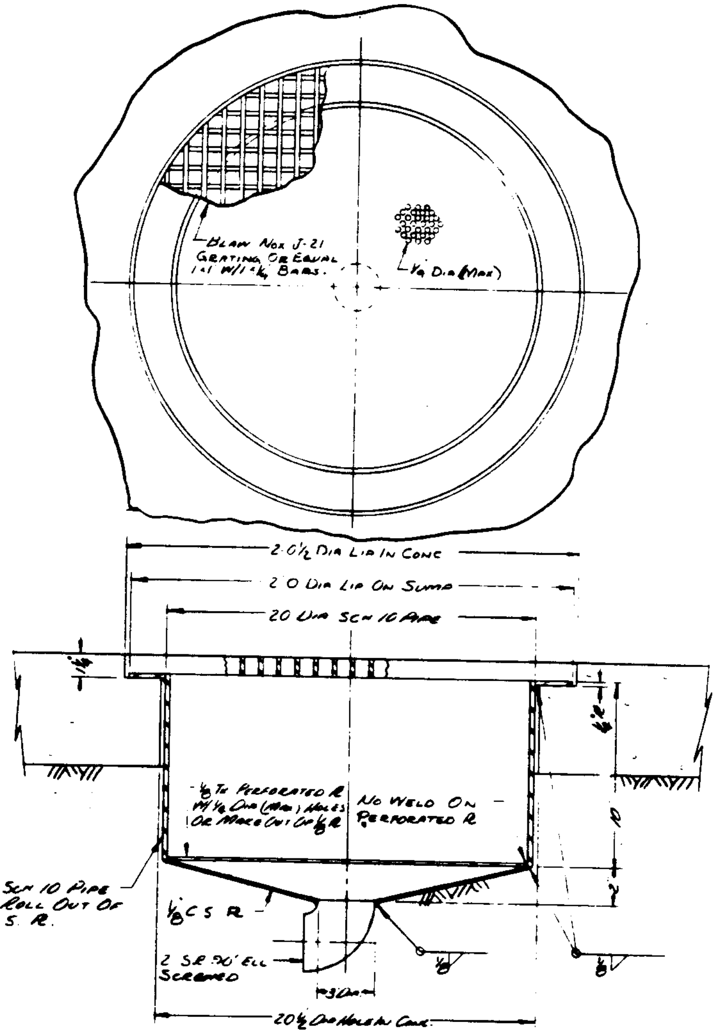
Principal Flow Path

In the event the oil overflows the berm, the oil spill will proceed downhill toward the Machodoc River. After reaching the Machodoc River, the oil will flow southward with the river for 25 miles before it combines with the Spotsylvania River. The Machodoc River is a relatively small river which meanders mostly through forest land spotted with small farms. This river is abundant in aquatic life and is popular with sports fishermen.





SECTION ~ "A-A"
SCALE ~ ⅜"=1'-0"



DETAIL ~ C, SUMP
SCALE ¼"=1"

NOTE!
1. Epoxy Coating Is To Be Applied To Inside Of Dike Wall & Floor & Inside & Outside Of Sump. Coating Is To Be Done Before Installing Sump.
2. Before Concrete Is Poured Roughen Portions Of Exist. Pad That Will Be In Contact With New Concrete & Apply Bonding Cement.
3. Concrete To Have Compressive Strength Of 3000 PSI @ 28 Days.

PLAN
SCALE ~ ¾"=1'-0

DRAWING LD-4

The Machodoc River between the Lee's Landing Substation and the Spotsylvania River has the following hydraulic properties:

Average flow rate - 2,000 cu. ft/sec.
Average flow velocity - .9 ft/sec.
Heavy rain flow velocity - 1.9 ft/sec.
Width - 15 to 35 ft.
Depth - 2 to 12 ft.

Based on the hydraulic properties of the Machodoc River, the following oil movement time table has been approximated to help in the determination of the possible oil movement under various river conditions.

Downstream Movement of Spilled Oil	Time After Spill	Stream Condition: Flood Stage	Normal Flow	Low Flow
	15 minutes	1/2 mi.	1/8 mi.	1/16 mi.
	30 minutes	3 mi.	1/2 mi.	1/8 mi.
	1 hour	4 mi.	1 mi.	1/4 mi.
	2 hours	6 mi.	1-1/2 mi.	1/2 mi.
	4 hours	8 mi.	3 mi.	3/4 mi.
	8 hours	20 mi.	4 mi.	1 mi.
	16 hours	22 mi.	6 mi.	1-1/2 mi.

Based on Penn West's available manpower, transportation time, response time, and predicted oil movement, easy to reach cleanup sites (Drawing LD-5) have been preselected to minimize lost personnel manhours and aid in the establishment of control points.

Equipment

In the event of an oil spill, Penn West Cooperative has equipment available for use in limiting the spread of oil at the Lee's Landing Substation site. Most of this equipment is always available at the Langley Warehouse 12 miles away from the substation site, phone (215) 555-1214, and can be immediately dispatched and be available on the site within 1 hour of notification. The equipment consists of the following:

1 - 2,500 gallon oil tank truck with self-contained pumping equipment

2 - backhoes and front-end loaders

5 - electric submersible sump pumps

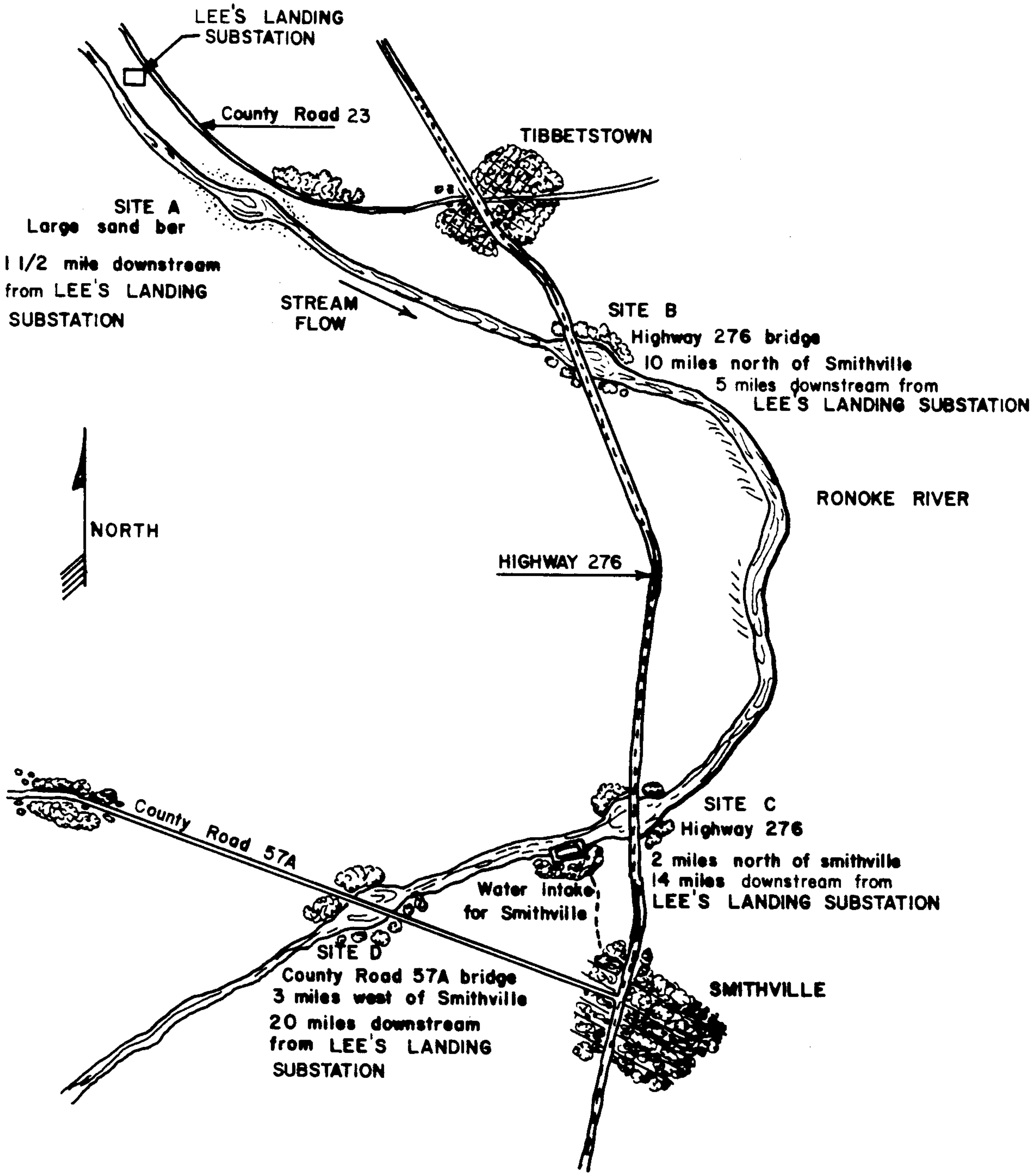
10 - 20 foot sections of booms with 12 inch skirt

15 - 10 foot sections of booms (sorbent)

Approximately seventy-five 50 gallon drums

Oil Cleanup Sites to Use Depending on River Condition and Spill Time for Lee's Landing Substation	Stream Condition	Time of Spill: Daytime	Nighttime	Weekend
	Flood State	B	C	D
	Normal Flow	A	B	B
	Low Flow	A	A	A

Site	Description	Mode of Transportation to Site
A	Large sand bar 1-1/2 miles downstream near County Road 23	Boat
B	Highway 276 bridge 10 miles north of Smithville	Pickup
C	Highway 276 bridge 2 miles north of Smithville	Pickup
D	County Road 57A 3 miles west of Smithville	Pickup



DRAWING LD-5

Absorbent materials in sufficient quantity to absorb approximately 2,000 gallons of oil including pillows, absorbent sheets, water sweeps, and rolls are stored.

Also, sand bags, lumber, utility poles, fencing, hand tools, and other necessary equipment are available. (See reference drawings - Sketches 1 and 2.)

Penn West has also made special arrangements with HRL Construction Company, Phone (215) 555-7619, to have available the following additional equipment upon request:

2 - 2 cubic yard front-end loaders

4 - backhoes

5 - tank trucks ranging in capacity from 2,500 to 5,500 gallons

lot - straw bales

If needed, one of the following professional cleanup contractors will be notified in the event that the spill exceeds the capacity that our cooperative is capable of handling (approximately 2,000 gallons):

Water Cleanup	Industrial Oil Removal	Waste Chemical Removal
P.O. Box 313	P.O. Box 6	P.O. Box 117
Portage, PA	Vienna, PA	Chaddo, PA
(215) 555-9310	(215) 555-0101	(215) 555-9370

<u>Notification and Log Keeping</u>

It is the responsibility of all cooperative employees who observe any oil spill at the Lee's Landing Substation to immediately report the following information to the dispatcher via telephone (215) 555-6712, or by two-way radio:

- Source of spill
- Estimated volume of spill in gallons
- Direction of flow
- Extent of spill within property or beyond

The dispatcher will contact the cooperative manager or designated representative who will serve as director of control and cleanup operations.

The system dispatcher will also contact the cooperative's Environmental Affairs Engineer, Mr. D. Kline, Phone (215) 555-6737, Home (215) 555-3201, who will assist with operations, and contact the following appropriate governmental agencies and/or cleanup contractors, as required:

1. U. S. Environmental Protection Agency, Oil and Hazardous Materials Section, Phone (215) 597-9800.

2. U. S. Coast Guard, (National Response Center) Phone (800) 424-8802.

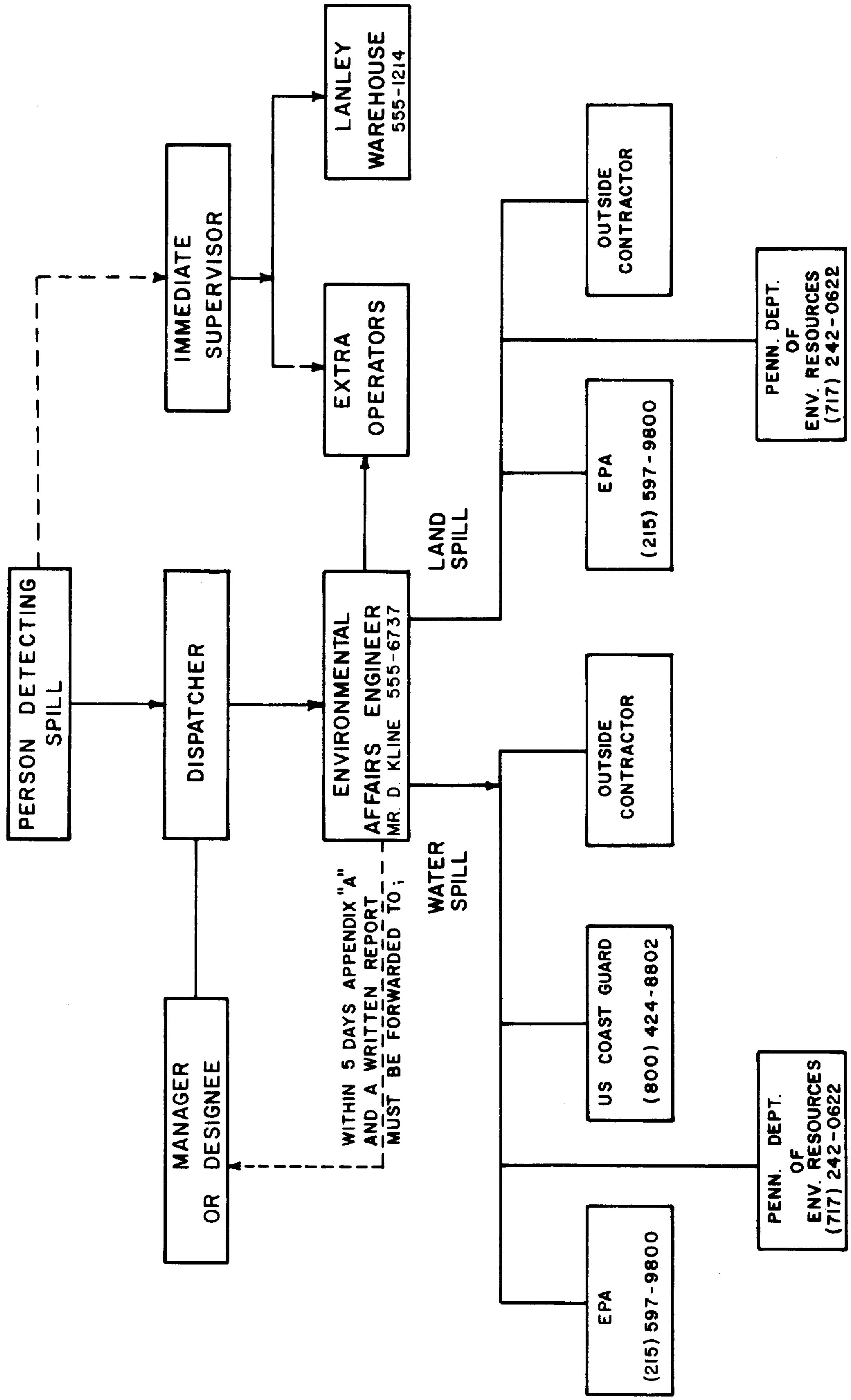
3. Pennsylvania Department of Environmental Resources, Phone (717) 242-0622.

4. Specialized Cleanup Contractor, when oil discharge is estimated to be in excess of 2,000 gallons. The recommended specialists are:

Water Cleanup	Industrial Oil Removal	Waste Chemical Removal
P. O. Box 313	P. O. Box 6	P. O. Box 117
Portage, PA	Vienna, PA	Chaddo, PA
(215) 555-9310	Business: (215) 555-0101	(215) 555-9370
	Emergency: (215) 555-0215	

The director of cleanup and control is responsible for keeping an accurate log of all events and calls relating to the oil spill by date and time, the name and position of the personnel involved in the notification, the reported and precise information, and the action taken. Notations will also be made of any unsuccessful attempts to contact parties involved. In addition, the attached notification form (forms section) will be filled out and maintained in current conditions.

OIL SPILL REPORTING PROCEDURE



Personnel Training

To promote environmental awareness, a program has been initiated for acquainting substation personnel at the worker level with the various environmental laws and regulations affecting the installation and operation of this and other facilities. With this program, the substation maintenance personnel will recognize the importance of the need for prevention and control of oil spills.

Employees specifically responsible for handling and installation of the oil are thoroughly trained as to the proper techniques that must be used to reduce the probability of an oil spill. Special emphasis is directed toward these employees since the likelihood of an oil spill is more prevalent during this handling process.

Spill prevention briefings are periodically added to monthly scheduled safety meetings to assure that all substation personnel have an adequate understanding of SPCC plans and applications. These briefings highlight and describe recent spill events or failures and newly developed precautionary measures.

Waste Disposal

Disposal of any sizable quantity of contaminants will be coordinated with the Pennsylvania Department of Environmental Resources as to the best disposal method with the least environmental impact. The method chosen will depend on many factors to include the size of spill, time of the year, amount of precipitation, and economics. The following materials may, upon approval, be disposed of as follows:

Oil and Oil-Water Solutions - Let the retrieved solution settle in drums or oil storage tanks. After settling, drain the water off the bottom of the drum or siphon off the oil. The oil can then be reprocessed if practical, or may be mixed with Monroe Generating Station No. 2 oil for burning in the boiler. In addition, line maintenance personnel may use contaminated oil in their herbicide spray program along rights-of-way.

Oil-Soaked Gravel - Drain off excess oil and dispose of gravel by hauling to an approved land-fill or by spreading on gravel roads. (An alternate to disposal of the stone is to stockpile the gravel, until such time as the rainfall runoff effluent is clean, and then reuse. The rainfall effluent during this period of storage will be collected and treated for oil.)

Oil-Soaked Ground - Dispose in approved landfill areas or can be washed. This can be done by digging a basin, lining it with plastic, and filling it with water. Oily soil is washed by dumping in the basin and skimming off the oil.

Oil-Soaked Rags - Remove excess oil, if it doesn't take too many rags. Incinerate or dispose of them in an approved landfill.

Oil-Soaked Sorbent Sheets, Remove excess oil and incinerate or dispose of them in an approved landfill: Do not store used absorbent sheets.

Oil-Soaked Sorbent Boom - Remove excess oil and dispose of booms in an approved landfill; do not store used booms.

Sequence of Events

Any employee who notes an oil spill on substation property will promptly assess the situation and take the following specific action.

1. Determine source of spill.

2. Take action to stop the source of the spill. For example, close necessary valves or temporarily plug holes to stop or limit spill.

3. Determine approximate size of spill in gallons and direction of flow.

4. Report to dispatcher who will notify cooperative manager or designated representative.

5. If oil spill has left substation property, take all steps necessary to divert oil from entering river.

6. Keep oil spill as small as possible by digging diversion ditches, by sandbagging or other means.

Containment/Cleanup

Oil spills which may be experienced at the Lee's Landing Substation can be classified into two categories: land and water. Water spills have much more serious consequences since they will migrate downstream and cause visual impact as well as ecological damage on a much larger scale. Land spills, on the other hand, are much more likely to occur without being followed by a water spill since most of the equipment located within the substation contains limited quantities of oil. The likelihood of a complete 1,700 gallon transformer discharge is very unlikely, and if it does occur, the likelihood of the spill leaving the property is remote due to the substation's berm construction.

Containment and/or cleanup operations will vary according to the nature of the spill within the substation.

A. Oil Spill on Land: Containment action must start immediately. The immediate problem with an accidental oil spill is to contain the oil, preferably within the substation.

1. Gasket Leaks (Sketch 3 under Reference Drawings): Leaks which cannot always be repaired promptly due to materials not being available or due to problems of obtaining an immediate outage can be temporarily controlled by either diverting the oil into a container or absorbing it with commercial oil sorbents.

2. Plugging Drain Tile - Pneumatic Plug (Sketch 4 under Reference-Drawings): Pneumatic plugs made of an elastomeric compound are carried on all substation maintenance trucks. These pneumatic plugs are inflated with an ordinary tire pump and will be used as a backup system to the imbiber bead catch basin. The pneumatic plug will be inserted in the downhill side of the 2 inch water outfall pipe whenever a spill has occurred or is likely to occur, or if oil transferring is anticipated.

3. Oil Spill in Substation: In the event of a large spill within substation property, poles, boards, signs, sandbags, plastic sheeting, or any other material which is readily available should be used to form a barrier or dam to contain the spread of oil within as small an area as possible. This should first be accomplished by placing these materials on the downhill side (generally west side) of the equipment and proceeding in an uphill direction to prevent the spread of oil. A Bentonite and soil mixture can then be obtained from the upper portions of the substation and compacted around the inside portion of this dam in order to prevent the oil from leaking under or through the dam. Care should be exercised to insure that the Bentonite soil mixture, directly beneath the oil, is not removed or disturbed in order to prevent leaching of the oil into the soil.

4. Berm Failure (Sketches 5, 6, and 7 of the Reference Drawings): If oil is released from the substation site as a result of a berm failure or removal of imbiber beads, effort must be made to contain the oil before it reaches the river. This will be accomplished by the construction of a temporary dam in the ravine leading into the river (Sketches 5 and 6), and/or by the digging of sump pits and trenches (Sketch 7).

   The dam may consist of plastic sheeting draped over a ditch bank support. This bank-to-bank support can be anything from a shovel to a length of pipe. Plastic sheeting will be the type normally available around construction sites used for temporary shelters. Since oil floats, holes can be poked in the bottom of the dam to let water through if rain occurs.

Plastic sheets should be placed in front of all dams, in all sump pits and trenches, and on the ground directly in front of the oil flow path to minimize the leaching of the oil into the soil and eventually into the shallow water table.

B. Land Cleanup: Each spill on land must be evaluated with regard to its size and location before deciding the best method for cleanup. Possible cleanup action is listed below.

1. Leaks (Sketch I of Reference Drawings): The most effective method of cleaning up oil from a leak is with reusable commercial oil sorbent sheets or straw. These materials may be laid directly under the leak to catch and absorb the leaking oil. Also, these materials will absorb the majority of the oil around the concrete pads. If the yard surfacing is saturated with oil, remove and replace the affected Bentonite mixture and rock. Do not remove more than 12 inches of soil because of potential damage to the ground mat. When the commercial sorbents become saturated with oil, squeeze out into a bucket and reuse the sorbent sheet. If straw is used, replace with new straw when saturated.

2. Major Oil Spills:

a. Pump Spilled Oil into Tanks (Sketch 8)

Pump standing oil or oil-water solution into oil storage tanks, tanker trucks or oil drums, or any storage vessel available. Pump or skim the spilled oil from catch basins or holes dug in the yard. If pumping oil-water solutions, it is best to use large, open vane pumps--not gear pumps. Gear pumps will emulsify the oil requiring several days for the water to settle out. For oil-water solutions, it is best to use a vacuum pump, by pulling a vacuum on a tank and sucking the oil into the tank. Float sorbent material on top of the catch basin or sand to absorb the last traces of oil leaking from the ground (Sketch 8).

b. Oil Removal from Ground Water Table (Sketches 9 and 10)

Oil which is spilled on the ground and seeps around or through the Bentonite soil will tend to seep toward the water table. Rain will tend to carry the oil into the ground, whereas snow will tend to absorb the oil spilled upon it.

There are three main methods of removing oil from the water table. The first method is to drill a well and pump the oil-water solution up (Sketch 9). A second method is done by enhancing leaching and pumping. This is done by adding water on top of the oil spill to force the oil down to the water table where it can be pumped out.

The third method is ditching and skimming downhill from the oil spill (Sketch 10).

Unusual situations which may occur, with oil spills on land are shown in Sketch 11. Oil can be spilled in one location and surface in different locations at a later time.

Sketch 12 shows how the different soils found in this area may affect oil movement.

None of the above procedures should be used without the approval of the Pennsylvania Department of Environmental Resources.

C. Water Spill Containment

This section deals with containment and cleanup of oil spills which have spread beyond the substation and are flowing towards or down the Machodoc River.

The most important thing in dealing with oil spills on water is speed. The faster the river flows, the faster the containment and cleanup must be accomplished. The higher the water temperature, the faster the oil will move. The more wind, wave action and rain, the more emulsion of the oil will occur. Oil will follow the currents. In streams, it tends to end up on the shore as debris, due to the crowning of the stream. The larger the spill, the more dispersion of the oil occurs.

Commercial oil sorbents and straw are efficient ways to handle small oil spills on water. They normally float and are highly sorbent. Availability of these sorbents can hinder speed of containment. Major oil spills which have reached the Machodoc River will most likely involve Pennsylvania State Environmental Agencies and possibly the Federal Environmental Protection Agency.

1. Drainage Ditch:

a. Solid dams if little stream or no flow (Sketch 13)

If there is little or no flow in the ravine, and if construction equipment is available, use it to form dams. Tile can be buried on an incline in the dam to maintain stream flow. If tile is not available, use PVC bus or pipe. Block tile input to maintain level behind dam so spilled oil is not passed. Plywood also makes good temporary dams. Use steel posts or pipe driven in the ravine to hold the plywood in place.

b. <u>Booms and Skimmers (Sketches 14, 15, 16, 17, 18)</u>

If the oil enters the Machodoc River, immediate steps should be taken in order to minimize the oil flow down river. Since the Machodoc River has an average flow rate of approximately .9 feet per second throughout most of the year, booms and skimmers will be well suited for use on this river.

If wood construction materials are readily available at the site, a hastily constructed boom deflector (Sketch 14) or straw skimmer (Sketches 15 and 16) can be built, and used until such time as booms (Sketch 17) and other equipment are available.

These boom deflectors can be made from such commonly available materials as utility poles, fallen trees, lumber, or barrels which may be tied or joined together and lined with straw, hay, dry grass, or commercial sorbents.

Straw skimmers may be constructed from chain link fence, reinforcing mesh, chicken wire, snow fence, fish netting, or any other suitable mesh-type material which will adequately retain the sorbent materials.

Due to the relative low average velocity (.9 ft/sec) of the river, the booms and skimmers can be placed at right angles to the river flow, from ditchbank to ditchbank, without loss of oil due to oil breakaway. If, due to heavy rain, the water flow rate is appreciably above this rate, i.e., the current will start to carry the oil under the boom or over the boom, a second or even a third boom should be placed downriver from the first.

If oil breakaway is still prevalent or in areas where the river is too wide for a barrier to be placed directly across the river, it will be necessary to deploy booms at an angle to the shoreline depending on the water current. Sketch 18 shows the relationship between the angle of deployment and current speed. The booms should be placed in a river bend or other location where stream flow carries the oil near the shore. These booms will deflect the oil toward the bank where it can be absorbed with straw, commercial oil sorbents, and/or pumped up by vacuum trucks. The bank adjacent to these booms should, if possible, be protected from oil damage by the placement of booms parallel to the shoreline.

D. Water Spill Cleanup:

For oil spills on the Machodoc River, pumping, skimming and oil sorbents are the only practical methods of retrieving the oil due to the depth and narrowness of the river. Rainbow sheens are most effectively removed by the use of commercial sorbents.

1. Pump and skim oil off the water (Sketches 19 and 20): Pump and skim up as much of the oil and oil-water solution from behind the boom as practical. As the oil is pumped, pull the boom around to keep confining the spill to as small an area as possible. After the majority of oil has been retrieved by skimmers, the remainder should be removed by sorbent materials.

2. Sorbents (Sketches 21 and 22): Sheets are one of the best forms of commercial sorbents to use. Do not use wood chips or sawdust particle sorbent materials because retrieval is difficult, if not impossible. Sanding should never be used on water to sink the oil since this method is irretrievable and illegal. Oil can be kept from contaminating a shore by unrolling a roll of commercial sorbent material at the waterline or by placing a boom parallel to the shore. Sheets of commercial sorbent material should be used on rocky shorelines. Sheets of oil-soaked sorbent material or straw can be lifted by pitchforks or hooks into a boat or at the shore directly into a retainer, garbage can, or garbage dump box. Be sure containers for sorbent material are leak-proof because a portion of the oil will leak from the sorbent material. Booms of sorbent material should be dismantled as they are pulled from the water and placed on plastic sheeting to prevent additional ground contamination.

3. Removing Rainbow Sheen and Thin Slicks

   Remove the rainbow sheen by pulling a boom across the water surface slowly. At the end of a sweep, encircle the boom and remove any large quantity of oil with sheets or pillows. To remove the final traces of the sheen, coil the boom within itself on the water surface or use sorbent sheets.

NOTIFICATION FORM

Date ______________

1. Name of Company ______________________________
2. Date of Spill ______________________________
3. Time of Spill ______________________________
4. Location of Spill ______________________________
5. Name of Receiving Body of Water ____________________
6. Material and Amount Spilled ____________ Gals. of ____________
7. Probable Source ______________________________
8. Actions Initiated to Contain or Clean Up

9. Person to Contact on Scene

   Name ____________________________

   Phone ____________________________

10. Report Initiated By

   Name ____________________________

   Title ____________________________

   Phone ____________________________

11. EPA Person Notified

   Name ____________________________ Date ______________

   Title ____________________________

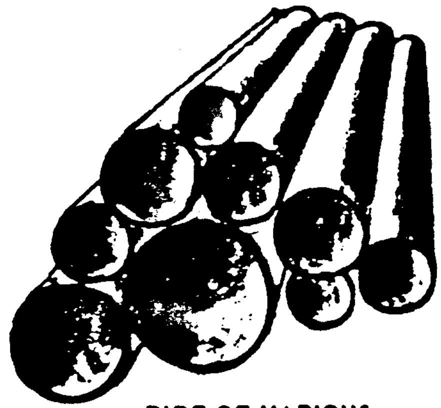
   Phone ____________________________

REFERENCE DRAWINGS

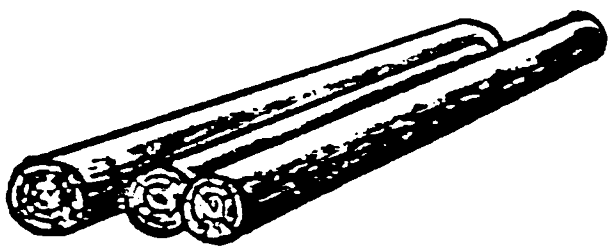
SKETCH 1

EQUIPMENT

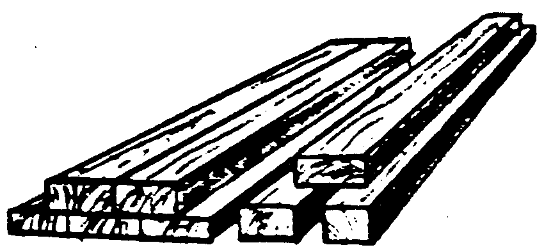
An adequate supply of hand tools and other equipment and materials should be stocked and available for immediate dispatch to the scene of an oil loss. Knowledge of the area serviced by the pipe line will dictate the specific types of equipment necessary to deal effectively with breaks which may occur. Too much emphasis cannot be directed to the importance of prompt action by trained personnel working with the proper type and amount of equipment.



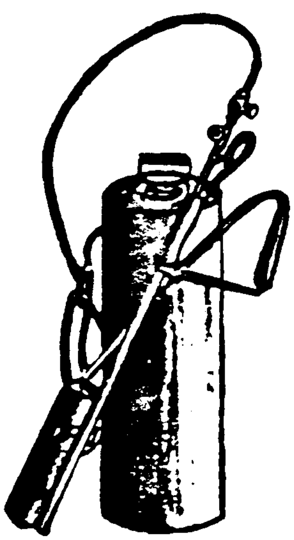
PIPE OF VARIOUS SIZES & LENGTHS



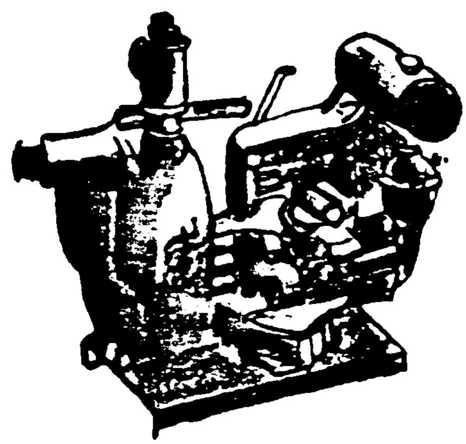
POLES OR LOGS



TIMBERS

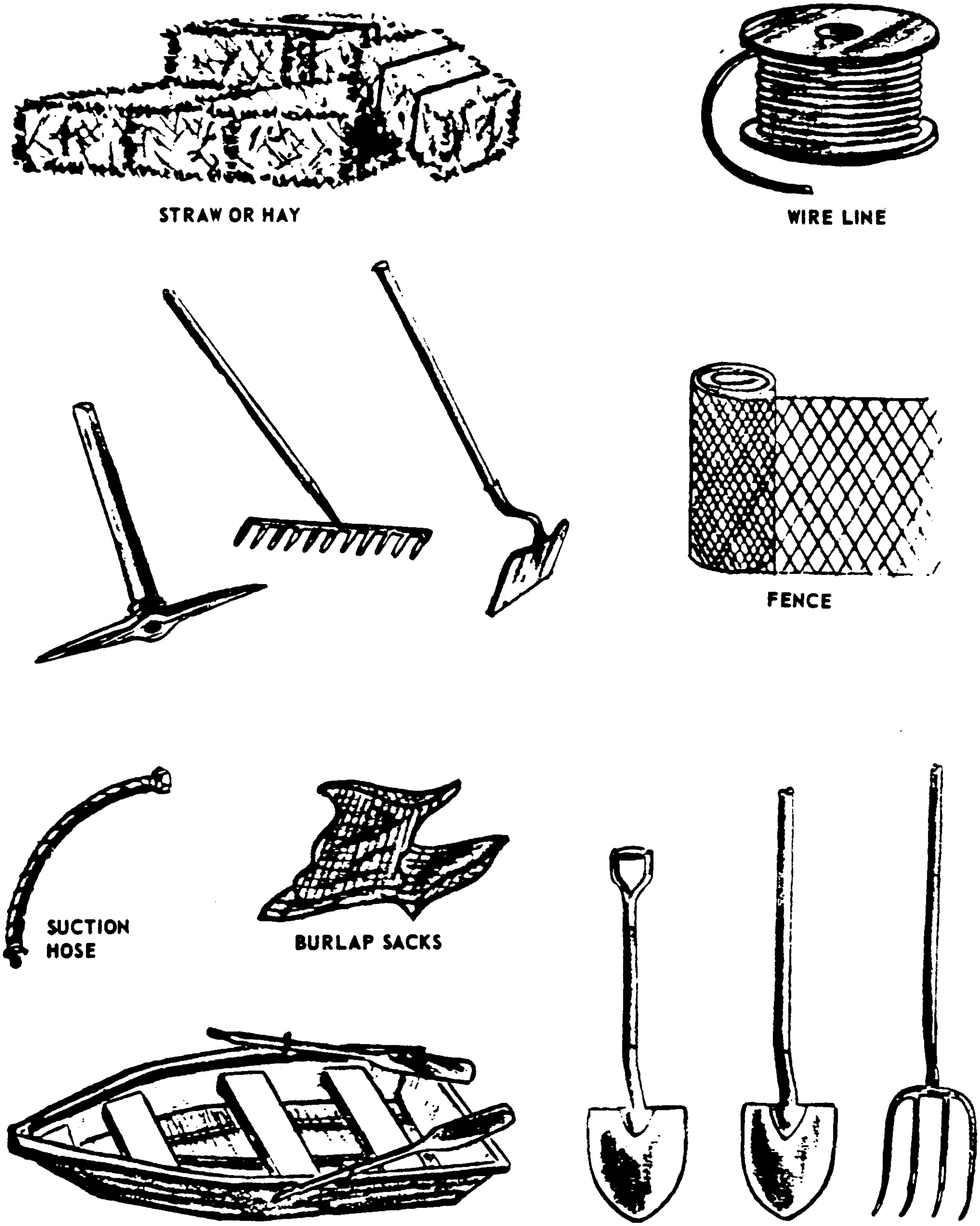


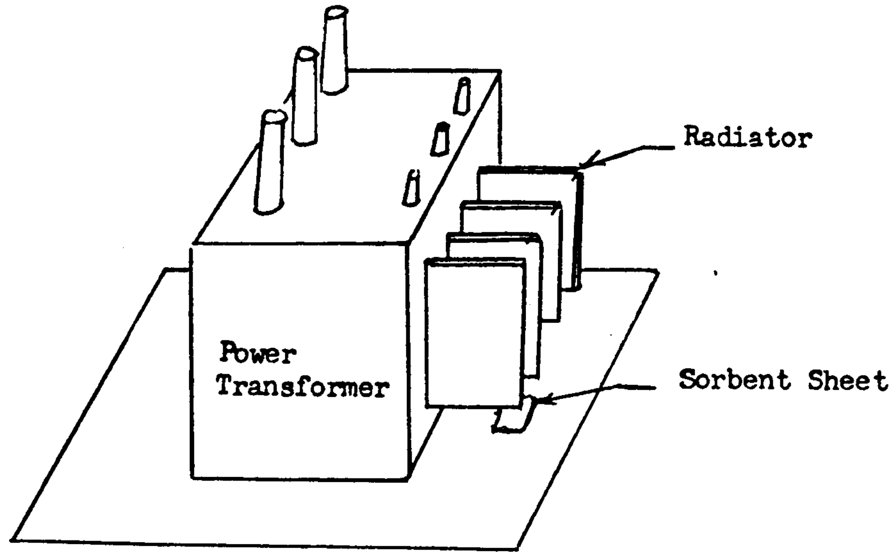
PRESSURE BURNER



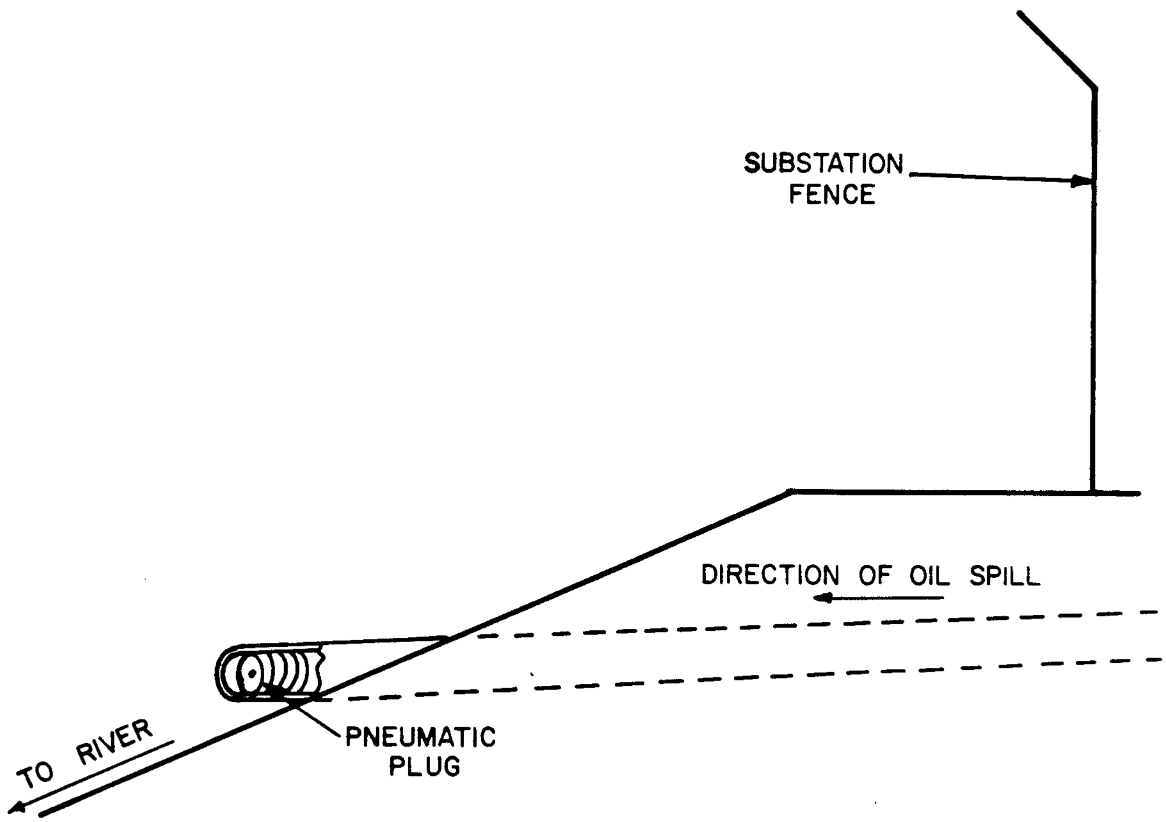
SUCTION PUMP

SKETCH 2





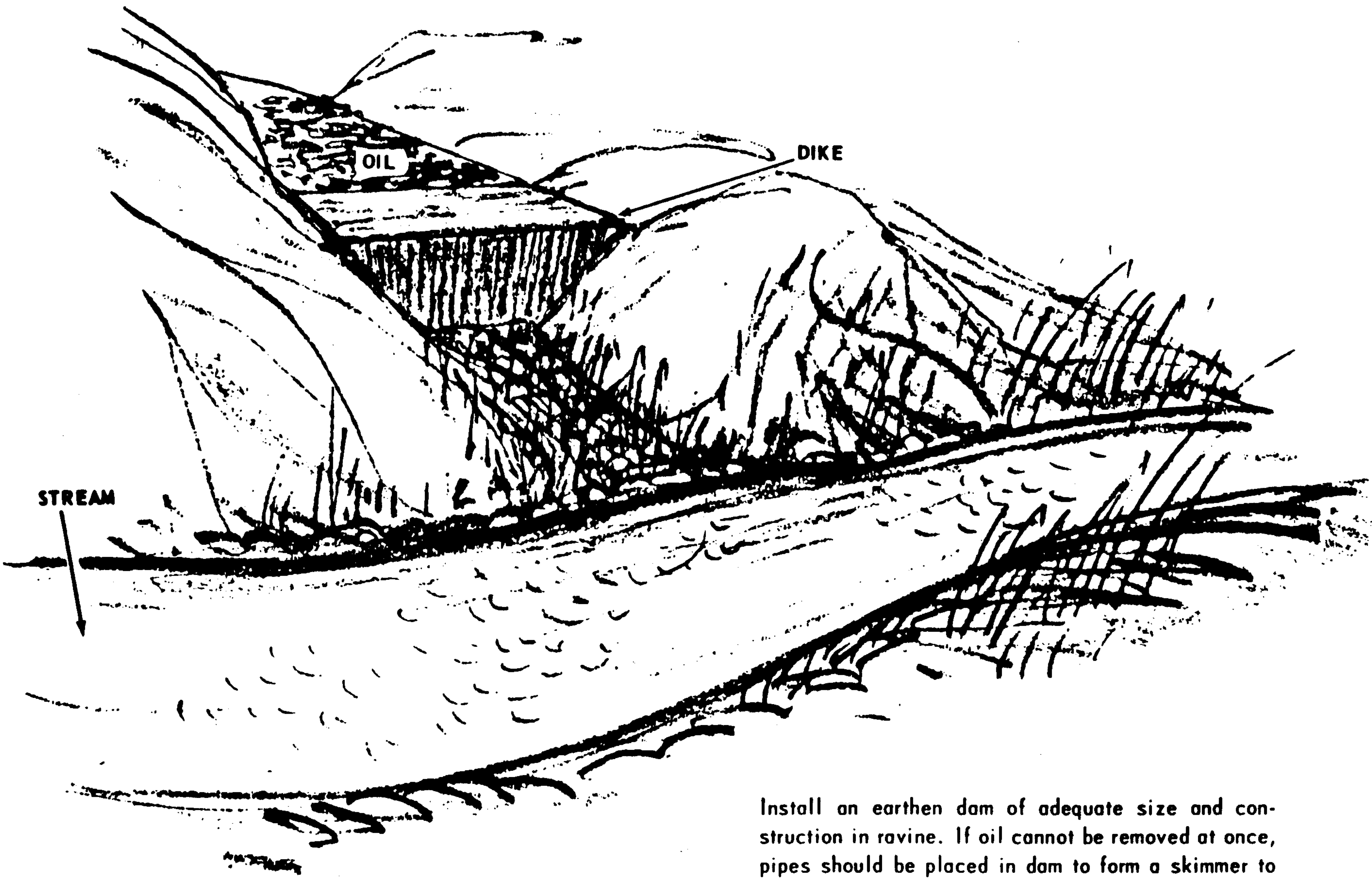
SKETCH 3 - Gasket Leaks - Divert and catch leaking oil or absorb oil with sorbent sheets



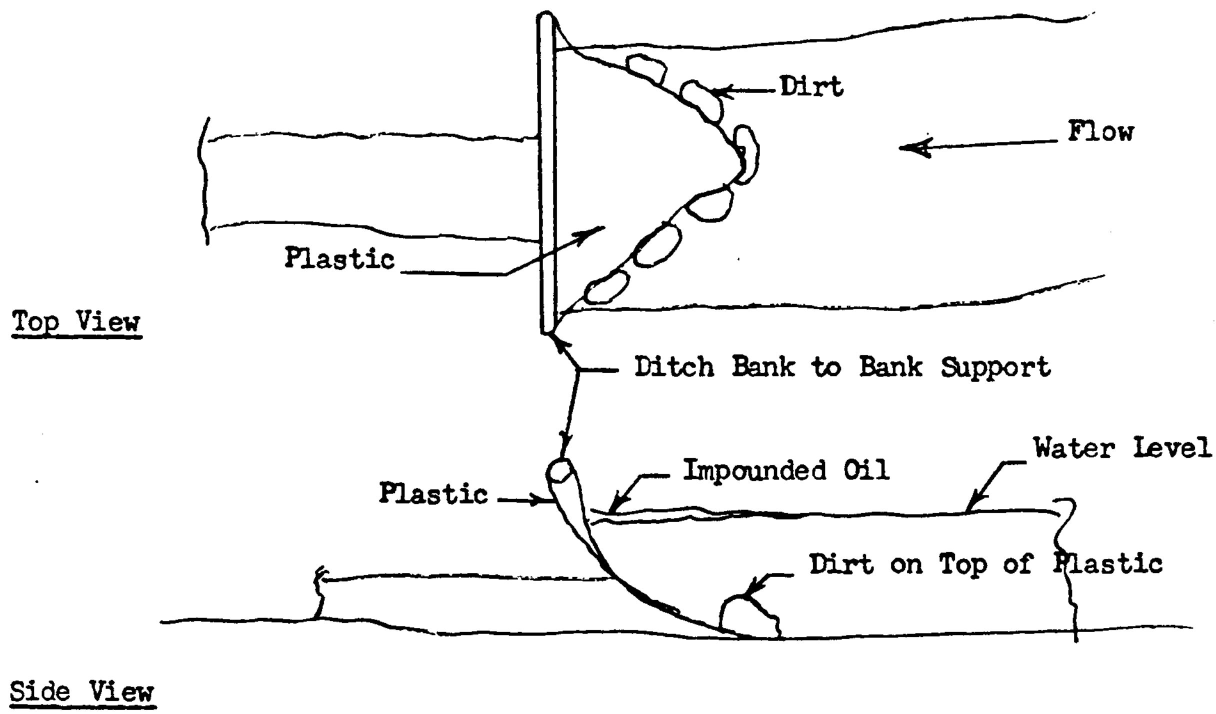
SKETCH 4 - Pneumatic Plug - Use for plugging drain tile to contain oil spill. Pump oil from catch basin and use sorbent sheets to absorb oil after spill.

SKETCH 5

OIL LOSS IN RAVINE LEADING TO WATER



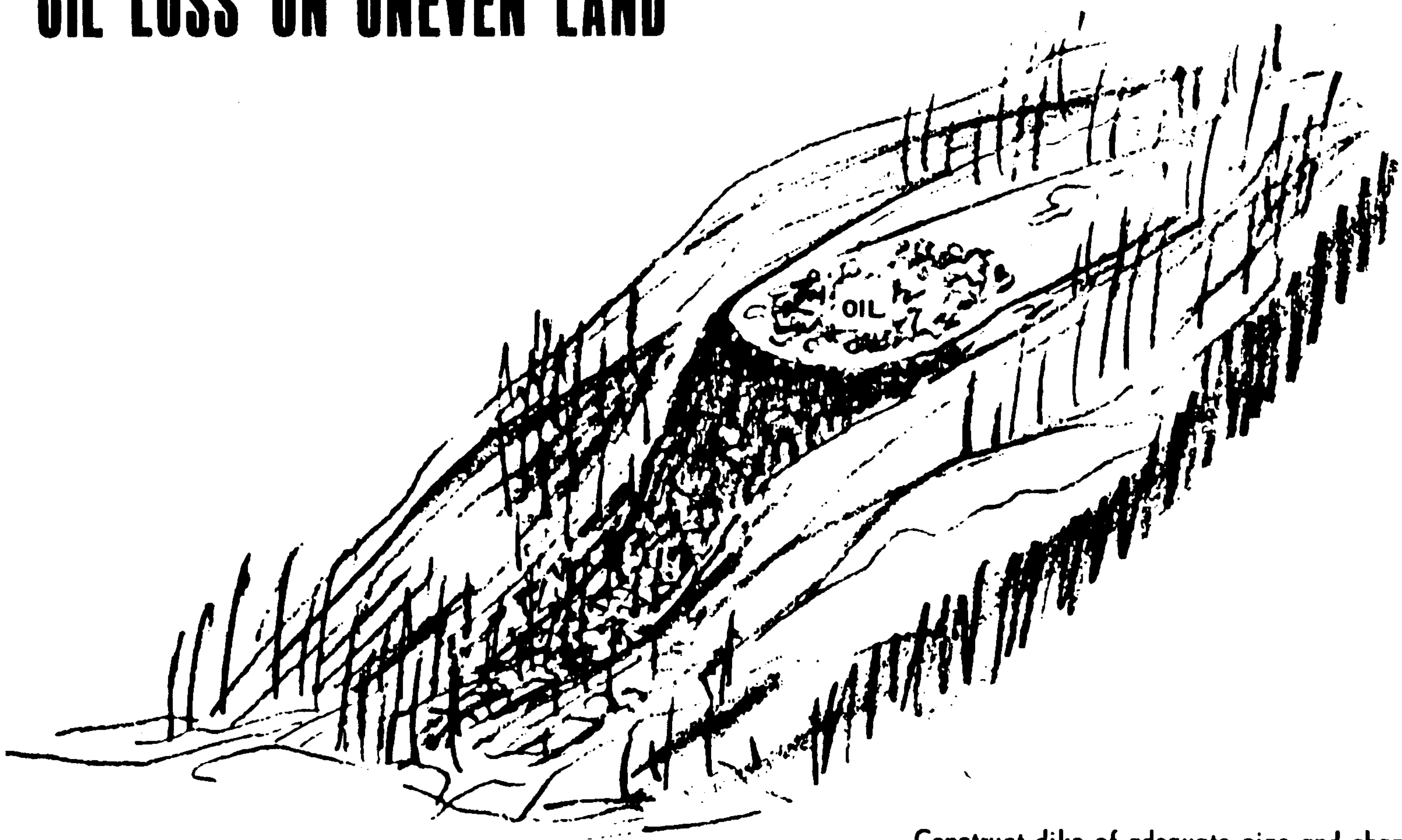
Install an earthen dam of adequate size and construction in ravine. If oil cannot be removed at once, pipes should be placed in dam to form a skimmer to take care of water from possible storm.



SKETCH 6 - Temporary Dam - Drape plastic sheeting over ditchbank to bank support. Pile dirt or rocks on plastic to hold in place. Skim or pump oil off water. Can siphon streamflow over dam or let leak by.

SKETCH 7

OIL LOSS ON UNEVEN LAND

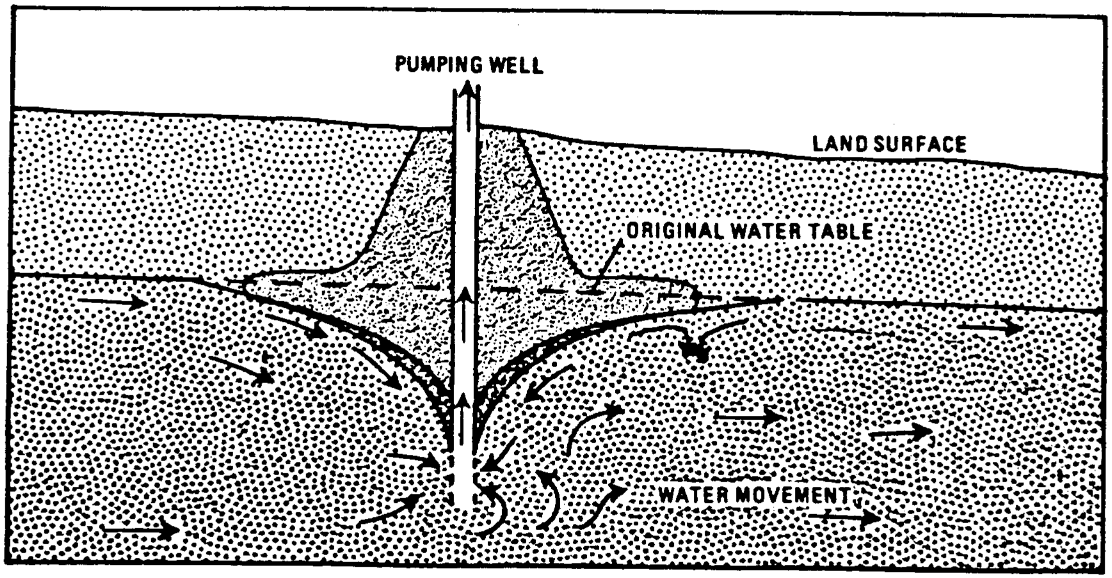


Construct dike of adequate size and shape on down-grade side of oil loss on uneven land. If land is only gently sloping, it may be necessary to dig sump pits or trenches for collection and removal of oil. If slope of land is radical, collection of oil becomes no problem except that dike used to prevent movement of oil must be very well constructed and maintained during period oil is impounded.

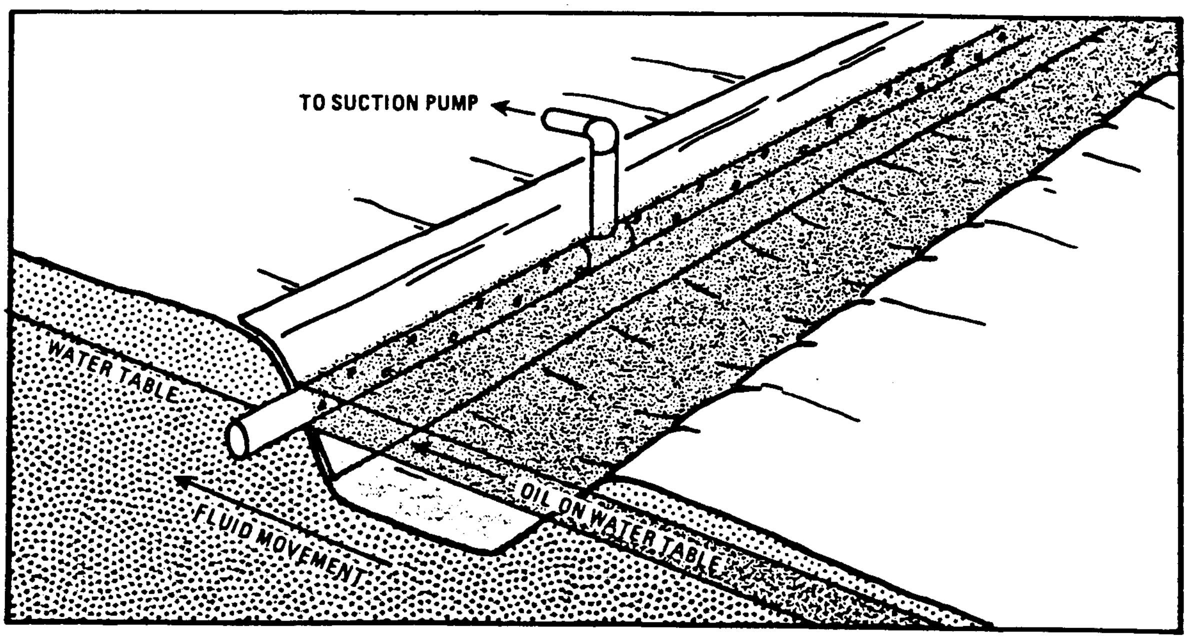
SKETCH 8

COVERING OIL BY SANDING

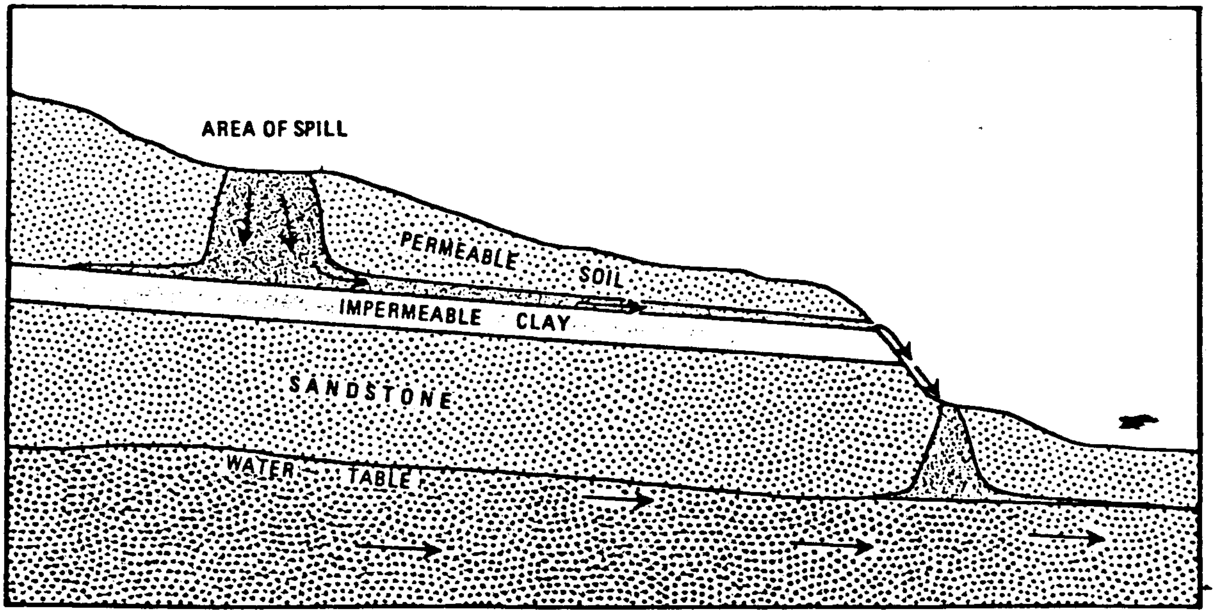
The final traces of an oil loss may be removed by covering the affected area with a coating of sand. Heavy sanding is recommended as a means of controlling the surface movement of oil from an oil-saturated area in close proximity to a stream. No attempt should be made to eliminate oil by sanding alone when a large amount of free oil is in evidence on the surface of the ground.



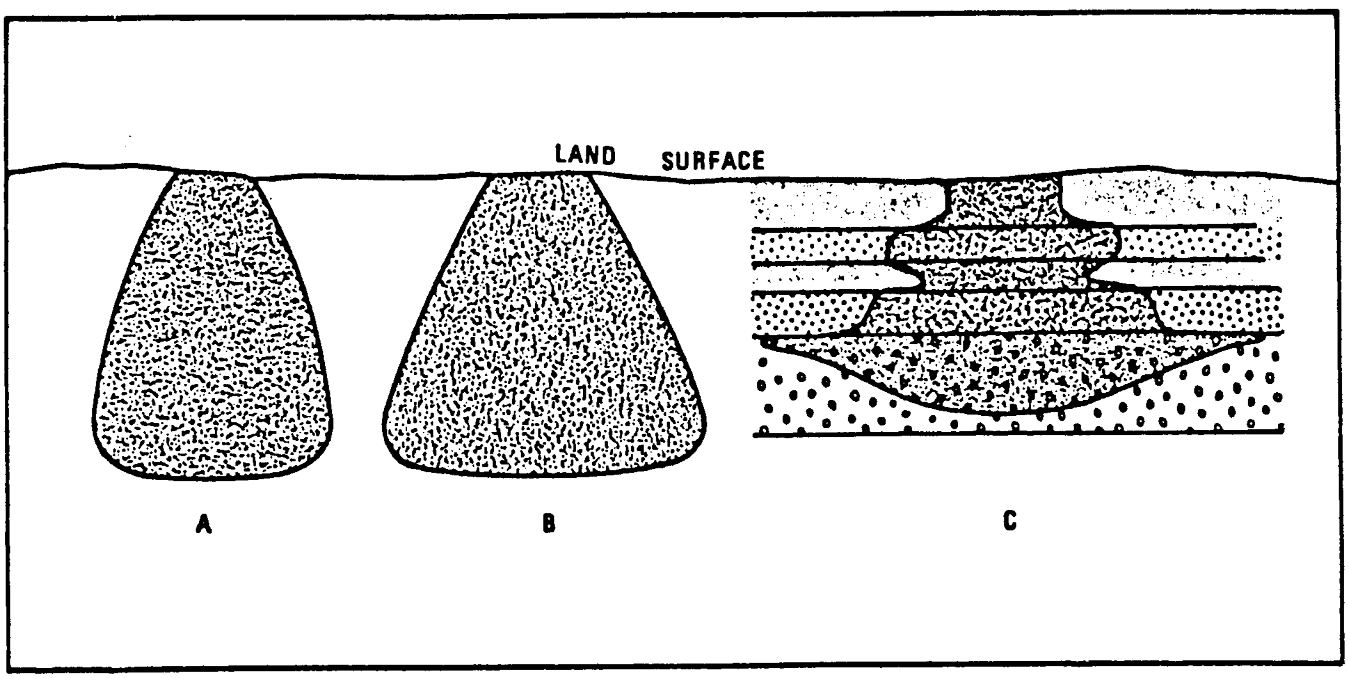
SKETCH 9 - Oil on Water Table is Trapped in Cone of Depression Created by Drawdown of Pumping Well



SKETCH 10 - Systems for Skimming Water Surface in Ditches



SKETCH 11 - Demonstrated Possible Migration to Outcrop, Followed By Second Cycle of Ground Water Contamination

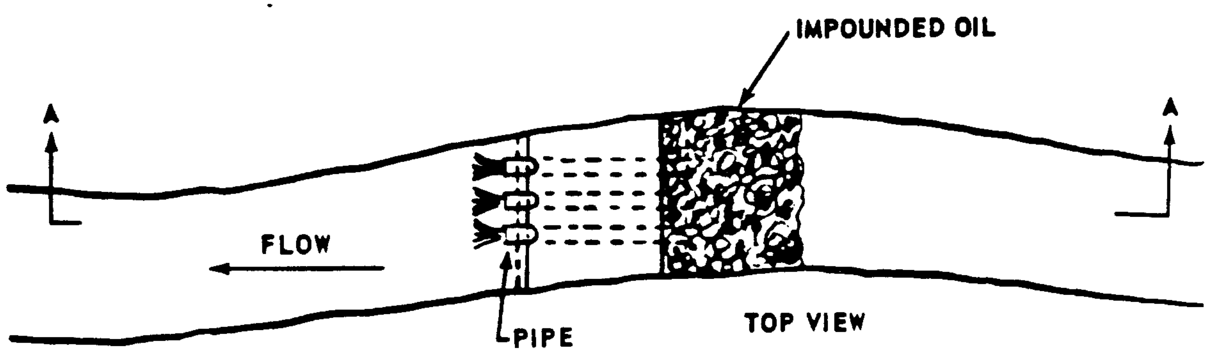


SKETCH 12 - Generalized Shapes of Spreading Cones at Immobile Saturation

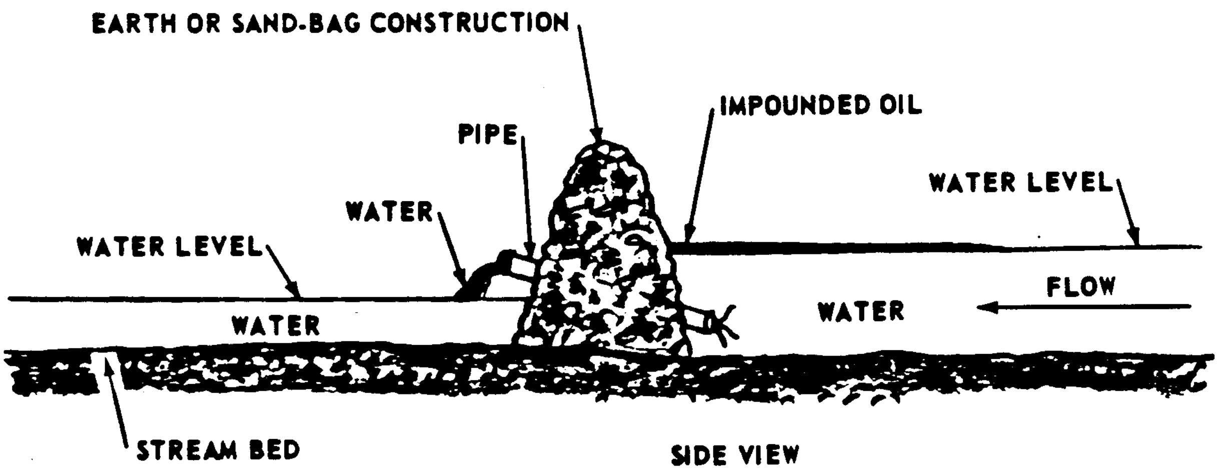
A - Highly Permeable, Homogeneous Soil
B - Less Permeable, Homogeneous Soil
C - Stratified Soil with Varying Permeability

SKETCH 13

PIPE SKIMMING DAM



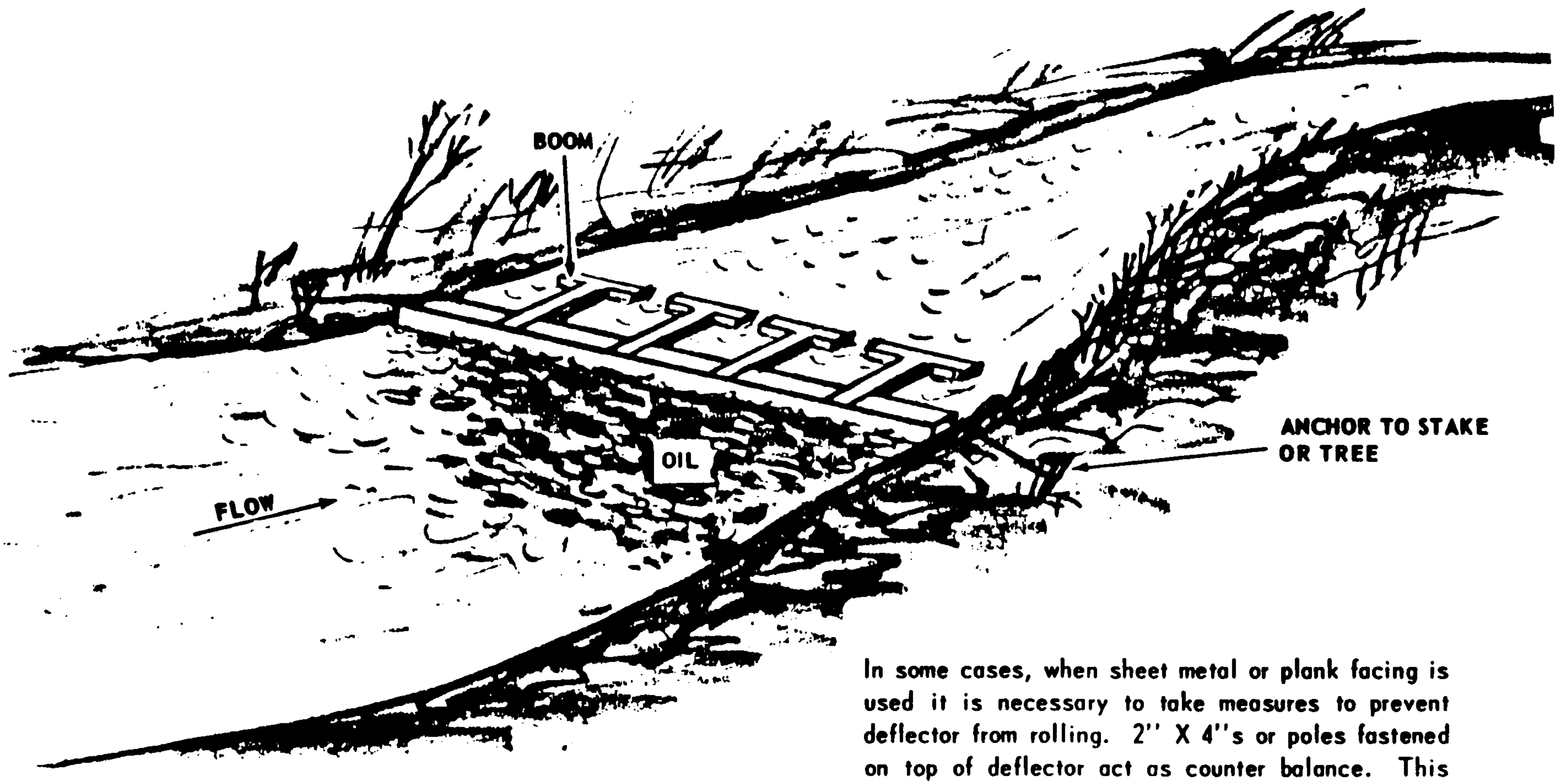
Sufficient pipe must be used to handle maximum stream flow. This type of installation is not satisfactory for large volume of water such as river, large creek, etc.



Number, size, length and exact position of pipe vary with volume of water, velocity, width of stream and other circumstances.

SKETCH 14

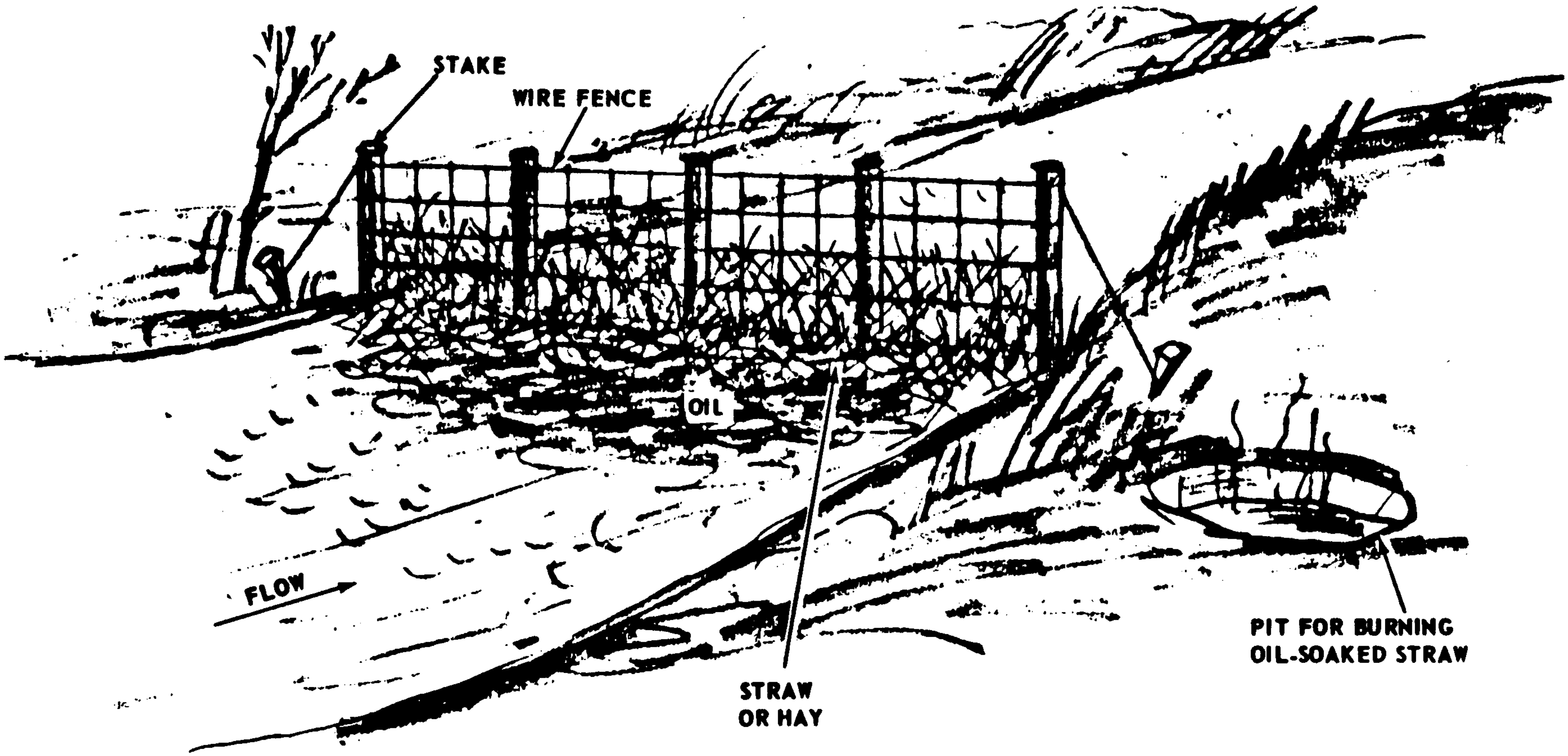
BOOM DEFLECTOR



In some cases, when sheet metal or plank facing is used it is necessary to take measures to prevent deflector from rolling. 2'' X 4''s or poles fastened on top of deflector act as counter balance. This type of deflector must be securely anchored.

SKETCH 15

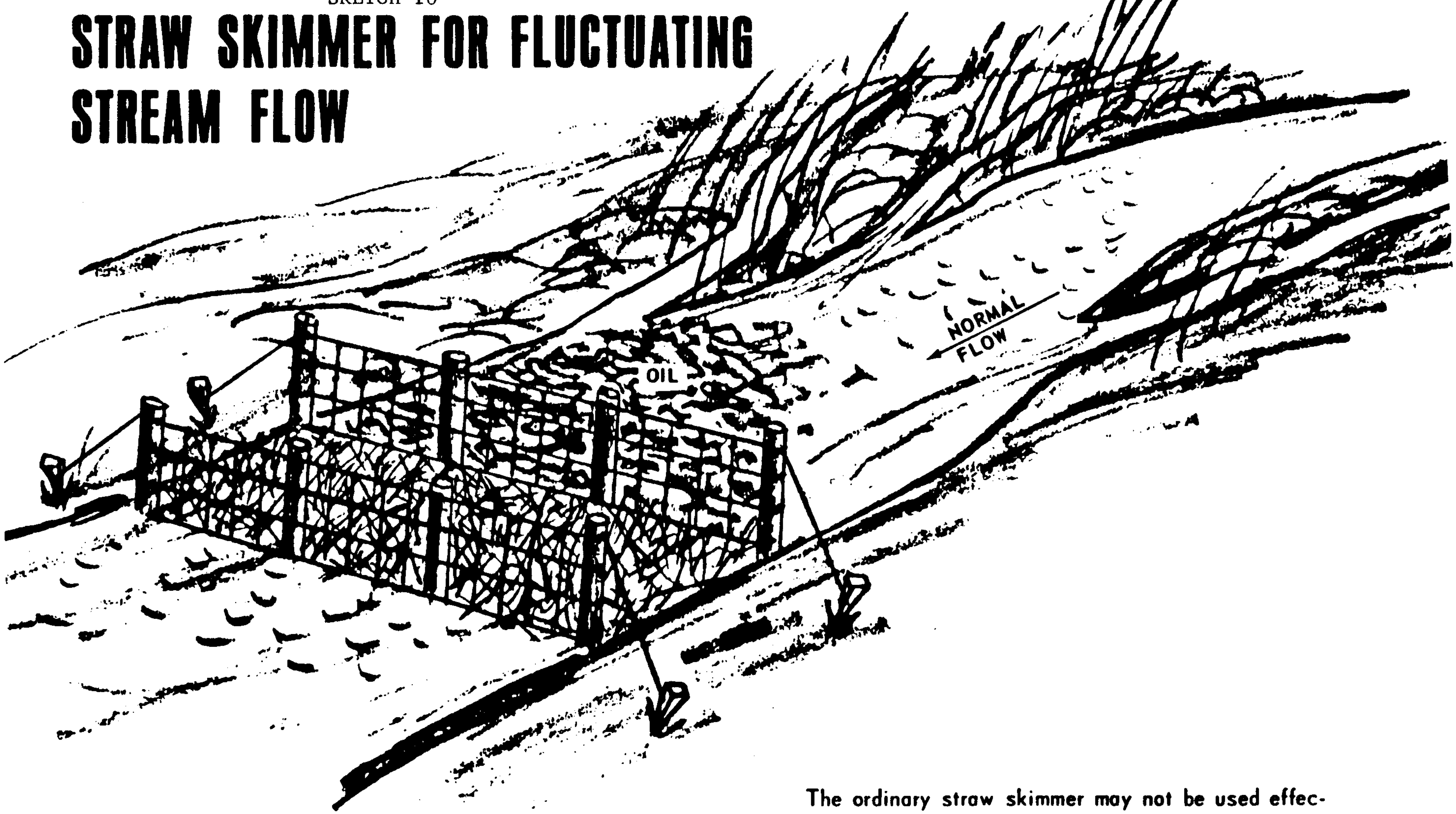
STRAW SKIMMING INSTALLATION



Stretch wire fence across stream and anchor securely. Straw is placed on upstream side of fence. This type of installation should be used in a location where the stream banks are of sufficient height and movement of water is relatively slow.

SKETCH 16

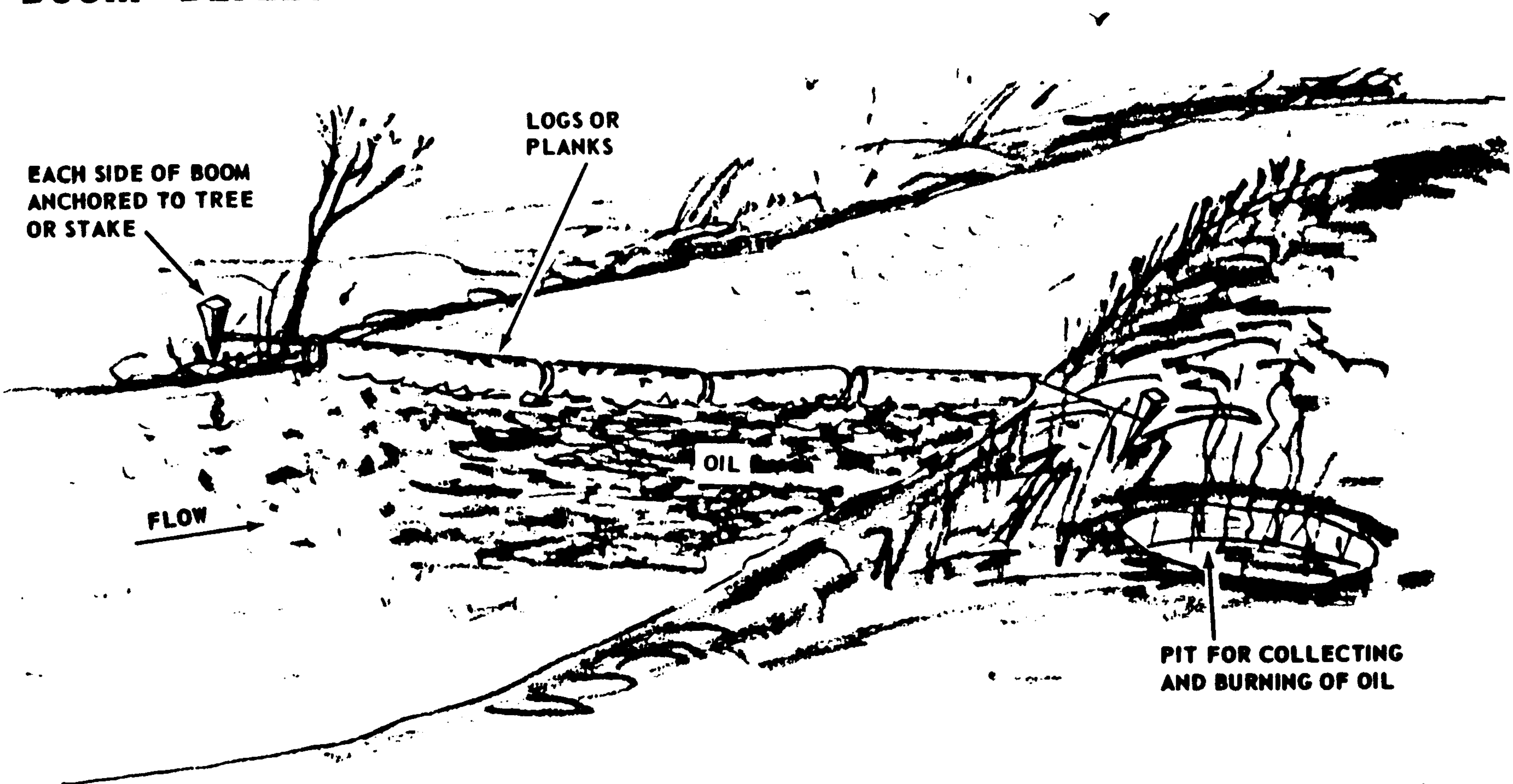
STRAW SKIMMER FOR FLUCTUATING STREAM FLOW



The ordinary straw skimmer may not be used effectively in a stream having a constantly changing flow direction. When this type of skimmer is installed in a body of water which is subject to a fluctuating flow movement, the straw must be held in place by wire fence on both sides of the straw.

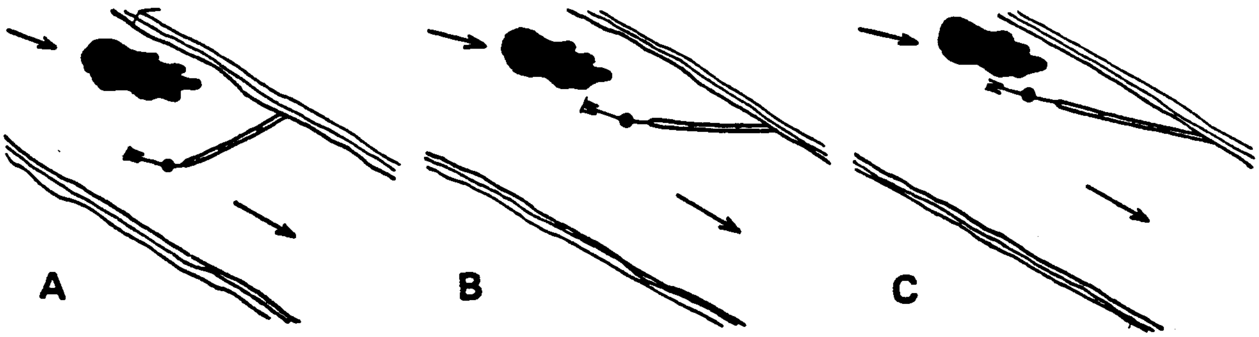
SKETCH 17

BOOM DEFLECTOR

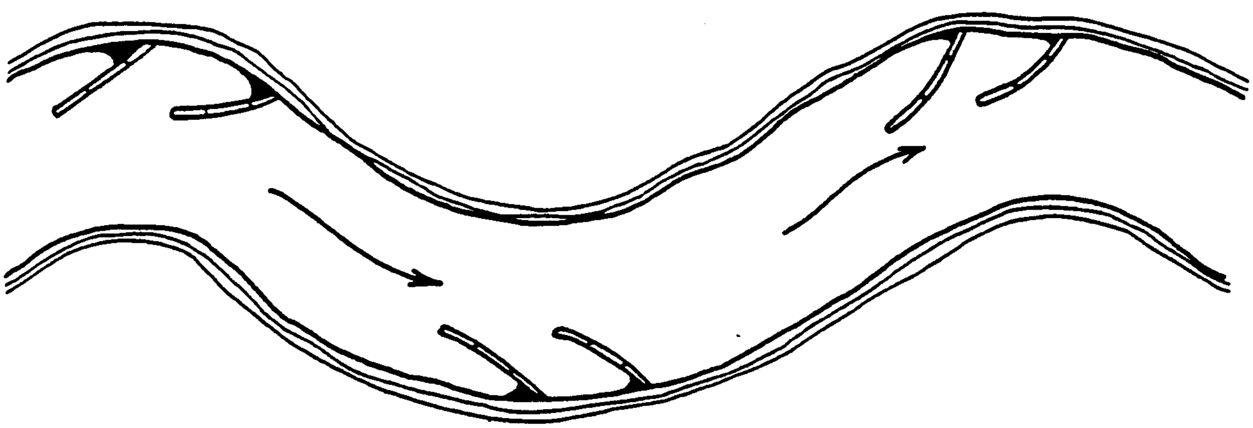


The boom deflector installation is used to control the movement of oil in rivers where it is necessary to contend with a large volume of water and where the use of a straw skimming installation is impossible or impractical. Proper construction of a plank or telephone pole boom deflector permits the removal of oil from the river at one point of collection.

SKETCH 18



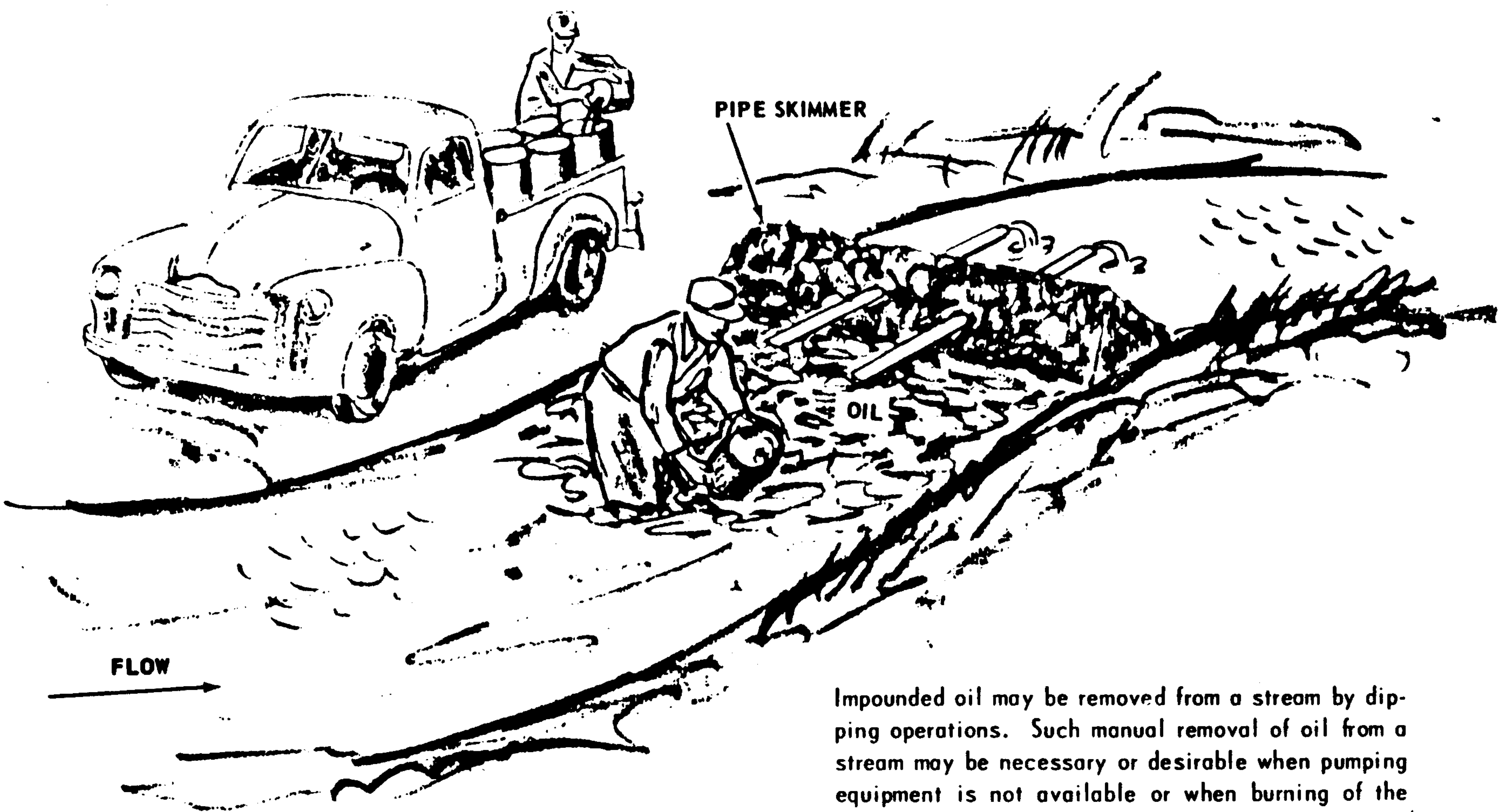
Suggested boom-to-shoreline angles for different current velocities. A) With a current of about 0.85 mi/h, the angle can be 60^{o}. B) A current of 1.5 mi/h requires a 30^{o} angle. C) A current of 2.75 mi/h can be handled with a 15^{o} angle. When stream current velocity exceeds 3 mi/h, seek out bends or other places where the current naturally slows down to a more reasonable speed.



A current alone (no wind) will direct oil into these areas along a stream, which can be chosen for containment.

SKETCH 19

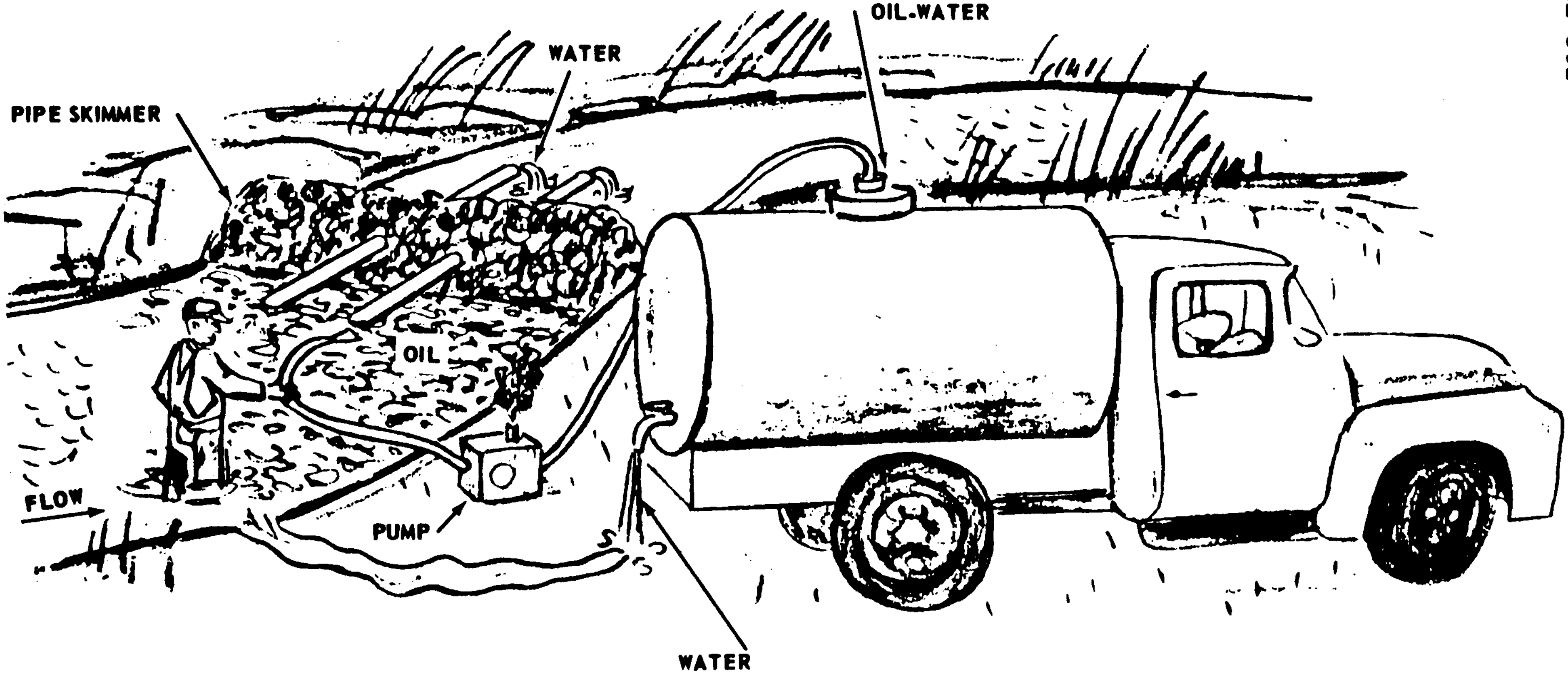
USE OF OIL DRUMS



Impounded oil may be removed from a stream by dipping operations. Such manual removal of oil from a stream may be necessary or desirable when pumping equipment is not available or when burning of the oil will destroy or endanger forest growth. The oil thus removed may be deposited in drums and trucked away from the vicinity of the stream to be salvaged or burned in a safe location.

SKETCH 20

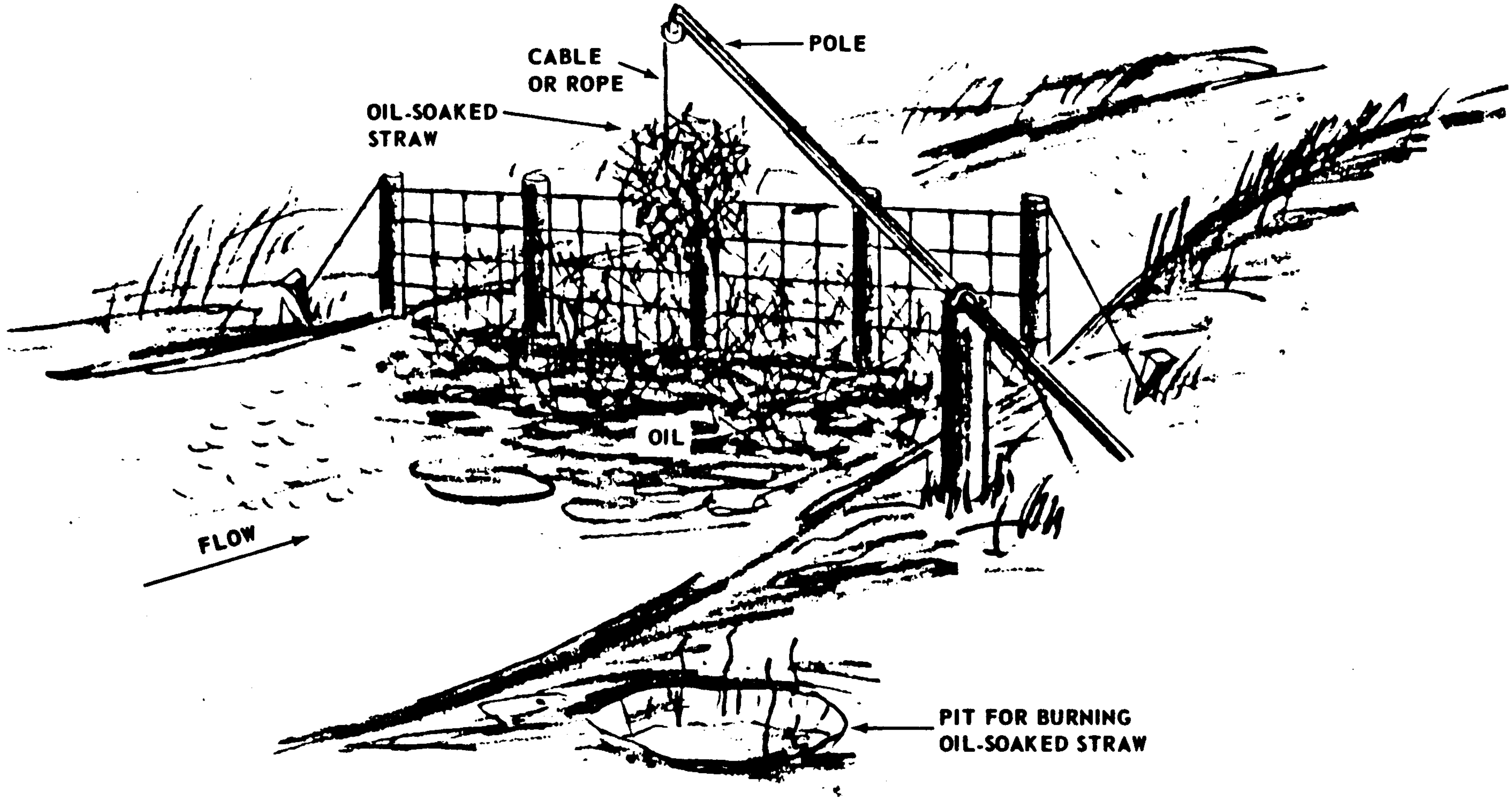
USE OF TANK TRUCK



Impounded oil may be removed from a stream by pumping it into a tank truck. The oil-water mixture is pumped into the top of the tank and, after separation of oil and water, the water may be returned to the stream by opening a valve at the bottom of the tank. Sufficient settling time should be allowed to permit a fairly complete separation.

SKETCH 21

REMOVAL OF OIL-SOAKED STRAW



A pole arrangement can be built to remove oil-soaked straw and replace it with fresh straw. The oil-soaked straw should be burned upon removal from stream.

SKETCH 22

Easily fabricated paddle rakes are a good tool for removing clumps of oil saturated straw, debris or solidified globs of heavy oil which become tarry in water during cold weather.

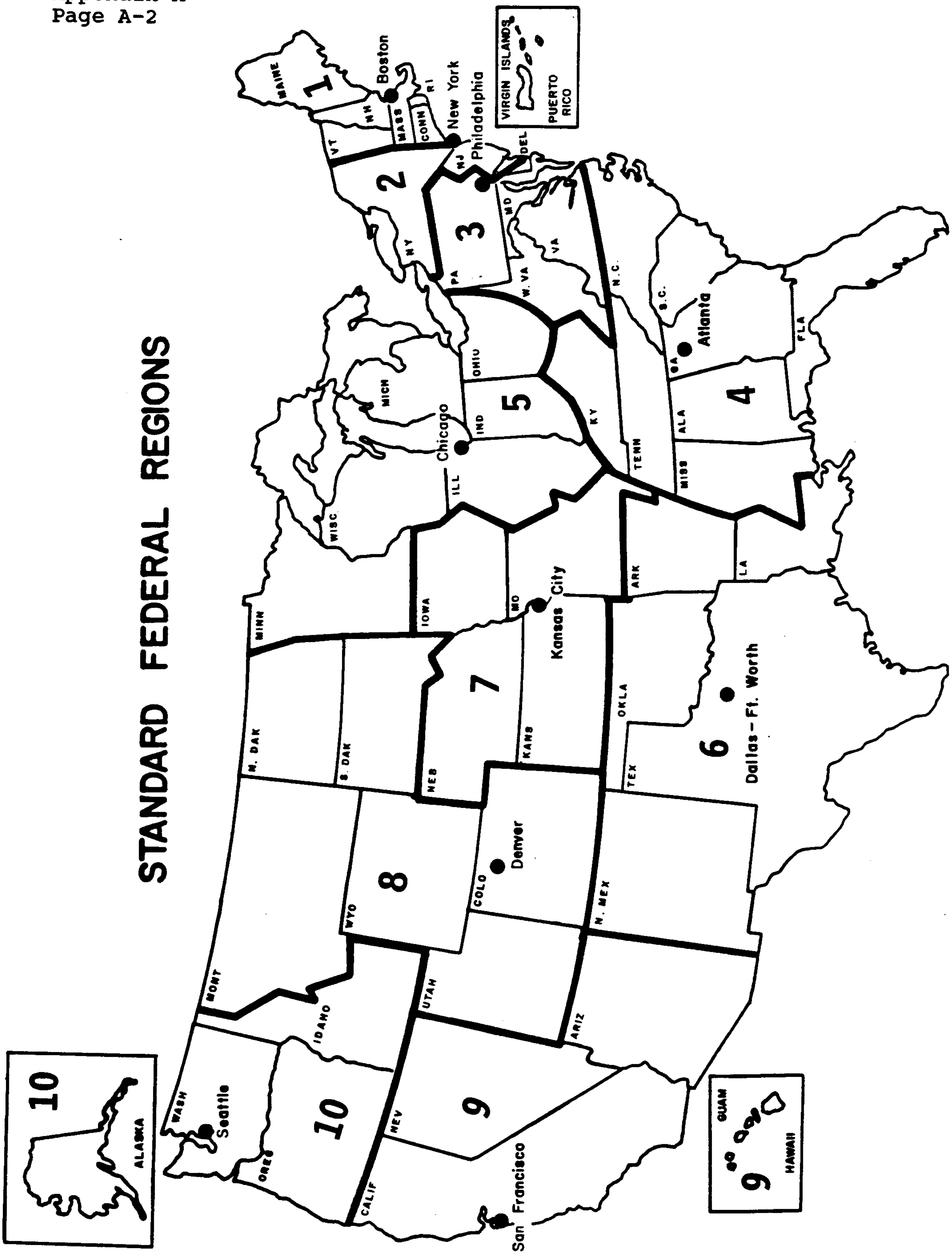
Appendix A

Federal EPA Regions

and

Addresses

STANDARD FEDERAL REGIONS



EPA ADDRESSES

Region 1
Environmental Protection Agency
John F. Kennedy Federal Building
Boston, MA 02203

Region 2
Environmental Protection Agency
26 Federal Plaza
New York, NY 10278

Region 3
Environmental Protection Agency
841 Chestnut Street
Philadelphia, PA 19107

Region 4
Environmental Protection Agency
345 Courtland Street, N.E.
Atlanta, GA 30305

Region 5
Environmental Protection Agency
230 South Dearborn Street
Chicago, IL 60604

Region 6
Environmental Protection Agency
1445 Ross Avenue
12th Floor, Suite 1200
Dallas, TX 75202

Region 7
Environmental Protection Agency
726 Minnesota Avenue
Kansas City, KS 66101

Region 8
Environmental Protection Agency
999 18th Street, Suite 500
Denver, CO 80202-2405

Region 9
Environmental Protection Agency
1235 Madison Street
San Francisco, CA 94103

Region 10
Environmental Protection Agency
1200 Sixth Avenue
Seattle, WA 98101

REGIONS

4 -- Alabama
10 -- Alaska
9 -- Arizona
6 -- Arkansas
9 -- California
8 -- Colorado
1 -- Connecticut
3 -- Delaware
3 -- D.C.
4 -- Florida
4 -- Georgia
9 -- Hawaii
10 -- Idaho
5 -- Illinois
7 -- Indiana
7 -- Iowa
7 -- Kansas
4 -- Kentucky
6 -- Louisiana

REGIONS

1 -- Maine
3 -- Maryland
1 -- Massachusetts
5 -- Michigan
5 -- Minnesota
4 -- Mississippi
7 -- Missouri
8 -- Montana
7 -- Nebraska
9 -- Nevada
1 -- New Hampshire
2 -- New Jersey
6 -- New Mexico
2 -- New York
4 -- North Carolina
8 -- North Dakota
5 -- Ohio
6 -- Oklahoma
10 -- Oregon

REGIONS

3 -- Pennsylvania
1 -- Rhode Island
4 -- South Carolina
8 -- South Dakota
4 -- Tennessee
6 -- Texas
8 -- Utah
1 -- Vermont
3 -- Virginia
10 -- Washington
3 -- West Virginia
5 -- Wisconsin
8 -- Wyoming
9 -- American Samoa
9 -- Guam
2 -- Puerto Rico
2 -- Virgin Islands

APPENDIX B

Normal Precipitation Tables

(From "Comparative Climatic Data for United States Through 1990"
National Oceanic and Atmospheric Administration
National Climatic Data Center
Asheville, North Carolina)

NORMAL PRECIPITATION : INCHES

NORMALS 1951-80	YRS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
BIRMINGHAM C.O.,AL	30	4.97	4.64	6.55	5.30	3.80	3.17	4.19	3.88	4.55	2.77	3.51	4.83	52.16
BIRMINGHAM AP,AL	30	5.23	4.72	6.62	5.00	4.53	3.61	5.39	3.85	4.34	2.64	3.64	4.95	54.52
HUNTSVILLE, AL	30	5.17	4.79	6.78	4.92	4.60	3.74	5.05	3.11	3.99	2.90	4.24	5.43	54.72
MOBILE, AL	30	4.59	4.91	6.48	5.35	5.46	5.07	7.74	6.75	6.56	2.62	3.67	5.44	64.64
MONTGOMERY, AL	30	4.20	4.51	5.92	4.38	4.00	3.45	4.78	3.17	4.72	2.27	2.98	4.78	49.16
ANCHORAGE, AK	30	0.80	0.93	0.69	0.66	0.57	1.08	1.97	2.11	2.45	1.73	1.11	1.10	15.20
ANNETTE, AK	30	9.98	10.14	9.11	8.83	6.72	4.97	4.71	7.32	9.92	17.58	13.29	12.90	115.47
BARROW, AK	30	0.21	0.17	0.17	0.21	0.16	0.37	0.86	0.98	0.59	0.55	0.30	0.18	4.75
BARTER IS.,AK	30	0.50	0.27	0.24	0.22	0.35	0.56	1.03	1.08	0.80	0.81	0.40	0.23	6.49
BETHEL, AK	30	0.78	0.68	0.80	0.71	0.80	1.34	2.11	3.46	2.22	1.29	0.96	0.98	16.13
BETTLES,AK	30	0.76	0.68	0.71	0.60	0.50	1.37	1.64	2.34	1.68	1.21	0.95	0.82	13.26
BIG DELTA,AK	30	0.31	0.27	0.27	0.24	0.92	2.38	2.37	1.95	1.10	0.55	0.39	0.37	11.12
COLD BAY,AK	30	2.70	2.27	2.31	1.95	2.47	2.16	2.50	3.70	3.77	4.29	4.04	2.85	35.01
FAIRBANKS, AK	30	0.53	0.42	0.40	0.27	0.57	1.32	1.77	1.86	1.09	0.74	0.67	0.73	10.37
GULKANA,AK	30	0.45	0.50	0.34	0.19	0.63	1.47	1.81	1.47	1.43	0.89	0.75	0.89	10.82
HOMER, AK	30	1.65	1.93	1.28	1.31	1.07	1.05	1.47	2.36	2.86	3.28	2.91	2.58	23.75
JUNEAU, AK	30	3.69	3.74	3.34	2.92	3.41	2.98	4.13	5.02	6.40	7.71	5.15	4.66	53.15
KING SALMON, AK	30	1.04	0.88	1.13	1.05	1.18	1.50	2.08	3.13	2.78	1.92	1.40	1.24	19.33
KODIAK, AK	30	8.29	6.29	4.06	4.84	7.73	3.37	3.91	5.21	7.60	9.99	6.67	6.28	74.24
KOTZEBUE, AK	30	0.35	0.30	0.31	0.31	0.31	0.53	1.46	2.03	1.50	0.61	0.47	0.35	8.53
MCGRATH, AK	30	0.81	0.63	0.72	0.79	0.72	1.44	2.06	2.74	2.04	1.14	1.16	1.05	15.30
NOME, AK	30	0.81	0.52	0.57	0.64	0.54	1.19	2.20	3.11	2.34	1.26	0.94	0.65	14.77
ST. PAUL ISLAND, AK	30	1.78	1.28	1.26	1.21	1.23	1.24	2.02	3.07	2.52	2.85	2.49	1.76	22.71
TALKEETNA, AK	30	1.45	1.53	1.49	1.36	1.39	2.50	3.37	4.26	3.97	2.63	1.87	1.41	27.23
UNALAKLEET, AK	30	0.50	0.53	0.60	0.49	0.71	0.92	2.32	3.89	2.20	1.03	0.56	0.41	14.16
VALDEZ, AK	30	5.05	4.10	3.46	3.13	2.44	2.13	3.95	3.72	8.26	9.12	6.00	5.34	56.70
YAKUTAT, AK	30	9.39	10.02	9.55	8.62	9.12	5.56	8.26	10.06	15.78	20.12	15.50	12.98	134.96
FLAGSTAFF, AZ	30	2.10	1.95	2.13	1.35	0.75	0.57	2.47	2.62	1.47	1.54	1.65	2.26	20.86
PHOENIX, AZ	30	0.73	0.59	0.81	0.27	0.14	0.17	0.74	1.02	0.64	0.63	0.54	0.83	7.11
TUCSON, AZ	30	0.83	0.63	0.68	0.32	0.14	0.22	2.42	2.13	1.33	0.88	0.62	0.94	11.14
WINSLOW, AZ	30	0.43	0.46	0.51	0.32	0.30	0.35	1.14	1.41	0.83	0.90	0.41	0.58	7.64
YUMA, AZ	30	0.38	0.26	0.18	0.13	0.04	0.01	0.15	0.42	0.25	0.29	0.20	0.34	2.65
FORT SMITH, AR	30	1.86	2.53	3.88	4.20	4.79	3.67	3.15	3.02	3.22	3.24	3.50	2.85	39.91
LITTLE ROCK, AR	30	3.91	3.83	4.69	5.41	5.29	3.67	3.63	3.07	4.26	2.84	4.37	4.23	49.20
NORTH LITTLE ROCK, AR	30	3.70	3.72	4.89	5.29	5.00	3.23	3.12	2.68	3.82	2.72	4.08	4.02	46.27
BAKERSFIELD, CA	30	0.98	1.07	0.87	0.70	0.24	0.07	0.01	0.05	0.13	0.30	0.65	0.65	5.72
BISHOP, CA	30	1.32	0.98	0.43	0.31	0.30	0.11	0.19	0.11	0.18	0.17	0.49	1.02	5.61
BLUE CANYON, CA	30	14.11	9.93	8.96	5.45	2.70	0.86	0.30	0.55	0.97	3.93	8.41	11.70	67.87
EUREKA, CA.	30	6.99	5.20	5.05	2.91	1.60	0.56	0.10	0.37	0.90	2.71	5.90	6.22	38.51
FRESNO, CA	30	2.05	1.85	1.61	1.15	0.31	0.08	0.01	0.02	0.16	0.43	1.24	1.61	10.52
LONG BEACH, CA	30	2.98	2.50	1.69	0.83	0.16	0.04	0.00	0.09	0.16	0.15	1.36	1.58	11.54
LOS ANGELES AP, CA	30	3.06	2.49	1.76	0.93	0.14	0.04	0.01	0.10	0.15	0.26	1.52	1.62	12.08
LOS ANGELES C.O., CA	30	3.69	2.96	2.35	1.17	0.23	0.03	0.00	0.12	0.27	0.21	1.85	1.97	14.85
MOUNT SHASTA, CA	30	7.21	5.69	4.23	2.75	1.55	0.80	0.25	0.45	0.85	2.01	5.19	6.07	37.05
REDDING, CA	30	8.51	6.19	4.96	2.82	1.28	0.83	0.18	0.51	1.05	2.03	5.56	7.03	40.95
SACRAMENTO, CA	30	4.03	2.88	2.06	1.31	0.33	0.11	0.05	0.07	0.27	0.86	2.23	2.90	17.10
SAN DIEGO, CA	30	2.11	1.43	1.60	0.78	0.24	0.06	0.01	0.11	0.19	0.33	1.10	1.36	9.32
SAN FRANCISCO AP, CA	30	4.65	3.23	2.64	1.53	0.32	0.11	0.03	0.05	0.19	1.06	2.35	3.55	19.71
SAN FRANCISCO C.O., CA	30	4.48	2.83	2.58	1.48	0.35	0.15	0.04	0.08	0.24	1.09	2.49	3.52	19.33
SANTA BARBARA, CA	30	3.83	3.46	2.43	1.35	0.22	0.03	0.02	0.02	0.25	0.35	1.89	2.33	16.18

NORMAL PRECIPITATION : INCHES

NORMALS 1951-80	YRS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
SANTA MARIA, CA	30	2.43	2.63	1.87	1.17	0.24	0.04	0.01	0.04	0.27	0.46	1.37	1.82	12.35
STOCKTON, CA	30	3.02	2.03	1.81	1.36	0.30	0.08	0.05	0.07	0.23	0.62	1.77	2.43	13.77
ALAMOSA, CO	30	0.27	0.26	0.36	0.50	0.70	0.55	1.23	1.13	0.74	0.68	0.35	0.36	7.13
COLORADO SPRINGS, CO	30	0.27	0.31	0.78	1.35	2.28	2.02	2.85	2.61	1.31	0.78	0.54	0.32	15.42
DENVER, CO	30	0.51	0.69	1.21	1.81	2.47	1.58	1.93	1.53	1.23	0.98	0.82	0.55	15.31
GRAND JUNCTION, CO	30	0.64	0.54	0.75	0.71	0.76	0.44	0.47	0.91	0.70	0.87	0.63	0.58	8.00
PUEBLO, CO	30	0.25	0.27	0.68	1.00	1.47	1.16	1.81	1.83	0.81	0.78	0.49	0.31	10.86
BRIDGEPORT, CT	30	3.25	3.00	3.93	3.74	3.44	2.90	3.46	3.68	3.29	3.33	3.79	3.75	41.56
HARTFORD, CT	30	3.53	3.19	4.15	4.02	3.37	3.38	3.09	4.00	3.94	3.51	4.05	4.16	44.39
WILMINGTON, DE	30	3.11	2.99	3.87	3.39	3.23	3.51	3.90	4.03	3.59	2.89	3.33	3.54	41.38
WASHINGTON DULLES AP, D.C.	30	2.83	2.64	3.43	3.14	3.62	4.23	3.75	4.16	3.26	3.01	2.99	3.29	40.35
WASHINGTON NAT'L AP, D.C.	30	2.76	2.62	3.46	2.93	3.48	3.35	3.88	4.40	3.22	2.90	2.82	3.18	39.00
APALACHICOLA, FL	30	3.51	3.64	4.04	3.25	2.94	4.81	7.09	7.53	8.66	3.19	2.82	3.50	54.98
DAYTONA BEACH, FL	30	2.37	3.11	2.99	2.25	3.38	6.41	5.52	6.34	6.68	4.62	2.59	2.20	48.46
FORT MYERS, FL	30	1.89	2.06	2.85	1.52	4.11	8.72	8.57	8.58	8.56	3.86	1.35	1.57	53.64
GAINESVILLE, FL	30	3.23	3.92	3.53	2.94	4.14	6.34	6.99	8.07	5.50	2.45	2.04	3.24	52.39
JACKSONVILLE, FL	30	3.07	3.48	3.72	3.32	4.91	5.37	6.54	7.15	7.26	3.41	1.94	2.59	52.76
KEY WEST, FL	30	1.74	1.92	1.31	1.49	3.22	5.04	3.68	4.80	6.50	4.76	3.23	1.73	39.42
MIAMI, FL	30	2.08	2.05	1.89	3.07	6.53	9.15	5.98	7.02	8.07	7.14	2.71	1.86	57.55
ORLANDO, FL	30	2.10	2.83	3.20	2.19	3.96	7.39	7.78	6.32	5.62	2.82	1.78	1.83	47.82
PENSACOLA, FL	30	4.47	4.90	5.66	4.45	3.87	5.75	7.18	7.04	6.75	3.52	3.42	4.15	61.16
TALLAHASSEE, FL	30	4.66	5.00	5.60	4.13	5.16	6.55	8.75	7.30	6.45	3.10	3.31	4.58	64.59
TAMPA, FL	30	2.17	3.04	3.46	1.82	3.38	5.29	7.35	7.64	6.23	2.34	1.87	2.14	46.73
VERO BEACH, FL	30	2.43	2.86	3.05	2.59	4.39	6.52	5.76	5.39	7.96	5.94	2.55	1.97	51.41
WEST PALM BEACH, FL	30	2.71	2.62	2.69	3.21	6.02	7.92	6.06	5.78	9.29	7.77	3.39	2.26	59.72
ATHENS, GA	30	4.85	4.16	5.81	4.04	4.78	4.00	5.18	3.64	3.58	2.70	3.32	4.09	50.15
ATLANTA, GA	30	4.91	4.43	5.91	4.43	4.02	3.41	4.73	3.41	3.17	2.53	3.43	4.23	48.61
AUGUSTA,GA	30	3.99	4.04	4.92	3.31	3.73	3.88	4.40	3.98	3.53	2.02	2.07	3.20	43.07
COLUMBUS, GA	30	4.52	4.52	5.96	4.50	4.44	4.16	5.50	4.02	3.59	2.07	3.06	4.75	51.09
MACON, GA	30	4.26	4.56	5.18	3.51	3.79	3.83	4.46	3.64	3.29	1.98	2.32	4.04	44.86
SAVANNAH, GA	30	3.09	3.17	3.83	3.16	4.62	5.69	7.37	6.65	5.19	2.27	1.89	2.77	49.70
HILO, HI	30	9.42	13.47	13.55	13.10	9.40	6.13	8.68	10.02	6.63	10.01	14.88	12.86	128.15
HONOLULU,HI	30	3.79	2.72	3.48	1.49	1.21	0.49	0.54	0.60	0.62	1.88	3.22	3.43	23.47
KAHULUI, HI	30	4.21	3.27	3.00	1.18	0.66	0.28	0.41	0.50	0.36	0.87	2.26	2.85	19.85
LIHUE, HI	30	6.24	3.68	4.52	3.29	2.99	1.64	2.03	1.85	2.25	4.52	5.55	5.46	44.02
BOISE, ID	30	1.64	1.07	1.03	1.19	1.21	0.95	0.26	0.40	0.58	0.75	1.29	1.34	11.71
LEWISTON, ID	30	1.37	0.91	1.00	1.13	1.41	1.40	0.52	0.79	0.78	1.01	1.16	1.30	12.78
POCATELLO, ID	30	1.13	0.86	0.94	1.16	1.20	1.06	0.47	0.60	0.65	0.92	0.91	0.96	10.86
CAIRO,IL	30	3.47	3.42	4.96	4.44	4.90	4.36	3.96	3.97	3.50	2.54	3.97	4.16	47.65
CHICAGO,IL	30	1.60	1.31	2.59	3.66	3.15	4.08	3.63	3.53	3.35	2.28	2.06	2.10	33.34
MOLINE, IL	30	1.64	1.30	2.77	3.97	4.21	4.32	4.88	3.76	3.74	2.70	1.96	1.92	37.17
PEORIA, IL	30	1.60	1.41	2.86	3.81	3.84	3.88	3.99	3.39	3.63	2.51	1.96	2.01	34.89
ROCKFORD, IL	30	1.42	1.18	2.59	4.22	3.75	4.58	4.50	3.71	3.70	2.92	2.30	1.91	36.78
SPRINGFIELD, IL	30	1.56	1.78	3.14	3.97	3.34	3.71	3.53	3.20	3.05	2.52	1.93	2.05	33.78
EVANSVILLE, IN	30	2.99	3.02	4.58	4.08	4.37	3.50	3.98	3.07	2.67	2.48	3.36	3.45	41.55
FORT WAYNE, IN	30	2.07	1.96	2.94	3.56	3.47	3.62	3.39	3.29	2.53	2.56	2.57	2.44	34.40
INDIANAPOLIS, IN	30	2.65	2.46	3.61	3.68	3.66	3.99	4.32	3.46	2.74	2.51	3.04	3.00	39.12
SOUTH BEND, IN	30	2.48	1.99	3.05	4.06	2.81	3.94	3.67	3.94	3.22	3.22	2.83	2.95	38.16
DES MOINES, IA	30	1.01	1.12	2.20	3.21	3.96	4.18	3.22	4.11	3.09	2.16	1.52	1.05	30.83
DUBUQUE,IA	30	1.43	1.31	2.92	4.17	4.43	4.17	4.33	4.47	4.13	2.89	2.47	1.87	38.59

NORMAL PRECIPITATION : INCHES

NORMALS 1951-80	YRS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
SIOUX CITY, IA	30	0.60	0.94	1.71	2.29	3.43	3.99	3.36	3.14	2.51	1.73	0.93	0.74	25.37
WATERLOO, IA	30	0.81	1.02	2.24	3.56	4.15	4.31	4.70	3.69	3.43	2.37	1.67	1.15	33.10
CONCORDIA, KS	30	0.61	0.84	1.86	2.26	3.99	4.25	3.37	3.35	3.00	1.83	1.05	0.70	27.11
DODGE CITY, KS	30	0.45	0.57	1.47	1.84	3.28	3.02	3.08	2.54	1.86	1.27	0.76	0.52	20.66
GOODLAND, KS	30	0.38	0.37	1.04	1.17	2.92	2.72	2.41	1.94	1.44	0.91	0.60	0.41	16.31
TOPEKA, KS	30	0.88	1.05	2.18	3.08	3.99	5.14	4.04	3.69	3.45	2.82	1.75	1.31	33.38
WICHITA, KS	30	0.68	0.85	2.01	2.30	3.91	4.06	3.62	2.80	3.45	2.47	1.47	0.99	28.61
GREATER CINCINNATI AP	30	3.13	2.73	3.95	3.58	3.84	4.09	4.28	2.97	2.91	2.54	3.12	3.00	40.14
JACKSON, KY	30	3.93	3.69	4.62	4.00	3.52	3.78	4.90	3.63	3.10	2.11	3.18	3.53	43.99
LEXINGTON, KY	30	3.57	3.26	4.83	4.01	4.23	4.25	4.95	3.96	3.28	2.26	3.30	3.78	45.68
LOUISVILLE, KY	30	3.38	3.23	4.73	4.11	4.15	3.60	4.10	3.31	3.35	2.63	3.49	3.48	43.56
PADUCAH KY	30	3.67	3.39	4.96	4.57	4.65	4.45	3.69	3.22	3.49	2.60	4.04	4.16	46.89
BATON ROUGE, LA	30	4.58	4.97	4.59	5.59	4.82	3.11	7.07	5.05	4.42	2.63	3.95	4.99	55.77
LAKE CHARLES, LA	30	4.25	3.88	3.05	4.06	5.14	4.19	5.55	5.39	5.21	3.47	3.76	5.08	53.03
NEW ORLEANS, LA	30	4.97	5.23	4.73	4.50	5.07	4.63	6.73	6.02	5.87	2.66	4.06	5.27	59.74
SHREVEPORT, LA	30	4.02	3.46	3.77	4.71	4.70	3.54	3.56	2.52	3.29	2.63	3.77	3.87	43.84
CARIBOU, ME	30	2.36	2.14	2.44	2.59	2.88	3.18	4.03	3.97	3.52	3.11	3.22	3.15	36.59
PORTLAND, ME	30	3.78	3.57	3.98	3.90	3.27	3.06	2.83	2.82	3.27	3.83	4.70	4.51	43.52
BALTIMORE, MD	30	3.00	2.98	3.72	3.35	3.44	3.76	3.89	4.62	3.46	3.11	3.11	3.40	41.84
BLUE HILL, MA	30	4.57	4.20	4.73	3.97	3.68	2.99	2.94	4.29	4.03	4.05	4.67	5.02	49.14
BOSTON, MA	30	3.99	3.70	4.13	3.73	3.52	2.92	2.68	3.68	3.41	3.36	4.21	4.48	43.81
WORCESTER, MA	30	3.82	3.29	4.16	3.90	3.86	3.46	3.58	4.42	4.25	4.21	4.43	4.22	47.60
ALPENA, MI	30	1.65	1.34	1.93	2.50	2.83	3.16	3.11	3.17	2.92	1.99	2.21	1.95	28.76
DETROIT, MI	30	1.86	1.69	2.54	3.15	2.77	3.43	3.10	3.21	2.25	2.12	2.33	2.52	30.97
FLINT, MI	30	1.59	1.46	2.14	3.05	2.78	3.23	2.81	3.38	2.35	2.13	2.29	2.00	29.21
GRAND RAPIDS, MI	30	1.91	1.53	2.48	3.56	3.03	3.86	3.02	3.45	3.14	2.89	2.93	2.55	34.35
HOUGHTON LAKE, MI	30	1.49	1.30	1.88	2.58	2.59	3.10	2.89	2.96	2.77	2.28	2.26	1.89	27.99
LANSING, MI	30	1.74	1.56	2.30	2.88	2.57	3.50	2.78	3.04	2.54	2.13	2.33	2.21	29.58
MARQUETTE, MI	30	2.00	1.87	2.83	3.63	3.96	3.85	3.21	3.25	3.92	3.25	2.92	2.44	37.13
MUSKEGON, MI	30	2.37	1.65	2.54	3.16	2.54	2.52	2.42	3.13	2.92	2.78	2.87	2.60	31.50
SAULT STE. MARIE, MI	30	2.20	1.69	2.03	2.38	2.90	3.26	3.00	3.46	3.90	2.89	3.20	2.57	33.48
DULUTH, MN	30	1.20	0.90	1.78	2.16	3.15	3.96	3.96	4.12	3.26	2.21	1.69	1.29	29.68
INTERNATIONAL FALLS, MN	30	0.89	0.70	1.11	1.60	2.44	3.66	3.85	2.95	3.18	1.78	1.26	0.93	24.35
MINNEAPOLIS-ST.PAUL, MN	30	0.82	0.85	1.71	2.05	3.20	4.07	3.51	3.64	2.50	1.85	1.29	0.87	26.36
ROCHESTER, MN	30	0.74	0.69	1.73	2.50	3.42	4.12	3.82	3.85	3.07	2.08	1.39	0.84	28.25
SAINT CLOUD, MN	30	0.83	0.79	1.43	2.26	3.25	4.51	3.35	4.30	2.78	2.06	1.29	0.87	27.72
JACKSON, MS	30	5.00	4.48	5.86	5.85	4.83	2.94	4.40	3.71	3.55	2.62	4.18	5.40	52.82
MERIDIAN, MS	30	4.99	4.58	6.65	5.41	4.20	3.49	5.32	3.36	3.57	2.59	3.48	5.66	53.30
TUPELO, MS	30	5.65	4.63	6.94	5.66	5.22	3.72	4.59	2.84	3.64	2.99	4.63	5.61	56.12
COLUMBIA, MO	30	1.57	1.86	3.19	3.83	4.47	3.76	3.51	2.93	3.64	3.34	2.02	1.95	36.07
KANSAS CITY, MO	30	1.08	1.19	2.41	3.23	4.42	4.66	4.35	3.57	4.14	3.10	1.63	1.38	35.16
ST. LOUIS, MO	30	1.72	2.14	3.28	3.55	3.54	3.73	3.63	2.55	2.70	2.32	2.53	2.22	33.91
SPRINGFIELD, MO	30	1.60	2.13	3.44	4.03	4.32	4.66	3.58	2.83	4.24	3.20	2.89	2.55	39.47
BILLINGS, MT	30	0.97	0.71	1.05	1.93	2.39	2.07	0.85	1.05	1.26	1.16	0.85	0.80	15.09
GLASGOW, MT	30	0.46	0.38	0.40	0.87	1.76	2.47	1.65	1.43	0.89	0.56	0.31	0.37	11.55
GREAT FALLS, MT	30	1.00	0.75	0.93	1.49	2.52	2.75	1.10	1.31	1.03	0.82	0.74	0.80	15.24
HELENA, MT	30	0.66	0.44	0.69	1.01	1.72	2.01	1.04	1.18	0.83	0.65	0.54	0.60	11.37
KALISPELL, MT	30	1.62	1.06	0.84	1.06	1.76	2.24	0.94	1.44	1.11	0.98	1.29	1.59	15.93
MISSOULA, MT	30	1.41	0.81	0.83	1.01	1.62	1.85	0.85	0.95	1.02	0.85	0.88	1.21	13.29
GRAND ISLAND, NE	30	0.52	0.81	1.55	2.64	3.70	3.72	2.71	2.59	2.51	1.09	0.80	0.67	23.31

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LINCOLN, NE	30	0.64	1.01	1.94	2.81	3.84	3.84	3.20	3.42	2.93	1.68	0.96	0.65	26.92
NORFOLK, NE	30	0.52	0.80	1.54	2.21	3.71	4.35	3.21	2.65	2.09	1.36	0.72	0.63	23.79
NORTH PLATTE, NE	30	0.40	0.55	1.12	1.85	3.36	3.72	2.98	1.92	1.67	0.91	0.56	0.43	19.47
OMAHA EPPLEY AP, NE	30	0.77	0.91	1.91	2.94	4.33	4.08	3.62	4.10	3.50	2.09	1.32	0.77	30.34
OMAHA (NORTH), NE	30	0.70	0.95	2.00	2.74	4.26	4.21	3.50	4.19	3.36	2.11	1.16	0.76	29.94
SCOTTSBLUFF, NE	30	0.44	0.37	0.97	1.43	2.66	2.93	1.96	0.97	1.08	0.75	0.52	0.51	14.59
VALENTINE, NE	30	0.28	0.52	0.83	1.82	2.86	2.97	2.42	2.42	1.42	0.83	0.41	0.33	17.11
ELKO, NV	30	1.16	0.81	0.85	0.79	1.03	0.91	0.33	0.58	0.47	0.56	0.83	0.98	9.30
ELY, NV	30	0.72	0.68	0.91	0.92	1.08	0.80	0.65	0.62	0.70	0.59	0.60	0.75	9.02
LAS VEGAS, NV	30	0.50	0.46	0.41	0.22	0.20	0.09	0.45	0.54	0.32	0.25	0.43	0.32	4.19
RENO, NV	30	1.24	0.95	0.74	0.46	0.74	0.34	0.30	0.27	0.30	0.34	0.60	1.21	7.49
WINNEMUCCA, NV	30	0.89	0.67	0.67	0.81	0.80	0.92	0.18	0.39	0.34	0.59	0.75	0.86	7.87
CONCORD, NH	30	2.78	2.47	2.93	3.01	2.93	2.91	2.93	3.26	3.12	3.10	3.66	3.43	36.53
MT. WASHINGTON, NH	30	7.31	8.01	8.19	7.03	6.46	7.06	6.90	7.60	7.15	6.73	8.54	8.94	89.92
ATLANTIC CITY AP, NJ	30	3.47	3.34	4.04	3.20	3.07	2.78	4.02	4.72	2.89	3.06	3.73	3.61	41.93
ATLANTIC CITY C.O.,NJ	30	3.25	3.22	3.71	3.12	2.91	2.88	3.89	4.54	2.73	2.76	3.54	3.51	40.06
NEWARK, NJ	30	3.13	3.05	4.15	3.57	3.59	2.94	3.85	4.30	3.66	3.09	3.59	3.42	42.34
ALBUQUERQUE, NM	30	0.41	0.40	0.52	0.40	0.46	0.51	1.30	1.51	0.85	0.86	0.38	0.52	8.12
CLAYTON, NM	30	0.27	0.28	0.59	1.05	2.23	1.74	2.53	2.43	1.48	0.75	0.48	0.29	14.12
ROSWELL, NM	30	0.24	0.28	0.27	0.37	0.77	0.91	1.38	2.17	1.72	0.99	0.33	0.27	9.70
ALBANY, NY	30	2.39	2.26	3.01	2.94	3.31	3.29	3.00	3.34	3.23	2.93	3.04	3.00	35.74
BINGHAMTON, NY	30	2.54	2.33	2.94	3.07	3.19	3.60	3.48	3.35	3.32	3.00	3.04	2.92	36.78
BUFFALO, NY	30	3.02	2.40	2.97	3.06	2.89	2.72	2.96	4.16	3.37	2.93	3.62	3.42	37.52
NEW YORK C.PARK, NY	30	3.21	3.13	4.22	3.75	3.76	3.23	3.77	4.03	3.66	3.41	4.14	3.81	44.12
NEW YORK (JFK AP), NY	30	2.93	3.20	3.99	3.76	3.40	2.98	3.56	4.10	3.51	2.98	3.73	3.62	41.76
NEW YORK (LAGUARDIA AP), NY	30	3.11	3.08	4.10	3.76	3.46	3.15	3.67	4.32	3.48	3.24	3.77	3.68	42.82
ROCHESTER, NY	30	2.30	2.32	2.53	2.64	2.58	2.78	2.48	3.20	2.66	2.54	2.65	2.59	31.27
SYRACUSE, NY	30	2.61	2.65	3.11	3.34	3.16	3.63	3.76	3.77	3.29	3.14	3.45	3.20	39.11
ASHEVILLE, NC	30	3.48	3.60	5.13	3.84	4.19	4.20	4.43	4.79	3.96	3.29	3.29	3.51	47.71
CAPE HATTERAS, NC	30	4.72	4.11	3.97	3.21	4.09	4.22	5.36	6.11	5.78	4.83	4.84	4.48	55.72
CHARLOTTE, NC	30	3.80	3.81	4.83	3.27	3.64	3.57	3.92	3.75	3.59	2.72	2.86	3.40	43.16
GREENSBORO-WNSTN-SALM-HGHPT,NC	30	3.51	3.37	3.88	3.16	3.37	3.93	4.27	4.19	3.64	3.18	2.59	3.38	42.47
RALEIGH, NC	30	3.55	3.43	3.69	2.91	3.67	3.66	4.38	4.44	3.29	2.73	2.87	3.14	41.76
WILMINGTON, NC	30	3.64	3.44	4.04	2.98	4.22	5.65	7.44	6.64	5.71	2.97	3.19	3.43	53.35
BISMARCK, ND	30	0.51	0.45	0.70	1.51	2.23	3.01	2.05	1.69	1.38	0.81	0.51	0.51	15.36
FARGO, ND	30	0.55	0.42	0.83	1.90	2.24	3.06	3.34	2.67	1.87	1.29	0.79	0.63	19.59
WILLISTON, ND	30	0.55	0.50	0.57	1.29	1.85	2.68	1.83	1.42	1.37	0.74	0.50	0.55	13.85
AKRON, OH	30	2.56	2.18	3.37	3.26	3.55	3.27	4.01	3.31	2.96	2.24	2.54	2.65	35.90
CLEVELAND, OH	30	2.47	2.20	2.99	3.32	3.30	3.49	3.37	3.38	2.92	2.45	2.76	2.75	35.40
COLUMBUS, OH	30	2.75	2.18	3.23	3.41	3.76	4.01	4.01	3.70	2.76	1.91	2.64	2.61	36.97
DAYTON, OH	30	2.57	2.11	3.08	3.43	3.69	3.81	3.37	3.10	2.39	2.01	2.64	2.51	34.71
MANSFIELD, OH	30	2.25	1.86	3.00	3.55	3.75	3.44	3.73	3.25	3.04	1.94	2.66	2.40	34.87
TOLEDO, OH	30	1.99	1.80	2.64	3.04	2.90	3.49	3.26	3.19	2.53	1.94	2.41	2.59	31.78
YOUNGSTOWN, OH	30	2.69	2.23	3.29	3.46	3.29	3.53	4.04	3.47	3.10	2.65	2.82	2.76	37.33
OKLAHOMA CITY, OK	30	0.96	1.29	2.07	2.91	5.50	3.87	3.04	2.40	3.41	2.71	1.53	1.20	30.89
TULSA, OK	30	1.35	1.74	3.14	4.15	5.14	4.57	3.51	3.01	4.37	3.41	2.56	1.82	38.77
ASTORIA, OR	30	11.29	7.81	7.26	4.60	2.84	2.43	1.04	1.56	3.11	6.21	9.88	11.57	69.60
EUGENE, OR	30	8.39	5.12	5.11	2.76	1.97	1.24	0.27	0.95	1.45	3.47	6.82	8.49	46.04
MEDFORD, OR	30	3.42	2.12	1.85	1.07	1.19	0.67	0.25	0.46	0.75	1.68	2.89	3.49	19.84
PENDLETON, OR	30	1.73	1.11	1.06	0.99	1.09	0.70	0.30	0.55	0.58	0.95	1.48	1.66	12.20

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PORTLAND, OR	30	6.16	3.93	3.61	2.31	2.08	1.47	0.46	1.13	1.61	3.05	5.17	6.41	37.39
SALEM, OR	30	7.05	4.56	4.31	2.41	1.95	1.23	0.35	0.76	1.59	3.33	5.71	7.10	40.35
SEXTON SUMMIT, OR	30	7.00	4.35	4.02	2.14	1.86	0.96	0.27	0.70	1.31	3.15	5.96	6.42	38.14
GUAM, PC	30	5.43	4.76	4.19	4.14	6.41	5.53	10.31	13.92	14.25	13.87	8.98	6.07	97.86
JOHNSTON ISLAND, PC	30	2.35	1.88	2.72	2.41	1.81	0.92	1.05	2.11	2.09	3.02	3.06	3.10	26.52
KOROR, PC	30	11.14	8.02	8.19	10.21	13.09	14.69	16.32	15.20	13.06	13.68	10.95	12.95	147.50
KWAJALEIN, MARSHALL IS., PC	30	4.91	2.97	5.17	7.60	11.24	10.11	10.30	10.30	10.94	12.24	10.97	7.96	104.71
MAJURO, MARSHALL IS, PC	30	7.99	6.37	8.96	11.91	12.32	12.04	12.65	11.61	13.09	15.24	13.47	11.52	137.17
PAGO PAGO, AMER SAMOA, PC	30	12.78	12.53	11.38	11.25	10.72	8.56	6.51	7.08	6.69	11.05	11.20	14.21	123.96
POHNPEI, CAROLINE IS., PC	30	11.31	11.06	14.51	18.98	20.36	17.39	17.69	17.13	15.95	15.99	16.91	15.65	192.93
CHUUK, E. CAROLINE IS., PC	30	8.36	6.67	9.11	12.76	15.64	12.37	14.32	14.04	13.23	14.68	12.07	12.59	145.84
WAKE ISLAND, PC	30	1.17	1.20	1.94	2.09	1.87	2.34	3.84	5.46	5.66	4.76	2.77	1.76	34.86
YAP, W CAROLINE IS., PC	30	7.92	5.54	6.28	6.56	9.96	11.39	14.24	14.64	13.18	12.56	9.84	10.07	122.18
ALLENTOWN, PA	30	3.35	3.02	3.88	3.93	3.57	3.45	4.13	4.44	4.03	3.05	3.73	3.73	44.31
ERIE, PA.	30	2.49	2.12	2.91	3.49	3.28	3.72	3.28	3.85	3.89	3.37	3.74	3.25	39.39
HARRISBURG, PA	30	2.96	2.73	3.50	3.19	3.67	3.63	3.32	3.29	3.60	2.73	3.24	3.23	39.09
PHILADELPHIA, PA	30	3.18	2.81	3.86	3.47	3.18	3.92	3.88	4.10	3.42	2.83	3.32	3.45	41.42
PITTSBURGH, PA	30	2.86	2.40	3.58	3.28	3.54	3.30	3.83	3.31	2.80	2.49	2.34	2.57	36.30
AVOCA, PA	30	2.27	2.05	2.63	3.01	3.16	3.42	3.39	3.47	3.36	2.78	2.98	2.54	35.06
WILLIAMSPORT, PA	30	2.88	2.83	3.66	3.53	3.66	3.88	3.92	3.26	3.57	3.22	3.63	3.24	41.28
BLOCK IS.,RI	30	3.53	3.38	3.98	3.55	3.37	2.28	2.71	4.06	3.51	3.21	3.99	4.34	41.91
PROVIDENCE, RI	30	4.06	3.72	4.29	3.95	3.48	2.79	3.01	4.04	3.54	3.75	4.22	4.47	45.32
CHARLESTON AP,SC	30	3.33	3.37	4.38	2.58	4.41	6.54	7.33	6.50	4.94	2.92	2.18	3.11	51.59
CHARLESTON C.O.,SC	30	3.17	3.09	4.27	2.38	3.79	5.53	6.11	6.07	5.19	2.84	2.04	2.86	47.34
COLUMBIA, SC	30	4.38	3.99	5.16	3.59	3.85	4.45	5.35	5.56	4.23	2.55	2.51	3.50	49.12
GREENVILLE-SPARTANBURG AP, SC	30	4.21	4.39	5.87	4.35	4.22	4.77	4.08	3.66	4.35	3.49	3.21	3.93	50.53
ABERDEEN, SD	30	0.49	0.64	0.99	1.94	2.56	3.22	2.42	1.95	1.50	1.01	0.60	0.47	17.79
HURON, SD	30	0.42	0.77	1.22	1.99	2.72	3.31	2.26	2.01	1.36	1.39	0.69	0.52	18.66
RAPID CITY, SD	30	0.42	0.62	1.02	1.96	2.63	3.26	2.12	1.44	1.03	0.81	0.51	0.45	16.27
SIOUX FALLS, SD	30	0.50	0.93	1.58	2.36	3.21	3.70	2.71	3.13	2.79	1.57	0.92	0.72	24.12
BRISTOL-JHNSN CTY-KNGSPRT,TN	30	3.56	3.43	4.29	3.46	3.61	3.46	4.19	3.23	3.00	2.50	2.98	3.53	41.24
CHATTANOOGA, TN	30	5.20	4.69	6.31	4.57	4.00	3.32	4.55	3.41	4.30	2.92	4.19	5.14	52.60
KNOXVILLE, TN	30	4.65	4.18	5.49	3.87	3.71	3.95	4.33	3.02	2.99	2.73	3.78	4.59	47.29
MEMPHIS, TN	30	4.61	4.33	5.44	5.77	5.06	3.58	4.03	3.74	3.62	2.37	4.17	4.85	51.57
NASHVILLE, TN	30	4.49	4.03	5.58	4.47	4.56	3.70	3.82	3.40	3.71	2.58	3.52	4.63	48.49
OAK RIDGE,TN	30	5.25	4.60	6.21	4.41	4.23	4.26	5.21	3.75	3.80	2.89	4.50	5.65	54.76
ABILENE, TX	30	0.97	0.96	1.08	2.35	3.25	2.52	2.11	2.47	3.06	2.32	1.32	0.85	23.26
AMARILLO, TX	30	0.46	0.57	0.87	1.08	2.79	3.50	2.70	2.95	1.72	1.39	0.58	0.49	19.10
AUSTIN, TX	30	1.60	2.49	1.68	3.11	4.19	3.06	1.89	2.24	3.60	3.38	2.20	2.06	31.50
BROWNSVILLE, TX	30	1.25	1.55	0.50	1.57	2.15	2.70	1.51	2.83	5.24	3.54	1.44	1.16	25.44
CORPUS CHRISTI, TX	30	1.63	1.55	0.84	1.99	3.05	3.36	1.96	3.51	6.15	3.19	1.55	1.40	30.18
DALLAS-FORT WORTH, TX	30	1.65	1.93	2.42	3.63	4.27	2.59	2.00	1.76	3.31	2.47	1.76	1.67	29.46
DEL RIO, TX	30	0.51	0.89	0.63	1.85	1.99	1.72	1.69	1.60	2.73	2.24	0.80	0.55	17.20
EL PASO, TX	30	0.38	0.45	0.32	0.19	0.24	0.56	1.60	1.21	1.42	0.73	0.33	0.39	7.82
GALVESTON, TX	30	2.96	2.34	2.10	2.62	3.30	3.48	3.77	4.40	5.82	2.60	3.23	3.62	40.24
HOUSTON, TX	30	3.21	3.25	2.68	4.24	4.69	4.06	3.33	3.66	4.93	3.67	3.38	3.66	44.76
LUBBOCK, TX	30	0.38	0.57	0.90	1.08	2.59	2.81	2.34	2.20	2.06	1.81	0.59	0.43	17.76
MIDLAND-ODESSA, TX	30	0.42	0.58	0.51	0.84	2.05	1.44	1.72	1.60	2.08	1.41	0.60	0.45	13.70
PORT ARTHUR, TX	30	4.18	3.71	2.93	4.05	4.50	3.96	5.37	5.45	6.13	3.63	4.33	4.55	52.79
SAN ANGELO, TX	30	0.64	0.84	0.79	1.75	2.52	1.88	1.22	1.85	3.04	2.05	0.97	0.64	18.19

NORMAL PRECIPITATION : INCHES

NORMALS 1951-80	YRS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
SAN ANTONIO, TX	30	1.55	1.86	1.33	2.73	3.67	3.03	1.92	2.69	3.75	2.88	2.34	1.38	29.13
VICTORIA, TX	30	1.87	2.24	1.34	2.61	4.47	4.53	2.58	3.33	6.24	3.31	2.24	2.14	36.90
WACO, TX	30	1.69	2.04	1.99	3.79	4.73	2.58	1.78	1.95	3.18	3.06	2.24	1.92	30.95
WICHITA FALLS, TX	30	0.93	1.00	1.82	2.99	4.34	2.85	2.00	2.14	3.41	2.61	1.42	1.22	26.73
MILFORD, UT	30	0.69	0.74	0.99	0.96	0.73	0.42	0.61	0.71	0.69	0.73	0.69	0.63	8.59
SALT LAKE CITY, UT	30	1.35	1.33	1.72	2.21	1.47	0.97	0.72	0.92	0.89	1.14	1.22	1.37	15.31
BURLINGTON, VT	30	1.85	1.73	2.20	2.77	2.96	3.64	3.43	3.87	3.20	2.81	2.80	2.43	33.69
LYNCHBURG, VA	30	3.06	2.93	3.69	2.90	3.65	3.47	3.85	3.69	3.23	3.36	2.92	3.16	39.91
NORFOLK, VA	30	3.72	3.28	3.86	2.87	3.75	3.45	5.15	5.33	4.35	3.41	2.88	3.17	45.22
RICHMOND, VA	30	3.23	3.13	3.57	2.90	3.55	3.60	5.14	5.01	3.52	3.74	3.29	3.39	44.07
ROANOKE, VA	30	2.83	3.19	3.69	3.09	3.51	3.34	3.45	3.91	3.14	3.48	2.59	2.93	39.15
WALLOPS ISLAND, VA	30	3.13	3.22	3.69	2.77	3.52	3.62	3.75	4.31	3.31	3.35	2.81	3.31	40.79
OLYMPIA, WA	30	8.50	5.77	4.85	3.13	1.85	1.44	0.76	1.34	2.36	4.68	7.58	8.70	50.96
QUILLAYUTE, WA	30	15.07	12.10	11.27	7.10	4.70	3.06	2.32	2.85	5.27	10.51	13.94	16.31	104.50
SEATTLE C.O., WA	30	5.94	4.20	3.70	2.46	1.66	1.53	0.89	1.38	2.03	3.40	5.36	6.29	38.84
SEATTLE SEA-TAC AP, WA	30	6.04	4.22	3.59	2.40	1.58	1.38	0.74	1.27	2.02	3.43	5.60	6.33	38.60
SPOKANE, WA	30	2.47	1.61	1.36	1.08	1.38	1.23	0.50	0.74	0.71	1.08	2.06	2.49	16.71
STAMPEDE PASS, WA	30	14.59	10.19	8.88	6.28	3.97	3.84	1.56	2.85	4.65	7.74	12.14	15.88	92.57
WALLA WALLA, WA	30	2.12	1.40	1.41	1.35	1.40	0.93	0.35	0.71	0.83	1.40	1.87	2.19	15.96
YAKIMA, WA	30	1.44	0.74	0.65	0.50	0.48	0.60	0.14	0.36	0.33	0.47	0.97	1.30	7.98
SAN JUAN, PR	30	3.01	2.02	2.31	3.62	5.64	4.66	4.87	5.93	5.99	5.89	5.59	4.46	53.99
BECKLEY, WV	30	3.44	3.19	4.13	3.59	3.86	3.82	4.46	3.68	3.38	2.54	2.81	3.23	42.13
CHARLESTON, WV	30	3.48	3.11	4.00	3.52	3.68	3.32	5.36	4.15	3.01	2.63	2.90	3.27	42.43
ELKINS, WV	30	3.39	2.84	3.66	3.71	3.82	4.35	4.68	4.20	3.21	2.97	2.69	3.33	42.85
HUNTINGTON, WV	30	3.24	2.83	4.08	3.48	3.94	3.56	4.47	3.73	3.07	2.40	2.82	3.12	40.74
GREEN BAY, WI	30	1.19	1.05	1.90	2.70	3.13	3.17	3.25	3.16	3.17	2.10	1.76	1.42	28.00
LA CROSSE, WI	30	0.94	0.89	1.96	3.05	3.61	4.15	3.83	3.70	3.47	2.08	1.50	1.07	30.25
MADISON, WI	30	1.11	1.02	2.15	3.10	3.34	3.89	3.75	3.82	3.06	2.24	1.83	1.53	30.84
MILWAUKEE, WI	30	1.64	1.33	2.58	3.37	2.66	3.59	3.54	3.09	2.88	2.25	1.98	2.03	30.94
CASPER, WY	30	0.50	0.56	0.99	1.51	2.13	1.24	1.06	0.63	0.76	0.88	0.66	0.51	11.43
CHEYENNE, WY	30	0.41	0.40	0.97	1.24	2.39	2.00	1.87	1.39	1.06	0.68	0.53	0.37	13.31
LANDER, WY	30	0.48	0.63	1.13	2.22	2.69	1.45	0.71	0.49	0.87	1.20	0.76	0.53	13.16
SHERIDAN, WY	30	0.74	0.76	1.06	2.00	2.42	2.24	0.94	0.96	1.16	1.16	0.81	0.68	14.93