

**FREE-PRODUCT RELEASE DETECTION FOR
UNDERGROUND STORAGE TANK SYSTEMS**

VOLUME 1

**CAPABILITIES AND LIMITATIONS OF WELLS FOR
DETECTING AND MONITORING PRODUCT RELEASES**

PREPARED FOR:

**U. S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF UNDERGROUND STORAGE TANKS
WASHINGTON, D.C.**

SUBMITTED TO:

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1.0 INTRODUCTION

Free product detection with monitoring wells is one of several methods of release detection that may be allowed under the new U.S. Environmental Protection Agency (EPA) regulations of underground storage tanks. Although several other guidance documents are available concerning the application of monitor wells for detecting and monitoring ground-water contamination at RCRA and CERCLA sites, there is little or no available information on the use of wells to detect/monitor separate organic liquids, specifically lighter-than-water petroleum products.

The purpose of this document is to describe the capabilities and limitations of free-product monitoring with wells. Volume 1 deals primarily with the limitations, rather than capabilities, of wells for detecting releases. Volume 2 presents a brief survey of the Florida UST program and how wells are being used successfully to detect and monitor releases. In developing both volumes, EPA's intent is to encourage owner/operators and qualified professionals involved with well design and installation to predict, recognize, and avoid any potential problems associated with using wells.

The need to generate such information for owner/operators and regulators has resulted in the preparation of several new documents under the auspices of the Office of Underground Storage Tanks (OUST). This particular document is directed towards both technical and non-technical personnel in government or industry who will be making decisions about the use of wells to detect and monitor free product. To reach the widest audience and limit the use of technical jargon, the writers have chosen to present the information in a brief outline form with accompanying figures.

Those readers who are interested in more technical information about well design and placement, mechanics of product migration through the subsurface, interpretation of free-product accumulation in wells, and practical aspects of the recovery of free product from wells are referred to the technical background document entitled "Corrective Action for Petroleum Underground Storage Tanks," especially Chapter 3 and Appendix A, entitled "Technical Issues in Free Product Monitoring and Removal." Most of the capabilities/limitations discussed here are covered in that document in greater detail. Those readers seeking help with how to recognize and deal with these problems should consult the background document.

Some of the technical terminology discussed in great detail in the technical background document and associated appendices is used here. A petroleum product is defined as liquid phase hydrocarbon that may range from unrefined crude oil to highly refined gasoline. Free product is product that saturates the voids of an earth material and will flow in response to gravity. Residual product is product occupying a small fraction of the void space which will not move in response to gravity. Only free product can accumulate in wells and other subsurface structures open to the atmosphere. Residual product may exist in a pendular state of saturation with air and water above the water table, or in an insular state with water below the water table. The transfer of product from one state to another with a moving water table is discussed in Appendix A to the technical background document.

2.0 MONITOR WELL CAPABILITIES/LIMITATIONS

Table 1 is a list of site conditions under which monitor wells are generally capable or significantly limited in either detecting or monitoring product releases.

2.1 Good Conditions/Capabilities of Wells

Under some site conditions, the ideal environment for release detection with a well is within an engineered backfill around the UST system. The backfill should be clean, well-sorted, coarse-grained sand or fine-grained gravel. As shown in Figure 1, two other conditions are needed to insure that the released product does not escape into the adjoining earth materials before it can be detected in the well. First, the excavation should either be installed into low-permeability earth materials, or it should be lined to seal off any escape pathways. Second, it is highly beneficial if there is a shallow water table within and near the base of the excavation on which the free product can accumulate and spread. Figure 2 shows that installation of a well through the base of the excavation to reach a deeper water table is ill-advised. Even though this design effectively provides a way to detect releases, it also provides a pathway for contaminants to enter the local ground-water system.

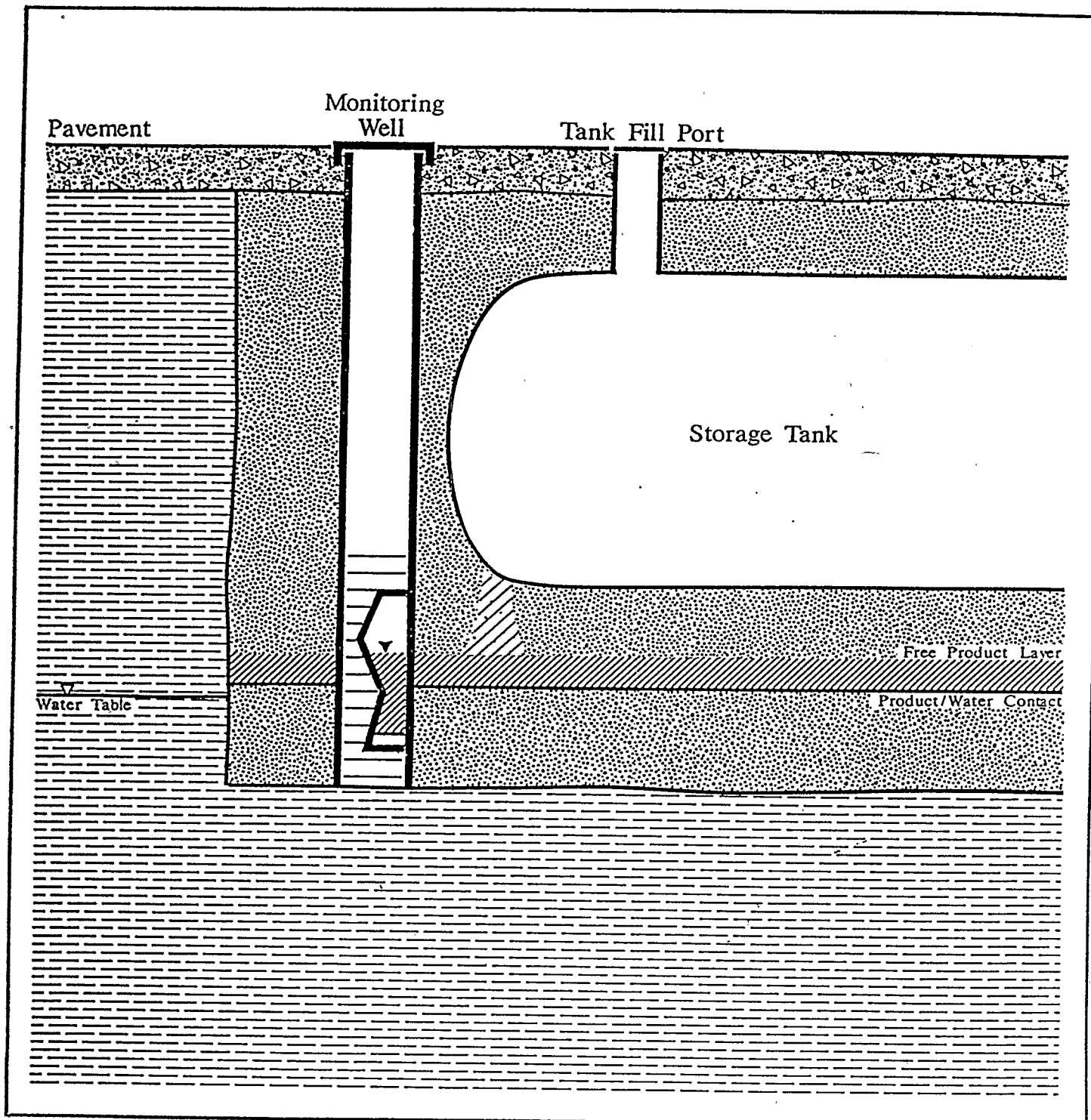
TABLE 1.
CONDITIONS THAT AFFECT MONITOR-WELL
CAPABILITIES AND LIMITATIONS

Good Conditions for Monitoring -- Capabilities

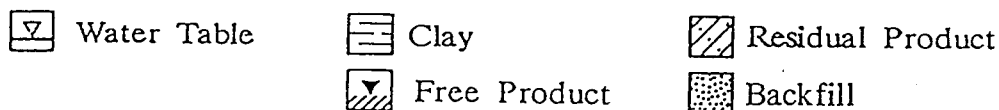
- . UST backfill materials
- . Granular earth materials outside the UST backfill
- . Absence of, or consideration for, perching horizons
- . Knowledge of water-table depth and fluctuations

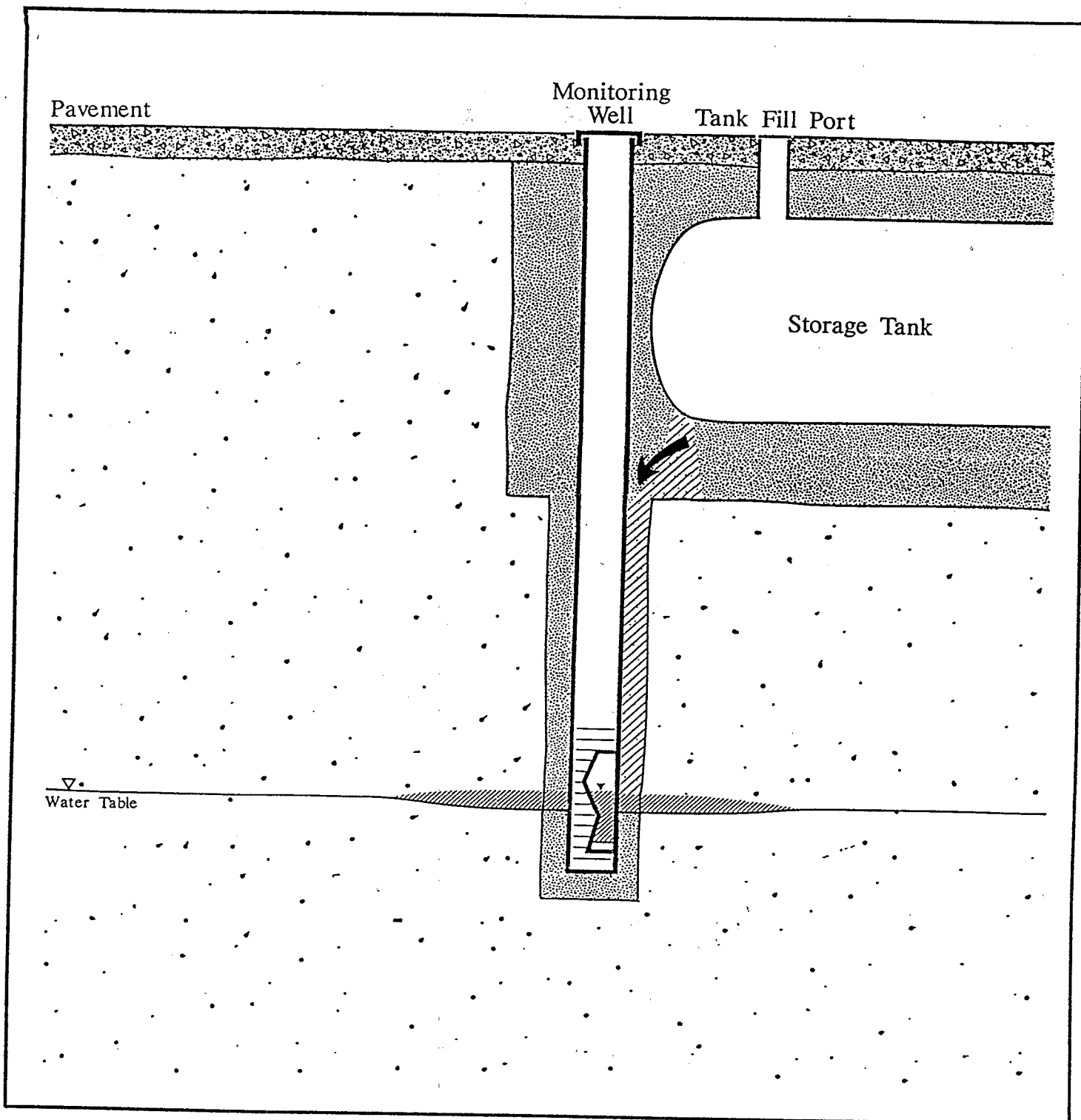
Poor Conditions for Monitoring -- Limitations

- . Site hydrogeology
 - Undefined fracture pattern and solution cavities
 - Unknown perching horizon or confining unit
 - Excessively deep or shallow water table
 - Buried utilities, fill, or drainage control structures
- . Well construction
 - Well production zone placement relative to water table
 - Well screen design flaws
 - Well casing materials and miscellaneous design problems
- . Well location
 - Consideration for other contaminant sources
 - Spacing and proximity to USTs



Wells Can Readily Detect Free Product in The UST Excavation Zone When: a. Native Materials Are Less Permeable Than Backfill, b. A Shallow Water Table Exists Within Backfill





Wells Completed Through the Excavation Zone Will Allow Free Product Detection at the Expense of Aquifer Contamination



Water Table



Clay



Residual Product



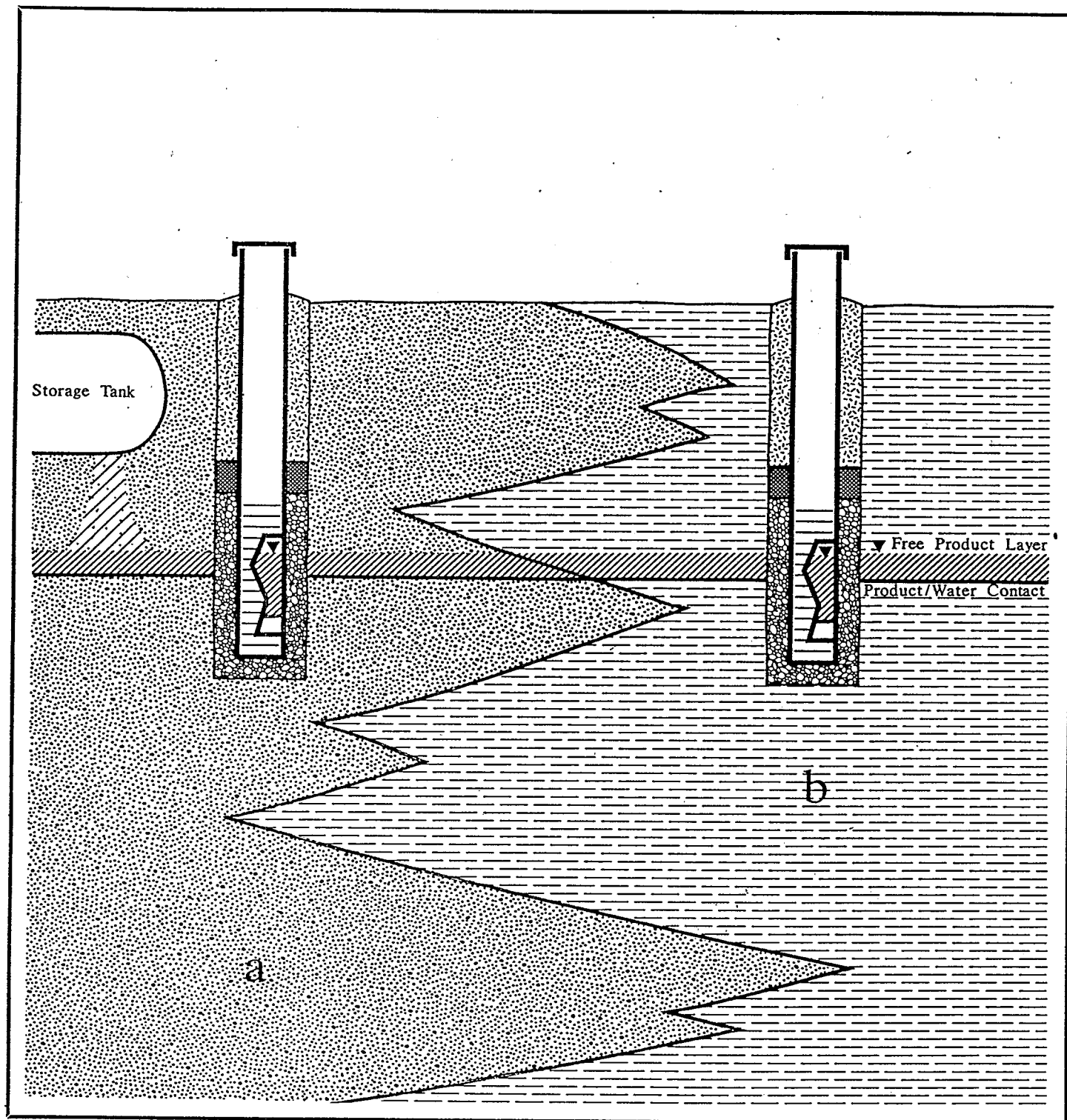
Free Product



Backfill

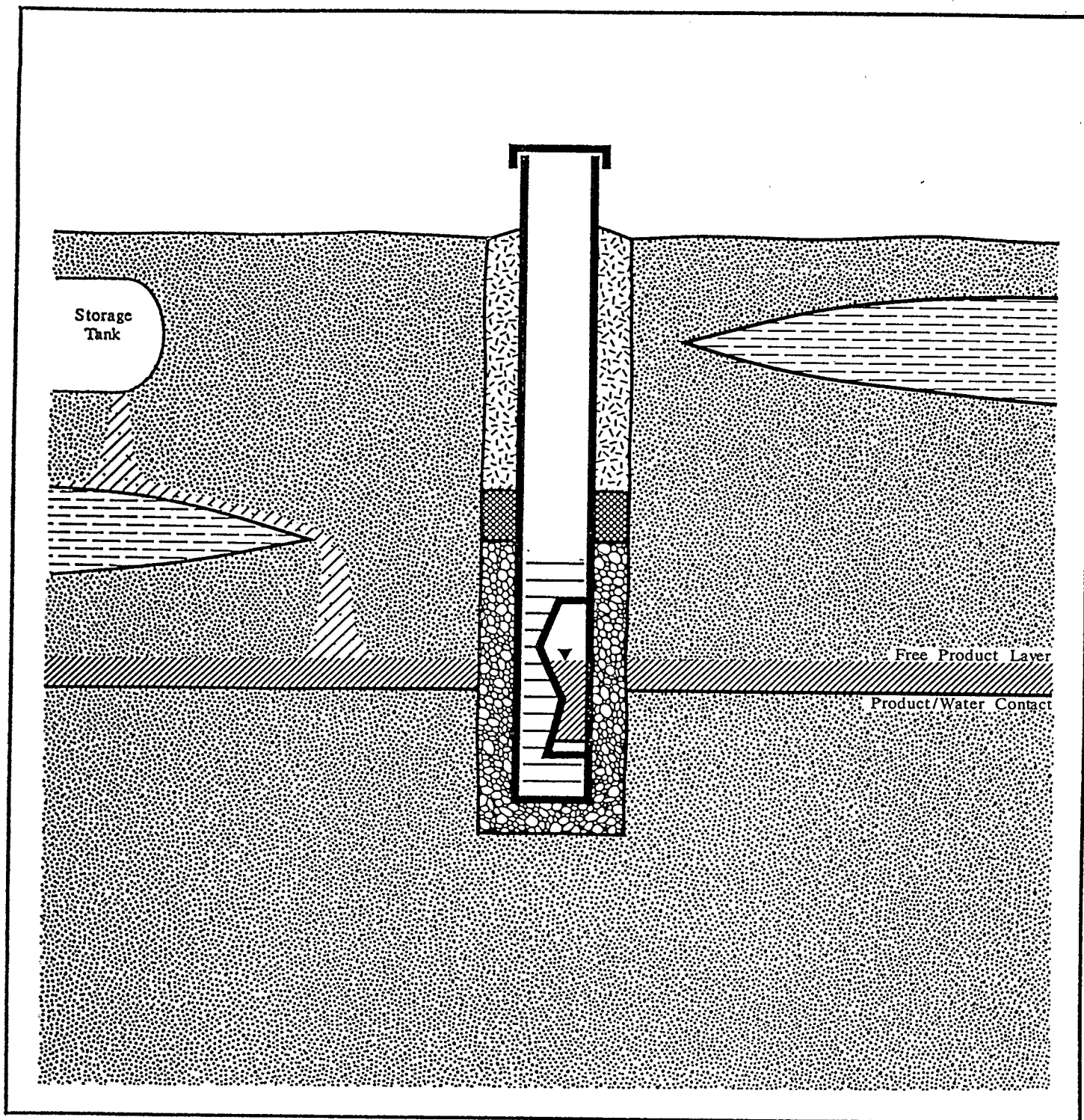
When properly designed and installed outside the UST excavation zone, monitor wells are applicable to free product detection in granular earth materials such as sands, gravels, silts, and some clays (Figure 3). The optimum hydrogeologic condition is the presence of a shallow water table less than 20 feet deep in fairly permeable earth materials that exhibit small variations in grain size and texture across the site. A knowledge of local geology and hydrology can be very helpful in anticipating these conditions and can often be obtained from government publications.

Monitor wells are most directly applicable where there are no laterally continuous, virtually impermeable zones between the leak source and the water table to prevent free product from reaching the regional water table (Figure 4). Special consideration must be given to monitor-well construction in areas where free product is perched on a low-permeability layer above the regional water table. For example, consider a well screened as shown in Figure 5a, the purpose of which is to detect free product that might have accumulated on the regional water table. If the grout seal is emplaced above the low-permeability layer, free product can migrate downward through the gravel pack until it reaches the regional water table.



Monitor Wells Can Be Used to Detect Free Product in
 (a) Coarse Grained, and
 (b) Fine Grained Granular Earth Materials.

Grout	Water Table	Residual Product	Silt and Clay
Bentonite or Grout Seal	Gravel Pack	Free Product	Sand And Gravel



Monitoring for Free Product is Feasible When Migration of Free Product to the Water Table is Not Impeded

Grout	Water Table	Clay	Residual Product
Bentonite or Grout Seal	Gravel Pack	Free Product	Sand And Gravel

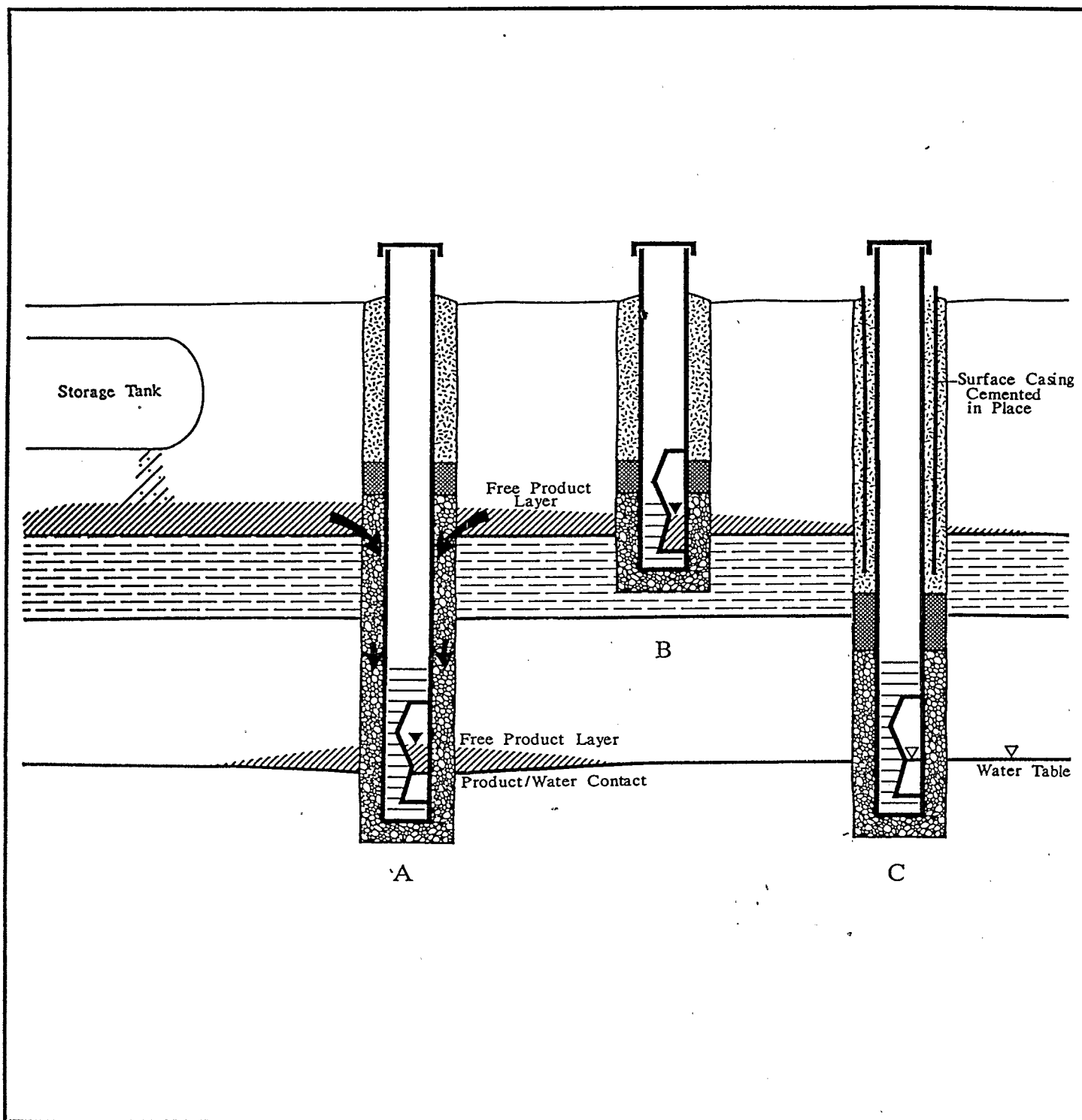
Installation of two vertically nested monitor wells is recommended in areas where free product is anticipated to have accumulated above a low-permeability zone. One well would be screened to detect free product associated with this layer (Figure 5b). A second well would be completed through the layer and screened to monitor the regional water table (Figure 5c). In the latter case it is recommended that surface casing be set and cemented in place prior to installing the monitor well to preclude migration of free product via the annular space. Detailed description of materials encountered during drilling (e.g., use of continuous split spooning) allows identification of low-permeability layers and associated high-product saturation zones.

A properly constructed monitor well has a screened interval that extends over the entire range of expected water-table fluctuation. This is done to assure continuous free product detection in the well (Figure 6). Defining this range of fluctuation can be based on long-term hydrographs from wells in the same aquifer and area and sometimes on the basis of soil morphology and color.

2.2 Poor Conditions Limiting Use of Monitoring Wells

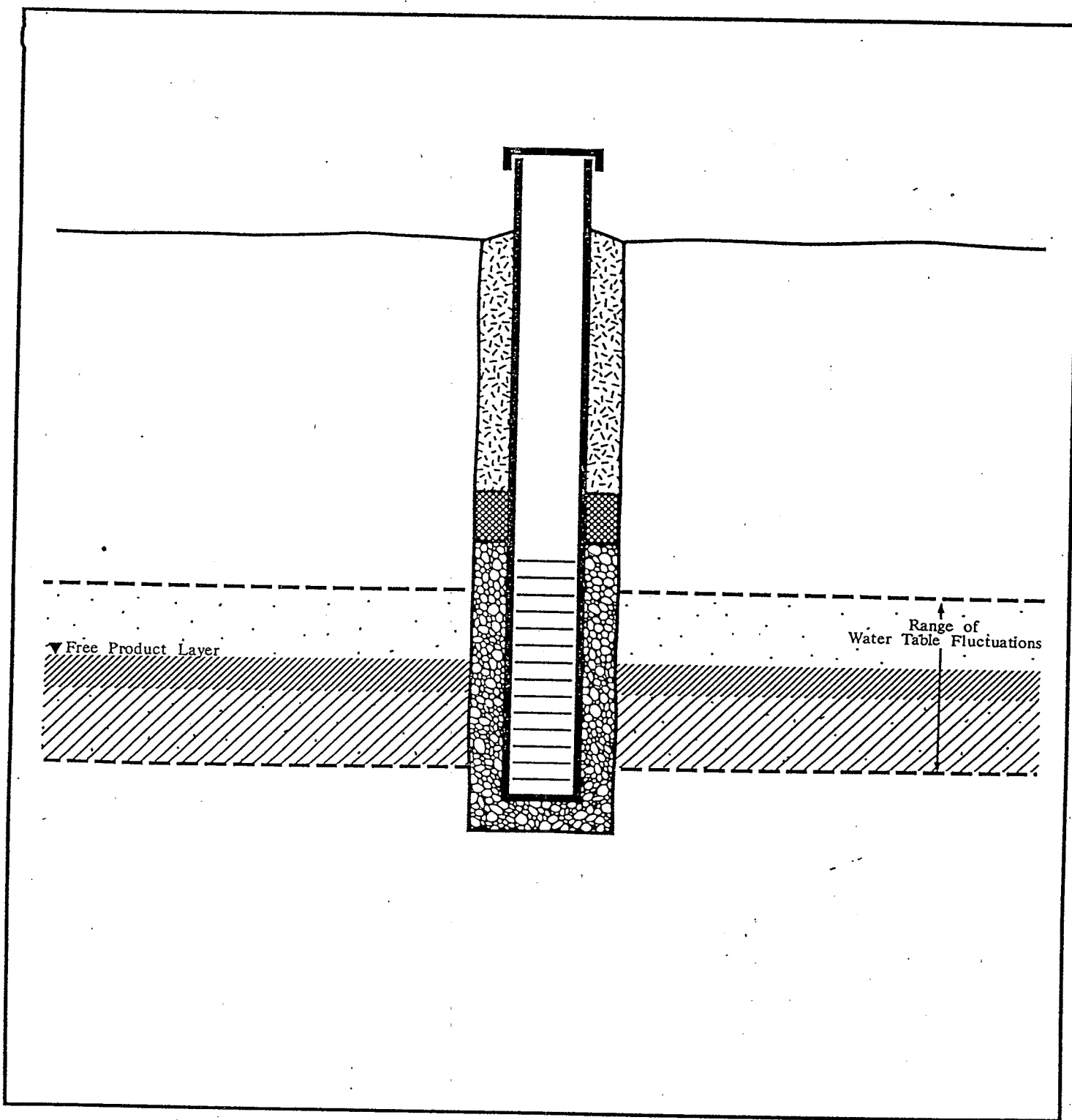
2.2.1 Hydrologic Considerations

The use of individual monitor wells is not always reliable for detecting free hydrocarbons in fractured rock,










Wells Must Be Properly Constructed to Monitor Perched Free Product Accumulations and Prevent Contamination of the Aquifer

 Grout	 Water Table	 Clay
 Bentonite or Grout Seal	 Gravel Pack	 Free Product
		 Residual Product



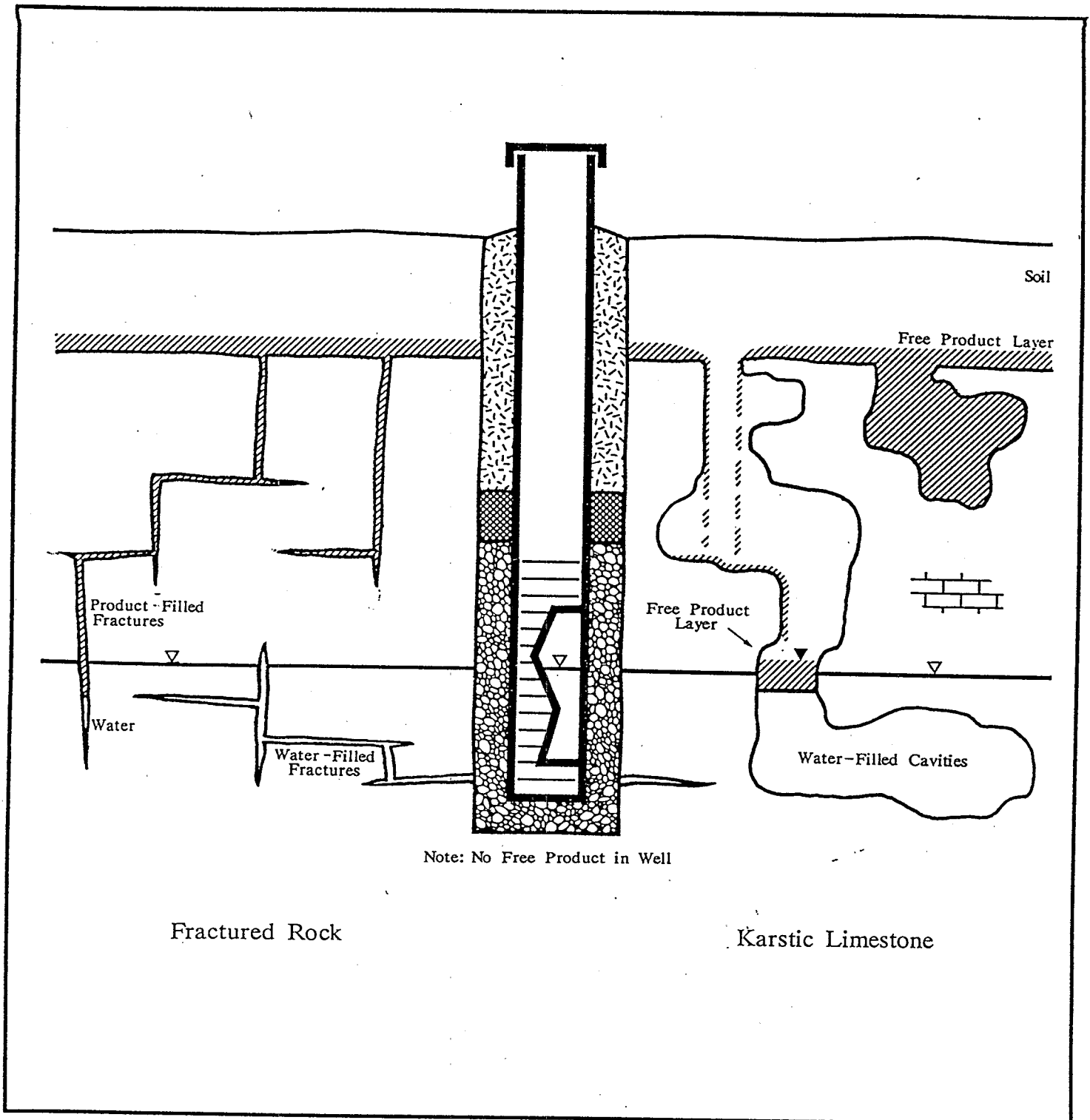
The Well Screen Should Be Positioned to Coincide with the Expected Range of Water Table Fluctuations

- | | | |
|--|---|---|
|  Grout |  Water Table |  Residual-Insular Product |
|  Bentonite or Grout Seal |  Gravel Pack |  Free Product |
| | |  Residual-Pendular Product |

karst, some metamorphic, and igneous terrains (Figure 7). If the well does not intercept a fracture or solution zone containing free product, no free product will be detected by the well. Monitor wells screened below laterally continuous, low-permeability layers would not normally be applicable for monitoring free product. Free product floating on the layer would not migrate to the screened interval if the well is properly constructed (Figure 8).

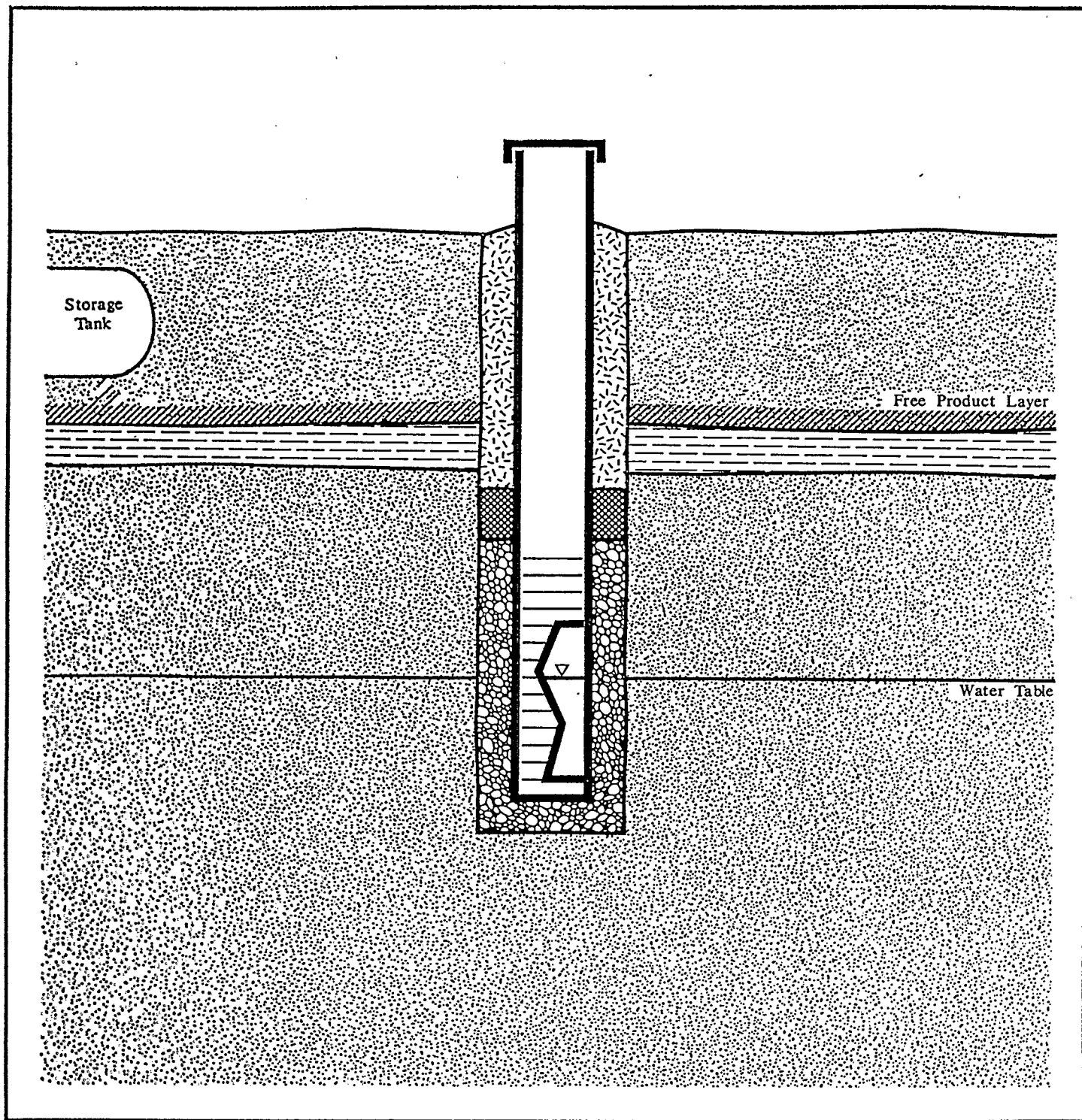
The water table in some regions can be too deep to allow detection of free product using monitoring wells (Figure 9). Depending upon the volume of the spill or leak, the product can be absorbed on earth materials above the water table in a residual pendular saturation. Monitor wells completed and screened in these contaminated materials will not detect free product, but are capable of monitoring vapors. Wells completed in the ground-water zone would not detect separate liquid product, but may ultimately allow detection of dissolved materials. Free product will most likely accumulate in monitor wells installed in areas with shallow water tables and permeable earth materials.

In other regions, the water table can be too shallow to allow detection of free product while maintaining typical surface seal requirements around the well (Figure 10). A monitor well properly constructed with a surface seal would






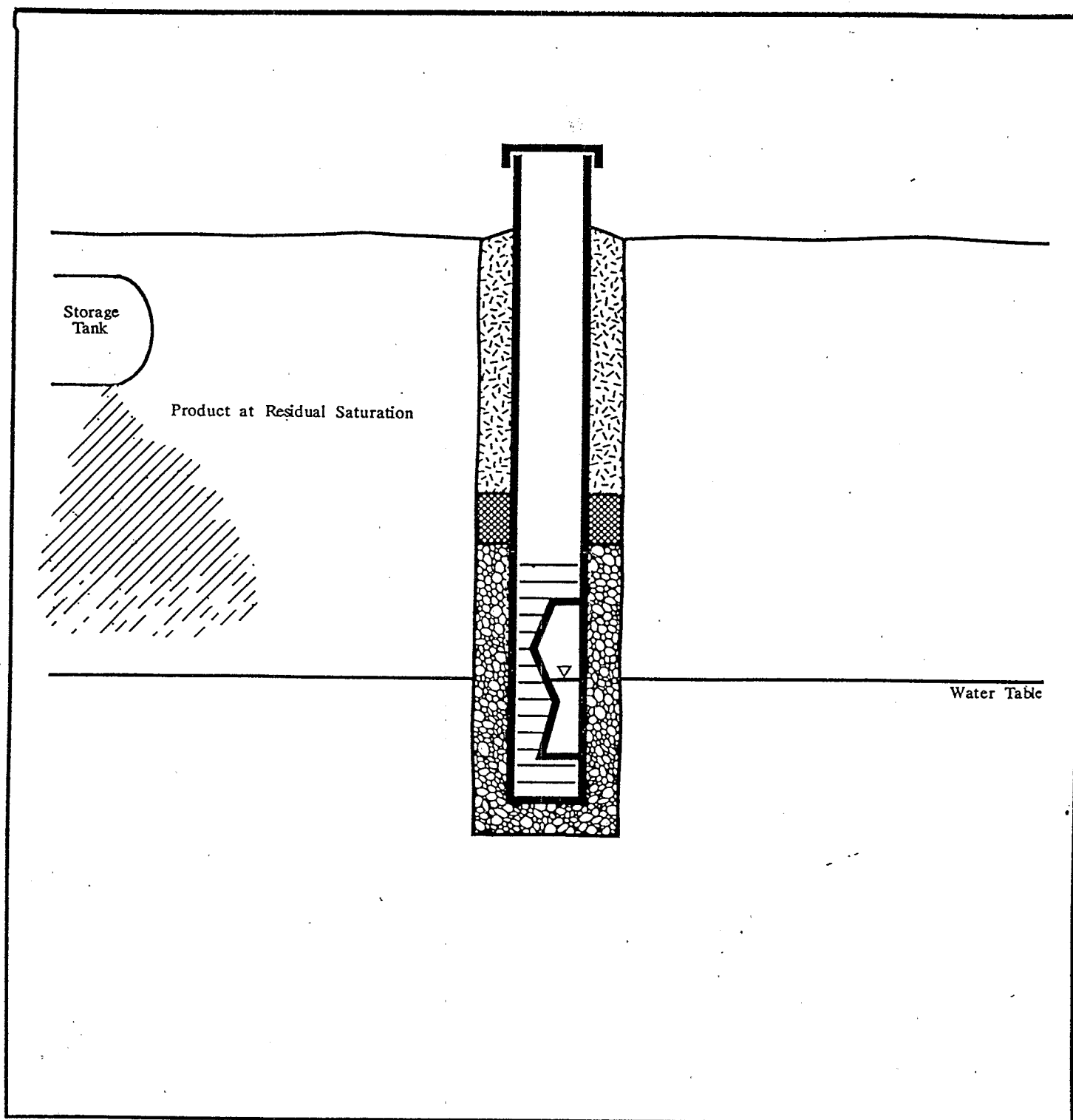
Wells That Do Not Intersect Fractures and Cavities Containing Free Product Will Not Allow Free Product Detection

- | | | |
|-------------------------|-------------|--------------|
| Grout | Water Table | Limestone |
| Bentonite or Grout Seal | Gravel Pack | Free Product |









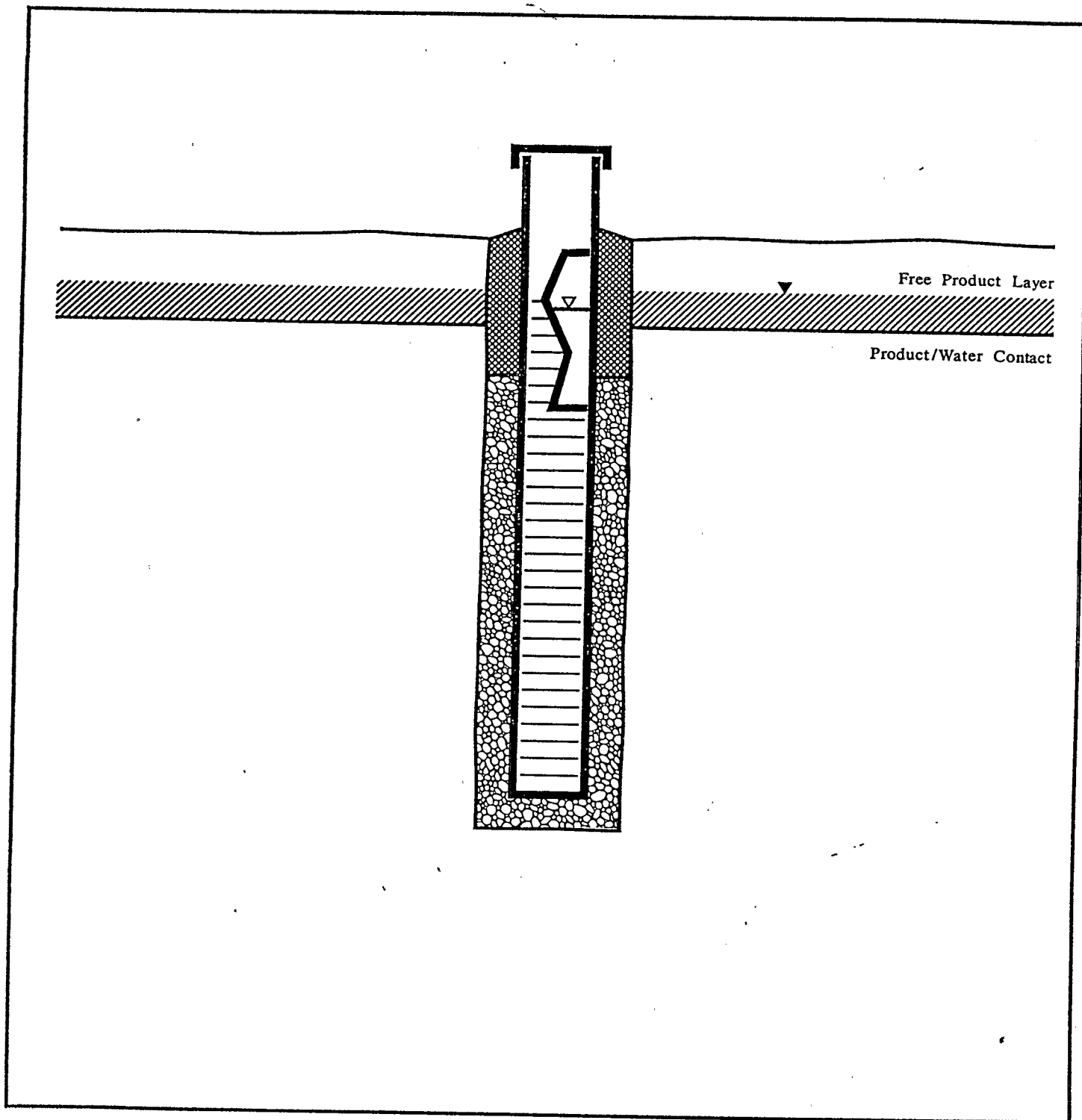
Free Product Accumulated Above a Low Permeability Zone Cannot Enter a Well Screened Below the Zone

- | | | |
|---|---|---|
|  Grout |  Water Table |  Clay |
|  Bentonite or Grout Seal |  Gravel Pack |  Free Product |
| | |  Sand and Gravel |







Wells Cannot Detect Product (as a Separate Liquid Phase) That Does Not Accumulate Near the Water Table

- | | | |
|---|---|--|
|  Grout |  Water Table |  |
|  Bentonite or Grout Seal |  Gravel Pack |  Free Product |



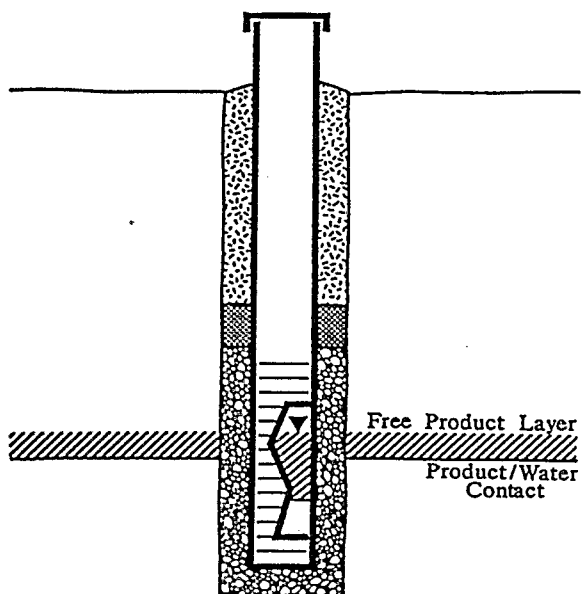
Free Product May Be Sealed Off from a Well by the Surface Grout Seal, Especially When the Water Table is Shallow.

- | | |
|---|---|
|  Free Product |  Water Table |
|  Bentonite or Grout Seal |  Gravel Pack |

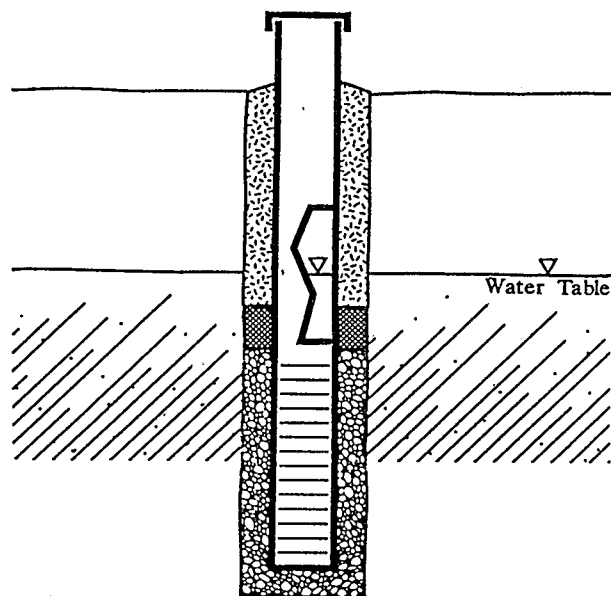
prevent floating product from entering the well through the screen if the water table is within a foot or two of the land surface. Attempts to construct the well to accommodate the shallow conditions could result in surface contamination entering the well.

After free product is discovered in a well, water-table changes can mask the presence of product by trapping it below the water table in an insular state of saturation (Figure 11). Free product accumulations in wells usually decrease with a significant rise in the water table and increase with a decline in the water table. The sudden appearance of free product in a well may not be due to a new release, but rather, the transfer of product from one saturation state to another in response to a falling water table. After initial detection, fluid levels in a monitoring well can be measured during different seasons to define the range of water-table and product-thickness variations.

Utility lines, pipelines, and buried facilities (sewers, water lines, drainage tiles, old trenches, etc.) and construction fill can serve as preferential pathways for product migration, making wells less effective as detection devices (Figure 12). These pathways can alter expected directions and rates of free product movement. All underground lines should be located as accurately as possible to account for



a. Before Rise in Water Table



b. After Rise in Water Table

Free Product May Disappear During Rising Water Table
Conditions and Accumulate During Falling Water Table
Conditions



Grout



Water Table



Residual Product



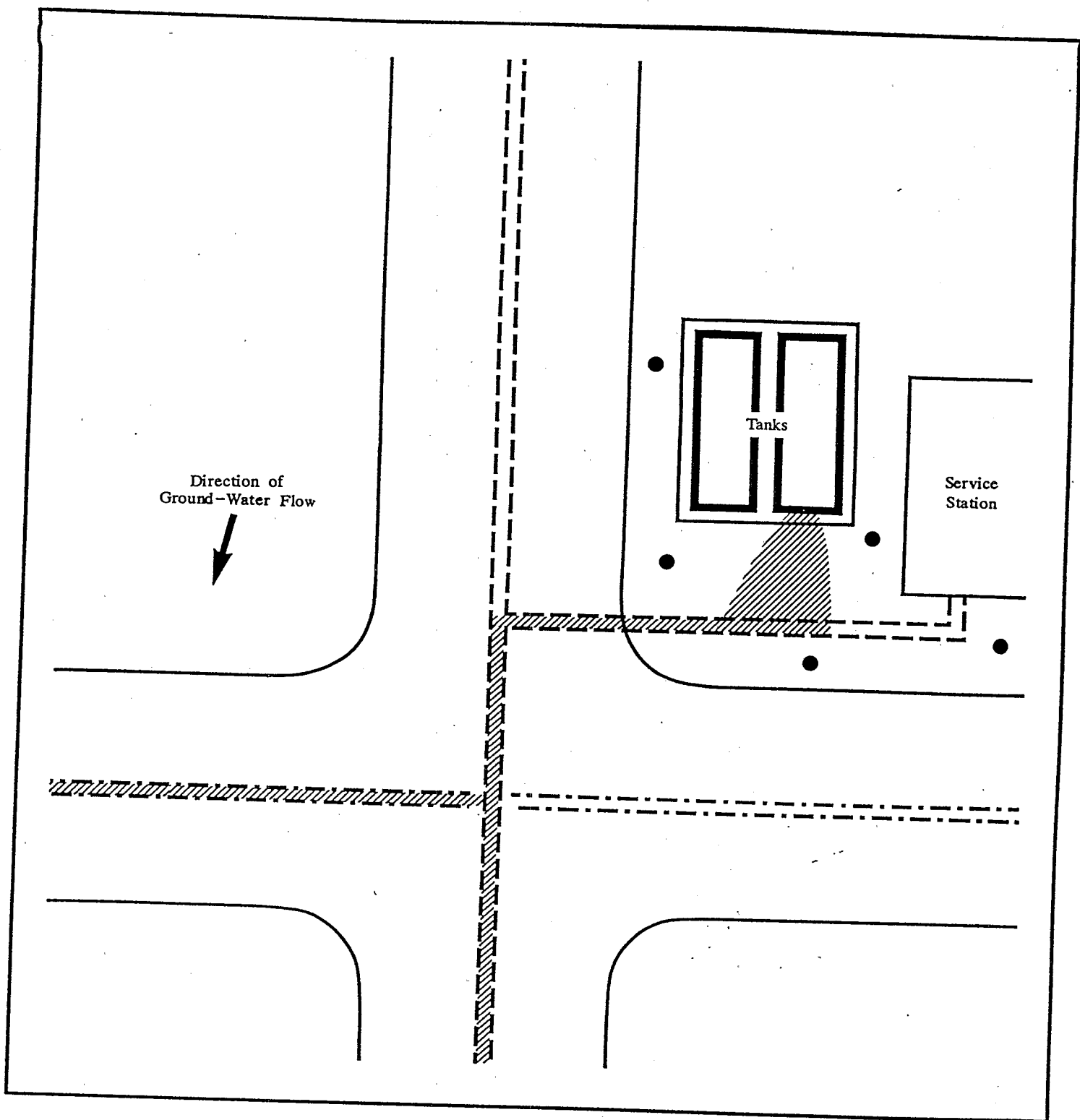
Bentonite or
Grout Seal



Gravel Pack



Free Product



Preferential Flow of Product Through Buried Utilities Prevents Detection With Wells.

• Monitoring Well

▨ Free Product

--- Sewer Line

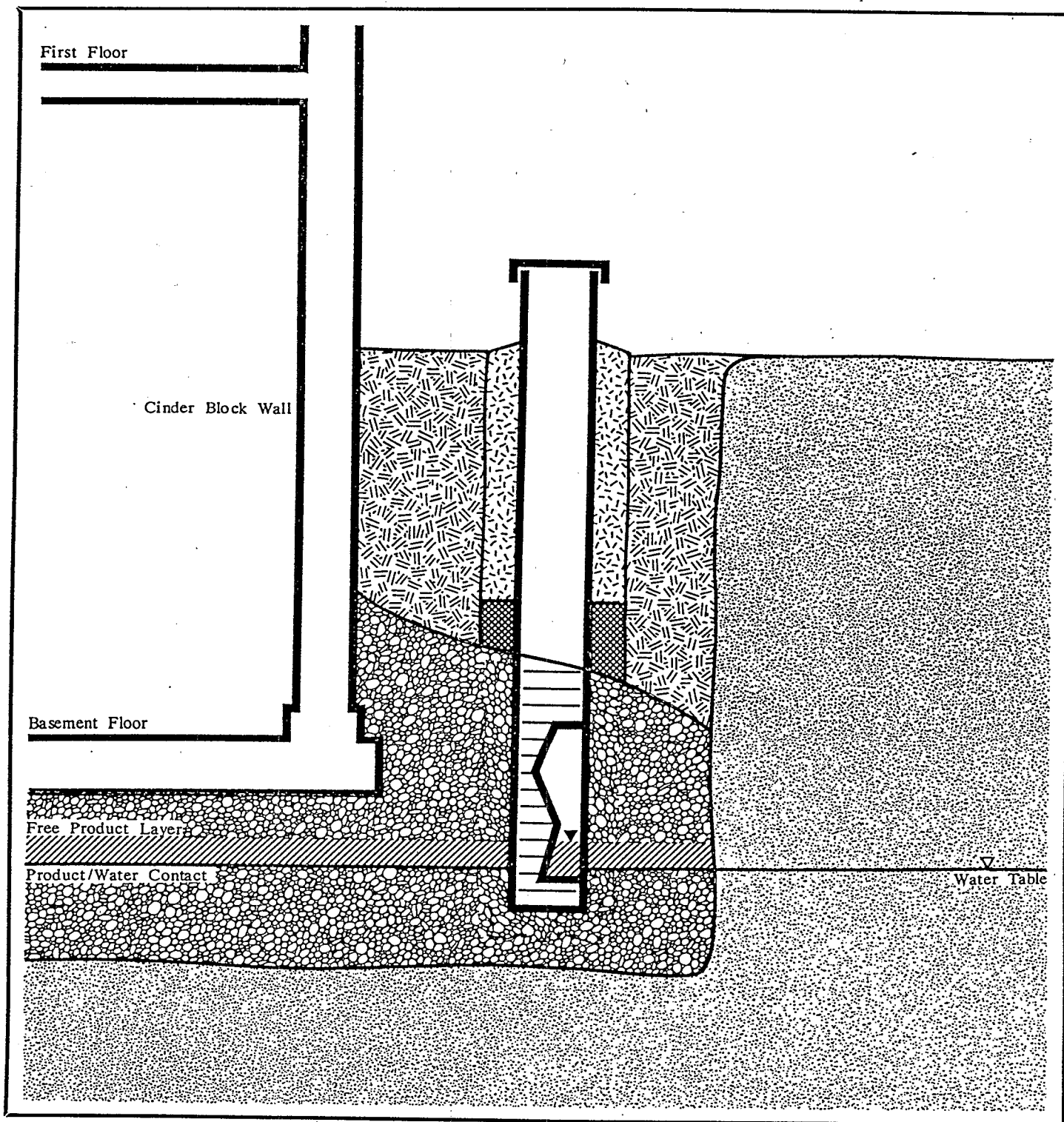
-.-.- Water Line

this condition. Product that seeps into an underdrain beneath a building can be detected and monitored by completing a well in the drain rock along the outside wall of a building (Figure 13).

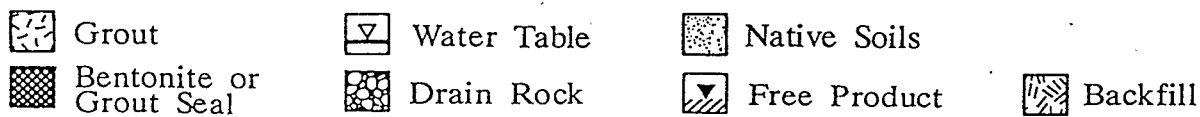
2.2.2 Well Construction Considerations

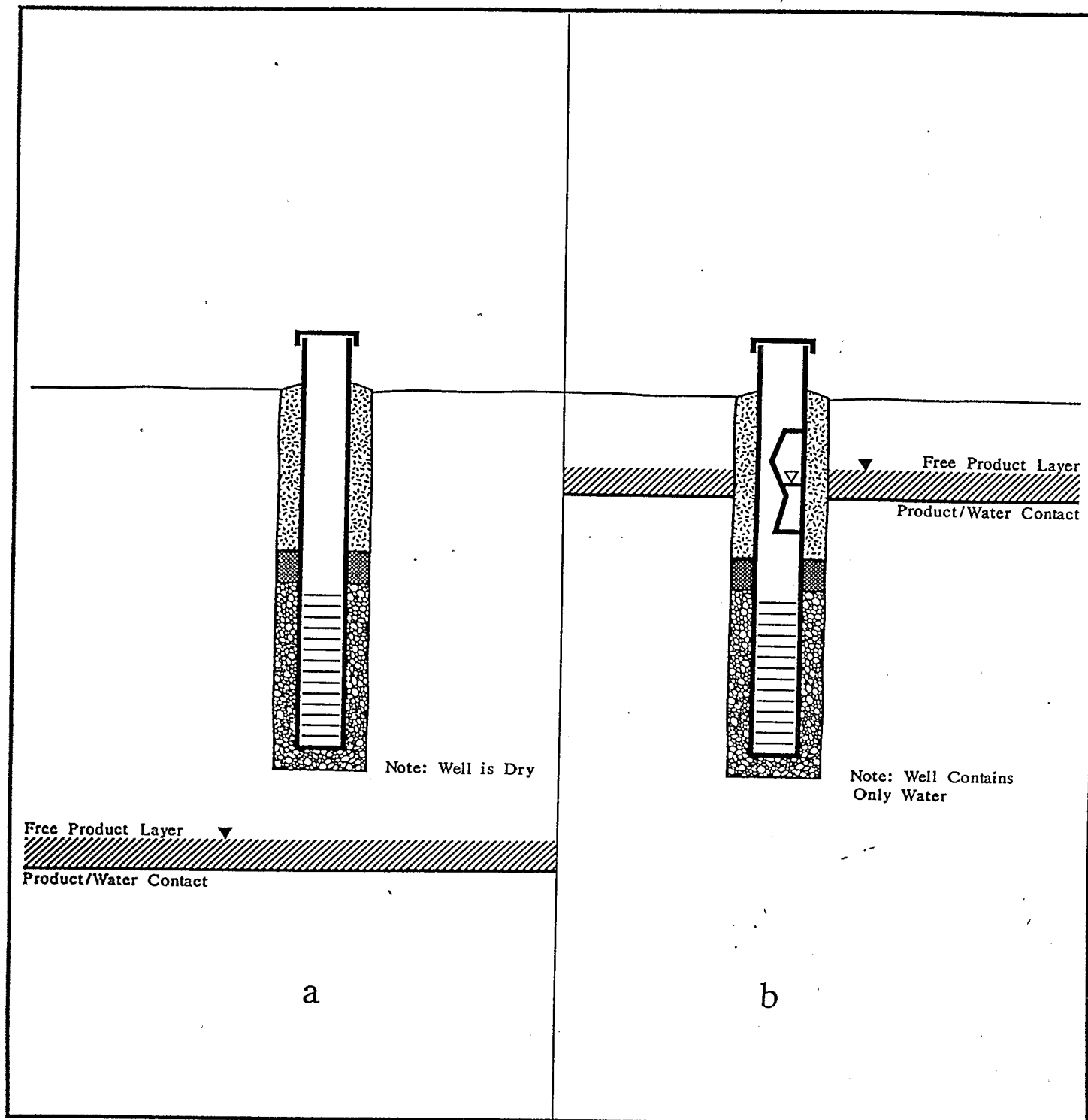
Free product will not be effectively detected if the water table is significantly below or above the screened interval (Figure 14 a,b). Care must be taken in the selection of the proper screen/gravel pack depth interval. Accurate measurement of the product thickness cannot be made in the well if the screen length is not sufficient to intercept the product/water interface (Figure 15). When the screen/gravel pack interval is sufficiently long to cover the entire product plume, the free product thickness inside the well will exceed the free-product thickness outside the well.

Some petroleum products may not migrate through a screen with slot openings that are too small (Figure 16). Some screen materials are preferentially wet to water in the presence of free product. The interfacial capillary tension that exists between the water and the product must be overcome before free product can flow through the narrow slot openings. Also, slot openings that are too narrow may








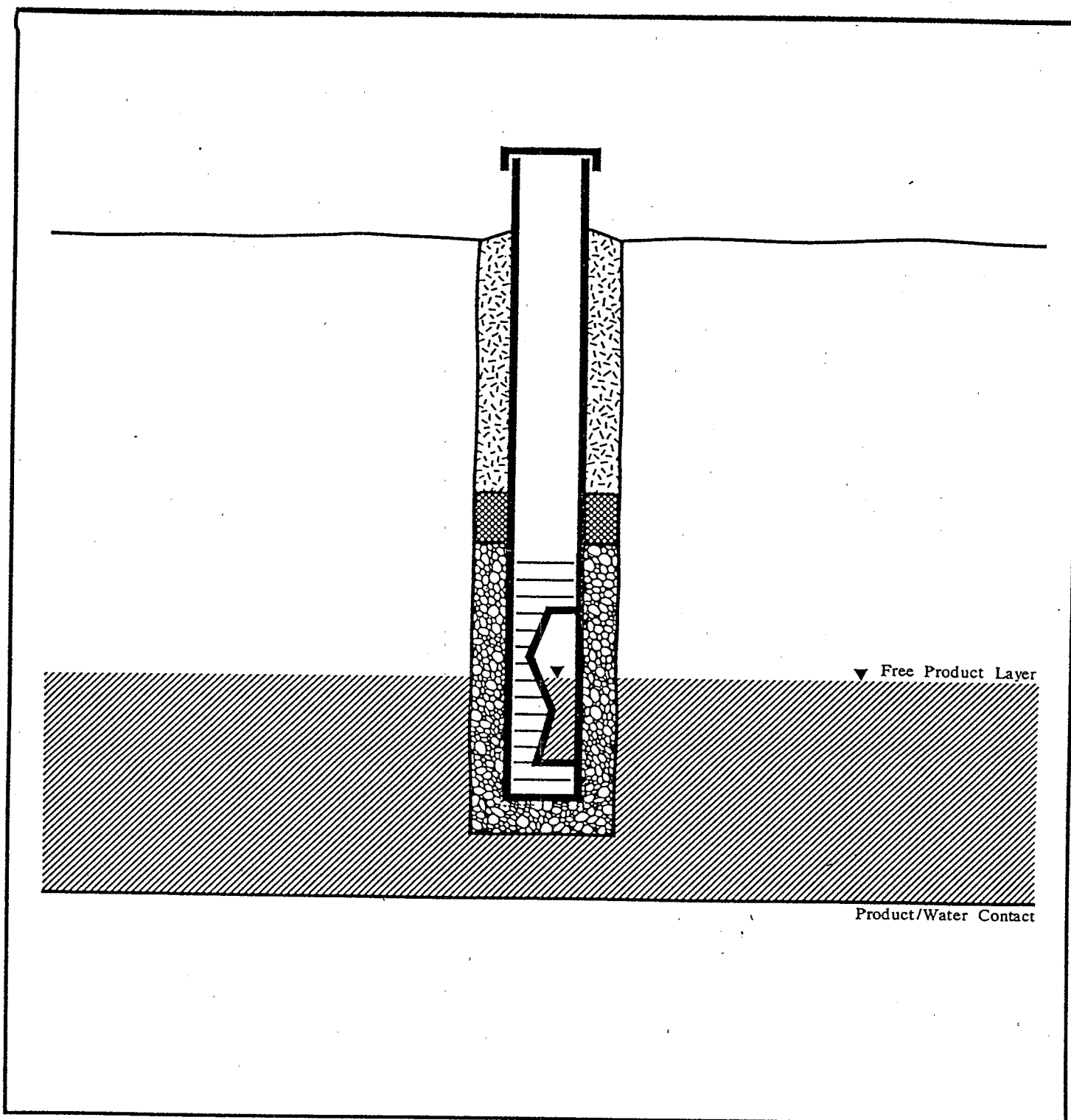
Monitoring Well Installation into Footing Drain of a Building







Incorrect Installation of Well Screen Below (a) or Above (b) the Water Table Can Prevent Free Product Detection


- | | | |
|---|---|--|
|  Grout |  Water Table | |
|  Bentonite or Grout Seal |  Gravel Pack |  Free Product |



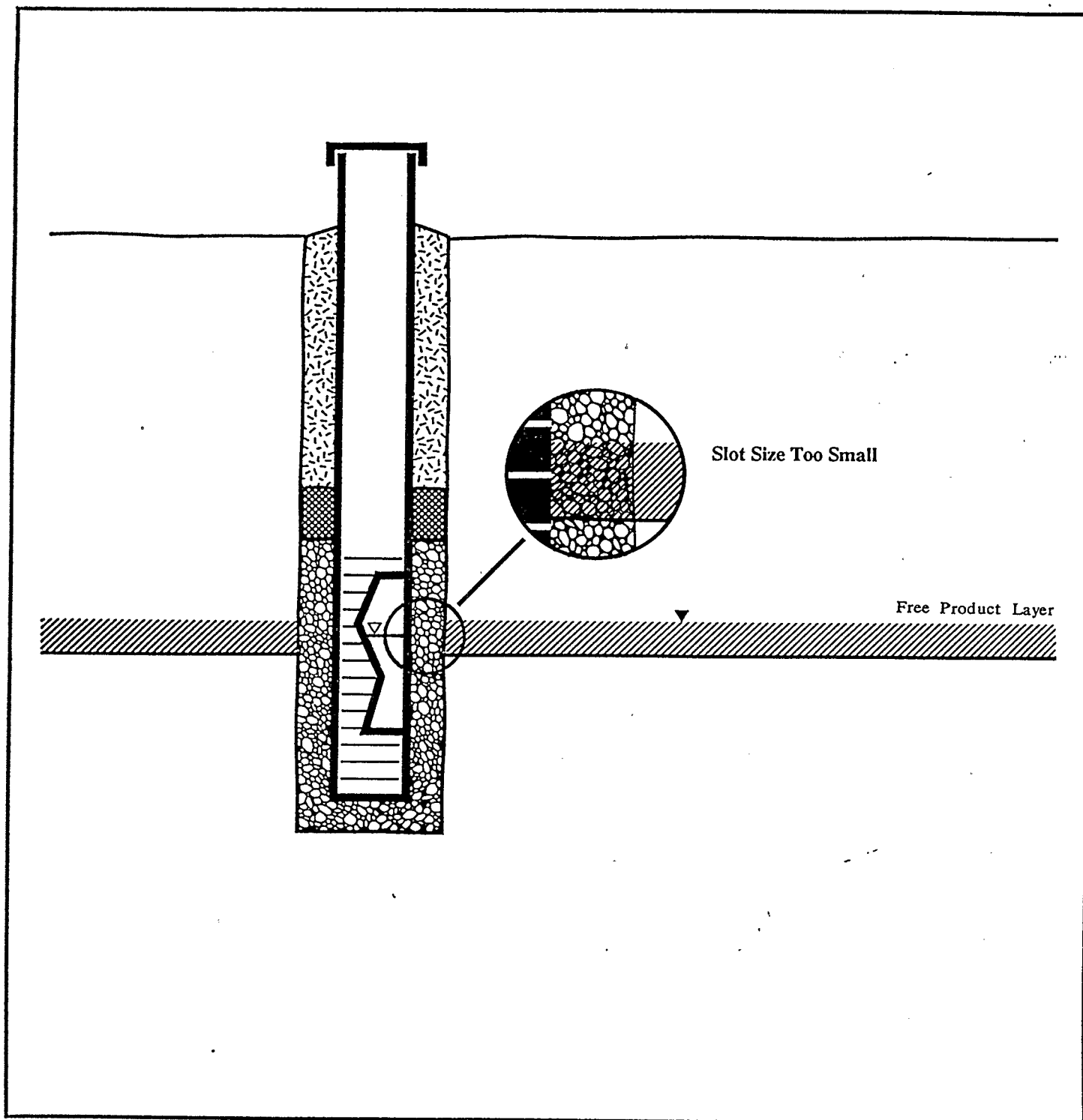
The Well Screen Interval Must Extend Below the Product/Water Contact in Order to Estimate the Product Thickness

 Bentonite or Grout Seal

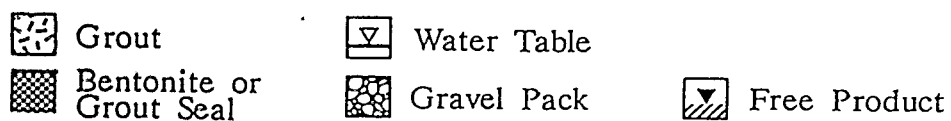
 Gravel Pack

 Free Product

 Grout



Narrowly Slotted Well Screens that are Preferentially Water Wet May Not Allow Free Product Entry

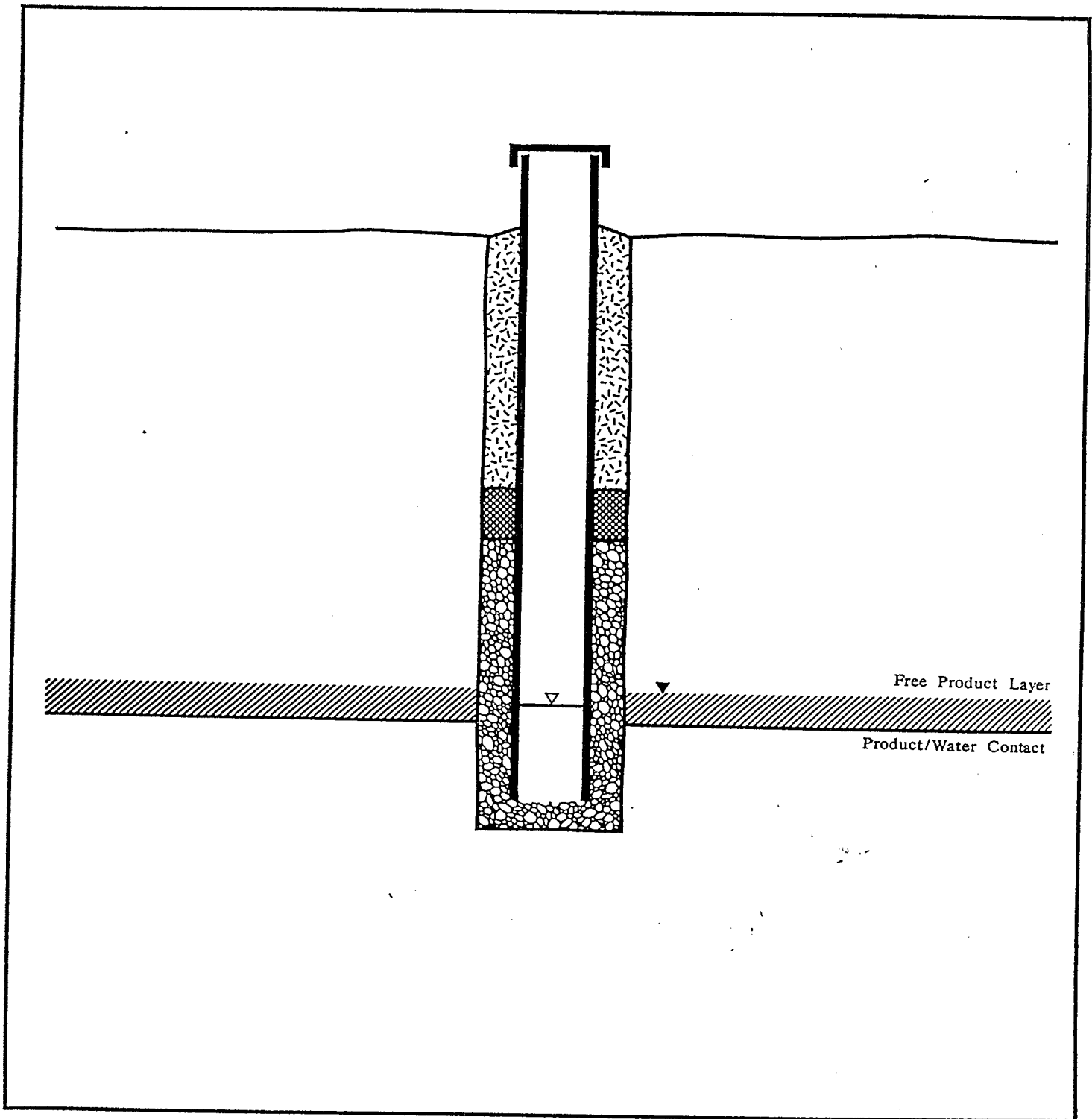


prevent more viscous petroleum products from moving into the well.


An open-ended, unscreened well restricts the entry of free product. Free product may not be detected even though it is present outside the well (Figure 17). Also, an open-ended well will tend to allow fine-grained materials to enter the casing, making further monitoring impractical as the well fills with sediment.


Improper well-construction materials can affect the viability of a monitoring well. For example, wells constructed with sections of loosely joined concrete culvert will not allow detection of free product if the product is in contact with a solid portion of the culvert (Figure 18a).


Well casing and screen constructed of materials that are incompatible with free product can lose rigidity and collapse, thereby ruining the well (Figure 18b). ABS plastic pipe is an example of a material that is not compatible with petroleum products. Generally, PVC, Teflon, and stainless steel are adequate for monitoring-well materials. PVC is the lowest cost material and is widely used for monitoring free-product spills or leaks. Because PVC may swell in the presence of free product, screen slot sizes may need to be larger than in more stable materials.





Wells Open Only at the Bottom of an Unslotted Casing
are Not Suited for Free Product Detection

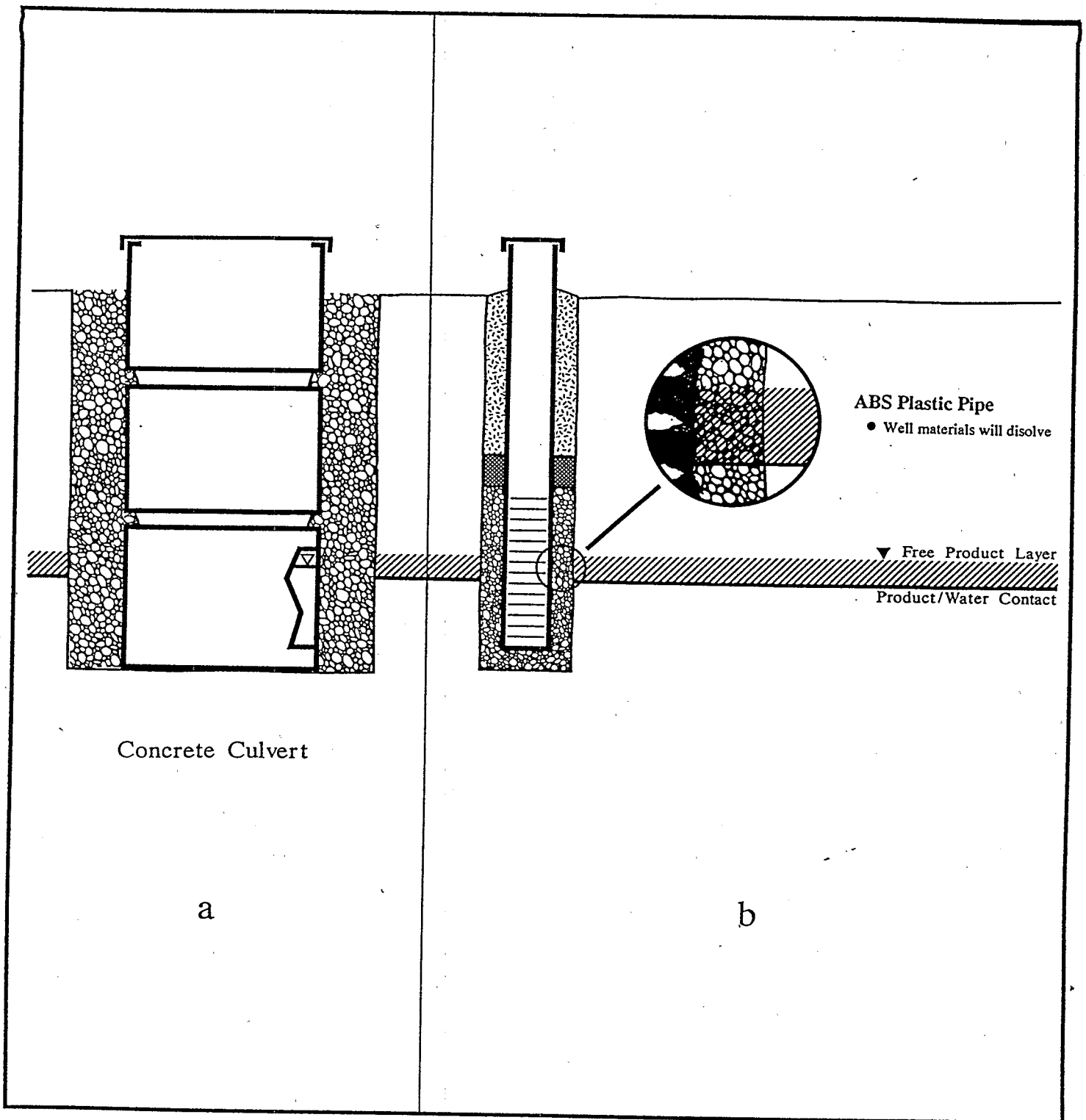
 Grout

 Water Table

 Bentonite or
Grout Seal

 Gravel Pack

 Free Product



Selection of Improper Well Casing and Screen Materials Can Prevent Free Product Detection

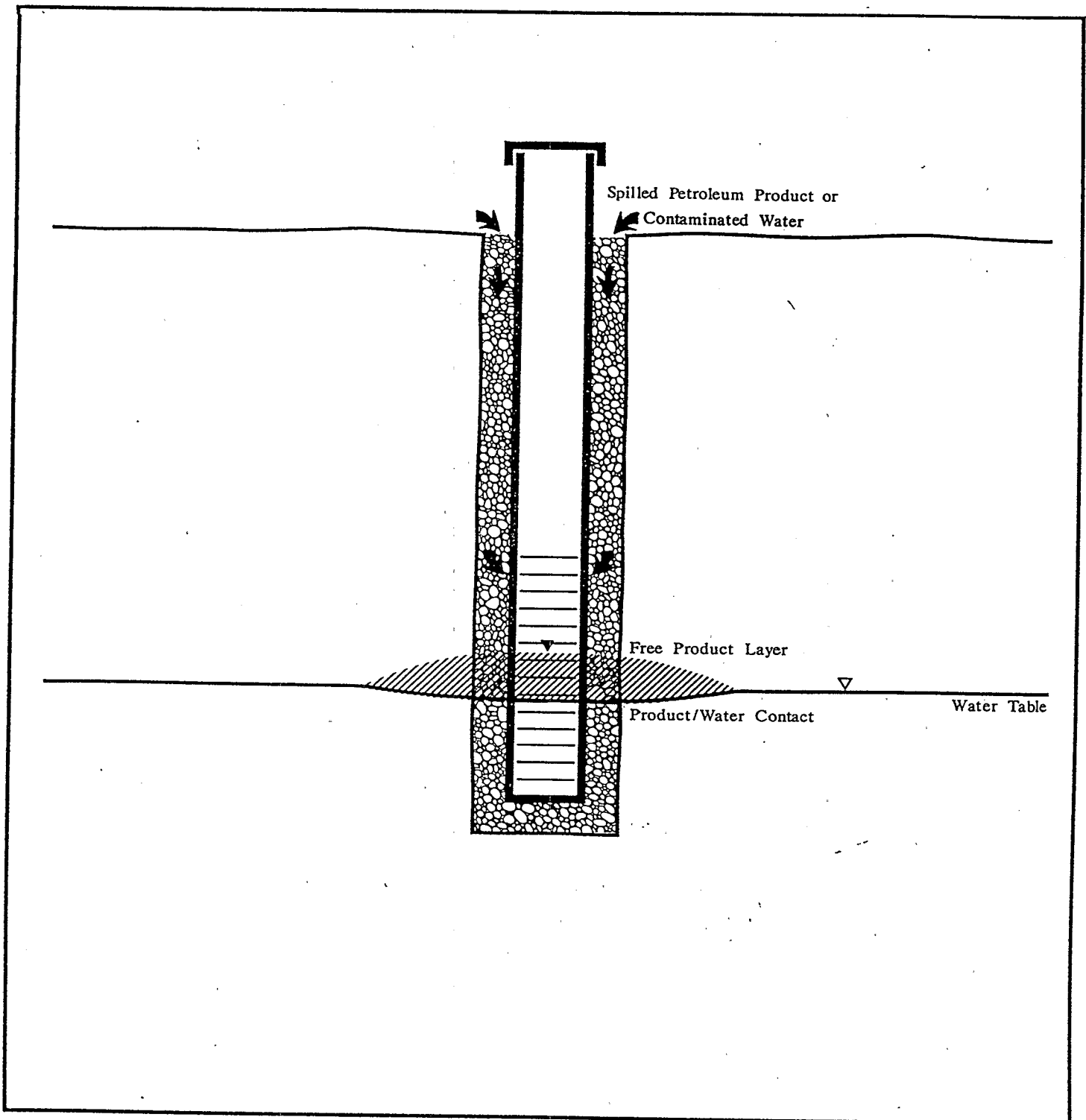
- | | |
|-------------------------|--------------|
| Grout | Water Table |
| Bentonite or Grout Seal | Gravel Pack |
| | Free Product |

Improper sealing of the near-surface annular space can allow contaminated surface water or spilled petroleum product to enter the gravel pack around the well (Figure 19). This can cause contamination of ground water and may lead to a false alarm of a tank or piping leak. The materials used to seal the top of the well generally consist of bentonite or a cement grout.

2.2.3 Well-Location Considerations

The influence of nearby potential contaminant sources, especially other UST systems, must be considered to properly assess a site (Figure 20). Monitoring wells should be installed in areas which will allow detection of contamination migrating onto the property from other sources located upgradient.

The proximity of monitor wells to a leak source must be considered (Figure 21). Wells might be located improperly to detect a plume of liquid hydrocarbons from a leaking underground storage tank near the property boundary. In this instance, upon determination of the direction of ground-water flow, additional wells should be located to detect releases and/or to delineate the plume.



Monitor Wells Should Be Sealed to Prevent Entry of Surface Spills and Eliminate this Cause of "False Positives" of UST Releases.



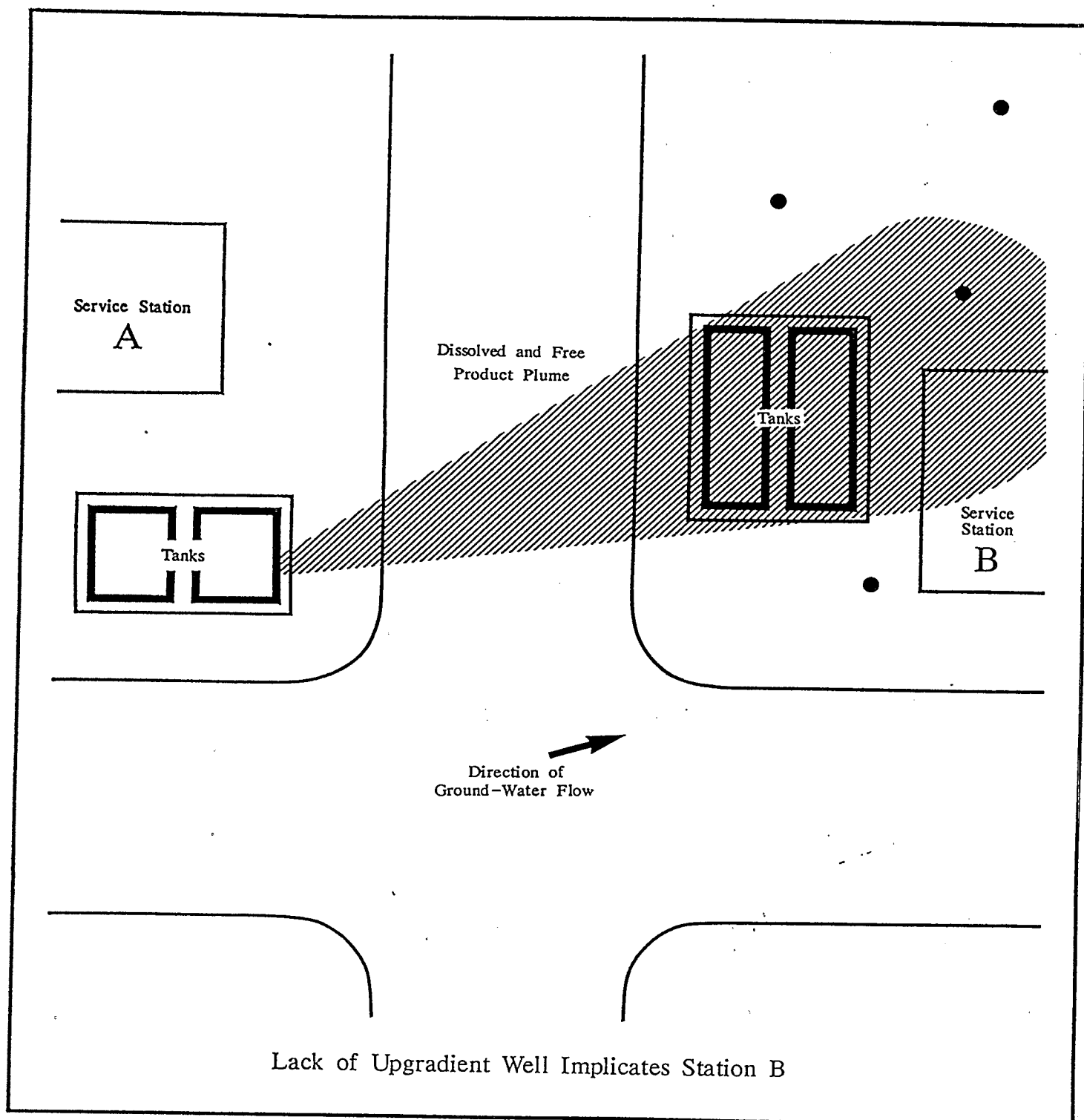
Water Table



Gravel Pack

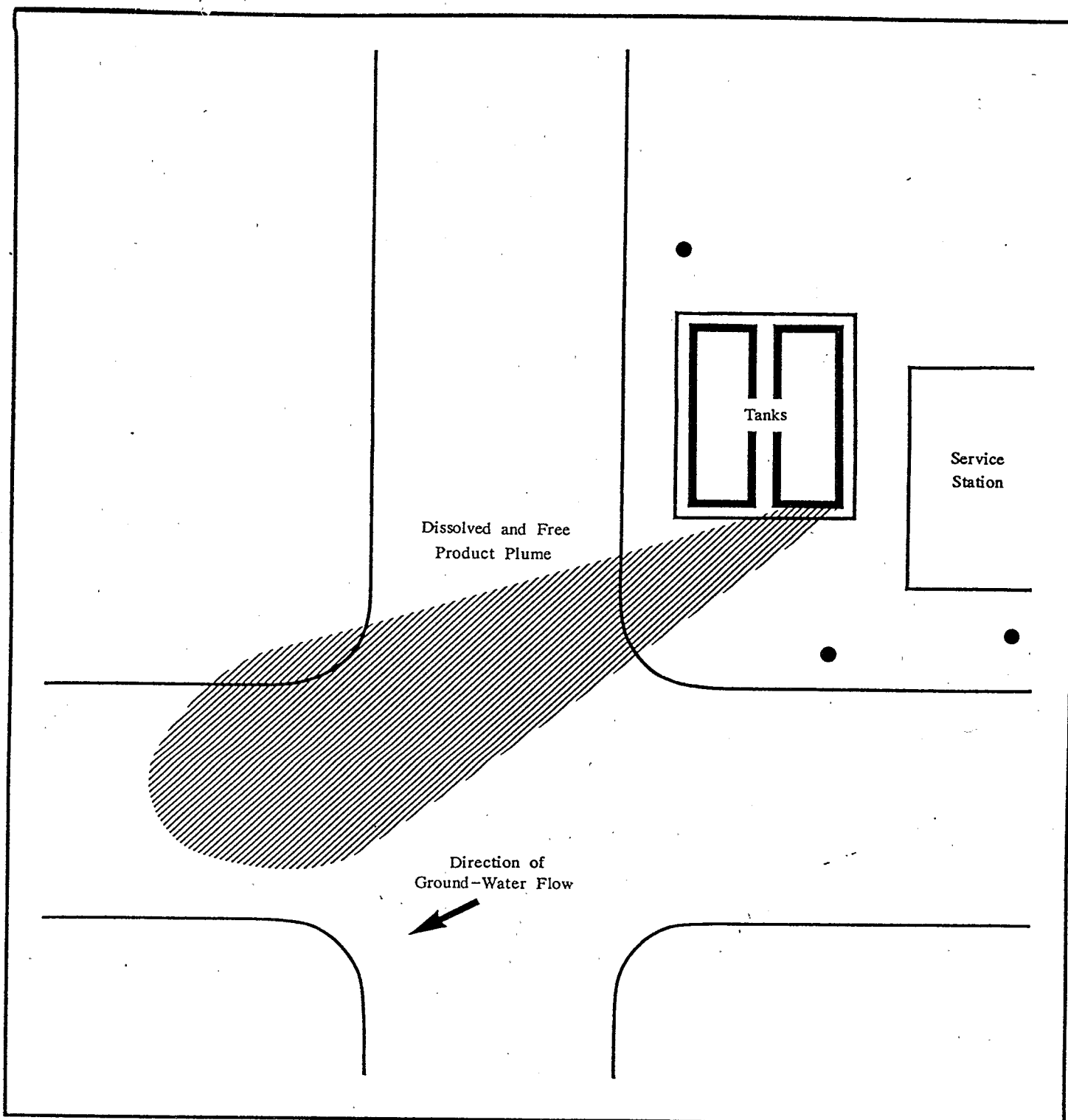


Free Product



Monitor Wells Should Be Located
To Allow Detection of Contamination from Other Sources

- Monitoring Well
- ▨ Product Plume



Widely Spaced Monitor Wells May Not Detect an UST Release

● Monitoring Well

▨ Product Plume

