Commonwealth of Massachusetts
Department of Environmental Protection
Bureau of Resource Protection
Drinking Water Program

Guidelines For
Ground Source Heat Pump Wells

Underground Injection Control Program
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GROUND SOURCE HEAT PUMPS

1.0 Introduction

The purpose of this document is to provide guidelines for the installation of Ground Source Heat Pump (GSHP) wells in Massachusetts. The installation and operation of GSHP wells requires adherence to requirements that are administered by the following Massachusetts Department of Environmental Protection (MassDEP), Bureau of Resource Protection (BRP) programs:

- Underground Injection Control Program;
- Groundwater Discharge Program;
- Well Driller Certification Program; and,
- Water Management Act Program.

Proponents of GSHP well installation/construction techniques and/or well operation techniques and materials not included in this guidance document shall submit detailed information regarding these techniques and/or materials to the MassDEP UIC program for consideration for inclusion in future updates of these guidelines. Any such techniques or materials shall not be used in Massachusetts prior to its inclusion in the guidelines without prior approval from MassDEP UIC Program.

MassDEP recognizes the environmental benefits associated with the use of GSHP systems for heating and cooling. GSHP systems offer the benefit of reduced generation of air pollution (including greenhouse gases) in comparison with conventional heating and cooling systems. The potential environmental and human health risks associated with an accidental release of the GSHP fluids that are permitted under these guidelines are relatively low. The main goal of these guidelines is to have GSHP wells installed in a manner that will not provide potential contaminant pathways that would allow surface runoff to enter groundwater aquifers or the transfer of natural or man-made contamination between two different aquifers or between aquifers and surface water bodies. An additional goal of these guidelines is to minimize the potential for subsurface system leaks.

Typical volumetric flow rates for open-loop (or open-transfer) GSHP systems for a residential application will exceed the typical domestic water consumption volumes for that same residence. Therefore, MassDEP requires that, when feasible, GSHP return flows be directed to the same aquifer from which they are withdrawn to avoid long term declines in water storage in the donor aquifer. Although individual residential applications may not have a significant impact on long term aquifer storage, the cumulative effect of multiple residential applications in the same neighborhood has the potential to impact long term aquifer storage if GSHP return flows are transferred between aquifers that have poor hydraulic connection or from an aquifer to a surface water body.

Many GSHP well installations will occur in settings where land use and water quality concerns would discourage the installation of a potable water supply well. In these settings there may be contamination concerns related to indoor air quality and potential contaminant transport that are not encountered at the typical potable water supply well site. GSHP wells shall not be located, constructed, or operated in a manner that will cause further degradation of aquifers, wetlands, or surface water bodies.

This guidance document is not intended to address all aspects of GSHP system design and installation, especially the above ground/indoor portions of the system which are regulated by other state and local entities. However, given MassDEP's interest in the pollution reduction aspects of GSHP systems, MassDEP recognizes the importance of properly sizing a GSHP system using detailed heating and cooling load calculations. An improperly sized system will result in losses in heating/cooling efficiencies

which will translate into losses in the pollution reduction potential of the system and reductions in the long-term cost savings to the owner.

At this time MassDEP has not established the criteria that would allow for the use of a public water supply well as an open-loop GSHP well.

1.1 Definitions

CGC	**Canadian Geoexchange Coalition**
Closed-Loop Well	**A GSHP well that uses a closed-loop fluid system to prevent the discharge or escape of its fluid into the subsurface. Closed-loop heat pump wells shall not be used to produce water.**
Confining Units	**Impermeable overburden deposits or overburden deposits of a distinctly lower permeability than underlying water-bearing formations.**
Direct Exchange (DX) Well	**A GSHP well that circulates a refrigerant through a closed-loop fluid/vapor system to prevent the discharge or escape of its fluid into the subsurface. DX wells shall not be used to produce water. Direct exchange GSHP systems are also commonly referred to as direct expansion systems.**
Ground Source Heat Pump (GSHP) System	**A heating and/or cooling system that transfers heat to or from the earth in which the naturally occurring, ambient ground temperature (prior to GSHP operations) is 90 degrees Fahrenheit or less.**
Ground Source Heat Pump (GSHP) Well	**Any excavation by any method for the purpose of transferring heat to or from the earth for heating and cooling purposes in which the ambient ground temperature (prior to GSHP operations) is 90 degrees Fahrenheit or less.**
High Solids Bentonite Grout	**A fluid mixture of water and a minimum of 20 percent by weight of bentonite clay with no additives to promote temporary viscosity.**
Horizontal Closed-Loop/DX Well	**A closed-loop or DX well in which the closed-loop/DX fluid/refrigerant tubing is installed in an excavation trench or pit or on ground surface that is subsequently buried rather than in a drilled borehole. The depth of horizontal closed-loop or DX wells shall not exceed 20 feet below finished grade above the footprint of the closed-loop/DX field.**
IGSHPA	**International Ground Source Heat Pump Association**
Open-Loop Well	**A GSHP well that is part of a GSHP system that withdraws groundwater and discharges it back to an aquifer. An open-loop well may also be used to produce water for other purposes such as private potable water, process water, or irrigation; and, those uses shall not be considered as part of the system bleed. What the GSHP industry refers to as a standing column well is, for the purpose of these guidelines, an open-loop well.**
Open-Transfer GSHP System	**A GSHP system utilizing open-loop wells where greater than 5 percent of the return flow (including system bleed) is discharged to a different aquifer or surface water body than the aquifer from which the water was withdrawn.**
Return Flow	**Return flow refers to the majority of the water (on an annual basis) that is discharged from an open-loop GSHP system (not including water that is used for potable, process, or irrigation uses).**
Standing Column Well	**A standing column well serves as both the supply well and the discharge well for a GSHP system.**

System Bleed	**A portion (less than half on an annual average basis) of the open-loop return flow that is occasionally discharged to a different aquifer or surface water body from which it was withdrawn, for the purpose of controlling the temperature in the GSHP well.**

2.0 UIC General Requirements

The federal Underground Injection Control (UIC) Program regulates every injection of fluid into the subsurface. For the purposes of the UIC Program the term "injection" applies to any subsurface emplacement of fluids regardless of whether or not the "injection" requires the application of pressure. Furthermore, the term "fluid" is defined as any liquid, gas or semisolid which can be made to flow. The intent of the program is to preserve and protect underground water from becoming polluted.

Discharge wells for open GSHP systems and wells used for closed-loop GSHP systems are classified as Class V injection wells by the U.S. EPA and the MassDEP UIC Program. If installed, operated, and decommissioned properly, such wells have been determined not to pose a significant threat to the environment.

Proper well construction and maintenance can protect human health and ground water quality and help avoid problems with heat pump system operation. As with other well types, only Massachusetts Registered Well Drillers are permitted to construct, alter, or decommission drilled wells for geothermal heating and cooling systems. The specific type of GSHP well and operational details determine what permits, registration and/or notification are required.

GSHP wells fall into three types within the Class V program. The three types are:

5A6	**Ground Source Heat Pump Return Flow Wells (Major)** – GSHP system(s) consisting of at least one return flow well of greater than 750 feet in depth or greater than 5 return flow wells of any depth
5A7	**Ground Source Heat Pump Return Flow Wells (Minor)** – GSHP system(s) consisting of no more than 5 wells, none of which exceeds 750 feet in depth
5A8	**Groundwater Aquaculture Return Flow Wells** – includes both of the above categories but is related to aquaculture operations

The owner or operator of a GSHP well, or trench must register with the MassDEP UIC Program (per 310 CMR 27.05 (2)(a) and 310 CMR 27.08 (1)) unless the GSHP system requires permitting under the MassDEP Groundwater Discharge Program (per 310 CMR 27.07 (3)(b)).

Prior to the construction of a GSHP system, the owner/operator/installer must submit to the UIC Program a notification of intent to construct. This notification requirement includes GSHP systems that do not include the use of wells. After construction of the well(s) and GSHP system is complete, a UIC Program inspector may inspect the well(s) and system.

3.0 Responsibilities

UIC registration applications for GSHP wells require the following two signatures: the operator (i.e. tenant and/or business owner) and the property owner. In addition, the applicant must indicate who will be the GSHP system designer, GSHP system installer, and, if the installation of a drilled well is proposed, the MassDEP certified well driller.

The operator is responsible for the following:

1. Applying for and obtaining a MassDEP UIC registration number prior to the installation of the GSHP well(s) (except where converting an existing well to a GSHP well) and the GSHP system.

2. Operating and maintaining the GSHP system in the manner for which it was designed by the GSHP system designer;

3. Notifying the UIC Program if the system becomes inactive;

4. Notifying the UIC Program of any significant modifications to the GSHP system or GSHP system operations (including increases in the discharge volumes for system bleed or return flow for open-loop systems).

5. Notifying the MassDEP UIC Program of any change in property ownership;

6. Properly registering any GSHP wells that are installed in addition to those that were included in any previous UIC registrations; and,

7. Properly decommissioning any GSHP well that is taken out of service in accordance with local and state regulations and submittal of a UIC registration closure form.

The owner is responsible for all of the operator's responsibilities listed above if the operator leaves the property and a new operator isn't established and reported to the UIC Program.

The Mass DEP certified well driller is responsible for obtaining the UIC registration number from the operator/owner prior to installing any GSHP well. The well driller is also responsible for installing GSHP wells in accordance with these guidelines and all other applicable state and local guidelines, regulations, and ordinances. Specifically, the installation of the well includes drilling the well boring, the placement of all materials (including well casing, well screens, PVC liners, and tubing) that comprise the well (does not include liquid contents of closed-loop and DX tubing), installation of pitless adapters, and grouting the well boring. In addition any cutting or extension of any well casing is the responsibility of the registered well driller.

The GSHP system installer is responsible for obtaining the UIC registration number from the operator/owner prior to installing any components of a GSHP system. The installer is also responsible for making certain that all the tubing and connections from the well to the building and the GSHP system are installed, tested, and backfilled in a manner that is consistent with these guidelines and any other applicable local, state, or federal guidelines, regulations, and ordinances. In addition, for a horizontal GSHP system, the GSHP installer is responsible for the installation of all subsurface closed-loop or DX tubing. The GSHP system installer shall demonstrate to MassDEP that he/she has successfully completed an installers training course from International Ground Source Heat Pump Association (IGSHPA), Canadian Geoexchange Coalition (CGC), or the applicable GSHP equipment manufacturer and has received certification from that entity to install GSHP systems. A person who has received training from IGSHPA, CGC, or a manufacturer only for open-loop or closed-loop GSHP system design is not

considered to have the necessary training for the installation of a DX system. Furthermore, a person that has only received training from a DX GSHP manufacturer is not considered to have the necessary training for the installation of an open-loop or closed-loop GSHP system.

The GSHP system designer is responsible for confirming that the GSHP system was installed as designed and to notify the UIC program of any and all modifications from the original design. The GSHP system designer shall either be a Massachusetts licensed professional engineer (PE) or demonstrate to MassDEP that he/she has successfully completed a training course from IGSHPA, CGC, or the applicable GSHP equipment manufacturer and has received certification from that entity to design GSHP systems. Some certification programs may be listed as an installer's certification but may include system design training. A person who has received training from IGSHPA, CGC, or a manufacturer only for open-loop or closed-loop GSHP system design is not considered to have the necessary training for the design of a DX system. Furthermore, a person that has only received training from a DX GSHP manufacturer is not considered to have the necessary training for the design of an open-loop or closed-loop GSHP system.

4.0 Water Testing Requirements

All open-loop GSHP wells must complete and submit the following laboratory analyses to complete their application for a UIC registration of the well(s). The local board of health may require additional laboratory analyses. Owners of all currently registered Class V UIC open-loop GSHP wells must complete and submit the following laboratory analyses, to maintain their registration, if they have not already done so.

All analyses for the parameters listed below in Tables 1, 3, and 4 and the sodium analysis listed in Table 2 must be performed by a MassDEP laboratory certified for testing drinking water for those parameters.

All registrations issued will be "conditional" until the laboratory results are submitted to and reviewed by the MassDEP UIC program. MassDEP will notify the applicant(s) after reviewing the laboratory results which of the following items apply to their well(s):

1. Additional testing is required.

2. Testing shows one or more parameters are above the primary standards that have been established by MassDEP for public water systems and MassDEP has determined that treatment is required to ensure that the well(s) does not endanger sources of drinking water or result in a worsening of existing contamination issues.

3. Testing shows one or more parameters are above the secondary standards that have been established by MassDEP for public water systems and at concentrations that MassDEP has determined that treatment is required in order to ensure that the well(s) does not endanger sources of drinking water or the environment.

4. The registration has been changed from "conditional" to fully registered UIC Class V Well.

4.1 Raw Water Testing

The raw intake water from the open-loop GSHP Wells [5A6 & 5A7] must be analyzed for the following primary and secondary parameters using a method approved by MassDEP for potable water. A minimum of three well volumes shall be removed from the well prior to collecting the sample for laboratory analysis. MassDEP may require analyses for additional parameters based upon site or area specific

concerns. Unless there are site specific concerns, MassDEP does not require gross alpha, radium, and uranium testing for overburden wells installed on the Cape, the Islands, and in the Plymouth-Carver Aquifer.

Table 1: Raw Water Analytes with Primary Massachusetts Maximum Contaminant Level for Drinking Water

SUBSTANCE	PRIMARY MMCL[1] (mg/L)
Arsenic	0.010
Nitrate (as N)	10
Nitrate/Nitrite (total)	10
Nitrite (as N)	1
Gross alpha radiation	15 pCi/L
Radium (226 + 228)[3]	5 pCi/L
Uranium[4]	0.030
Benzene	0.005
Carbon Tetrachloride	0.005
Dichloromethane (methylene chloride)	0.005
1,2-Dichlorobenzene (o-DCB)	0.6
1,4-Dichlorobenzene (p-DCB)	0.005
1,2-Dichloroethane	0.005
1,2-Dichloroethylene (cis)	0.07
1,2-Dichloroethylene (trans)	0.1
1,1-Dichloroethylene	0.007
1,2-Dichloropropane	0.005
Ethylbenzene	0.7
Methyl Tertiary Butyl Ether (MTBE)	*0.07* [2]
Monochlorobenzene (chlorobenzene)	0.1
Styrene	0.1
Tetrachloroethylene (PCE)	0.005
Toluene	1
Trichloroethylene (TCE)	0.005
1,1,1-Trichloroethane (1,1,1-TCA)	0.2
1,2,4-Trichlorobenzene	0.07
1,1,2-Trichloroethane	0.005
Vinyl Chloride (VC)	0.002

SUBSTANCE	PRIMARY MMCL[1] (mg/L)
Xylenes (total)	10

[1] Massachusetts Maximum Contaminant Level
[2] Office of Research and Standards Guideline (ORSG)
[3] If the gross alpha result is less than 5 picocuries per liter (pCi/L) then radium 226 and radium 228 analyses are not required.
[4] If the gross alpha result is less than 15 picocuries per liter (pCi/L) then uranium analysis is not required.

Table 2: Raw Water Analytes with Secondary Maximum Contaminant Level for Drinking Water

SUBSTANCE	SECONDARY MCL[1] (mg/L)
Sodium	*20* [2]
Chloride	250
Corrosivity	non-corrosive
Iron	0.3
Manganese	0.05
pH	6.5 - 8.5

[1] Massachusetts Maximum Contaminant Level
[2] Office of Research and Standards Guideline (ORSG)

4.2 Discharge Water Testing

1. The discharge from the heat pump (prior to discharge into the GSHP return flow well) must be analyzed for the following parameter using a method approved by MassDEP for potable water, during start-up of the system.

Table 3: System Startup Sampling Requirements for GSHP Discharge

Substance	Primary MMCL
Total coliform bacteria (including fecal coliform and *E. coli*)	refer to 310 CMR 22.05

2. The discharge from the heat pump (prior to discharge into the open-loop or open-transfer GSHP return flow well) must be analyzed for the following parameters using a method approved by MassDEP for potable water, 90 to 120 days after start-up of the system. This requirement shall be waived if the proponent provides documentation indicating that all components of the GSHP system that come into contact with the return flow have received NSF International and

Massachusetts Board of State Examiners of Plumbers and Gas Fitters approval for use with potable water and the water is non-corrosive.

Table 4: Post System Startup Sampling Requirements for GSHP discharge

Substance	Primary MMCL (mg/L)
Copper	Treatment Technique, 1.3 (Action Level)
Lead	Treatment Technique, 0.015 (Action Level)

5.0 Open-Loop Return Flow and System Bleed Requirements

If feasible, open-loop return flows shall be returned to the same aquifer from which it was withdrawn and shall not be altered from the water that was withdrawn from the aquifer. Open-transfer GSHP system return flow (including system bleed) discharges shall be considered on a case-by-case basis. MassDEP defines an open-transfer GSHP system as one in which greater than 5 percent of the return flow (including system bleed) is discharged to a different aquifer or surface water body than the aquifer from which the water was withdrawn. The proponent for an open-transfer GSHP system shall provide justification for the application that includes a discussion of the feasibility of routing the return flow to the same aquifer. In most instances in which the water quality of the return flow is below primary MMCLs, the applicant shall be allowed to assume that all bedrock fractures in the GSHP well are part of the same aquifer.

Return flows shall not be allowed to freefall (cascade) into the well. Return flow piping shall extend below the estimated low water elevation to minimize the introduction of oxygen into the well water. If groundwater chemistry would indicate the need for chemical additives or disinfectants then alternatives to the open-loop system should be considered. A proponent for an open-loop system requiring a chemical additive shall require a Groundwater Discharge Permit from MassDEP rather than a UIC registration.

If the return flow is discharged to a well other than the withdrawal well(s) then it shall be equipped with a level sensor and the GSHP system shall have an automatic shut-down mechanism that will be activated in the event that the water level or pressure in the well exceeds an acceptable level. In aquifers in which the static water table or potentiometric head is below ground surface, the automatic shut-down shall occur when the level sensor indicates that the well is at risk of overflowing. In confined aquifers in which the potentiometric head of the aquifer is above ground surface, the injection pressure that triggers a system shut-down shall be established by MassDEP. MassDEP strongly recommends that conservative assumptions be made relative to the long term volumetric injection rate for a well that is exclusively used for return flows as injection wells typically lose capacity more rapidly than withdrawal wells.

See Section 9.3 for backflow prevention requirements on the system bleed discharge line.

In some open-loop systems where the withdrawal well is also the point of discharge (standing column well), system bleed is occasionally discharged to an alternate location for the purpose of controlling the temperature in the GSHP well. If the bleed water is discharged to a sewer system, or to a municipal stormwater system, the proponent shall submit to MassDEP either a copy of a letter or a permit from the applicable sewer authority or stormwater authority that indicates that entity's approval of discharge of the GSHP system bleed. System bleed water discharged to a jurisdictional surface water body requires a National Pollutant Discharge Elimination System (NPDES) permit. System bleeds to retention basins such as a wet basin, bioretention

area, or extended dry detention basin shall submit a copy of either an approval letter from MassDEP Wetlands Program or the local conservation commission, if applicable.

6.0 Dual Use (Open-Loop and Private Potable Water Supply) Wells

A common practice at single-family residential properties in New England is to have one well serve as both the source of potable water supply and as the supply and discharge well for an open-loop GSHP system. A proponent of such a well should be aware that although MassDEP issues UIC registrations for these types of dual use wells, the MassDEP approval only applies to the GSHP discharge to that well. Only the local plumbing inspector and board of health may approve of the use of a well for connection to the potable water system. MassDEP strongly recommends that the applicant contact these local authorities prior to installing the GSHP well and system as they may have additional requirements for, or prohibitions against, such dual use.

See Section 9.3 regarding backflow prevention device requirements for dual use wells.

In addition to the backflow prevention device requirement, MassDEP requires that the pump intake for a standing column dual use GSHP and potable water supply well be placed at a lower elevation than the drop pipe outlet for the GSHP discharge line. The purpose of the combination of backflow prevention device (see Section 9.3) and pump intake elevation requirements are to minimize the chance for significant concentrations of refrigerant vapors from entering the potable water plumbing in the event of a breach between the water and refrigerant loops in the GSHP system. The highest elevation of perforated pipe in a Porter Shroud is considered the pump intake elevation for a well so equipped.

7.0 General Well Construction (Open-Loop, Closed-Loop, and DX Wells)

Certain engineering or geologic circumstances may require site specific well construction adaptations. All open-loop GSHP wells shall be installed in conformance with MassDEP's *Private Well Guidelines* (as amended) or MassDEP's *Guidelines and Policies for Public Water Systems* (as amended), whichever is applicable. All GSHP wells shall be installed in conformance with 313 CMR 3.00: *Registration of Well Drillers and Filing of Well Completion Reports*.

Subsurface closed-loop and DX tubing running between the closed-loop and DX wells and the heated structure shall be placed on and covered with suitable clean material that will not result in damage to the tubing as excavation trenches and pits are backfilled and compacted. At least three feet of back-fill, that is no more permeable than the surrounding soil, shall be placed above the embedding sands for the tubing. If less than three feet is used (other than the location where the tubing may daylight along the building foundation) measures shall be taken to prevent long term damage to the tubing from freeze-thaw cycles and accidental damage from shallow excavation activities (caution tape alone is not considered sufficient protection). Back-fill materials shall be clean and shall be adequately compacted to minimize the potential for forming a depression or sump that would allow infiltration of surface run-off or other fluids.

It shall be left to the discretion of MassDEP to allow deviation from the following well construction criteria:

7.1 Well Casing

1. Steel well casing wall thickness shall be dependent on casing length and shall be determined using American Petroleum Institute (API) or American Water Works Association (AWWA) standard but in no circumstance shall have less than a .233-inch wall thickness.

2. Plastic well casing or screen shall not be driven. Plastic well casing shall meet the requirements specified in the American Society for Testing and Materials (ASTM) Standard F480, Standard Specification for Thermoplastic Well Casing Pipe and Couplings Made in Standard Dimension Ratios (SDR) as amended and supplemented. Plastic casing shall also meet the requirements of the NSF International Standard Number 14, "Plastic Piping System Components and Related Materials" as amended.

3. All open-loop bedrock wells shall be cased and sealed a minimum of 15 feet into competent and unweathered bedrock. A casing with a drive shoe advanced into bedrock is not a sufficient seal.

4. Closed-loop and DX wells will not be required to be cased into bedrock; however, special grouting requirements (see Section 7.3) shall be met if the above item #3 requirement is not met.

Temporary casing shall be installed to prevent overburden cave-in prior to the installation of tubing material and grouting of closed-loop and DX wells unless other means to temporarily stabilize the open boring are used. If temporary casing is not installed, the completion of well construction should proceed as soon as possible upon completion of the borehole.

7.2 Tubing Material, Below Grade Connections, and Tubing Installation Requirements for Closed-Loop and DX Wells

For both closed-loop and DX wells, the tubing shall not be forced into the borehole. For instance, if cave-in of overburden has occurred in a boring that did not have a temporary protective casing, or if a piece of bedrock become(s) dislodged and partially blocks the borehole, the tubing shall not be forced past the obstruction in such a manner that the short- or long-term structural integrity of the tubing may be compromised.

1. Closed-loop wells

   The tubing material and connection requirements for closed-loop GSHP wells are regulated under 780 CMR 71.00 *State Board of Building Regulations and Standards*. The applicable ASTM standards for the polyethylene (PE) tubing material are provided in 780 CMR 71.00, Section 7101.2. Section 7104.2 provides the tubing connections requirements.

   All heat exchange loop pipe connections to be placed in the borehole shall be by heat-fusion or electrofusion joints as described in 780 CMR 71.00 Section 7104.2. In addition to heat fusion or electrofusion joints, non-metallic mechanical stab-type insert fittings that meet ASTM D-2513, Section 6.10.1, Category 1, may be used in the header assembly and manifold.

2. DX wells

   If copper tubing is used for DX applications, all below grade copper connections shall be brazed. Prior to installation MassDEP approval is required for any tubing material other than copper that is used in a DX well. As of the release date of these guidelines, 780 CMR 71.00 does not specifically address DX wells; however, future updates to those regulations may include DX wells.

7.3 Grouting and Backfilling Requirements

All open-loop GSHP wells shall have the same grouting and casing requirements as public or private water supply wells, whichever is applicable.

For all GSHP wells that are not defined in these guidelines as horizontal, grouting and installation of any backfill material shall take place by pumping through a tremie pipe and shall be applied from the bottom of the section being grouted upward and completed in one continuous motion. Any deviation from this methodology requires approval from MassDEP. After cement grouting is applied, work on the well shall be discontinued until the cement or concrete grout has properly set in accordance with manufacturers recommendations. Activities associated with the storage, preparation, and installation of grout and backfill material shall minimize the potential for the introduction of oil, chemical, and microbial contamination. The water content of any grout/backfill material and water used to clean grouting equipment shall be obtained from a potable water source. Where grouting material extends through zones of salt water, a salt water resistant grout material shall be used.

Closed-loop wells that utilize a plastic loop require the placement of a high solids bentonite slurry grout (at least 20 percent solids by weight) for any interval of the boring that is in confining or semi-confining layers (layers containing significant silt and/or clay). In addition, a high solids bentonite slurry grout shall be installed from the bedrock surface to a minimum depth of 15 feet into competent bedrock.

For DX wells that only utilize copper loops, the grouting requirements in the preceding paragraph apply with the exception of the grout material. Thermally enhanced grouts that achieve a cured hydraulic conductivity of 10^{-7} centimeters per second (cm/s) or less may be utilized in place of a high solids bentonite slurry grout. The following types of grout from MassDEP's *Guidelines and Policies for Public Water Systems* (as amended) are also acceptable:

1. Neat Cement Grout

   Type II cement conforming to ASTM standard C150 and water must be used for 1.5 inch openings, with not more than six gallons of water per 94 lbs of cement.

2. Concrete Grout

   a. Concrete grout shall contain equal parts of type II cement conforming to ASTM standard C150 and sand, with not more than six gallons of water per 94 lbs of cement. Concrete grout must be used for openings larger than 1.5 inches.

   b. Where an annular opening larger than four inches is available, gravel not larger than one-half (1/2) inch in size may be used in the concrete grout.

For closed-loop wells, a minimum of five feet of high solids bentonite slurry grout seal will be required within the boring at the upper terminus of the vertical closed-loop tubing.

For DX wells utilizing a copper loop, at a minimum, the upper five feet of each of the borings beneath the installation pit shall be sealed with a type of grout described in this Section.

For closed-loop and DX wells the borehole diameter shall, at a minimum allow for the insertion of a 1.25 inch diameter tremie pipe with the loop tubing installed for the purpose of filling the annulus between the tubing and the borehole with sand and grout material. It is recommended that the tremie pipe be installed with the loop tubing for ease of placement.

For closed-loop and DX wells, no section of the annulus between the tubing and borehole wall shall remain open after completion of the well. However, outside of the depth intervals that require a high solids bentonite slurry grout or a grout that achieves a cured hydraulic conductivity of 10^{-7} cm/s, other types of thermal grouts or fill material, including clean permeable sands shall be allowed for the remainder of the depth intervals in the well.

7.3.1 Additional Grouting Requirements - Special Conditions

1. Wells installed in or through sand and gravel aquifers

    a. For open-loop wells, if clay or hardpan is encountered above a water bearing formation, the permanent casing and grout shall extend through the clay and/or hardpan. For closed-loop and DX wells a grout seal shall extend through the entire interval of clay and/or hardpan. The grout seal shall consist of bentonite clay slurry for all closed-loop wells.

    b. If temporary casing is used, it shall be completely withdrawn as grout is applied.

    c. Protection from grout leakage into the gravel pack or screen of an open-loop well shall be provided through the use of transition sand.

2. Wells installed in or through confining units

    If confining units are encountered during drilling operations, those units shall be sealed at the depth intervals of these confining units with a grout seal. For any such confining units that are less than 10 feet in thickness, the grout seal shall extend a minimum of five feet above and below the confining unit. The grout shall consist of high solids bentonite slurry for all closed-loop wells.

3. Naturally flowing wells

    a. Open-loop wells: Flow that exceeds system demand shall be controlled to prevent damage to the well or its associated piping, equipment, and building structures (i.e. damage caused by freezing or erosion). Any damage prevention controls that involve "bleeding" water from the wellhead shall be installed in such a manner as to prevent rainwater or potential floodwater from entering the well, and the outfall shall be covered with a 24-mesh, corrosion resistant screen.

    b. All wells: If erosion of the confining bed or grout seal appears likely, special protective construction may be required by MassDEP.

7.4 Capping Requirements

At all times during the progress of work, the contractor shall provide protection to prevent tampering with, or entrance of foreign materials into the well.

7.5 Sampling Taps

Sampling taps shall be required on the withdrawal and discharge lines for all open-loop withdrawal and discharge wells (including wells that serve as both withdrawal and discharge wells). One sample tap shall be required for wells that are manifolded to supply flow to an open-loop GSHP system, including an open-loop

GSHP system that is composed of multiple GSHP heat exchange units operating in parallel. One sample tap shall be required for the return flow from each individual GSHP heat exchange unit in a manifolded open-loop GSHP system unless each individual unit can be operated independently for sample collection purposes. If individual GSHP heat exchange units in an open-loop GSHP system can be operated independently, then one sample tap shall be required for the combined manifolded return flow line.

7.6 Mapping and Marking Locations of Subsurface Components of GSHP System

Underground caution tape shall be installed above all borehole locations that are finished below final grade. Underground caution tape shall also be installed over all sections of underground piping associated with the GSHP system. Scaled site schematics that tie underground GSHP well locations and underground piping to above ground reference points shall be provided to the property owner upon completion of the system.

8.0 General Well Construction (Horizontal Closed-Loop, and Horizontal DX Wells)

Subsurface closed-loop and DX tubing shall be placed on and covered with suitable clean material that will not result in damage to the tubing as excavation trenches and pits are backfilled and compacted. At least three feet of back-fill shall be placed above the embedding sands for the tubing that is no more permeable than the surrounding soil. If less than three feet is used (other than the location where the tubing may daylight along the building foundation) measures shall be taken to prevent long term damage to the tubing from freeze-thaw cycles and accidental damage from shallow excavation activities (caution tape alone is not considered sufficient protection). Back-fill materials shall be clean and shall be adequately compacted to minimize the potential for forming a depression or sump that would allow infiltration of surface run-off or other fluids.

9.0 GSHP System Requirements

9.1 Refrigerants, Plasticizers, Antifreeze, Denaturants, Lubricating Oils, and Corrosion Inhibitors

The use of refrigerants, antifreeze chemicals, and lubricating oils is prohibited in water that is returned to the subsurface via open-loop GSHP systems. The use of plasticizers in grout used in well construction is prohibited for open-loop GSHP wells. Following are the only currently MassDEP approved refrigerants, plasticizers, antifreeze, lubricating oils, and corrosion inhibitors that are allowed for closed-loop GSHP wells.

Propylene glycol (CAS No. 57-55-6) and ethanol (CAS No. 64-17-5) are the only acceptable antifreeze additives for closed-loop GSHP wells. MassDEP has also determined that denatonium benzoate (CAS No. 3734-33-6), ethyl acetate (CAS No. 141-78-6), isopropanol (CAS No. 67-63-0), and tertiary butyl alcohol (CAS No. 75-65-0) are acceptable denaturants for ethanol additives. All other antifreeze chemicals and denaturants must be approved by MassDEP prior to use.

Food grade lubricating oils are acceptable for closed-loop and DX wells. DX wells may also use polyol ester as a lubricant. All other lubricating chemicals or oils must be approved by MassDEP prior to use.

R-22 refrigerant and its EPA recommended substitutes R-407C and R-410A are acceptable for use in DX systems. All other refrigerants must be approved by MassDEP prior to use.

Sodium naphthalene sulfonate conforming to ASTM C 494 Type F is an acceptable plasticizer for use in grouts that contain cement. Plasticizers shall not be used for the construction of GSHP wells that will also serve as sources of potable water.

Corrosion inhibitors must be approved by MassDEP prior to use.

9.2 Leak Detection, Emergency Shut-Offs, and Makeup Fluid

The GSHP system shall have an automatic shutdown device(s) to minimize refrigerant, antifreeze or oil leaks in the event of a pressure/fluid loss. The shutdown mechanism shall be such that the system can only be reactivated by the GSHP system vendor or other qualified service representative that is qualified to detect and fix (if possible) the leak and conduct a post repair pressurization test. The GSHP that has been shut down due to fluid/pressure loss shall not be reactivated until the final pressurization testing described below in Section 9.6 has successfully been completed. The ability to reactivate the GSHP system that has been shut down due to a pressure/fluid loss shall not be provided to unqualified persons, including the home/building owners/occupants.

A makeup fluid tank for either closed-loop or DX GSHP systems shall only be operated manually. The concern is that an automatic makeup fluid injection system could potentially result in the prevention of the activation of the automatic shutdown device in the event of a system fluid leak, thereby resulting in the release of additional refrigerant or antifreeze.

9.3 Backflow Prevention Device

Open-loop GSHP systems that are connected to a potable water supply (including private) shall be installed with a backpressure backflow prevention device after the split between the potable supply and the GSHP supply, prior to the GSHP heat exchanger. The purpose of the backflow prevention device is to prevent a refrigerant leak from traveling directly to potable water taps.

For all open-loop systems equipped with a system bleed, a backflow prevention device shall be installed on the bleed line to prevent back siphoning.

9.4 Signage

Information regarding who to contact in the event of a system shutdown or for routine maintenance shall be prominently displayed on the heat pump. Information regarding the type of refrigerant in the GSHP system and, for closed-loop GSHP systems, the type of antifreeze used shall also be prominently displayed on the heat pump.

9.5 Cathodic Protection Requirements

All DX systems shall be installed with cathodic protection unless soil chemistry indicates that corrosive conditions are not expected to exist and the bottom of the GSHP well(s) is greater than 20 feet above highest observed static (non-pumping) water level in a deeper well located within 300 feet of the GSHP well(s). If no deeper wells are located within 300 feet of the GSHP well(s) then cathodic protection shall be required. The cathodic protection system shall be maintained in operating condition. The cathodic protection system shall be tested once per year in order to maintain long term corrosion protection of the subsurface tubing.

9.6 Final Pressurization Testing

Following completion of installation and grouting of a closed-loop or DX well (including horizontal), a final pressure test shall be performed. Additional pressure testing prior to grouting is encouraged due to the capital investment in the GSHP well boring.

For closed-loop wells (including horizontal) 780 CMR 71.00, Section 7105 *State Board of Building Regulations and Standards* requires that the assembled GSHP loop system be pressure-tested with water at 100 psi (690 kPa) for 30 minutes prior to backfilling of connection (header) trenches.

Following completion of installation and grouting of DX wells (including horizontal), the final testing of the DX loop shall be performed with water or air that shall be applied at a minimum pressure of 150 percent of the manufacturer's heat pump operating specifications. Once pressurized the closed system pressure shall be observed for at least 30 minutes.

For both closed-loop and DX wells (including horizontal) if pressure testing shows that any GSHP loop leaks, the leaking loop shall be repaired or replaced. If the loop can't be repaired or replaced, the loop and borehole shall be decommissioned in accordance with Section 10.0 below. Following any loop repair or replacement work, an additional final pressure test shall be performed as described above in this section.

9.7 Setback Distances

Open-loop GSHP wells that also serve as potable water supply wells shall meet the setback requirements of MassDEP's *Private Well Guidelines* (as amended) or MassDEP's *Guidelines and Policies for Public Water Systems* (as amended), whichever is applicable.

All setback distances in this section are horizontal measurements and apply to the horizontal distance between the GSHP well and the referenced land use/feature. For example, the setback distances from an angled well are measured from the land surface overlying the entire length of the angled well; whereas, the measurements from a vertical well are measured from the wellhead.

All open-loop, closed-loop, and DX wells shall be located at least 10 feet from potable water and sewer lines.

Open-loop GSHP wells that do not also serve as a potable water supply source shall be located at least 25 feet from private potable water supply wells and from existing and potential sources of contamination including, but not limited to septic tanks/fields, lagoons, livestock pens, and oil or hazardous materials storage tanks. An open-loop GSHP discharge well shall not be permitted within the Zone I of a public water supply well.

Closed-loop and DX wells shall also be located at least 25 feet from these potential sources of contamination. Closed-loop and DX wells shall be located at least 50 feet from private potable water supply wells. Closed-loop and DX wells shall not be permitted within the Zone I of public water supply wells. Closed-loop and DX wells shall be located at least 10 feet from surface water bodies. MassDEP recommends against the installation of angle GSHP wells through unconsolidated overburden deposits under existing or planned building structures or in close proximity. If such an installation is to be performed, great care should be taken to minimize the risk of immediate or future damage to the building structure. No GSHP borehole or well shall extend to within 10 feet (horizontal distance) of a property boundary for a property belonging to another owner without the expressed written consent of that/those owner/owners.

It is good practice to conduct a review of MassDEP Bureau of Waste Site Cleanup's (BWSC) oil and/or hazardous materials database prior to the initiation of any GSHP well drilling project. The rationale for

conducting such a review is even greater for potential GSHP well sites that may be located in areas that are otherwise not considered for potable water supply due to the surrounding land use activities.

Hydrogeologic mounding calculations shall be performed for any open-loop GSHP well that is used only as a discharge well if that well could potentially impact nearby storm drains, Title 5 or other soil absorption systems, or cause emerging groundwater (break-out at ground surface) or basement flooding. Note that our concerns for impacts to a Title 5 leaching system are not restricted to whether or not the leaching beds of the soil absorption system would become submerged but whether the required separation distance would be met between the leaching beds and the estimated mounding height under estimated high water table conditions and design load. If required, hydrogeologic mounding calculations shall be performed by a professional engineer or a hydrogeologist.

10.0 Well Decommissioning

Decommissioning refers to the physical closure of the well.

1. Decommissioning of an open-loop GSHP

   Decommissioning of an open-loop GSHP well shall be completed in conformance with MassDEP's *Private Well Guidelines* (as amended) or MassDEP's *Guidelines and Policies for Public Water Systems* (as amended) and 313 CMR 3.00: *Registration of Well Drillers and Filing of Well Completion Reports*.

   In addition to the well decommissioning guidelines provided in MassDEP's *Private Well Guidelines*, the following guidelines from MassDEP's *Guidelines and Policies for Public Water Systems* (as amended) should also be considered for the decommissioning of private GSHP wells:

   a. Sand and Gravel Wells

      Sealing materials are watertight substances that prevent water and contaminants from entering and seeping through abandoned wells. The proper procedure for the decommissioning of these wells will be the following: the casing will be cut off 4 feet below the surface. Fill material (clean sand, gravel or pea gravel or crushed stone) will be used to fill the casing to within 10 feet of the top of the cut off casing. The upper 10 feet will be filled with a mixture of neat cement and six percent bentonite by weight. The plugging material shall be allowed to flow out the top and along the sides of the casing to assure that a proper seal is established. The upper four feet of soil from the top of the casing to the surface shall be properly compacted.

   b. Bedrock Wells

      Bedrock well casings will be cut off four feet below the surface. To prevent the transport of fill material into fractures, it is recommended that larger diameter fill material, such as gravel or pea gravel, be used. The well will be filled to the base of the well casing. The casing shall then be filled with a mixture of neat cement and six percent bentonite by weight. The plugging material shall be allowed to flow out and along the sides of the casing to assure that a proper seal is established. The upper four feet of soil from the top of the casing to the surface shall be properly compacted.

c. Confined Aquifer Wells

The low permeability layer that creates the confined aquifer must be sealed so that there is no chance of leakage between aquifers and the yield and hydrostatic head of the aquifer can be retained. A mixture of neat cement and six percent bentonite by weight shall be used to seal the confining layer and will extend 10 feet below and 10 feet above the confining layer. Clean fill can be used to plug the remainder of the well in the confined and unconfined aquifers. The well casing will be cut off four feet below ground surface and the top 10 feet of the casing will be filled with a mixture of neat cement and six percent bentonite by weight. The upper four feet of soil from the top of the cut off casing to the surface shall be properly compacted.

2. Decommissioning of a closed-loop GSHP well

The decommissioning of a closed-loop GSHP well shall involve the following:

a. All fluid in the heat exchange loop shall be displaced/removed and disposed of properly.

b. A hole shall be excavated at least 5 feet below the ground surface around the well. The loop pipe in this excavation shall be removed.

c. The remaining loop shall be completely filled with a high solids bentonite slurry. The slurry shall be allowed to spill into the excavation to provide a cap at least one foot thick above the loop pipe. The remainder of the excavation shall be filled with compacted earth or pavement.

3. Decommissioning of a DX well

The decommissioning of a DX GSHP well shall involve the following:

a. All fluid in the heat exchange loop shall be displaced/removed and disposed of properly.

b. A hole shall be excavated at least five feet below the ground surface around the well. The loop pipe in this excavation shall be removed.

c. The remaining loop shall be completely filled with a cement grout. The plasticizer sodium naphthalene sulfonate conforming to ASTM C 494 Type F may be added to the cement to improve the ability to pump it through the loop. The grout shall be allowed to spill into the excavation to provide a cap at least one foot thick above the loop pipe. The remainder of the excavation shall be filled with compacted earth or pavement.

11.0 Other Regulatory Requirements

1. Bureau of Pipefitter, Refrigeration Technicians, and Sprinklerfitters

Massachusetts General Laws and the Massachusetts Bureau of Pipefitter, Refrigeration Technicians, and Sprinklerfitter regulations (528 CMR 10-13) require that a Massachusetts licensed refrigeration technician perform the installation, repair, replacement, and maintenance of any refrigerant containing part of any refrigerant system of a ten ton capacity, or greater.

2. Bureau of Waste Site Cleanup

   The discovery of any contaminants in excess of the reportable concentration limits established in 310 CMR 40.0000: Massachusetts Contingency Plan (MCP) shall require reporting to MassDEP Bureau of Waste Site Cleanup (BWSC) per 310 CMR 40.0300.

3. Groundwater Discharge Program Requirements

   Any open-loop GSHP system that introduces chemical additives to the discharged water must be permitted by the Groundwater Discharge Program (per 314 CMR 5.05 (5)).

   Groundwater Discharge Permits are usually issued for five-year intervals. Any exemption in accordance with the provisions of 314 CMR 5.05 does not relieve the owner, operator, and installer of their responsibilities under other state regulations including, but not limited to 310 CMR 27.00 Underground Injection Control (UIC) Program.

4. NPDES Program Requirements

   The MassDEP National Pollutant Discharge Elimination System (NPDES) regulations regarding the surface water discharge of GSHP wastewater has recently expired. Until the regulation is either re-instated or revised, the NPDES Program currently is not processing NPDES Permits for GSHP systems. Any ground surface discharge of GSHP wastewater that infiltrates into the ground prior to reaching a surface water feature (including lakes, ponds, rivers, streams, and wetlands) would not require a NPDES permit; however, it would be considered a UIC discharge and would therefore require registration with the UIC Program.

5. Storm Water Discharge Program Requirements

   Any owner, operator, or installer of a GSHP system planning to discharge to an existing storm water drainage system must check with the owner of the storm water system to determine whether the discharge meets the acceptance criteria for that system and obtain written approval from that owner for the GSHP discharge.

6. Water Management Act Program Requirements

   Withdrawals of water that, in the opinion of MassDEP, constitute a nonconsumptive use are exempt from the need to file a registration statement or a permit application pursuant to MGL c. 21 G. or 310 CMR 36.00.

   The regulations define nonconsumptive use as any use of water that results in its being discharged back into the same water source at or near the withdrawal point in substantially unimpaired quality and quantity.

   There are several types of industrial cooling processes that transfer heat from the process to water, then to the air, the water source or the ground. Non-evaporative cooling processes must demonstrate no significant water quality impacts. Evaporative cooling is considered consumptive and must be permitted because water mass is lost by the design.

   Withdrawals of water for GSHP systems are generally considered nonconsumptive provided the water is returned at or near the withdrawal point and within the same water source in essentially unimpaired quality and quantity. In order for MassDEP to determine if the proposed use is considered non-consumptive, the applicant for an open-loop GSHP well(s) with a system design

rate of greater than 100,000 gpd must file a Statement of Non-Consumptive Use (Water Management Act Program's Form I).

The form for requesting a determination of non-consumptive use is available at: http://www.mass.gov/dep/water/approvals/wmgforms.htm

If a GSHP receives a determination of nonconsumptive use and there should be any change in the water volumes withdrawn, its use, the volume discharged, or the discharge location, the nonconsumptive use status may be withdrawn and the withdrawal may be subject to a Water Management Act Permit.

7. Wetlands Protection

   In accordance with MGL Chapter 131, Section 40 and 310 CMR 10.00, Wetlands Protection, any person proposing construction or alteration of the land within 100 feet of a wetland or within the 100-year floodplain of any river or stream must apply to the local Conservation Commission for a Determination of Applicability. The Commission evaluates the impact prior to issuing a permit or denial and must ensure that "the capacity of an area to prevent pollution of groundwater shall not be adversely affected." The Commission's decision may be appealed to MassDEP.

8. Other Regulatory Requirements:

   The installation and operation of GSHP systems must also comply with other applicable regulations and statutes, including but not limited to M.G. L. c. 21 & 43; the State Environmental Code, Title 5, 310 CMR 15.000; and the Massachusetts Uniform Plumbing Code, 248 CMR 2.00. In addition to state regulations and statutes, there may also be local ordinances, Board of Health regulations, and Conservation Commission requirements for discharges associated with GSHP systems.

12.0 References

248 CMR 1.00 – 11.00: *Uniform State Plumbing Code*

310 CMR 10.00: *Wetlands Protection*

310 CMR 15.000: *The State Environmental Code, Title 5: Standard Requirements for the Siting, Construction, Inspection, Upgrade and Expansion of On-Site Sewage Treatment and Disposal Systems and for the Transport and Disposal of Septage*

310 CMR 27.00: *Underground Injection Control Regulations*

310 CMR 36.00: *Massachusetts Water Resources Management Program*

310 CMR 40.00: *Massachusetts Contingency Plan*

313 CMR 3.00: *Registration of Well Drillers and Filing of Well Completion Reports*

314 CMR 5.00: *Ground Water Discharge Permit Program*

528 CMR 10 – 13: Massachusetts Department of Public Safety, Bureau of Pipefitters, Refrigeration Technicians, and Sprinklerfitters Regulations

780 CMR 71.00 *State Board of Building Regulations and Standards*

MassDEP, 2008 *Guidelines and Policies for Public Water Systems, Volume 1: Guidelines*

MassDEP, *Guidelines and Policies for Public Water Systems*