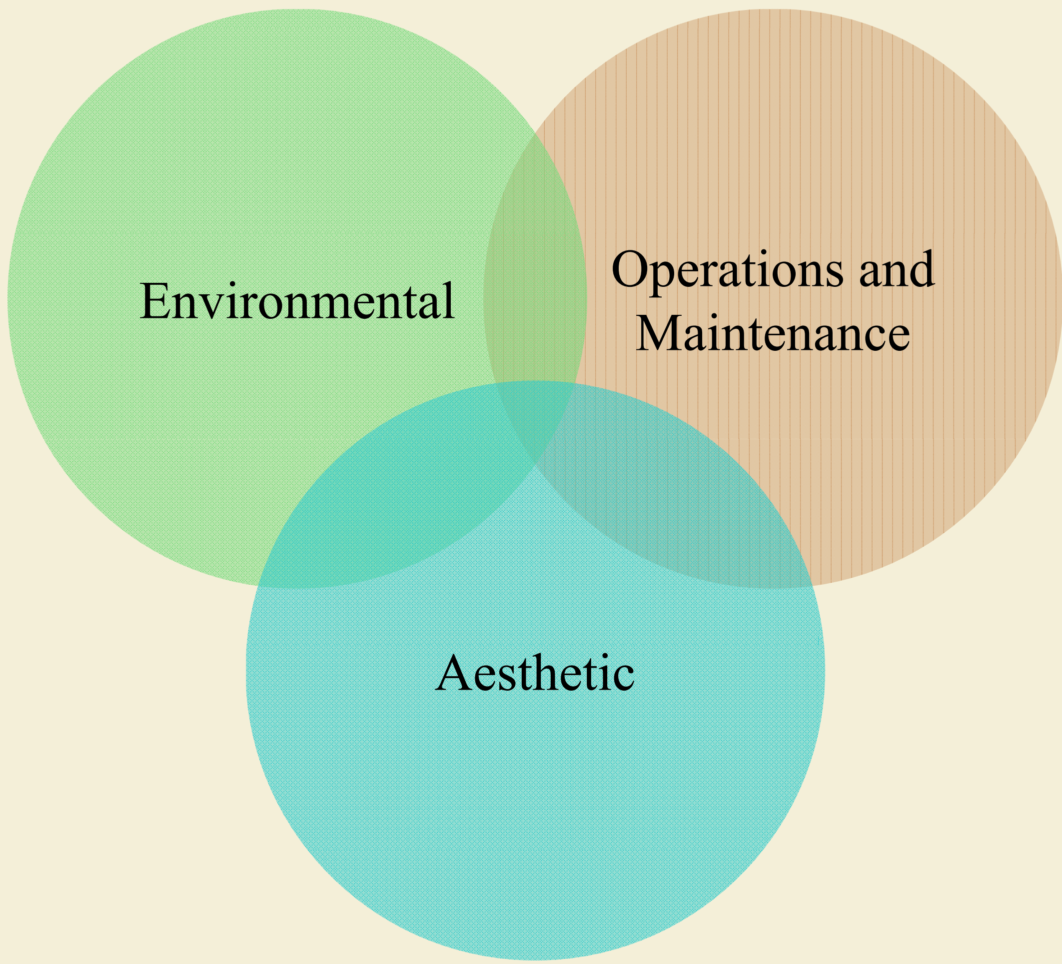
Geothermal Wells at Harvard LESSONS LEARNED

Presented by Harvard University Campus Services:

- Facilities Maintenance Operations
- The Office for Sustainability

1. Are GSHPs Good for Harvard?
2. How GSHPs Work
3. Lessons Learned from Current Campus Installations
4. Environmental Permitting

Are GSHPs Good for Harvard?



Environmental Benefits

- Use less energy than conventional HVAC systems
  - Can significantly reduces emissions of greenhouse gasses by using "free" energy from the earth
  - More efficient performance
    - COP of 3 to 6 versus 1.5 to 2.5 (Source: DOE)
- Can be more efficient than conventional heating systems
  - Up to 44% more efficient than air source heat pumps, 72% more efficient than electrical resistance heating (Source: DOE)
    - *COP* (coefficient of performance)

O&M Benefits

- Lower energy costs than conventional air source cooling
  - 20-50% reduction in energy bills (Source: EPA)
- Lower maintenance costs
  - No equipment is exposed to weather
  - Fewer moving parts to fail

Aesthetic Benefits

- No cooling towers or other HVAC equipment on roofs
- No noise from HVAC equipment

GSHPs Can Be Good For Harvard

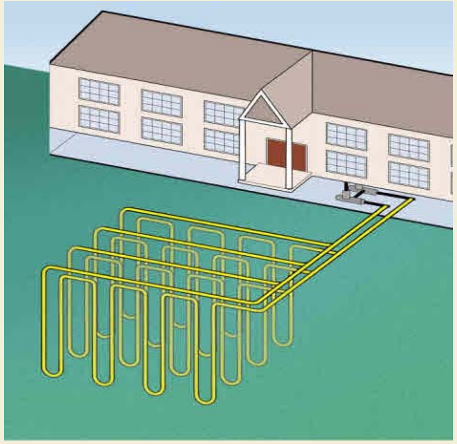
- Properly designed, installed, permitted and maintained systems can be an effective alternative to conventional heating and cooling technology
- Appropriately scaled GSHP systems can be a successful part of Harvard's energy portfolio

Part II: How GSHPs Work

Types of GSHP Systems

Closed Loop

Uses the earth as the heat source and heat sink with anti-freeze additive to the loop water

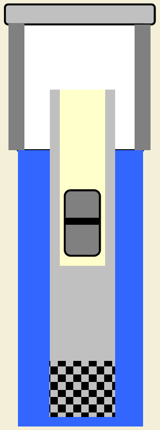


All existing installations at Harvard are open loop, standing column wells!

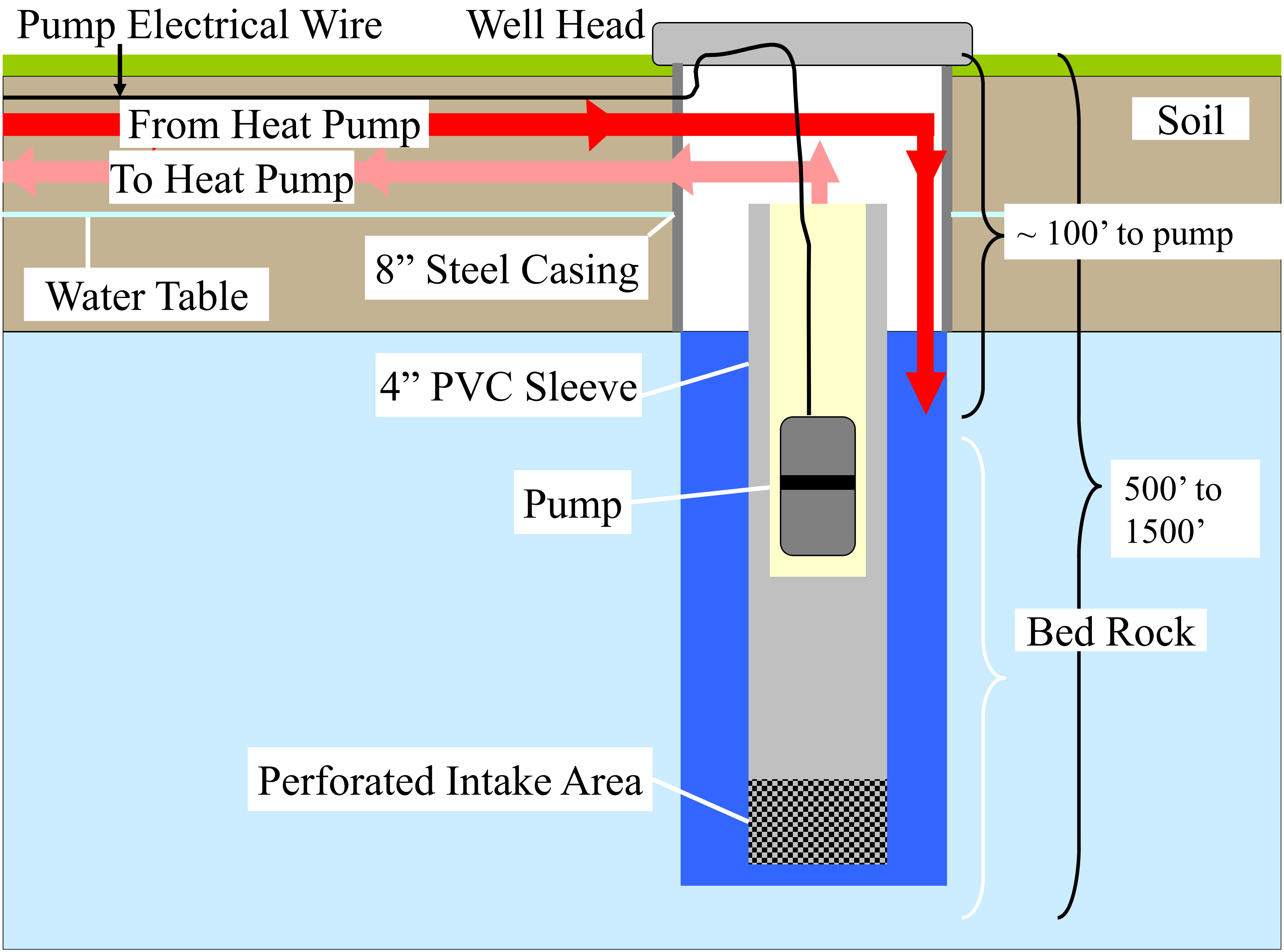
Open Loop

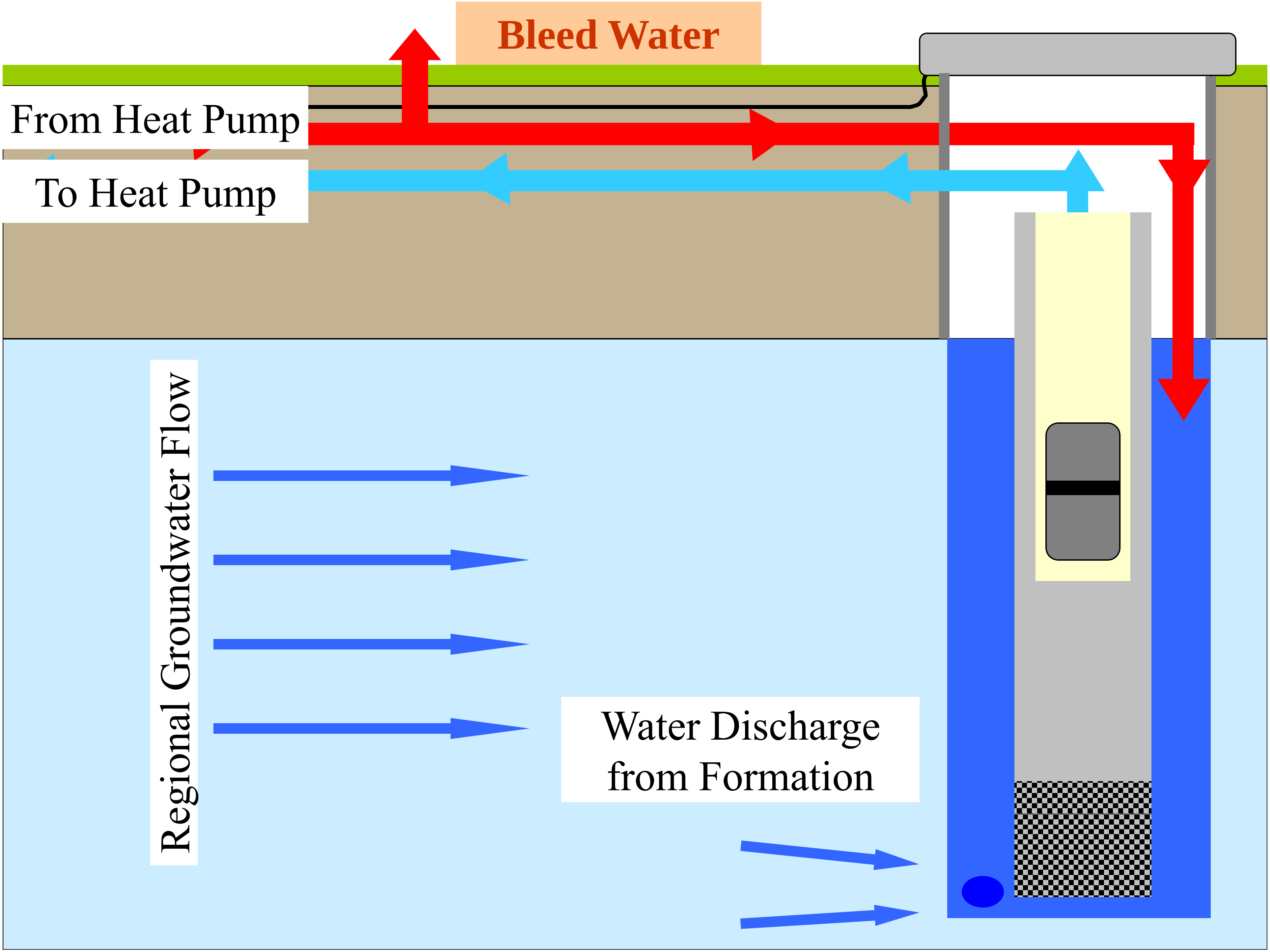
Uses a surface or underground water source (lake, river, or well) as both the heat source and the heat sink

Standing Column Well



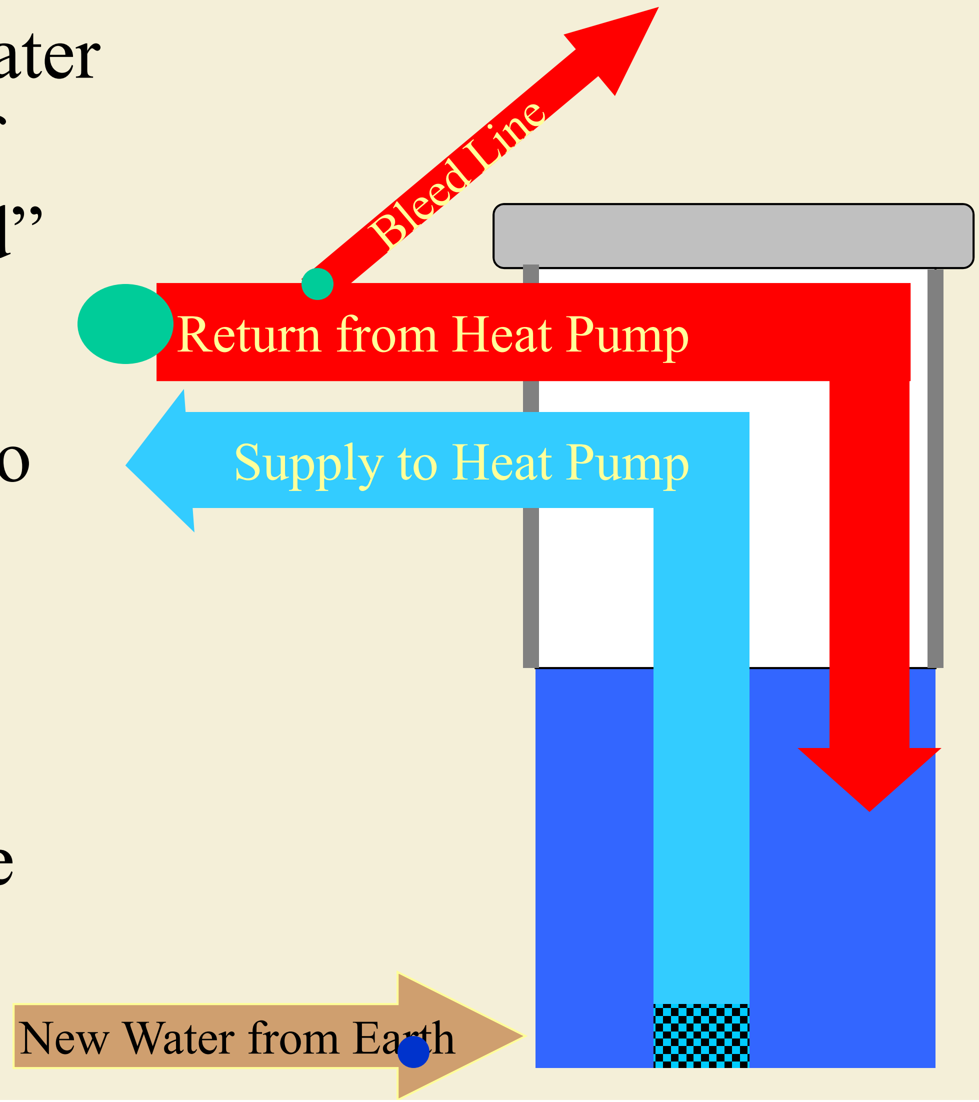
Layout of a Typical Standing Column Well Installation at Harvard


Pump Electrical Wire
Well Head
From Heat Pump
To Heat Pump
Soil
~ 100’ to pump
Water Table
8” Steel Casing
4” PVC Sleeve
Pump
500’ to
1500’
Bed Rock
Perforated Intake Area


Bleed Water
From Heat Pump
To Heat Pump
Regional Groundwater Flow
Water Discharge
from Formation

Understanding Bleed

- To raise or lower well water temperature, a portion of return water can be “bled” from the well
- This allows fresh water to enter the well column, raising or lowering the temperature of the well
- Bleed water must then be reused or disposed of



Typical water-to-water heat pumps (30 tons each)

Harvard Well Inventory

	Wells	Depth (feet)	Designed to Bleed	Pump Depth (feet)	Pump Capacity (GPM)	VFDs*
Blackstone	2	1500	Yes	110	180	Yes
QRAC	2	1500	Yes	100	180	Yes
90 Mount Auburn	3	450 - 650	Yes	100	270	Yes
Radcliffe Gym	2	1500	Yes	100	160	Yes
2 Arrow St (condo).	3	1500	No			Yes
1 Francis Ave.	2	750, 850	Yes	100	160	Yes
Future Projects						
Byerly Hall	5	1500	No	100	410	Yes
Weld Hill (Closed Loop)	88	500	No	N/A	680	Yes

* Variable Frequency Drives allow a pump to run at partial capacity, reducing energy cost

Part III: Lessons Learned from Current Campus Installations

Lessons and Recommendations

- Design
- Installation
- O&M

Design Lesson 1

Know the condition and temperature of the groundwater

- Heat pumps and piping for several Harvard projects were not designed for brackish water
  - Salinity has been encountered in some of Harvard's Wells
- Ground water temperatures may vary from predictions by the project engineer
  - Can dramatically affect bleed rate and disposal strategy
- A geotechnical engineer cannot accurately predict groundwater conditions

Design Lesson 1

Recommendations

- **Identify local water conditions before making piping and heat pump selections**
  - Some of Harvard wells installed at 1500’ have brackish water
  - All Harvard wells have some level of iron Bactaria in the water
  - Native water temperatures can range from 55 to 65 degrees
- **Drill a test well** or consider phasing construction so that wells are completed before pipe and equipment selection
  - Average cost to drill a well is ~$125/ft
- **Use PVC for all internal system piping for deep well installations**

Design Lesson 1

Recommendations

- **Install a Heat Exchanger to isolate the Heat Pumps from the Well Water**
  - Some of Harvard wells installed at 1500’ have brackish water
  - All Harvard wells have some level of iron Bacteria in the water
  - Heat Exchangers in a Heat Pump cannot tolerate any contamination

* Harvard has installed Heat Exchangers on two systems, this has reduced maintenance and increased overall efficiency.

Design Lesson 1

Recommendations

- **Install a Coupon Rack to measure corrosion on metal components throughout the system (heat exchanger, valves, pumps, etc)**
- **Examples:**
  - Copper
  - Iron
  - Stainless Steel
  - Bacteria

- **Ever thirty days have an authorized Chemical Company analyze the coupons to determine rate of metal erosion**

Design Lesson 2

Understand the function of the well as a heat exchanger

- Geothermal wells transfer heat to or from the ground along their vertical length
  - The longer the well, the more heat exchange capacity it can provide
- The surface area of the well (length) is **critical** to its function and capacity
- Well drillers may want to stop drilling once sufficient water flow rate is achieved
  - This can save money on drilling costs but can lead to serious problems

www.bestwaterwelldriller.com

Design Lesson 2

Recommendations

- **Drill well to design depth**
- **Do not short drill!**
  - Short drilling reduces the heat exchange capacity of the well
    - Likely to necessitate more frequent bleeding
    - Reduces the overall output capacity of the system

Design Lesson 3

Understand the relationship between heat exchange capacity of the well and bleed

- Geothermal wells can be bled to increase their capacity
  - When a system is bleeding, it is operating at reduced efficiency
- Disposal of bleed water introduces regulatory issues and added cost
  - Due to salinity at 1500’ depth, bleed water reuse options may be limited
  - Regulation may ultimately prohibit bleed entirely

Design Lesson 3

Recommendations

- **Design your system for Zero Bleed**
  - Include this requirement in construction specifications and enforce it!
  - Strategies include increasing capacity of the well field or fracturing wells to increase hydraulic flow
- **Well Yield* = One Ton per 72' at 75° F (1,500' well produces 21 tons not 30!)**

Brevardcounty.us

*** Harvard ES-96 Class Research Results, April 2007**

Design Lesson 4

Metering and controls are critical

- Without metering, well performance and bleed rate is unknown
- Without monitoring well water supply and return flows, it is possible to draw the water level below the pump
- Metering and controls provide capability to diagnose problems, trend well performance, and collect compliance data

Design Lesson 4

Recommendations

- **Specify and install adequate well monitoring and controls, including**
  - Measure flow rate and temperature on:
    - Supply
    - Return
    - Bleed
  - Flow switch on well supply line
  - Full integration with building automation controls
  - Install a level meter on each well
- **Resist temptation to eliminate controls and metering during Value Engineering!**

Design Lesson 5 Site Wells Appropriately

- **Allow for future access to wells for maintenance and repairs**
- **Consider well spacing when reviewing the site plan**
    - Thermal interactions between closely spaced wells can reduce system efficiency

Design Lesson 6

Select refrigerants carefully

- R-410A, the environmentally preferable refrigerant, has a smaller working range than conventional R-22 (which is being phased out)
  - Heat pumps operating with R-410A can handle water up to 98 degrees before cycling off
  - Heat pumps operating with R-22 can handle water up to 105 degrees
  - BUT warmer condenser water reduces heat pump efficiency

Design
Lesson 6

Recommendations

- **Avoid R-22 refrigerant**
  - 2010: no new equipment manufactured with R-22
  - 2020: no new R-22 will be produced

Design Lesson 7

Use Wells for Heating AND Cooling

- Wells are designed to transfer heat to and from the ground
- Ideally, net transfer of heat into the ground in summer and out of the ground in winter should be zero

www.istockphoto.com

Design Lesson 8

Consider Interactions with Neighboring Wells

- While installing a second set of wells, HPs at a nearby existing building were affected by excessive mud, rocks, and stone dust trapped in the condensing water filters
- **Conclusion:** Drilling the new wells generated debris that was drawn into the existing wells (exacerbated during periods of bleed)
  - Clogged strainers caused the heat pumps difficulties

Design Lesson 8

Recommendations

- Closely monitor water conditions in nearby wells whenever drilling new installations
- If possible, do not bleed neighboring wells when new wells are being drilled
- If existing wells have already been affected by drilling, possible solutions include:
  - Flush existing wells and inspect discharge
  - Re-circulate water in existing wells without running it through a heat pump and monitor well water level
  - If wells are blocked, develop a cleaning process

Design Lesson 9

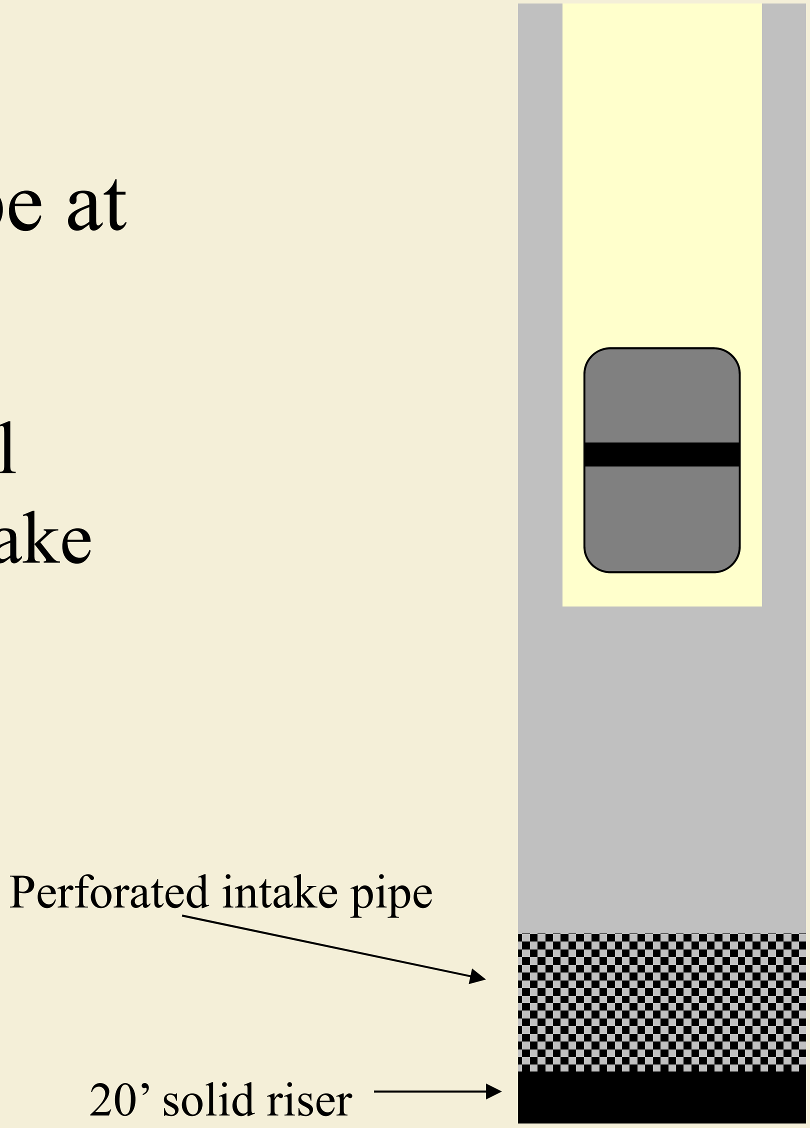
Prevent Sediment from Entering the Intake Sleeve

- Sediment quickly clogs filters and reduces efficiency
- Found to be a particular problem on start-up and early operation of all systems across campus

Design Lesson 9

Recommendations

- Design a 20' solid riser below the perforated pipe at the bottom of the well
  - Prevents sediment at well bottom from entering intake piping



Not to scale

Install
Lesson 1

Understand piping and balancing issues

- Poorly designed pipe runs can prevent water from returning evenly to the wells
- Imbalances in water flow to wells can reduce system capacity
- Proper controls can reveal these imbalances before they become problematic

Install Lesson 1

Recommendations

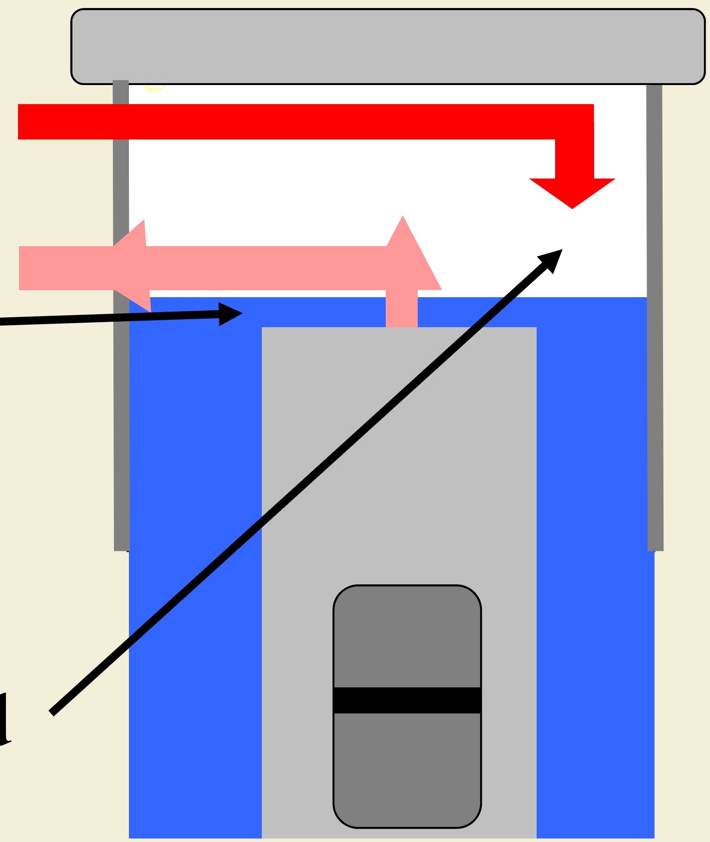
- Insist on Coordination Drawings prior to layout and installation of piping
- Develop an owner's acceptance process to ensure proper balancing and full commissioning of all systems

www.nj.com

Install Lesson 2

Improper positioning of well sleeve and return piping can impact performance

- Wells can short cycle if the sleeve is installed below the water level
    - Return water can enter the supply feed and dilute the supply water temperature
- Incorrectly installed or positioned return water pipe can cause air to enter the well, resulting in pump cavitation and failure



*Not to scale

Install
Lesson 2

Recommendations

- **Utilize an owner's acceptance process to verify proper installation, start up, and turnover of the well system**

Eticonformity.com

Prevent solvents from entering groundwater

- If using PVC ensure that adhesives on well piping are fully cured so that VOCs (from solvents) are not introduced into groundwater
- Most well drillers do not allow proper curing of adhesives before installing PVC well pipe
  - ***Volatile organic compounds*** (***VOCs***)

Install Lesson 3

Recommendations

- Use Certa-Lok™ Pipe as alternative to PVC
  - **No adhesives needed!**
- Monitor pipe joining process in field to ensure compliance with specifications

O&M Lesson 1

Maintenance starts on Day One!

- Plugged strainers can reduce water flow and cause evaporators to freeze (if internal heat pump safety controls do not engage)
- Warranties do not cover damage caused by improper maintenance!

Iron sludge from a blocked strainer

Recommendations

- Have a preventative maintenance plan in place before your system comes online
- Clean strainers frequently, especially during the first months of operation
- Require installing contractor or manufacturer to train local building operations team on primary equipment prior to start up

O&M
Lesson 2

Do not put bleach into wells!

- Consultants may recommend periodically adding bleach directly to well water to sterilize the well
- Any additive to well ***<u>must be</u>*** pre-approved by DEP
  - Bleach poured into the well can enter the aquifer and contaminate it or cause unintended chemical reactions

Part IV: Environmental Permitting

The following slides are specific to Harvard and Massachusetts. Consult your local authorities for permitting information relevant to geothermal systems.

Design Lesson 8

Identify and examine all permitting implications during design

- Refer to EH&S CAPS specification
- **Department of Environmental Protection (DEP) may require:**
  - Open Loop – Groundwater Discharge Permit
  - Closed Loop – Underground Injection Registration
- **Massachusetts Water Resources Authority (MWRA)**
  - Bleed discharge prohibition?
- **Environmental Protection Agency (EPA) regulates:**
  - Bleed discharge to surface waters

Design Lesson 9

Design for NO BLEED to sewer

- Regulation may eventually prohibit bleed discharge to sewer
- Investigate reuse options
  - Reuse of bleed water in facility applications
  - Discharge drywell system
  - Discharge to surface water (NPDES permitting)

Design Lesson 10

Investigate site soil/groundwater conditions

- Assess potential for historical soil or groundwater contamination
- Establish plan to re-use any soil on-site
- Obtain de-watering permit (EPA/MWRA)

Design Lesson 11

Initiate DEP Permitting early

- Allow at least 3-6 months for the Permitting Process
  - Open Loop and Closed Loop installations must go through an application process, well water sampling, public comment period and must pay a fee
  - Non-Consumptive Determination (Water Management)

Design Lesson 12

Understand metering/monitoring for DEP permit requirements

- Permits require submission of specific data, so wells must be able to provide the following information:
  - Flow/Temp (continuous reading daily)
  - pH, chloride, specific conductance, water treatment chemicals (grab samples/monthly)
  - Bleed discharge volume
- Specify CertaLok™ piping
- No additives to well without prior DEP approval
- Understand permit reporting/maintenance program

Environmental Summary

- Assess regulatory permitting requirements during design
  - Refer to EH&S CAPS specifications
- Assess site soil/groundwater conditions – historical contamination
  - Plan to re-use soils on-site
- Design system for zero bleed discharge to sewer
- Schedule - accommodate lead time for dewatering permit and DEP permitting (3-6 months)
- Specify monitoring and metering controls, CertaLok piping
- Determine permit reporting/maintenance program

Questions?

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