ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

DIVISION OF SPILL PREVENTION AND RESPONSE
CONTAMINATED SITES PROGRAM

Monitoring Well Guidance

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TABLE OF CONTENTS

1 Applicability

This document fulfills the regulatory requirements of 18 AAC 75 and 18 AAC 78 for monitoring well design, construction, installation, maintenance, and decommissioning. The Alaska Department of Environmental Conservation (ADEC) recommends that staff and third party consultants use this document in place of the April 1992 guidance titled *Recommended Practices for Monitoring Well Design, Installation and Decommissioning*, adopted by reference in 18 AAC 75 and 78.

The practices described in this document are not applicable to all situations; the department recognizes that regional, climatic, and geographic variables can influence monitoring well design and construction. While each monitoring well installation may differ, site-specific application should be technically sound. This document is applicable to all groundwater monitoring wells including drilled wells, direct push wells, and excavation installed wells.

2 Introduction

This document presents standards for the location, design, installation, decommissioning, and documentation of monitoring wells and well points for piezometers and transducers associated with the investigation and cleanup of contaminated sites in Alaska. The goal is to obtain reliable and representative information regarding aquifer characteristics, groundwater flow directions, groundwater chemical and physical characteristics, and groundwater samples. Generally, the purpose of a monitoring well is to document the presence or absence of contamination or establish long-term groundwater contaminant trends and to confirm that cleanup levels have been met in a known contaminated aquifer.

Monitoring wells fall into two categories, long term and short term. Short term monitoring wells are installed to evaluate the presence or absence of contamination and are intended for sampling once, unless otherwise approved by ADEC. Long term monitoring wells are intended for multiple sampling events. Short term monitoring wells may or may not have a filter pack, interstitial seal or surface seal, depending on their application. Whereas, long term monitoring wells must have a filter pack, interstitial seal and surface seal, unless otherwise approved by ADEC. All short term and long term monitoring wells, including well points for piezometers and transducers, must be decommissioned in accordance with this document.

Investigation of a contaminated site requires establishing clearly defined objectives before fieldwork commences. Identifying the type of contaminant and the manner of release to the environment is a primary step. Contaminant releases to land require an understanding of partitioning between the hazardous substance released, and soil, water, and air or soil gas. Water often acts as a carrier for contaminants as they move through the soil. If contaminant migration results in groundwater contamination, monitoring wells are required to assess groundwater quality. The installation, development, and decommissioning of monitoring wells and well points must be done in accordance with this guidance document, or other methods approved by ADEC (18 AAC 75.345(j)).

Before installing a monitoring well or a well point, ADEC recommends developing a conceptual model of the site geology and hydrology. The purpose of a hydrogeologic conceptual model is to estimate the distribution of the predominant geologic units and flow conditions at the site. The conceptual model may include estimates of the distribution of aquifer(s) and aquitards at or near the site, hydrologic boundaries, the water table surface, and other pertinent hydrogeologic properties. The hydrogeologic conceptual model should be updated with new data as it is obtained.

This guidance document includes the basic steps for recording a vertical soil profile, advancement of soil borings, general best practices for design and installation of any monitoring well along with specific guidelines for certain types of wells and concludes with instructions for both well development and well decommissioning. The references titled *Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells*, EPA/600/4-89/034 (hereafter referred to as EPA, 1991), and American Society for Testing and Materials (ASTM) D5092-04e1 *Standard Practice for Design and Installation of Ground Water Monitoring Wells* (2005) provide more comprehensive guidance.

3 General Best Practices for Monitoring Well Design and Installation

This section provides broad, basic guidelines for monitoring well construction and features. Not all of these guidelines will be pertinent to every type of monitoring well. Subsequent sections of this guidance provide detailed instructions on design and installation of specific types of wells that may be appropriate for certain site and soil conditions or a project's monitoring needs.

Key Principals, Specifications, and Precautions

1. Determine the purpose of the well.
2. Evaluate site-specific hydrogeologic information from all available sources, including the physical and chemical properties of the groundwater and any contaminants known or suspected to be present in the groundwater.
3. Develop a conceptual hydrogeologic model of the site.
4. Determine screened interval.
5. Select method of monitoring well installation.
6. Determine the diameter of the well.

Discussion

There are several purposes for groundwater monitoring, such as ambient monitoring, source monitoring, case preparation monitoring, and research monitoring (Barcelona et al., 1985). Wells installed for each of these purposes must satisfy different requirements, and may require different strategies for well design and installation. Prior to design and installation there should be a clear understanding of what the monitoring program is intended to accomplish. Is the monitoring well intended for site characterization or plume delineation, long term monitoring, contaminant screening, final compliance with cleanup standards for site closure, product recovery or a remedial action, or some other purpose?

Selection of monitoring well type, materials, and installation method is a site-specific determination. Site logistics and economics often influence choices. Locations without road access can be logistically challenging and incur increased project costs for site investigation. In all cases, clearly identify project objectives in a work plan developed in consultation with ADEC.

Proper well spatial and vertical location is critical to ensure accurate monitoring of the groundwater flow regime. Monitoring wells and well points are typically installed in the uppermost permeable water-bearing zone under or adjacent to a regulated facility or potential source of contamination. Consider natural, seasonal, and anthropogenic fluctuations in water table elevation in determining the well location. Natural fluctuations are typically due to infiltration of snowmelt or precipitation, proximity to rivers with seasonal high water levels, or tidal fluctuations. Anthropogenic fluctuations can result from pumping, wastewater disposal, or paving to decrease infiltration rates. Consider the behavior of a contaminant plume over distance to ensure that placement and construction of monitoring wells is appropriate (Wiedemeier et al., 1999).

Well design and installation must be appropriate to ensure that groundwater samples and water level measurements characterize discrete stratigraphic intervals. Location of the screened interval relative to the water table elevation may influence sampling results. For example, a well screened at the water table, with some screen above the water table and some below the water table, will intercept floating petroleum product; a well with the top of the screened interval located below the water table will not intercept floating petroleum product under static conditions.

Well design and installation must prevent the introduction of surface contaminants into the groundwater and prevent leakage of groundwater or contaminants between stratigraphic intervals in the well bore or along the well annulus. If the well leaks, correct the leak or decommission the well. Do not install monitoring wells in locations where they are subject to periodic or seasonal inundation by floodwaters, unless the well has special watertight construction. Protect monitoring wells from loss of integrity by soil erosion, soil settlement, shrink-swell soil conditions, frost heaving of soils, damage by vehicles or heavy equipment, and other site-specific hazards. Completion of monitoring wells at- or below-grade is less preferable than above-grade completions due to the potential for surface water infiltrating the monitoring well casing.

A drilled, long-term monitoring well is generally composed of well casing, well screen, and filter pack (Figure 1). Construct monitoring wells with new materials that will not physically, chemically, or biologically affect the groundwater quality, or be deleteriously affected by the subsurface environment. The well screen is an intake where groundwater can flow into the well; the filter pack surrounds the well screen. Install the well in an open borehole created by advancing a soil boring, usually with a hollow-stem auger drill rig. Advance the soil boring until the soil core (s) demonstrates saturated soil conditions, indicating that the groundwater table has been encountered. After the water table has been identified in the soil boring, remove the drill rods from the open borehole and install the monitoring well.

Survey monitoring wells vertically and horizontally. Survey the top of the well casing and ground surface for use as a reference point to determine water-level elevations and sampling depths and to evaluate groundwater flow direction. All survey data must be recorded in the field notes and submitted with the report. The location survey must achieve a horizontal accuracy of 1.0 feet, and the elevation surveys must achieve a vertical accuracy of 0.01 foot. Sites undergoing contaminant assessment monitoring must have the wells surveyed as described above, and re-survey monitoring wells every year, unless otherwise approved by ADEC on a site-specific basis. Based on site conditions ADEC may require that a survey be completed by a registered professional surveyor or registered professional engineer.

For accurate water level measurements, permanently mark the monitoring well with a reference point on the actual monitoring well casing, not the outer surface casing. Permanently attach a facility or project-unique identification number on the inner and outer well casings. All well construction logs with soil boring information are required to be submitted to the Alaska Department of Natural Resources Division of Mining Land and Water in accordance with 11 AAC 93.140(g).

Also submit documentation of the well design, well construction logs, and the materials used to ADEC. This information is useful for determining if the monitoring well design, installation, or history may be affecting sampling results or the interpretation of site conditions.

3.1 Construction Procedures

Key Principals, Specifications, and Precautions

1. Properly decontaminate well construction materials prior to installation.
2. Prevent contamination when joining casings and attaching the screen.
3. For long-term monitoring wells, place the filter pack into the annulus to a minimum of two feet above the top of the screen and one foot beneath the well end cap.
4. Use bottom caps or end plugs.
5. Use permanent or temporary surface casing if contamination or sloughing is a potential issue (drill augers should never be removed from the hole without concurrently filling borehole voids with appropriate sealant media).
6. For long-term monitoring wells, reduce the required filter pack height to allow for annular space sealant.
7. For long-term monitoring wells following installation, “sound” the filter pack for proper placement.
8. For long-term monitoring wells, apply grout or bentonite chips to seal the annular space.
9. If the borehole or monitoring well is advanced through an aquitard, the penetration through the aquitard must be sealed at the same interval using grout or bentonite chips, unless otherwise approved by ADEC.
10. For all wells, pour grouts or slurries freely with or without the use of a tremie pipe.
11. Take appropriate precautions during drilling to avoid introducing contaminants into the well. Prevent vertical movement of water or contaminants between water-bearing zones in either the boring or the well annulus.
12. Avoid using drilling mud, synthetic drilling fluids, or petroleum- or metal-based pipe joint compounds and other potential contaminants unless necessary.
13. If it is necessary to add water during drilling, use only potable water and first identify the water source.
14. If it is necessary to add drilling mud to stabilize the hole or control down-hole fluid losses, use only high yield sodium bentonite clay free of all organic polymer additives.
15. Properly decontaminate all equipment placed into the well by steam cleaning, high-pressure hot water, or similar methods between well installations.
16. Manage cuttings, or water, removed from the well in accordance with 18 AAC 75 or 18 AAC 78.
17. Complete an “as built” drawing/schematic for each constructed monitoring well.
18. Survey wells vertically and horizontally with survey loops that close within 0.01 foot vertically, and 1.0 feet horizontally. The well survey data must be provided to ADEC in a written report. Submit a record of the well design, installation, and the materials used to ADEC.
19. Install a cement or asphalt surface seal, where appropriate.

Discussion

Design and install monitoring wells and well points under the direct supervision of a geologist, engineer, or other professional with direct experience in the design and installation of monitoring wells and well points.

Properly decontaminate well casing and screen materials with detergent before use (EPA, 1991), unless the casing and screen have been factory cleaned and wrapped in protective plastic sheathing and the integrity of the protective sheathing has been maintained up to the point of installation. Well construction begins with lowering a screened section connected to a section of casing into the open borehole. Care should be taken while joining the casings and attaching the screen to prevent contamination. Center the monitoring well and well screen in the borehole, then pour the filter pack into the annulus surrounding the well screen to a height of no less than two feet above the top of screen and one foot beneath the well end cap. Use centering guides to center the well screen in the borehole in deeper wells. Use bottom caps or end plugs on all monitoring wells.

Use permanent or temporary surface casing during well drilling and installation in all cases where: 1) contaminated groundwater could migrate in the borehole by gravity flow or under artesian pressure into other water-bearing zones, and 2) the formations penetrated have a tendency to slough or cave into the borehole and affect filter pack and annular seal placement or integrity.

For long-term monitoring wells, unless using pre-packed filters, place the filter pack using a method that ensures positive placement opposite the well screen without bridging or size segregation of the filter pack material. If necessary, reduce the required filter pack height above the top of the well screen to six inches to allow for placement of the required volume of annular space sealant.

As the auger flights are retrieved, installers should continually measure the depth to the top of the sand pack to ensure it extends two feet above the screened intake. Place a finer-grained sand filter six inches to two feet thick at the top of the filter pack and below the annular seal to help prevent infiltration of bentonite into the filter pack. Above the filter pack, install the annular seal to protect the well intake. Lastly, fill the annular space above the seal with grout or bentonite chips or inert material, as discussed above.

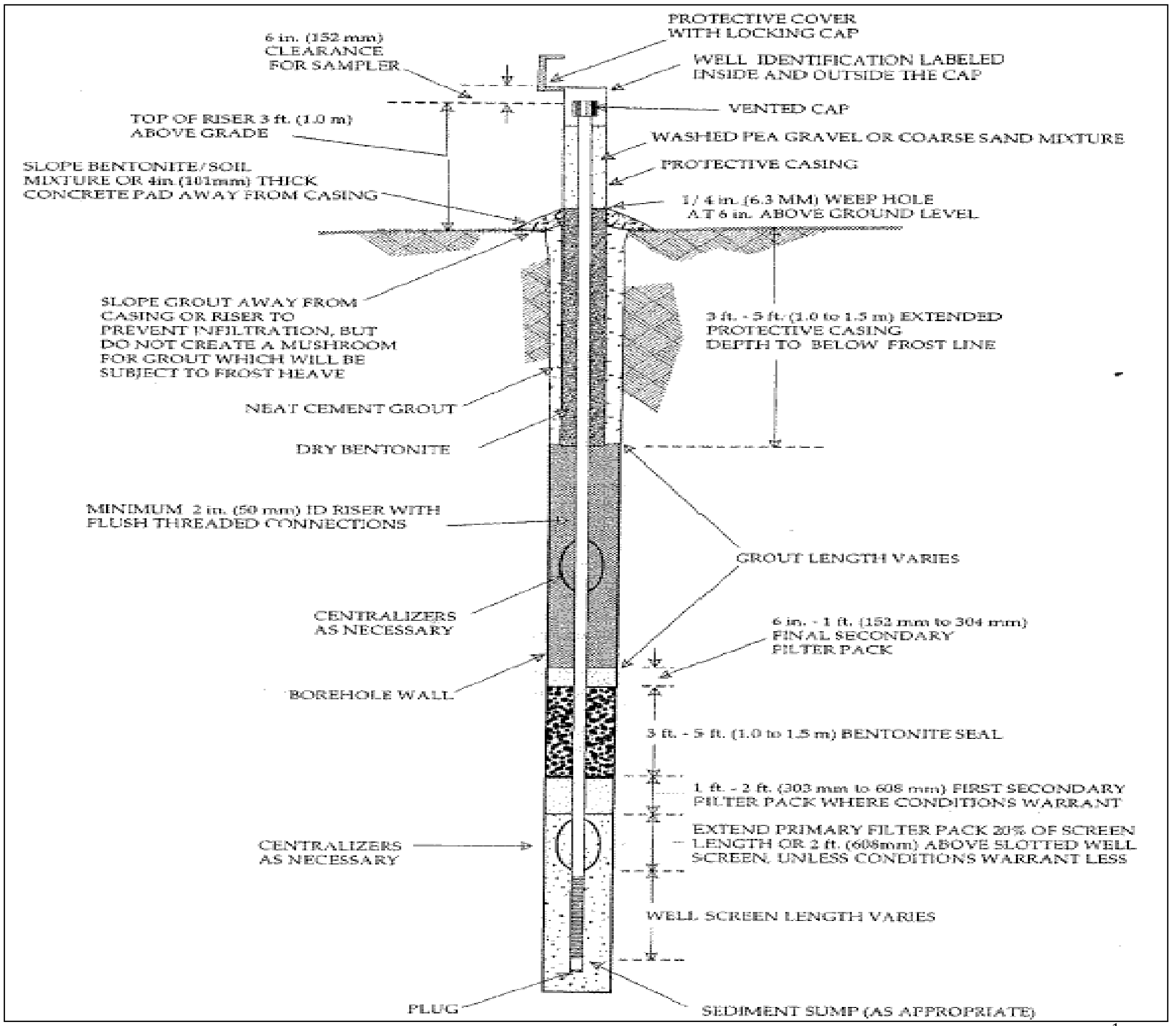


Figure 1. Example monitoring well construction design with filter pack. From ASTM 5092 (2005)[1].

3.2 Well Casing

Key Principals, Specifications, and Precautions

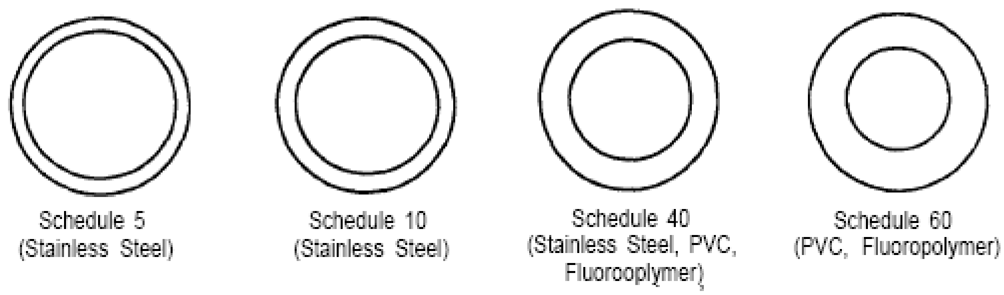
1. Determine the appropriate casing material for the application.
2. Determine the proper casing length and diameter.
3. Join casing sections properly.

Discussion

The casing should be non-reactive with the subsurface environment and any contaminant the monitoring well may encounter. Casing length is determined based on the borehole depth and the data quality objectives on a site-specific basis. Join casing sections together with threads and

[1] Extracted, with permission, from the D5092-04e1 Standard Practice for Design and Installation of Ground Water Monitoring Wells, copyright ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428. A copy of the complete standard is available ASTM (www.astm.org).

couplings or solvent welds, rather than glues, in order to eliminate the introduction of contaminants when sampling. Threaded connections should have o-rings to complete the seal, and casings should be flush-fit on the inside. Casing diameter is also determined on a site-specific basis. The inside diameter of the well casing should be at least 1.9 inches, with the exception of well points for piezometers, and transducers. Monitoring wells in Alaska are commonly schedule 40 polyvinyl chloride (PVC), nominal 2-inch diameter casing. Deep wells, product recovery wells, or those that need larger-sized, dedicated pumps or tubing may require 4-, 6-, or 8-inch casings. See Figure 2 for a table of the inner diameters of various well casing schedules.



Wall Thickness (Inches)	Sch 5	Sch 10	Sch 40	Sch 80	Outside Diameter (Standard)
Nominal 2	0.066	0.109	0.164	0.218	2.375
Nominal 3	0.063	0.120	0.216	0.300	3.500
Nominal 4	0.083	0.120	0.237	0.337	4,500
Nominal 5	0.109	0.134	0.258	0.375	5.563
Nominal 6	0.109	0.134	0.280	0.432	6.625
Inside Diameter	**Sch 5**	**Sch 10**	**Sch 40**	**Sch 80**	
Nominal 2	2.245	2.157	2.067	1.939	
Nominal 3	3.334	3.260	3.068	2.900	
Nominal 4	4.334	4.260	4.026	3.826	
Nominal 5	5.345	5.285	5.047	4.813	
Nominal 6	6.407	6.357	6.065	5.761	

Figure 2. Casing thickness and diameter for monitoring well materials. From EPA (1991).

There are many different casing materials used in the design of a monitoring well; however, thermoplastic materials (such as PVC) and stainless steel are the most widely used. PVC is commonly used because of its high strength, low maintenance, and chemical resistance. EPA (1991) discusses special applications to monitoring wells for materials other than PVC. All monitoring well materials should conform to ASTM Standards.

Consider chemical resistance/interference during monitoring well design; many well materials may react with the groundwater, resulting in poor or erroneous data. EPA (1991) and Driscoll (1986) offer in-depth discussion of the limitations of each material. In most cases in Alaska, PVC will provide a durable monitoring well with good chemical resistance (EPA, 1991, page 79).

When choosing monitoring well and well point casing material, three parameters determine its strength: tensile, compressive, and collapse strength. Poor tensile and collapse strength are the main drivers for failure. The tensile strength of the casing joints is critical because the joint is typically the weakest point in a casing string. Tensile forces are generally greatest on a dry string of casing hung in the open boring hole during installation. See Figure 3 for illustration of these forces on the well casing.

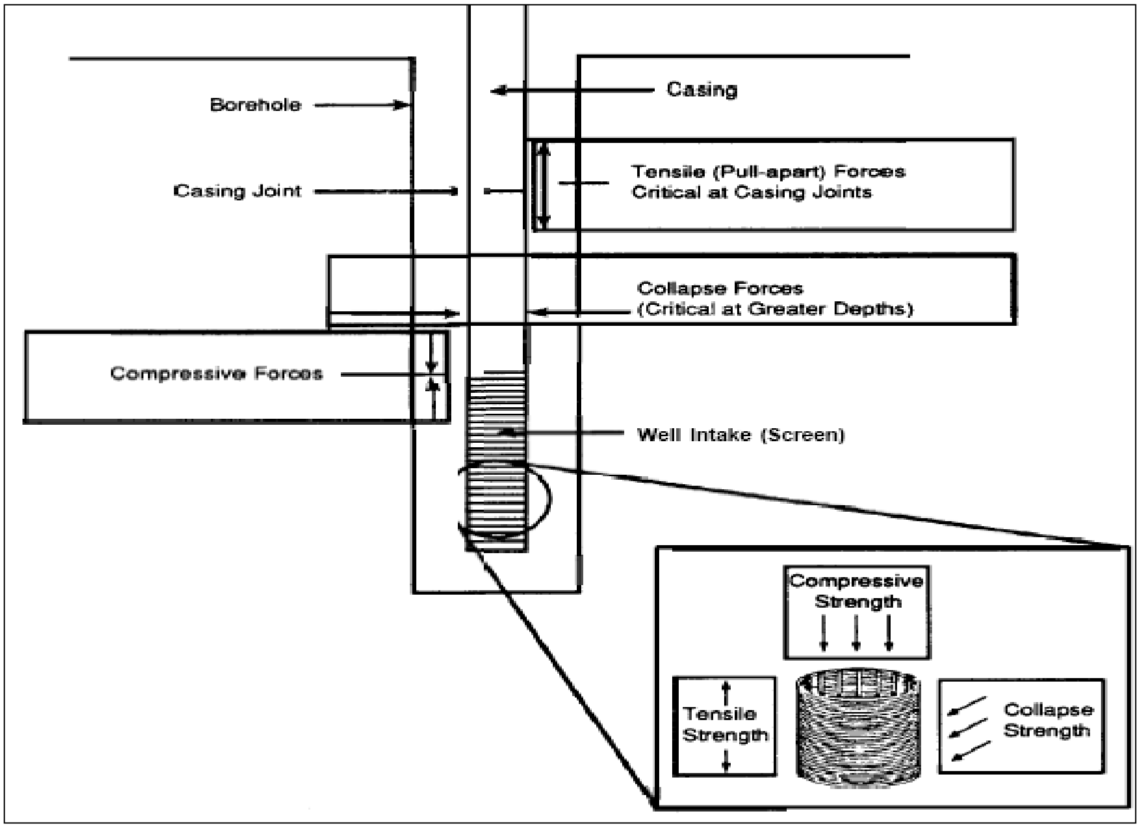


Figure 3. Forces acting on a monitoring well casing during installation. EPA (1991).

The outside diameter and wall thickness determines the resistance of casing to collapse. Casing collapse strength is directly proportional to the cube of the wall thickness. Therefore, a small increase in wall thickness provides a substantial increase in collapse strength. Properly installed casing, supported by the filter pack and annular seal, seldom leads to collapse (National Water Well Association and Plastic Pipe Institute, 1981).

Freeze-thaw processes can “jack” wells from the ground, due to freezing and upward expansion of the soil. Frost heaving will change the height of the well casing, and in some cases overcome the tensile strength of the casing joint and separate casing sections. Minimize damage by installing a surface outer casing to a depth of 5-10 feet below ground surface and a steeply inclined cement cap around the surface casing (Driscoll, 1986). When frost heaving occurs and pressure is exerted on the cement cap, the surface casing may rise without affecting the monitoring well casing (Driscoll, 1986). More information about frost heave and frost heave susceptible soils is available in ASTM standard D5918 (2001).

3.3 Filter Pack

Key Principals, Specifications, and Precautions

1. Determine the appropriate filter pack application (natural or artificial).
2. Use clean, chemically inert, and well-rounded siliceous material.
3. Determine appropriate filter pack thickness (2-8 inches).
4. Extend filter pack at least two feet above well screen.

Discussion

Surrounding the monitoring well intake with materials that are coarser, of uniform grain size, and have a higher permeability than natural formation material allows groundwater to flow freely into the well from adjacent formation material while minimizing or eliminating the entrance of fine-grained materials. Typically, installing an artificial filter pack meets these objectives. Alternatively, develop a natural well where the formation consists of suitable material that does not require a filter pack. Deciding between these two options depends on the grain-size distribution of the natural formation materials in the monitored zone. Grain size distribution can be determined by conducting a sieve analysis of a sample collected from the intended screened interval. Naturally developed wells can be used when the maximum borehole diameter closely approximates the outside diameter of the well, and when the surrounding formation is coarse-grained and permeable (EPA, 1991). Size the filter pack for wells installed in unconsolidated material to retain most of the surrounding formation. However, most monitoring wells installed in Alaskan unconsolidated soils are artificially filter-packed, typically with a No.10-20 or 20-40 silica sand pack. Artificial filter pack is more appropriate to use under the following circumstances (EPA, 1991).

- Natural formation is uniformly fine grained
- Long screened interval required and/or the intake spans highly variable lithology
- Formation is a poorly cemented sandstone
- Formation consists of fractured rock or karst
- Formation consists of shales or coals that will act as a constant supply of turbidity
- Borehole diameter is significantly greater than the screen

The filter pack should extend above the well screen to a length of 20% of the well screen length, but no less than 2 feet (ASTM D5092, 2005). The thickness of the filter pack should be at least 2 inches between the borehole and the well screen, and no greater than 8 inches (EPA, 1991).

The filter pack should consist of clean, chemically inert, and well-rounded siliceous material. Do not use crushed limestone or dolomite, material containing clay, or filter fabrics. The sand or gravel used for filter packs should be of uniform size, hard and durable, and should have an average specific gravity of 2.50 or greater. The sand and gravel should be well washed and free of clay, dust, and organic matter. Not more than five percent of the sand or gravel should be soluble in hydrochloric acid. Additional information regarding the filter pack is provided in EPA (1991), ASTM D5092 (2002), and Driscoll (1986).

3.4 Well Intake

Key Principals, Specifications, and Precautions

1. Determine the proper slot size (intake opening) based on the selected filter pack.
2. Ensure the screen retains at least 90% of the filter pack.
3. Use commercially manufactured well intakes only.
4. Account for resistance to corrosion and chemical degradation.
5. Determine the proper well screen length; minimize screen length to avoid dilution during sampling.
6. Install well clusters as individual wells in close proximity.

Discussion

The well intake is the aquifer access location. Except for wells in bedrock, install well screens in all monitoring wells.

Determine the slot size for the screened section based upon the filter pack selected for the monitoring well, as discussed above. Select the appropriate screen slot size by sieve analysis of the formation material in which the well screen will be positioned. The screen should be capable of retaining at least 90% of the filter pack. However, this step is laborious, and may be bypassed if the site is understood well enough from previous investigation. Typical installations in Alaska for unconsolidated soil use a 20-slot intake with a No. 10-20 silica sand pack, or 10-slot intake with a No. 20-40 silica sand pack. Commercially manufactured well intakes are required for use in monitoring wells because commercial manufacturers follow stricter quality control measures. All wells require machine slotted well screens. Do not use hand cut screens.

Screened interval location relative to the water table elevation can influence sample results. Increased open area in the monitoring well intake allows effective development and easy flow of water from the formation into the well. The type of well intake and slot size controls the amount of open area in a well intake (EPA, 1991). Consider water table variations, site stratigraphy, expected contaminant behavior, and groundwater flow when selecting the screen length and position in the borehole. When existing contamination is suspected or known, down-hole geophysical techniques or groundwater sampling may be necessary to aid in selecting the location of the screened interval.

Determine the well screen length on a site-specific basis and project objectives. Minimize the length of well screens to avoid dilution during sampling. Well screens typically measure one (1) to 10 feet in length, and only rarely equal or exceed 20 feet in length (EPA, 1991). For conventional monitoring wells at petroleum-contaminated sites in Alaska, the well screen length is typically ten (10) feet long and placed with some well screen above the high water table. However, there are several instances where this convention is not appropriate (API, 2006). A short-screened interval will provide data from a specific discrete interval, whereas a long screen length accounts for water table fluctuations and the inherent variability between water levels during and after drilling. However, this application may result in composite groundwater samples, even in relatively homogeneous formations (Church and Granato, 1996; Britt, 2005).

Monitoring wells installed at multiple depths to determine the vertical hydraulic or contaminant concentration gradient, also known as piezometers, are typically screened less than five feet. Install piezometers as either nested or clustered. ADEC does not recommend wells consisting of multiple aquifer completions in a single borehole. Well clusters should consist of individual wells in close proximity, screened at varying depths, each installed in its own borehole. For well clusters, drill the deepest well in the cluster first. Use borehole sampling information to determine what formation interval to screen, or where to place seals to prevent communication between the aquifers.

3.5 Annular Space Seals

Key Principals, Specifications, and Precautions

1. Seal the well casing to the adjacent soil formation.
2. Seal with grout, bentonite chips, or similar material at a minimum of two feet above the filter pack and two feet below the ground surface.
3. Install bentonite chips in one or two foot increments and hydrate before placing the next layer.

Discussion
Install annular seals to restrict vertical movement of water or contaminants by sealing the well casing to the adjacent soil formation. The annular seal should consist of grout or bentonite chips from the filter pack to the ground surface.

Construct all long term monitoring wells with a seal at the top of the filter pack. Install this seal to confine the well screen to the sampling interval. Extend the seal a minimum of two feet upward from the top of the filter pack to prevent seal material from leaching into the filter pack. This annular seal should consist of bentonite pellets, bentonite slurry, or similar material.

To protect the screened interval from “cross contamination” from infiltration of runoff and potential contaminants at the ground surface, install an annular seal in the annulus at the ground surface. Extend this annular seal from the ground surface to 2-3 feet below the ground surface. For shallow wells, it is common to grout the annulus with bentonite from the annular seal above filter pack to the annular seal at the ground surface. For deeper wells, there is often inert material, typically sand, between these two seals.

For monitoring wells other than direct push, ADEC recommends boreholes with a minimum inside diameter at least four inches larger than the outside diameter of the riser pipe and screen. This recommendation is to allow for proper installation of materials within the annular space and to ensure an adequate annular seal.

EPA (1991) and ASTM 5092 (2005) discuss the properties of annular seals and grout as well as the uses. Nested or clustered wells require special care to seal off water bearing zones from cross contamination.

3.6 Well Protection

Key Principals, Specifications, and Precautions

1. Construct all long term monitoring wells with a surface monument to protect the well casing from damage. Install the concrete around the monument to slope away from the well casing so that it sheds water away from the well.
2. Install protective casings and locks for wells completed above ground.
3. For a well completed below the ground surface, install a lockable vault or equivalent.
4. Install protective guard posts, if necessary.

Discussion

If the well casing is composed of metal and completed above the ground surface, attach a lockable cap to the top of the casing. If the well is not cased with metal and completed above the ground surface, install a metal protective casing around the well. Extend the protective casing at least six inches above the top of the well casing, and at least two feet into the ground. Attach a lockable cap to the top of the protective casing. For a well completed below the ground surface, install a lockable vault or equivalent around the well. Install a protective cover, level with the ground surface, with a waterproof seal to prevent the inflow of surface water. Design the cover to withstand the maximum expected loadings.

Install guard posts for monitoring wells completed above the ground to protect the wells from damage. Guard posts should consist of three metal posts at least three inches in diameter set in concrete. Install the posts in a triangular array around the casing, and at least two feet from it. Extend the posts at least three feet above and below the ground surface. Paint the above ground portion with a bright colored paint. Other surface protection methods may be used if they meet the intent of protecting the above ground portion of a monitoring well.

Restore damaged wells with well protection measures and casing as prescribed by this chapter. Decommission wells that are damaged beyond repair.

4 Procedures for Specific Types of Wells

4.1 Drilled Wells

Key Principals, Specifications, and Precautions

1. Select the proper drill rig.
2. Evaluate site-specific hydrogeologic information from all available sources, including the physical and chemical properties of the groundwater and any contaminants known or suspected to be present in the groundwater.
3. Develop a conceptual hydrogeologic model of the site.
4. Determine screened interval.
5. Determine the diameter of the well
6. Determine the proper inside diameter of the borehole (at least 4 inches larger than the riser and screen diameter).
7. Take appropriate precautions during drilling to avoid introducing contaminants into the borehole.
8. Proceed with soil recovery per the ADEC approved Work Plan
9. Complete an “as built” drawing/schematic for each constructed monitoring well
10. Avoid using drilling mud, synthetic drilling fluids, or petroleum- or metal-based pipe joint compounds and other potential contaminants unless necessary.
11. If it is necessary to add water to the borehole during drilling, use only potable water and first identify the water source.
12. If it is necessary to add drilling mud to the borehole during drilling to stabilize the hole or control down-hole fluid losses, use only high yield sodium bentonite clay free of all organic polymer additives.
13. Properly decontaminate all equipment placed into the borehole by steam cleaning, high-pressure hot water, or similar methods before and after use at the site and between boreholes.
14. Manage cuttings, or water, removed from the borehole in accordance with 18 AAC 75 or 18 AAC 78.
15. Survey wells vertically and horizontally with survey loops that close within 0.01 foot vertically, and1.0 foot horizontally. The well survey data must be provided to ADEC in a written report. Submit a record of the well design, installation, and the materials used to ADEC
16. Maintain a boring log.

Discussion
Soil borings assess the lithology of the subsurface and are often required during the installation of monitoring wells. Selection of the drill rig used to advance a soil boring (or install a groundwater monitoring well) must be appropriate to gather the project-specific data required. A common drill rig used for contaminated site investigation is the hollow-stem auger. The hollow-stem auger allows for continuous soil recovery and monitoring well installation. American

Society for Testing and Materials (ASTM) standard D6151 (2003) provides detailed information on the use of hollow-stem augers for soil sampling. Direct push techniques are also popular in Alaska for advancing soil borings and installing monitoring wells. ASTM standards D6724 (2004) and D6725 (2002) provide detailed guidance on the installation of direct push monitoring wells. Air rotary drilling techniques may be useful when drilling through consolidated materials; ASTM standard D5782 (2000) provides a detailed discussion. Additionally, comprehensive evaluations of drilling methods are in Driscoll (1986) and EPA (1991).

Soil recovery from split spoons must proceed in accordance with the ADEC approved Work Plan to generate an accurate record of the soil lithology, soil moisture content, and allow for soil sample collection. Continuous soil recovery may be appropriate at some locations at some sites, depending on the objectives, goals, and data requirements.

ASTM standard D5434 (2003) provides detailed guidance on the type of information included in the boring log. An example log is in EPA (1991). Digital imagery is also a useful tool for recording boring information. When the soil boring is completed as a groundwater monitoring well, the well construction and completion information should be provided as a detailed "as-built" drawing. An example of an as-built drawing showing well construction and completion information is in EPA (1991).

When describing frozen soils, ASTM standard D4083 (2001) can be used as guidance. Rock core logs should describe the lithology, mineralogy, color, grain size, degree of cementation, degree of weathering, density and orientation of fractures, other primary and secondary features and physical characteristics of the rock, and the rock quality designation. Include a clearly labeled photographic record of all rock cores with the rock core logs.

4.2 Direct Push Wells

Key Principals, Specifications, and Precautions

1. Determine the purpose of the well.
2. Evaluate site-specific hydrogeologic information from all available sources, including the physical and chemical properties of the groundwater and any contaminants known or suspected to be present in the groundwater.
3. Develop a conceptual hydrogeologic model of the site.
4. Determine screened interval.
5. Determine the diameter of the well
6. Take appropriate precautions during installation to avoid introducing contaminants into the well. Prevent vertical movement of water or contaminants between water-bearing zones in either the boring or the well annulus.
7. Properly decontaminate all equipment placed into the well by steam cleaning, high-pressure hot water, or similar methods between well installations.
8. Manage cuttings, or water, removed from the well in accordance with 18 AAC 75 or 18 AAC 78.

9. Complete an “as built” drawing/schematic for each constructed monitoring well.
10. Survey wells vertically and horizontally with survey loops that close within 0.01 foot vertically, and1.0 foot horizontally. The well survey data must be provided to ADEC in a written report. Submit a record of the well design, installation, and the materials used to ADEC.
11. Maintain a boring log.

Discussion
Direct push monitoring wells have improved in technology over the last several years and have become increasingly common at contaminated site investigations. Significant cost savings can be achieved with direct push wells due to faster installation, replacement, and decommissioning. While the method of well installation and construction materials differs from traditional drilled wells, direct push wells are still subject to the considerations discussed in this guidance to yield representative groundwater samples.

The design and installation of direct push wells varies with the intended use. Direct push wells consist of a steel drive rod with a protected screen or an exposed screen. Depending on the application, direct push wells may or may not use seals and filter packs. However, direct push wells without seals and filter packs are for short-term applications of one sampling event, unless otherwise approved by ADEC.

Install direct push wells using steel drive rods advanced by hydraulic hammers or rams, directly emplacing the well screen and riser, or providing subsurface access for installation of well components similar to drilled wells. These differing installations are classified as either exposed-screen or protected-screen installations (see Figure 6). In exposed screen installation, the casing and screen surrounds the drive rods, or are used as the drive rod. During installation, the well screen is directly exposed to the formation, and installation is completed without a filter pack or annular seal. In the protected-screen installation, the casing and screen are inside the drive rod, or lowered as the drive rods are advanced. The filter pack and annular seal can be installed in the protected installation as discussed above. Alternatively, pre-packed well screens and expanding foam annular seals are commonly available for direct push wells.

Advantages of Direct Push

- Faster installation rate
- Small well diameters allows for rapid purge volume removal
- Sampling may occur immediately after installation
- Individual wells can be sequentially sampled at successive depths for a complete aquifer profile
- No soil cuttings
- More accessible in remote locations because the equipment is smaller and easier to transport
- Facilitates more complete site characterization.

Disadvantages of Direct Push

- Some installations have no filter pack, which can possibly lead to well silting
- Exposed-screen installations can "drag down" contamination
- Some conventional instruments, such as submersible pumps, may not fit in smaller diameter wells,
- Recharge rates may not be sufficient for some pump test volume requirements
- Depth for well installation is less than with a drill rig
- Cobbles in unconsolidated deposits can limit direct push rods

ASTM Standards D6001-05 (2005), D6724-04 (2004), 6725-01 (2002) ASTM D6282-98 (2005) provide detailed instructions on direct-push methods for drilling, and soil and groundwater sampling. A common problem experienced with this method in Alaska is difficult advancement of drive points and casing in some soil conditions, such as cobbles or glacial tills. Depending on lithology and the size of the rig, maximum achievable depth is estimated at between 80 and 100 feet below ground surface.

Comparison studies between direct push and hollow-stem auger drilled wells in a wide range of formations show little difference in performance. Studies conducted by BP Corporation North America Inc. and the UST Programs of the USEPA Regions 4 and 5 (2002) and Kram et al. (2001) were of short duration, but found that water-level elevations and contaminant concentrations were statistically comparable between the two well types. Bartlett et al. (2004) and BP and USEPA (2002) found that some types of direct push wells yielded slightly lower hydraulic conductivity values than drilled wells, but that proper well development and variables other than well construction were of greater significance. Direct push wells installed with proper filter packs and annular seals may be approved by ADEC for long term monitoring. The lack of an annular seal in exposed-screen installations may result in the introduction of water or contaminants from the ground surface or across water bearing zones. This type of direct push wells are therefore not approved for long term monitoring, but may be appropriate for collecting grab samples during site characterization as long as the well is properly developed prior to sampling. It is important to note that the resultant data will be restricted in use and site closure may require that samples be collected using drilled wells or direct push wells with filter packs, surface seals, flanges, and annular seals.

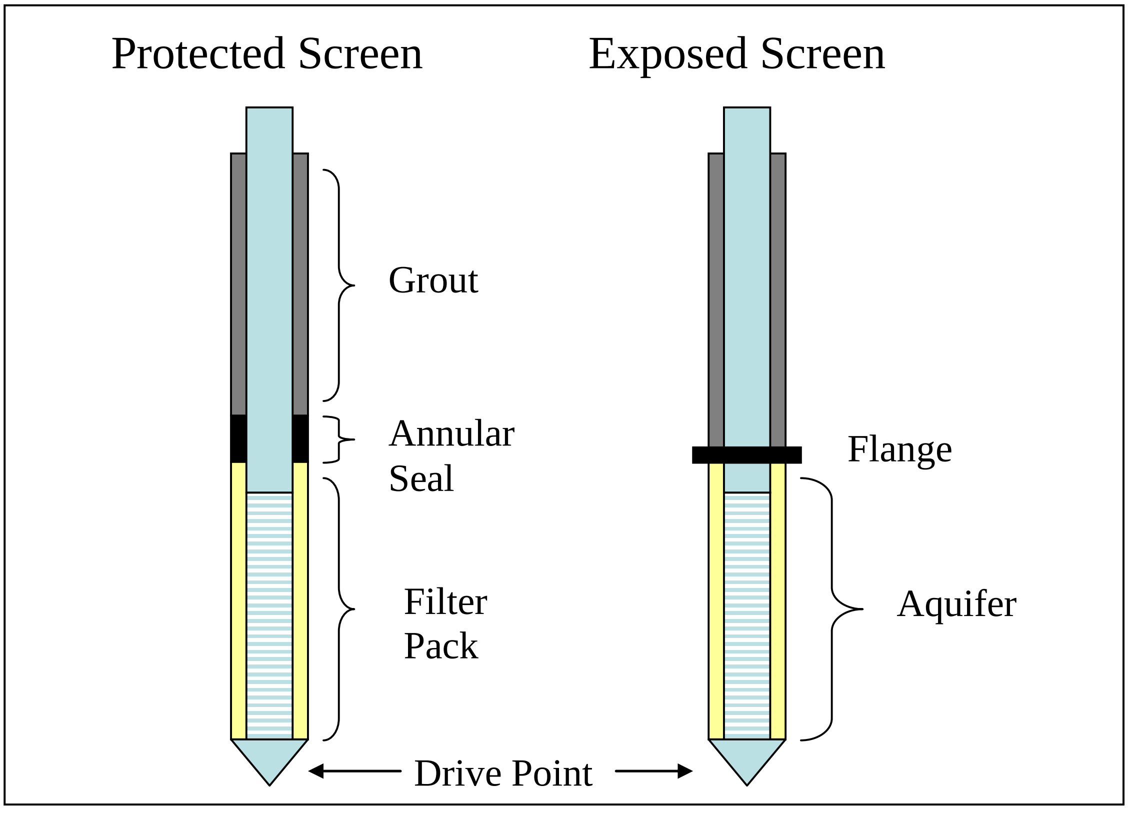


Figure 6: This diagram illustrates two different types of well installations, a "protected" screen direct push installation, and an "exposed" screen direct push installation (Naval Facilities Engineering Command, 2005).

An alternate method for the installation of direct push wells is to excavate a test pit or hand auger to within several feet of the water table, then push a well point the final few feet into the water table. This method creates fewer disturbances in the aquifer allowing for a shorter development time and short term or long term monitoring wells may be installed as detailed in the next section.

4.3 Excavation Installed Wells

Key Principals, Specifications, and Precautions

1. Determine the purpose of the well.
2. Evaluate site-specific hydrogeologic information from all available sources, including the physical and chemical properties of the groundwater and any contaminants known or suspected to be present in the groundwater.
3. Develop a conceptual hydrogeologic model of the site.
4. Determine screened interval based on known groundwater levels.
5. Determine the diameter of the well.

6. Take appropriate precautions during excavation/placement to avoid introducing contaminants into the well. Prevent vertical movement of water or contaminants between water-bearing zones.
7. Properly decontaminate all equipment placed into the well by steam cleaning, high-pressure hot water, or similar methods between well installations.
8. Manage water removed from the well in accordance with 18 AAC 75 or 18 AAC 78.
9. Complete an "as built" drawing/schematic for each constructed monitoring well.
10. Survey wells vertically and horizontally with survey loops that close within 0.01' vertically and 0.2' horizontally. The well survey data must be provided to ADEC in a written report. Submit a record of the well design, installation, and the materials used to ADEC.

Discussion
Excavation installed wells are placed into an open excavation or test pit, then backfilled, developed, purged and sampled as traditional wells. The well casing is constructed in its entirety prior to placement into the excavation. Care should be taken to locate the screened interval within the desired sampling interval.

Similar to all techniques for monitoring well installation, the longer the period that has elapsed since the date of installation, the more representative the water quality of the water sample obtained from the well. Because of the disturbance that results from this particular installation method, excavation installed wells typically require a longer period of time to re-establish equilibrium conditions. Multiple rounds of purging and bailing can assist in development of these wells (see Section 5), but several weeks or more may be required before water in these wells will yield a true reflection of surrounding GW quality.

Excavation installed wells are typically used for short term monitoring only and are therefore installed without a filter pack or annular seal. If this type of well is proposed for long term monitoring, it must be installed with a filter pack and annular seal by placing the well into another casing that is screened across the same interval, then filling the annular space with a sand pack and annular seal as during drilled well construction. Alternatively, a pre-packed well point may be placed inside another casing screened across the same interval then additional sand pack and sealing material added as needed to complete the well to the surface.

4.4 Monitoring Wells in Frozen Ground

Key Principals, Specifications, and Precautions

1. Minimize effects on the subsurface thermal regime.
2. Maintain wells to ensure sample collection at any time of year.
3. Seal the annular space between the casing and any permafrost to prevent upward seepage.

Discussion
For environments with frozen ground conditions, design and construct monitoring wells and well points to minimize effects on the subsurface thermal regime (permafrost) and to withstand

freeze-thaw forces (seasonal frost). Design and construct monitoring wells installed above permafrost (i.e. screened in the seasonally active layer) to obtain a representative groundwater sample during the period of thaw. Additionally, groundwater that rises in the casing up into the permafrost or frozen ground zone may freeze.

Wells installed in a permafrost layer require special attention. Use caution when installing a well through permafrost that may be acting as a confining unit because flowing artesian conditions may occur. In addition, firmly seal the thawed annulus between the pipe and the permafrost to prevent seepage upward from the confined aquifer.

5 Well Development and Maintenance

Key Principals, Specifications, and Precautions

1. Develop the well by surging, pumping, and bailing.
2. Monitor water quality parameters.
3. Do not develop the well for at least 24 hours following installation.

Discussion

The primary function of a monitoring well is to provide a representative sample of groundwater as it exists in the formation. The goal of well development is to repair the damage caused during drilling, direct-push emplacement or excavation well installation to the area immediately adjacent to the well, ensuring proper hydraulic connection to the aquifer. Formation changes during well installation are variable, but are usually the compaction of unconsolidated particles surrounding the annulus. In fine-grained soils, this can result in a “mudwall” around the boring annulus, which can impede free flow of the formation water into the well. Development should agitate the adjacent formation and pull fines into the well, where they can be removed along with the development water. Well installations in finer-grained deposits are more difficult as the filter pack will not completely stop fines from entering the well.

Common well development methods are a combination of surging, pumping, air or water injection and bailing. In relatively permeable formations, lower a bailer to the water column and surge by use of a surge block attached to tubing to help breakdown any mud wall and prevent particle bridging. Unidirectional flow into the well can cause formation particles to “bridge” together and form blockages. Stopping and starting the pump can aid in a surge toward the formation, which can help break up bridged particles. It is more effective to alternate between using a surge block and bailing or pumping so that there is multidirectional flow on the filter pack around the well. Continue pumping, bailing, and surging until the turbidity decreases. Ideally, the formation water pulled from the well will now be clear. However, it is important not to overdevelop a well by overly aggressive surging. Occasionally, it may not be possible to clear the water from a well due to high concentrations of naturally occurring suspended solids in the aquifer.

Develop groundwater monitoring wells that can be purged dry by first purging the well and then allow the well to refill with formation water. If the recovery rate by the formation water is too slow then add up to one well casing volume of potable water to the well. With water in the well, surge the well vigorously for approximately 10 minutes by using either a surge block or bailer. Add more water as necessary. After surging the well, purge it dry again to complete the development process

Alternative development procedures may be used if they will not affect the ability of the well to provide representative samples. Wells installed with an annular seal must not be developed until 24 hours after well installation to allow annular seal materials to set or cure. ADEC recognizes that remote site work may make this impractical. Contact your ADEC project manager for site-specific approval if development is to be conducted prior to the 24 waiting period. Sample the monitoring well in accordance with the ADEC Draft Field Sampling Guidance.

ADEC decisions are based on trends over time, not a single sampling event. More than one water sample is required to establish the water quality in any monitoring well, especially a newly installed well. The water quality in a newly installed monitoring well becomes more reliable over time, as the aquifer and the newly installed well reach a state of chemical equilibrium.

ASTM standard D5521 (1994) provides guidance on the development of monitoring wells, and standard D5978 (2000) provides guidance on maintaining and repairing a monitoring well. Additionally, EPA (1991) provides a detailed discussion on well development.

6 Monitoring Well Decommissioning

Key Principals, Specifications, and Precautions

1. Decommission monitoring wells and well points as soon as practicable, once ADEC has determined that it is no longer needed.
2. The preferred method is to decommission a well leaving the screen in place.
3. Fill the screened interval with sand or grout.
4. Fill the blank casing with grout or bentonite chips
5. Remove the blank casing above the screen
6. Fill the borehole with grout or bentonite chips as the blank casing is extracted.
7. Ensure that sealing grouts, when used, are properly mixed and prepared in accordance with manufacturer recommendations prior to placement.
8. If using cement grout, neat cement, or puddled clay as sealing materials below the static water level in the well, introduce sealant from the bottom up.
9. For wells completed in a confined aquifer, place grout or bentonite chips in the confining stratum to prevent migration through the confining layer.
10. Fill the remainder of the borehole with or grout or bentonite chips to within two feet of the surface.
11. Fill the remaining two feet with sand or gravel.
12. Record decommissioning procedures and report to ADEC.

Discussion
The goal in decommissioning monitoring wells, well points, piezometers and transducers is to protect the aquifer. The preferred method is to the leave the well screen in place, fill the screened interval with grout or bentonite chips, remove the blank casing above the screen, and fill the borehole with grout or bentonite chips as the casing blank is being removed. Blank casing removal is important because the outside of the casing can act as a conduit through horizontal formation changes. ADEC approval of decommissioning methods must be obtained prior to any monitoring well decommissioning. Decommission wells that are damaged beyond repair, abandoned, or not intended for future use. A well that is no longer maintained and secured is susceptible to damage that can prevent proper future decommissioning, and is a potential conduit for direct surface contamination to the aquifer. Unless ADEC approves an alternative schedule, decommission monitoring wells and well points as soon as practicable, once ADEC has determined that it is no longer needed

Most monitoring wells are constructed of PVC casing and screen, with flush-threaded joints. Well casing or screen should typically never be removed unless sealing grout or bentonite chips are concurrently placed in the vacated borehole during removal. Alternate decommissioning methods are discussed below.

<u>Decommissioning – Well Casing and Screen Remaining In-Place</u>: Permafrost or other unique circumstances may prevent the removal of the well casing and screen assembly at the time of decommissioning. If the original construction of the well is known to have included a competent

annular seal of grout or bentonite chips, surrounding the well casing, the screen/casing should be completely sealed in-place up to the casing cutoff point located near the ground surface.

Decommissioning - Well Removal: If the selected decommissioning method is to remove the well entirely, the screen and casing should not be withdrawn without first being completely filled to near the ground surface with grout or bentonite chips. Removing the well casing and screen without the concurrent placement of grout sealant will lead to a collapsed and lost borehole that may never be properly sealed. Use the following procedure for decommissioning:

- Puncture or separate the bottom well cap by driving a steel drill rod or steel pipe against/through the end cap. The well casing/screen/end cap assembly can be lifted from the borehole slightly prior to driving off the end cap, in order to raise the end cap above the underlying compacted soil and assist in breaking it off the end of the well casing/screen.
- After the end cap has been ruptured or separated, sealing grout or bentonite chips are pumped/placed at the bottom of the well until a column of material fills the casing to the near ground surface.
- The well casing can now be withdrawn; however, the grout level within the casing will lower as the casing is withdrawn and grout or bentonite chips will flow out the base of the well casing/screen to fill the borehole void space. The fill material should be periodically added as the casing is removed to keep a column of fill near the ground surface. This will prevent the sloughing of the borehole, and fill any borehole void space, should the casing break while being pulled from the borehole.

Re-drilling the Well: Re-drilling should only be used when neither decommissioning method described above can be successfully employed. This can be an effective fallback option in circumstances where the well has been damaged, broken, filled, or plugged with soil or other extraneous media, preventing successful decommissioning using either of the prior two described methods. The concern with re-drilling a monitoring well borehole is there is no way to ensure that the augers will follow the original borehole to the completed well depth.

Using this method PVC casing and well screen may be destroyed and broken into multiple pieces while re-drilling the borehole. After the auger string has been drilled to the total depth of the well, grout or bentonite chips are placed at the bottom of the auger until a fill column is established within the auger to near the ground surface and the top of the drill string. Then the augers are methodically withdrawn while adding grout or bentonite chips to maintain the fill column within the auger to near the ground surface until the entire auger has been removed. EPA (1991) and ASTM standard D5299 (2005) discuss well decommissioning in more detail.

Alaska Drinking Water regulations (18 AAC 80.015(e)) require that a person who decommissions a monitoring well, public water supply well, an observation well associated with testing a public water system supply well, or a private well shall use a method that conforms to ANSI/AWWA Standard A100-97, adopted by reference in 18 AAC 80.010 or an alternate method approved by the ADEC; however, the alternate method must be submitted to the ADEC under the signature and seal of a registered professional engineer, prior to ADEC review and approval.

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8 Definitions

1) Active thaw layer - Surface layers of organic matter and mineral soil that thaw each year

2) Annular space seal - (a) For wells constructed with filter packs, the material above the top of the filter pack seal up to the surface concrete seal, and between the well casing and the adjacent formation. (b) For wells constructed in bedrock formations and without well screens, the material placed from the bottom of the enlarged drill hole up to the surface concrete seal, and between the well casing and the adjacent formation.

3) Aquifer - Geologic formation, group of formations, or part of a formation that is saturated, and is capable of providing a significant quantity of water

4) Aquitard - Lithologic unit that impedes groundwater movement and does not yield water freely to wells or springs but that may transmit appreciable water to or from adjacent aquifers.

5) Assessment monitoring - An investigative monitoring program that is initiated after the presence of a contaminant in groundwater has been detected to determine the concentration of constituents that have contaminated the groundwater and to quantify the rate and extent of migration of these constituents

6) ASTM - American Society for Testing and Materials

7) Bailer - Hollow tubular receptacle, fitted with a check valve at the bottom, used to facilitate withdrawal of fluid from a well or borehole

8) Bentonite cement grout - Mixture of five pounds of sodium based montmorillonite clay with 94 pounds of Portland cement and fix to six gallons of water

9) Bentonite chips-Impure clay consisting mostly of montmorillonite and coming in two basic size range - 1/4 to 3/8-inch, and 1/2- to 3/4-inch.

10) Bentonite slurry - Mixture of sodium based montmorillonite clay and water that has a minimum mud weight of 10 pounds per gallon

11) Borehole - Circular hole deeper than it is wide constructed in earth material for the purpose of either installing a well or obtaining geologic or groundwater related data

12) Borehole log - Record of geologic units penetrated, drilling progress, depth, water level, sample recovery, volumes and types of materials used, or other significant observations regarding the drilling of an exploratory borehole or well

13) Casing - Pipe finished in sections with either threaded connections or beveled edges to be field welded, which is installed temporarily or permanently to counteract caving to advance the borehole, and/or to isolate the zones being monitored

14) Casing (Protective) - Section of large diameter pipe placed over the upper end of a smaller diameter monitoring well riser or casing to provide structural protection to the well and restrict access to the well.

15) Casing (Surface) - Pipe used to stabilize a borehole near the surface during and following the drilling of the borehole

16) Concrete grout - Slurry mixture of 94 pounds of cement, equal volumes of dry sand and gravel, and five to six gallons of water. The ratio of sand and gravel should not exceed three parts to one.

17) Detection monitoring – Program of monitoring for the express purpose of determining whether or not here has been a contaminant release to groundwater.

18) Drillhole – Equivalent to borehole

19) Filter pack - Clean silica sand or sand and gravel mixture of rounded grains with a selected grain size and graduation that is installed in the annular space between the borehole wall and the well screen, extending an appropriate distance above the screen for the purpose of retaining and stabilizing the particles from the adjacent strata

20) Flush-joint or flush-coupled - Casing or riser with ends threaded such that a consistent inside and outside diameter is maintained across the threaded joints or couplings

21) Grout – Low permeability material placed in the annulus between the well casing or riser pipe and the borehole wall (i.e., in a single cased monitoring well), or between the riser and casing i.e., in a multi-cased monitoring well), to maintain the alignment of the casing and riser and to prevent movement of groundwater or surface water within the annular space

22) Inside diameter - Distance, perpendicular to the long axis of the casing

23) Long term monitoring well- A monitoring well that is comprised of a filter pack, annular seal and surface seal. Long term monitoring wells are applicable when two or more sampling events will be conducted.

24) Neat cement grout - Slurry mixture of 94 pounds of Portland cement mixed with 5 to 6 gallons of water.

25) Piezometer - Well installed for the specific purpose of determining the elevation of the potentiometric surface

26) Purge - An action that removes water from a well, commonly accomplished using a pump or bailer

27) Riser pipe - Pipe extending from the well screen to or above the ground surface

28) Rotary drilling method - Drilling method whereby the drillhole is constructed to the depth of casing setting and the well casing is set to the bottom of the drillhole rather than driven

29) Short term monitoring well- A monitoring well installed for the purpose of one monitoring event, Short term monitoring wells may or may not have a filter pack, annular seal or surface seal, depending on their application.

30) Sodium based bentonite - Clay consisting of at least 85 percent sodium montmorillonite

31) Static water level - The elevation of the top of a column of water in a monitoring well or piezometer that is not influenced by pumping or conditions related to well installation, hydrologic testing, or nearby pumpage

32) Surge - An action causing water to move rapidly in and out of the well screen thereby removing fine material from the surrounding aquifer

33) Top of bedrock - The top of firm rock, as indicated by at least 70 percent of the drill cuttings being either (1) angular rock fragments, as in the case of crystalline rock or (2) rock fragments composed of individual grains or rock particles that are cemented together to form an aggregate

34) Top of filter pack seal - Sealing material at least two feet in length placed in the annular space above the filter pack and below the annular space seal

35) Tremie pipe - Metal pipe or steel wire-braided, rubber-covered hose used to convey well construction materials down a drillhole

36) Unconsolidated material - Material found above firm bedrock, composed of single sediment particles, individual grains or rock fragments

37) Water table - The surface of unconfined groundwater where the pressure is equal to atmospheric pressure

38) Water table observation well - Any groundwater monitoring well installed for the specific purpose of determining either the elevation of the water table, or the physical, chemical, biological, or radiological properties of groundwater at the water table or both

39) Well depth - Distance from the land surface to the bottom of the well screen or drill hole

40) Well screen - Filtering device used to retain the primary or natural filter pack, usually a cylindrical pipe with openings of a uniform width, orientation, and spacing

41) Well volume - Volume of water standing in the well casing

42) Zone of saturation - A hydrologic zone in which all the interstices between particles of geologic material or all of the joints, fractures, or solution channels in a consolidated rock unit are filled with water at pressure greater than that of the atmosphere