Topic: Ground-Water Monitoring

Ground-Water Monitoring

The Texas Commission on Environmental Quality (TCEQ) recommends that Class 1 and 2 industrial solid waste land disposal units should have associated with them a properly designed and installed ground-water monitoring system. Proper installation of monitor wells starts with proper planning. A general approach to planning which can add efficiency to the design and installation of a monitoring system is summarized below:

- Define the objectives of the monitoring program. An operator should take into account the type of facility operated, characteristics of the waste disposed, geologic setting, hydrogeology in the area, and other pertinent factors.

- Perform a preliminary investigation of available regional geologic and hydrogeologic information and any available site-specific data. Develop a conceptual model of the program based on this preliminary data.

- Conduct an actual field investigation to obtain site-specific data. Based on the results of the field investigation, refine the model and design the actual ground-water monitoring system. Install the system.

- Take measurements, perform sampling and analyses, and evaluate the data. Evaluate the system with respect to the objectives of the program. Make any necessary adjustments.

A source of more detailed information on the planning and design of a monitoring system is the United States Environmental Protection Agency's (U. S. EPA) *RCRA Ground-Water Monitoring: Draft Technical Guidance* (1992). This information may be found at the U.S. EPA website: http://www.epa.gov/

In addition, this Guideline discusses factors to consider when choosing a drilling method; although specific methods are described in greater detail in the U. S. EPA's published guidance, *Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells,* (EPA/600/4-89/034). This Guideline also touches on specific record-keeping practices that will be pertinent from a regulatory standpoint and useful to the operator of a ground-water monitoring system. Both of these topics are also covered in the 1992 Draft Technical Guidance document mentioned above.

Other issues addressed in this Guideline include design components, the proper development of monitor wells, maintenance and operation, concepts for determining background values for a monitoring system and an appropriate statistical method, measurement, sampling, and analytical methods, and plugging and abandoning of wells. Some miscellaneous considerations are also noted. More specific details on these topics can be found in additional U. S. EPA guidance documents mentioned later in this Guideline.

This Guideline is intended for the design and installation of detection ground-water monitoring systems for non-hazardous waste land-based units. In the event that a release from a waste management unit is confirmed, the operator of the unit and monitoring system is required by Chapter 26.121 of the Texas Water Code to report the contamination to the Executive Director of the TCEQ. When a release is detected, further investigation is needed to measure its extent and concentration. Additional information on the direction and rate of migration will be needed for remediation planning. No discussion of plume characterization, recovery wells, or other corrective action components is included here.

Initial Considerations in Well Design and Construction

To establish an effective monitoring program an operator must keep in mind the overall reason for the system, which is to detect a release from the unit to be monitored. The need for reliability in obtaining data from the monitoring system is basic to the design. Thought must be given to the nature of the aquifer underlying the site and to the possibility that a deeper aquifer might need to be monitored as well.

An operator can do preliminary planning using regional information, with the knowledge that areas of similar rock composition and structure tend to form similar ground-water regimes. In Texas these ground-water regimes include alluvial basin, non-glaciated central region, high plains, and Gulf Coastal plain. Distinctions aid in predicting the movement of ground water and contaminant transport in the subsurface. Boring logs at the site may or may not be available at this point. Still, a conceptual model can be developed with the regional information and site-specific information such as type of unit to be monitored and waste characteristics.

A field investigation using geophysical methods, aerial photography, field mapping, and other investigatory techniques is necessary to characterize the geology at the site. A site investigation using exploratory borings can help determine the extent of an aquifer and confining layers, chemical properties of the aquifer, flow direction and velocity, hydraulic gradient and other factors helpful in designing a monitoring system. This information is valuable in planning the locations and depths of each well in a monitoring program.

Boring logs are used to correlate stratigraphic units across the site. The number of borings is determined by the complexity of the geology at the site and the amount of other geological/geophysical information already available. An understanding of the stratigraphy, including the horizontal continuity and vertical thickness of formations beneath the site, is necessary to identify zones of highly permeable materials or features such as bedding planes, fractures or solution channels. These zones will affect the direction of ground-water flow and/or contaminant transport beneath the site. Because the occurrence and movement of ground water in the subsurface are closely related to the geology, the geologic conditions at the site influence the location, design and methods used to install monitoring wells.

Preliminary borings can also reveal whether pertinent formations are consolidated or unconsolidated, which may determine the choices of completion methods. They will help determine the necessary completion depth. Each drilling method has its approximate depth limit which will influence the choice of drilling methods.

The overall performance standard is that the monitoring system should rapidly detect a release from a waste management unit. The monitoring system should detect a release early enough to allow time for corrective action to keep released contamination from reaching potential receptors. Normally, the travel time from a waste unit to a detection well should be less than six months. The spacing of the wells should be narrow enough so that a plume coming from a point in the deposited waste could not pass between wells without being detected. Because a plume normally widens due to dispersion as it moves, waste disposal points nearest to the monitor well usually are most critical for determining well spacing.

Information obtained during the site characterization should be used to determine the lateral placement of downgradient wells and to determine the depth interval where the screen will be placed. No more than one transmissive zone should be screened in each well, so that the wells do not conduct contamination from one zone to another. The wells should be installed adjacent to the land disposal unit, usually along its downgradient limit. In cases where ground-water flow direction reverses seasonally or where mounding may occur at the unit, detection monitor wells should be installed around the perimeter of the waste management area.

Monitor well design and construction should take into account the kind of waste-management unit that is being monitored and the fate and transport characteristics of the specific waste materials. The well must accommodate water-level measurement equipment, sampling equipment, and possibly testing equipment.

A facility should submit to the TCEQ Industrial & Hazardous Waste Division, Permits Section, a proposed location map with an explanation of how the locations were chosen, along with drilling and construction designs prior to the actual well installation.

Once the system is installed, depth measurements should be taken and a round of sampling should be done to verify the integrity of the well. The system as a whole can then be evaluated with respect to the objectives of the program and any adjustments can be made. The actual location and "as-built" construction details for each well should be submitted to TCEQ Industrial & Hazardous Waste Division, Permits Section, as required by 30 TAC §335.6.

Selection of Drilling Methods

There are many techniques available for drilling. Selection of the proper method is done by considering the hydrogeologic conditions and the purpose of the monitoring program. In some areas, choices of drilling methods may be limited by availability and cost. Desired diameter and depth will determine which methods are practical.

The chosen well drilling method should minimize the impact to the natural properties of the subsurface materials and to the quality of water samples. Foreign fluids should not be introduced. Water added as a drilling fluid to a well should contain no bacteriological or chemical constituents that could interfere with the formation or with any chemical constituents being monitored. Cross contamination between formations or aquifers also should be avoided.

A detailed design should be prepared so that nothing is left for interpretation when the well is being installed.

Documentation and Record Keeping

Proper record keeping of the drilling processes is vital to an accurate evaluation of a well's integrity and performance. Copies of drilling and construction details should be kept on site. This record should include at least the following information:

- name/number of well (well designation);
- intended use of the well(sampling, recovery, etc.);
- date/time of construction;
- drilling method and drilling fluid used;
- well location (± 0.5 ft.);
- bore hole diameter and well casing diameter;
- well depth (± 0.1 ft.);
- drilling and lithologic logs;
- depth to first saturated zone;
- casing materials;
- screen materials and design;
- casing and screen joint type;
- screen slot size/length;
- filter pack material/size;

- filter pack volume (how many bags, buckets, etc.);
- filter pack placement method;
- sealant materials;
- sealant volume (how many bags, buckets, etc.);
- sealant placement method;
- surface seal design/construction;
- well development procedure;
- type of protective well cap;
- ground surface elevation (± 0.01 ft. M.S.L.);
- top of casing elevation (± 0.01 ft. M.S.L.); and
- detailed drawing of well (include dimensions).

The owner or operator should complete construction or abandonment and plugging of each well in accordance with the requirements of 16 TAC §76.702 and §76.1004 and should certify such proper construction or abandonment within sixty days of installation or abandonment. If any additional or replacement wells are installed, well completion logs for each well should be submitted within sixty days of well completion and development in accordance with 16 TAC §76.700. Certification of each well should be submitted within sixty days of installation for either an individual well project or a multiple well installation project. The certification should be prepared by a qualified geologist or geotechnical engineer. Each well certification should be accompanied by a certification report, including an accurate log of the soil boring, which thoroughly describes and depicts the location, elevations, material specifications, construction details, and soil conditions encountered in the boring for the well. A copy of the certification and certification report should be kept on-site, and a second copy should be submitted to the Industrial & Hazardous Waste Permits Section, TCEQ. Required certification should be in the following form:

> "This is to certify that installation (or abandonment and plugging) of the following facility components has been completed, and that construction (or plugging) of said components has been performed in accordance with and in compliance with acceptable design and construction specifications:" (Include a description of the facility components).

Well Design Components and Completion Techniques

Proper design components are determined by the hydrogeologic setting, type of contaminants involved, the purpose of the monitoring program, and other site-specific variables.

Casing materials are chosen on the basis of required strength and chemical resistance or interference. The following recommendations cover most monitoring locations. If site-specific factors call for other designs, a facility should submit proposed plans and specifications with an explanation and a request for an alternate recommendation.

Above the saturated zone, the well casing should be two-inch diameter or larger schedule 40 or 80 polyvinyl chloride (PVC) rigid pipe, stainless steel, polytetrafluoroethylene (PTFE or "Teflon ®"), or some other pre-approved alternate material. The PVC casing should bear the National Sanitation Foundation logo for potable water applications (NSF-pw). Solvent cementing compounds should not be used to bond joints and all connections should be flush-threaded. In and below the saturated zone, the well casing should be stainless steel or PTFE. PVC or fiberglass-reinforced resin may be used as an alternate well casing material below the saturated zone provided that it yields samples for ground-water quality analysis that are unaffected by the well casing material.

Because shorter screen lengths are more reliable in detecting and identifying a release, screen lengths should be no more than ten feet. Where an aquifer is thick or where several zones are to be monitored, a cluster of wells should be installed, with each well screened at a different depth. Screen lengths exceeding ten feet may be appropriate in ground-water recovery or injection wells to optimize the ground-water remediation process in accordance with standard engineering practice. In no case should a screen span more than one transmissive zone.

The intake portion of a well should be designed and constructed to allow sufficient water flow into the well for sampling purposes and to minimize the passage of formation materials into the well during pumping. It should consist of commercially manufactured stainless steel or PTFE screen or an approved alternate material.

The annular space between the screen and the borehole should be filled with clean siliceous granular material (i.e., filter pack) that is coarser, and has a higher permeability than the natural formation material. It also should have uniform grain size. A filter pack with these properties supports the formation and optimizes the ability to obtain sediment-free samples. The well-screen slot size should be compatible with the filter pack size as determined by sieve analysis data. The filter pack should extend no more than three feet above the well screen. A silt trap, no greater than one foot in length, may be added to the bottom of the well screen to collect any silt that may enter the well. The bottom of the well casing should be capped with PTFE or stainless steel or approved alternate material.

A minimum of two feet of pellet or granular bentonite should immediately overlie the filter pack in the annular space between the well casing and borehole. Where the saturated zone extends above the filter pack, pellet or granular bentonite should be used to seal the annulus throughout the upper saturated zone. The bentonite should be allowed to settle and hydrate for a sufficient amount of time prior to placement of grout in the annular space. Above the minimum two-foot thick bentonite seal, the annular space should be sealed with a cement/bentonite grout mixture. The grout should be placed in the annular space by means of a tremie pipe or pressure grouting methods equivalent to tremie grouting standards. The cement/bentonite grout mixture or TCEQ-approved alternative grout mixture should fill the annular space to within two feet of the surface. A suitable amount of time should be allowed for settling to occur. The annular space should be sealed with concrete, blending into a cement apron at the surface that extends two feet or more from the outer edge of the borehole for above-ground completions. If necessary, alternative annular-space seal material may be proposed.

In cases where flush-to-ground completions are unavoidable, a protective structure such as a utility vault or meter box should be installed around the well casing and the concrete pad design should prevent infiltration of water into the vault. In addition, the well/cap juncture must be watertight, the bond between the cement surface seal and the protective structure must be watertight, and the protective structure with a steel lid or manhole cover must have an effective rubber seal or gasket.

Where the well is completed above grade, the well should be equipped with a locking cap. This is intended to protect the aquifer and prevent access by anyone but authorized personnel.

A well's screened interval should be appropriately designed and installed to meet the well's specific objective. To detect dense non-aqueous phase liquids (DNAPL), wells must be drilled to intercept the bottom confining layer of the aquifer. The screened interval for wells designed to detect light non-aqueous phase liquids (LNAPL) must extend high enough into the vadose zone to always intersect the seasonally fluctuating water table.

Well Development

Once a well is installed, it must be developed to remove any fluids used during well drilling and to remove fines from the formation immediately outside the filter pack sand. Proper development will increase the flow capacity of the well and reduce the amount of suspended solids in water from the well. Development should be accomplished by reversing flow direction, surging the well, or by air lift procedures, depending on the characteristics of the formation and how the well was completed. No fluids other than formation water should be added during development of a well unless the aquifer to be screened is a low-yielding water-bearing aquifer. In these cases, the water to be added should be chemically analyzed to evaluate its potential impact on in-situ water quality, and to assess the potential for formation damage.

Monitor wells should be constructed so that they routinely can be sampled with a pump, bailer, or alternate sampling device. Piping associated with recovery wells should be fitted with sample ports to facilitate sampling of the recovered ground water on a well-by-well basis.

Operation and Maintenance of Wells

Monitor well systems should be evaluated periodically to determine if they are functioning properly. The depth of each well should be recorded each time a water sample is collected or a water-level measurement is taken. This data is useful in determining if the well is filling with sediment. When samples taken are turbid, this may be an indication that the well needs to be redeveloped. Well tests, which can indicate changes in the integrity of the well or in situ changes, are usually performed every five years. Potentiometric surface maps should be plotted and reviewed at least annually. This ensures that the wells continue to function at their location as they were intended. Wells with consistently low water levels year after year may need to be replaced; those with screen blockage from scale, bacteria, etc., can be treated to remove the blockage.

Background Determination and Statistical Analyses

A background well should yield samples which represent the quality of ground water in the uppermost (monitored) aquifer, that has not been affected by waste at the facility. Usually this is accomplished by placing background wells upgradient of the waste management unit. The direction of ground-water flow, and hence the upgradient direction, may change seasonally or with local changes in ground water pumping or recharge. If a waste management unit is located above a ground-water mound or if the upgradient area is inaccessible, the background wells may be located in an uncontaminated area which would not be contaminated if the unit leaks. The background well(s) also will be used to establish expected variability of the water quality measurements, for use in the statistical analysis of monitoring results. Sampling the background well(s) quarterly or more frequently will allow estimation of seasonal ground-water variability. Usually data from more than one background well is necessary to assess spatial variability; using only one background well increases the risk of false indication of contamination.

The statistical method used to analyze data from the ground water monitoring system should be appropriate for the design of the monitoring system and the number and type of sampled data. The method should provide a proper balance of nominal Type I (“false positives”) and Type II (“false negatives”) error rates and should be used only if there is adequate assurance that the actual error rates approach the nominal levels. For further guidance, consult the EPA documents *Statistical Analysis of Ground-water Monitoring Data at RCRA Facilities*, (1989), *Statistical Analysis of Ground-water Monitoring Data at RCRA Facilities - Addendum to Interim Final Guidance*, (1992), or, *Statistical Training Course for Ground-Water Monitoring Data Analysis*, (1992).

Measurement, Sampling, and Analytical Methods

An operator can use geologic and hydrogeologic information to determine how frequently to sample the wells in a monitoring system. In general, quarterly sampling is recommended as an initial frequency. Within the first few years of monitoring, an operator will be able to determine the optimum sampling frequency.

Appropriate parameters and constituents for which well samples are to be analyzed should be determined. At a minimum, pH, temperature, and specific conductance should be tested, in the field. In addition, chemical constituents and indicator parameters which are based on the type of waste placed in the unit should be included in the suite to be analyzed. Persistent waste constituents that occur in high enough concentrations to be reliably detected and have high mobility rates in the given setting are ideal indicator parameters for early detection of a release.

Once sampling begins, keep in mind that every sample collected to reliably identify and quantitize the constituents of concern must be representative of the ground water in the aquifer. This requires that fresh formation water be sampled. There are two generally accepted approaches achieve this objective. One is a general purge of standing water in the well bore, usually at least 3 well volumes, prior to collecting the sample; the other is referred to as low-flow, or, micro-purging, which specifically targets a sampling zone and draws water from it without including a significant amount of well bore water. Each method has advantages and disadvantages. More extensive discussion can be found in the following EPA documents: *RCRA Groundwater Monitoring Draft Technical Guidance* (November, 1992), and EPA 542-S-02-001, *Groundwater Sampling Guidelines for Superfund and RCRA Project Managers* (May, 2002).

Records of sampling activities, such as field notes, chain of custody sheets, and sample analysis request sheets, along with laboratory analytical results pages, and quality assurance/quality control data should be kept on site for inspection by TCEQ personnel. They should be evaluated for any potential release and confirmed releases must be reported to the Executive Director of the TCEQ.

More detailed coverage can be found in the previously mentioned RCRA Ground-Water Monitoring: Draft Technical Guidance (1992).

Considerations in Abandoning and Plugging Wells

Soil test borings and wells removed from service should be plugged with a cement/bentonite grout mixture so as to prevent the preferential migration of fluids in the area of the borehole. Certification of each plugging should be reported as stated above. Wells should be plugged in accordance with 16 TAC §76.702 (relating to Responsibilities of the Licensee and Landowner Well Drilling, Completion, Capping, and Plugging) and §76.1004 (relating to Technical Requirements Standards for Capping and Plugging of Wells and Plugging Wells that Penetrate Undesirable Water or Constituent Zones.

Miscellaneous Considerations

- The Permittee should replace any well that has deteriorated due to incompatibility of the casing material with the ground-water contaminants or due to any other factors. Replacement of the damaged well should be completed within ninety days of the date of discovery of the deterioration.

- Well casings and screens should be steam cleaned prior to installation to remove all oils, greases, and waxes. Well casings and screens made of fluorocarbon resins should be cleaned by detergent washing.

- Each well should be secured and/or designed to maintain the integrity of the well borehole and ground water. The above-ground portion of the well should be protected by bumper guards and/or metal outer casing protection. The well number should be clearly marked and maintained on each well at the site.

- The elevation of the top of each well casing from a permanently marked measuring point on the well, in feet above mean sea level to the nearest 0.01 foot, should be measured and elevation records kept. A comparison of old and new elevations from previously surveyed wells can assist in determining a frequency of surveying, which should not exceed five-year intervals.

- A well should be replaced when it no longer is able to yield samples which are representative of ground-water quality. Inadequate sampling could be due to compromised well integrity or materials of construction, or inappropriate well location. A replacement well design proposal and location should be submitted to the TCEQ.

- Temporary ground-water monitoring wells may be installed according to less stringent standards than are specified for permanent wells but they should also be submitted for TCEQ review in advance of installation. Temporary wells should be properly plugged within 120 days after their installation to avoid contamination of the ground water. Temporary wells are also subject to the Well Plugging and Capping requirements of 16 TAC §76.702 and §76.1004.

- Ground water monitoring wells in Texas must be installed by a licensed water well driller. All licensed water well drillers are subject to the requirements of 16 TAC §76, dealing with water well drillers and water well pump installers.