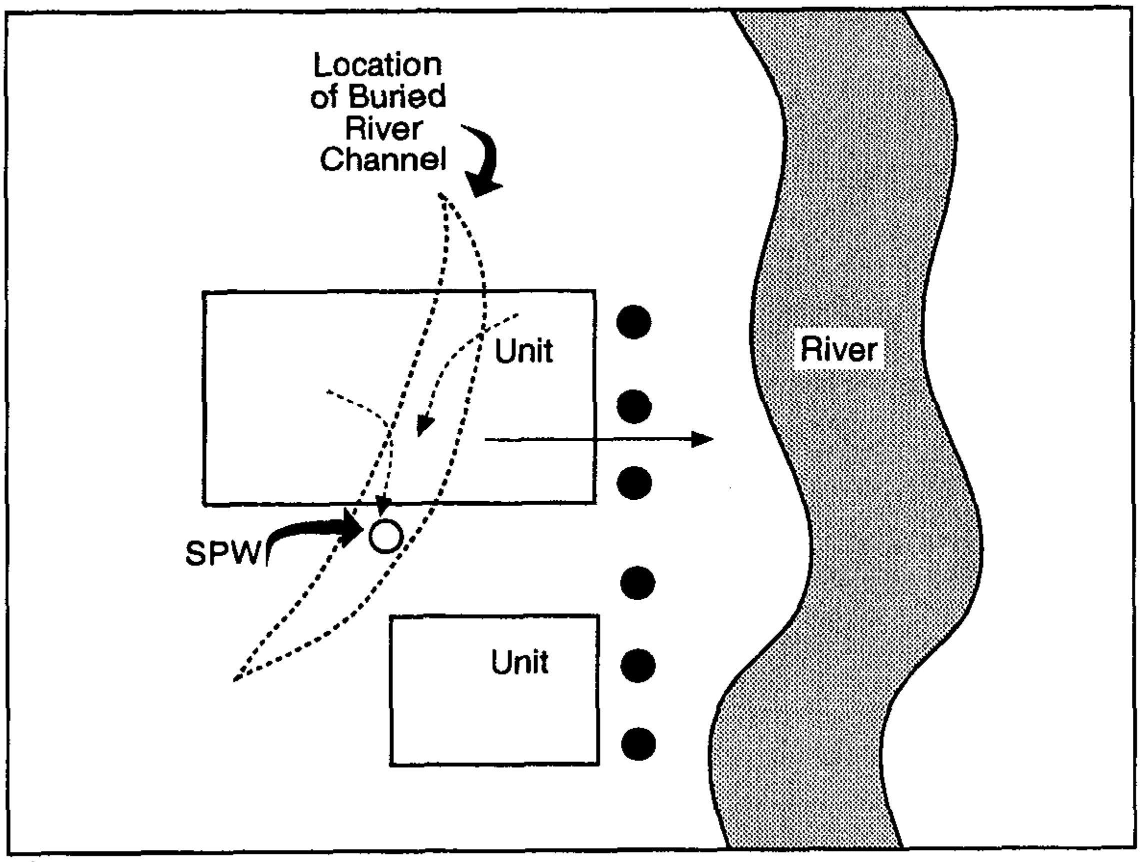
SPW Example 1

Zones of High Hydraulic Conductivity

The figure below depicts a geologic setting where ground-water flow under a waste management unit is affected by a buried river channel. The hydraulic conductivity of the channel deposit is significantly greater than the surrounding geologic materials and provides a preferential pathway for ground-water flow and contaminant migration. The ground-water flow direction under the waste management unit is complex, with flow lines on the left side of the unit converging towards the buried channel, because it has high hydraulic conductivity. A SPW was placed within the buried channel to detect releases that could potentially migrate down the channel deposits away from the POC wells.



● POC Well

○ SPW

- - -► Preferential pathway of contaminant migration into the buried river channel

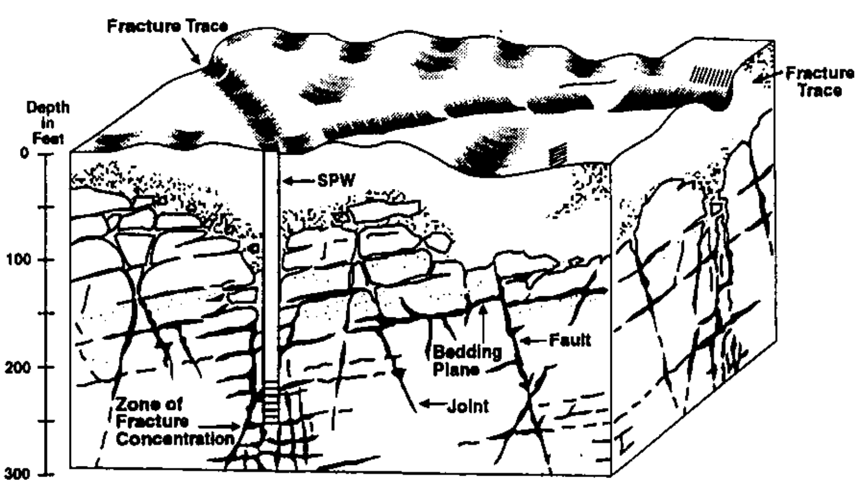
——► Local ground-water flow direction

SPW Example 2

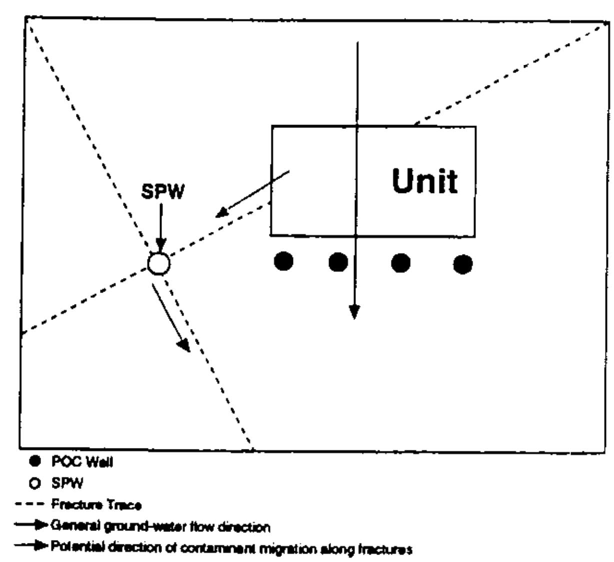
Supplemental Wells to Monitor Contaminant Migration in Fractures

At a RCRA facility located in Tennessee, contaminants were released into fractured bedrock. The bedrock is made up of highly faulted and jointed siltstones, shales, and limestones with complex ground-water flow that is difficult to monitor. The facility performed a fracture trace analysis, drilled soil borings, and performed surface and borehole geophysical investigations to determine the probable locations of subsurface fracture zones that might act as preferential pathways of contaminant migration from the unit. Because the studies revealed that the POC wells were not located in subsurface fracture zones, a SPW was installed at the intersection of two identified fracture traces to intercept a release that might not be detected by the POC wells, as depicted in the plan view below. The cross section depicts the subsurface in the vicinity of the SPW.

CROSS SECTION



PLAN VIEW



(Modified from USEPA, 1991)

3.3.3 Perched Water Tables

Geologic formations consisting of interbedded lenses or units of sand and silt or clay may contain lower hydraulic conductivity lenses that create perched water tables. In some cases, perched zones have not been considered part of the uppermost aquifer, and have not been monitored by Subpart F POC wells. Nevertheless, these zones of saturation may be hydraulically connected to the uppermost aquifer (on a permanent or intermittent basis), and may provide a primary pathway for contaminants to migrate past the POC. Permit writers may need to require SPWs in perched tables to detect releases that migrate past the POC wells undetected. In addition, if perched conditions cause a release to enter the aquifer downgradient of the POC wells, SPWs may be installed in the aquifer downgradient of the compliance wells. Example 3 illustrates a situation where SPWs have been used to detect contaminant migration in perched water tables.

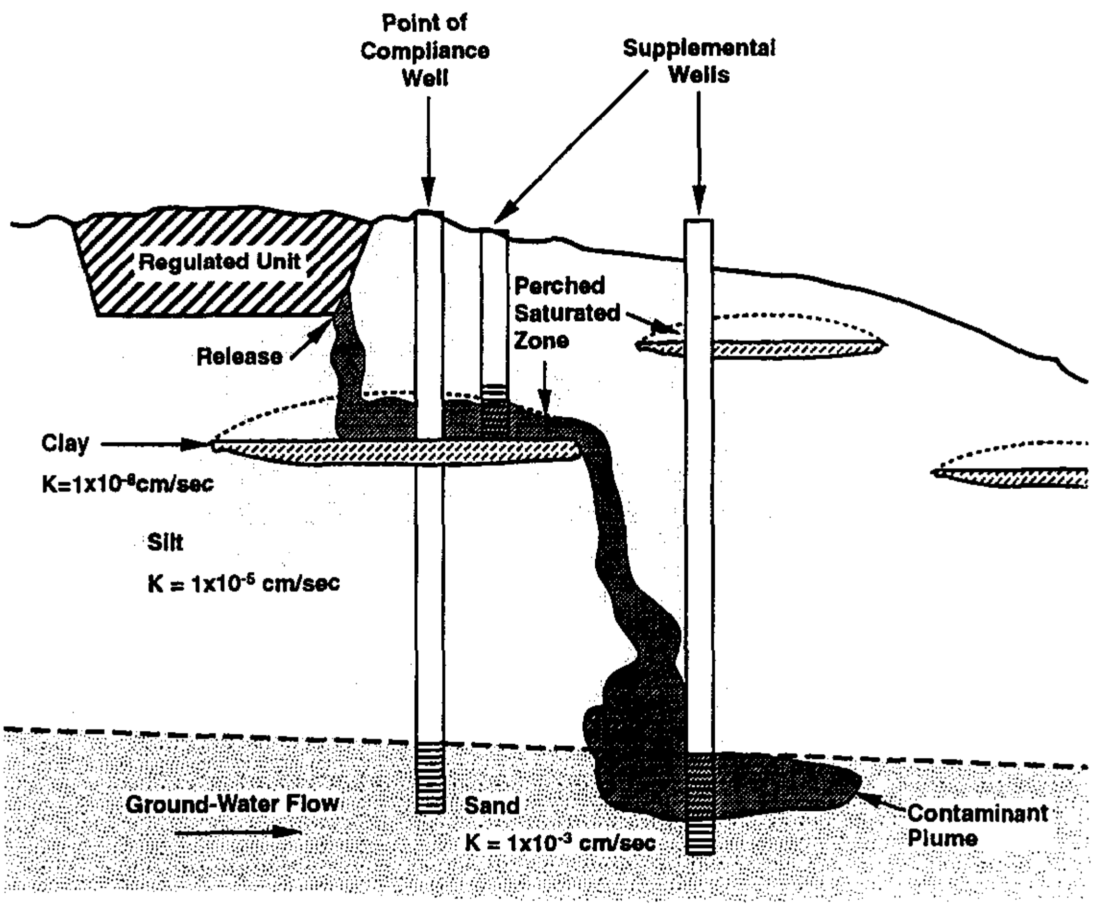
3.3.4 Conduits and Conduit Flow in Karst Terrains

In aquifers in karst terrains dominated by conduit flow, contaminant releases primarily migrate through subsurface conduits. The placement of POC wells in aquifers dominated by conduit flow is rarely effective. Conduits often drain to springs which discharge on land or along surface water bodies. Early and reliable detection of contaminant releases in many karst settings can be performed only at springs and caves, which are commonly outside the boundary of the facility. EPA recommends the monitoring of seeps, springs, and cave streams to supplement POC monitoring well systems in aquifers dominated by conduit flow. Springs and cave streams with proven hydraulic connections to a facility (e.g., as demonstrated by tracer studies) are the easiest and most reliable sites at which to monitor ground-water quality in terrains where conduit flow predominates (Field, 1988; Quinlan, 1989; Quinlan, 1990). A discussion of the sample frequency in aquifers dominated by conduit flow is given in the November 1992 RCRA Ground-Water Monitoring: Draft Technical Guidance (pages 5-18 through 5-21). Example 4 illustrates the use of supplemental monitoring points at off-site springs in a karst area.

SPW Example 3

Intermittent or Perched Water Tables

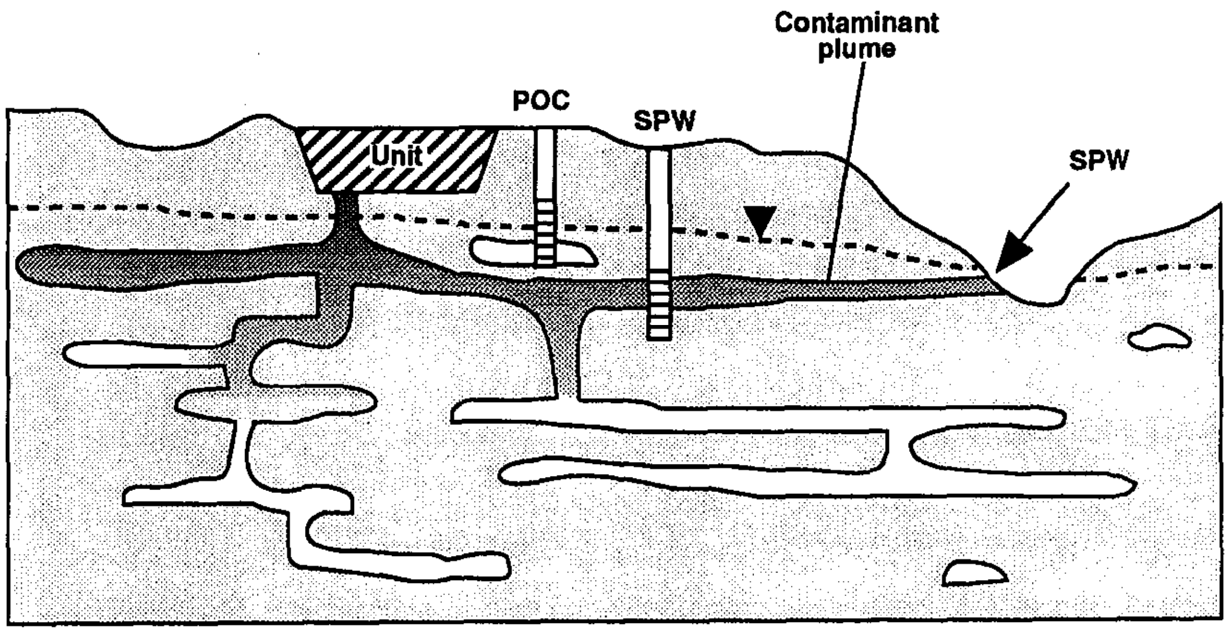
At a chemical manufacturing facility in West Virginia, POC wells were installed at the downgradient limit of a regulated waste management unit containing filter press sludge. The POC wells were screened in the uppermost aquifer, a well-sorted sand. Ground water perched on clay lenses within an overlying silt layer served as an additional pathway of contaminant migration from the unit. A number of borings were drilled to define the horizontal extent of potentially low hydraulic conductivity zones above the uppermost aquifer. Geologic cross-sections helped identify potential zones of perched water. To ensure that contaminant migration within the perched zones would be monitored, SPWs were screened in the perched zones. SPWs were also screened in the uppermost aquifer at locations downgradient from the POC wells to detect releases that might migrate past the POC wells along unidentified perched zones. A schematic cross-section of the subsurface hydrogeology and the placement of the SPWs is shown in the figure below.



SPW Example 4

Supplemental Monitoring Points in Karst Terrains

The figure below is an example of a site that is located in a karst terrain where ground-water flow is predominantly through conduits. Monitoring wells installed at the POC may not intercept conduits that are hydraulically connected with the hazardous waste management unit, even though the POC wells are located more closely to the unit than off-site springs. Through dye tracing, investigators can determine if there is a hydraulic connection between the waste management unit and local springs. The permit writer can require a monitoring program for hydraulically connected springs that will aid in the detection of a release from the waste management unit. In some cases, it also may be possible to locate SPWs in conduits that are hydraulically connected to the waste management unit.



3.3.5 Dipping Geologic Units

In settings where interbedded geologic units of differing hydraulic conductivities exhibit structural or stratigraphic dip, ground-water flow can occur in the down-dip direction or along strike in one or more of the geologic units. As a result, ground-water flow in dipping geologic units can be locally complex and might not be in the direction of regional ground-water flow. Consequently, dipping geologic units may create a preferential pathway for contaminant migration past the POC.

3.3.6 Strong Vertical Gradients

Strong vertical gradients can cause ground water to take long or complex flow paths that are difficult to monitor with standard POC monitoring systems. Monitoring wells must be placed to reflect both the horizontal and the vertical components of flow. In Example 5, an upper unit has a strong downward gradient with a small westward flow component. This westward flow defines the downgradient side in the upper unit from a standard POC perspective. In contrast, flow in the connected underlying unit is primarily horizontal, and to the east, in the opposite direction. SPWs can be used in conjunction with POC wells to monitor both zones of the uppermost aquifer.

3.3.7 Natural Fluctuations in Ground-Water Flow Direction

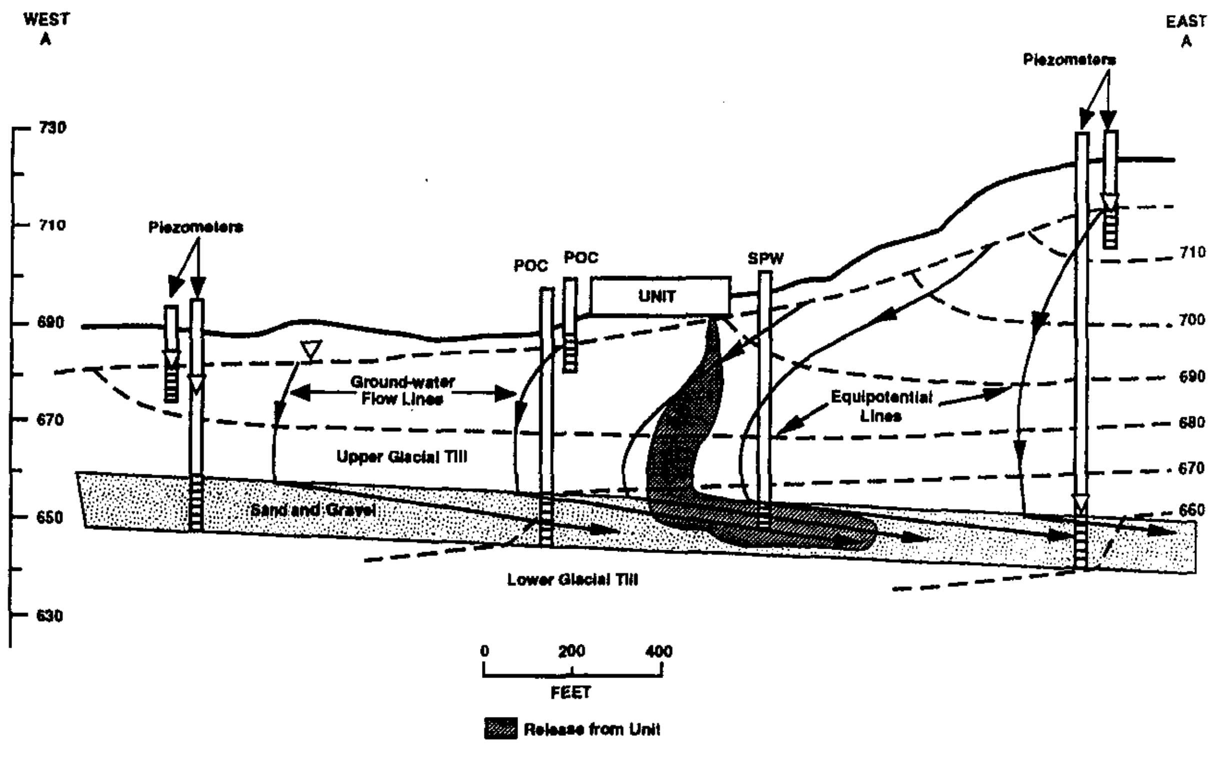
Natural fluctuations in ground-water flow direction may result from tidal or riverine influences, changes in recharge rates, seasonal effects, or precipitation events. SPWs may be necessary in areas where natural fluctuations in water level elevations are suspected to cause variations in ground-water flow directions that might result in contaminant migration past the POC. Example 6 illustrates the placement of SPWs for waste management units that are influenced by lake levels.

Permit writers also may consider imposing additional WMAs to provide a more protective monitoring system in settings where reversals in ground-water flow direction occur. This approach would allow for the waste management unit in Example 6 to be a

SPW Example 5

Complex Flow With a Strong Vertical Gradient

In the figure below, an upper flat-lying glacial till is hydraulically connected to a lower sand and gravel unit that constitutes a regional aquifer. Ground-water flow in the upper till unit is to the west and has a strong downward gradient. In the lower sand and gravel unit however, ground-water flow is to the east. Consequently, POC wells installed at the downgradient limit (the western boundary) of the WMA in the upper till unit would be ineffective in intercepting a contaminant release migrating downward to the lower sand and gravel unit. Accordingly, SPWs should be installed in the sand and gravel unit on the eastern side of the waste management unit (the upgradient side of the waste management unit in the till). Alternatively, if the unit were designated as a single WMA, standard POC wells monitoring the uppermost aquifer could be installed on both sides of the WMA.

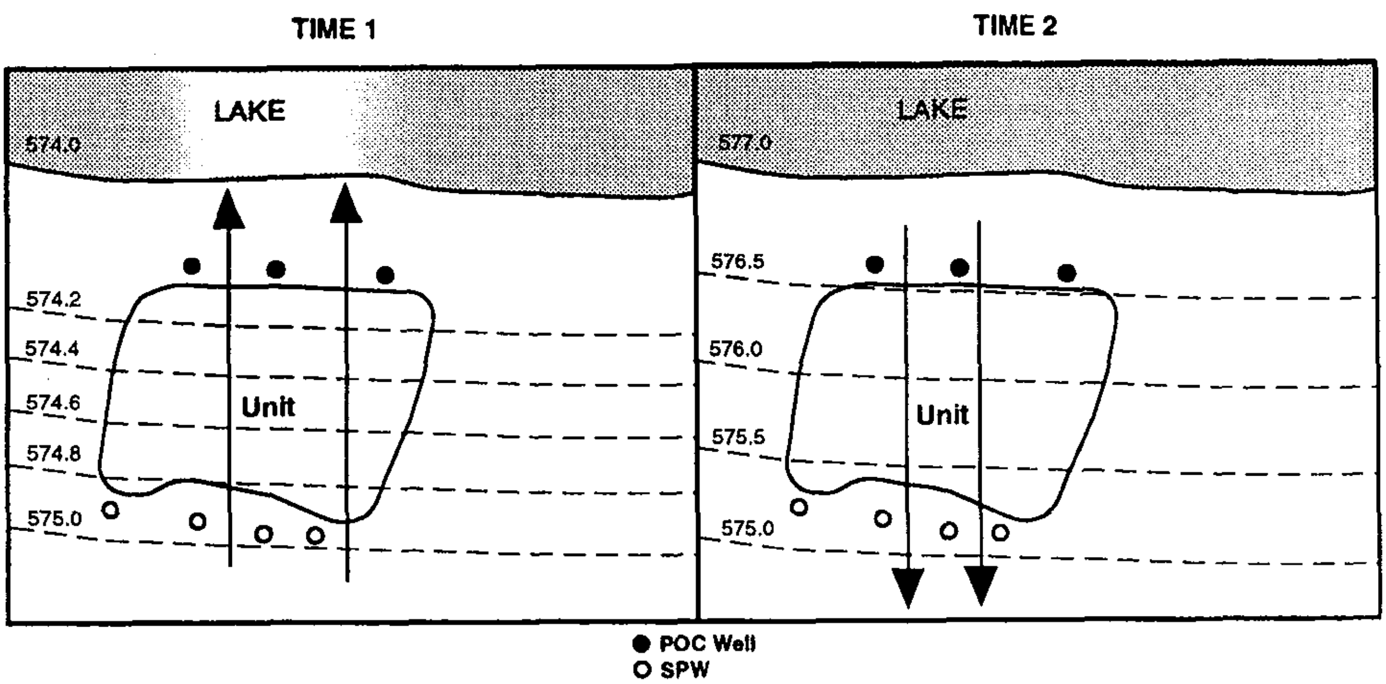


(Modified from Sara, 1991)

SPW Example 6

Fluctuation in Ground-Water Flow Direction Caused by a Surface Water Body

Natural fluctuations in ground-water flow directions may result from fluctuating water levels in nearby surface water bodies, including lakes, rivers, estuaries, and oceans. A facility in northern New York provides an example of how fluctuating lake levels can result in a reversal of ground-water flow direction, particularly in areas where the hydraulic gradient is very low. Water levels measured at Time 1 indicate ground-water flow towards the lake, which is the prevalent ground-water flow direction. Water levels measured at Time 2, however, indicate ground-water discharge from the lake that results in a complete reversal of ground-water flow direction. Depending on the magnitude and frequency of such reversals, it may be necessary to install SPWs to detect contaminant releases in the alternate ground-water flow direction. The permit could be structured, for example, to require monitoring of the SPWs only during high lake levels. Alternatively, if the reversals are frequent, the unit could be designated as a WMA and all the wells could be designated as POC wells. Similar natural fluctuations in ground-water flow direction may be caused by seasonal fluctuations in the water table or by major precipitation events.



separate WMA, and for POC wells to surround the periphery of the unit. This option may be preferred where the fluctuations in ground-water flow are frequent, such as might occur under tidally influenced conditions. If flow reversals are infrequent, SPWs may be more appropriate. For example, the monitoring requirements for SPWs might be only to sample when the lake level reaches a certain critical height that generates flow reversals. Chapter 2 of this document discusses the designation of additional WMAs.

3.3.8 Human-Induced Fluctuations in Ground-Water Flow Direction

Various human activities can alter ground-water flow directions at a site either on a continuous or intermittent basis. These activities include:

- On- or off-site pumping wells;
- Artificial recharge;
- Irrigation; and
- Changes in land use patterns (e.g., paving, construction).

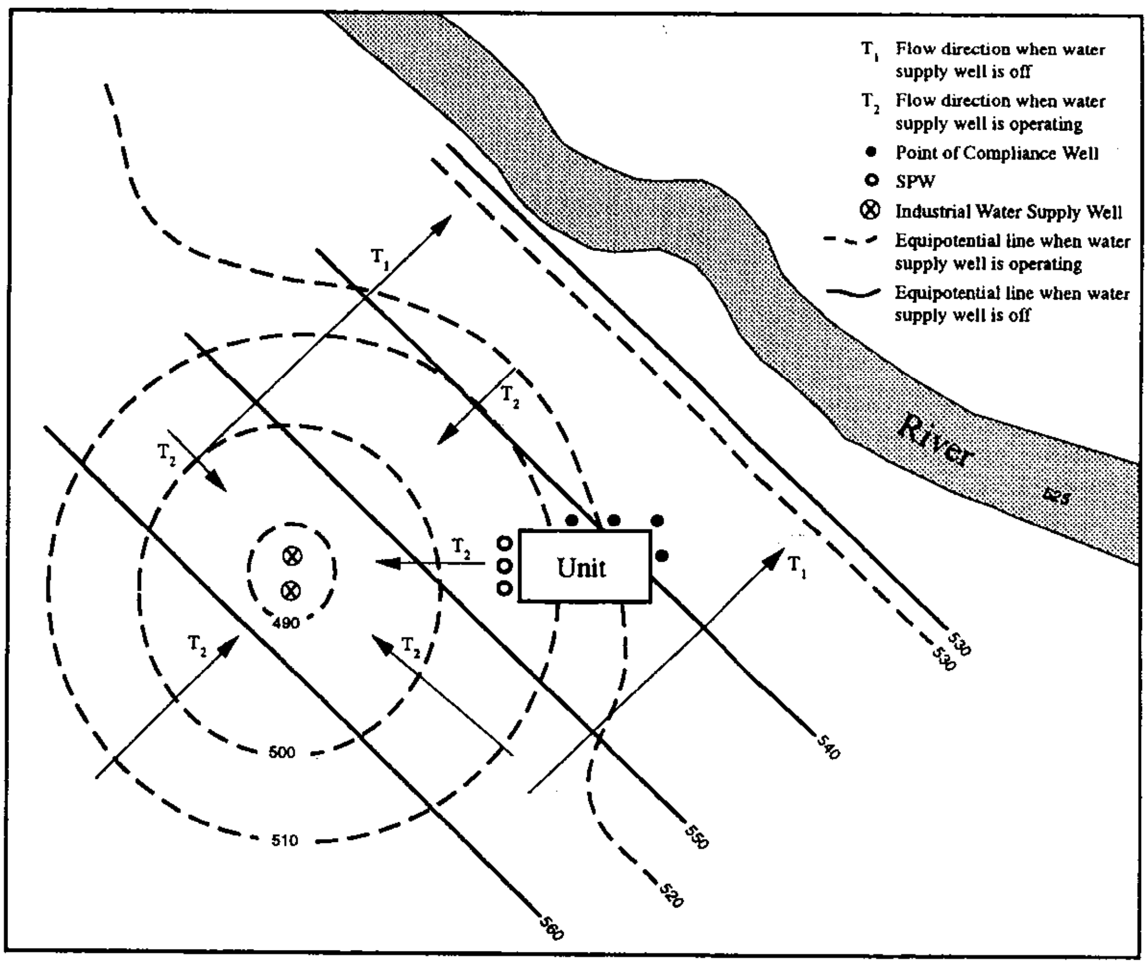
If artificially-induced temporal changes in ground-water flow direction are occurring or are suspected to occur, SPWs should be installed to monitor for contaminant releases when ground-water flow is not in the typically downgradient direction. Example 7 illustrates the use of SPWs for a waste management unit where ground-water flow is influenced by pumping wells. Careful consideration should be given to the need for additional background monitoring wells under conditions where flow direction varies (discussed further in Section 3.5.2).

As discussed in Section 1.3, the authorities of the proposed WMA and SPW provisions overlap because both provisions allow for extra wells in cases where releases might not be detected by POC systems. When changes in flow direction are regular or frequent, the multiple WMA approach may be implemented more appropriately for installing wells that monitor the POC. However, if as in Example 7, where production wells that cause a local flow reversal are used infrequently, SPWs are more appropriate.

SPW Example 7

Fluctuation in Ground-Water Flow Direction Caused by Pumping Wells

Human-induced fluctuations in ground-water flow direction may be produced by pumping wells located near a site, as shown in the figure below. The pumping wells at this facility are only operated certain times of the year for specific batch processes. The pumping wells produce a cone of depression in the water table and cause ground water to flow radially towards the pumping wells. A pumping well can produce either temporal or continual local and regional changes in ground-water flow direction, depending on the magnitude of drawdown at the pumping well, the operating schedule of the well, and aquifer characteristics (hydraulic conductivity, recharge, etc.). Under these conditions, SPWs may be required to detect contaminant releases flowing towards the pumping wells and away from the POC as illustrated below.



3.4 Presence of Nonaqueous Phase Liquids (NAPLs)

Permit writers should carefully consider how the characteristics of wastes and contaminants present at a site may influence their migration such that they might migrate past the POC undetected. In particular, waste management units that contain NAPLs may be candidates for SPWs. This section discusses the migration of NAPLs and provides examples that describe how SPWs may be used to detect NAPLs.

NAPLs are liquids that have low solubilities in water and densities that may be greater than or less than that of water. NAPLs have distinctive properties that govern their fate and transport and may prevent the early detection of contaminant releases or result in contaminant migration past the POC. Therefore, when contaminants that have the potential to exist as NAPLs are present in facility wastes, the need for SPWs to detect their release should be considered.

NAPLs are typically divided into two general categories: Light nonaqueous phase liquids (LNAPLs), which have a specific gravity less than water, and dense nonaqueous phase liquids (DNAPLs), which are denser than water. Most LNAPLs are hydrocarbon oils and fuels. Most DNAPLs are highly chlorinated hydrocarbons (e.g., carbon tetrachloride, tetrachloroethylene, and PCBs). Identifying whether or not a compound exists as an DNAPL or an LNAPL can be complicated by the substance in which it is dissolved. For example, free phase PCBs may be denser than water (DNAPL), but PCBs in oil can be transported as an LNAPL. Additional information on NAPL migration is provided by USEPA (1989), USEPA (1991) and Huling and Weaver (1991).

If wastes at a site contain contaminants that potentially exist as LNAPLs, it may be necessary to install SPWs at the water table to prevent contaminants from migrating past the POC wells undetected. SPWs for monitoring LNAPLs should be screened at the water table and the screened interval should intercept the water table at its minimum and maximum elevation as determined from historical water level data. LNAPLs may become trapped in residual form in the vadose zone and become periodically remobilized and contribute further to aquifer contamination, either as free phase or dissolved phase contaminants, as the water table fluctuates and precipitation infiltrates the subsurface.

The migration of free-phase DNAPLs may be primarily influenced by the geology, rather than the hydrogeology, of the site. That is, DNAPLs migrate downward through the saturated zone because their density is greater than that of water, and then migrate by gravity along less permeable geologic units (e.g., sloping confining units, sloping clay lenses in more permeable strata, or bedrock troughs). Consequently, if wastes disposed at the site are anticipated to exist in the subsurface as a DNAPL, the potential DNAPL should be monitored:

- At the "base" of an aquifer (immediately above a major confining layer);
- In structural depressions (e.g., bedrock troughs) in lower hydraulic conductivity geologic units that act as confining layers;
- Along lower hydraulic conductivity lenses within units of higher hydraulic conductivity;
- "Down-dip" of lower hydraulic conductivity units that act as confining layers, both upgradient and downgradient of the WMA; and
- In higher conductivity lenses or within fractures.

Because of the nature of DNAPL migration (i.e., along structural or stratigraphic trends, rather than along hydraulic gradients), SPWs installed to monitor DNAPLs might need to be installed both upgradient and downgradient of the WMA. It may be useful to construct a structure contour map of lower hydraulic conductivity strata and identify lower hydraulic conductivity lenses, both upgradient and downgradient of the unit, along which DNAPLs may migrate, and locate SPWs accordingly. The reader is cautioned however, that the fate and transport of free phase DNAPL is very complex, and cannot be covered in sufficient detail in this document. Huling and Weaver (1991) provide a useful explanation (with additional references) of the properties and behavior of DNAPLs in the subsurface.

Although NAPLs are frequently described as "immiscible" based on the physical interface that exists between a mixture of NAPLs and water, certain compounds found in NAPLs can dissolve into water in concentrations that are harmful to human health and the environment. Free phase DNAPL trapped in intergranular pore spaces or existing as pools or pockets can "bleed" off low but harmful levels of dissolved contaminants that can contaminate large volumes of water over decades or longer. The dissolved constituents from LNAPL and DNAPL contamination will migrate in the direction of ground-water flow in the same fashion as other dissolved constituents. Consequently, dissolved phase LNAPL and DNAPL plumes can be detected downgradient of WMAs in POC wells (an exception exists when a NAPL is diverted by structural or stratigraphic features so that it comes into contact with the water table downgradient of POC wells, as is illustrated in Example 8). However, free phase LNAPLs and DNAPLs may not be detected by POC wells, and may create an additional dissolved phase that is not detected by POC wells. Example 8 illustrates the use of SPWs to monitor DNAPL migration in shallow sand lenses. Example 9 illustrates the use of SPWs at one site to monitor for both LNAPLs and DNAPLs.

3.5 Relationship Between SPWs and Point of Compliance (POC) Wells

3.5.1 Can Supplemental Monitoring Wells be Used for the Same Purpose as Point of Compliance Wells?

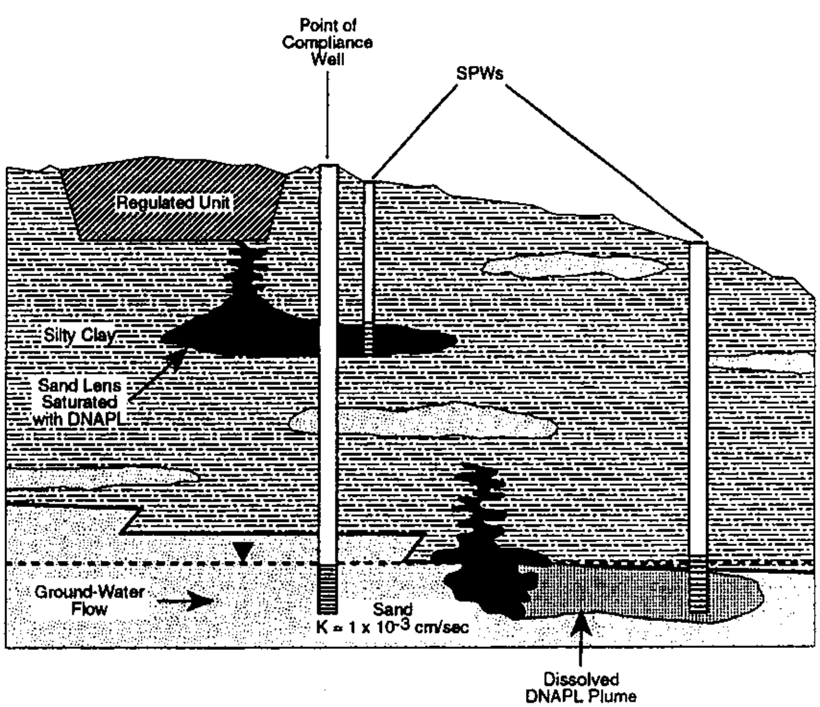
The monitoring requirements for POC wells may be applied to SPWs when necessary to protect human health and the environment. In certain cases, the overseeing Agency would determine that wells at the POC may not require monitoring or may require a modified monitoring program if SPWs provide better information on potential contaminant releases. Ground-water monitoring systems at RCRA facilities are intended to be tailored to the specific site characteristics and contaminants expected at a facility; as more ground-water data and site characterization data are gathered, more appropriate monitoring locations could be identified.

SPW Example 8

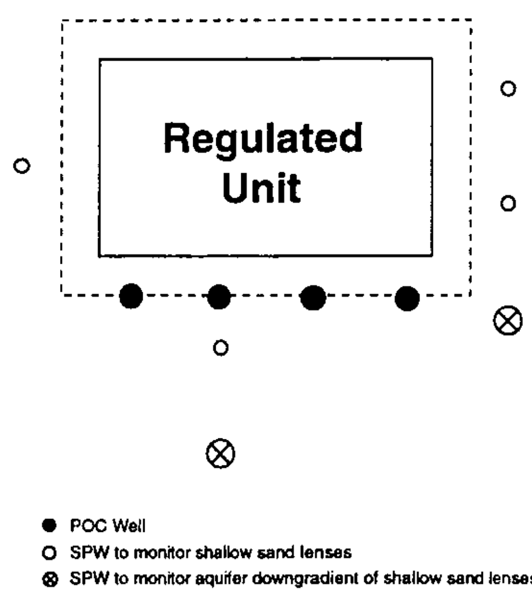
Supplemental Wells Used to Monitor DNAPL in Shallow Sand Lenses

This example is based on a case study of a wood preserving facility located in the Upper Coastal Plain in South Carolina. The geologic setting is characterized by an upper silty clay unit that overlies a sand unit. DNAPL has migrated along grain-size discontinuities and in sand lenses within the unsaturated zone of the upper silty clay unit. In some areas, shallow sand lenses encountered during drilling contain DNAPL, while adjacent over and underlying silty clays contain no DNAPL. Moreover, the shallow sand lenses have promoted DNAPL migration laterally from the unit, and away from POC wells. Therefore, suction lysimeters were installed as SPWs to monitor for DNAPL migration in the shallow sand lenses. [Note that most published diagrams depict DNAPL pooling on top of low permeability lenses, rather than contained within high permeability lenses, as is the case at this actual site. DNAPL fate and transport in the vadose zone can be very complex and is a function of a number of factors, including degree of saturation, entry pressure of DNAPL, pore configuration, viscosity of DNAPL, and other factors.] SPWs also were installed in the uppermost aquifer to detect potential dissolved phase contamination emanating from DNAPL.

CROSS SECTION



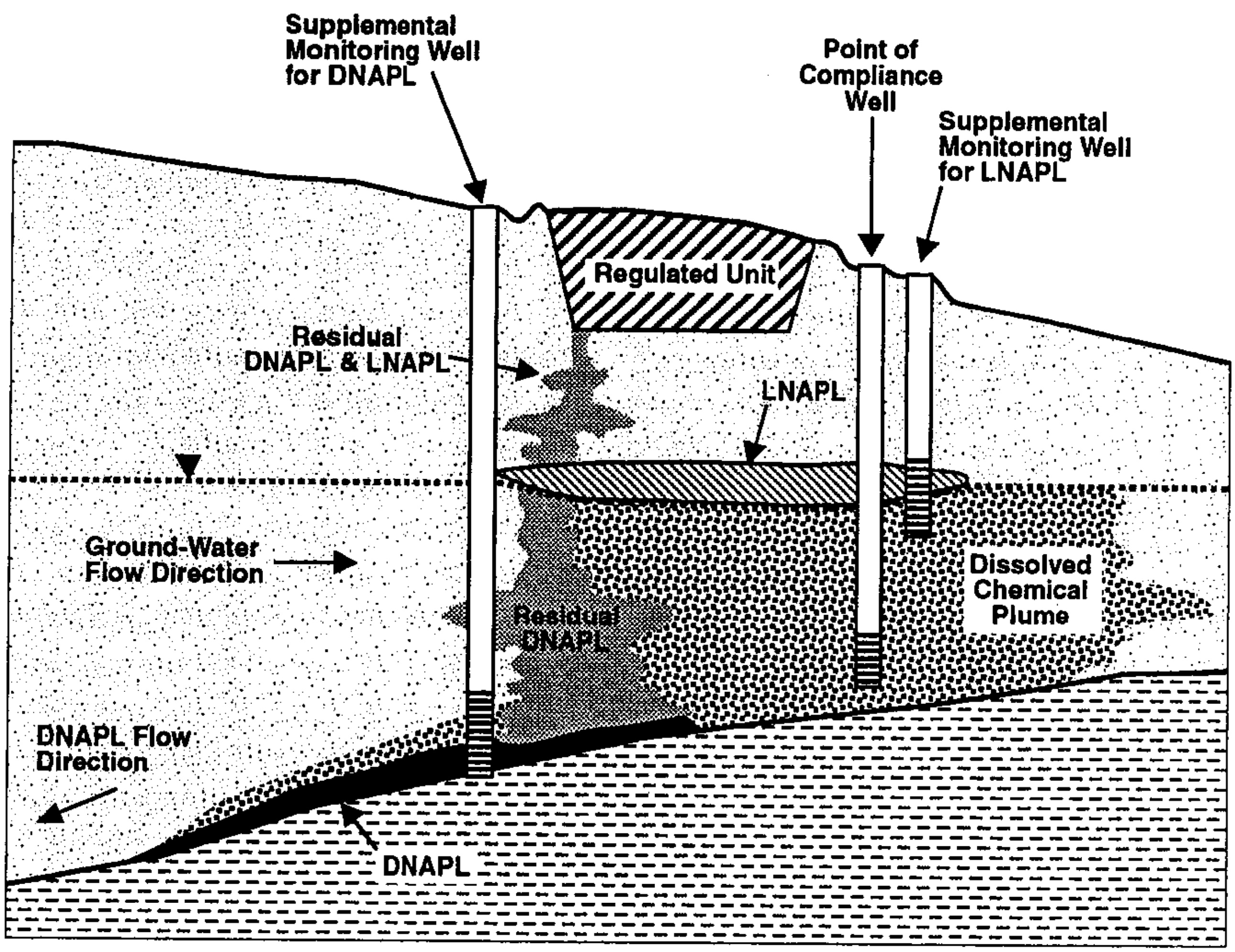
PLAN VIEW



SPW Example 9

Supplemental Wells Used to Monitor LNAPL and DNAPL Plumes

This example is based on a case study of a chemical manufacturing facility in Texas. LNAPL, DNAPL, and dissolved phase contaminants have been detected in ground water at the site. The migration of the dissolved contaminant and LNAPL plumes is in the opposite direction of DNAPL migration. The DNAPL plume has migrated down dip along the boundary of a confining layer, and occurs at a depth of approximately 60 feet, despite a generally upward vertical hydraulic gradient. SPWs have been installed specifically to detect the LNAPL and DNAPL plumes.



3.5.2 What is the Relationship Between Supplemental Monitoring Wells and Background Monitoring Wells?

Background wells installed as part of the ground-water monitoring system under §264.97(a)(1) are not considered SPWs. However, in certain instances, SPWs may be designated under the omnibus authority in addition to the required background wells to obtain supplemental information regarding background or upgradient conditions at a site. For example, a SPW piezometer may be installed to measure upgradient water-level changes that are induced by intermittent pumping of agricultural wells.

Many of the site-specific hydrogeological complexities that warrant the use of SPWs also will make background wells difficult to place. For example, at sites with locally complex flow paths, such as might be caused by fractured and folded bedrock, determining hydraulically connected upgradient locations will require thorough site investigation. In all cases where SPWs are determined necessary, an assessment of the adequacy of existing background wells, and the need for additional wells should be made.

3.6 The Use of SPWs for Interim Measures and Corrective Action

3.6.1 What if Supplemental Monitoring Wells Indicate the Need for Corrective Action?

The RA has the authority to require corrective action when necessary to protect human health and the environment if constituents are detected above specified concentrations in SPWs.

3.6.2 Can Supplemental Monitoring Wells be Used to Implement a Corrective Action?

The use of SPWs for corrective action purposes is appropriate in some circumstances (such as for ground-water extraction, soil flushing, venting, or vapor extraction). The RA has the authority to require the use of SPWs for corrective action purposes under the omnibus and corrective action authorities of RCRA §§3004(a) and (u), 3005(c)(3), and 3008(h).

3.6.3 Can Supplemental Monitoring Wells be Used to Monitor the Effectiveness of Corrective Action?

SPWs can be used to monitor the effectiveness of corrective action. SPWs may be used to collect routine corrective action performance data such as water level measurements, vadose zone sampling (of soil gas as well as pore water), and sampling of ground water in the uppermost aquifer. SPWs that are installed to detect NAPL releases can be used for monitoring the effectiveness of corrective action measures to remediate NAPL contamination.

3.6.4 Can Supplemental Monitoring Wells be Used to Implement or Monitor the Effectiveness of Interim Measures or Stabilization?

Similar to their use in corrective action, SPWs may be used to implement and monitor the effectiveness of measures taken to stabilize the migration of contaminants until a final corrective action is selected.

CHAPTER 4

IMPLEMENTING THE MULTIPLE WMA AND THE SPW APPROACHES

The multiple WMA and the SPW approaches in this guidance may be applied under three circumstances: permit application, permit modification, and permit renewal. Pending promulgation of the final Amendments Rule, the RCRA omnibus provision (RCRA §3005 (c)(3) and 40 CFR 270.32(b)(2)) provides authority for designating multiple WMAs and requiring SPWs. For each facility, information relevant to the designation of WMAs or SPWs will be recorded in the administrative record for the permit as required under §124.9. As with other permitting decisions, if the permittee does not agree with the oversight authority's decision regarding the WMAs or SPWs, he or she has the right to administrative or judicial appeal.

4.1 Permit Application

WMAs should be designated in a facility's permit application. Under §270.14(c)(3), the owner/operator must submit a proposed WMA delineation with Part B of the permit application. During the permit application process, the permit writer may advise owners and operators to carefully evaluate the WMA delineation based on the considerations set out in this guidance and the proposed Amendments Rule. The considerations, which are discussed in Chapter 2, include the number, spacing, and orientation of waste management units; waste type handled; hydrogeologic setting; site history; and engineering design of units. Depending on the conditions at the site, each one of these criteria can affect the designation of WMAs. The RA has the authority to accept or modify the proposed WMAs submitted by the owner or operator under §270.14(c)(3), and should select the appropriate WMA(s) necessary to protect human health and the environment by considering the criteria previously mentioned. The permit must specify those actions necessary to minimize monitoring and response complications posed by the modification to the WMA.

SPWs also should be designated in a facility's permit application. Under §270.14(c)(3) and (5), the owner/operator must submit in the permit application the proposed locations of ground-water monitoring wells and a description of the proposed ground-water monitoring program required under Subpart F. If the need for SPWs is apparent during the initial drafting of the permit, the number, location, and depth of SPWs should be specified in the permit application.

4.2 Permit Modification

The multiple WMA and the SPW approaches in this guidance may be applied as part of a permit modification. Permit modifications may take place at the request of either the RA or the owner/operator pursuant to §§270.41 or 270.42, respectively. If the RA feels that there is a need for designating multiple WMAs or SPWs to protect human health and the environment, he or she can request a modification of the permit pursuant to §270.41, and cite the omnibus provision as authority for the modification.

If the RA or the facility owner/operator initiates a permit modification because of the generation of new wastes; the construction of new, expansion, or replacement waste management units; evidence of a release; removal or delisting of waste, etc., the permit writer should assess the existing WMA configuration at the facility. The assessment will need to determine if the designated WMAs continue to be sufficiently protective of human health and the environment. The assessment could result in a single WMA being divided into multiple WMAs, or multiple WMAs being even further divided. The assessment also could result in consolidating WMAs into fewer WMAs or into a single WMA. An owner/operator with a multi-unit facility designated as a single WMA also may request delineation of multiple WMAs. This request may be made to avoid a facility-wide response action after compliance monitoring or corrective action has been triggered (until the permit is modified, the owner/operator would have to implement compliance monitoring or corrective action at the designated WMA). However, the designation of multiple WMAs does not limit or otherwise affect the site-wide and off-site corrective action authorities under §§3004(u), 3004(v), and 3008(h).

The proposed SPW provision also can be applied as part of a permit modification if the need for SPWs becomes apparent after permit issuance. Hydrogeologic or contaminant characteristics that create complex contaminant flow patterns might not be evident until the implementation of the monitoring program. For example, the RA may consider the necessity for SPWs after a Comprehensive Ground-Water Monitoring Evaluation (CME) or Operation and Maintenance (O&M) Inspection is performed. The CME is a detailed evaluation of the adequacy of the design and operation of ground-water monitoring systems at RCRA facilities. The CME or O&M may show that the existing ground-water monitoring wells would not detect the release of contaminants from the WMA. (Chapter 3 discusses reasons why existing wells might not detect contamination.) Under these circumstances, it might be necessary for the EPA to modify an existing permit to require SPWs.

4.3 Permit Renewal

At the time of permit renewal, the RA and the owner/operator should evaluate the effectiveness of the existing ground-water monitoring system. If a review of the criteria discussed in Chapter 2 indicates the need to establish more than one WMA, the RA should establish multiple WMAs under the authority of the RCRA omnibus provision (RCRA §3005(c)(3) and 40 CFR 270.32(b)(2)). Similarly, if a review of site hydrogeologic conditions reveals that POC wells are not sufficient for monitoring regulated units, the RA should consider installing SPWs pursuant to the omnibus provision.

4.4 Designating Multiple Monitoring Programs in the Permit

The proposed Amendments Rule would give the RA the authority under 40 CFR 264.91 to designate different monitoring programs (i.e., detection, compliance, or corrective action) for different WMAs defined at a multi-unit facility. This amendment would reduce the potential, in the event of a one-unit release, of one unit unnecessarily causing all other units to adopt the same monitoring or response program, regardless of the source and extent of contamination.

Separate ground-water monitoring systems are not required for each regulated unit when the RA approves a single WMA encompassing multiple units. If it is necessary to have multiple WMAs, then the permit will need to describe the monitoring program for each WMA pursuant to the requirements in §§264.98, 264.99, and 264.100.

REFERENCES

American Water Works Association. 1984. Appendix I: Abandonment of Test Holes, Partially Completed Wells and Completed Wells. American Water Works Association Standard for Water Wells, American Water Works Association, Denver, Colorado, pp. 45-47.

Field, M.S. 1988. U.S. Environmental Protection Agency's Strategy for Ground-Water Quality Monitoring at Hazardous Waste Land Disposal Facilities in Karst Terrains, in Karst Hydrogeology and Karst Environmental Protection, International Association of Hydrogeologists (21st Congress, Guilin, China), Proceedings, v. II, pp. 1006-1011.

Heath, Ralph C. 1982. Basic Ground-Water Hydrology. U.S. Geological Survey Water-Supply Paper 2220, 84 pp.

Huling, Scott G. and James W. Weaver. March 1991. Dense Nonaqueous Phase Liquids. EPA/540/4-91-002.

Quinlan, J.F. 1990. Special Problems of Ground-Water Monitoring in Karst Terranes, in D.M. Nielsen and A.I. Johnson, eds., Ground Water and Vadose Zone Monitoring. ASTM STP 1053, American Society for Testing and Materials, Philadelphia, pp. 275-304.

Quinlan, J.F. 1989. Ground-Water Monitoring in Karst Terranes: Recommended Protocols and Implicit Assumptions. USEPA EPA/600/X-89/050, 79 pp.

Sara, Martin N. 1991. "Ground-Water Monitoring System Design." In Nielsen, D.M., ed. Practical Handbook of Ground-Water Monitoring. Lewis Publishers, Chelsea, MI, pp. 17-68.

USEPA. 1992. RCRA Ground-Water Monitoring: Draft Technical Guidance. USEPA Office of Solid Waste, EPA/530R-93-001.

USEPA. November 1991. Seminar Publication: Site Characterization for Subsurface Remediation. EPA/625/4-91/026.

USEPA. 1989. Seminar Publication: Transport and Fate of Contaminants in the Subsurface. EPA/625/4-89/019.

USEPA. 1986. Permit Guidance Manual on Unsaturated Zone Monitoring for Hazardous Waste Land Treatment Units. EPA/530-SW-86-040.

USEPA. 1980. Monitoring in the Vadose Zone: A Review of Technical Elements and Methods. EPA/600/7-80-134.

APPENDIX I

Changes to the September 1988 Model Permit Module X to Incorporate Supplemental Well and Multiple Waste Management Area Provisions

(Note: Additions to 1988 module are given in __underlined bold__.)**

MODULE X - GROUND-WATER DETECTION MONITORING for WASTE MANAGEMENT AREAS AND SUPPLEMENTAL WELLS

[Note: This permit module contains conditions that apply to storage, treatment, or disposal of hazardous wastes in any of the following units: surface impoundments, waste piles, land treatment units or landfills. These units require ground-water monitoring unless exempted under 40 CFR 264.90(b).] The goal of detection monitoring is to ensure the earliest possible detection of contaminant leakage from the regulated units. Detection monitoring requires detected leakage to be characterized and determines if further action is warranted. Detection monitoring entails the following:

1. Development of a list of ground-water indicator parameters and monitoring constituents used to indicate a release from the regulated unit(s).

2. Establishment of sampling and statistical analysis requirements to determine if a release has occurred.

3. Establishment of additional requirements if a statistically significant release occurs.]

[Note: On July 9, 1987, a federal rule was finalized to require analysis for 40 CFR 261, Appendix IX, rather than Appendix VIII, hazardous constituents pursuant to 40 CFR 264.98 and 264.99, if a statistically significant increase occurs for any detection monitoring parameters or constituents. The Appendix IX list is an abbreviated Appendix VIII list with several constituents added. This permit module incorporates the new rule.]

[Note: Under 40 CFR 264.91(b) the Regional Administrator may include one or more of the following programs in a permit: (1) detection monitoring (Module X), (2) compliance monitoring (Module XI), and (3) corrective action [Module XII(A)]. __**Multiple waste management areas at a facility may be designated and more than one monitoring program at a facility may be operated where deemed necessary to protect human health and the environment pursuant to RCRA §3005(c)(3) and 40 CFR 270.32 (b)(2). Separate programs for each supplemental monitoring well installed pursuant to RCRA §3005(c)(3) and 40 CFR 270.32(b)(2) may also be established. Monitoring programs for supplemental wells can be**__

established based on hydrogeologic data and contaminant characteristics as necessary to protect human health and the environment, and can include sampling parameters and frequency, and appropriate response actions. If more than one program is included in the Permit, the Permit Writer is to specify the circumstances or conditions under which each program will be required. It is possible that more than one program will be operable at the same time at a facility, or that the programs will be conditional based on a sequence of events. For example, the sequence set up in the Permit could include a detection monitoring program that triggers an Appendix IX analysis that triggers a Permittee option to apply for a variance (e.g., other contamination source or sampling error) and if the Permittee fails to seek or fails to obtain a variance, then compliance monitoring is triggered. The Permit could also set the ground-water protection standard, with a provision for the Permittee to apply for an Alternate Concentration Limit (ACL), and in the absence of an ACL application or denial of an ACL, or exceedence of an ACL or pre-set limit, the triggering of the corrective action program. The corrective action program could include plume assessment, correction measures study and design, and implementation of corrective action. Setting up such a sequence in the Permit reduces the number of permit modifications that may be needed and decreases the administrative time needed to get on with subsequent steps in the process and ultimately, the time required to get corrective action under way, if needed.]

[Note: The Permit Writer should refer to the RCRA Permit Quality Protocol for additional guidance in developing or reviewing permit conditions. See discussion of the RCRA Permit Quality Protocol in the Introduction to this Model Permit.]

X.A. MODULE HIGHLIGHTS

[The Permit Writer should include a general discussion of the activities covered by this module. The discussion should contain the following information: description of the waste management units (including type and number that require detection monitoring); **description of the waste management areas (including which waste management units comprise each waste management area);** number, location and depth of wells; **which wells are supplemental monitoring wells;** which wells are upgradient and downgradient; the indicator parameters and monitoring constituents specified and their background concentrations; any unique or special features associated with the operation; and a reference to any special permit conditions.]

X.B. WELL LOCATION, INSTALLATION AND CONSTRUCTION

[Note: For specific Agency guidance on monitoring well design and construction, hydrogeologic site characterization and location of monitoring wells, consult the EPA RCRA Ground-Water Monitoring Technical Enforcement Guidance Document (September 1986).]

The Permittee shall install and maintain a ground-water monitoring system as specified below: [40 CFR 264.97]

X.B.1. The Permittee shall (install and) maintain ground-water monitoring wells at the locations specified on the map in Permit Attachment X-1 and in conformance with the following list:

> **[Note: For each waste management area, the map must show all monitoring well locations and provide unique identifiers for each well. The number and location of monitoring wells utilized for ground-water monitoring is site-specific. The number and location of the wells must meet the requirements of 40 CFR 264.95 (Point of Compliance) and 40 CFR 264.97(a) and (b), if applicable (number, location, and depth of wells). The ground-water monitoring system must: yield samples in upgradient wells that represent the quality of the background ground water unaffected by leakage from any regulated unit(s), and in downgradient wells yield samples that represent the quality of water passing the point of compliance. The number and location of monitoring wells must be sufficient to identify and define all logical release pathways from the regulated units based on site-specific hydrogeologic characterization. The Permit Writer may require the Permittee to install and monitor supplemental monitoring wells where deemed necessary to protect human health and the environment, where hydrogeology or contaminant characteristics can allow contaminants to move past or away from the point of compliance without being detected (e.g., perched water table).]**

X.B.2. The Permittee shall **(construct and)** maintain the monitoring wells identified in Permit Condition X.B.1., in accordance with the detailed plans and specifications presented in Permit Attachment X-2.

> **[Note: The plans and specifications must meet the requirements of 40 CFR 264.97(a) and (c), and should consist of design drawings and design criteria applicable to all wells, and individual well specifications identifying total well depth and location of screened intervals.]**

[Note: If determined to be necessary to protect human health or the environment, the Permit Writer should include Permit Conditions X.B.3., specifications on how monitoring wells are plugged and abandoned. HSWA Section 212 provides EPA with this authority. Several states also have regulations which cover monitoring well abandonment.]

X.B.3. All wells deleted from the monitoring program shall be plugged and abandoned in accordance with Permit Attachment X-3. Well plugging and abandonment methods and certification shall be submitted to the Regional Administrator within **[The Permit Writer should specify the submittal period.]** from the date the wells are removed from the monitoring program.

APPENDIX II

Waste Management Area(s) and Corrective Action Management Units: Comparison and Contrast

Both waste management areas (WMAs) and corrective action management units (CAMUs) circumscribe areas or units containing hazardous wastes or constituents. The objectives and use of WMAs and CAMUs are different, however, as described below.

Regulatory Authority

-- A single WMA at a site is authorized by §264.95 of Subpart F. Subpart F regulates ground-water monitoring at regulated units[1]. Multiple WMAs at a site can be designated under the authority of the omnibus provision, as is discussed in this guidance document.

-- A CAMU is authorized by §264.552 of Subpart S (58 FR 8658; February 16, 1993). Subpart S governs corrective action of solid waste management units (SWMUs)[2].

Description and Intent of WMA

-- A WMA is established for the purposes of defining a ground-water monitoring program and the point of compliance (POC). The POC is a vertical surface located at the hydraulically downgradient limit of the WMA. The POC represents the location(s) at which the ground-water protection standard of §264.92 must be met and at which monitoring must be conducted.

A WMA circumscribes regulated units and includes the space taken up by any liner, dike, or barrier designed to contain waste. Under §264.95, if a facility contains more than one regulated unit, a single WMA is described by a line (specified in a RCRA permit) encircling the regulated units. The proposed §264.95(b)(3) would allow the Regional Administrator to designate multiple waste management areas at a facility.

---

1 Regulated units are surface impoundments, waste piles, land treatment units or landfills that receive hazardous waste after July 26, 1982 subject to the requirements of §§ 264.91 through 264.100.

2 A SWMU is defined as any discernible unit, at a RCRA facility, at which solid wastes have been placed at any time, irrespective of whether the unit was intended for the management of solid and/or hazardous wastes. This definition includes tanks, surface impoundments, waste piles, land treatment units, landfills, incinerators, etc., as well as areas contaminated by "routine and systematic discharges" of wastes from process areas. All regulated units are SWMUs, but a SWMU is not necessarily a regulated unit (see footnote 1).

Description and Intent of CAMU

-- A CAMU refers to an area within a facility, designated by the implementing agency, that is used for management of remediation wastes. CAMUs may or may not include pre-existing "units" such as SWMUs or, in some cases, regulated units[3]. CAMU boundaries will typically be specified on a facility map in the permit or 3008(h) order.

CAMUs are intended to provide flexibility for decision-makers in implementing protective, reliable and cost effective remedies. For example, under the CAMU provisions, remediation wastes can be placed into a CAMU without triggering land disposal restrictions and other RCRA hazardous waste disposal requirements.

Other Primary Differences and Related Issues

-- Although the WMA is a surface delineation, it is linked to the POC which extends to the base of the uppermost aquifer; a CAMU is primarily a surface designation and is not linked directly to any characteristic of the underlying aquifer.

-- WMA and CAMU boundaries could coincide all or in part at a facility. However, the two designations are made for different purposes and are independent of one another from a regulatory standpoint. For example, under the present CAMU rule, the designation of a CAMU does not relieve the owner/operator from requirements to monitor ground water at regulated units that are included within the CAMU.

---

[3] In certain circumstances, the Regional Administrator has the discretion to designate a regulated unit as a CAMU, or to include a regulated unit as part of a larger CAMU. However, only closed or closing regulated units would be able to be so designated. The CAMU rule discusses in greater detail the circumstances under which this designation could be made.

Description and Intent of CAMU

-- A CAMU refers to an area within a facility, designated by the implementing agency, that is used for management of remediation wastes. CAMUs may or may not include pre-existing "units" such as SWMUs or, in some cases, regulated units[3]. CAMU boundaries will typically be specified on a facility map in the permit or 3008(h) order.

CAMUs are intended to provide flexibility for decision-makers in implementing protective, reliable and cost effective remedies. For example, under the CAMU provisions, remediation wastes can be placed into a CAMU without triggering land disposal restrictions and other RCRA hazardous waste disposal requirements.

Other Primary Differences and Related Issues

-- Although the WMA is a surface delineation, it is linked to the POC which extends to the base of the uppermost aquifer; a CAMU is primarily a surface designation and is not linked directly to any characteristic of the underlying aquifer.

-- WMA and CAMU boundaries could coincide all or in part at a facility. However, the two designations are made for different purposes and are independent of one another from a regulatory standpoint. For example, under the present CAMU rule, the designation of a CAMU does not relieve the owner/operator from requirements to monitor ground water at regulated units that are included within the CAMU.

---

[3] In certain circumstances, the Regional Administrator has the discretion to designate a regulated unit as a CAMU, or to include a regulated unit as part of a larger CAMU. However, only closed or closing regulated units would be able to be so designated. The CAMU rule discusses in greater detail the circumstances under which this designation could be made.