Doc. No. : CLEJ- 00560 - 12.03 - 06/01/80

Underground Spill Cleanup Manual

API PUBLICATION 1628
FIRST EDITION, JUNE 1980

American Petroleum Institute
1220 L Street, Northwest
Washington, D.C. 20005

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I. GEOLOGY AND GROUNDWATER

When gasoline, kerosine or similar petroleum product is lost into the ground, its behavior and ultimate fate will depend on the hydrogeology, or underground water conditions. Although spills involving hazardous materials or large volumes of fluids should be handled by an experienced professional familiar with this kind of problem, an understanding of certain elements of geology and groundwater hydrology can be useful to anyone dealing with an underground spill. For purposes of this discussion, the terms "gasoline," "petroleum," "oil" and "product" can be used interchangeably.

1.1 Rocks and Soils

The term "soil" is used here to mean loose, unconsolidated surface material, such as sand, gravel, silt or clay. "Bedrock" is the hard, consolidated material that usually lies under the soil, which commonly includes sandstone, limestone or shale. Most areas have a soil cover ranging in thickness from a few feet to hundreds of feet. Less commonly, bedrock may be at the surface with little or no soil cover.

Generally, rocks and soils are composed of small fragments or grains, such as sand. When these fragments are pressed together, small voids or "pores" exist between the grains in which fluid may be contained. Measurement of the total volume of these voids is called the "porosity" of the rock or soil. If the pores are interconnected, the rock or soil 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 have many, but extremely small, pores that are poorly interconnected. Since fluids cannot pass readily through such materials, they are "impermeable."

The term "aquifer" refers to a permeable section of soil or rock capable of transmitting water.

The more common rocks and soils usually occur in distinct layers or beds created by successive deposits of different types of rock and soil material. Such beds are commonly exposed in road cuts and may be horizontal, but more often will slope or "dip" in some direction. Such dips, in addition to the varying porosities and permeabilities of the different layers, can affect the movement of fluids underground.

Bedrock near the surface frequently is cracked and fluid movement can be confined to these fractures, rather than through connecting pores. The number, size and location of these fractures govern the movement of fluids in this environment and may vary greatly from one location to another.

Limestone near the surface may develop openings and fissures ranging in size from less than an inch to large caverns. In other instances, limestone may have low porosity and permeability.

The movement of fluids in a bedrock aquifer will be similar to those in a soil aquifer, although there are additional constraints. Because of these complications, a rather detailed geological study may be required to determine the proper approach for handling a spill in bedrock.

1.2 Groundwater

In most places, water exists at some depth in the ground. The source of most groundwater is precipitation over land, which percolates into porous soils and rocks at the surface. Depending on the location, a second important source may be rivers and streams that seep water into the subsurface. In many areas, enough groundwater is present to provide all or a major part of the water supply for towns, cities and rural areas. Details of a hypothetical groundwater system are shown in Figure 1.

The position of the water table is indicated by the level to which water rises in wells. Starting at the surface, there is a zone of partial saturation called the "zone of aeration." Pores in this zone contain some water, but are mostly filled with air. 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 "groundwater" (see Figure 2).

The water table surface usually conforms to the general topography of the land. The table fluctuates, rising during rainy seasons and falling during dry periods. Immediately above the water table is the "capillary zone," a complex section which greatly affects the movement of spilled oil, and which will be discussed later.

Most layers of rock or soil in a groundwater system can be classified as either "aquifers" or "aquicludes" (Figure 1). An aquiclude is a rock or soil layer sufficiently impermeable to prevent the passage of water.

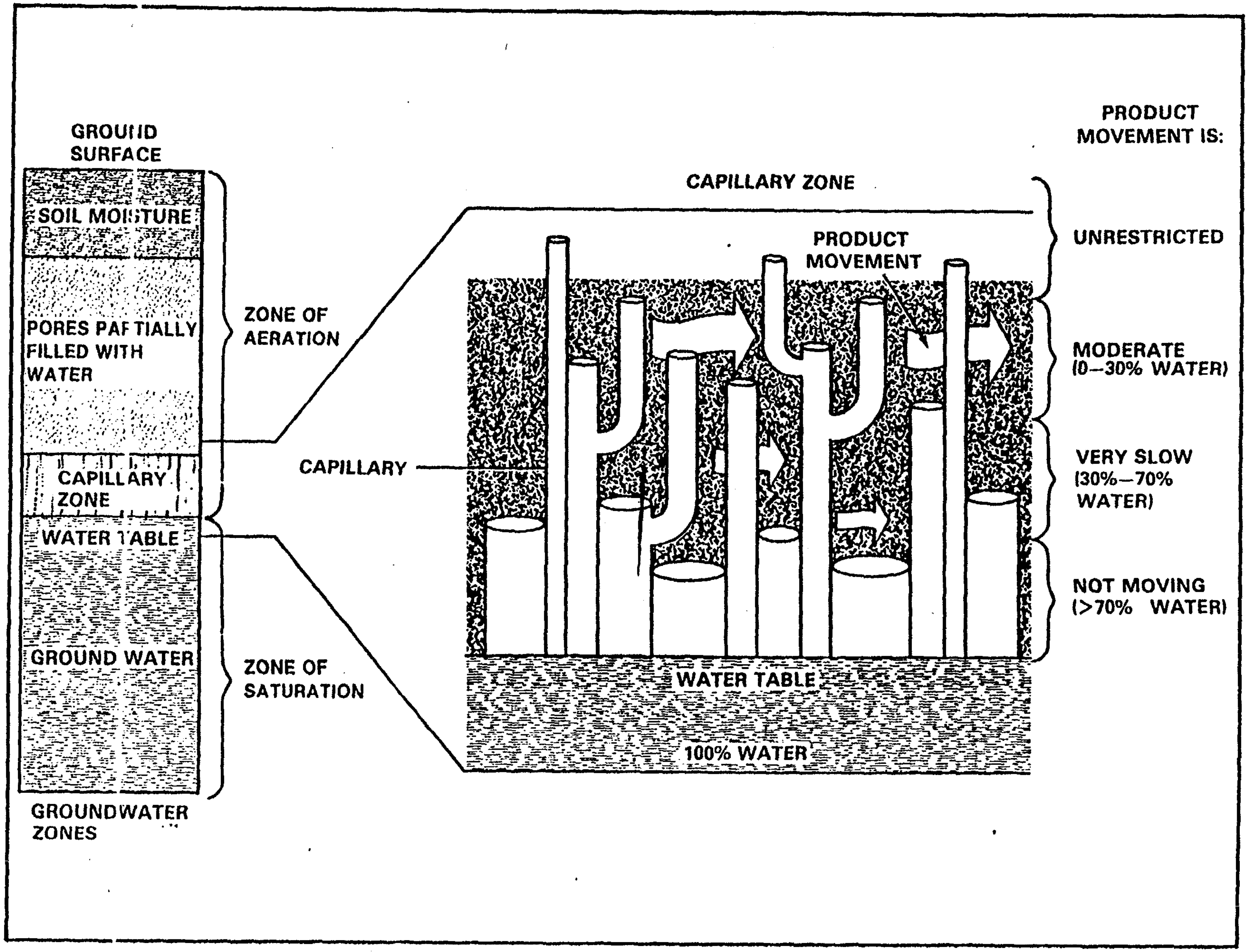

Figure 2 — Diagramatic Illustration of Water Rising in Capillaries of Varying Diameters and the Restricting Effect on Product Movement Through the Zone

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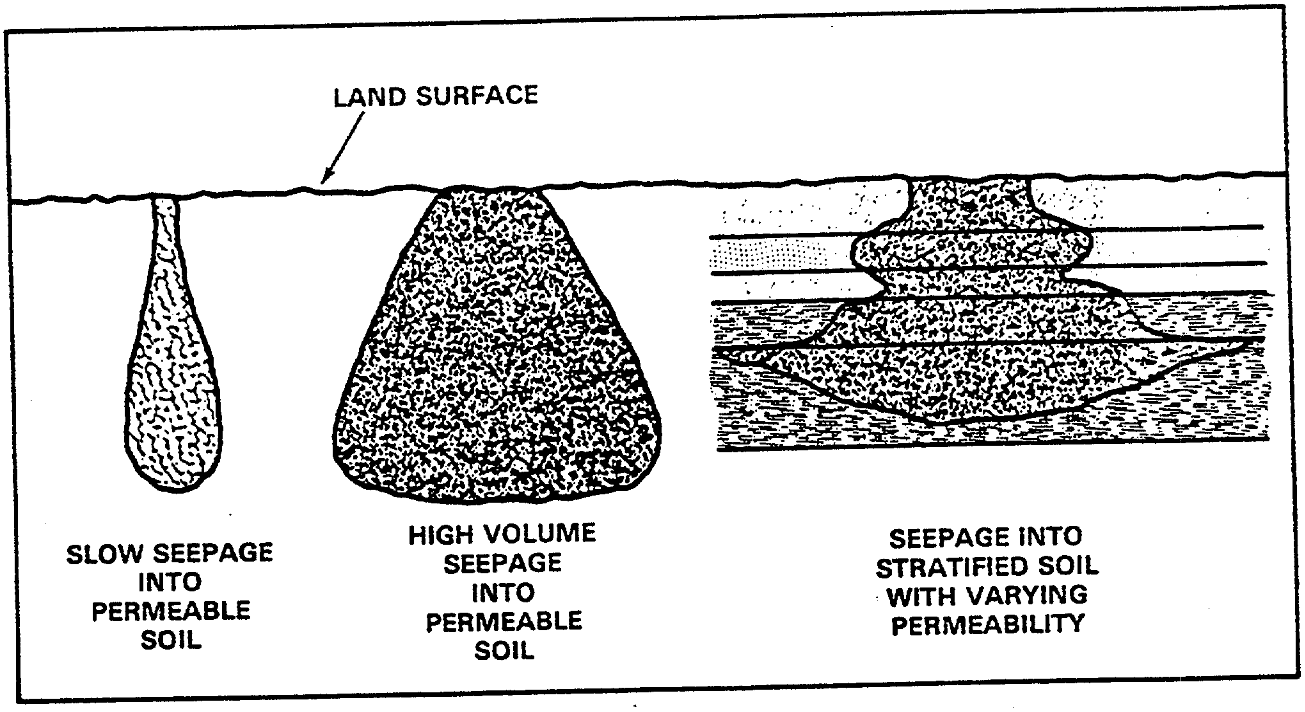

Figure 3 — Product Seepage

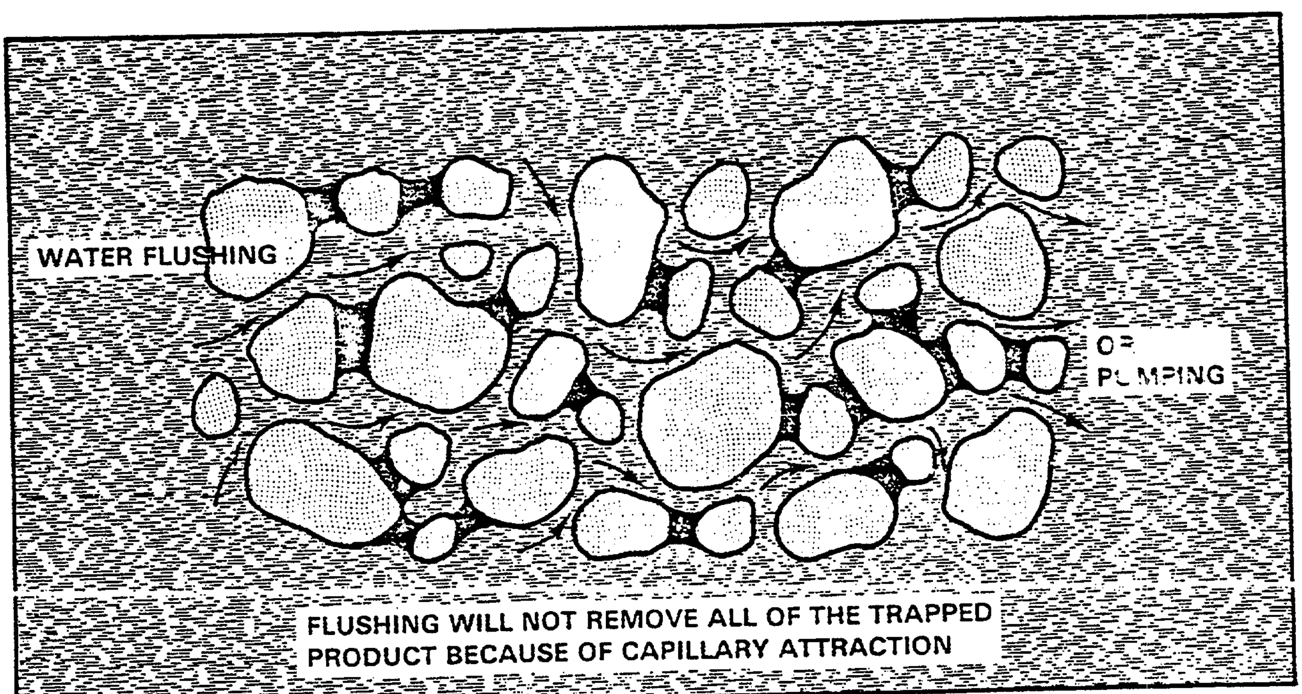

Figure 4 — Trapped Product Droplets

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III. PRODUCT ON THE WATER TABLE

3.1 Movement on Groundwater

The contact of spilled product with the water table usually is the most troublesome result of an on-land spill. This condition greatly increases the risk of polluting a water supply, and may increase the chance of movement to some underground structure, such as a basement, sewer or conduit. The degree of risk depends on the nature of the groundwater system and the way it is utilized.

Figure 7 illustrates a pattern of oil descent to a water table. A sudden, large-volume spill will depress the water table and spread in all directions in a layer above the water table. As the layer becomes thinner, it will begin to move in the direction of groundwater flow (Figure 8).

A slower leak will descend in a narrow cone and spread in the direction of water movement, Lateral spreading will usually be slower than the flow rate of the groundwater.

Theoretically, the spread of a hydrocarbon spill on a water table can be calculated. In an actual field situation, however, so many assumptions and estimates are required that accurate calculations of the product spread cannot be made. Usually, it is better to monitor directly the spread of the contaminant through the use of observation wells.

3.2 Capillary Zone

The upper surface of a groundwater body is very unlike that of water aboveground. Groundwater exists in innumerable small pores between the soil grains, which connect vertically to form capillary tubes rising above the water table. Each of these tubes will cause water to rise some distance, depending on the size of the capillary. Thus, there is a substantial amount of water held in the soil structure above the water table, in what is called the "capillary zone" (Figure 2).

The thickness of the capillary zone is primarily a function of pore and grain size. Coarse-grained soils will have a relatively thin zone; fine-grained soil will produce a thicker zone. These intervals commonly may range from a few inches to three or more feet, although averages of typical aquifers might be on the order of 10 to 20 inches.

The upper surface of the product will also be affected by capillarity and will experience a similar rise. This

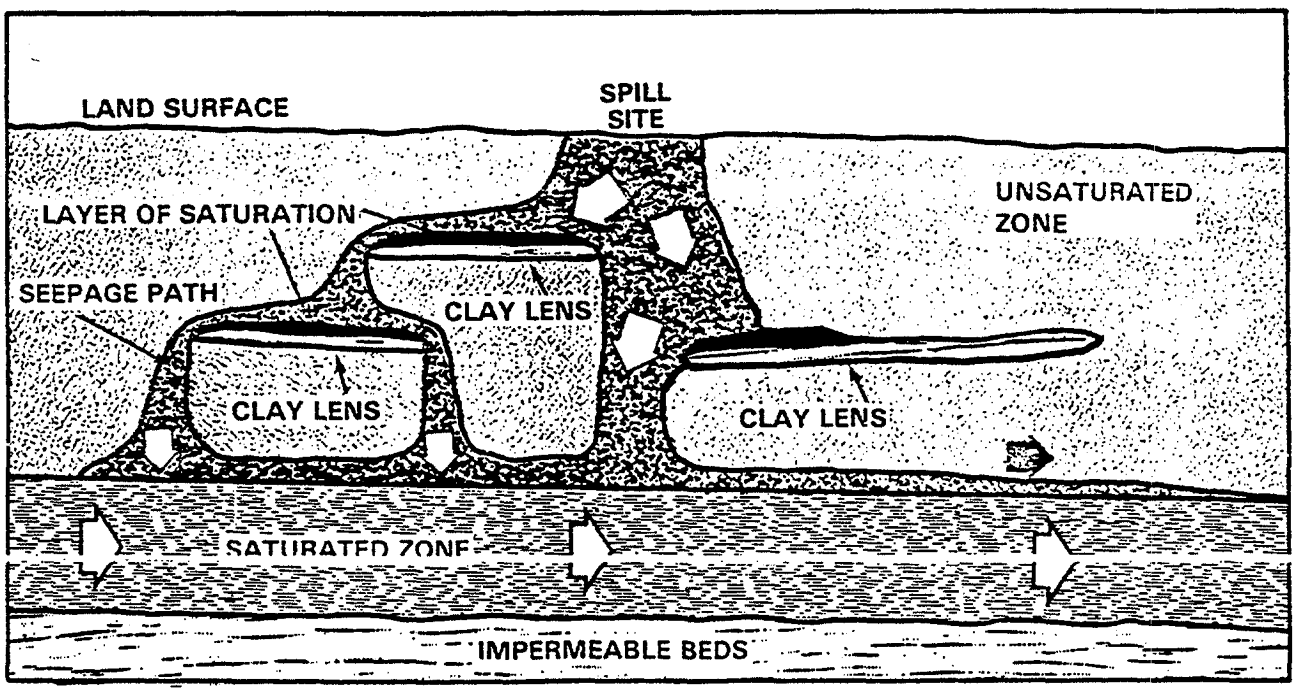

Figure 6 — Effect of Clay Lens in Soil

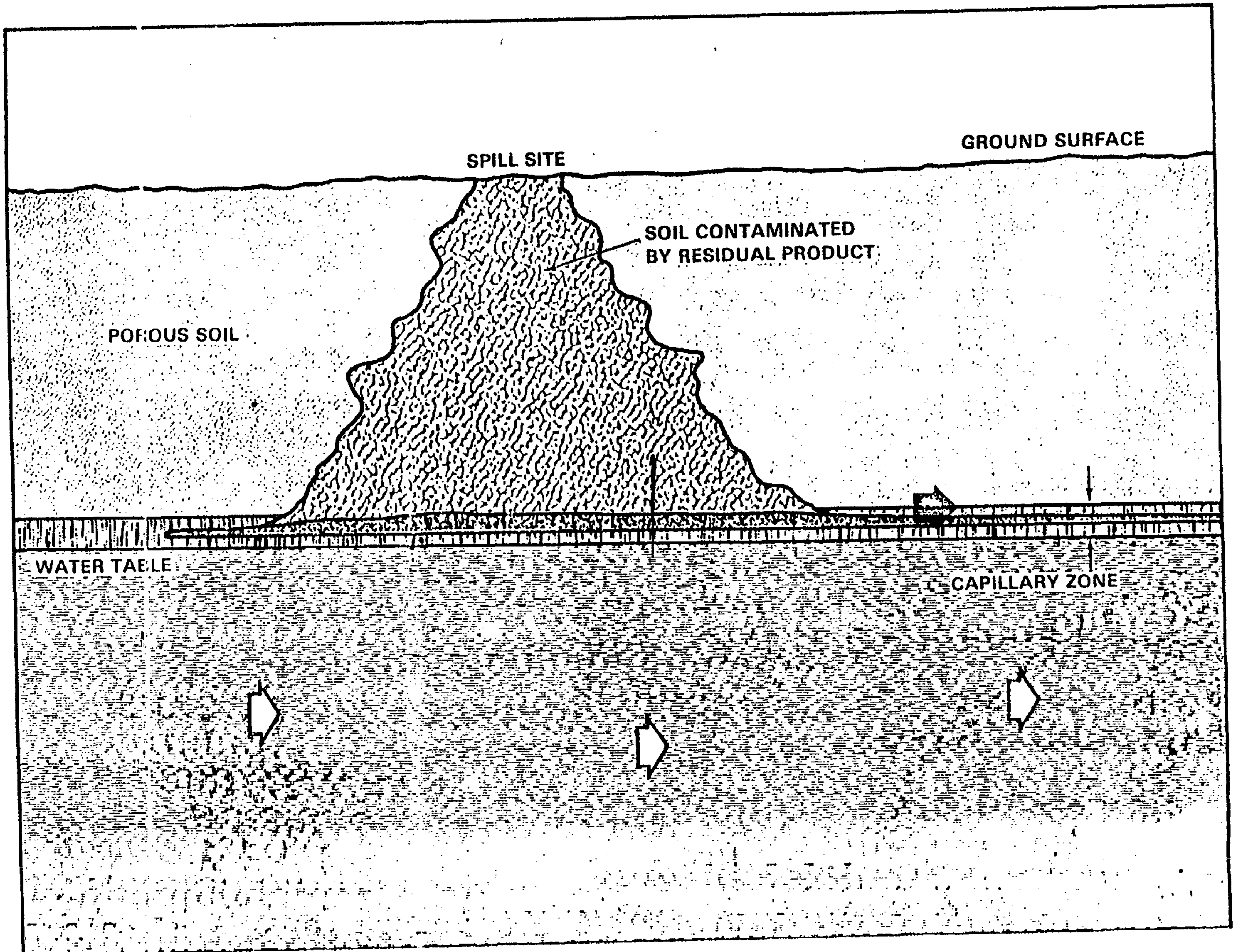

Figure 8 — Behavior of Product After Spill Has Stabilized

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product rise has the potential for producing vapor problems in buildings even when the water table lies several feet below a floor. Immediately above the water table, the capillary zone will be 100 percent saturated with water. This will decrease gradually upward, until it reaches near zero saturation at the top of the capillary zone. Water held by capillary action will not flow into a well.

As descending oil approaches the water table, it cannot displace much of the capillary water. Therefore, it will move downward around the water-filled pores and through the larger pores until it encounters water which it cannot bypass. The weight of the oil will depress the water table and the capillary zone will follow it downward, since each capillary must remain attached to its source. The amount of oil at any position in the capillary zone will depend on the amount of capillary water present. The least oil will be near the bottom of the zone, which is heavily saturated with water, and the most oil will be at the top, where there is less water saturation.

The amount of water in the capillary zone inhibits the lateral movement of the oil. In the upper portion of the zone, where there is little water, product may move with only minor interference. Near the middle, movement will be greatly restricted. And, in the lower portion, movement may not be possible at all. This is illustrated in Figure 2.

Consequently, a body of spilled oil will spread over and through the capillary zone, as shown in Figure 8. Eventually, with enough time and no addition of new product, the layer of gasoline will reduce to a critical thickness and stop moving. The thickness is determined by existing permeability and gradient. The ultimate thickness of the mobile product will be only a fraction of the thickness of the capillary zone.

Consideration of these conditions also makes it evident that the thickness of oil measured in a well will be much greater than the corresponding thickness in the aquifer. This occurs because the layer of mobile product in the capillary zone is some distance above the water table. When this product encounters the open space in a well bore, it "pours" in and accumulates on the water surface. As it accumulates, its weight begins to depress the water surface. It continues to thicken until the top of the oil in the well is level with the top of the oil in the mobile layer in the aquifer. Consequently, any estimate of the total spill volume based on the oil thickness in wells will result in a considerable overestimate (see Figure 9). *It is important to recognize that the thickness of the mobile product in the capillary zone may be less than an inch, while the thickness in a test well may be several inches or more.*

3.3 Vertical Movement

A typical water table will fluctuate up and down in response to seasonal changes and short-term variations in rainfall. If a petroleum product is present on the water table during this fluctuation, it will be carried vertically on the changing water surface and will leave behind a residue of product in the soil (Figure 10). Large fluctuations can result in immobilization of a great quantity of product.

3.4 Contamination by Solution

Oil generally will not mix with water and will simply float on the surface. Many oils and refined products, however, contain certain components which are slightly soluble in water. Solubility is greatest with the lighter, aromatic components.

Gasoline is high in water-soluble hydrocarbons. Concentrations of gasoline, when dissolved in water, produce odor and taste that can be detected by many people at levels of only a few parts per million. Although most contamination by water-soluble hydrocarbons occurs at the oil-water interface, when rainwater infiltrates contaminated soil, it may pick up additional soluble components and carry them into the groundwater system. Under normal conditions, these dissolved components are restricted to the upper part of the aquifer. Pumping may cause some downward movement and increase the risk of contaminating the aquifer. Expansion of the contaminated zone may occur as a result of high-volume pumping within the area of influence of the well.

representing local public authority) to specific areas on the map. The search should begin with the nearest and most obvious potential sources from the point of discovery, and worked outward from there. The team should concentrate on moving uphill, upstream of underground water flow, or upstream of sewer or conduit flow.

If this initial investigation fails to discover an obvious or very likely source within the first few hours, it is advisable, while the primary search continues, to begin testing equipment for concealed leaks at the closest and most probable sources.

Products usually travel slowly underground, perhaps a few feet per day, or may not move at all until the water table rises. There can be considerable time lapse between a leak or spill and the finding of liquid or vapor. All potential sources, regardless of how long ago they occurred, should be investigated. No potential source should be eliminated on the basis of time, until there is enough information to justify elimination of that suspected source.

The list below should be used to check for leaks, spills or other possible sources by asking questions and by simple inspection of the premises and equipment. Unless an obvious source is found, the search should not stop at the first sign of a potential source. There may be more than one source contributing to the spill.

1. *Possible sources to check:*
   a. Service stations
   b. Motor vehicle garages
   c. Automobile dealerships
   d. Convenience stores
   e. Municipal garages
   f. Abandoned or converted service stations
   g. Fleet operators such as taxicab companies, bakeries, dairies and contractors
   h. Cleaning establishments
   i. Industrial plants, including refineries, terminals and bulk plants
   j. Schools, hospitals and other institutions with underground or surface fuel oil tanks
   k. Pipelines
   l. Abandoned oil and gas wells
   m. Subsurface disposal and injection systems.
2. *Procedures and data required for investigation:*
   a. It should be determined if accurate daily inventory control records are maintained at the facilities. In most locations, regulations now specify that such records must be maintained and be available for inspection by an enforcing authority. If records are not maintained in good order, the facility should be considered a primary potential source of the fugitive petroleum, and the tanks and underground lines should be tested for tightness as soon as possible at the expense of the property owner or operator. If records are properly maintained and reconciled, they should be carefully reviewed for discrepancies or loss trends. (Further information on inventory control may be found in *API Publication 1621, "Recommended Practices for Bulk Liquid Stock Control at Retail Outlets."*)
   b. It should be determined if a recent spill or overfill occurred during delivery of product to the facility.
   c. It should be determined if there has been a tank or pipe leak at the facility anytime during the past few years. Leaked product often takes several weeks, months, or years before it migrates to a location where it presents a hazard. The owner or operator should be asked if he has any knowledge of a leak occurring at neighboring facilities.
   d. A check should be made for recent excavations or new or patched concrete or asphalt, often a sign that a tank or piping system has been repaired.
   e. Product dispensers should be inspected to determine if they are out of plumb or badly dented, an indication that they may have been struck by a vehicle, with resulting damage to the underground piping system.
   f. It should be determined if water had been previously found or is presently in an underground tank.
   g. Remote pumps should be inspected to determine if they are leaking or if the soil or sand around the pumping unit is saturated with gasoline.
   h. With the panels removed, dispensers should be observed while in operation, to determine if leaks exist in the dispenser itself or in any of the exposed piping.
   i. If leak detectors are installed on remote pumping systems, it should be determined if they are functioning properly.

If the investigation fails to locate the source, owners of facilities should be asked for their cooperation in performing tests on the underground equipment. A governmental official, such as a fire marshal or environmental agent, may need to exercise the necessary authority to require tests, particularly at facilities where inventory records have not been maintained.

When leaks in equipment are discovered, the owner should stop further use of the equipment until the leak

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When such liquids escape into the ground, they flow downward to the groundwater and float on top of it. An understanding of groundwater movement (Section I) is therefore basic to tracing underground product.

When a petroleum product is floating on the water table, one can determine the extent of contamination, the direction of flow, and the source of the contaminant by digging, or preferably drilling, observation wells. Prior to installation of the wells, covered in Section IV, several steps should be completed:

1. Permission should be obtained, preferably in writing, from property owners, including private individuals, the city, county, township or state.
2. Utility companies should be advised of the project, so that buried pipes and cables can be located. Often one telephone call to a "central utility notification number" will put a person in contact with individuals who can locate underground utilities. Facilities which should be located exactly and marked on the ground surface include:
   a. Gas pipes
   b. Water pipes
   c. Power cables
   d. Telephone cables
   e. Sanitary and storm sewers
   f. Oil pipelines.

   Service lines branching from the main lines to buildings should also be located, as well as other buried structures, such as fuel oil tanks and related piping.
3. The municipality's department of public works or similar agency should be contacted. Department employees can often provide valuable information, indicating the types of materials encountered during excavations, water table depths, and probable direction of flow. Copies of maps and diagrams of sewer systems and utilities should be requested.
4. Accurate topographic maps of the area as well as aerial photographs, if available, should be obtained. Common sources for such maps and photos include:
   a. United States Geological Survey
   b. The Soil Conservation District Offices
   c. The municipal tax offices
   d. The engineering or architectural firms which designed or built nearby structures
   e. Local surveyors
   f. The town or city department of public works
   g. Libraries, stationery stores, or look under "Maps" in the *Yellow Pages*.
5. All materials and equipment necessary to install the wells should be obtained. A check list of needed materials appears in Section V.
6. Several observation wells should be drilled in the contaminated zone and around its periphery, and a log maintained of the operation to record the types of soil, clay and rocks encountered, and the depth of groundwater.
7. After a well has been drilled and cased, groundwater and contaminant should be allowed to stabilize before depth measurements are taken. Stabilization will normally occur within two to 24 hours.
8. A bench mark should be established and the elevation of each well casing surveyed. These elevations must be exact, usually to 0.01 of a foot.
9. A steel measuring tape with a small weight affixed to the end should be used to determine the depth to the water table and the thickness of the layer of contaminant. Large weights should not be used, since they will displace the liquid and invalidate the measurement. The use of gauge sticks in holes with diameters less than 4 inches also should be avoided. The use of water finding and gasoline finding pastes will greatly increase the accuracy of such measurements. The mechanics of this procedure are described in Figure 11.
10. The measured depths should be subtracted from the surface elevation. This will produce the elevations of the fluid surfaces. By plotting the groundwater elevations on a map or sketch of the area, the direction of flow of the contaminant can be determined, since product floating on top of the water table will normally flow from higher to lower elevations.
11. By determining the area of contamination and the direction of flow, recovery systems may be located and installed where they will be most effective.
12. Once a test well has been installed, it normally should be covered and secured. The well may need to stay functional for several years, to allow for monitoring during the recovery program or thereafter.

4.4 Product Sampling

Correct methods of sampling and identifying hydrocarbons are essential, and can be crucial in identifying the source of petroleum spills. The samples must be taken in a manner so as to provide a representative specimen of the product.

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Samples of product in liquid form or contained in groundwater can be used to determine the nature and the concentration of hydrocarbons. Product samples should be taken from the fluid surface by bailing or from a pump discharge.

Samples can be collected in either clean glass or metal containers, but metal containers have the advantage of not being easily broken. Suitable containers can be obtained from drug stores, supermarkets or laboratories. Lids or caps with aluminum-coated cardboard or teflon inserts should be used. Plastic, wax-coated or aluminum foil caps, lid inserts or seals should be avoided, because hydrocarbons can escape, be contaminated, or absorbed. Also, plastic or polyethylene bottles should not be used. All sample containers must be absolutely clean and free of foreign materials.

Sample bottles should be filled 3/4 to 4/5 full to avoid loss of floating oil and to permit the entire sample to be extracted, if required.

4.5 Water Sampling

Water samples may be obtained by thieving or pumping from selected depths. For extraction-type analyses, it is satisfactory to use gallon jugs, acid bottles (2.2 liter) or, in some cases, quart containers. Smaller samples are of little value for extraction, but are suitable for some of the newer analytical techniques. If the water sample cannot be analyzed within two hours after it is taken, it should be preserved against bacterial attack. This can be done by adding 5ml per liter of a solution of one part water and one part hydrochloric or sulfuric acid.

4.6 Labeling and Shipment

It is important to label the source of the sample and the conditions under which it was collected. Useful data, if applicable, for most product and groundwater samples include:

*a. Geographical location
*b. Source of collection
*c. Name of collector
*d. Date of collection
e. Witness
f. Point of collection (from pump or open water)
g. Principal use of the water
h. Water-bearing formation(s)
i. Depth to the water table
j. Depth of well
k. Diameter of well
l. Length of casing and position of screens
m. Yield of well in normal operation
n. Appearance at time of collection
o. Any other information that may assist in interpreting the sample.

*Minimum required information.

Labels should be attached securely to each sample container. The sample is of little value if this information is not available.

When shipping petroleum samples to the laboratory for analysis, it is necessary to observe all local, state and federal regulations regarding shipping of volatile hydrocarbons. Volatile hydrocarbon samples will not be accepted for transport by bus, passenger aircraft, U.S. mail or parcel post.

4.7 Detection of Hydrocarbons in the Field

Hydrocarbons in subsurface or surface waters can often be detected by sight, smell or taste. Refined products such as gasoline and distillate fuels can be nearly colorless and difficult to see, particularly in a thin film, unless they are colored. Residual fuels and crude oil are easily seen, as a rule, even in a very thin film. Extremely thin films may appear to be iridescent or silvery.

All but the most highly refined petroleum products, such as white oil or mineral oil, have a characteristic odor. An experienced person can often judge, to some extent, the type of hydrocarbon causing a particular odor. However, the sense of smell becomes fatigued quickly. An odor that "disappears" can create a false sense of security where vapors are involved. If hydrocarbon vapors have been detected by odor, further search should be made with an instrument for measuring combustible gas.

4.8 Identification Procedures

Because of the complex nature of petroleum and the difficulty in identifying a product source, laboratories skilled in the use of modern techniques should be consulted in the identification of unknown products. There are very few commercial laboratories that have such skill. It follows that methods to be used in the field are virtually nonexistent. Since identification usually consists of comparing unknown product to known products, the interpretation of such data should be left to persons who have the necessary experience. In all cases, the possible effects of weathering of light hydrocarbons must be considered.

There are two sources of methods generally accepted in the area of oil identification. One is the *Annual Book of ASTM Standards*. It contains specification tests for motor gasoline, aviation gasoline, aircraft turbine fuel, diesel fuel and fuel oils. Tests for heavy fuel oil are

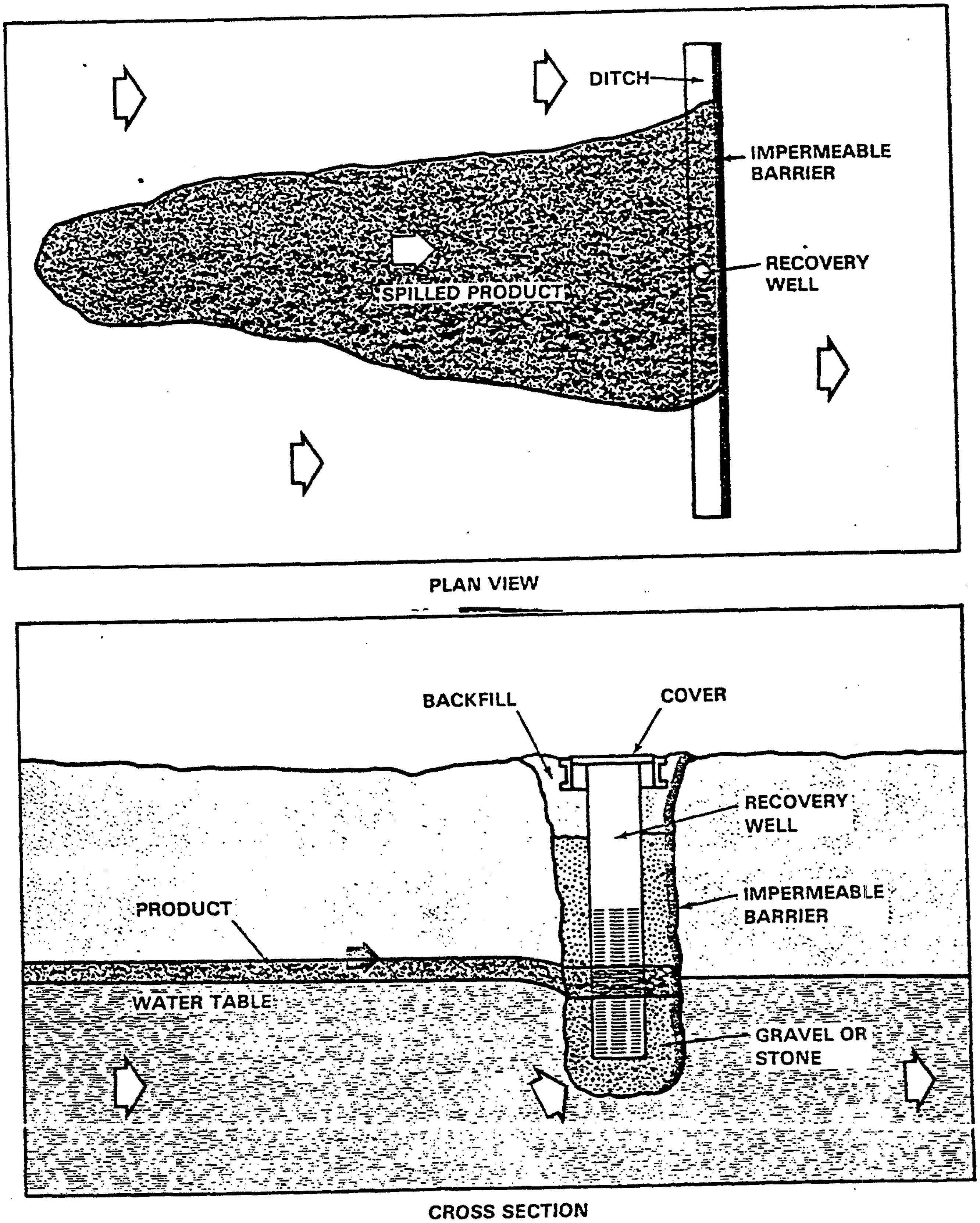

Figure 12 — Interceptor Trench

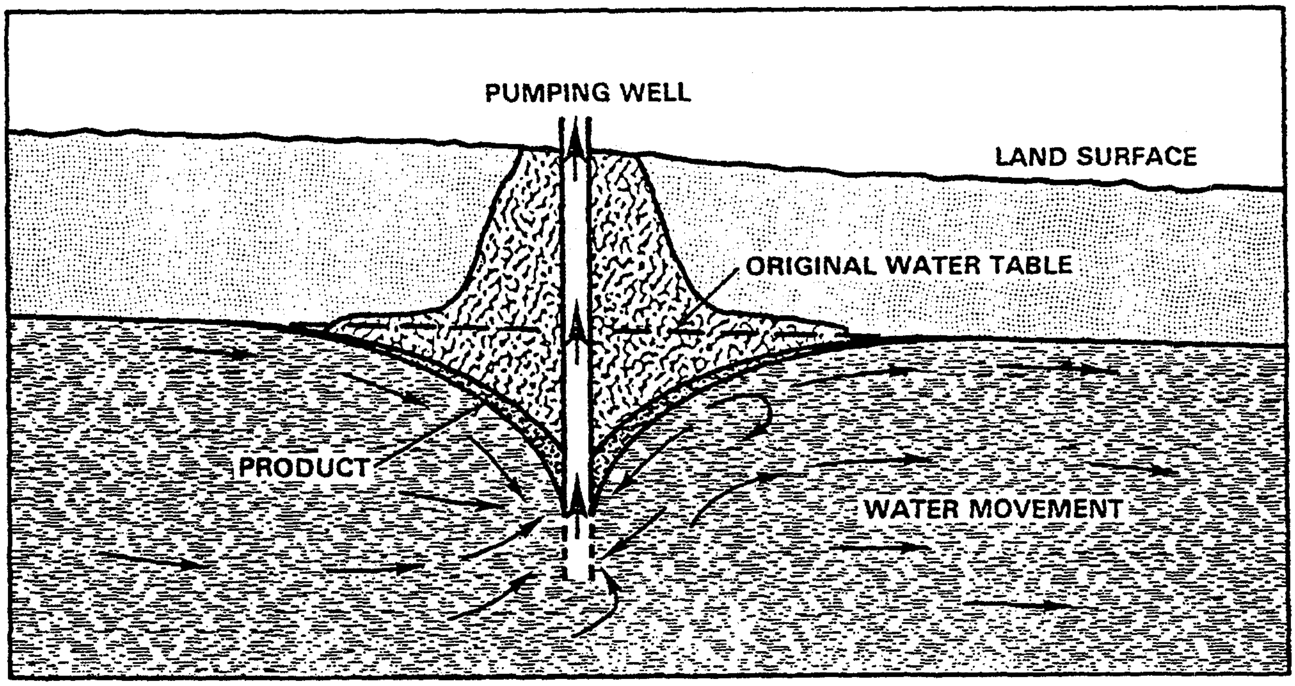

Figure 13 — Oil on Water Table is Trapped in Cone of Depression Created by Drawdown of Pumping Well

tion is known about an aquifer, the behavior of the depression cone some distance from the well can be calculated quite accurately. Within 100 to 200 feet of the well, however, such calculations are unreliable because of local characteristics of the aquifer.

A standard procedure is to sink two or three monitor wells in one or more straight lines away from the recovery well. Fluid levels in these wells can be observed to determine the exact time and amount of drawdown. From these data, expansion of the depression cone can be predicted. Withdrawal rates should be adjusted to maintain a cone only large enough to contain the oil.

5.6 Well Drilling Equipment and Techniques

When it has been determined that either test wells or recovery wells are to be installed, the size and depth of holes will determine the drilling equipment that should be used. Care should be taken to use equipment capable of installing wells to required specifications. Use of expensive equipment should be avoided where it is not required.

In virtually every area where groundwater is used, well drillers can be found who have drilling equipment for installing both test wells and recovery wells. In urban areas, equipment can be obtained from foundation testing contractors or soil testing firms. Although hand-operated equipment is available which can be useful in certain circumstances, commercial drilling equipment is generally more suitable.

5.7 Well Completion Techniques

Casing is necessary in test and recovery wells. Any steel, polyvinyl chloride (PVC) or other strong pipe or tubular product may be used. PVC pipe is usually recommended, as it is readily available, light, easy to handle, relatively inexpensive and available in diameters from one to 18 inches. This pipe also can be purchased factory-slotted (known commercially as "well screen") or perforations may be cut in the field. Acrylonitrile-butadiene-styrene (ABS) pipe should not be used, as it tends to become brittle with weathering and dissolves upon contact with petroleum hydrocarbons.

Test wells typically range from 1 to 4 inches in diameter. They should be installed to a minimum depth of about five feet below the probable low water table. The slotted or perforated section of pipe, known as the screen, should extend both five feet above and below the water table to assure the fluctuation of the water table will be within the perforated section. This will allow the product to migrate into the pipe.

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The size and location of the perforations are dependent on the soil characteristics and gravel-packing around the exterior of the well pipe. Factory slotted PVC pipe should be used when possible. A Schedule 40 PVC pipe with random slots of twenty-thousandth of an inch (0.020) will handle most soil conditions. When properly gravel-packed, it minimizes or eliminates the infiltration of fine sands or the need for additional screening.

Gravel-packing is important to establishing a good well. The test well hole should be drilled a minimum of 4 inches larger than the test well pipe diameter. The area outside of the pipe should be packed uniformly with coarse masonry sand, pea gravel, one-fourth inch crushed rock, or quartz blasting sand larger than the screen perforations.

The bottom end of the pipe should be capped. The top may be above the ground level and capped to keep debris out of the well. However, security and safety considerations may require that the top of the casing be set below ground level. Each well should be vented with 1/4" hole in the cap or at the top of the casing.

Proper installation of a recovery well is critical. The installation is similar to that of a test well, but there are important differences. A recovery well will normally be larger in diameter to accommodate the pumps and controls designed for recovery operations, and extended to greater depth below the water table. The depth will depend on the aquifer and soil characteristics, the area of contamination and the area of the cone of depression. Figures 14 and 15 illustrate proper installation of test and recovery wells. To eliminate expenditures for wells or equipment that may be unnecessary or may not perform as planned, recovery well design should be left to professionals.

5.8 Emergency Recovery Systems

When underground flammable or combustible liquids are creating hazardous conditions by entering buildings, underground utility vaults or sewers, the immediate installation of a recovery system often will be necessary. In such cases, systems constructed from materials commonly available in most communities can be used during the period required to install test wells and design and construct a permanent recovery system.

A recovery system employing readily available materials, as shown in Figure 16, usually can be placed in operation in the matter of a few hours. It utilizes a length of culvert pipe, with randomly located torched or cut perforations, which is wrapped with ordinary screen. As well-drilling equipment often is not available on short notice, a backhoe usually is used to excavate to the water table and contaminant.

Once such a well is in place and significant amounts of petroleum products are encountered, a vacuum truck can be used to recover the bulk of the contaminant. It is not recommended, however, that vacuum trucks be used for extended recovery. Their use should be limited to the initial emergency period or during the time necessary to install an adequate pumping system.

Quickly installed emergency recovery systems often make use of a single submersible or suction pump, such as those used at service stations. With a single pumping system that recovers both groundwater and floating product, it is necessary to construct a separator to process the oil/water mixture. A 55-gallon drum or fuel oil tank can be adapted to separate such mixtures by standard pipe and fittings available from a plumbing supply company. A shop-built, temporary separator of the type shown in Figure 16 can be constructed in an hour's time with common welding equipment.

Although systems utilizing such materials may be invaluable during the time of an emergency, a permanent system designed by a person knowledgeable in subsurface petroleum recovery should be installed as soon as possible, and the initial system removed or properly abandoned.

5.9 Well Pumping Equipment and Techniques

In an emergency, any safe means of pumping may be used. As soon as possible, however, a submersible or positive displacement pump should be installed. Submersible pumps are available that can operate in wells as small as 4 inches in diameter. Discharge capacities range from a few gallons to hundreds of gallons per minute, depending on pump size, casing diameter and well depth. Submersible pumps are most suitable for this type of operation, but they must be properly installed and maintained, as some will burn out quickly if operated dry.

Pumps should be ordered with the maximum gallons per minute (GPM) flow rates anticipated for establishing the depression cone and for the desired product recovery rate. Flow rates can be reduced by valve controls, if necessary.

When ordering pumping equipment, it should be made certain that the supplier is aware of the proposed use, so that proper seals, impellers, gears, etc. may be provided. Most fractional horsepower pumping equipment has plastic, fiber or metal impellers and gears that may not be compatible with certain hydrocarbons.

When using positive displacement suction pumps,

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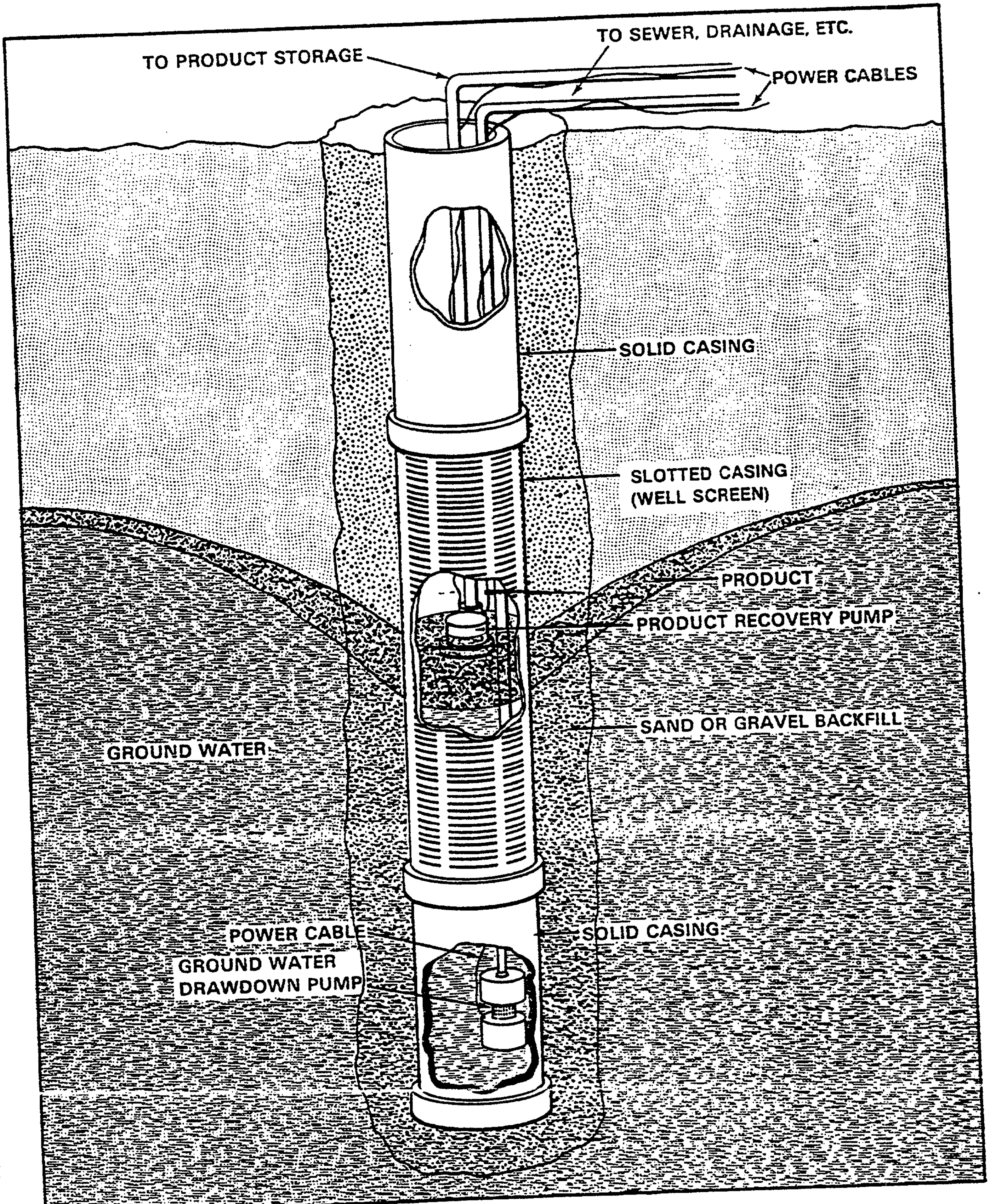
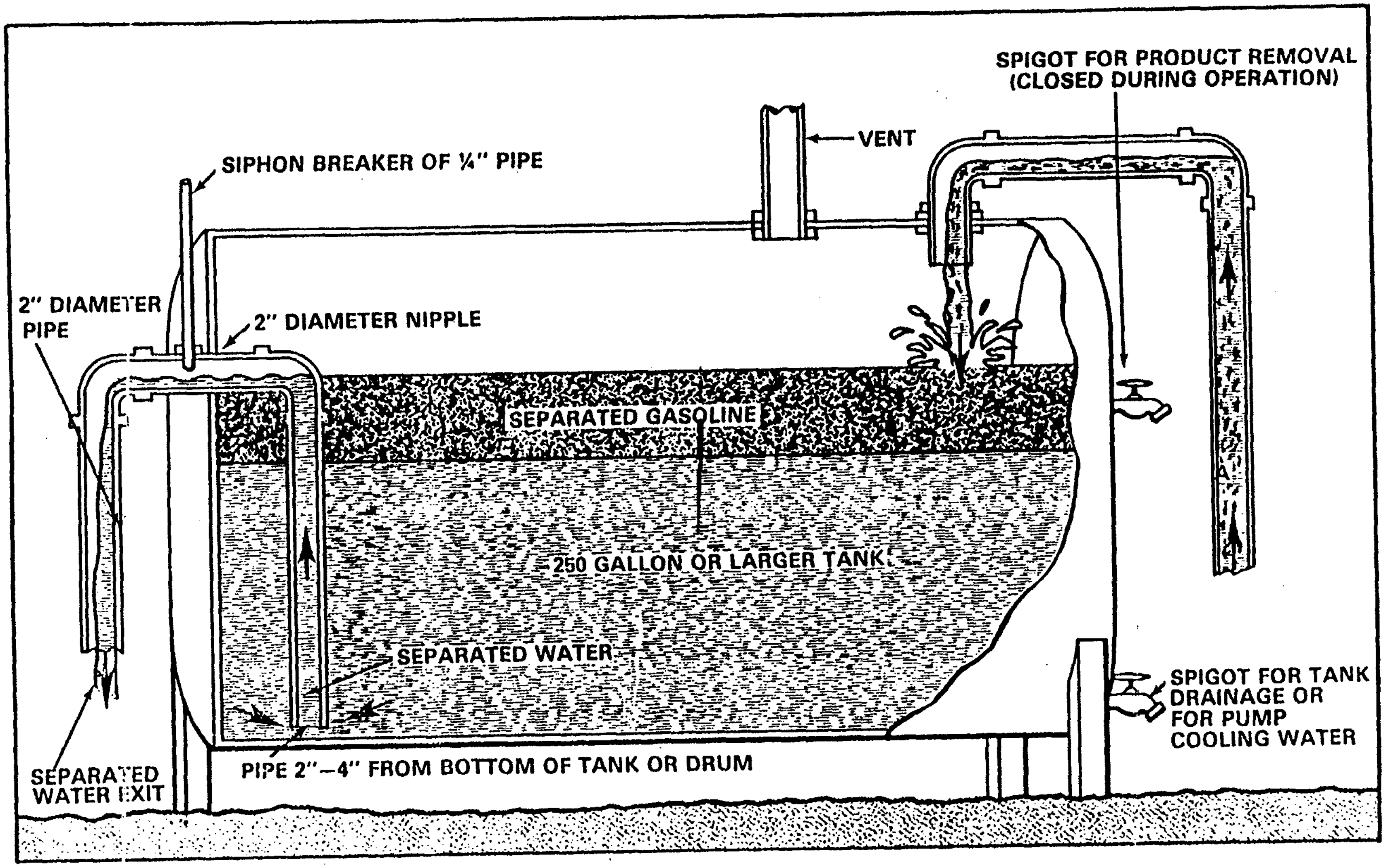


Figure 15 — Double Pump Recovery Well



TANK SEPARATOR (ALTERNATE 1)

Figure 16 — Recovery System

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protective screening or a filter ahead of the pump should be used to protect it from dirt or debris. High-speed rotary pumps should be avoided when pumping combinations of oil and water since they encourage formation of oil-water emulsions, that are difficult to separate.

Where extended recovery operations are anticipated, an automated system should be designed and installed. Automated systems will reduce the number of man-hours required to operate and monitor the recovery operation. They also can maintain a continuous depression cone necessary to contain and recover the product.

Precautions should be taken in the design and installation of recovery systems to eliminate the risk of explosive vapors in the area of pumping operations. One technique is to keep the pump unit submerged in liquid at all times. Electrical cable for pumps and automated float control systems must be of materials that are unaffected by the liquids or vapors which will be encountered. All cables from pumps to the power should be continuous with no intermediate connections. The power source connection should be a minimum of five feet from the well opening.

Electrical pumps or gasoline powered engines should not be used within five feet of the recovery well opening, unless they are classified explosion-proof for Class I, Division I, Group D use in accordance with NFPA-30. Suction pumps used on volatile products from test or recovery wells should be explosion-proof regardless of their distance from the well.

5.10 Recovered Product and Waste Water

Recovered product which is only slightly contaminated with waste water normally can be stored in tanks on site, or placed in trucks that will haul it to acceptable disposal facilities for reclamation.

Treatment and disposal procedures of recovered waste water will depend on the volume of water produced and its degree of contamination. Large volumes of contaminated waste water may be too difficult and costly to transport to an acceptable disposal facility. In such cases, it will be necessary to construct an on-site treatment unit or redesign the recovery system to reduce the volume of produced water.

Uncontaminated groundwater produced from a drawdown pump may be disposed into sanitary or storm sewer systems or into ditches or streams with appropriate approval. Proper well design can assure that excessive drawdown does not occur and that contaminated water or product will not be discharged.

Before recovery equipment is designed and placed in operation, approval should be obtained from necessary authorities for the disposal of treated waste water into a storm sewer or surface drainage system. Normally, this requires approval by the local or state fire marshal and a state environmental agent or the Federal Environmental Protection Agency (EPA). When designing waste water treatment facilities, the volume of water to be treated and the requirements of authorities must be considered. As there are many requirements for permission to discharge, and a violation can void permits, a professional should be consulted during the design of sampling, collection, monitoring and treatment facilities.

5.11 Avoiding Common Problems in Recovery Operations

Some common problems encountered during recovery operations may be avoided by considering the following:

a. Recognize that mobile product, as it moves down to the water table or other natural barrier, will seek an escape route from the spill area by every means available, including sewer lines, underground utility lines or vaults, drain fields and basements.
b. Determine the source of a spill and eliminate its continued contribution to the hazardous conditions or to the contamination of the environment.
c. Install an adequate number of test wells to determine the full extent of the area of contamination. The cost of additional test holes will be far less than having the drilling equipment return.
d. Install test wells deep enough into the water table to determine both the product levels and the water level.
e. Use well screen or properly perforated pipe in test wells, so that the product on the water table can be measured accurately.
f. Use gravel packing when recovery or test wells are installed. Proper packing helps ensure the efficiency of wells.
g. Prior to installing a recovery well, determine if the dewatering for a depression cone will contaminate additional areas or create problems in adjoining buildings.
h. Obtain the necessary approvals for discharge of the waste water produced from recovery wells.
i. Install recovery wells that both contain and recover the mobile product.
j. Use equipment that is suited for the recovery project. The use of improper equipment often will cause excessive loss of time and may increase the cost of the recovery project.

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VI. SAFETY

Most petroleum products are flammable liquids and may be explosive when confined. When leaked or spilled, they can create a definite fire and explosion hazard. The danger may be increased if people unfamiliar with the physical characteriestics of flammable liquids attempt to handle the problem.

The problems created by oil seepage vary widely, and the step-by-step procedures for handling them will vary accordingly. Certain broad guidelines discussed in this chapter nevertheless can be applied to most such situations to protect life and property.

It should be clearly understood that safety is an extremely complex subject. Consequently, not all aspects of safety are covered in this manual. For a more thorough coverage of safety precautions and actions to be observed, consult the current edition of the National Fire Protection Association recommended practice, "NFPA 329, Underground Leakage of Flammable and Combustible Liquids."

Petroleum products in basements, subways, tunnels, sewers, utility conduits, or groundwater usually will be reported because of an odor. A quick, reasonable effort must be made to determine the degree and extent of the problem, and judgment must be exercised to protect life and property without creating unnecessary alarm.

Gasoline and most refined petroleum products have a strong distinctive odor. They can be detected in extremely low concentrations when they pose no hazard of explosion and fire. If vapors or liquids have been detected in a confined structure and a rapid assessment indicates the potential danger of explosion or fire, the following general safety measures should be taken at once:

1. All people should be kept way from the danger area, except those properly trained and equipped.
2. The local fire department should be alerted.
3. A trained operator of a combustible gas indicator should determine if vapors are present, and, if so, their concentration.
4. If the combustible gas indicator confirms the presence of dangerous concentrations of flammable vapors or if liquid or vapors are increasing to dangerous levels, the following procedures should be implemented:
   a. Those responsible for the building or facility should be notified and the danger area isolated.
   b. Sources of ignition should be eliminated.
   c. Confined areas should be ventilated with proper equipment and procedures to remove flammable vapors.
   d. Points of entry of liquid or vapor should be sealed off.
   e. Proper authorities should determine if vapors or liquids have entered neighboring confined structures including, buildings, sanitary and storm sewers, and telephone vaults.

Those responsible for the endangered building or facility often can provide a logical explanation for the problem and possibly a solution. They are familiar with the facility and with the normal storage sites for the fuels that serve it. They may know of some recent incident that might have caused the problem, or the problem may have occurred before. The responsible persons also can most effectively eliminate sources of ignition and isolate the danger area to protect human life.

Persons in charge of nearby petroleum storage and handling facilities, such as service station or bulk plant managers, usually are well informed on how to handle petroleum products safely under various conditions. When advised of the problem, whether or not their own facilities are involved, they may be able to advise or assist in initiating prompt corrective action.

When danger to life and property has been confirmed by a combustible gas indicator, or is otherwise obvious, steps must be taken to protect people in and around the area. The nature of the facility will dictate the specific safety measures required.

When hydrocarbons are entering a building basement, the evacuation of all people in and around the danger area, and possibly the entire building, must be considered. The owner or manager normally is best prepared to handle the evacuation. The building engineer or maintenance supervisor may be very helpful with additional safety measures, such as eliminating sources of ignition. If the hydrocarbons are in the basement of a private home, the occupants should remain outside until qualified personnel determine that no danger of explosion or fire exists.

When product vapors are detected in buildings, a quick inspection will often reveal their point of entry is a floor drain with a dry trap. Water should be poured into the drain to fill the trap, thus shutting off the entrance of the vapors into the building.

Sewer service connections in some older buildings were not constructed with traps. For these drains, a plumber's plug, a layer of plastic film such as polyethylene, or a section from a shower curtain can be used

Doc NO: CLEJ-00560-12.03-06/01/80

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