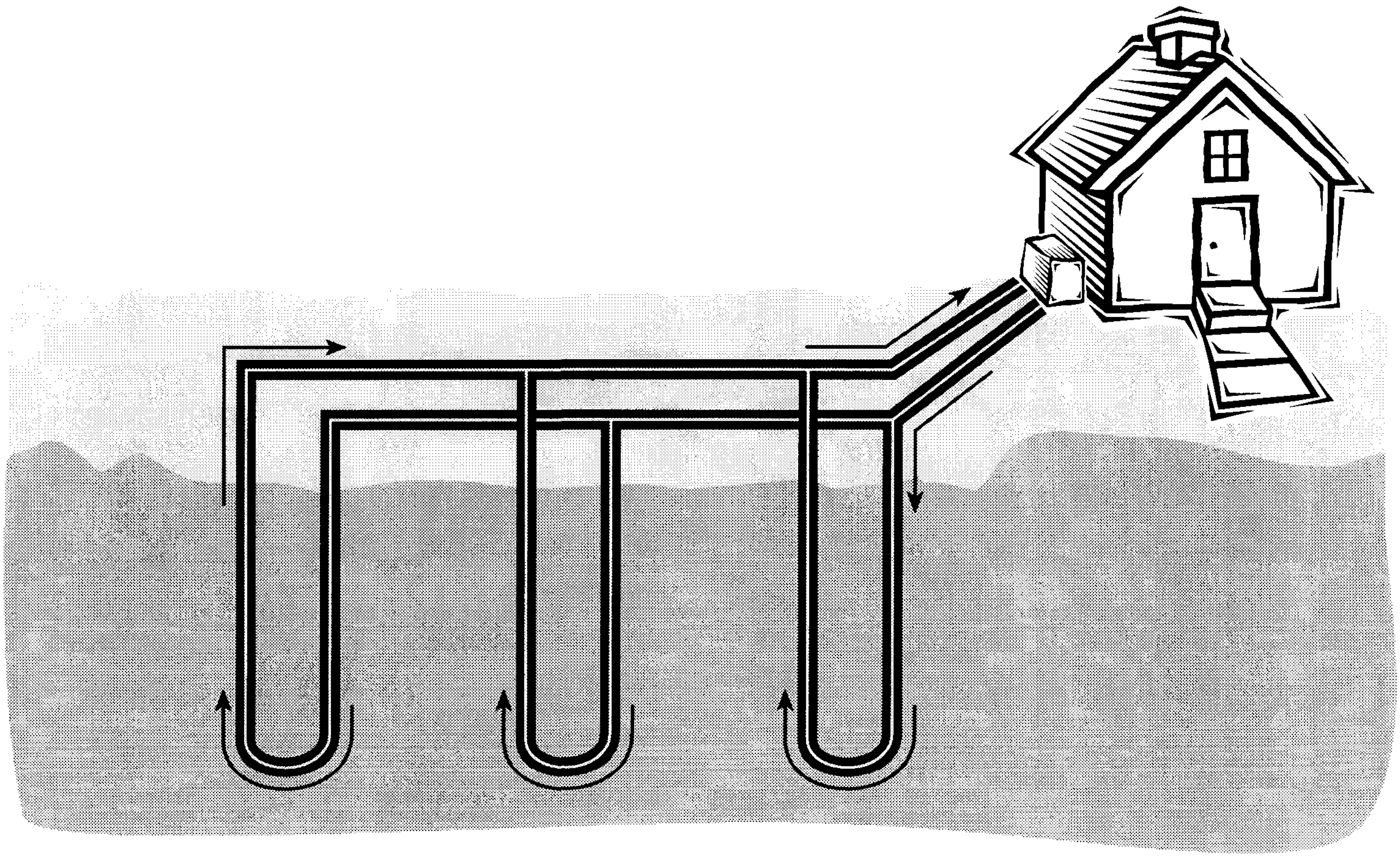
EPA

United States
Environmental Protection
Agency

Air and Radiation
(6202J)

EPA 430-B-97-028
September 1997

Manual on Environmental Issues Related to Geothermal Heat Pump Systems



Reviewed and
approved by

national ground water association

Contents

Introduction

Introduction

This document highlights the environmental issues which are relevant to three broad categories of geothermal heat pump (GHP) systems: vertical closed loop systems; horizontal closed loop systems; and open loop systems. Based on available information, the document suggests regulatory options and best management practices for addressing those environmental issues. This Manual is intended to provide regulators and GHP professionals with a greater understanding of the key environmental issues as they relate to GHP system type and life cycle phase. It will assist these parties by providing a common language about GHP systems and an awareness of best practices for installing, operating, and decommissioning in an environmentally responsible manner.

This document was developed by the EPA because regulators and GHP professionals requested EPA to provide guidance on some of these issues. It has been reviewed and accepted by the National Ground Water Association (NGWA) as well. This manual is not intended to be the last word in GHP system regulation or best management practices. EPA expects that as regulators and GHP system professionals gain further experience, certain recommendations may be modified to reflect that experience. In that sense, this is a living document.

Background

Geothermal heat pump systems are often referred to as geothermal, earth-coupled, water coupled, groundwater, ground-coupled, closed-loop, coiled, Slinky™, GeoExchange℠, open, and water-source heat pump systems. Regardless of what they are called, GHP systems all rely on energy stored in the ground (or groundwater) to provide heating and cooling to buildings. A more comprehensive discussion on GHPs can be found in Appendix A.

GHP systems are an important alternative to conventional heating and cooling systems. GHP systems can significantly reduce the consumption of fossil fuels by using existing energy within the ground. Hence, GHP systems can be a source of clean energy, with only minimal risk of environmental contamination resulting from their use.

The United States General Accounting Office report, *Geothermal Energy: Outlook Limited for Some Uses but Promising for Geothermal Heat Pumps* states that "Geothermal heat pumps are the most energy-efficient means of heating and cooling buildings in most areas of the United States." Use of GHP systems in place of traditional systems will result in significant reductions in emissions of greenhouse gases, as well as reductions in emissions of SO_x and NO_x. Accordingly, the Energy Policy Act of 1992 contains provisions to encourage the use of geothermal systems as alternative energy sources.

In a 1993 EPA report, *Space Conditioning: The Next Frontier*, a comparison of energy efficient technology for residential dwellings was performed. In this study, geothermal heat pumps were identified as one of the most energy efficient technologies available. Based on this study, EPA initiated activities to aggressively promote this technology. In 1995, EPA established the ENERGY STAR® HVAC Equipment Labeling Program. This program is designed to identify and promote energy efficient residential HVAC technologies including geothermal heat pump systems.

Although the potential for energy savings and greenhouse gas reduction with GHP systems is great, their use in homes is not widespread in the United States. Two key, interrelated factors have influenced this situation:

- Lack of awareness of the benefits of GHP systems on the part of home builders and home buyers; and
- Lack of knowledge about the technology on the part of regulatory officials coupled with the lack of clear and consistent regulations on the technology.

Many home builders and home buyers are unfamiliar with the GHP systems, how they work, and their benefits. Hence, home buyers generally do not ask for a GHP system on their own, and home builders do not specify GHP systems for installation. This lack of information about GHP systems is beginning to be addressed through various marketing efforts by local utilities and associations promoting use of GHP systems. Information provided through these efforts typically includes a discussion about the potential environmental and economic benefits compared to traditional systems, and descriptions of how GHP systems work.

While there is a growing awareness of GHP systems on the part of state and local regulators and permitting agencies, this technology is not well understood in most of the regulatory arena. Consequently, regulatory officials often times avoid addressing GHP specific regulations. Since many GHP systems require drilling holes in the ground that are similar to water wells, state and local environmental regulators have tended to regulate GHP systems using the same tools and rationales as for water wells. In part, this approach is justified. However, these regulatory approaches can be improved to better address the unique needs of GHP systems.

It is important to note that the lack of regulation in many states should not be interpreted as a lack of risk. On the contrary, most states have been slow to react unless and until a significant contamination issue has come to their attention. In addition, legislators are often slow to draft legislation to deal with problems they do not fully understand. Conversely, the number of concerns highlighted in this document should not suggest that this method of space conditioning is necessarily environmentally risky. As shown in this document, relatively simple precautions will ensure that any environmental impact is negligible.

There are three basic types of GHP systems:

1. Vertical Closed Loop Systems;
2. Horizontal Closed Loop Systems; and
3. Open Loop Systems.

EPA has identified a number of environmental concerns that may affect GHP systems. Each of these concerns is addressed in this document to the extent that information about them exists and is available. The environmental concerns identified are:

1. Near surface disturbances, including sediment and storm water runoff, and surface contaminant infiltration along the borehole;
2. Inter-aquifer water flow;
3. Placement of ground loops;

4. Backfilling trenches;

5. Antifreeze solutions;

6. Water withdrawal;

7. Thermally altered discharge water; and

8. Decommissioning procedures, including sealing ground loops to eliminate physical hazards and potential migration of surface contaminants.

The relevant environmental issues vary by GHP system type. For example, water withdrawal is only an issue with open loop GHP systems.

From a regulatory perspective, each type of GHP system has a life cycle consisting of three phases:

1. Installation;

2. Operation; and

3. Decommissioning.

The relevant environmental issues also vary by GHP life cycle phase. For example, near surface physical disturbances are only an issue during the installation phase of the system life cycle.

Regulatory Overview

States and local jurisdictions generally rely on one of three different regulatory approaches to address GHP systems:

1) Regulate GHP systems specifically;

2) Apply existing regulations (e.g., drinking water well regs) to GHP systems; or

3) Apply *no* regulations, so that GHP systems are essentially unregulated.

In addition, the International Ground Source Heat Pump Association (IGSHPA) and the National Ground Water Association (NGWA) have developed installation standards for GHP systems. These standards are designed to ensure that all new GHP systems are installed in ways that minimize the potential for environmental harm. IGSHPA also has a contractor certification program that is intended to guarantee that personnel involved in the installation of GHP systems are aware of proper procedures and capable of performing the work correctly. In states without GHP-specific regulations, the IGSHPA standards ensure that each system is properly installed by a qualified individual. Generally, the IGSHPA standards are consistent with the GHP-specific regulations of those states that have developed them, as well as the best management practices identified throughout this document. Training programs are also available through the Geothermal Heat Pump Consortium (GHPC). These programs include best management practices for GHP installations.

Table 1 below was created to provide a rough summary assessment of state regulatory approaches for GHP systems. It represents the authors' **subjective** assessment of data collected by the National Rural Electric Cooperative Association (NRECA). EPA recognizes that regulations are changing and being revised constantly and that the information presented in this table may become outdated.

Organization of This Document

This document is divided into three sections that correspond to the three GHP system types. Each section is further subdivided into a description of the GHP system and the three GHP system life cycle phases (i.e., installation, operation, and decommissioning). Relevant environmental issues are discussed under the appropriate life cycle phase.

Three states, Delaware, New Jersey and Missouri, were used as examples throughout the document to help clarify particular points. These three states were selected because they represent a range of different approaches for addressing GHP management and regulation. While the approaches used by these three states to regulate and manage GHPs is illustrative, other states are likely to develop their own unique approaches to managing GHPs based on the specifics of their regulatory and geologic circumstances.

This document focuses primarily on the environmental issues and requirements associated with residential GHP systems, and does not attempt to address commercial systems in detail. The concept and technology behind the two types of systems are similar, although commercial systems are usually much larger in scale. A draft report[1] that addresses the thermal effects of a large commercial GHP system on aquifer microbiota and surface biota is available through EPA's Atmospheric Pollution Prevention Division distribution center at (202) 775-6650.

In addition to the body of the text, there are two appendices:

- Appendix A Introduction to Geothermal Heat Pumps; and
- Appendix B State Contacts.

Appendix A provides an overview on the fundamentals of geothermal heat pumps. Appendix B provides a list of state contacts where more information on geothermal heat pumps may be obtained.

[1] *Preliminary Studies on the Thermal Effects of the Stockton College Geothermal Heat Pump Installation on Aquifer Microbiota and Surface Biota*, EPA Project ID Number X824245-01-1, August 1996.

Table 1
Summary of Federal and State Regulations for Geothermal Heat Pump Systems

State	Closed Systems						Open & Closed Systems		Open Systems		
	Installation				Operation		Installation		Installation		Operation
	Horiz. Trench Systems	Vertical Systems	Specific to Grouting	Heat Xchngr Construction	Heat Transfer Fluids	DX Systems	Well Driller Licensing	Pump Inst'lr Licensing	Water Well Construction	Inject. Well Construction	Surface Water Discharge
Alabama							○		○	○	○
Alaska			○						○	○	
Arizona		○	○				○		○		
Arkansas	○	○	○	○	○		○	○	○	○	
California		○					○		○	○	
Colorado		●	●	●	●		○	○	●	○	○
Connecticut		○	○				○	○	○	○	○
Delaware		○	○				○	○	○	○	○
Florida		○					○		○	○	○
Georgia		○					○		○	○	○
Hawaii							○	○	○	○	○
Idaho		○			●		○		○	○	○
Illinois	○	○	○		○		○	○	○	○	○
Indiana		○	○				○		○	○	○
Iowa							○		○	○	○
Kansas		○	○		○		○		○	○	○
Kentucky	○	○					○		○	○	○
Louisiana		○	○	○	○		○		○	○	○
Maine							○	○	○	○	○
Maryland		○	○		○		○		○	○	○
Massachusetts		○					○		○	○	○
Michigan		○					○	○	○	○	○
Minnesota		●	●	●	●		○	○	●	○	○
Mississippi		○	○				○		○	○	○
Missouri	●	●	●	●	●	●	●	●	●	●	●

Symbol Legend: ○ Existing water well regulations are applied
● Specific GHP regulations are applied

Table 1 (cont.)
Summary of Federal and State Regulations for Geothermal Heat Pump Systems

State	Closed Systems						Open & Closed Systems		Open Systems		
	Installation				Operation		Installation		Installation		Operation
	Horiz. Trench Systems	Vertical Systems	Specific to Grouting	Heat Xchngr Construction	Heat Transfer Fluids	DX Systems	Well Driller Licensing	Pump Inst'lr Licensing	Water Well Construction	Inject. Well Construction	Surface Water Discharge
Montana							○		○	○	○
Nebraska	●	●	○	●	●		○	○	●	●	○
Nevada			○				○		○	○	○
New Hampshire							○	○			○
New Jersey		●	●	●	●	●	○	○	○	○	○
New Mexico		○	○				○		○		○
New York				○		○				○	○
North Carolina		○	○	○	●				○	●	○
North Dakota	●	●			●		○	○	●	○	○
Ohio		●					○				
Oklahoma	○	●	●			●	○	○	●	○	○
Oregon							○			○	○
Pennsylvania							○	○	○	○	○
Rhode Island							○	○	○	○	○
South Carolina		○					○		○		
South Dakota	●						○		○	○	○
Tennessee		○	○				○	○	○	○	
Texas		○	○				○		○	○	
Utah		○	○				○		○	○	○
Vermont		●	○		●	○	○	○	○	○	○
Virginia		●	○	○		○	○	○	○	○	○
Washington		○					○		○	○	○
West Virginia							○		○	○	○
Wisconsin		●	○	○	○	○	○	○	○	○	○
Wyoming	●	●	○		●						○

Symbol Legend: ○ Existing water well regulations are applied
● Specific GHP regulations are applied

Section I
Vertical Closed Loop Systems and Related Environmental Issues

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Introduction

System Description

Closed loop GHP systems rely on the contained circulation of fluids through an underground loop of pipes, which act as a heat exchanger by transporting heat to or from the ground. Vertical loops are most often installed in boreholes drilled into the ground. The pipes in which the heat exchange fluid circulates are typically installed to depths up to 400 feet. The horizontal spacing between boreholes typically is between 10 and 25 feet. The distance between boreholes is selected to optimize system efficiency and the long and short term ability of the ground to retain or give off heat. The heat exchange fluid used in such systems is water. In many cases, antifreeze is added to the water to protect the fluid from freezing conditions, and to extend the operating range of the GHP system. [*PA GSHP Manual*, pp 2-4, 3-7, 3.6.2]

Key Environmental Concerns

The key environmental concern associated with vertical closed loop GHP systems is groundwater contamination resulting from:

- Antifreeze leaks that could migrate to the groundwater; or
- Improperly constructed boreholes that could potentially serve as channels of contamination from the surface to the subsurface, or from one aquifer to another.

Because of these potential problems, care should be taken during installation, operation and decommissioning of GHP systems to avoid unnecessary environmental risks. [*PA GSHP Manual*, pg 5-1] Exhibit 1-1 provides an overview of the regulations and best management practices associated with the environmental issues relevant to each life cycle phase.

Overview of Regulatory Approaches

There are differing views on how to regulate vertical closed loop GHP systems. State regulatory approaches for vertical closed loop GHP systems range from specific GHP regulations, to treating the GHP systems as drinking water wells, to having no regulations at all. Some opinions liken the installation of vertical closed loop GHP systems to decommissioning an abandoned well: they both have holes in the ground which are sealed to prevent any environmental contamination. The various opinions on regulations and best management practices for vertical closed loop GHP systems are presented in this section. It is also highly recommended that one refer to the NGWA's *Guidelines for the Construction of Vertical Boreholes for Closed Loop Heat Pump Systems* for more detailed best practices.

Exhibit 1-1

Overview of Environmental Concerns, Corresponding Regulations and Best Management Practices That Apply to Vertical Closed Loop GHP Systems

Environmental Issue	*Regulations*	*Best Management Practices*
Installation		
• Sediment and storm water runoff	• Generally exempt from regulations.	• Ensure that disturbed soil is seeded to reduce risk of runoff.
• Surface contaminant infiltration along the borehole	• Most state regulations address grouting and precautions to prevent contamination at the surface from entering the borehole.	• During construction, the area surrounding the well should be maintained in a clean condition and surface drainage should be diverted away from the well. • The top of the borehole should be sealed with suitable grout. [Refer to IGSHPA's *Grouting Procedures for Ground-Source Heat Pump Systems.*]
• Inter-aquifer flow	• Regulations apply to borehole diameter and length, and grout materials and methods. • Installers may also be responsible for the integrity of the annular seal for a specified period of time.	• There are differing views from full length grouting of the borehole using the grout pipe (tremie) method to grouting at least 10 feet above and below the affected aquifers. [Refer to IGSHPA's *Grouting Procedures for Ground-Source Heat Pump Systems* for grouting methods, and also NGWA's *Guidelines for the Construction of Vertical Boreholes for Closed Loop Heat Pump Systems.*] • In addition, refer to your state and local requirements that apply to drinking water wells or specifically to GHP systems.
• Loop placement	• Regulations generally do not specify distances necessary between heat pump loop and existing or potential pollution sources.	• Follow drinking water well placement requirements.
• Grouting	• State regulations generally exist for the grouting material and method.	• There are differing views on the best grouting materials and placement methods. In general, full length grouting of the borehole using the tremie method and a proper grout can help maximize thermal performance and environmental safety. [Refer to IGSHPA's *Grouting Procedures for Ground-Source Heat Pump Systems* for more information.]
Operation		
• Antifreeze solutions	• Regulations range from very specific listings of acceptable antifreezes and the properties they must possess, to no regulations at all.	• Choose antifreeze for low toxicity, high heat transfer, and low viscosity. The greatest risk of exposure comes from handling antifreeze solutions—use masks and protective clothes during installation or maintenance. • To reduce potential for leaks in the system, follow the pipe manufacturer's installation and testing procedures.
Decommissioning		
• Physical hazard of the well and pathway for migration of contaminants	• Regulations generally require all abandoned wells to be decommissioned so that they will not produce water or act as a conduit for mixing poor quality waters with good quality water, or present a hazard to the safety and well being of people and animals.	• Pump out the heat transfer fluid. Clear the borehole of any obstructions. Seal the borehole with grout.

Installation Issues

There are five environmental issues related to installation of vertical closed loop GHP systems:

1. Sediment and storm water runoff from the site;
2. Surface contaminant infiltration along the borehole;
3. Inter-aquifer flow;
4. Loop placement; and
5. Grouting.

1. Sediment and Storm Water Runoff From the Site

Installation of vertical closed loop GHP systems requires that boreholes be drilled, resulting in removal of soil and rock chips from the boreholes. This soil may be left adjacent to the borehole and regraded, or removed from the site. If the soil is left on-site, use care to ensure that the soil doesn't migrate to nearby surface waters or sewers.

Why should I be concerned about sediment and storm water runoff from the site during vertical closed loop GHP system installation?

Eroded soil migrating offsite can temporarily foul streams, and clog sewers. Proper soil containment can minimize soil erosion and potential impacts on streams and sewers, reduce potential for citizen or government complaints, as well as improve project aesthetics before, during and after development. [*VA Erosion and Sediment Control Handbook*, pg I-1]

What are the best practices to minimize the potential for sediment and storm water runoff from the site during vertical closed loop GHP system installation?

There are two basic requirements that a best practice must satisfy. First, it must meet state and local regulatory and permit requirements. Second, it must prevent erosion, especially water erosion, of exposed soil. Typically construction sites require that exposed soil be covered or that a runoff control barrier be erected. However, most residential GHP installations result in little soil disturbance and the soil that is disturbed is usually exposed for only a very short period of time (i.e., one or two days). Hence, the best management practice under these circumstances is to seed the disturbed soil upon completion of the installation. If the disturbed soil will be exposed for a lengthy period of time, then another measure may need to be implemented. For example, at Fort Polk, where over 8,000 vertical loops were recently installed, the Louisiana environmental agency had the drillers use large holding tanks for the drilling mud in order to avoid problems associated with erosion and runoff.

What regulations do I need to know that apply to sediment and storm water runoff from the site during vertical closed loop GHP system installation?

In general, existing single family residences are exempt from sediment and storm water regulations when small areas of land are disturbed. The State of Missouri, for example, excludes single family residences and heat pump wells from the State's storm water operating permit program under the Missouri Clean Water Law; and in addition, exempts from sediment and storm water controls all projects disturbing less than five acres and trenches two feet in width or less. The States of New Jersey and Delaware have similar regulatory exemptions for storm water runoff from residential property.

How do I find out what laws in my state apply to sediment and storm water runoff from the site during vertical closed loop GHP system installation?

State laws and regulations are evolving constantly. You should, therefore, contact appropriate officials in your state, as identified in Appendix B. The National Ground Water Association (NGWA) or the National Rural Electric Cooperative Association (NRECA) can also provide a list of state officials that oversee implementation of relevant laws and regulations in each state.

2. Surface Contaminant Infiltration Along the Borehole

Aquifer contamination can occur when vertical GHP heat exchanger boreholes are drilled in an unconfined water table aquifer. Downward leakage from the surface can occur along ungrouted or uncased boreholes, polluting the water table aquifer with surface contaminants. [*Grouting Procedures for Ground-Source Heat Pump Systems*, pg 2]

Why should I be concerned about infiltration of surface contaminants along the borehole?

Infiltration of surface contaminants can directly or indirectly contaminate the groundwater, depending on the depth of the water and local hydrogeological conditions. Groundwater is often a source for drinking water and, if contaminated, may be rendered unfit to drink. Further, in some states you may be legally and economically liable for potential damage to the aquifer.

What are the best practices to prevent infiltration of surface contaminants along the borehole?

To minimize the risks of infiltration along the borehole, care should be taken to maintain a clean site while drilling the hole, and afterwards, the well should be completed according to local regulations, or following IGSHPA or NGWA practices.[2] In general, the well water community and many states consider sealing the top of the borehole to be the preferential method of segregating surface contamination from groundwater.

What regulations do I need to know that apply to infiltration of surface contaminants along the borehole?

It is very important that contamination from the surface be prevented from polluting groundwater resources. Many states require that boreholes be drilled only by licensed water well drillers. Regulations addressing methods for preventing surface contamination of boreholes vary significantly by state and even local jurisdiction. In general, the preferred method in states with regulations is to seal the top of the borehole so that surface contamination will not reach groundwater via the borehole.

Because many types of grouts and placement methods exist, it is best to determine the specific requirements for acceptable types of grout and application methods in your state. If there are no GHP specific

[2] Detailed information on proper grouting procedures can be found in IGSHPA's *Grouting Procedures for Ground-Source Heat Pump Systems and NGWA's Manual for Water Well Construction Practices* (EPA 570/9/75/001).

regulations that address this issue, follow state regulations that apply to water well construction. Although Missouri, New Jersey and Delaware do not address requirements for preventing infiltration along the borehole in the context of GHP systems, they do recommend highly, and in some cases require, that boreholes be grouted. [Refer to IGSHPA's *Grouting Procedures for Ground-Source Heat Pump Systems.*]

How do I find out what laws in my state apply to infiltration of surface contaminants along the borehole?

(see response Installation Issues, subsection 1)

3. Inter-aquifer Flow

While drilling boreholes for the installation of vertical loop geothermal heat exchangers, it is possible to penetrate one or more aquifers. When two aquifers are penetrated, a potential path exists for the waters of the two to mix. If one of the aquifers is contaminated or contains non-potable water, the other aquifer could also potentially become contaminated.

Why should I be concerned about inter-aquifer flow?

Uncontaminated groundwater is one of our most precious natural resources. Preventing inter-aquifer flow is essential to preserving the purity of uncontaminated aquifers and sealing off formations that are known to be contaminated. Moreover, most states have regulations that apply to this issue; thus owners and operators of boreholes may be liable for civil or criminal penalties if they ignore regulatory requirements.

What are the best practices to prevent inter-aquifer flow?

There are differing views on the preferred method of preventing inter-aquifer flow. One perspective is that full length grouting of the borehole using the grout pipe (tremie) method is best.[3] Another is that grouting at least 10 feet above and below the affected aquifers is sufficient. Other methods, such as sleeves, packers, and other devices, are also employed to prevent inter-aquifer flow. In any case, the formations which yield polluted water or water of an undesirable quality must be adequately sealed off to prevent pollution or contamination of the overlying or underlying water-bearing zones.

What regulations do I need to know that apply to inter-aquifer flow?

With regard to the issue of inter-aquifer flow, GHP system boreholes are no different than water wells, hence most states apply their water well drilling regulations to GHP system boreholes. Regulations addressing methods for preventing inter-aquifer flows vary by state and even local jurisdiction. GHP system installers should follow state and local regulations that apply to grouting water wells (or those regulations that pertain specifically to GHP systems).

For example, the State of Missouri addresses inter-aquifer flow through both GHP and non-GHP specific regulations. It is aggressive in developing GHP-specific regulations, but also relies on water well regulations on this issue. Missouri requires that all wells be watertight to the depth necessary to exclude

[3] Detailed information on proper grouting procedures can be found in IGSHPA's *Grouting Procedures for Ground-Source Heat Pump Systems and NGWA's Manual for Water Well Construction Practices* (EPA 570/9/75/001).

contaminants. For GHP systems, Missouri requires full-length grout in some cases, while only recommending it in other cases. Only three types of grout are permitted for use in vertical heat pump wells in Missouri: 1) bentonite slurry, 2) non-slurry bentonite, and 3) other grout if advance approval is granted. Further information on these grouts and grouting procedures can be found in Section 3 of *Grouting Procedures for Ground-Source Heat Pump Systems*, International Ground Source Heat Pump Association, 1991. GHP system installers are specifically held responsible for proper system construction and installation.

The States of Delaware and New Jersey apply existing water well construction regulations to GHP system installations. These regulations address well construction methods and require specific types of grouts for different geologic formations, and prescribe grouting methods that depend on whether or not the well penetrates an aquifer. New Jersey requires cement grout in consolidated geologic formations and bentonite in non-consolidated formations. In Delaware, the only approved grouting materials are also cement and bentonite clay, although there is no indication of specific requirements to use one or the other in different geologic formations.

How do I find out what laws in my state apply to inter-aquifer flow?

(see response Installation Issues, subsection 1)

4. Loop Placement

Boreholes should not be sited near (next to, on top of, or underneath) sources of pollution or contamination, and the site selected should have good surface drainage.

Why should I be concerned about loop placement?

As indicated in the discussions on infiltration and inter-aquifer flow, boreholes in vertical loop systems could act as potential conduits for contaminant migration into groundwater. Potential sources of contamination include commercial fertilizers or chemicals, landfills, lagoons, underground storage tanks, and septic systems. In addition, other opinions suggest that if the borehole is not situated on a site with good surface drainage, contaminated standing water could seep down along the borehole and affect the underlying groundwater.

What are best practices for siting the loop system?

Boreholes should not be located near sources of pollution or contamination. The appropriate distances vary depending on the hydrogeology of the site and the potential pollutants or contaminants. It may be beneficial, however, to locate the loop system upgradient from the pollution source if installation of the system near such an area is unavoidable. Other opinions also recommend that the borehole be sited at a location with good surface drainage, away from low-lying areas where water may pool. [*Missouri Code of State Regulations, 10 CSR 23-5.040*] In general, if GHP specific regulations do not exist, the best solution to siting the loop system is to follow the same guidance and requirements as for drinking water wells.

It is very important to note that the horizontal portion of a vertical loop requires the same degree of care as the placement of a horizontal loop. For more information on practices for placing horizontal loops, see Section II of this document.

What are the regulations that I need to know that affect siting of the loop system?

Regulations to address the siting of closed loop GHP systems (or any GHP system) vary significantly by state. In addition, local regulations and permit conditions may also apply. Some states, such as Missouri, require that GHP system loops be located a specified minimum distance from certain sources of potential contaminants. Other states have no regulatory requirements that apply to GHP system siting. States without requirements that apply specifically to GHP system siting may default to the siting requirements for drinking water wells.

The State of Missouri very specifically defines the minimum distance requirements between GHP boreholes and sources of pollution. These distances vary depending on contaminant. For example, GHP systems must be sited at least 300 feet from storage areas for fertilizers or chemicals, landfills, lagoons, and underground storage tanks; at least 100 feet from below-grade manure storage areas and cesspools; and at least 50 feet from an existing operating well or buried sewer.

How do I find out what laws in my state apply to siting a closed loop GHP system?

(see response Installation Issues, subsection 1)

5. Grouting

Grouting of the borehole simply refers to the refilling of the hole which surrounds the well pipe after it is inserted into the vertical hole. The grout can be the cuttings which were removed from the borehole during drilling, or it can be another material such as sand, cement or bentonite. Depending on the material, the grout can be placed back into the hole in one of two basic methods: top-down, or bottom-up. Each method and grouting material has its own advantages and disadvantages, including degree of environmental protection, effect on system's thermal performance, and cost.

Why should I be concerned about grouting?

In addition to eliminating the physical hazard of the boreholes, there are two reasons to grout boreholes. First, grouting can provide environmental protection. Grouting can prevent surface contamination from infiltrating the aquifer, and also prevent cross-aquifer contamination. Cross-aquifer contamination could result if the borehole penetrates more than one aquifer, and contaminated water from one aquifer flows along the borehole and mixes with clean water from another. Second, grouting can affect the GHP system's thermal efficiency. Certain grouting methods can be more prone to creating air voids around the piping and the grout itself could create voids due to shrinkage as it dries. These pockets of air can decrease the thermal connection between the ground and the heat exchanger. In addition, the thermal conductivity of the grout itself has an effect on the system's efficiency.

Is full-length grouting always necessary?

Several grouts and methods of grouting exist, and they all have tradeoffs in terms of environmental protection, system performance and cost. The decision of which grout to use and how to grout a borehole will be based primarily on local conditions. Because the cost of full-length (top-to-bottom) grouting may affect the overall cost-effectiveness of the decision to install a GHP, it makes sense to know when it is and is not necessary.

From an environmental viewpoint, full length grouting will most likely be necessary when more than one aquifer is penetrated by the borehole, so that both surface and cross-aquifer contamination will be prevented. In contrast, if only one aquifer is penetrated it may only be necessary to grout the top of the borehole to exclude surface contamination. In general, grouting should be performed to the extent dictated by local geologic conditions.

From a technical heat transfer viewpoint, full length grouting using proper grouting materials and placed with the tremie method (bottom-up) will ensure optimal thermal performance of the GHP system. Other methods may be environmentally sound, but could leave air voids around the piping, thus reducing the effectiveness of the ground heat exchanger.

In addition, the thermal conductivity of the grout will have important effects on the overall performance of the system. Some grouts have been found to be insulators, which can negatively affect the performance of the heat pump by preventing an efficient exchange of heat between the ground loop and the soil. A condition called "hot loops" can occur when the ground loop is unable to dissipate heat fast enough to satisfy the cooling load. As a result, grout manufacturers have been working to develop grouts with higher rates of thermal conductivity than the standard bentonite clay grout frequently used. One brand, Thermal Grout 85, is a mixture of bentonite clay and sand that has twice the thermal conductivity of conventional grout, and can reduce the required loop length by 20 to 30 percent and save approximately $200 per ton in installation cost [*Energy Design Update*, pp. 8-9, November 1996]. Other developments with regard to more conductive grouts are also ongoing.

In essence, the decision of full-length grouting will be based primarily on local conditions. Where full-length grouting is unnecessary for environmental reasons, it may make sense to grout only the top of the borehole. However, the system's thermal performance may improve by full-length grouting using a proper grout. The bottom line is that the cost and performance issues discussed above should be weighed relative to other factors on a site-specific basis.

What are the best practices for grouting?

The practice of shoveling (top-down) drill cuttings, sand, or pea gravel into the borehole has been considered by some to be adequate grouting. However, cuttings replaced in the borehole could function as proper grout only if they have been compacted to their original density and placed at the same level and over the same interval from which they had been removed. That is, sand cuttings would have to be returned to the interval in the borehole where the sand originally was drilled, clay returned to the clay layers, etc. Even if this exact replacement of cuttings could be achieved, it would be difficult to ensure that bridging of the cuttings does not occur somewhere in the borehole. Bridging occurs when the cuttings wedge together and form a horizontal layer, or bridge, in the borehole before the space below it is completely filled. This results in potentially large air voids around the piping, and can significantly reduce the effectiveness of the heat transfer.

Another method of grouting is that of placing or leaving drilling mud in the borehole. This method has also been practiced under the mistaken impression that it was a proper grouting technique. Drilling mud is a low solids mixture. It has been shown that the small amount of solids in the mixture will settle to the bottom of the borehole, leaving only water and mud in the upper part of the hole. This water can eventually be lost to the permeable zones of the borehole, resulting in air voids around the piping. Therefore, this method also has the potential to significantly reduce the effectiveness of the heat transfer.

A third method of grouting involves the placement of proper grouting materials using the grout pipe or tremie method (bottom-up). The grout can be made of low permeability cement, bentonite or other mixture. A proper grout for vertical closed loop systems will have the following properties:

- high thermal conductivity to allow heat transfer;
- low viscosity to allow the grout to wrap around the pipe, leaving no voids; and
- low shrinkage volume to ensure that the grout will not pull away from the pipe. [*PA GSHP Manual*, p 3-8]

Using this method will ensure environmental protection as well as maximize the thermal connection between the ground and the heat exchanger. More information on grouting can be found from the International Ground Source Heat Pump Association's (IGSHPA) manual *Grouting Procedures for Ground-Source Heat Pump Systems* and NGWA's *Guidelines for the Construction of Vertical Boreholes for Closed Loop Heat Pump Systems*.

What regulations do I need to know that apply to grouting?

Most states will likely have some sort of regulations regarding grouting. Thermal performance and cost effectiveness issues are usually not addressed in these regulations.

The State of Missouri, for example, has a list of approved grout materials which are permitted for use. The State also recommends full length grouting, and may require it in certain circumstances. The State of Minnesota also has a list of approved grout materials and requires all boreholes to be sealed with the tremie pipe (bottom-up) method.

How do I find out what laws in my state apply to siting a closed loop GHP system?

(see response Installation Issues, subsection 1)

Operation Issues

Closed loop systems use water as the heat exchanging circulating fluid in the outside loop. Antifreeze is sometimes added to protect the fluid from freezing conditions and to extend the operating range of the GHP system. The primary environmental concern related to operation of vertical closed loop GHP systems is potential groundwater contamination resulting from an antifreeze leak in the loop.

1. Antifreeze Solutions

The types of heat exchange solutions used in closed loops vary with designer and contractor preference, local climate conditions, and state and local regulation, but are typically composed of one of the following:

- water;
- potassium acetate and water;
- sodium chloride and water;
- calcium chloride and water;
- ethanol and water;
- methanol and water;
- ethylene glycol and water; or
- propylene glycol and water.

Should I be concerned about the antifreeze used in GHP systems?

The potential environmental impact resulting from a leak in the outside GHP loop is primarily dependent on the toxicity and volume of antifreeze released into the environment. Exhibit 1-2 presents a summary comparison of commonly used GHP antifreeze solutions. The comparison covers the following four characteristics of antifreeze solutions:

- **Toxicity.** The relative ranking of the antifreezes is based on their environmental fate and transport characteristics and toxicity;
- **Heat transfer.** The relative ranking is based on the effectiveness of the antifreeze solution in transferring a given unit of heat;
- **Pump energy.** The relative ranking is based on the energy required to maintain system circulation, based on the viscosity of the antifreeze solution; and
- **Cost.** The relative ranking is based on the cost of the solutions.

Using this exhibit, it is possible to assess the relative trade offs among toxicity, performance and cost. The comparisons are expressed as a percentage of the highest value in each category. Thus, the lower the number, the better. For example, propylene glycol is the least toxic, while methanol is the most toxic. Similarly, calcium chloride has the best heat transfer characteristics, while propylene glycol has the worst.

Exhibit 1-2

Relative Comparison of GHP Antifreeze Solutions

Antifreeze Solution	*Toxicity* [4]	*Heat Transfer*	*Pump Energy*	*Cost*
Organic Compounds				
Propylene Glycol	0.1 (least toxic)	1.0 (worst)	1.0	1.0 (highest cost)
Ethanol	0.8	0.9	0.8	0.4
Methanol	1.0 (most toxic)	0.7	0.7 (least energy)	0.1 (lowest cost)
Ethylene Glycol	0.9	0.8	0.9	0.6
Inorganic Compounds				
Potassium Acetate (KOAc)	0.3	0.8	0.8	0.8
Potassium Carbonate ($K2CO_3$)	0.5	0.6	0.9	0.9
Sodium Chloride (NaCl)	0.4	0.6	0.9	0.2
Calcium Chloride ($CaCl_2$)	0.6	0.6 (best)	1.0 (most energy)	0.3

Sources: Fogg, [1997] and Caneta Research Inc. [1995].

While Exhibit 1-2 presents a relative comparison of GHP antifreeze solutions, the reader should remember that not all GHP systems use antifreeze. In addition, some of the organic antifreezes biodegrade in a matter of days. Even in a worst case scenario, the risk of antifreeze used in GHPs is not likely to be greater than that posed by a septic tank. [Fogg, pg 41] More information on the risks of GHP antifreezes and their properties, including corrosivity and flammability, can be found in the following three documents: Fogg [1997], Heinonen, Tapscott, Wildin and Beall [1997], and Caneta Research Inc. [1995].

How much antifreeze will be lost if a leak occurs and how much damage will it cause?

After assembly, the heat exchange loop is normally tested for leaks. This is typically done hydrostatically at a pressure of 100 psi, for four hours — system pressure under normal operating conditions is usually 20 to 30 psi. If a leak is detected, the defect should be removed and replaced. This ensures the integrity of the loop before being placed into the ground. Once the system is properly installed and operating, the chance of a leak is small to none.

If, however, a leak did occur, the amount of antifreeze lost would be minimal. For example, a GHP system with a cooling capacity of 5 tons has approximately 60 gallons of fluid in the loop heat exchanger. If ethanol were used as the antifreeze, 15 gallons (25%) would be required to produce a 14 F freeze protection. Leakage will typically cause a drop in pressure in the loop, cavitation at the circulating pump,

[4] Based on Fogg [1997].

and system shutdown, resulting in reduced circulation of the fluid. In this circumstance, very little fluid would leak out of the system (e.g., less than 10%).

In a more unlikely scenario, a rupture to the pipe (e.g., due to being hit by a backhoe) could result in a moderate to major loss of fluid. The amount of fluid lost would be dependent on where the cut occurs, and whether the loop is horizontal or vertical. The environmental and human health risks associated with these scenarios are dependent on a variety of factors and are evaluated in Fogg [1997].

What are the best practices to minimize potential exposure to antifreeze and minimize potential groundwater contamination?

Many antifreeze agents are harmful to people in varying degrees. However, with proper handling methods, the risks of exposure can be reduced or eliminated. Factors affecting the risks associated with exposure to antifreeze include degree of toxicity, nature of toxic effects, and likelihood and duration of exposure. The most common pathway for exposure to antifreeze solution is during the installation or maintenance of the system. Workers may inhale antifreeze-contaminated dust or vapors, or the antifreeze may come into contact with a worker's skin or eyes. Using protective measures such as masks and protective clothing will virtually eliminate these dangers.

A leak in the heat exchanger piping will allow the antifreeze to escape into the ground. Human exposure may result if the antifreeze enters the groundwater and migrates to wells and lakes. Following the pipe manufacturer's installation and testing procedures will minimize the possibility of leaks. In the unlikely event that a leak develops, use of an approved antifreeze will limit toxicity concerns. More detailed information on the immediate, long-term, and environmental concerns of exposure to antifreeze solutions can be found in the *Commercial/Institutional Ground-Source Heat Pump Engineering Manual, Appendix B, Assessment of Anti-Freeze Solutions for Ground-Source Heat Pump Systems*, and Fogg [1997].

In general, the safest approach for the environment and from a liability perspective is to use the least toxic antifreeze available that will do the job.

What regulations do I need to know that apply to use of antifreeze in vertical closed loop GHP systems?

Regulations on use of antifreezes in GHP systems range from very specific listings of acceptable antifreezes and their required properties to no regulations at all. Performance and toxicity trade-offs are not addressed in these regulations.

For example, the State of Missouri allows only pure glycerin solution, food grade propylene glycol, dipotassium phosphate, sodium chloride, potassium acetate, methanol or ethanol to be used. The State of New Jersey regulates antifreeze use through its permit program, and has approved six types of antifreezes. The State of Minnesota, however, does not generally regulate residential GHP systems, although for commercial systems, the only acceptable antifreeze solution is food grade propylene glycol. On the other end of the spectrum, some states do not regulate antifreezes in GHP systems, except implicitly through penalties for groundwater contamination.

How do I find out what laws in my state apply to use of antifreeze in vertical closed loop GHP systems?

(see response Installation Issues, subsection 1)

Decommissioning Issues

Unsealed or improperly sealed boreholes may threaten public health and safety, and the quality of groundwater resources. Therefore, the proper abandonment (decommissioning) of boreholes is a critical final step in their service life. [*PA, 7.1*]

Proper GHP abandonment accomplishes the following: 1) eliminates the physical hazard of the well (the hole in the ground), 2) eliminates a pathway for migration of contamination, and 3) prevents hydrologic changes in the aquifer system, such as the changes in hydraulic head and the mixing of water between aquifers. The proper decommissioning method will depend on both the reason for abandonment and the condition and construction details of the borehole or well.

Why should I be concerned about decommissioning vertical closed loop GHP systems?

Most states regulate procedures for abandoning wells. In addition, many states make it the responsibility of a well owner to properly seal an abandoned well. Improperly decommissioned or abandoned wells may result in future groundwater contamination and create physical hazards. Most states do not specifically regulate the decommissioning of GHP systems, instead applying water well regulations.

What are best practices for decommissioning vertical closed loop GHP systems?

Based on Missouri well construction rules [*Miscellaneous Publication No. 50*], the basic decommissioning procedure of GHP wells involves two steps:

1) Pump out the heat transfer fluid (antifreeze); and

2) Seal the borehole with grout, or other approved material.

What regulations do I need to know that apply to decommissioning vertical closed loop GHP systems?

Most states regulate the decommissioning of drinking water and other wells. Hence, most states have applied the requirements for water well decommissioning to GHP decommissioning when they have addressed the GHP issue.

The *State of Delaware* requires that all abandoned wells be fitted so that they will not produce water, act as a conduit for the interchange of good and poor quality water, or present a hazard to the safety and well being of people and animals. Delaware does not specifically address decommissioning GHP systems, and it is unclear whether they would be affected by existing statutes and regulations. The *State of New Jersey* is very specific and aggressive in addressing decommissioning of wells. New Jersey is also in the process of promulgating new regulations that specifically address GHP systems, so it is likely that decommissioning of GHP systems will be addressed after the proposed rule becomes final. The *State of Missouri* regulates decommissioning of GHP systems and requires that heat transfer fluid be pumped out of the system and the borehole be sealed. It is important to note that the tops of boreholes will not be dug up as part of decommissioning; rather, the bores are properly sealed when originally installed. In addition, the process of "pumping out" antifreeze actually is accomplished by water displacement. Because this is a rapidly evolving field, however, state authorities should be consulted on the proper regulatory requirements for decommissioning.

How do I find out what the laws in my state apply to decommissioning vertical closed loop GHP systems?

(see response Installation Issues, subsection 1)

Section II
Horizontal Closed Loop Systems and Related Environmental Issues

Section II
Horizontal Closed Loop Systems and Related Environmental Issues

Introduction

System Description

Closed loop GHP systems rely on the contained circulation of fluids through an underground loop of pipes, which act as a heat exchanger by transporting heat to or from the ground. Horizontal loops are typically installed in narrow trenches, about 5 feet deep, and up to several thousand feet long. Trenches should be located sufficiently far away from the house so that any freezing surrounding the pipe does not affect the foundation. The heat exchange fluid used is water. Antifreeze is often added to the water to enable the system to function at temperatures below 32 degrees Fahrenheit. [*PA GSHP Manual*, pp 2-4 & 3-3]

Key Environmental Issues

The primary environmental concern associated with horizontal closed loop systems is groundwater contamination resulting from antifreeze leaks that could migrate to the groundwater. Because of the potential for groundwater contamination, care should be taken at each stage of the GHP system life cycle — installation, operation and decommissioning — to avoid unnecessary environmental risks. Exhibit 2-1 provides an overview of the regulations and best management practices associated with the environmental issues relevant to each life cycle phase.

Overview of Regulatory Approaches

There are very few regulations that apply to horizontal closed loop GHP systems. The various opinions on regulations and best management practices for horizontal closed loop GHP systems are presented in this section.

Exhibit 2-1

Overview of Environmental Concerns, Corresponding Regulations and Best Management Practices That Apply to Horizontal Closed Loop GHP Systems

Environmental Issue	*Regulations*	*Best Management Practices*
Installation		
• Sediment and storm water runoff from the site	• Generally exempt from regulations.	• Ensure that disturbed soil is seeded to reduce risk of runoff.
• Backfilling the trench	• No regulations exist currently.	• Ensure that no sharp rocks are in contact with the pipe, and ensure that the backfill is compacted so that it contains no air voids.
• Loop placement	• Regulations generally specify distances necessary between heat pump loop and areas of existing and potential pollution including septic fields. In addition, distances are specified when loop intersects other underground piping.	• Refer to your state and local requirements for placement of drinking water wells. In addition, locate loop at least 2 feet from any other intersecting underground piping. See page II-5 for further explanation of loop placement concerns.
Operation		
• Antifreeze solutions	• Regulations range from very specific listings of acceptable antifreezes and the properties they must possess, to no regulations at all.	• Choose antifreeze for low toxicity, high heat transfer, and low viscosity. By far, the greatest risk of exposure comes from handling antifreeze solutions — use masks and protective clothes during installation or maintenance of the system. • To reduce potential for leaks in the system, follow the pipe manufacturer's installation and testing procedures.
Decommissioning		
• Potential for ground contamination	• While regulations exist for the decommissioning of vertical closed loop heat pump wells, no regulations currently exist for horizontal closed loop heat pump systems.	• Pump out the heat transfer fluid and ensure loop location is labeled.

Installation Issues

There are three environmental issues that are related to the installation of horizontal closed loop systems. They are:

1. Sediment and storm water runoff from the site;
2. Backfilling the trench; and
3. Loop placement.

1. Sediment and Storm Water Runoff From the Site

Installation of horizontal closed loop GHP systems requires that temporary trenches be dug, resulting in temporary removal of soil from the trenches. This soil may be left adjacent to the trench and regraded, or removed from the site. If the soil is left on-site, use care to ensure that the soil doesn't migrate to nearby surface waters or sewers.

Why should I be concerned about sediment and storm water runoff from the site during horizontal closed loop GHP system installation?

Eroded soil migrating offsite can temporarily foul streams, and clog storm sewers. Proper soil containment can minimize soil erosion and potential impacts on streams and sewers, reduce potential for citizen or government complaints, as well as improve project aesthetics during and after development. [*VA Erosion and Sediment Control Handbook*, pg I-1]

What are the best management practices to minimize the potential for sediment and storm water runoff during horizontal closed loop GHP system installation?

There are two basic requirements that a best practice must satisfy. First, it must meet state and local regulatory and permit requirements. Second, it must prevent erosion, especially water erosion, of exposed soil. Typically construction sites require that exposed soil be covered or that a runoff control barrier be erected. However, most residential GHP installations result in little soil disturbance and the soil that is disturbed is usually exposed for only a very short period of time (i.e., less than 24 hours). Hence, the best management practice under these circumstances is to seed the disturbed soil upon completion of the installation.

What regulations do I need to know that apply to sediment and storm water runoff from the site during horizontal closed loop GHP system installation?

In general, single family residences are exempt from sediment and storm water regulations when small areas of land are disturbed. It is prudent, however, to check state and local permit conditions. The State of Missouri, for example, excludes single family residences and heat pump wells from the State's storm water operating permit program under the Missouri Clean Water Law, and also exempts from sediment and storm water controls all projects disturbing less than five acres and trenches two feet in width or less. The States of New Jersey and Delaware have similar regulatory exemptions for storm water runoff from residential property.

How do I find out what laws in my state apply to sediment and storm water runoff during horizontal closed loop GHP system installation?

State laws and regulations are evolving constantly. You should, therefore, contact appropriate officials in your state, as identified in Appendix B. The National Ground Water Association (NGWA) or the National Rural Electric Cooperative Association (NRECA) can also provide a list of state officials that oversee implementation of relevant laws and regulations in each state.

2. Backfilling the Horizontal Loop Trench

After the horizontal ground loop system has been installed, tested, and charged, the trench is backfilled (filled in), usually with the soil that was removed from the trench originally. If the soil is not replaced properly, heat transfer may be poor (thus reducing the efficiency of the system), or the pipe could be broken or otherwise damaged, thereby creating the potential for environmental contamination due to leaking antifreeze.

Why should I be concerned about backfilling the horizontal loop trench?

The soil must be backfilled into the trench carefully so that it has good contact with the loop system to ensure effective heat transfer. However, if sharp rocks are present in the soil, they may puncture or otherwise damage the pipe. Ensuring that the trench is backfilled carefully and effectively is a critical step in horizontal GHP system installation, and must be done properly to ensure that the GHP system realizes the technical and economic efficiency for which it was designed.

What are best practices for backfilling the horizontal loop trench?

When backfilling a horizontal loop, the installer should ensure that no sharp rocks come into contact with the pipe. The contractor may need to place a bed of sand or limestone "crackerdust" at the bottom of the trench to insulate the pipe from rocky soil while providing a conductive medium. Sand also may be required to surround the entire pipe before the native soil is returned to the trench. Compaction machinery may be necessary to develop good contact between the soil and the pipe. [*PA*, pg 3.8.1]

A new approach in some states (e.g., Pennsylvania) is to use flowable backfill that surrounds the pipe in the trench. Flowable backfill has the advantage of complete contact of a highly conductive material with the pipe. The backfill material typically consists of water, sand, and cement. Virginia Power has been using this approach for the past few years, incorporating the accumulated fly ash from its facilities.

In addition, a tracer wire should be buried at a 6 inch depth for easy location of the horizontal loop with a metal detector. The end of the wire should be brought through the foundation wall and terminated. The tracer wire also serves as a warning to future backhoe digging which can help prevent catastrophic leaks from the system. [*Manual of Acceptable Practices for Installation of Residential Earth-Coupled Heat Pump Systems*, pg 18]

What regulations do I need to know that apply to backfilling a horizontal loop trench?

There are currently no Federal regulations addressing the issue of acceptable backfilling approaches. State and local laws, regulations and permit conditions may vary, and should be reviewed prior to backfilling.

How do I find out what laws in my state apply to backfilling the horizontal loop trench?

(see response Installation Issues, subsection 1)

3. Loop Placement

Horizontal loop systems need enough uninterrupted horizontal space to enable effective heat transfer to take place. Beyond this generic requirement, the most important factor in horizontal loop placement is to avoid locating it near (next to, on top of, or underneath) sources of pollution or contamination, or other underground pipes. In addition, the loop system should be located a sufficient distance from houses so that any freezing surrounding the pipe does not affect their foundations.

Why should I be concerned about placement of horizontal closed loops?

Horizontal trenches with gravel bases could act as potential conduits for contamination migration. Potential sources of contamination include commercial fertilizers or chemicals, landfills, lagoons, underground storage tanks, and septic systems. In addition to acting as a potential conduit for sewage, disturbing the soil underneath a septic bed can lead to inadequate treatment of sewage. Also, heat from the pipes can increase biological growth in the septic tanks, which could lead to costly septic system repairs. Moreover, repair of sewer pipes or the septic system would require excavation of the horizontal loop system; alternatively, repair of the horizontal loop system would require excavation of the sewer or septic system, thus increasing dramatically the cost of repairs for either system. [*PA*, pg 3.10.1] Finally, a horizontal GHP loop located too close to another underground pipe could result in the freezing and potentially bursting of that pipe.What are best practices for placement of a horizontal closed loop GHP system?

While the potential for a trench to act as a conduit for contamination is typically not a major concern, it could be if the trench intersects groundwater or leads to a sensitive area. It is best to avoid bringing potential sources of contamination into the installation area and locate the trenches far enough away from potential sources of contamination so as to avoid this threat. Horizontal GHP loops should never be located underneath a septic bed and should be at least two feet above or below any other intersecting underground piping or wiring (except for a soaker pipe which may be used in conjunction with the system to keep the soil moisture constant.) If placement of a horizontal loop GHP near a source of pollution is unavoidable, it should be located a certain distance away upgradient from the contamination source.

What regulations do I need to know that apply to placement of a horizontal closed loop GHP system?

While some states regulate the distances GHP loops need to be from potential areas of contamination, others do not. In addition, local regulations and permit conditions may apply.

For example, the State of Missouri regulates the distance between a horizontal GHP loop and any other intersecting pipes. While the State of Pennsylvania does not generally regulate residential GHP systems, they do produce a guidance document which recommends keeping GHP loops away from septic fields and other sources of potential contamination. The State of Delaware has no regulations that apply to placement of horizontal GHP systems. The State of New Jersey is considering comprehensive GHP regulations that may regulate placement of horizontal GHP systems when the rule becomes final.

How do I find out what laws in my state apply to placement of a horizontal closed loop GHP system?

(see response Installation Issues, subsection 1)

Operation Issues

Horizontal and vertical closed loop systems are virtually identical with respect to their operations. They therefore share the same primary environmental concern, namely the potential for groundwater contamination resulting from an antifreeze leak in the loop. See Operation Issues in Section I, for a full discussion of antifreeze related issues.

Decommissioning Issues

An unused and undrained horizontal loop may deteriorate and eventually leak antifreeze and ultimately contaminate groundwater. Even more importantly, the loop location may be lost over time and future construction could rupture the loop, resulting in a total leak of antifreeze solution. This potential for leakage poses a threat to the environment, especially the quality of groundwater resources, that is at worst comparable to that of a "lost" septic system. More detailed information on the immediate, long-term, and environmental concerns of exposure to antifreeze solutions can be found in the *Commercial/ Institution Ground-Source Heat Pump Engineering Manual, Appendix B, Assessment of Anti-Freeze Solutions for Ground-Source Heat Pump Systems,* and Fogg [1997]. Therefore, the proper abandonment (decommissioning) of a horizontal system is a critical final step in its service life. [*PA*, pg 7.1]

Why should I be concerned about decommissioning horizontal closed loop GHP systems?

While little is written about the decommissioning of horizontal loop systems, it is prudent to remove all loop fluid when shutting down the system. Even in a system not in use, the potential exists for a leak or rupture to occur that would allow the antifreeze to escape. If pollution occurs, the system owner may be liable for cleanup of the soil and/or aquifer.

What are best practices for decommissioning a horizontal closed loop GHP systems?

Pump out the antifreeze solution from the system and either reuse it in a different system, recycle it, or dispose of it properly.

What regulations do I need to know that apply to decommissioning a horizontal closed loop GHP systems?

Most states and local jurisdictions do not appear to regulate decommissioning of horizontal closed loop GHP systems. Check with state and local authorities to determine whether any requirements apply. The State of Missouri regulates decommissioning of GHP systems and requires that antifreeze solutions be removed from the system. New Jersey and Delaware currently do not regulate decommissioning of horizontal GHP systems.

How do I find out what laws in my state apply to decommissioning a horizontal closed loop GHP systems?

(see response Installation Issues, subsection 1)

Section III
Open Loop Systems
and Related Environmental Issues

Section III
Open Loop Systems and Related Environmental Issues

Introduction

System Description

Open loop GHP systems, also known as groundwater heat pump systems, typically depend upon groundwater as a source or sink of heat. Unlike closed loop systems, open systems do not confine the heat exchange fluid to a loop of pipes. Rather, open systems pump water from a well, pass it through the heat pump, and then discharge it. Although surface water can be used, most open systems rely on groundwater. The used water is discharged to surface waters, discharged to a buried drain field, or reinjected into the aquifer. The water supply well must yield enough water to transport the required amount of heat, and the discharge medium must be of sufficient size to accept the discharged water. [*PA GSHP Manual*, pg 4-1]

Because the boreholes for open loop systems function like wells, the term "well" is used interchangeably with "borehole" in this section.

Key Environmental Concerns

The key environmental concerns associated with vertical open loop systems are:

- Improperly constructed wells or boreholes could serve as channels of contamination from the surface to the subsurface, or from one aquifer to another;
- The rate at which water is pulled from the aquifer may affect a groundwater supply; and
- Environmental problems resulting from the rate at which water is discharged (e.g., runoff, erosion, thermal impacts).

Because of these potential problems, care should be taken at each stage of the GHP system life cycle — installation, operation and decommissioning — to avoid unnecessary environmental risks. [*PA GSHP Manual*, pg 5-1]

Overview of Regulatory Approaches

While there are differing views on how to regulate vertical open loop GHP systems, the prevalent view is to treat GHP systems as drinking water wells. When water is reinjected into the aquifer, most states require that the injection wells be inventoried through their UIC regulations. Therefore, the appropriate state UIC representative should be contacted. A list of state UIC representatives can be found in Appendix B. The various opinions on regulations and best management practices for vertical open loop GHP systems are presented in this section.

Exhibit 3-1

Overview of Environmental Concerns, Corresponding Regulations and Best Management Practices That Apply to Open Loop Systems

Environmental Issue	*Regulations*	*Best Management Practices*
Installation		
• Sediment and storm water runoff from the site	• Generally exempt from regulations.	• Ensure that disturbed soil is seeded to reduce risk of runoff.
• Surface contaminant infiltration along the borehole	• Sealing the top of the borehole and other precautions to prevent contamination on the surface from entering the borehole are usually regulated.	• During construction, the area surrounding the well should be maintained in a clean condition and surface drainage should be diverted away from the well. • The top of the well casing should be sealed. [For more information, see *Manual of Water Well Construction Practices*, EPA 570/9-75-001, pg 77.]
• Inter-aquifer flow	• Regulations apply to borehole diameter and length, and grout materials and methods. • Installers may also be responsible for the integrity of the annular seal for a specified period of time.	• Refer to your state and local requirements that apply to drinking water wells or specifically to GHP systems.
• Borehole placement	• Regulations generally specify distances necessary between water well location and areas of existing and potential pollution including septic fields.	• Refer to your state and local requirements for placement of drinking water wells.
Operation		
• Water withdrawal	• Regulations vary in dealing with water withdrawal, but generally do not regulate the small volumes that are associated with residential GHP systems.	• The yield of the aquifer should be assessed and an assessment of use should be made to avoid problems associated with aquifer draw down.
• Water disposal	• Surface disposal may be regulated if the drainage leaves the landowner's property, and may require a NPDES permit if discharge enters surface waters. Disposal to sanitary sewers may be prohibited by local ordinances. • Subsurface disposal may be regulated under the UIC program, though GHPs are considered a very small risk and usually not regulated. Most states, however, do require that injection wells be inventoried through their UIC regulations. Therefore, the appropriate state UIC representative should be contacted (see Appendix B).	• For surface disposal, ensure drainage occurs in a manner that does not result in soil erosion. Also, the disposal method must be compatible with the volume of water that will be discharged and be able to handle extreme weather conditions (i.e., freezing). • For vertical and horizontal subsurface disposal, ensure the well/drain is of sufficient diameter and depth to accept the maximum discharge from a system. In addition, horizontal subsurface drains must be deep enough to avoid freezing in the winter.

Environmental Issue	*Regulations*	*Best Management Practices*
Operation (cont.)		
• Thermally altered discharge water	• For surface disposal, heat is categorized as a pollutant under NPDES. However, states either do not regulate GHP systems or the volumes and temperatures generated by residential systems are less than what is regulated.	• Well must be of sufficient diameter and depth to accept the maximum discharge from a system (prevents eventual clogging due to the precipitation of minerals resulting from the temperature change). • For subsurface disposal, large GHP systems could introduce a thermal plume that could affect another well. The potential for this should be assessed during the design of a large system.
Decommissioning		
• Physical hazard of the well and pathway for migration of contamination	• Regulations generally state that all abandoned wells shall be fitted in such a way that they will not produce water or act as a conduit for the interchange of waters of undesirable quality with those whose quality is desirable, or present a hazard to the safety and well being of people and animals. Often, it is the responsibility of the well owner to properly seal an abandoned well.	• Follow state and local regulations for decommissioning drinking water wells, but generally clear the borehole of any obstructions. Seal the borehole with grout.

Installation Issues

Much of this section parallels information from Section I. It is repeated here for the reader's convenience. There are four environmental issues related to the installation of a open loop GHP systems:

1. Sediment and storm water runoff from the site;
2. Surface contaminant infiltration along the borehole;
3. Inter-aquifer flow; and
4. Borehole placement.

1. Sediment and Storm Water Runoff From the Site

Installation of open loop GHP systems requires that a well be drilled, resulting in removal of soil or rock from the hole. This soil may be left adjacent to the borehole and regraded, or removed from the site. If the soil is left on-site, use care to ensure that the soil doesn't migrate to nearby surface waters or sewers.

Why should I be concerned about sediment and storm water runoff from the site during installation of open loop GHP systems?

Eroded soil migrating offsite can temporarily foul streams, and clog sewers. Proper soil containment can minimize soil erosion and potential impacts on streams and sewers, reduce potential for citizen or government complaints, as well as improve project aesthetics before, during, and after development. [*VA Erosion and Sediment Control Handbook*, pg I-1]

What are the best practices to minimize the potential for sediment and storm water runoff from the site during installation of open loop GHP systems?

There are two basic requirements that a best practice must satisfy. First, it must meet state and local regulatory and permit requirements. Second, it must prevent erosion, especially water erosion, of exposed soil. Typically construction sites require that exposed soil be covered or that a runoff control barrier be erected. However, most residential GHP installations result in little soil disturbance and the soil that is disturbed is usually exposed for only a very short period of time (i.e., one or two days). Hence, the best management practice under these circumstances is to seed the disturbed soil upon completion of the installation. If the disturbed soil will be exposed for a lengthy period of time, then another measure may need to be implemented. For example, at Fort Polk, where over 8,000 bore holes were recently installed, the Louisiana environmental agency had the drillers use large holding tanks for the drilling mud in order to avoid problems associated with erosion and runoff.

What regulations do I need to know that apply to sediment and storm water runoff from the site during installation of open loop GHP systems?

In general, existing single family residences are exempt from sediment and storm water regulations when small areas of land are disturbed. The State of Missouri, for example, excludes single family residences and heat pump wells from the State's storm water operating permit program under the Missouri Clean Water Law, and also exempts from sediment and storm water controls all projects disturbing less than five acres and trenches two feet in width or less. The States of New Jersey and Delaware have similar regulatory exemptions for storm water runoff from residential property.

How do I find out what laws in my state apply to sediment and storm water runoff from the site during installation of open loop GHP systems?

State laws and regulations are evolving constantly. You should, therefore, contact appropriate officials in your state, as identified in Appendix B. The National Ground Water Association (NGWA) or the National Rural Electric Cooperative Association (NRECA) can also provide a list of state officials that oversee implementation of relevant laws and regulations in each state.

2. Surface Contaminant Infiltration Along the Borehole

Aquifer contamination can occur when boreholes are drilled in an unconfined water table aquifer. As with any well, downward leakage from the surface can occur along ungrouted or uncased boreholes, polluting the water table aquifer with surface contaminants. [*Grouting Procedures for Ground-Source Heat Pump Systems*, pg 2]

Why should I be concerned about infiltration of surface contaminants along the borehole?

Infiltration of surface contaminants can directly or indirectly contaminate the groundwater, depending on the depth of the water and local hydrogeologic conditions. Groundwater is often a source for drinking water and, if contaminated, may be rendered unfit to drink. Further, in some states owners of wells or other boreholes may be legally and economically liable for potential damage to the aquifer.

What are the best practices to prevent infiltration of surface contaminants along the borehole?

To minimize the risks of infiltration along the borehole, care should be taken to maintain a clean site while drilling the hole, and afterwards, the well should be completed according to local regulations, or following IGSHPA or NGWA practices.[5] In general, the well water community and many states consider sealing the top of the borehole to be the preferential method of segregating surface contamination from groundwater.

What regulations do I need to know that apply to infiltration of surface contaminants along the borehole?

Many states require that drinking water wells be drilled only by licensed water well drillers. Because open loop GHP systems are very similar to drinking water wells, they are often regulated under the same rules. Regulations addressing methods for preventing surface contamination of boreholes vary significantly by state and even local jurisdiction. In general, the preferred method in states with regulations is to seal the top of the borehole.

Because many types of grouts and placement methods exist, it is best to determine the specific requirements for acceptable types of grout and application methods in your state. If there are no GHP specific regulations that address this, follow state regulations that apply to water well construction. Although Missouri, New Jersey and Delaware do not address requirements for preventing infiltration along the borehole in the context of GHP systems, they do recommend highly, and in some cases require, that boreholes be grouted.

[5] Detailed information on proper grouting procedures can be found in IGSHPA's *Grouting Procedures for Ground-Source Heat Pump Systems* and NGWA's *Manual for Water Well Construction Practices* (EPA 570/9/75/001).

How do I find out what laws in my state apply to infiltration of surface contaminants along the borehole?

(see response Installation Issues, subsection 1)

3. Inter-aquifer Flow

While drilling boreholes for the installation of open loop geothermal heat exchangers, it is possible to penetrate one or more aquifers. When two aquifers are penetrated, a path exists for the waters of the two to mix. If one of the aquifers is contaminated or contains non-potable water, the other aquifer will also become contaminated.

Why should I be concerned about inter-aquifer flow?

Uncontaminated groundwater is one of our most precious natural resources. Preventing inter-aquifer flow is essential to preserving the purity of uncontaminated aquifers and sealing off formations that are known to be contaminated. Moreover, in most states there are regulations that apply to this issue; thus owners and operators of boreholes may be liable for civil or criminal penalties if they ignore regulatory requirements.

What are the best practices to prevent inter-aquifer flow?

The formations which yield polluted water or water of an undesirable quality must be adequately sealed off to prevent pollution or contamination of the overlying or underlying water-bearing zones. There are several ways to prevent inter-aquifer flow, and practices vary regionally. One practice is to grouting the full length of the borehole using the grout pipe (tremie) method[6]. Another is that grouting at least 10 feet above and below the affected aquifers is sufficient. Other methods, such as sleeves, packers, and other devices, are also employed to prevent inter-aquifer flow.

What regulations do I need to know that apply to inter-aquifer flow?

Open loop GHP system boreholes are essentially the same as potable water wells, hence most states apply their water well drilling regulations to GHP system boreholes. Regulations addressing methods for preventing inter-aquifer flow vary by state and even local jurisdiction. GHP system installers should follow state and local regulations that apply to grouting water wells (or those regulations that pertain specifically to GHP systems).

For example, the State of Missouri addresses inter-aquifer flow through its domestic water well standards. The standards require casing for permanent wells and states that all wells be watertight to the depth necessary to exclude contaminants. This protection is achieved through grouting and four types of grout are permitted for use: 1) neat cement grout, 2) bentonite grout, 3) bentonite slurry grout, and 4) other grout if advance approval is granted. GHP system installers are specifically held responsible for proper system construction and installation.

The States of Delaware and New Jersey also apply existing water well construction regulations to GHP system installations. These regulations address well construction methods and require specific types of

[6] Detailed information on proper grouting procedures can be found in IGSHPA's "Grouting Procedures for Ground-Source Heat Pump Systems and NGWA's Manual for Water Well Construction Practices " (EPA 570/9/75/001).

grouts for different geologic formations, and prescribe grouting methods that depend on whether or not the well penetrates an aquifer. New Jersey requires cement grout in consolidated geologic formations and bentonite in non-consolidated formations. In Delaware, the only approved grouting materials are also cement and bentonite clay, although there is no indication of specific requirements to use one or the other in different geologic formations.

How do I find out what laws in my state apply to inter-aquifer flow?

(see response Installation Issues, subsection 1)

4. Borehole Placement

Boreholes should not be sited near (next to, on top of, or underneath) sources of pollution or contamination, and the site selected should have good surface drainage.

Why should I be concerned about borehole placement in open loop GHP systems?

As indicated in the discussions on infiltration and inter-aquifer flow, boreholes in vertical open loop systems could act as potential conduits for contaminant migration into groundwater. Potential sources of contamination include commercial fertilizers or chemicals, landfills, lagoons, underground storage tanks, and septic systems. In addition, if the borehole is not situated on a site with good surface drainage, contaminated standing water could seep down along the borehole and affect the underlying groundwater.

What are best practices for siting the borehole in an open loop GHP system?

A borehole should be sited at a location with good surface drainage, away from low-lying areas where water may pool. In addition, wells should not be located near sources of pollution or contamination. The appropriate distances vary depending on the hydrogeology of the site and the type of potential pollutants or contaminants. It may be beneficial, however, to locate the loop system upgradient from the pollution source if installation of the system near such an area is unavoidable. In general, the best solution to siting an open loop system is to follow the same guidance and requirements as for drinking water wells.

What regulations do I need to know that apply to borehole placement in an open loop GHP system?

Open loop GHP system supply boreholes are no different from drinking water wells, hence most states apply their water well drilling regulations to the placement of GHP system boreholes. Note that discharge wells are different from water wells, but similar. The regulations vary significantly by state. In addition, local regulations and permit conditions may also apply. Some states, such as Missouri, have regulations that apply to GHP system siting that provide for minimum distances from specific sources of potential contaminants. Other states have no regulatory requirements that apply to GHP system siting. States that do not have requirements that apply specifically to GHP system siting usually default to the siting requirements for drinking water wells.

The State of Missouri very specifically defines the minimum distance requirements between GHP wells and sources of pollution. These distances vary depending on contaminant. For example, GHP systems must be sited at least 300 feet from storage areas for fertilizers or chemicals, landfills, lagoons, and underground storage tanks; at least 100 feet from below-grade manure storage areas and cesspools; and at least 50 feet from an existing operating well or buried sewer. The State of Delaware requires that water withdrawn from an aquifer for an open loop GHP system be reinjected back into the same aquifer, and that reinjection (recharge) wells be constructed at least 50 feet from any source of pollution, including septic tanks, tile fields, and manure piles.

How do I find out what laws in my state apply to borehole placement in an open loop GHP system?

(see response Installation Issues, subsection 1)

How do I know when grouting of the borehole is necessary?

The primary reason to grout boreholes is to provide environmental protection. Grouting prevents surface contamination from infiltrating the aquifer, and also prevents cross-aquifer contamination. This could result if the borehole penetrates more than one aquifer, and contaminated water from one aquifer flows along the borehole and mixes with clean water from another.

Site-specific factors will determine when and what type of grouting will be most appropriate. Because the cost of full-length (top-to-bottom) grouting may affect the overall cost-effectiveness of the decision to install a heat pump, it makes sense to know when it is and is not necessary. Full length grouting will most likely be necessary when more than one aquifer is penetrated by the borehole, so that both surface and cross-aquifer contamination will be prevented. In contrast, if only one aquifer is penetrated, it may only be necessary to grout the top of the borehole to exclude surface contamination. In general, grouting should be performed to the extent dictated by local geologic conditions.

Operation Issues

There are three environmental issues related to the operation of vertical open loop GHP systems. They are:

1. Water withdrawal;
2. Water disposal; and
3. Thermally altered discharge water.

1. Water Withdrawal

Open loop GHP systems usually withdraw water from underground aquifers to use as a heat transfer fluid. This water is then either reinjected into the aquifer or discharged to the surface.

Why should I be concerned about water withdrawal?

Legal and environmental considerations on water withdrawal may have an effect on homeowners using open loop GHP systems. Legally, homeowner rights to withdraw groundwater differ considerably among states and local jurisdictions. Perhaps the most significant difference is between jurisdictions in the relatively wet eastern half of the United States and jurisdictions in the relatively arid western half of the United States. Even within the wet portion of the country, homeowner water withdrawal rights may differ significantly between states and local jurisdictions.

In addition to legal considerations, there are environmental considerations related to the issue of the recharge capacity of the local aquifer. If water is withdrawn from the aquifer at a faster rate than it can be replenished, the level of water in the aquifer will begin to diminish. Should this occur, some wells may experience reduced water flows, which, if severe enough may render the open loop GHP system much less efficient or inoperable.

What are best practices for water withdrawal?

A hydrogeological investigation of the site should be performed by a qualified professional, such as a hydrogeologist, to assess the groundwater resource. [*Caneta Research Inc.*, pp 2-3] Depending on the climate and hydrogeology of the region, aquifer recharge rates may be very slow or quite rapid. Common sense dictates that in areas with relatively slow recharge rates, water should be withdrawn at a slower rate; and in areas with more rapid recharge rates, water may be withdrawn at a faster rate. For more information please refer to Caneta Research Inc.'s *Commercial/Institutional Ground-Source Heat Pump Engineering Manual.*

What regulations do I need to know that apply to water withdrawn for open loop GHP systems?

Most states do not regulate the small volumes of water withdrawn in residential open loop GHP systems. Western states may be more likely to regulate water withdrawal because of generally arid conditions. Because open loop GHP systems operate like drinking water wells, the same state and local regulations will most likely be applied.

The State of Missouri does not regulate water withdrawal for residential GHP systems. New Jersey does not require water withdrawal permits unless the well owner exceeds, has permitted capacity to exceed, or claims a right to exceed withdrawal of 100,000 gallons or more per day. The State of Delaware does not regulate water withdrawal for GHP systems that use less than 50,000 gallons per day. By comparison, it is unlikely that any residential GHP system would withdraw more than 20,000 gallons per day, even under the most extreme circumstances.

How do I find out what laws in my state apply to water withdrawn for open loop GHP systems?

(see response Installation Issues, subsection 1)

2. Water Disposal

Water withdrawn for circulation through open loop GHP systems is disposed of through one of two methods:

I) Surface Disposal; or

II) Subsurface Disposal.

Because of the expense involved in the construction of a second (return) well, the installer may prefer surface or near surface disposal methods. However, many situations will not allow these methods. [*PA, 4.4*]

I. Surface Disposal

Surface disposal (or discharge) is generally the easiest method for disposing of the groundwater that has passed through an open loop GHP system. The disposal locations typically include on-site or off-site ponds, streams, or other bodies of water. Each disposal method poses its own environmental and operational advantages and disadvantages. [*PA, 4.4.*1]

Why should I be concerned about surface disposal of water from open loop GHP systems?

Water from open loop GHP systems may be discharged to a public surface water body, such as a lake or stream; depending on state requirements, however, this action may require a permit under the National Pollutant Discharge Elimination System (NPDES) for the discharge. The method of conveyance from point of discharge to the receiving body of water must be secure to avoid problems with erosion and sedimentation, which can impact the stream or lake. Additional problems may occur in the winter because of freezing conditions. For example, if the lake or stream is frozen over, discharge water may flood nearby areas. Further, as discussed above, long-term impacts to groundwater levels are possible if the rate of water withdrawal from an aquifer exceeds its rate of recharge.

Water may be channeled to a private, on-site collection basin where it infiltrates into the ground. This type of disposal is generally successful only where the basin bottom is composed of highly permeable sands and gravels. Otherwise, infiltration tends to be too slow. Along with silting, microbial and bacterial plugging are the chief causes of permeability reduction, and periodic maintenance must be done to clean the basin. Basins also require large areas of property, although disposal to a private basin would not require a permit. [*PA, 4.4.*1]

Disposal to sanitary sewers is often prohibited by local ordinances. Such discharges can lower a sewage treatment plant's efficiency, thereby raising operating costs. [*PA, 4.4.*1]

It is very important to understand that surface disposal may not be advisable in areas where groundwater depletion may occur. In such situations, aquifer recharge should be seriously considered. Local knowledgeable professionals, such as hydrogeologists, should be consulted on the advisability of water withdrawal and discharge.

What are best practices for surface disposal of water from open loop GHP systems?

Discharge to surface waters in a manner that does not cause erosion is perhaps the best method for off-site surface disposal of water from open loop GHP systems. However, it is very important to understand that surface disposal may not be advisable in areas where groundwater depletion may occur.

What regulations do I need to know that apply to surface disposal of water from open loop GHP systems?

For systems that discharge to surface waters, discharge water temperatures must be consistent with existing regulations, and a NPDES permit may be required. Other state and local regulations and permit conditions may also apply.

How do I find out what laws in my state apply to surface disposal of water from open loop GHP systems?

(see response Installation Issues, subsection 1)

II. Subsurface Disposal

Some GHP systems dispose of water through subsurface methods. [*PA, 4.4.2*] These methods include:

- **Vertical injection wells** (a two-well system). Most subsurface water disposal methods return water to the aquifer using a vertical injection well. One well is used to withdraw water from the aquifer, while another well is used to reinject the warmed or cooled water back into the aquifer. This method conserves groundwater and tends to limit environmental problems. When water is returned to the same aquifer, groundwater quality and quantity are generally maintained.
- **Standing column well** (a one-well system for both supply and discharge). A well used for both supply and discharge is known as a standing column system. For this technique, a pipe with the bottom portion screened is placed down the well. Groundwater is pulled through the screen using a submersible pump, located near the bottom of the well. After the water circulates past the heat pump, it is then returned to the well using a drop pipe at the top of the well, below the standing water level. The water flows down the outside of the pipe and cools or warms, depending on how the water had been used. [*PA, 4.4.2.1*] There are many variations on this method; various regions have used similar methods to achieve similar results.
- **Horizontal drains or a subsurface drain field.** This method is similar to a drain field that accompanies a septic system.

Why should I be concerned about subsurface water disposal from open loop GHP systems?

Horizontal drains or subsurface drain fields must have the capacity to accept the volume of flow from an open loop GHP system; and they must also be constructed deep enough to avoid freezing during the winter. [*PA, 4.4.2*]

Vertical injection wells must have enough capacity to accept the volume of flow from the open loop GHP system. Experience has shown that few contractors test the return capacity of their subsurface disposal system. The relative capacity of a drain field and the ability of a well to accept water in a discharge mode should be thoroughly established prior to system installation. Failure to do so has been the most frequent failing of system installations to date.

With both vertical injection wells and turbulent wells, some chemical changes can occur when the groundwater is injected because of changes in water temperature and pressure. These changes can lead to eventual clogging of the return well. For example, return wells can be clogged because of changes in pressure and carbon dioxide concentrations which lead to precipitation of minerals, development of iron oxides caused by aeration of the water, or precipitation of iron as a result of bacterial growth. Suspended sediment can also block openings in the well. [*PA, 4.4.2*]

What are best practices for subsurface disposal of water from open loop GHP systems?

The return well must have adequate capacity to accommodate the volume of water that passes through the open loop GHP system. Aquifer characteristics such as the permeability of the area surrounding the well should be considered. Hydrogeological characteristics can be estimated based on the geology of the well area. [*PA, 4.4.2.2*]

In choosing whether or not to install a subsurface water disposal system or in choosing between the various subsurface water disposal systems, installers should consider a number of additional factors, including: 1) distance from existing wells, 2) volume of discharge water, 3) length of the well available for injection of the water, 4) design of the well screen (if used), 5) local water quality, and 6) local and state well construction codes. [*PA, 4.4.2.2*]

Return well siting. The return well must be adequately isolated to allow the discharge water to reach the ambient temperature of the aquifer before being withdrawn again. The wells typically should be isolated at distances greater than 100 feet (horizontal distances). Larger capacity wells or wells in thin or poorly transmissive aquifers should have greater isolation distances. [*PA, 4.4.2.2*]

Return well construction. The construction of the return well is critical to the effectiveness of this type of water disposal. A well that is not constructed properly can at some point cause the entire system to fail. The most common problem is well clogging or slowing because of poor construction or development of mineral precipitate. [*PA, 4.4.2.2*] It is very important to properly seal the return well with grout. Water in the return well is forced back into the aquifer by the pressure created by the column of water in the well. If the pressure resisting flow back into the aquifer is significant, there is a chance that rapid flow into the return well could cause a rupture of the casing seal. Grouting the borehole will help prevent such ruptures. Water injection tests should be performed prior to installation to see how the well reacts.

Preventing mineral precipitation. Several actions can help prevent mineral precipitation, although results cannot be guaranteed. First, most precipitation can be avoided by ensuring that the waters do not free fall back into a return well (e.g., through the use of a simple dip tube). Second, wells must be of sufficient diameter and depth to accept the maximum discharge from an open loop GHP system. The screened or open rock portion should be greater than that of the supply well. A return well constructed in rock typically requires twice the capacity of the supply well. Third, aeration of the water to be returned should be avoided, as aeration accelerates mineral precipitation, particularly precipitation of iron. In particular, if a storage tank is used, it should be a diaphragm type, and the discharge should be below standing water level. Fourth, the use of a backvalve can help to prevent pressure differences that could result in precipitation of minerals. An extended pumping test (12-24 hours) is recommended to help determine hydraulic characteristics of the return well. [*PA, 4.4.2.2*] Fifth, and finally, all wells or boreholes should be disinfected to prevent the proliferation of bacteria (most commonly iron bacteria).

Proper return well development. Return wells should be properly developed to remove fines and stabilize the borehole so that they do not collapse (e.g., install a borehole casing) or clog. Mechanical surging and some types of chemical treatment can promote a stable well, or successfully treat a clogged well. [*PA, 4.4.2.2*]

What regulations do I need to know that apply to subsurface disposal of water from open loop GHP systems?

Return wells for GHP systems are classified as Class V injection wells by the U.S. Environmental Protection Agency (EPA). Such wells have been determined not to pose a significant threat to the environment. However, EPA requires that owners and operators of injection wells, including those for GHPs, report at least the following *(40 CFR Section 144.26):*

- facility name and location
- name and address of legal contact
- ownership of the facility
- nature and type of injection well
- operating status of injection well

This information is requested by EPA on the national form, *Inventory of Injection Wells, OMB No. 158-R0170.* [*PA, 1.3.1*] The appropriate state UIC representative, found in Appendix B, should be contacted for further assistance on this reporting.

While most states require that injection wells be inventoried through their UIC regulations, other GHP subsurface discharge regulations vary by state. The State of Missouri exempts all residential GHP systems from permit regulations with regard to thermally altered water discharges. In New Jersey reinjection wells for residential GHP systems are regulated as Class V wells and are permitted by rule. The State of Delaware does not address thermally altered water discharges in the context of GHP systems.

How do I find out what laws in my state apply to subsurface discharge of water from open loop GHP systems?

(see response Installation Issues, subsection 1)

3. Thermally Altered Water Discharge

Water used in open loop GHP systems and returned to the ground (reinjected or percolating from a drain field) or surface waters will either be warmer or cooler than when it was originally withdrawn. For open loop GHP systems, the temperature change is usually less than ten degrees Fahrenheit. Whether or not the temperature difference of the discharged water will have an impact on the aquifer or surface water depends on various factors such as the volume discharged, or the temperature and flow of the receiving water. If water used in GHP systems is returned to the same aquifer throughout the year, temperature contrasts may be neutralized. For surface disposal, heat is categorized as a pollutant under NPDES. [*PA, 4.6.1*]

Why should I be concerned about thermally altered water discharged from open loop GHP systems?

Temperature changes in water may cause subsequent chemical changes that affect not only equipment like reinjection wells, but also the local ecology that receives the discharged water. For example, as discussed earlier, changes in pressure and carbon dioxide concentrations could lead to the precipitation of minerals and the eventual clogging of return wells. Temperature changes can affect microorganisms and minerals in the groundwater and surface waters, as well as surface water vegetation, algae, and fish. In addition, open loop systems should not be exposed to air to aid cooling, because aeration can lead to mineral precipitation and clogging. EPA supported research work at The Richard Stockton College of NJ that investigated the thermal effects on microbiota resulting from the use of underground geothermal heat pump systems. A draft report from this research was completed in the fall of 1996 and is available from EPA's Atmospheric Pollution Prevention Division distribution center at (202) 775-6650.

What are best practices for minimizing the effect of thermally altered water discharges from open loop GHP systems?

Preventing mineral precipitation. See Preventing mineral precipitation in Subsection 2.ii of Section III, Operation Issues.

Proper return well development. Return wells should be properly developed to remove fines and stabilize the borehole. Mechanical surging and some types of chemical treatment can promote a stable well, or successfully treat a clogged well. [*PA, 4.4.2.2*]

No long term thermal imbalance occurs when the heating and cooling loads to the heat exchanger are about the same. Depending on the building type, the regional climate, and whether the cooling or heating cycle will dominate, a GHP system will either cool or warm the subsurface until an equilibrium is reached. Consequences (thermal, chemical, or biological) of this long-term heat gain or loss may need to be considered when nearby users could be affected. [*PA, 5.2.1.2*]

What regulations do I need to know that apply to thermally altered water discharged from open loop GHP systems?

Federal law and regulation requires every state to have an approved Underground Injection Control (UIC) program. Currently there are few if any criteria or standards for Class V injection wells. This class of wells generally presents a much smaller risk to drinking water as compared to Class I–IV wells. As a result, residential GHPs usually are not regulated under the UIC program. Every state is also required to enforce the minimum standards set forth in the NPDES program.

Most states do not regulate residential GHP injection wells. Missouri sets forth temperature criteria, but the small volumes and small temperature gradations generated by residential systems should not pose a problem and will likely go unregulated.

How do I find out what laws in my state apply to thermally altered water discharged from open loop GHP systems?

(see response Installation Issues, subsection 1)

Decommissioning Issues

Unsealed or improperly sealed wells may threaten public health and safety, and the quality of groundwater resources. Therefore, proper abandonment (decommissioning) of a well is a critical final step in its service life. [*PA, 7.1*]

Why should I be concerned about decommissioning open loop GHP systems?

Many states regulate procedures for abandoning wells. In addition, many states make it the responsibility of a well owner to properly seal an abandoned well. Open loop GHP systems are very similar to wells and are, therefore, likely to be regulated like wells with the same decommissioning requirements. Further, improperly decommissioned wells may result in future groundwater contamination and create physical hazards (e.g., falling into holes).

What are best practices for decommissioning open loop GHP systems?

Proper well abandonment accomplishes the following: 1) eliminates the physical hazard of the well (the hole in the ground), 2) eliminates a pathway for migration of contamination, and 3) prevents hydrologic changes in the aquifer system, such as the changes in hydraulic head and the mixing of water between aquifers. Although the basic decommissioning procedure involves sealing the borehole with cement or approved grout, the proper decommissioning method will depend on both the reason for abandonment and the condition and construction details of the borehole or well.

What regulations do I need to know that apply to decommissioning open loop GHP systems?

Open loop GHP systems are nearly identical to drinking water wells. Hence, most states apply the requirements for water well decommissioning to GHP system decommissioning.

How do I find out what laws in my state apply to decommissioning open loop GHP systems?

(see response Installation Issues, subsection 1)

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Division of Drinking Water Management
Bureau of Water Supply Management
Department of Environmental Protection
P.O. Box 8467
Harrisburg, PA 17105-8467
(717) 787-1421 (Central Office)
http://www.dep.state.pa.us/dep/DEPUTATE/Watermgt/WC/WC_WQAS/GENERA
L/SOURCE/gshpttoc.htm

Richard Stockton College of New Jersey. *Preliminary Studies on the Thermal Effects of the Stockton College Geothermal Heat Pump Installation on Aquifer Microbiota and Surface Biota.* EPA Project ID Number X824245-01-1, August 1996.

Virginia Department of Conservation and Recreation, Division of Soil and Water Conservation. *Virginia Erosion and Sediment Control Handbook.* [n.p.], 1992, Third Edition.

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Richmond, VA 23219-2094
(804) 786-2064

Appendix A
Introduction to Geothermal Heat Pumps

from *Ground-Source Heat Pump Manual* by the Pennsylvania Department of Environmental Protection, Bureau of Water Supply Management

Appendix A
Introduction to Geothermal Heat Pumps

from *Ground Source Heat Pump Manual* by the Pennsylvania Department of Environmental Protection, Bureau of Water Supply Management

The technique of applying a heat pump to a subsurface energy source has existed for over 50 years, and the technology of the heat pump has existed for over a hundred years. Before the 1970s, geothermal heat pump (GHP) systems were few in number. However, many types of energy systems grew in popularity and prominence as a result of the oil shortages in the 1970s. Contractors and homebuilders developed substantial interest in the heat pump. Although the promotion of energy alternatives slowed in the 1980s, the development of GHP systems expanded.

Closed-loop systems emerged in the early 1980s. Even in regions of abundant groundwater, these systems are now being installed. Significant improvements in technology such as fused joints, polyethylene pipe, and more efficient heat pumps have made these systems competitive with conventional heating and cooling systems. A wide variety of GHP systems are now available for the consumer. Continued improvements in technology and efficiency have increased energy savings and lowered installation and maintenance costs.

The United States General Accounting Office report *Geothermal Energy: Outlook Limited for Some Uses but Promising for Geothermal Heat Pumps* states that "Geothermal heat pumps are the most energy-efficient means of heating and cooling buildings in most areas of the United States." The Energy Policy Act of 1992 contained provisions to encourage the use of geothermal systems as alternative energy sources. In response to the President's Climate Change Action Plan, the Geothermal Heat Pump Consortium in cooperation with the U.S. EPA and the Department of Energy is working to reduce greenhouse gases and increase GHP unit sales to 400,000 annually by the year 2000.

PRINCIPLES OF OPERATION

GHPs take advantage of the natural heat stored underground. Using the same technology as does a refrigerator, a heat pump can move heat taken from the ground and apply it to a building. The process can also be reversed and the subsurface can be used as a drain for a building's excess heat.

The basic working principle of the heat pump (Figure 1) is that evaporation is a cooling process. When a substance evaporates (changes from a liquid to a gas), heat is absorbed into the gas. A common example is the evaporation of moisture from your skin. Heat is absorbed into the air which cools your body.

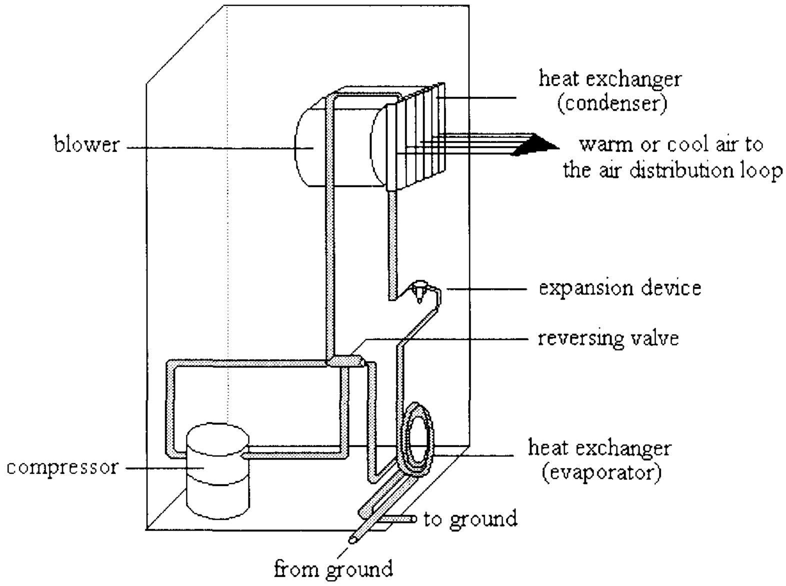

Figure 1: Basic components of a heat pump

The main heat pump components are the refrigerant, evaporator, compressor, condenser, and expansion valve. To heat or cool a building, a heat pump uses a liquid refrigerant such as R-22, which has a very low evaporation point: -40 degrees F. When heating a home, for example, the cold liquid refrigerant absorbs heat and evaporates as it passes next to warmer antifreeze solution or groundwater in the evaporator (heat exchanger). The refrigerant gas travels through a compressor where it is squeezed and heated further to about 180 degrees F. The refrigerant then moves to the condenser where heat is released to surrounding cooler air (forced air system) or to circulating water (hydronic system).

In forced air systems, a blower transports the warmed air around the building through a duct network. The venting is usually composed of insulated metal pipes, diffusers and grilles. The ducts carry the heated air, which usually has a temperature between 85-110 degrees F. This is much lower than temperatures produced by conventional furnaces. Therefore, the volume of air that must be moved to supply the same amount of heat is much greater — the duct system and blower must be larger than those for conventional heating and cooling. A hydronic system uses a pump to circulate the heated or cooled water through a series of radiators in the building.

As the refrigerant loses heat to the air or water, it condenses back to a liquid under high pressure. It then passes through an expansion device where the pressure is lowered and the refrigerant cools further. Finally, the refrigerant returns to the evaporator to repeat the cycle.

To provide cooling to a home in the summer, the process would be reversed by changing the direction of the reversing valve on the refrigerant loop. The roles of the condenser and the evaporator are reversed during the cooling cycle. Heat from the home would be absorbed by the refrigerant (at the air distribution loop) and then transferred to the water or antifreeze at the ground loop, which in turn carries the heat to the subsurface.

An additional device known as a desuperheater can be used in either the heating or cooling mode to apply existing compressor heat to heat water. The desuperheater is attached directly after the compressor.

TYPES OF SYSTEMS

There are two main types of GHP systems: 1) closed-loop systems, and 2) open systems. Variations of closed-loop systems are based on the configuration of the pipe, the type of antifreeze solution, and the amount of heating and cooling required. Open systems vary according to the use and disposal of groundwater.

The selection of the type of system (closed-loop or open) will depend on many factors. They include availability of groundwater, soil type, energy requirements, size of lot, and the experience of the local contractor. For example, a rocky soil may prevent trenching. In that case, the contractor could use boreholes to install a vertical loop system. A small lot may allow only a vertical loop system. Some homeowners could take advantage of a pond or lake, or a well that has a sufficient supply of groundwater.

Closed Loop Systems

The typical closed-loop GHP system consists of three types of loops: a subsurface loop, a refrigerant loop, and the cooling/heating distribution loop. The subsurface loop typically consists of polyethylene or polybutylene pipe, which is placed horizontally in a trench or vertically

in a borehole or well. This thin-walled pipe acts as a heat exchanger, which transfers heat from or to the ground. Antifreeze fluids inside the pipe are circulated to the heat exchanger of an indoor heat pump where it releases heat to the refrigerant. The refrigerant loop typically consists of copper pipes that contain a refrigerant. The last loop of the system consists of the forced air or hydronic system to distribute the heated or cooled air throughout the building.

Configuration of the subsurface loops can be almost any shape (Figure 2). Typical patterns include long trenches, parallel shorter trenches, radiating, coiled or slinky, and vertical boreholes. The loop can circle the building or be placed in a nearby water body, such as a pond.

The pipe can be placed in either series or in parallel if more than one trench or borehole is used. In series form, only one flow path is made; in parallel form more than one flow path is maintained using headers that branch off from the main supply or return pipe. Headers can be placed in a common area to allow individual flow paths to be checked for leaks without excavating a large area. Series setups usually require less fused joints, but larger diameter pipes than parallel configurations.

Another type of closed-loop system is the direct exchange (DX) heat pump system. In a DX system, the underground loop contains the refrigerant. This loop combines the refrigerant and underground loops. Although this method can be very efficient, the disadvantages are potentially significant. A DX system requires several times the amount of refrigerant normally used, and any holes in the copper tubing would cause a loss of the refrigerant. Typically 10 to 20 pounds of refrigerant are used for domestic systems. The copper pipes can be susceptible to corrosion in acidic soils. This type of system therefore poses a greater threat to the environment than other closed-loop GHP systems.

Heat from the pipes can bake fine-grained soils that surround a horizontal underground loop. This can reduce the efficiency of heat transfer and thus the performance of the system. Moist sandy soils are more suitable for the operation of DX systems.

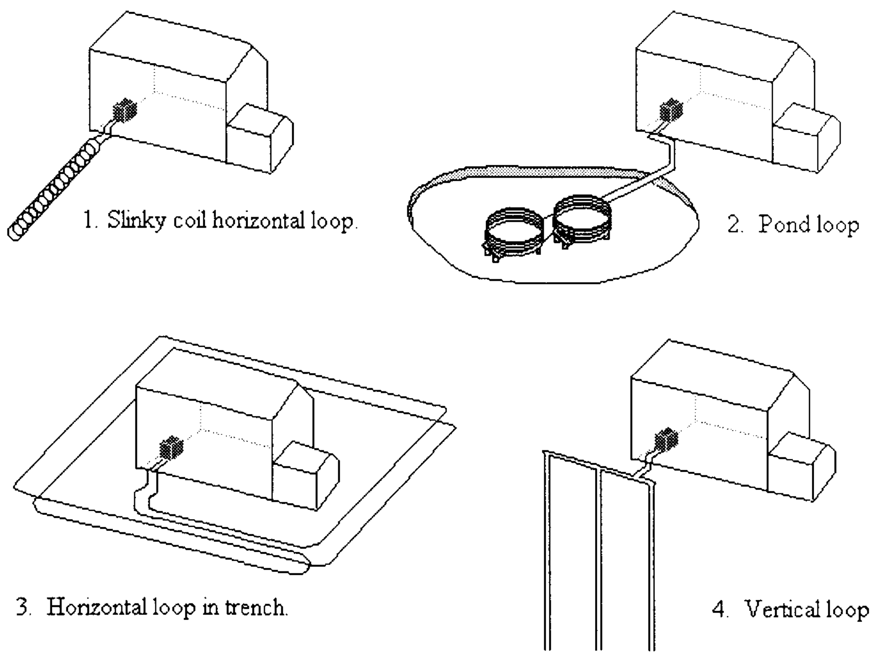

Figure 2. Series loop configurations

Open Loop Systems

Open GHP systems, also known as groundwater heat pump (GWHP) systems, typically depend upon groundwater to supply or accept heat. Open systems do not confine fluid to a loop of pipes; they use a pumping well to move water through the heat pump. Although surface water could possibly be used, most open systems rely on groundwater. The water is disposed of by a surface or subsurface method. The water supply well must yield enough water to transport the required amount of heat.

During the winter heating cycle, the GWHP system operates by extracting heat from the groundwater and transferring it to the building. During the summer cooling cycle, heat is transferred away from the building by the groundwater. A typical GWHP system is shown in Figure 3.

Groundwater is piped from the ground to the tubes of a heat exchanger (evaporator). The refrigerant, contained in tubing, surrounds the water pipes. The exchange of heat then occurs by the same process as described above with closed loop systems. Meanwhile, the groundwater exits the heat exchanger and proceeds to the disposal area. The selection of the size of the groundwater pump is an important decision. The pump must be large enough to overcome the friction in the piping and to supply enough water for the heat pump and other uses. On the other hand, the pump must be small enough to be efficient in energy usage and water supply.

Variations of GWHP systems are generally based on the arrangement of wells and the disposal method. Typically homeowners and commercial systems use a two-well system — one for supply and one for discharge. A supply well can also be used for discharge; this is known as a turbulent system. Several other disposal methods are possible including surface disposal (e.g., to a body of water), and subsurface disposal through horizontal drains. GWHP systems also may need different sized wells based on the amount of groundwater required.

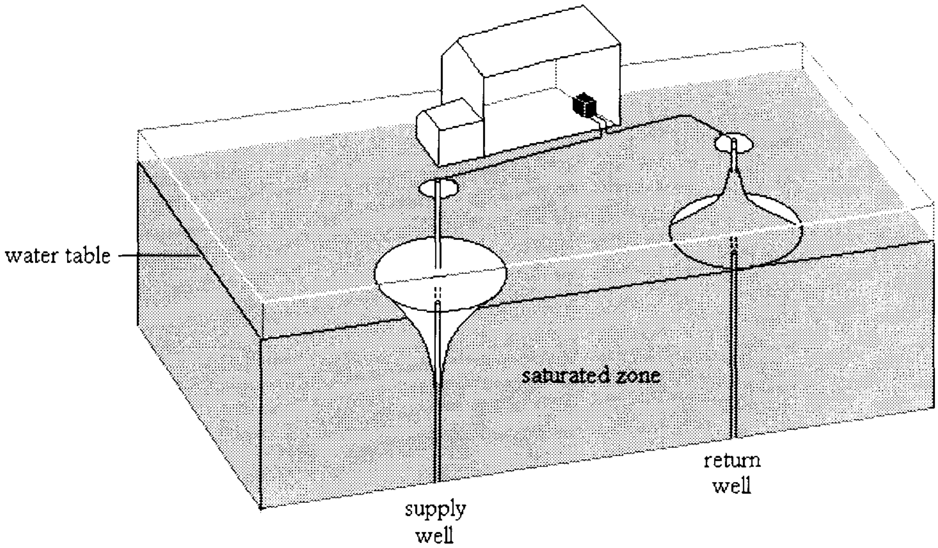

Figure 3. Groundwater heat pump system

Appendix B
State Contacts

Appendix B
State Contacts

This list of state contacts was compiled in 1996 and was obtained from the Geothermal Heat Pump Consortium's home page at *http://www.uidaho.edu/ghpc/*. Readers should be aware that some of the information presented here may be out of date. EPA recommends that you check the GHPC website for the most current information if you find any of the information here to be inaccurate.

Alabama

Well Driller and Pump Installer Licensing (Registration)

R.C. Mills
Department of Revenue
PO Box 327550
Montgomery, AL 36132-7550
334-242-9610, fax 334-242-0770

Water Well Construction Standards

Doug Cook
Department of Environmental Management
PO Box 301463
Montgomery, AL 36130-1463
334-271-7773, fax 334-279-3051

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Lynn Ford
Department of Environmental Management
PO Box 301463
Montgomery, AL 36130-1463
334-271-7862, fax 334-279-3051

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

Jimmy Coles
Department of Environmental Management
PO Box 301463
Montgomery, AL 36130-1463
334-271-7936, fax 334-279-3051

Closed System Boreholes

No state regulations were found although there may be local ordinances at the regional, county and/or city level.

Alaska

Well Driller and Pump Installer Licensing (Registration)

No state regulations were found although there may be local ordinances at the regional, county and/or city level.

Water Well Construction Standards

Stan Justice
Potable Water Program of
Environmental Conservation
610 University Ave.
Fairbanks, AK 99709-3643
907-451-2138, fax 907-451-2187

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Jonathan Williams
U.S. EPA Region 5
1200 6th Ave.
Seattle, WA 98101
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Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

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Industrial Operations Sec. Environ. Conservation
610 University Ave.
Fairbanks, AK 99709-3643
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Closed System Boreholes

No state regulations were found although there may be local ordinances at the regional, county and/or city level.

Arizona

Well Driller and Pump Installer Licensing (Registration)

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Water Resources
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Water Well Construction Standards

Mike Ball — see above

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Chou Chein
Aquifer Protection Program
Environmental Quality
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Phoenix, AZ 85012
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Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

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Closed System boreholes

Mike Ball — see Well Driller and Pump Installer Licensing (Registration) above

Arkansas

Well Driller and Pump Installer Licensing (Registration)

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Arkansas Water Well Construction Commission
One Capital Mall, Suite 2C
Little Rock, AR 72201
501-682-1025

Water Well Construction Standards

Kenneth Acklin — see above

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Kenneth Acklin — see above

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

Kenneth Acklin — see above

Closed System Boreholes

Kenneth Acklin — see above

California

Well Driller and Pump Installer Licensing (Registration)

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CA Environmental Protection Agency
Division of Water Quality
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Sacramento, CA 84244-2130
916-657-0876, fax 916-657-1011

Water Well Construction Standards

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Department of Natural Resources
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Sacramento, CA 94236-0001
916-327-8861

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

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US EPA Region 9
UIC Section DWB (w-6-2)
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San Francisco, CA 94105
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Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

Archie Matthews
Division of Water Quality
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Sacramento CA 84244-2130
916-657-0523, fax 916-657-2388

Closed System Boreholes

Jay Guettler
CA Energy Commission
Energy Technology Development Division
1516 9th St., MS-43
Sacramento, CA 95814-5512
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Colorado

Well Driller and Pump Installer Licensing (Registration)

Office of the State Engineer
1313 Sherman St., Rm 818
Denver, CO 80203

Water Well Construction Standards

Division of Water Resources: Records
1313 Sherman St., Rm 821
Denver, CO 80203

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Office of the State Engineer
1313 Sherman St., Rm 818
Denver, CO 80203

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

Colorado Health Department
Water Quality Control
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Denver, CO 80222
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Closed System Boreholes

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1313 Sherman St., Rm 818
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Connecticut

Well Driller and Pump Installer Licensing (Registration)

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Water Well Construction Standards

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150 Washington St.
Hartford, CT 06106
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Injection (Recharge) Wells — Underground Injection Control Program (UIC)

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Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

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Water Management Bureau
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Water Supply Section
150 Washington St.
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Delaware

Well Driller and Pump Installer Licensing (Registration)

Harry Hudson
Department of Natural Resources and
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Division of Water Resources
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Water Well Construction Standards

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Environmental Control
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Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Rick Rios — see above

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

Chuck Schadel
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Surface Water Discharge Section
P.O. Box 1401, 89 Kings Hwy.
Dover, DE 19903

Closed System Boreholes

Rick Rios — see Water Well Construction Standards above

Florida

Well Driller and Pump Installer Licensing (Registration)

No state regulations were found although there may be local ordinances at the regional, county and/or city level.

Water Well Construction Standards

Peter Wilkens
Department of Environmental Protection
Bureau of Drinking Water and
Groundwater Resources
Water Management Section
2600 Blair Stone Rd.
Tallahassee, FL 32399-2400
904-487-1762, fax 904-921-5655

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

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Water Facilities Division, UIC Sec
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Closed System Boreholes

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Orlando, FL 32801
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Georgia

Well Driller and Pump Installer Licensing (Registration)

Tony McCook
Department of Natural Resources
Environmental Protection Division
19 Martin Luther King Dr. SW, Rm 400
Atlanta, GA 30334
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Water Well Construction Standards

Tony McCook — see above

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

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Department of Natural Resources
Environmental Protection Division
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Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

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Closed System Boreholes

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Hawaii

Well Driller and Pump Installer Licensing (Registration)

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Honolulu, HI 96801
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Water Well Construction Standards

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Chauncy Hew — see above

Closed System Boreholes

Chauncy Hew — see above

Idaho

Well Driller and Pump Installer Licensing (Registration)

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Water Well Construction Standards

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Closed System Boreholes

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Illinois

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Water Well Construction Standards

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Closed System Boreholes

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Indiana

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Closed System Boreholes

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Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

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Closed System Boreholes

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Water Well Construction Standards

Don Taylor — see above

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

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Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

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Closed System Boreholes

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Kentucky

Well Driller and Pump Installer Licensing (Registration)

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Frankfort, KY 40601
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Water Well Construction Standards

Chester Bojanowski — see above

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Scott Hoskins
US EPA Region IV
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Atlanta GA 30365

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

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Closed System Boreholes

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Department for Environmental Protection
KPDES Branch
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Louisiana

Well Driller and Pump Installer Licensing (Registration)

Zahir "Bo" Bolourchi
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Baton Rouge, LA 70804-9245
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Water Well Construction Standards

Zahir "Bo" Bolourchi — see above

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

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Department of Natural Resources
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504-342-5562

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

Suzanne Gardner
Department of Environmental Quality
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Baton Rouge, LA 70884-2215
504-765-0634

Closed System Boreholes

Zahir "Bo" Bolourchi — see Well Driller and Pump Installer Licensing (Registration) above

Maine

Well Driller and Pump Installer Licensing (Registration)

Sandy Welton
Department of Human Services
Water Well Drilling Commission
10 State House Station
Augusta, ME 04333-0110
207-287-5699

Water Well Construction Standards

Mark Loiselle
Department of Conservation
Geological Survey
22 State House Station
Augusta, ME 04333-0022
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Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Kim Sargeant
Department of Environmental Protection
Division of Water Resource Regulation
Bureau of Land and Water Quality
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Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

Dennis Merrill
Department of Environmental Protection
Division of Water Resource Regulation
Bureau of Land and Water Quality
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Augusta, ME 04333-0022
207-287-7788, fax 207-287-7826

Closed System Boreholes

No state regulations were found although there may be local ordinances at the regional, county and/or city level.

Maryland

Well Driller and Pump Installer Licensing (Registration)

Willie Everett
Department of the Environment
Maryland Board of Well Drillers
2500 Broening Hwy.
Baltimore, MD 21224
410-631-3000, fax 410-631-3168

Water Well Construction Standards

Eric Dougherty
Department of the Environment
Groundwater Protection Division
Individual Septic and Wells Program
2500 Broening Hwy.
Baltimore, MD 21224
410-631-3000, fax 410-631-3093

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Roger Simon
Department of the Environment
Groundwater Permits Division, Water Management Administration
2500 Broening Hwy.
Baltimore, MD 21224
410-631-3323, fax 410-631-4894

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

Eric Dougherty — see Water Well Construction Standards above

Closed System Boreholes

Eric Dougherty — see Water Well Construction Standards above

Massachusetts

Well Driller and Pump Installer Licensing (Registration)

Tom Klock
Department of Environmental Management
Office of Water Resources
100 Cambridge St.
Boston, MA 02202
617-727-3267, fax 617-727-9402

Water Well Construction Standards

Local Health Boards

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Jacob Moss
Department of Environmental Protection
Division of Water Supply
1 Winter St.
Boston, MA 02108
617-556-1165, fax 617-556-1049

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

Paul Hogan
Department of Environmental Protection
Office of Watershed Management
Surface Water Permits Program
40 Institute Rd.
North Grafton, MA 01536
508-792-7470, fax 508-839-3469

Closed System Boreholes

Local Health Boards

Michigan

Well Driller and Pump Installer Licensing (Registration)

Mike Gaber
Department of Public Health
Bureau of Environmental and Occupational Health
Division of Water Supply
PO Box 30195
Lansing, MI 48909
517-335-8304, fax 517-335-9434

Water Well Construction Standards

Ronald Holben
Department of Public Health
Bureau of Environmental and Occupational Health
Division of Water
PO Box 30195
Lansing, MI 48909
517-335-8329, fax 517-335-9434

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Ross Micham
U.S. EPA, Region 5
UIC Sec
77 West Jackson Boulevard,
Chicago, IL 60604-3590
312-886-4237, fax 312-886-4235

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

Bill Shaw
Department of Natural Resources
Water Quality Division
PO Box 30273
Lansing, MI 48909
517-335-4118, fax 517-378-9958

Closed System Boreholes

Rodger Whitener
Department of Natural Resources
Geological Survey
PO Box 30256
Lansing, MI 48909
517-334-6976, fax 517-334-6038

Minnesota

Well Driller and Pump Installer Licensing (Registration)

Mike Convery
Department of Health
Division of Environmental Health,
Well Management Unit
PO Box 64975
St. Paul, MN 55164-0975
612-215-0827, fax 612-215-0978

Water Well Construction Standards

Ed Schneider
Department of Health
Division of Environmental Health,
Well Management Unit
PO Box 64975
St. Paul, MN 55164-0975
612-215-0827, fax 612-215-0978

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Gretchen Sabel
Minnesota Pollution Control Agency
Water Quality Division
520 Lafayette Rd.
St. Paul, MN 55155-4198
612-697-7574, fax 612-282-66247

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

Douglas Hall
Minnesota Pollution Control Agency
Division of Water Quality
520 Lafayette Rd.
St. Paul, MN 55155
612-297-1832, fax 612-297-8683

Closed System Boreholes

Ed Schneider — see Water Well Construction Standards above

Mississippi

Well Driller and Pump Installer Licensing (Registration)

Johnnie Biggert
Department of Environmental Quality
Office of Land and Water Resources
PO Box 10631
Jackson, MS 39289
601-961-5210, fax 601-354-6938

Water Well Construction Standards

Johnnie Biggert — see above

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Jamie Crawford
Department of Environmental Quality
Office of Pollution Control, Groundwater Division
PO Box 10385
Jackson, MS 39289-0385
601-961-5354

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

David Bailey
Department of Environmental Quality
Office of Pollution Control, Groundwater Division
PO Box 10385
Jackson, MS 39289-0385
601-961-5208

Closed System Boreholes

Charlie Smith
Department of Environmental Quality
Office of Pollution Control, Groundwater Division
PO Box 10385
Jackson, MS 39289-0385
601-961-5395

Missouri

Well Driller and Pump Installer Licensing (Registration)

Michelle Widener
Department of Natural Resources
Division of Geology and Land Survey
PO Box 250
Rolla, MO 65402
314-268-2165, fax 314-368-2317

Water Well Construction Standards

Bruce W. Netzler
Department of Natural Resources
Division of Geology and Land Survey
PO Box 250
Rolla, MO 65402
314-268-2165, fax 314-368-2317

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Evan Kifer
Department of Natural Resources
Division of Geology and Land Survey
PO Box 250
Rolla, MO 65402
314-368-2170, fax 314-368-2317

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

Tim Stallman
Department of Environmental Quality
Water Pollution Control Program
Permit Section, NPDES Permit Unit
PO Box 176
Jefferson City, MO 65102
314-751-7625

Closed System Boreholes

Michael Gawedzinski
Department of Natural Resources
Division of Geology and Land Survey
PO Box 250
Rolla, MO 65402
314-268-2165, fax 314-368-2317

Montana

Well Driller and Pump Installer Licensing (Registration)

Bob Rudio
Department of Natural Resources and Conservation
Board of Water Well Contractors
1520 East 6th Avenue
Helena, MT 59620
406-444-6643

Water Well Construction Standards

Bob Rudio — see above

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Ron Zdyb, UIC Coordinator
EPA Region 8
Drinking Water Branch
999 18th Street, Suite 500
Denver, CO 80202-2466
303-293-1429, fax 303-293-1234

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

Joe Strasko
Department of Health and Environmental Sciences
Water Quality Division
PO Box 200901
Helena, MT 59620-1374
406-444-2783, fax 406-444-1374

Closed System Boreholes

No state regulations were found although there may be local ordinances at the regional, county and/or city level.

Nebraska

Well Driller and Pump Installer Licensing (Registration)

Rod Tremblay
Department of Health
Division of Drinking Water and
Environmental Sanitation
PO Box 95007
Lincoln, NE 68509-5007
402-471-2541

Water Well Construction Standards

Rod Tremblay — see above

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Rod Tremblay — see above

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

Steve Walker
Department of Environmental Quality
Surface Water Sec
PO Box 98922
Lincoln, NE 68509
402-471-4227

Closed System Boreholes

Rod Tremblay — see Well Driller and Pump Installer Licensing (Registration) above

Nevada

Well Driller and Pump Installer Licensing (Registration)

Diana Lefler
Department of Conservation and
Natural Resources
Division of Water Resources
Office of the State Engineer
Capitol Complex, 333 W Nye Lane
Carson City, NV 89710
702-687-4381

Water Well Construction Standards

Diana Lefler — see above

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Marcia Greybeck
Department of Conservation and
Natural Resources
Division of Environmental Protection
Bureau of Water Pollution Control
Capitol Complex 333 W Nye Lane
Carson City, NV 89710
702-687-4670 ext 3146, fax 702-687-5856

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

John Nelson
Department of Conservation and
Natural Resources
Division of Environmental Protection
Capitol Complex, 333 W Nye Lane
Carson City, NV 89710
702-687-4670 ext 3145, fax 702-687-5856

Closed System Boreholes

No state regulations were found although there may be local ordinances at the regional, county and/or city level.

New Hampshire

Well Driller and Pump Installer Licensing (Registration)

Rick Schofield
Department of Environmental Services
New Hampshire Water Well Board
64 N. Main St., PO Box 2008
Concord, NH 03301-2008
603-271-3406, fax 603-271-7894

Water Well Construction Standards

Rick Schofield — see above

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Micheal Walker
Department of Environmental Services
Water Supply & Pollution Control Division
6 Hazen Drive, PO Box 95
Concord, NH 03302-0095
603-271-3644, fax 603-271-2181

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

Jeff Andrews
Department of Environmental Services
Water Supply and Pollution Control Division
6 Hazen Drive, PO Box 95
Concord, NH 03302-0095
603-271-2457, fax 603-271-7894

Closed System Boreholes

Rick Schofield — see Well Driller and Pump Installer Licensing (Registration) above

New Jersey

Well Driller and Pump Installer Licensing (Registration)

Dennis Schwab
Department of Environmental Protection
Bureau of Water Allocation
CN-426
Trenton, NJ 08625
609-292-2957

Water Well Construction Standards

Mike Miller
Department of Environmental Protection
Bureau of Water Allocation
CN-426
Trenton, NJ 08625
609-292-2957

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Ennice Szkoda
Department of Environmental Protection
Bureau of Operation Ground Permits
CN-029
Trenton, NJ 08625
609-292-0407, fax 609-984-7938

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

Ben Manhas
Department of Environmental Protection
Division of Water Quality
CN-029
Trenton, NJ 08625
609-292-4860, fax 609-984-7938

Closed System Boreholes

No state regulations were found although there may be local ordinances at the regional, county and/or city level.

New Mexico

Well Driller and Pump Installer Licensing (Registration)

Tom Morrison
State Engineer's Office
Special Projects Division
PO Box 25102
Santa Fe, NM 87504-5102
505-827-6135, fax 505-827-6188

Water Well Construction Standards

Tom Morrison — see above

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Eric Rounds
Ground Water Protection and Remediation Bureau
PO Box 26110
Santa Fe, NM 87502
505-827-0652, fax 505-827-2965

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

Eric Rounds — see above

Closed System Boreholes

Eric Rounds — see above

New York

Well Driller and Pump Installer Licensing (Registration)

No state regulations were found although there may be local ordinances at the regional, county and/or city level.

Water Well Construction Standards

Paul Kolakowski
Department of Environmental Conservation
Bureau of Water Facilities Design
50 Wolf Rd. Rm. 318
Albany, NY 12233-3505
518-457-1632, fax 518-485-7786

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Paul Kolakowski — see above

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

Paul Kolakowski — see above

Closed System Boreholes

Paul Kolakowski — see above

North Carolina

Well Driller and Pump Installer Licensing (Registration)

Karen Harmon
Department of Environment, Health, and Natural Resources
Division of Environmental Management
PO Box 29535
Raleigh, NC 27626-0535
919-733-3221 ext 431, fax 919-715-0588

Water Well Construction Standards

Karen Harmon — see above

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Karen Harmon — see above

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

Michael Allen
Department of Environment, Health, and Natural Resources
Division of Environmental Management, Groundwater Section
PO Box 29535
Raleigh, NC 27626-0535
919-733-3221 ext 547, fax 919-715-0588

Closed System Boreholes

Karen Harmon — see Well Driller and Pump Installer Licensing (Registration) above

North Dakota

Well Driller and Pump Installer Licensing (Registration)

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State Water Commission
Board of Well Water Contractors
900 E. Boulevard Ave.
Bismarck, ND 58501
701-328-2750, fax 701-328-3696

Water Well Construction Standards

Robert Biek
North Dakota Geological Survey
600 E. Boulevard Ave.
Bismarck, ND 58505-0840
701-328-4109, fax 701-328-3682

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Ed Murphy
North Dakota Geological Survey
600 E. Boulevard Ave.
Bismarck, ND 58505-0840
701-328-4109, fax 701-328-3682

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

Robert Biek
North Dakota Geological Survey
600 E. Boulevard Ave.
Bismarck, ND 58505-0840
701-328-4109, fax 701-328-3682

Closed System Boreholes

Robert Biek — see above

Ohio

Well Driller and Pump Installer Licensing (Registration)

Russel Smith
Department of Health
Division of Environment
PO Box 118
Columbus, OH 43266-0118
614-466-1390, fax 614-644-1909

Water Well Construction Standards

James M. Raab
Department of Natural Resources
Division of Water
1939 Fountain Square Court
Columbus, OH 43224-9971
614-265-6747, fax 614-447-9503

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Valerie Orr
Ohio EPA
Division of Drinking and Groundwater
UIC Program, PO Box 1049
Columbus, OH 43216-1049
614-644-3125, fax 614-664-2909

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

Mark Enoch
Ohio EPA, Division of Surface Water
NPDES Program, PO Box 1049
Columbus, OH 43216-1049
614-644-2032, fax 614-644-2329

Closed System Boreholes

No state regulations were found although there may be local ordinances at the regional, county and/or city level.

Oklahoma

Well Driller and Pump Installer Licensing (Registration)

Gary Glove
Water Resources Board
Water Management Division
PO Box 150
Oklahoma City, OK 73101-0150
405-525-4736

Water Well Construction Standards

Gary Glove — see above

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Rod Harden
Department of Environmental Quality
Waste Management Division
1000 NE 10th
Oklahoma City, OK 73117
405-281-1342

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

Gary Glove — see Well Driller and Pump Installer Licensing (Registration) above

Closed System Boreholes

Gary Glove — see Well Driller and Pump Installer Licensing (Registration) above

Oregon

Well Driller and Pump Installer Licensing (Registration)

Juno Trump
Water Resources Department
Field Operations Division
158 12th St. NE
Salem, OR 97310
503-378-8455 ext 218, fax 503-378-8130

Water Well Construction Standards

Rob Carter
Water Resources Department
Field Operations Division
290 N. Central St.
Coquille, OR 97423
503-396-3121 ext 254, fax 503-396-6233

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Oregon Department of Environmental Quality
811 SW 6th
Portland, OR 97204

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

Rob Carter — see Water Well Construction Standards above

Closed System Boreholes

Rob Carter — see Water Well Construction Standards above

Pennsylvania

Well Driller and Pump Installer Licensing (Registration)

Stuart Reese
Department of Environmental Resources
Bureau of Water Quality Management
PO Box 8465
Harrisburg, PA 17105
717-787-9633, fax 717-772-5156

Water Well Construction Standards

Stuart Reese — see above

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Stuart Reese — see above

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

Stuart Reese — see above

Closed System Boreholes

Stuart Reese — see above

Rhode Island

Well Driller and Pump Installer Licensing (Registration)

Susan Kiernan
Department of Environmental Management
Division of Ground Water
291 Promenade
Providence, RI 02908
401-277-2234, fax 401-521-4230

Water Well Construction Standards

Susan Kiernan — see above

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Terry Simpson
Department of Environmental Management
Division of Ground Water
291 Promenade
Providence, RI 02908
401-277-2234, fax 401-521-4230

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

Alisa Richardson
Department of Environmental Management
Division of Water Resources
291 Promenade
Providence, RI 02908
401-277-6519, fax 401-521-4230

Closed System Boreholes

Susan Kiernan — see Well Driller and Pump Installer Licensing (Registration) above

South Carolina

Well Driller and Pump Installer Licensing (Registration)

Bill Moore
Department of Labor and Licensing
Environmental Certification Board
2221 Divine St. Suite 320
Columbia, SC 29205
803-734-9140, fax 803-734-9137

Water Well Construction Standards

Jim Hesf
Department of Health and Environmental Control
Bureau of Drinking Water Program
2600 Bull St.
Columbia, SC 29201
803-734-5329, fax 803-734-3604

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Rob Devlin
Department of Health and Environmental Control
Bureau of Drinking Water Program
2600 Bull St.
Columbia, SC 29201
803-734-4672, fax 803-734-3604

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

Jason Gillespie
Department of Health and Environmental Control
Bureau of Water Pollution Control
2600 Bull St.
Columbia, SC 29201
803-734-5239, fax 803-734-5593

Closed System Boreholes

Jim Hesf — see Water Well Construction Standards above

South Dakota

Well Driller and Pump Installer Licensing (Registration)

Ken Buhler
Department of Environment and Natural Resources
Division of Water Rights
Joe Foss Bldg. 523 E. Capitol
Pierre, SD 57501
605-773-3352, fax 605-773-6035

Water Well Construction Standards

Ken Buhler — see above

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Sheldon Hamann
Department of Environment and Natural Resources
Division of Water Rights
Joe Foss Bldg. 523 E. Capitol
Pierre, SD 57501
605-773-3296, fax 605-773-6035

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

Kent Woodmansey
Department of Environment and Natural Resources
Division of Water Rights
Joe Foss Bldg. 523 E. Capitol
Pierre, SD 57501
605-773-3351, fax 605-773-6035

Closed System Boreholes

Ken Buhler — see Well Driller and Pump Installer Licensing (Registration) above

Tennessee

Well Driller and Pump Installer Licensing (Registration)

Luke Ewing
Department of Environment and Conservation
Division of Water Supply
401 Church St. L&C Tower 6th Floor
Nashville, TN 37243-1549
615-532-0176, fax 615-532-0503

Water Well Construction Standards

Robert Hall
Department of Environment and Conservation
Division of Water Supply
401 Church St. L&C Tower 6th Floor
Nashville, TN 37243-1549
615-532-7198, fax 615-532-0503

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Robin Bell
Department of Environment and Conservation
Division of Water Control
401 Church St. L&C Tower 6th Floor
Nashville, TN 37243-1549
615-532-0169, fax 615-532-0503

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

Robby Baker
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401 Church St. L&C Tower 6th Floor
Nashville, TN 37243-1549
615-532-0625, fax 615-532-0046

Closed System Boreholes

Scotty Sorrells
Division of Water Control,
Environment & Conservation
401 Church St, 6th floor L&C Tower
Nashville, TN 37243
615-532-0671, fax 615-532-0120

Texas

Well Driller and Pump Installer Licensing (Registration)

Texas Water Commission
Texas Water Well Drillers Board
PO Box 13087, Capitol Station
Austin, TX 78711

Water Well Construction Standards

Rick Wilder
Texas Natural Resource Conservation Commission
PO Box 13087
Austin, TX 78711-3087
512-239-0503, fax 512-239-0533

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Bob Traylor
Texas Natural Resource Conservation Commission
PO Box 13087
Austin, TX 78711-3087
512-239-0520, fax 512-239-1003

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

Lewis Heerin
Texas Natural Resource Conservation Commission
PO Box 13087
Austin, TX 78711-3087
512-239-4552, fax 512-239-4430

Closed System Boreholes

Bob Traylor — see Injection (Recharge) Wells — Underground Injection Control Program (UIC) above

Utah

Well Driller and Pump Installer Licensing (Registration)

Jerry Bronicel
Department of Natural Resources
1636 W. N. Temple Suite 220
Salt Lake, UT 84116-3156
801-538-7382, fax 801-538-7467

Water Well Construction Standards

Jerry Bronicel — see above

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Jerry Jackson
Department of Environmental Quality
Division of Water Quality
PO Box 144870 288
N 1460 W
Salt Lake, UT 84114-4870
801-538-6023, fax 801-538-6016

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

Donald Hilden
Department of Environmental Quality
Division of Water Quality
PO Box 144870 288
N. 1460 W
Salt Lake, UT 84114-4870
801-538-4870, fax 801-538-6016

Closed System Boreholes

Jerry Bronicel — see Well Driller and Pump Installer Licensing (Registration) above

Vermont

Well Driller and Pump Installer Licensing (Registration)

Jim Ashley
Department of Environmental Conservation
Water Supply Division
103 S. Main The Old Pantry
Waterbury, VT 05671-0403
802-241-3400, fax 802-241-3284

Water Well Construction Standards

Jim Ashley — see above

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Elizabeth Hansberger
Department of Environmental Conservation
Water Supply Division
103 S. Main The Old Pantry
Waterbury, VT 05671-0403
802-241-3409, fax 802-241-3284

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

Brian Kooiker
Department of Environmental Conservation
Waste Water Management
103 S. Main The Old Pantry
Waterbury, VT 05671-0403
802-241-3822, fax 802-244-5141

Closed System Boreholes

Jim Ashley — see Well Driller and Pump Installer Licensing (Registration) above

Virginia

Well Driller and Pump Installer Licensing (Registration)

Patricia Mealy
Department of Professional and Occupational Regulation
Boards of Contractors
3600 W. Broad St.
Richmond, VA 23230
804-367-8511, fax 804-367-2474

Water Well Construction Standards

Gary Hagy
Department of Health
Division of Onsite Sewage and Water Services
PO Box 2448 Suite 117
Richmond, VA 23218
804-786-1750, fax 804-225-4003

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Mark Nelson
U.S. EPA, Region 3
UIC Sec
841 Chestnut St.
Philadelphia, PA 19107
215-257-2783, fax 215-597-8541

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

David Mashaw
Department of Environmental Quality
Division of Water Permits
287 Pembroke Office Park
Suite 310 Bldg. #2
Virginia Beach, VA 23462
804-552-1125

Closed System Boreholes

Don Alexander
Department of Health
Division of Onsite Sewage and Water Services
PO Box 2448 Suite 117
Richmond, VA 23218
804-786-1750, fax 804-225-4003

Washington

Well Driller and Pump Installer Licensing (Registration)

Department of Ecology
PO Box 47600
Olympia, WA 98504
206-407-6420, fax 206-407-6426

Water Well Construction Standards

Richard Zmarek
Department of Ecology
Division of Water Resources
PO Box 47600
Olympia, WA 98504
206-407-6648

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Michael Hepp
Department of Ecology
Water Quality Program
PO Box 47600
Olympia, WA 98504-7600
206-407-6420, fax 206-407-6426

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

Gary Bailey
Department of Ecology
Water Quality Program
PO Box 47600
Olympia, WA 98504-7600
206-407-6433, fax 206-407-6426

Closed System Boreholes

No state regulations were found although there may be local ordinances at the regional, county and/or city level.

West Virginia

Well Driller and Pump Installer Licensing (Registration)

Gary Viola
Department of Health
Office of Environmental Engineering
815 Quarrier St. Suite 418
Charleston, WV 25301
304-558-2981

Water Well Construction Standards

Secretary of State
Bldg. 1, Suite 157K
1900 Kanawha Blvd. E
Charleston, WV 25305-0770
304-558-6000, fax 304-558-0900

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Secretary of State — see above

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

Jerry Ray
Department of Commerce
Office of Water Resources
1201 Green Brier St.
Charleston, WV 25311
304-558-0375, fax 304-558-5903

Closed System Boreholes

David P. Watkins
Department of Commerce, Labor, and Environmental Resources
Office of Water Resources
1201 Green Brier St.
Charleston, WV 25311
304-558-2108, fax 304-558-5905

Wisconsin

Well Driller and Pump Installer Licensing (Registration)

Bill Rock
Department of Natural Resources
Bureau of Water Supply
PO Box 7921
Madison, WI 53707
608-267-7649, fax 608-267-7650

Water Well Construction Standards

James F. Scarce
Department of Natural Resources
Bureau of Water Supply
PO Box 7921
Madison, WI 53707
608-267-7652, fax 608-267-7650

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

No state regulations were found although there may be local ordinances at the regional, county and/or city level.

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

Larry Benson
Department of Natural Resources
State Waste Water Bureau
PO Box 7921
Madison, WI 53707
608-266-8229, fax 608-267-7664

Closed System Boreholes

James F. Scarce — see Water Well Construction Standards

Wyoming

Well Driller and Pump Installer Licensing (Registration)

No state regulations were found although there may be local ordinances at the regional, county and/or city level.

Water Well Construction Standards

Ray Murphy
Department of Environmental Quality
Water Quality Division
Herschler Bldg. 122 West 25th St.
Cheyenne, WY 82002
307-777-6150, fax 307-777-5451

Injection (Recharge) Wells — Underground Injection Control Program (UIC)

Robert Lucht
Department of Environmental Quality
Water Quality Division
Herschler Bldg. 122 West 25th St.
Cheyenne, WY 82002
307-777-7095, fax 307-777-5973

Surface Water Discharge — National Pollution Discharge Elimination System (NPDES)

John Wagoneer
Department of Environmental Quality
Water Quality Division
Herschler Bldg. 122 West 25th St.
Cheyenne, WY 82002
307-777-7082, fax 307-777-5973

Closed System Boreholes

Robert Lucht — see Injection (Recharge) Wells — Underground Injection Control Program (UIC) above

*U.S. Government Printing Office: 1997 - 514-003/60605