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HOT WATER FLUSHING DESIGN REPORT

SKYKOMISH SCHOOL
105 6TH STREET
SKYKOMISH, WASHINGTON

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ACRONYMS AND ABBREVIATIONS

bgs	below ground surface
BNSF	BNSF Railway Company
C	degrees Celsius
CAP	*Cleanup Action Plan for BNSF Former Maintenance and Fueling Facility, Skykomish, Washington* dated October 2007, revised May 2009, prepared by the Washington State Department of Ecology.
CDF	controlled-density fill
DQOs	design quality objectives
Ecology	Washington State Department of Ecology
EPS	expanded polystyrene
F	degrees Fahrenheit
Farallon	Farallon Consulting, L.L.C.
GAC	granular activated carbon
gpm	gallons per minute
HCC	hydraulic control and containment
HWF	hot water flushing
LDRM	LNAPL Distribution and Recovery Model
LNAPL	light nonaqueous-phase liquid
mg/kg	milligrams per kilogram
µg/l	micrograms per liter
$\mu g/m^3$	micrograms per cubic meter
MSE	mechanically stabilized earth
NAPL	nonaqueous-phase liquid
SAER	*School Alternatives Evaluation Report Addendum, Skykomish School Cleanup, Skykomish, Washington* dated November 23, 2010, prepared by Farallon Consulting, L.L.C.
scfm	standard cubic feet per minute
School	Skykomish School building at 105 6th Street in Skykomish, Washington
School District	Skykomish School District
School property	Skykomish School property at 105 6th Street in Skykomish, Washington
SVE	soil vapor extraction

1.0 INTRODUCTION

This Hot Water Flushing (HWF) Design Report has been prepared on behalf of BNSF Railway Company (BNSF) to present the HWF Alternative modeling and design for cleanup of a portion of the Skykomish School property at 105 6th Street in Skykomish, Washington (herein referred to as the School property) (Figures 1 and 2). The School property cleanup is being performed as part of the BNSF Former Maintenance and Fueling Facility project located in Skykomish, Washington (Skykomish Site). This HWF Design Report presents the design basis and design details for the HWF Alternative for cleanup beneath and approximately 20 feet adjacent to all sides of the Skykomish School building (herein referred to as the School). Cleanup of the remaining portion of the School property, such as the school yard west of the School, is anticipated to proceed as currently described in the *2010 Engineering Design Report* dated May 4, 2010 (AECOM Environmental). BNSF and the Skykomish School District (School District) have negotiated an agreement that permits cleanup work on the western-most 50 feet of the School property to occur during 2011 while School is not in session. BNSF recently presented the School District with a proposed access agreement to complete cleanup of the School yard during 2011 while School is not in session. Cleanup of the entire School property will proceed in a manner consistent with the Cleanup Action Plan prepared by the Washington State Department of Ecology (Ecology) (2007, revised 2009) (CAP).

1.1 CLEANUP GOAL AND OBJECTIVE

The HWF treatment objective for the School established in the CAP is to reduce the amount of petroleum beneath the School to the extent technically possible, with the goal of removing separate-phase mobile or volatile liquid petroleum components or nonaqueous-phase liquid (NAPL). Soil vapor extraction will be implemented during treatment to reduce the potential for vapor intrusion.

In addition, longer-term protection against vapor intrusion may be required if concentrations of total petroleum hydrocarbons exceed 3,400 milligrams/kilogram (mg/kg) NWTPH-Dx in soil beneath the School following treatment. Long-term vapor intrusion mitigation will be implemented if compliance monitoring of indoor, subslab soil gas, and ambient air collected before, during, and after completion of active remediation indicates that vapor intrusion is causing indoor air to exceed the indoor air cleanup level of 1,346 micrograms per cubic meter ($\mu g/m^3$) NWTPH-Dx.

1.2 BACKGROUND

A reevaluation of cleanup alternatives for cleanup of NWTPH-Dx in soil and groundwater beneath the School was conducted in 2010, with the results of the reevaluation provided in the *School Alternatives Evaluation Report Addendum* (Farallon 2010b) (SAER Addendum). The SAER Addendum includes a discussion of the effects of the results of the subsurface investigation completed in 2010 on the viability of the cleanup alternatives evaluated in the CAP and a presentation of: the results of the reevaluation of feasible cleanup alternatives, conceptual schematic designs of the feasible cleanup alternatives, and the results of the comparison of the alternatives to the goals in the CAP and the Stakeholder criteria; and a description of BNSF's proposed cleanup alternative for the School. The cleanup alternatives evaluated in the SAER Addendum included:

- Subsurface Barrier;
- Cold Water Flushing;
- HWF; and
- Move School and Excavation.

Based on the results of the reevaluation, BNSF selected HWF as the only viable cleanup alternative that meets the cleanup goals for the School pursuant to Section 4.1.2.3 of the revised CAP. As described in this Design Report, the active construction and heating phases of HWF can be implemented while School is not in session, thereby minimizing adverse impacts on infrastructure and disruption of the learning environment. Also described are additional mitigation measures intended to reduce impacts on the learning environment during HWF treatment system operations while School is in session.

1.3 HWF DESIGN REPORT PURPOSE

The School District provided BNSF with comments on the SAER Addendum in February 2011, including a number of comments regarding the design elements, mitigation impacts, and schedule for HWF. Initial responses to the School District were provided by BNSF in March 2011 in a narrative, table format. This HWF Design Report has been prepared to provide more detailed information regarding the design, impact mitigation, and schedule elements that were raised by the School District during its review of the SAER Addendum.

1.4 REPORT ORGANIZATION

The HWF Design Report is organized into the following sections:

Section 1—Introduction. This section presents the cleanup goals and objectives and the purpose of the HWF Design Report.

Section 2—Conceptual Site Model. This section presents the current conceptual site model.

Section 3—Design Objectives. This section presents the cleanup objectives and design quality objectives (DQOs).

Section 4—Hydrogeologic Design. This section presents the results of the modeling of the containment wall and the extraction and injection systems.

Section 5—Hot Water Thermal Design. This section presents the hot water thermal design and modeling, including outputs and flow rates.

Section 6—NAPL Recovery Optimization. This section presents NAPL recovery design, including flow rates, equipment requirements, and durations.

Section 7—Vapor Mitigation Design. This section presents the vapor mitigation design.

Section 8—Constructability. This section presents the principal construction elements associated with implementation of HWF.

Section 9—Monitoring Requirements. This section presents the monitoring requirements that will be performed during the HWF implementation.

Section 10—Potential Impacts and Mitigation. This section presents the potential temperature, noise, vapor, aesthetic, and construction impacts during implementation of HWF, and proposed mitigation measures.

Section 11—Schedule. This section presents the HWF implementation and cleanup schedule.

Section 12—References. This section lists the documents used in preparation of the HWF Design Report.

2.0 CONCEPTUAL SITE MODEL

This section presents the current conceptual site model for the School and immediate surrounding area, which consists of a description of the geology, hydrogeology, and nature and extent of concentrations of NWTPH-Dx in soil and groundwater and as NAPL. The conceptual site model provides a design basis for the HWF treatment system.

2.1 GEOLOGY

The School is located in the Skykomish Valley, a steep-sided bedrock valley that has been partially filled with glaciofluvial sediments. The bedrock in the area consists of marine metasedimentary and metaigneous rocks overlain by volcanic and sedimentary rocks that have relatively low permeability. The glaciofluvial sediments filling the valley consist mainly of poorly to moderately sorted sand, gravel, cobbles, and boulders (The RETEC Group 1996). The Town of Skykomish is underlain by highly heterogeneous glaciofluvial sediments, which consist of sand and gravel and underlie a thin layer of topsoil and/or fill (The RETEC Group 2005).

The soil underlying the School consists of well-graded sands and gravels from the ground surface to the total depth explored of 75 feet below ground surface (bgs). Discontinuous, thin lenses of silty sand and sandy silt occur within sands and gravels. Recovery of rock flour and solid rock core from boreholes indicates the presence of cobbles and boulders from near the ground surface to the total depth explored of 75 feet bgs. Sandy silt and silt ranged from 15 to 20 feet bgs at thicknesses ranging from 2.5 to 5 feet.

2.2 HYDROGEOLOGY

Groundwater beneath the School was encountered between 5 and 10 feet bgs during drilling. The depth to groundwater measured in monitoring wells at the School has historically ranged from 3 to 8 feet bgs, with values typically ranging from 5 to 8 feet bgs. A water-bearing zone at the School is present within sands and cobbles containing thin discontinuous lenses of silt. At a depth of approximately 15 feet below grade, a semi-continuous silt layer underlies the primary water-bearing zone. A deeper zone of groundwater flow also occurs below this silt layer. As documented in the *2009/2010 Annual Site-Wide Groundwater Monitoring Report* dated February 21, 2011 prepared by AECOM Environment (2011), the groundwater flow direction at the School has been observed to be predominantly northwest, with seasonal variations indicating a west-northwest flow.

2.3 NATURE AND EXTENT OF CONTAMINATION

The nature and extent of NWTPH-Dx in soil and groundwater and as NAPL at the School are described in the following sections. The concentrations of NWTPH-Dx detected in soil and groundwater were compared against the site-specific Remediation Level of 3,400 mg/kg NWTPH-Dx for soil excavation[1]; 477 micrograms per liter (µg/l) NWTPH-Dx and absence of

[1] The performance standard for cleanup beneath the School was articulated in the 2007 CAP as: "[R]educe the amount of petroleum beneath the school to the extent technically possible, with the goal of removing separate phase

sheen or free product for groundwater down-gradient of the School; and 208 μg/l NWTPH-Dx and absence of sheen or free product at the point of compliance near the Skykomish River.

2.4 TOTAL PETROLEUM HYDROCARBONS IN SOIL

Concentrations of NWTPH-Dx in soil at the School ranged from not detected at laboratory method reporting limits to a maximum of 37,000 mg/kg (Farallon 2010a). Concentrations of NWTPH-Dx exceeding the Remediation Level were detected in soil samples collected from the cleanup excavation within the 6th Street and railroad rights-of-way in 2010 and from the test pits excavated on the southern portion of the School property in 2010, indicating that NWTPH-Dx in soil exceeds the Remediation Level beneath most if not all of the School (Figure 3). The vertical thickness of the soil containing concentrations of NWTPH-Dx exceeding the Remediation Level ranged from approximately 2 to 10 feet.

2.5 TOTAL PETROLEUM HYDROCARBONS IN GROUNDWATER

The groundwater monitoring wells at the School property were sampled in August 2008, March and September 2009, and March and September 2010. Concentrations of NWTPH-Dx exceeding the Remediation Level of 477 μg/l were detected in groundwater samples collected from all of the School property monitoring wells during one or more of the sampling events, with the exception of monitoring well 5-W-54. Measurable thicknesses of NAPL were not observed in any of the monitoring wells during the groundwater monitoring and sampling events, although sheen was noted on groundwater in monitoring well 5-W-51 during the 2009 and 2010 sampling events (AECOM Environment 2011) (Figure 3).

2.6 NONAQUEOUS-PHASE LIQUID

Although NAPL was observed in soil during drilling and test pit excavations at the School, measurable thicknesses of NAPL have not been detected in the monitoring wells (Farallon 2008). The soil samples collected and visual observations made during test pit excavations indicated a high degree of soil heterogeneity, which appears to have created preferential pathways for the movement of NAPL, resulting in distinct "fingers" of NAPL and concentrations of NWTPH-Dx in soil beneath the School. Field observations and laboratory data indicate there is a strong correlation between the observed presence of NAPL in soil and the concentrations of NWTPH-Dx exceeding 8,000 mg/kg in soil.

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mobile or volatile liquid petroleum components or nonaqueous phase liquid (NAPL)." (2007 Original CAP, Section 4.2.1.3, p. 22). This is still the standard for soil "[i]f treatment is implemented." (2009 Revised CAP, Section 4.1.2.3). The 2009 Revised CAP set a separate excavation standard of 3,400 mg/kg NWTPH-Dx in soil beneath the School "to the extent technically possible while protecting the structural integrity of the School building." (Id.)

3.0 DESIGN OBJECTIVES

This section presents the specific DQOs for major treatment system components required to achieve the overall project cleanup objective.

3.1 CLEANUP OBJECTIVE

As described in Section 1.1, Cleanup Goal and Objective, the cleanup objective associated with the design of the HWF treatment system is to reduce the amount of petroleum beneath the School to the extent technically possible, with the goal of removing separate-phase mobile or volatile petroleum constituents or NAPL. This objective will be accomplished by creating a closed-loop subsurface groundwater recirculation system and heating the groundwater to reduce NAPL viscosity, thereby mobilizing the NAPL for recovery via a groundwater extraction system. If present, volatile petroleum constituents will be recovered via a soil vapor extraction (SVE) system. The HWF treatment system footprint consists of the School footprint plus approximately 20 feet in all directions, extending to the areas previously excavated to 6th Street to the east, Railroad Avenue to the south, and the Teacherage to the north.

3.2 DESIGN QUALITY OBJECTIVES

DQOs were prepared to guide the HWF treatment system design (Table 1). DQOs serve to identify the specific design objectives in terms of requirements for functionality, reliability, performance, interchangeability, safety/security, and operations monitoring. DQOs were used to guide the design process by identifying the relevant system requirements to ensure that all elements of the design are addressed. DQOs were identified for these categories for the overall remedy, and for each major subsystem and the components of these subsystems.

The DQOs in Table 1 represent both the functional objectives that were the starting point for the design work and the specific design objectives related to performance, safety, reliability, environmental, and monitoring requirements. Many of the performance DQOs were developed through groundwater modeling and other work discussed later in this report. The key functional, performance, and monitoring objectives of the HWF system are reviewed here because they formed a basis for the more-detailed design work.

The functional objective of the overall HWF treatment system is to meet the cleanup objective for the School to reduce the amount of petroleum beneath the School to the extent technically possible, with the goal of removing separate-phase mobile or volatile petroleum components or NAPL. To achieve this objective, an HWF treatment system will be constructed at the School that will consist of the following major subsystems:

- Groundwater Recirculation and NAPL Recovery;
- Subsurface Heating;
- SVE/Subslab Depressurization; and
- Subsurface Sheet Pile Barrier.

The key functional, performance, and monitoring objectives for the major subsystems that compose the HWF remedy, as presented in the DQOs, are discussed below.

Groundwater Recirculation and NAPL Recovery. This major subsystem will provide a gradient toward the east side of the School property for NAPL recovery along 6^{th} Street and at the southeast and northeast corners of the School. The groundwater recirculation system also provides the driving force for heat transport throughout the treatment zone. The specific performance objectives presented in Sections 4 and 5 were developed using groundwater flow modeling and heat transport modeling. Monitoring will include measurements of water levels, drawdown and mounding, and NAPL recovery.

Subsurface Heating. The subsurface heating subsystem heats the subsurface to reduce NAPL viscosity, reduce NAPL residual saturation, and enhance removal of separate-phase mobile petroleum and NAPL. Specific performance objectives include reaching elevated operational temperatures rapidly during summer operational periods, recycling heat in extracted groundwater to control and maintain heated-area temperatures, and removing heat to rapidly cool the subsurface. Monitoring will include recording subsurface temperatures in the groundwater zone and recording temperatures in the soil immediately below the slab floor of the School.

SVE/Subslab Depressurization. The SVE/subslab depressurization subsystem will remove volatile petroleum constituents and prevent vapor intrusion into occupied space or outdoors by maintaining a negative soil vapor pressure in the subsurface. Vapor barriers also will be used both outdoors and indoors, as required, in areas not currently covered such as in crawlspace areas beneath the north and east entry steps. The size of the SVE system is sufficient to enable heat removal from directly beneath the School slab, maintaining comfortable conditions in the School. Monitoring will include pressure differential monitoring between beneath the floor slab of the School and the atmosphere as well as SVE off-gas monitoring. In addition, indoor and outdoor air monitoring will be performed during treatment.

Subsurface Sheet Pile Barrier. The sheet pile barrier subsystem will provide hydraulic control and prevent migration of contaminated groundwater or NAPL. The sheet pile barrier will extend around the complete footprint of the School and will tie into the existing mechanically stabilized earth (MSE) wall installed at the northern end of the School property in 2006. The subsurface barrier will also tie vertically into an existing silt layer at approximately 15 feet bgs. Monitoring will include installation of piezometers to enable measurement of water levels on both sides of the barrier to evaluate water balance and groundwater flow hydraulics.

4.0 HYDROGEOLOGIC DESIGN

The groundwater recirculation portion of the HWF treatment system is intended to provide a gradient toward the east side of the School property for NAPL recovery along 6th Street and at the southeast and northeast corners of the School. The groundwater recirculation system also provides the driving force for heat transport throughout the treatment zone. Groundwater flow modeling was conducted to evaluate the hydraulic performance of the HWF treatment system, including groundwater recirculation and the sheet pile barrier. In conjunction with the groundwater flow modeling described herein, the effects of injecting hot water on the groundwater temperature were simulated, as described in Section 5, Hot Water Thermal Design.

4.1 MODIFICATIONS TO PREVIOUS SITE-WIDE FLOW MODEL

A three-dimensional site-wide groundwater flow model based on the U.S. Geological Survey MODFLOW code was developed previously to support the design of a groundwater containment and extraction system for Skykomish (S.S. Papadopoulos and Associates 2007). The previous MODFLOW model input files provided by S.S. Papadopoulos and Associates served as a basis for model refinement with the intent to focus on the vicinity of the School. The revised model used herein retained the site-wide model features, with refinements added to address a greater level of detail at the School property. Significant refinements to the 2007 site-wide MODFLOW model in the vicinity of the School that were included for this design work included:

- Increasing the number of layers from 5 to 8.
- Defining an upper silt layer (layer 5) beneath the School.
- Inserting a barrier wall to represent the MSE wall between the Skykomish River and the model domain.
- Refining the grid spacing in the vicinity of the School to 1-foot spacing near the injection wells and other significant design features.
- Revising the extent of the excavated areas to the east, south, and west of the School yard to conform to the as-built information of the field work performed.
- Representing the MSE wall and eastern boundary in the model as narrow zones of low conductivity (0.006 foot per day). (The Hydrologic Barrier Package of MODFLOW was used previously.)
- Setting the hydraulic conductivity of the silt in layer 5 beneath the School to 0.16 foot per day horizontal and 0.04 foot per day vertical.
- Adjusting the barriers surrounding the School to a constant distance of 20 feet to allow room for construction activities.
- Extending the barriers to completely enclose the School. These barriers are completed in layers 2 through 4 of the model with an isotropic hydraulic conductivity of 0.006 foot per day.

4.2 PRELIMINARY MODEL RUNS

Preliminary model runs were conducted to evaluate a range of potential HWF hydraulic design scenarios. In all of these scenarios, the groundwater flushing pattern was directed from the west toward the east to drive NAPL from clean toward impacted areas. A hydraulic barrier surrounding the School was included and tied into the existing MSE wall to the north. A summary of observations from the preliminary model runs that were incorporated into the design of the HWF is presented below.

The MSE wall, down-gradient of the School property, may have some degree of hydraulic conductivity beneath the wall and above the underlying silt layer. Similarly, the silt layer is discontinuous in some areas of the School property. These features provide a potential path for groundwater flow into or out of the containment area. If groundwater extraction and injection rates are balanced, this flow tends to be minimal. If groundwater extraction rates exceed injection rates, the net flow tends to be inward. If injection rates exceed extraction rates, the net flow tends to be outward. For the various scenarios evaluated, the net inflow or outflow from within the sheet pile barrier area is generally on the order of 5 to 15 gallons per minute (gpm), which reflects a range of operational differences between injection and extraction rates that may need to be accommodated by the HWF system. Installation of piezometers on both sides of the sheet pile barrier at locations surrounding the School will provide data during start-up on the appropriate balance of injection and extraction rates.

Flow rates ranging from 30 to 50 gpm will maintain hydraulic control over NAPL flushing and can be achieved with groundwater mounding of less than 2 feet and drawdown of less than 1 foot. The sheet pile barrier is an integral part of the HWF system that allows these moderate flow rates to achieve strong hydraulic control over the treatment zone.

Based on NAPL recovery optimization work described in Section 6 that compared NAPL removal rates using wells to those using a recovery trench, groundwater extraction is designed to be accomplished using a trench. The recovery trench will extend along the east side of the School and extend approximately 50 feet east to west along the north and south sides of the School. The MODFLOW model also showed that the sweep pattern was more uniform when using a recovery trench. In the MODFLOW model, the trench was simulated using the drain boundary condition with the stage set at a fixed elevation of between 910.5 and 911 feet above sea level. The drain conductance was varied to achieve the desired capture rate of groundwater (i.e., 30 to 50 gpm).

Based on the thermal heat transport modeling described in Section 5, use of two infiltration galleries in addition to the injection wells was determined to be favorable for achieving uniform heat distribution and targeting heat within the most-impacted areas. This approach is discussed further in Section 4.3, Final Model Runs. A maximum of approximately one-third of the total injection rate can be applied to these infiltration galleries (i.e., the remaining two-thirds of the total to the injection wells) to avoid a gradient reversal and maintain consistent west-to-east gradients across the School property.

Hot water injection along the west side of the treatment zone was determined to be optimal using seven wells positioned in the approximately middle one-third of the west side of the School. Positioning the injection wells in the northern or southern one-third of the area was found to result in a preferential flow along the northern and southern boundaries of the treatment zone rather than a more uniform flow gradient across the treatment zone.

Based on the thermal transport modeling described in Section 5, the depth of the injection wells was limited to the upper 5 to 7 feet of the saturated zone (i.e., MODFLOW model layer 2) to focus heat delivery on the shallow NAPL-impacted portions of groundwater.

4.3 FINAL MODEL RUNS

Based on the observations made from the preliminary model runs, a final layout for the major elements of the groundwater recirculation system was developed (Figure 4), consisting of:

- Seven injection wells positioned in approximately the middle one-third of the west side of the School;
- Two infiltration galleries: one beneath the main hallway in the School and the other outside the School to the east; and
- A single recovery trench along the east side of the School and extending approximately 50 feet east to west along the north and south sides of the School.

A final model scenario with extraction equal to injection at 40 gpm is presented on Figure 5. The injection rates for the wells relative to the galleries is 65, 20, and 15 percent , respectively, with 26 gpm into the injection wells, 8 gpm into the central gallery, and 6 gpm into the eastern gallery. The maximum groundwater mounding under this scenario is 1.5 feet and the maximum drawdown is 0.7 foot. The average gradient over the treatment zone is approximately 0.01. Based on the thermal heat transport modeling described in Section 5, the 40-gpm scenario presented on Figure 5 is considered the baseline operating scenario for the HWF system.

The sensitivity of the gradient and flow patterns for lower and higher injection and pumping rates was tested at 30 and 50 gpm, respectively. The results are shown on Figures 6 and 7. Under these scenarios, the total injection and extraction rates are equal. The injection rates for the wells relative to the galleries are the same as shown above (65, 20, and 15 percent). Under the 30-gpm scenario, the maximum groundwater mounding is 1.4 feet and the maximum drawdown is 0.4 foot. The average gradient is approximately 0.008. Under the 50-gpm scenario, the maximum groundwater mounding is 2.0 feet and the maximum drawdown is 0.8 foot. The average gradient is approximately 0.014.

The change in groundwater elevation from the non-pumping case to a scenario in which the total injection is 40 gpm and the total extraction is 45 gpm is presented on Figure 8 (negative drawdown represents mounding). In this example, the gradient from west to east across the center of the School is -1.5 feet to 0.4 foot, approximately 1.9 feet total.

To depict the effect of potential leakage below the MSE wall along the north side of the School, Figure 9 shows the drawdown for the same injection and extraction rates as shown on Figure 5, but with a leaking MSE wall. The gradient under this scenario is from -1.4 feet to 0.2 foot, approximately 1.6 feet total, compared to 1.9 feet total under the better-sealed scenario. As described above, installation of piezometers on both sides of the sheet pile barrier at locations surrounding the School will provide data during start-up on the appropriate balance of injection and extraction rates to maintain the designed hydraulic gradients under actual hydrogeologic conditions.

5.0 HOT WATER THERMAL DESIGN

This section presents the approach to the thermal design for the HWF treatment system. Discussed is the selection of target subsurface temperature design criteria, the heating required to elevate subsurface temperatures to meet target temperature design criteria, and the heat removal by SVE to limit increases in the temperature of the first floor of the School.

5.1 THERMAL TREATMENT CONCEPTS

The heating subsystem heats the subsurface to reduce NAPL viscosity and reduce NAPL residual saturation, and thereby enhance removal of separate-phase mobile petroleum and NAPL.

Reduction in NAPL Viscosity. Figure 10 shows the changes in NAPL viscosity and specific gravity as a function of temperature in a NAPL sample collected from the School property in 2009, demonstrating a dramatic reduction in NAPL viscosity with increased temperature. A 10-fold reduction in NAPL viscosity is attained at a temperature of approximately 100 degrees Fahrenheit (°F). A 100-fold reduction in NAPL viscosity is attained at a temperature of approximately 140°F. Diminishing gains are attained at temperatures above 140°F. The reduction in NAPL viscosity attained through HWF will result in removal of a greater extent of NAPL and reduction in the time frame of active remediation operations.

Reduction in NAPL Residual Saturation. NAPL residual saturation represents the NAPL concentration at which separate-phase petroleum would become immobile. Above the residual saturation concentration, NAPL can be mobilized and recovered. Below the residual saturation concentration, NAPL is adhered to the surface of soil particles and/or trapped in pores between soil particles and is immobile. It has long been recognized that an increase in temperature reduces NAPL residual saturation (Edmondson 1965 and others). This phenomenon has two significant implications for the HWF functional objective of removing separate-phase mobile petroleum or NAPL. First, reduction in NAPL residual saturation results in increased NAPL mobility and removal of more NAPL when conditions are heated. Second, NAPL initially will be removed to a lower residual saturation; after treatment and subsurface cooling, the residual saturation will shift back to a higher value, resulting in NAPL concentrations below the residual saturation concentration at ambient temperatures, effectively immobilizing the petroleum that remains.

5.2 THERMAL MODELING

Thermal heat transport modeling was performed using the public domain U.S. Geological Survey code VS2DH to optimize the hot water delivery system and identify engineering requirements such as boiler size. This section presents the modeling inputs and results; engineering requirements are described in Section 5.3.

General Model Construction. The VS2DH model used consistent units of meters and days with energy units of Joules. The model was constructed as a two-dimensional cross-section oriented west to east across the treatment zone. The discretization of geologic textural classes within the model domain is presented on Figure 11.

Key Thermal Modeling Inputs. The VS2DH modeling assumed that treated groundwater would be heated to approximately 160°F (71 degrees Celsius [^{o}C]) prior to reinjection. This temperature was used because it is conservatively below the boiling point of water and would therefore avoid the potential for boiling or off-gas development within process piping and equipment. At this assumed injection temperature, the number of BTUs of heat energy input to the subsurface per day is a function of the number of gallons of water injected. Therefore, higher injection/recirculation flow rates lead to higher subsurface temperatures, which will increase treatment effectiveness.

The VS2DH model was constructed to simulate heat energy removal associated with the SVE system. Extraction of 200 standard cubic feet per minute (scfm) of water-saturated soil gas at 120^{o}F is equivalent to approximately 100,000 BTU per hour of energy removal, which equates to 5.9×10^{-7} Joules/day of energy removal per meter of cross-section. This value was used as an input for the total SVE energy removal for the entire 90-day period of heated injection.

Boundary conditions (Figure 12) were established to represent the sheet pile barrier, the injection wells/galleries, the groundwater/NAPL recovery trench, the subslab SVE system, and the natural gradient flow across the area in deeper geologic layers below the silt layer. The sheet pile barrier was modeled as a low-permeability zone ($K = 10^{-6}$ meters per day). The injection wells and galleries were modeled as constant flow boundaries with a specified temperature of either 15^{o}C (60^{o}F) (unheated) or 71^{o}C (160^{o}F) (heated). The groundwater/NAPL recovery trench was modeled as a constant flow boundary. The subslab SVE system was modeled only as an energy sink, removing heat energy as described above. Natural gradient flow across the deeper geologic strata at the School property was modeled using constant head boundaries.

The VS2DH model was run to simulate 30 days of unheated recirculation followed by 90 days of heated recirculation, followed by a 240-day period of injection of 15^{o}C (unheated) water.

Key Thermal Modeling Results. Figures 13, 14, and 15 (scale in meters; temperature in ^{o}C) depict the modeled temperature distribution after 30, 60, and 90 days, respectively, of injecting hot water (i.e., time = 60, 90, and 120 days in model-time) at 71^{o}C (160^{o}F) (63 boiler horsepower output) and a 40-gpm recirculation rate. This series of figures shows several key results that guide performance expectations. The 71^{o}C injection temperature is rapidly attenuated during heat transport, and lower temperatures will be observed across the treatment zone. With continued injection of hot water, subsurface temperatures increase gradually over time. After 90 days of heated injection (model time = 120 days), the average temperature in the treatment zone is expected to be approximately 54^{o}C (130^{o}F).

Following the summer HWF operational heating period, heat in the extracted groundwater potentially can be recycled into the injection water, or cold water can be injected if desired. Figures 16 and 17 show VS2DH simulation of cold water (15^{o}C/60^{o}F) flushing after 90 days of hot water injection. These model results show that relatively rapid subsurface cooling can be achieved if desired.

5.3 THERMAL SYSTEM ENGINEERING REQUIREMENTS

Specific performance objectives include rapidly reaching elevated operational temperatures during summer operational periods, recycling heat in extracted groundwater, and cooling the subsurface by removing heat in extracted groundwater and injecting cold water. Additionally, the HWF system has been designed to mitigate the potential warming of the School.

The SVE system described in Section 7.3 will serve to limit heat transfer from the underlying heated groundwater to the School floor slab by removing warm moisture-laden soil vapor from beneath the floor. Design requirements were determined for the SVE system to remove the total heat conductive flux upward from groundwater. Assumptions included a groundwater temperature of 140^{o}F at a depth of 7 feet bgs (based on Section 5.2, above), and heat removal by the SVE system should maintain a floor slab temperature of 70^{o}F. Calculations were made as follows:

Heat Conduction Upward from Groundwater (BTU per hour) = H = k*A*(delta T)/x
where:

k = thermal conductivity of soil = 1.4 (BTU/(feet*hour*^{o}F)

A = area of School footprint = approximately 13,600 feet^2

delta T = temperature differential between groundwater and floor slab = (140 ^{o}F – 70 ^{o}F) = 70^{o}F

x = distance from water table to floor slab = 7 feet

Based on the above, the total heat flux upward from groundwater toward the 70^{o}F floor slab would be as follows:

H = 1.4*13,600*70/7 = 190,000 BTU per hour.

At an SVE flow rate of 475 scfm and a temperature of 120^{o}F for moisture-laden soil vapor, the SVE system would remove approximately 192,000 BTU per hour from beneath the School, as follows:

SVE Energy Removal = Q*w*h

where:

Q = SVE flow rate = 475 scfm = 28,500 standard feet^3/hour

w = air specific weight = 0.06 pound/feet^3

h = enthalpy of water-saturated air at 120^{o}F = 112.5 BTU per pound

and:

28,500*0.06*112.5 = 192,000 BTU per hour.

The above calculations were verified using the VS2DH numerical model, as shown on Figure 18. In the VS2DH numerical model, a constant groundwater temperature of 140^{o}F (60^{o}C) was simulated at a depth of 7 feet (2.1 meters) below the floor slab. An initial temperature of 21^{o}C was established above the water table, and the model was run for 60 days, after which equilibrium conditions were established. Energy removal from beneath the slab was simulated at various rates ranging from 100,000 BTU per hour to 200,000 BTU per hour (scaled to the model dimensions). As shown on Figure 18, at an energy-removal rate of 100,000 BTU per hour, upward heat conduction from groundwater would not be fully offset by the SVE system, and the floor slab temperature would rise to approximately 85^{o}F. However, at an energy-removal rate of 150,000 BTU per hour or more, the VS2DH simulation indicated that a floor temperature of 70^{o}F (21^{o}C) would be maintained. This numerical modeling result is consistent with the calculated heat-removal requirement of 200,000 BTU per hour determined above.

Based on the above calculations and with the addition of a safety factor, the SVE system as designed will be capable of removing up to 500 scfm of water-saturated soil gas at up to 140^{o}F. Treatment of this SVE gas stream will require a condenser and an aftercooler prior to vapor treatment using granular activated carbon (GAC).

6.0 NAPL RECOVERY OPTIMIZATION

The NAPL recovery system design was optimized and evaluated using the LNAPL Distribution and Recovery Model (LDRM) version 1.2 developed by the University of Texas at Austin on behalf of the American Petroleum Institute. LDRM uses site-specific geologic and NAPL physical properties to evaluate and compare relative levels of separate-phase mobile petroleum NAPL recovery under different operational scenarios.

6.1 LDRM MODELING SETUP AND INPUT PARAMETERS

Data collected from the Skykomish Site were used as inputs to the LDRM. When site-specific data were not available for a required input parameter, literature values were used. Actual input data entered into the LDRM and their source are presented in Table 2.

In addition to the parameters presented in Table 2, the groundwater flow modeling described in Section 4 and the thermal modeling described in Section 5 were used to develop inputs for groundwater flow rates and ranges of expected temperature conditions.

6.2 NAPL RECOVERY SYSTEM CONFIGURATION OPTIMIZATION

The LDRM was used to compare the predicted NAPL recovery over time for a series of recovery wells with predicted NAPL recovery for a recovery trench. A total groundwater extraction rate of 40 gpm was used to asses both recovery well and trench scenarios. For the recovery well scenarios, the 40 gpm total flow rate was assumed to be divided among 10 recovery wells, yielding an extraction rate of 4 gpm for each well. The saturated thickness and trench depth evaluated were 10 and 7 feet, respectively. These values were selected based on the geometry of the treatment zone and historical groundwater elevations.

A comparison of NAPL recovery curves for an HWF system using 10 recovery wells with a system using a recovery trench is shown on Figure 19. The conditions presented are based on a subsurface temperature of 120°F and a resulting viscosity of 127 centipoise. The LDRM results represent a relative comparison of the duration over which NAPL recovery is expected. The LDRM does not account for geologic heterogeneity. The results suggest that a recovery trench would result in faster recovery rates, which is advantageous. Because a recovery trench would intersect all of the NAPL-bearing geologic zones in its path, it would inherently be more effective in NAPL removal than discrete recovery wells would be. For these reasons, a recovery trench is considered an optimal configuration for NAPL recovery at the School property, and is carried forward as the optimized design approach.

6.3 LDRM MODELING OF THERMAL ENHANCEMENT

The LDRM was used to assess the benefits of thermal enhancement for NAPL recovery. Model runs were made at a range of potential groundwater extraction flow rates and average subsurface temperatures. Using the LDRM outputs, the relative benefit of increasing subsurface temperatures and extraction flow rates can be assessed and optimized.

The recovery trench scenario was evaluated using input values ranging from 34 gpm at 110^{o}F to 51 gpm at 140^{o}F. This range of conditions spans the likely operational conditions anticipated based on the groundwater modeling described in Section 4 and the thermal modeling described in Section 5. Based on this range of conditions and the input parameters presented in Table 2, the LDRM estimates that 2 to 5 years will be required to remove mobile petroleum NAPL (Figure 20). Figure 20 also shows an estimated recovery curve generated using LDRM for a 40-gpm pumping scenario without the addition of heat, indicating that thermal enhancement has significant benefit for removal of mobile petroleum NAPL.

7.0 VAPOR MITIGATION DESIGN (DURING TREATMENT)

The HWF treatment system will elevate subsurface temperatures and increase the potential for migration of contaminant vapors. This potential will be mitigated by implementing three preventive measures: 1) sealing the School first-floor slab; 2) installing a surface cap around the perimeter of the School; and, 3) depressurizing the subsurface with SVE. These measures will prevent migration of vapors into the School and into the atmosphere outside the School.

The effectiveness of the vapor mitigation measures will be monitored by measuring subsurface-surface pressure differentials and monitoring interior air, as described in this section. The need for longer-term vapor intrusion mitigation measures will be assessed following treatment if soil exceeds 3,400 mg/kg NWTPH-Dx beneath the School.

7.1 FLOOR SLAB SEALING

The School first-floor slab is constructed of unreinforced concrete in thicknesses varying from approximately 4 to 6 inches. Visual inspection indicates that the slab was poured between structural footing walls, creating unsealed construction joints where the slab meets the walls. In addition to the construction joints, there are numerous penetrations and open areas in the floor slab. Many of these penetrations currently are in use where plumbing penetrates the slab. Many are open to the subsurface and have no current use.

All construction joints, floor cracks, floor penetrations, and open areas will be sealed with non-shrink concrete grout to mitigate the potential for vapor migration into the School.

7.2 SURFACE CAP

Unpaved areas outside the School within the treatment zone will be capped with an impermeable barrier to prevent vapor migration to ambient air. The cap will consist of a 20-mil geomembrane liner and a 4-inch gravel drainage layer. The liner and drainage layer will be covered with 8 inches of topsoil, and sod. The liner and drainage layer will be sloped away from the School to promote drainage. The location of the surface cap and a cross-section of the cap system installation are presented in the design drawings provided in Appendix A. Prior to installation of the cap, existing surface features will be removed, as practicable. Remaining features that cannot be removed will be sealed to the barrier by a suitable means.

Following remediation, the surface cap will be removed and the surface will be restored to match surrounding conditions. Trees that were removed will be replaced in kind. The area anticipated to be encompassed by the surface cap is shown on Drawing C-103 in Appendix A.

7.3 SVE SYSTEM

The subsurface beneath the School and the perimeter surface cap will be depressurized by an SVE system. The SVE system design includes conservative design criteria and safety factors, as presented in the DQOs (Table 1). Backup power will be available to maintain SVE operation in the event of a power failure.

The SVE system will consist of vacuum blowers connected to wells installed above the water table beneath and outside the School. The system will remove volatile petroleum constituents and prevent vapor intrusion into occupied spaces or the outdoors by maintaining a negative soil-gas pressure in the subsurface.

The SVE off-gas treatment system includes a condenser and a cooling tower to reduce the temperature of extracted soil-gas vapors to ensure that required GAC treatment efficiencies can be maintained. It is anticipated that the SVE system will also help control subslab temperatures and enable faster cooling of the HWF system by removing heat energy more quickly than if it was allowed to naturally dissipate. Based on the heat transfer modeling described in Section 5, an SVE flow rate of 500 scfm is anticipated to be sufficient to control both subslab depressurization and the temperature of the floor slab. The blower selected for the SVE system will have the capacity to meet this flow rate at the design conditions with an additional factor of safety.

The SVE system will create a low-pressure zone beneath the School and the surrounding cap that will be less than atmospheric pressure. This low-pressure condition will cause air above the School slab and the cap to flow down through any cracks or voids that may remain, and effectively prevent upward flow of vapors from below.

To monitor the effectiveness of the subslab depressurization, monitoring ports will be installed in the School first floor and in the cap. These monitoring ports will enable measurement of the pressure differential between beneath and above the floor slab and cap.

8.0 CONSTRUCTABILITY

The principal construction elements in the HWF treatment system are the following:

- Barrier wall constructed around the treatment area to provide hydraulic control and contain heat;
- Recovery trench constructed on the east side of the treatment area for NAPL removal;
- Hot water injection wells and laterals;
- Multi-phase extraction wells installed in the recovery trench;
- Piping systems;
- Water treatment/conditioning systems; and
- SVE system.

The constructability of these work elements is discussed in this section.

8.1 BARRIER WALL

A containment wall will be installed on the west, south, and east sides of the School a minimum of 20 feet from the School footings. The wall will intersect the impermeable MSE wall currently in place north of the School. The containment wall will be constructed of Z sheet pile with sealable joints. A similar sheet pile was installed at the Skykomish Site as part of the Hydraulic Control and Containment (HCC) system. The sheet pile will be driven into the silt layer present at approximately 15 feet below grade. The sheet pile will be driven to target depth with a vibratory hammer. Based on previous experience in sheet pile installation in the Town of Skykomish, it is anticipated that some or all of the trench alignment will require pre-excavation due to the large cobbles and boulders encountered at the site. Once the sheets are keyed into the silt, the excavation will be backfilled with clean backfill material and the joints will be flushed out with high-pressure water and grouted with a bentonite Portland cement slurry. The sheets will be cut to approximately 2 feet below grade, and the surface will be restored to pre-existing conditions. The underground and overhead utilities that will be encountered during installation of the sheet pile will be either temporarily disconnected and reconnected after the sheets have been installed, or rerouted and replaced after the sheets have been installed. The sheet piling is temporary and will be removed following acceptance and approval of the remedial activities beneath the School. Areas identified as potential leakage points under the wall or where the wall intersects the MSE wall will be pressure-grouted and sealed.

To monitor the effects of the pumping system on the hydraulics on either side of the wall, a series of piezometers will be installed and monitored during periods of groundwater pumping and flushing. Differences in water levels will be evaluated to determine:

- The potential for leakage of the barrier; and
- The water balance of extracted groundwater versus injected treated groundwater.

8.2 RECOVERY TRENCH

Based on hydraulic flow modeling that has been performed and the sensitivity analysis conducted using this model, it was determined that an HWF system design that includes a recovery trench will result in the most-efficient removal of LNAPL from the subsurface. Additionally, during prior test pit excavation in the area, LNAPL was observed in sand stringers, which are more easily intercepted with a trench recovery system.

The recovery trench will be constructed of a uniform gravel backfill that will help promote efficient NAPL removal, with collection sumps approximately every 30 feet. The recovery trench will be located on the east side of the School, with the ends wrapping around on the north and south sides of the contained area by approximately 50 feet. The area east of the School along 6th Street was recently excavated, with the angle of repose extending to the western edge of 6th Street. To maximize the effect of the trench and to avoid distribution of LNAPL into backfilled areas not previously impacted, the trench will be positioned as close as possible to the previously excavated native soil boundary, as shown on Drawing C-105 in Appendix A**.** The extraction trench will be located between the barrier wall and the east wall of the School. A trench box will be available during excavation to stabilize side walls if required.

The trench will extend to a depth of approximately 15 feet bgs, intersecting the areas with LNAPL present, above the silt layer and in the top 10 feet of the water column. Groundwater will be pumped from the sumps to create a hydraulic gradient to the well, and LNAPL will be pumped from the sumps using belt skimmers.

The screens for the sump will be designed to maximize the intake area for oil collection. The screen will be constructed of continuous wire-wrapped screen, which has significantly more open area to allow entrance of thin thicknesses of floating immiscible oil.

The amount of oil that enters each sump will be evaluated. The sumps containing the most oil will be adjusted to maximize flow and collection of LNAPL in that area.

8.3 HOT WATER INJECTION WELLS AND LATERALS

Hot water injection wells will be installed along the western perimeter of the treatment area using sonic drilling techniques due to the presence of large cobbles and boulders in the subsurface. Each well will be constructed of approximately 5-foot lengths of 4-inch-diameter steel casing and 5-foot lengths of stainless steel screen. The wells will terminate at the ground surface in concrete well vaults that will house injection piping connections. The injection wells are similar in construction to numerous wells that have been constructed on the Skykomish Site and are not anticipated to involve significant constructability issues.

The injection laterals are located in the main corridor of the School, and outside along the eastern edge of the School. These laterals will add heated water to the HWF system and will flush the vadose zone beneath the School. The injection laterals will be constructed of 2-inch-diameter carbon steel pipe. The pipe will be perforated throughout the injection gallery. The lateral trenches will be excavated to a depth of 4 feet below grade. The pipe will be laid in the trench in a 3/8-inch pea gravel backfill material. A 4-inch layer of closed-cell expanded polystyrene (EPS) insulation will be placed above the pea gravel. EPS is a common under-slab and subfloor insulation that will provide additional insulation value. A vapor barrier material consisting of polyethylene sheeting or similar with a minimum thickness of 10 millimeters will be placed beneath the EPS. Controlled-density fill (CDF) will be placed above the vapor barrier to adequately seal and separate the treated groundwater injection trench from the SVE trench. Each injection trench will have an SVE pipe located above the CDF and will be backfilled with gravel (Drawing C-105, Appendix A). The SVE will remove and control subsurface heat.

Construction activity in the School will be performed with extra care to minimize impacts. Prior to initiation of any work in the School, the work area will be partitioned off and lined with plastic sheeting dust barriers. The work areas will be ventilated to remove dust and equipment exhaust. The concrete floor will be wet-sawed to gain access to the injection galleries. Once the construction has been completed, the floors will be restored.

Each injection well and injection trench will have an associated subsurface vault. Each well vault will be located at the injection well. All of the injection trench well vaults will be located outside the School. Each injection leg will include a pressure indicator to determine injection pressures at each well head, a gate valve to adjust flow into each well, and a flow-totalizing indicator.

8.4 RECOVERY TRENCH EXTRACTION WELLS

Recovery trench extraction wells will be constructed in the recovery trench approximately every 30 feet. These extraction wells will house groundwater extraction wells and NAPL collection and recovery equipment. The equipment to be used for NAPL recovery will be the same as that currently being used for NAPL recovery at the railyard. This equipment has proven to effectively collect NAPL as part of the HCC system. In addition, use of similar equipment increases system reliability due to the increased experience of project personnel with the equipment, and interchangeability of parts and materials.

Each recovery trench extraction well will be located in a well vault that will house the belt skimmer, a container for collection of recovered NAPL, a sample port, an aboveground groundwater pump, a control valve, and a totalizing flow indicator. No significant constructability issues are anticipated to be associated with the recovery trench extraction wells.

8.5 PIPING SYSTEMS

The piping systems that will be used are standard pipe and pipe materials used in potable water-supply systems. Specific piping materials selected for treatment system components as shown on the drawings were selected to be compatible with the fluid being transported, including thermal, physical, and chemical compatibility.

8.6 WATER TREATMENT/CONDITIONING SYSTEMS

The water pumped from each of the recovery trench sumps will flow to the treatment system equipment enclosure, where it will be pretreated with a heat exchanger to reduce the temperature of the water prior to flowing to the HCC water treatment system. The HCC treatment system has been determined to have sufficient capacity to accept the extracted water flow. Because the water sent to the treatment system will be returned for heated water injection at the School following treatment, there will be little if any additional increase in the net discharge from the HCC system to the Skykomish River.

8.7 SVE SYSTEM

The SVE system is described in Section 7 and on the engineering drawings in Appendix A and is designed to meet several objectives, including to:

- Depressurize the subslab;
- Remove volatile organics, if present; and
- Control the temperature of the School slab.

Temperature control was the primary objective considered in sizing the system. The heat transfer from the heated water to the slab was both calculated and modeled to determine the amount of heat to be removed to keep the slab at a comfortable temperature. It was determined that 200,000 BTU per hour of SVE removal would capture the heat conducted from below. This total equates to an air flow rate of 500 cubic feet per minute and can be accommodated by commercially available blowers. The extracted air will be pulled first though a condenser, then through the extraction blower, an aftercooler, and finally vapor-phase carbon prior to discharge to the atmosphere.

A surface cap will be installed in all unpaved areas, extending from the School to the containment wall. The cap will consist of a readily available synthetic liner and covered with enough soil to support a vegetative layer. The surface cap will prevent short-circuiting and allow for SVE control of the remediation area.

9.0 MONITORING REQUIREMENTS

This section describes the HWF treatment system monitoring that will be performed during construction, start-up, and operation to ensure that the treatment system is operating as designed and impacts are controlled.

9.1 PROCESS MONITORING

Process monitoring includes measurement of parameters that relate to the operation of the system within intended engineering parameters. Process monitoring required during system operation and monitoring will include:

- Water flow rate and flow totals for water removed and water injected;
- Groundwater elevation mounding at injection wells;
- High-level groundwater elevation monitoring at infiltration galleries;
- Groundwater elevation drawdown at recovery trench sumps;
- Groundwater elevation and temperature monitoring at down-gradient monitoring wells and piezometers north and west of the school;
- Temperature of water sent to the treatment system and water returning from the treatment system;
- NAPL recovery rates and volumes;
- SVE flow rates and extracted temperature and humidity; and
- SVE off-gas temperatures and hydrocarbon vapor concentrations before and after GAC treatment.

9.2 PERFORMANCE MONITORING

Performance monitoring includes measuring parameters that relate to the effects of the HWF system. The performance monitoring required during system operation will include:

- Water-level and NAPL measurements at monitoring wells at the School property and surrounding areas, and at piezometers installed on both sides of the sheet pile barrier;
- Subslab soil temperature;
- Groundwater temperature;
- Atmospheric to subslab soil pressure differential; and
- Indoor/outdoor air monitoring for air petroleum hydrocarbons.

10.0 POTENTIAL IMPACTS AND MITIGATION

This section discusses potential impacts to the School infrastructure and learning environment from the remediation activities, and the mitigation measures that will be taken to reduce or eliminate these impacts. A summary of potential impacts is provided in Table 3.

10.1 TEMPERATURE IN SCHOOL FLOOR

Without mitigation measures, hot-water injection beneath the School first-floor slab would result in elevated slab surface temperatures. To control floor slab surface temperatures, the design incorporates two measures: installation of a vapor barrier and insulation above the hot water injection trenches; and installation of SVE laterals above the hot water injection trenches. The vapor barrier and insulation will reduce the conduction of heat from the injection piping to the floor slab. The SVE system will serve to extract heat-laden air to further reduce the conduction of heat to the slab above.

Thermal calculations indicate that these measures will reduce the conduction of heat to the School first-floor slab and will minimize increases in slab surface temperatures. During periods of hot water injection, the first floor slab likely will experience surface temperature increases to approximately 70°F. If elevated floor slab surface temperatures increase room temperatures above a comfortable level, air conditioning units will be installed in affected rooms.

10.2 NOISE

Noise will be associated with three phases of HWF: system installation, system operation, and system removal. Noise generated during the installation and removal phases of work will be typical of construction and similar to that experienced during the Levee Zone excavation work conducted north of the School in 2006, the piling installation and excavation work conducted along Railroad Avenue east of the School in 2008 and 2009, and the excavation conducted east of 6th Street immediately east of the School in 2010. The installation and removal phases of the work will be done during school summer break.

Noise generated by treatment system operation will be minimal and generally not noticeable. Aboveground treatment equipment will be housed in sound-insulated structures or located on railroad property south of the School. The only equipment that will be located on School property is groundwater extraction pumps and oil belt skimmers, which will be located in below-grade vaults to minimize the noise generated by their operation. If noise generated by equipment operation is determined to be above acceptable limits, additional sound-insulation provisions can be implemented as necessary.

10.3 ODORS

Elevating subsurface temperatures will create the potential for generating petroleum odors. This potential will be controlled by depressurizing the subsurface within the treatment area using SVE. The SVE system will extract soil vapor from within the thermal treatment area bounded by the sheet pile barrier and the MSE wall to create a negative-pressure condition. This negative-pressure condition will prevent subsurface vapors from migrating to the surface. Soil vapors will instead be extracted by the SVE system and treated by carbon contact to eliminate potential odors prior to their being emitted to the atmosphere.

10.4 VISUAL AND AESTHETIC IMPACTS

Visual and aesthetic impacts from HWF will be limited to those associated with construction and removal operations. Visual construction impacts will be similar to those experienced by the community during past remediation activities in the Town of Skykomish.

No significant visual or aesthetic impacts will result from treatment system operation. Treatment equipment on School property will be installed below grade. Above-grade treatment equipment installed on railroad property will be surrounded by chain link fencing that includes privacy slats to minimize visual impacts.

10.5 CONSTRUCTION AND DECOMMISSIONING

Construction and decommissioning impacts will be similar to those experienced in past phases of the Skykomish remediation project and will include noise, odors, and dust associated with excavation, well drilling, and sheet pile installation operations. These impacts will be mitigated to the extent practicable by implementing standard construction practices such as water spray to control dust, and restricting the hours of noise-generating operations. This work will be done during the school summer break.

11.0 SCHEDULE

A schedule incorporating the significant work elements of the project is presented on Figure 21. Work activities were scheduled taking into consideration the school year, which was assumed to run from September 1 through June 15. If actual school year dates differ, scheduled work activities will be performed after school hours, on weekends, or during school summer break to ensure that work activities do not disrupt the school day.

As shown on Figure 21, construction work on the School property will be completed during the summer of 2012. It is anticipated that the following critical path construction activities will be completed during the 2012 construction season:

- Mobilization;
- Barrier wall system installation;
- Recovery trench installation;
- Monitoring well and injection well installations;
- Hot water injection gallery and SVE system installations;
- Piping and conveyance system installations; and
- Surface cap installation.

Installation of the treatment system and the enclosure on the railroad property south of the School is not on the critical path and can be performed without disrupting school activities.

This schedule presented in Figure 21 is based on current engineering estimates for activity duration and sequencing. The actual construction schedule will be determined by the selected contractor, maintaining the general constraints described above.

The schedule contains three heating events and three groundwater-circulation events. The first event following treatment system installation and start-up will be a nonheated groundwater pumping event conducted during the school year. Groundwater pumping will begin the first winter (2012) and will be used to calibrate the system, ensure a balanced subsurface groundwater flow, and confirm the groundwater containment system. Heating will begin the summer of 2013. Data collected from each event will be evaluated to determine whether subsequent heating episodes will be required.

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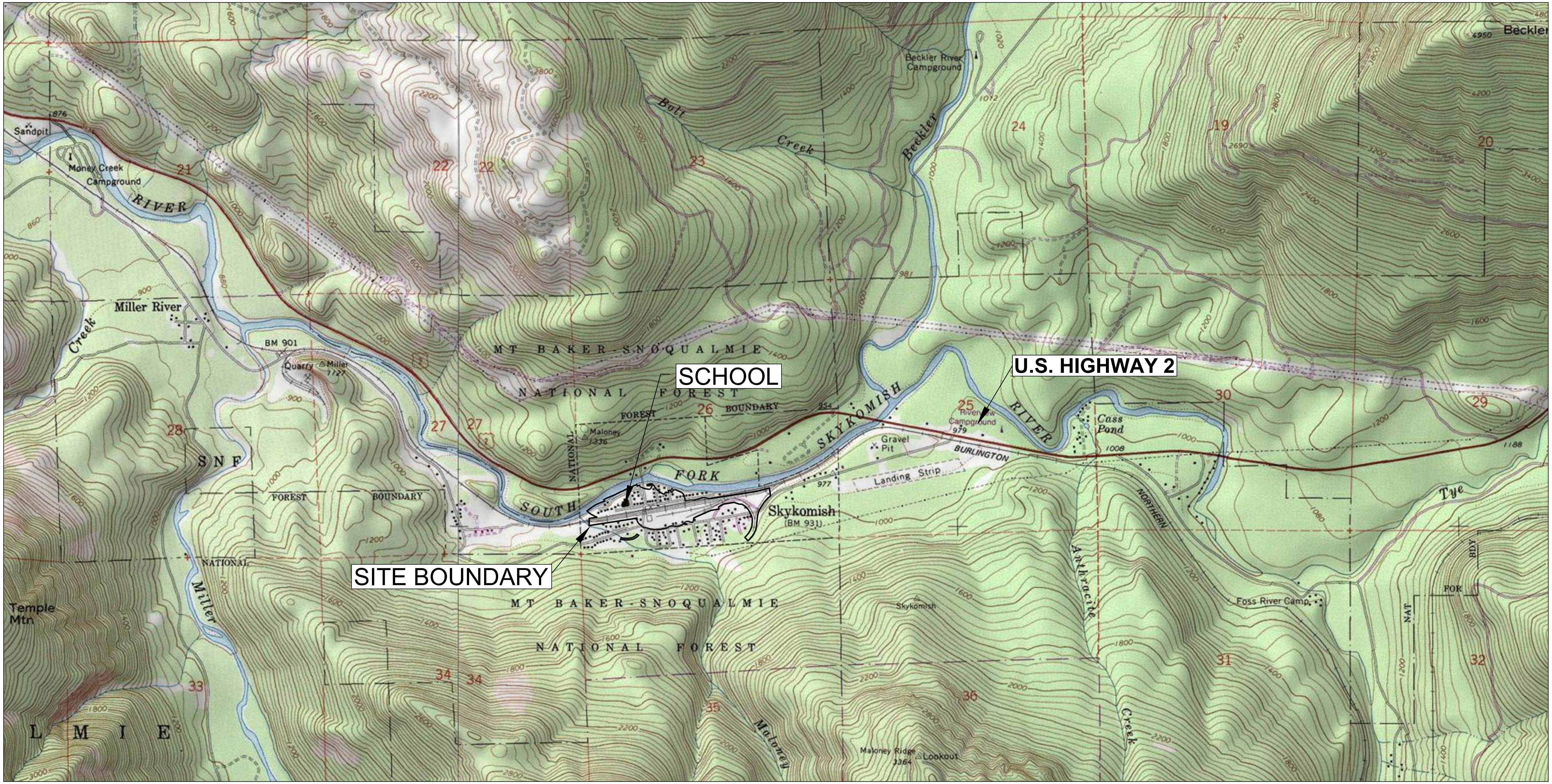
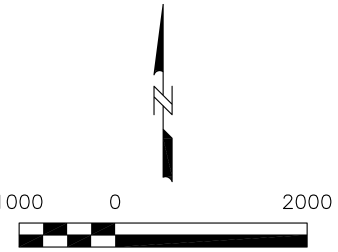
FIGURES

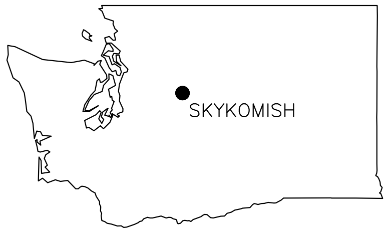
HOT WATER FLUSHING DESIGN REPORT
Skykomish School
105 6th Street
Skykomish, Washington

Farallon PN: 683-019



SOURCE: TOPO!, National Geographic Holdings, Inc.





FARALLON CONSULTING 975 5th Avenue Northwest Issaquah, WA 98027	FIGURE 1 SITE LOCATION MAP SKYKOMISH SCHOOL CLEANUP SKYKOMISH, WASHINGTON FARALLON PN: 683-019

Drawn By: DEW	Checked By: AED	Date: 11/15/10	Disk Reference: 16423308

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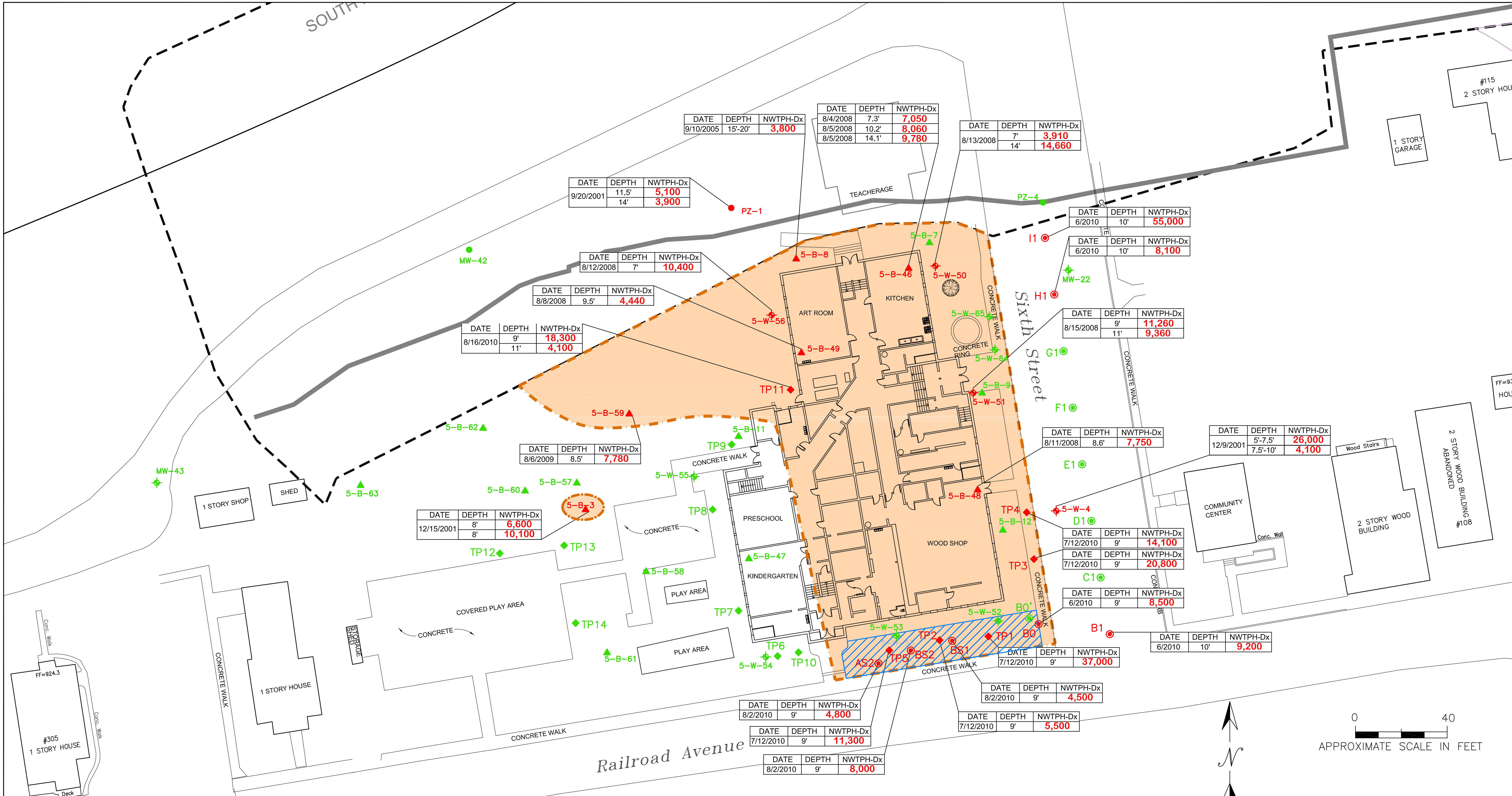
Issaquah, WA 98027

FIGURE 2
SCHOOL PROPERTY MAP
SKYKOMISH SCHOOL CLEANUP
SKYKOMISH, WASHINGTON

FARALLON PN: 683-019

Drawn By: DEW	Checked By: AED	Date 11/15/10	Disk Reference 683019a



LEGEND

- - - - INTERIM ACTION CLEANUP 2006 (EXCAVATION LIMITS)

—— EXISTING MSE WALL (INSTALLED 2006)

SURVEY PROVIDED BY: TRUE NORTH LAND SURVEYING, INC., DATED 10-23-07

- MONITORING WELL
- FORMER MONITORING WELL
- SOIL BORING
- SOIL SAMPLES COLLECTED FROM NWDZ EXCAVATION GRIDS
- SOIL SAMPLES COLLECTED FROM TEST PITS

ALL RESULTS IN MILLIGRAMS PER KILOGRAM (mg/kg)
DEPTH IN FEET BELOW GROUND SURFACE

= AREA EXCAVATED DURING 2010 REMEDIATION WORK

NWTPH-Dx = CONCENTRATION OF TOTAL PETROLEUM HYDROCARBONS (TPH) AS DIESEL-RANGE ORGANICS (DRO) AND OIL-RANGE ORGANICS (ORO) DETECTED BY NORTHWEST METHOD NWTPH-Dx

RED = INDICATES CONCENTRATIONS OF NWTPH-Dx EXCEED THE SITE-SPECIFIC REMEDIATION LEVEL OF 3,400 mg/kg

GREEN = INDICATES CONCENTRATIONS OF NWTPH-Dx DID NOT EXCEED THE SITE-SPECIFIC REMEDIATION LEVEL OF 3,400 mg/kg

= APPROXIMATE AREA WHERE CONCENTRATIONS OF NWTPH-Dx EXCEED THE SITE-SPECIFIC REMEDIATION LEVEL OF 3,400 mg/kg

FARALLON CONSULTING
975 5th Avenue Northwest
Issaquah, WA 98027

FIGURE 3

NWTPH-Dx SOIL ANALYTICAL RESULTS ABOVE REMEDIATION LEVEL
SKYKOMISH SCHOOL CLEANUP
SKYKOMISH, WASHINGTON

FARALLON PN: 683-019

Drawn By: DEW | Checked By: RM/AED | Date: 6/6/11 | Disk Reference: 683019b

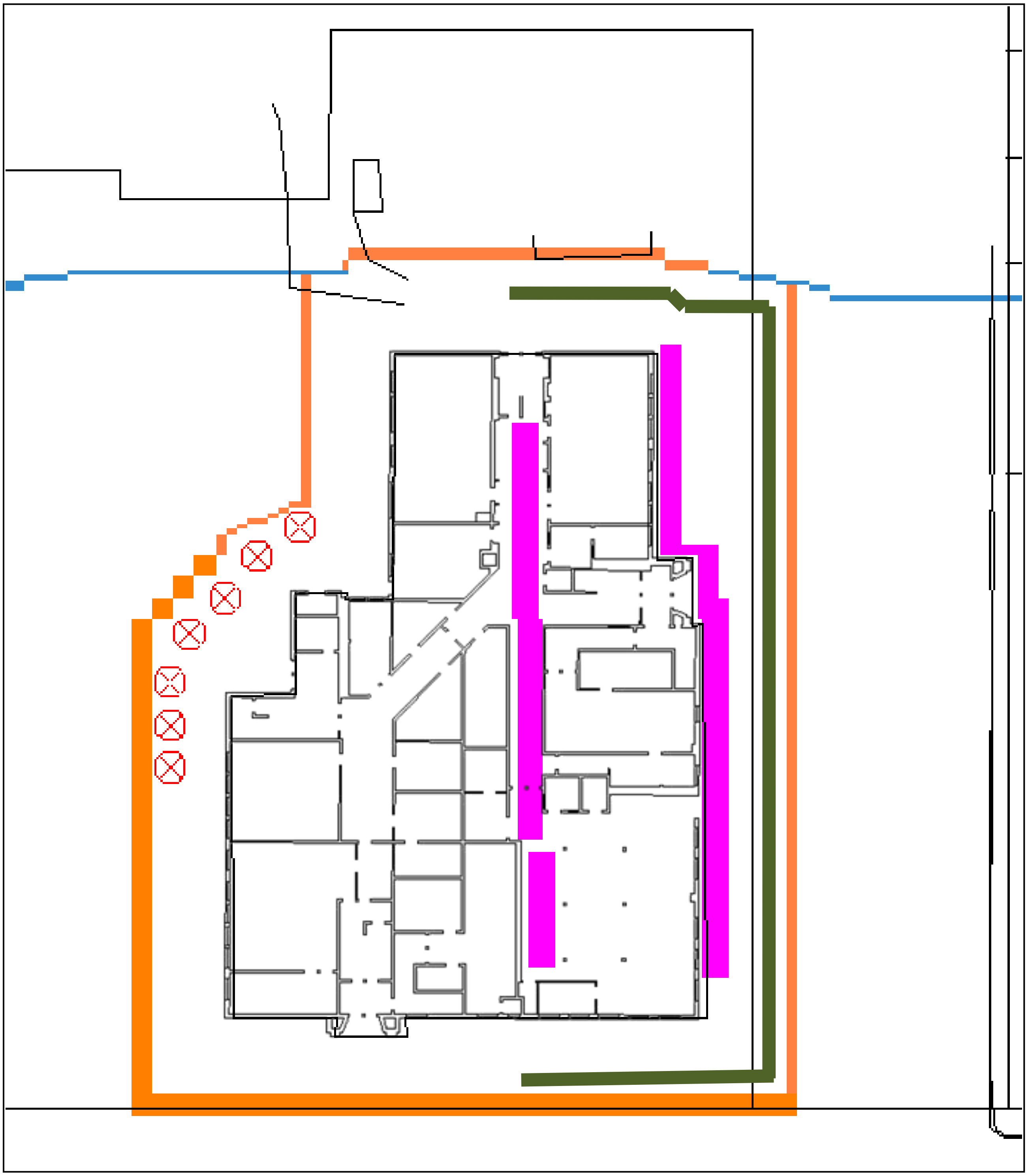


Figure 4. Final Groundwater Recirculation System Layout

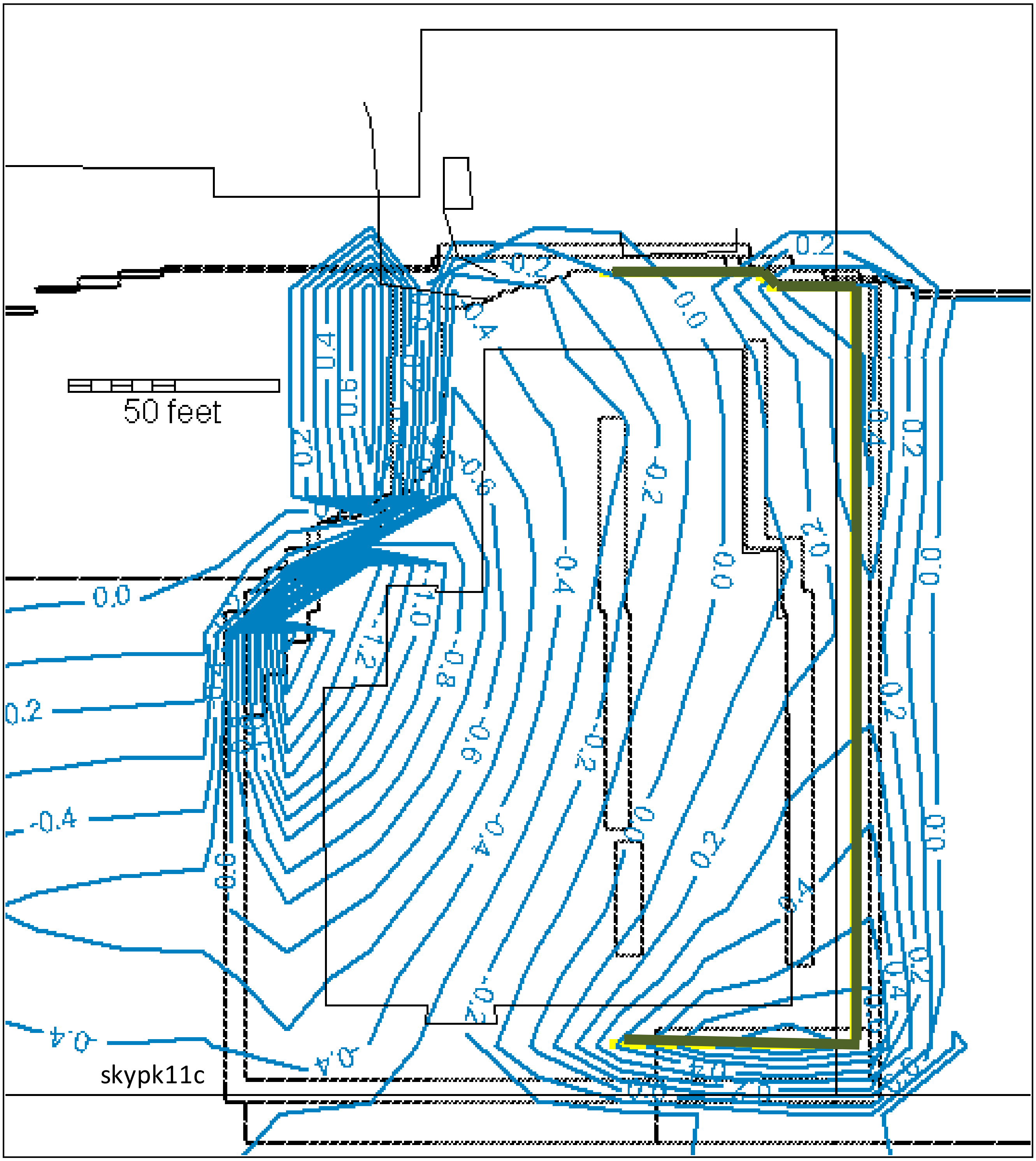


Figure 5. Final Model Scenario with Extraction Equal to Injection at 40 gpm

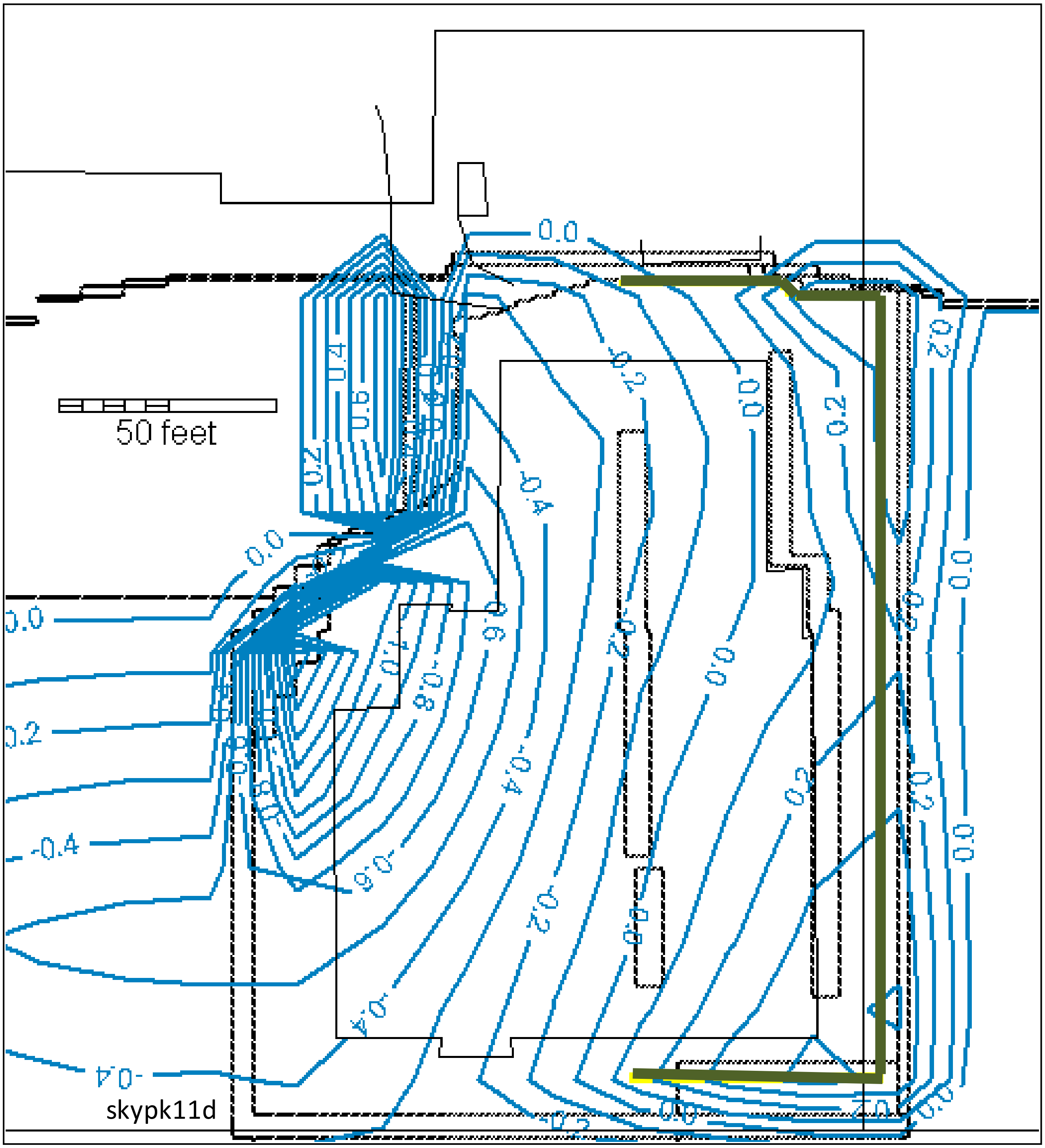


Figure 6. Final Model Scenario with Extraction Equal to Injection at 30 gpm

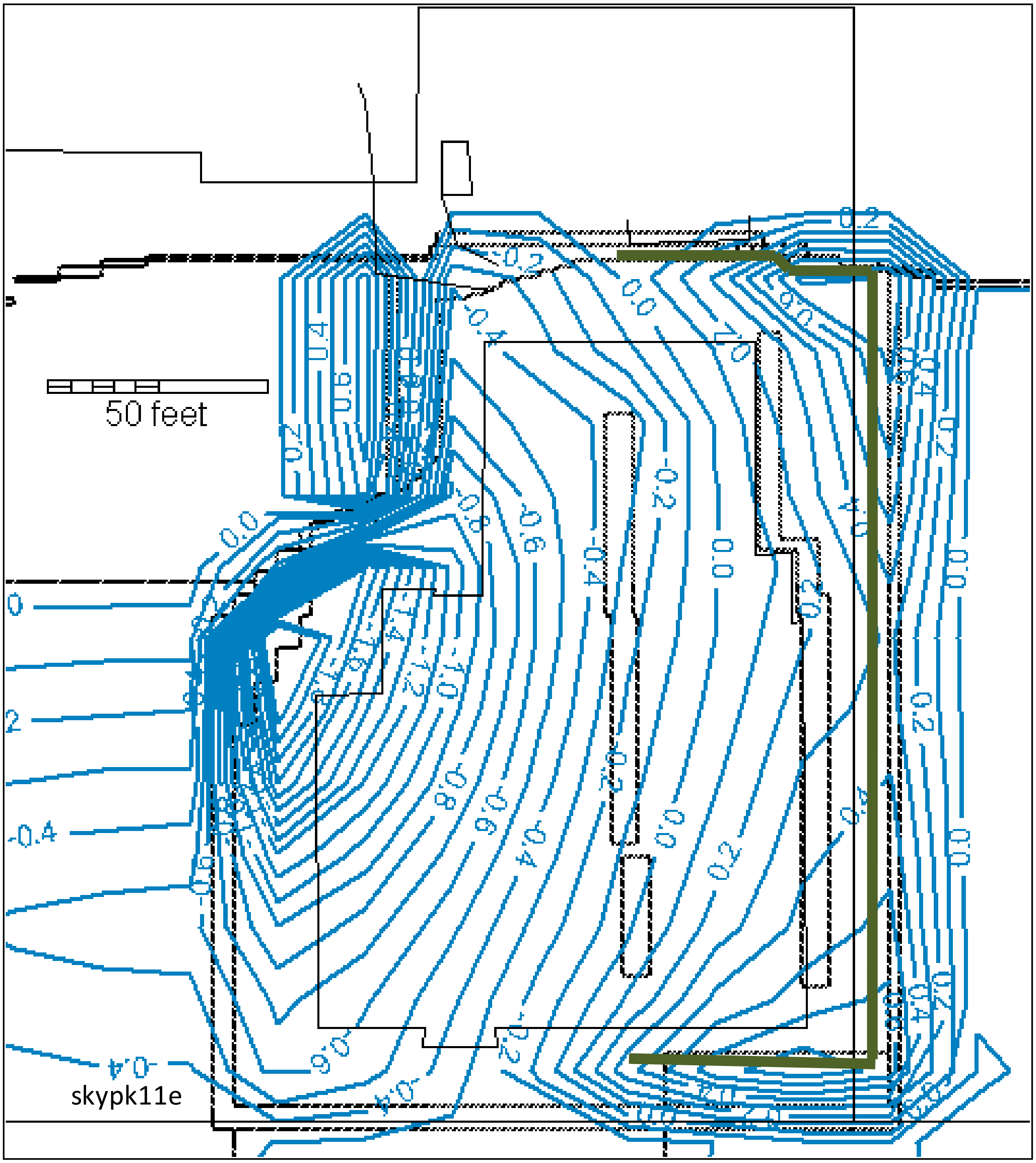


Figure 7. Final Model Scenario with Extraction Equal to Injection at 50 gpm

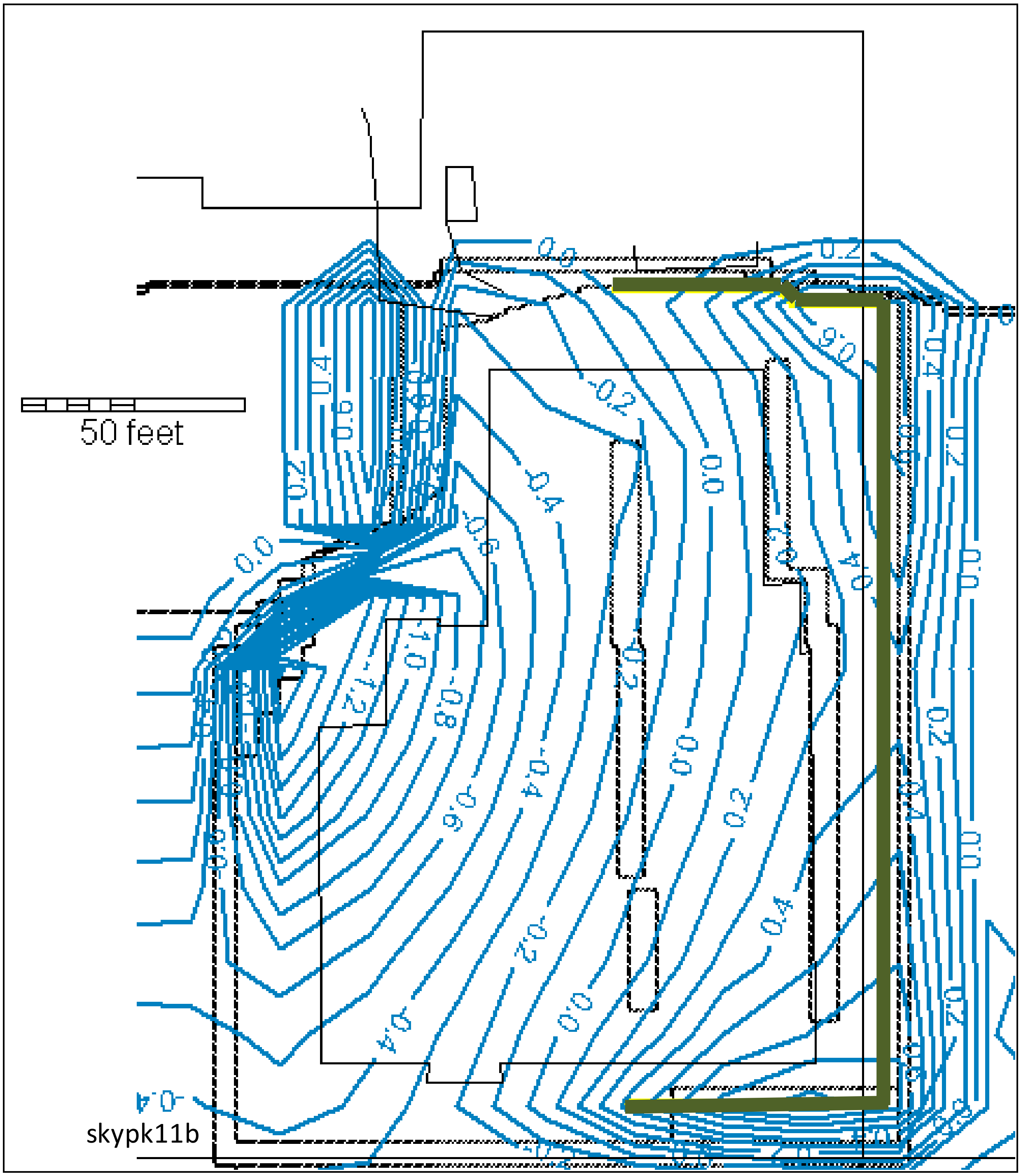


Figure 8. Change in Groundwater Elevation with Injection at 40 gpm and Extraction at 45 gpm

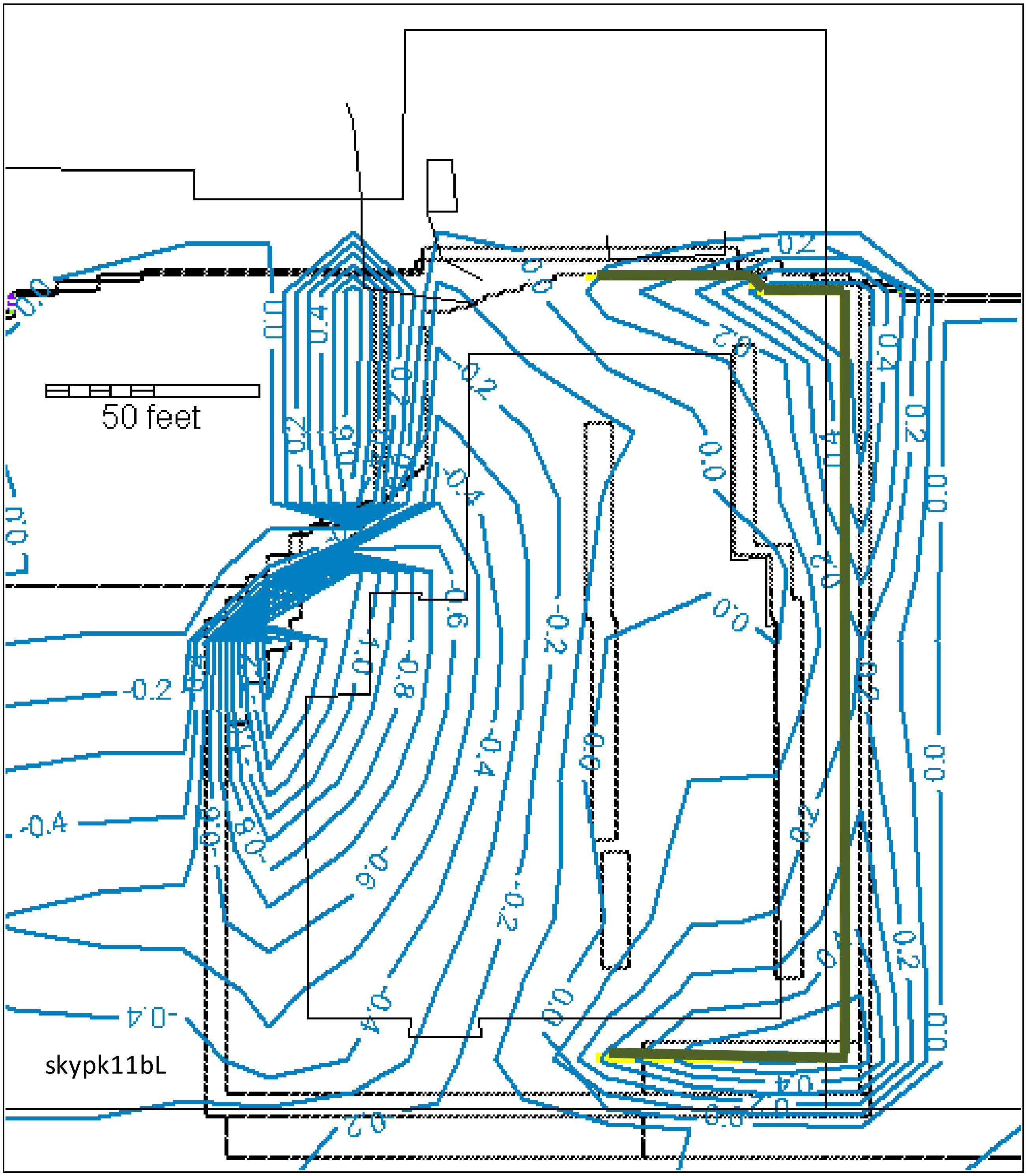


Figure 9. Final Model Scenario with Extraction Equal to Injection at 40 gpm and with Potential Groundwater Leakage at MSE Wall

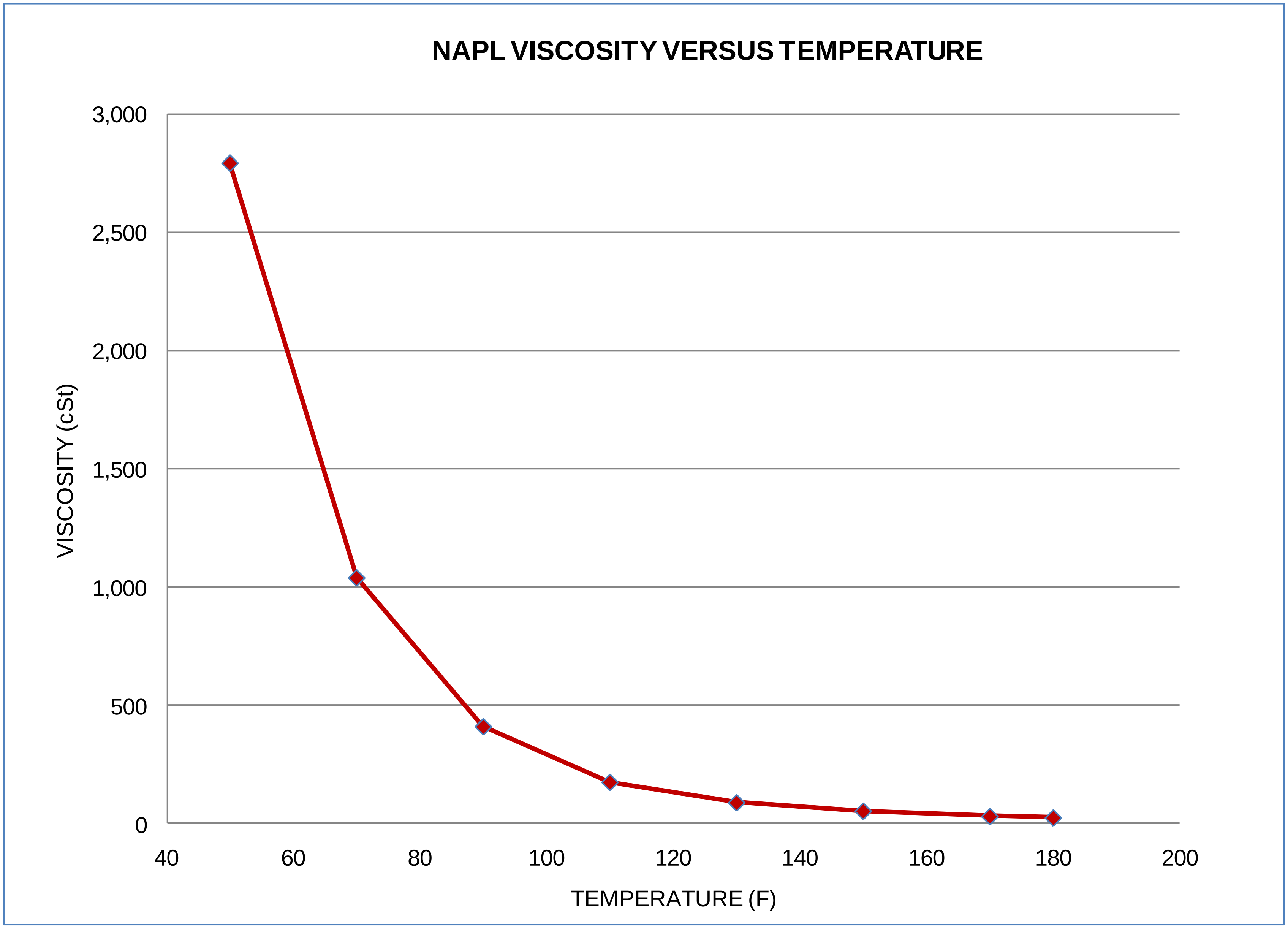


Figure 10. NAPL Viscosity as a Function of Temperature

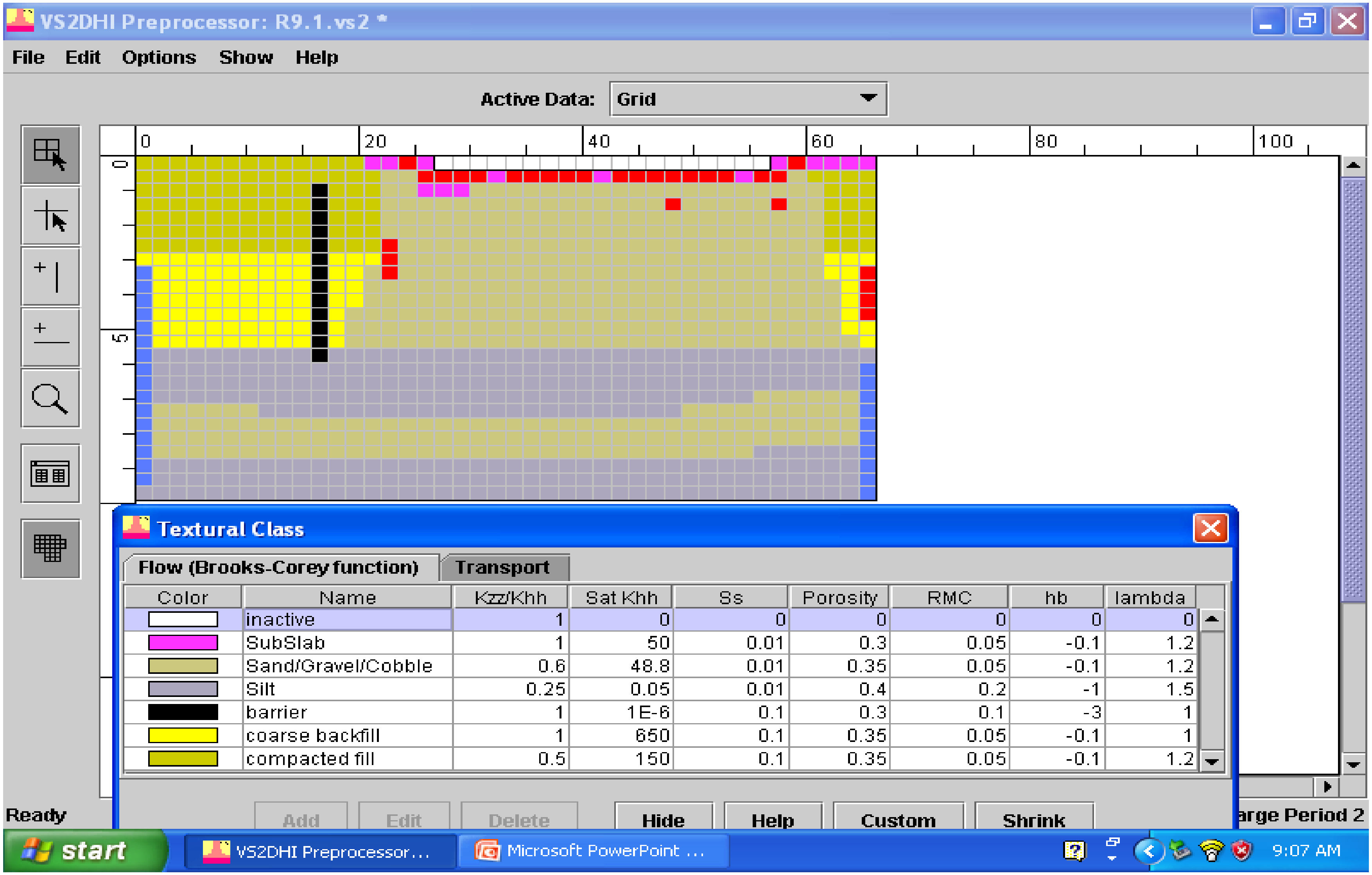


Figure 11. Geologic Discretization within VS2DH Model Domain

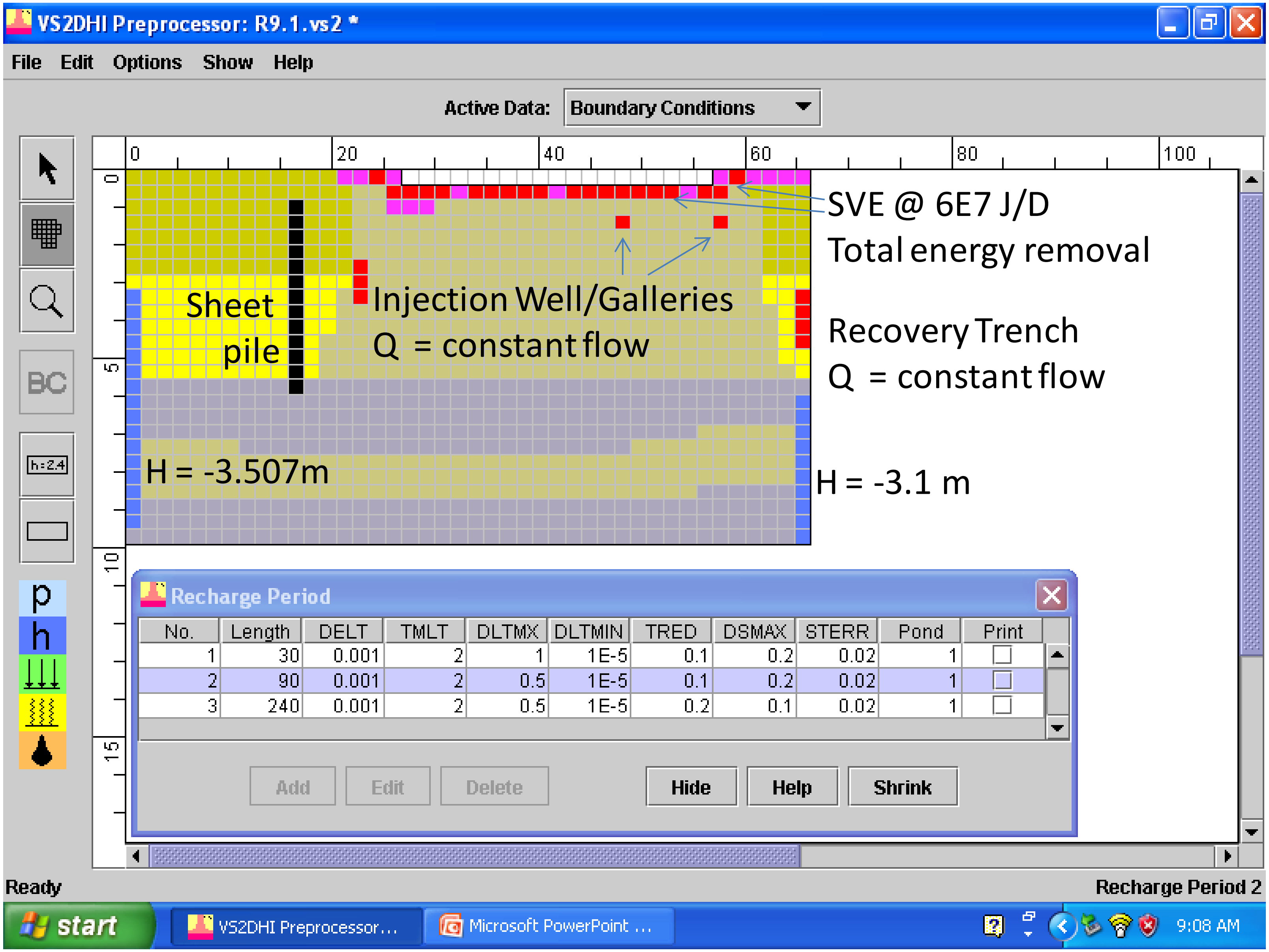


Figure 12. VS2DH Model Boundary Conditions

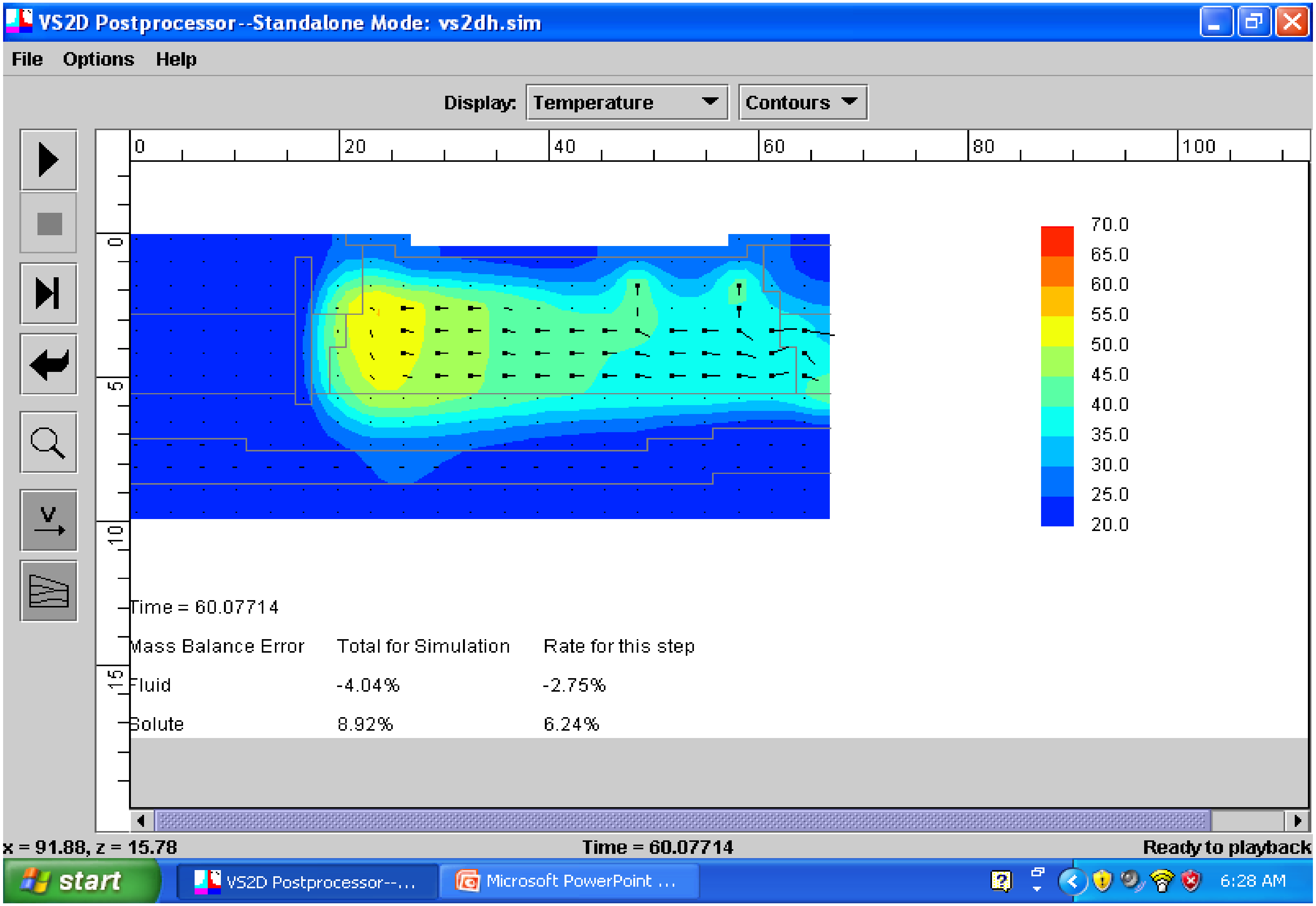


Figure 13. Subsurface Temperatures after 30 days of Hot Water Flushing

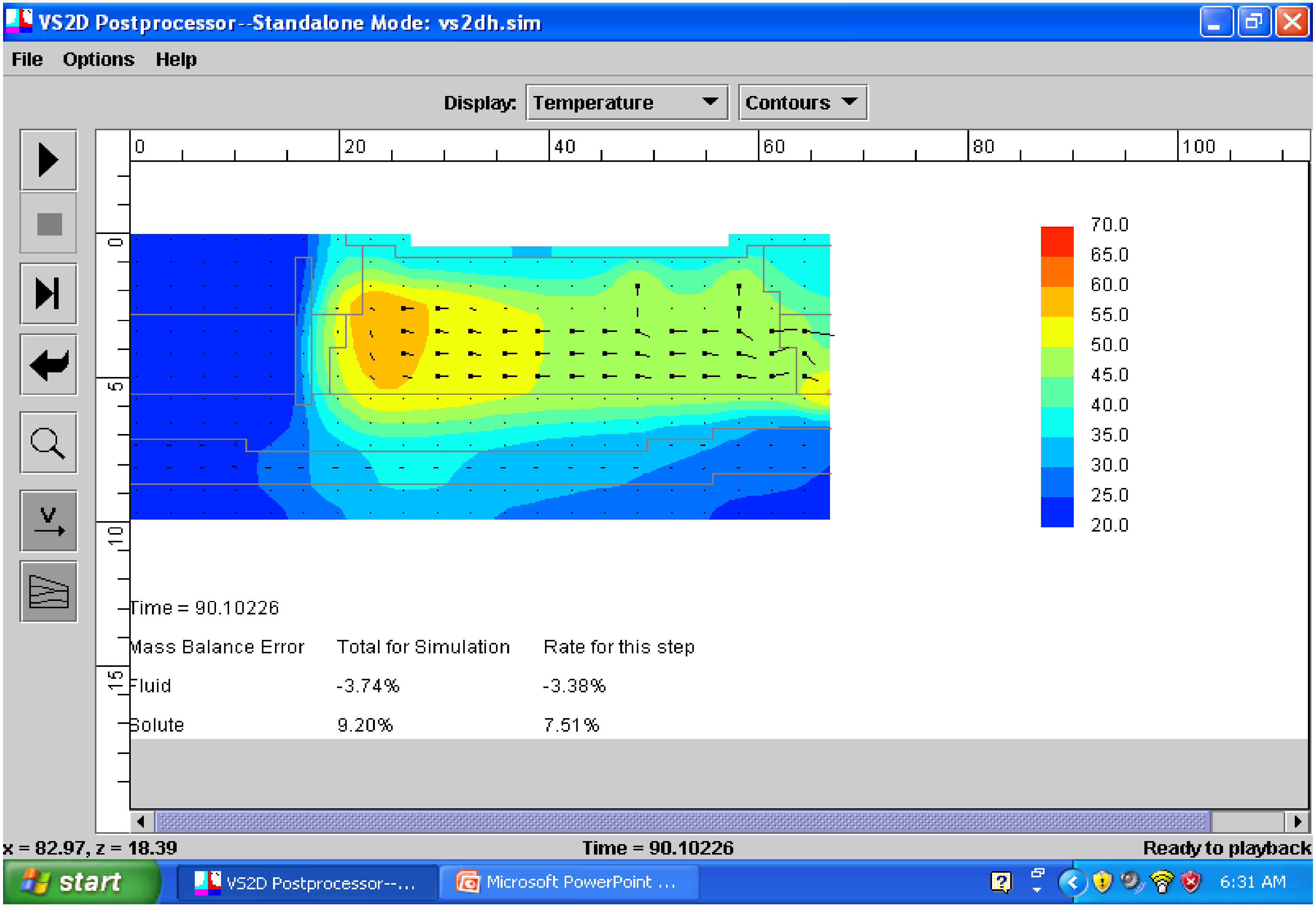


Figure 14. Subsurface Temperatures after 60 days of Hot Water Flushing

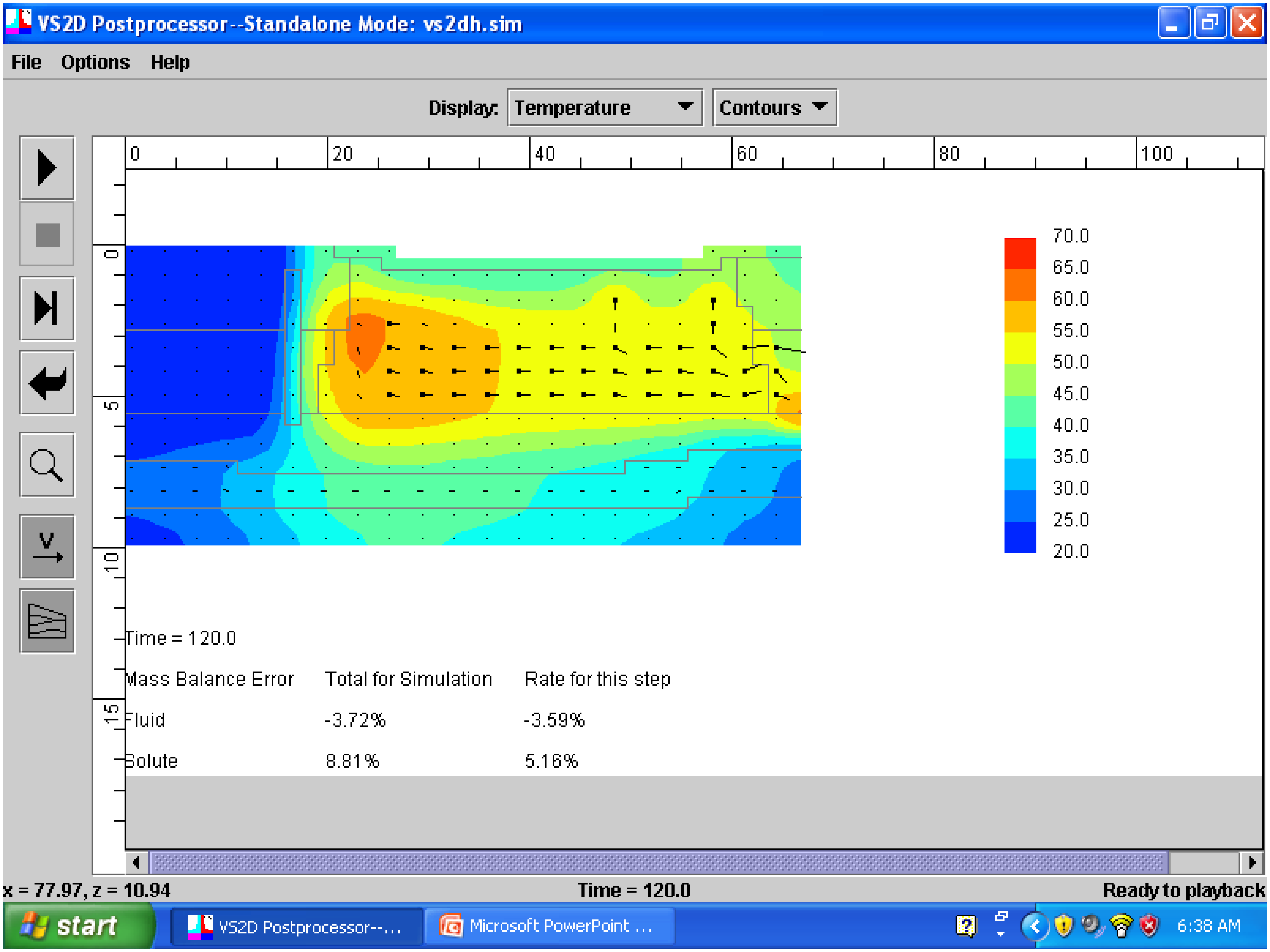


Figure 15. Subsurface Temperatures after 90 days of Hot Water Flushing

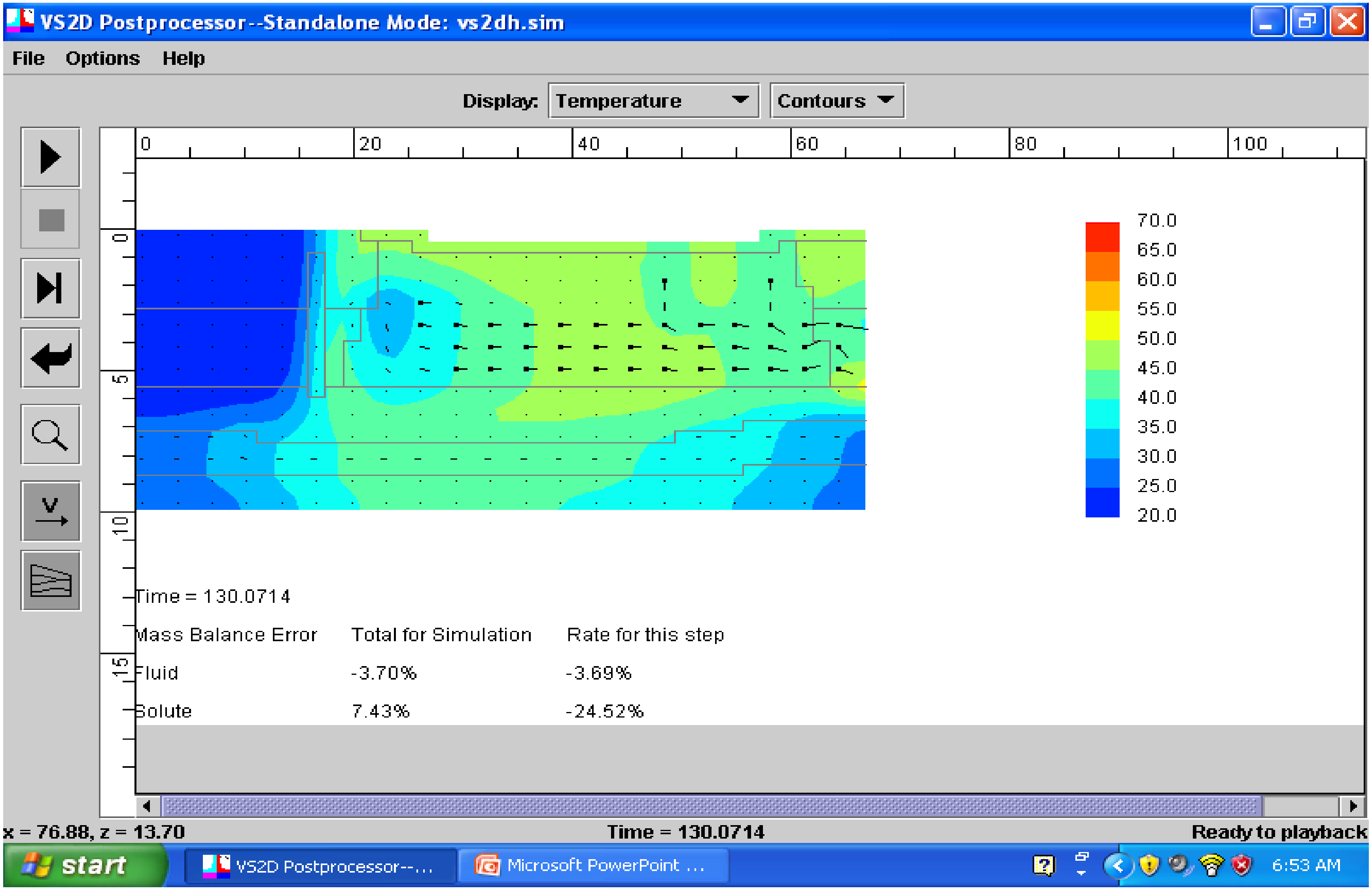


Figure 16. Subsurface Temperatures After 10 Days of Cool Water Recirculation

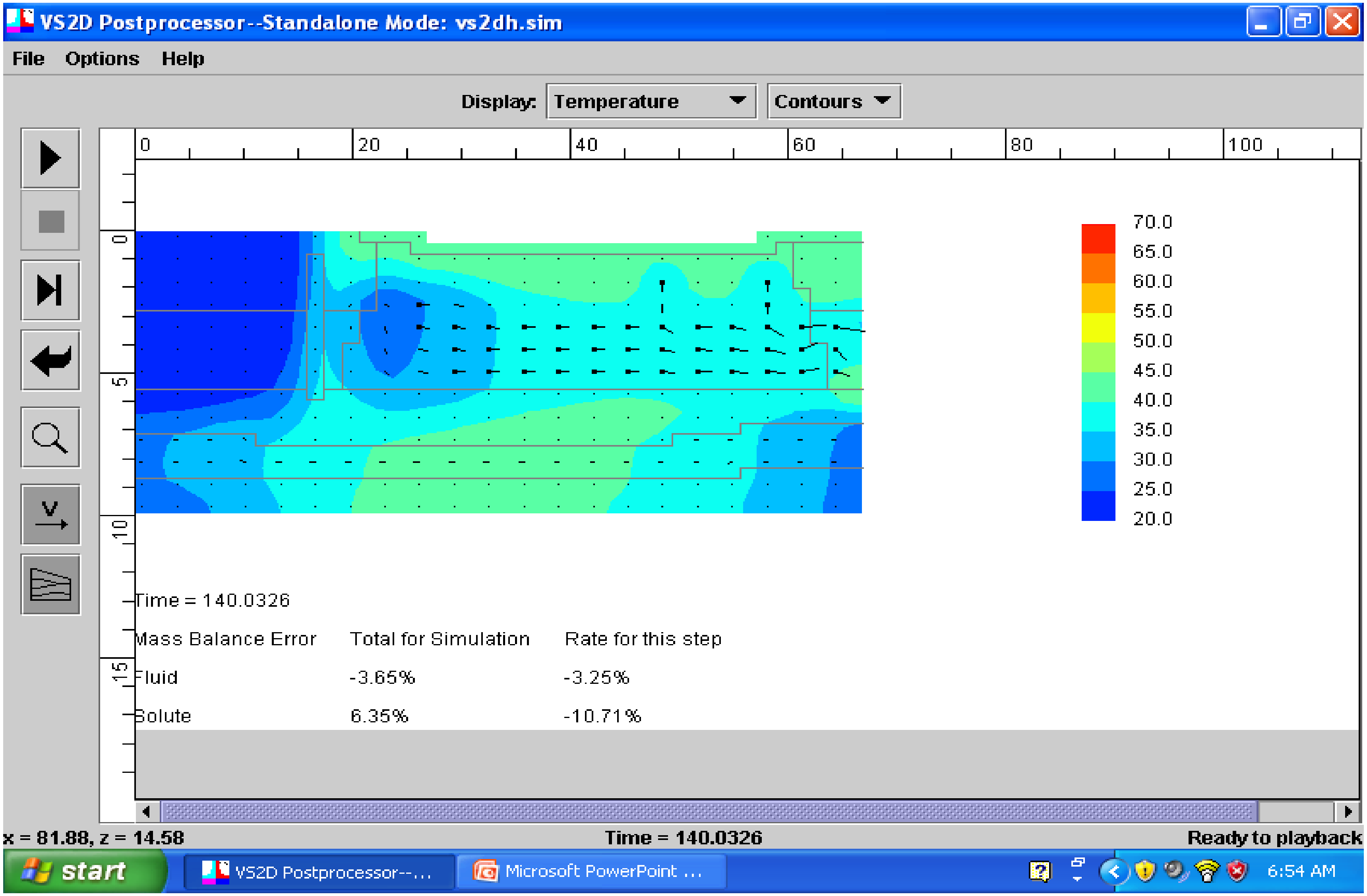


Figure 17. Subsurface Temperatures After 20 Days of Cool Water Recirculation

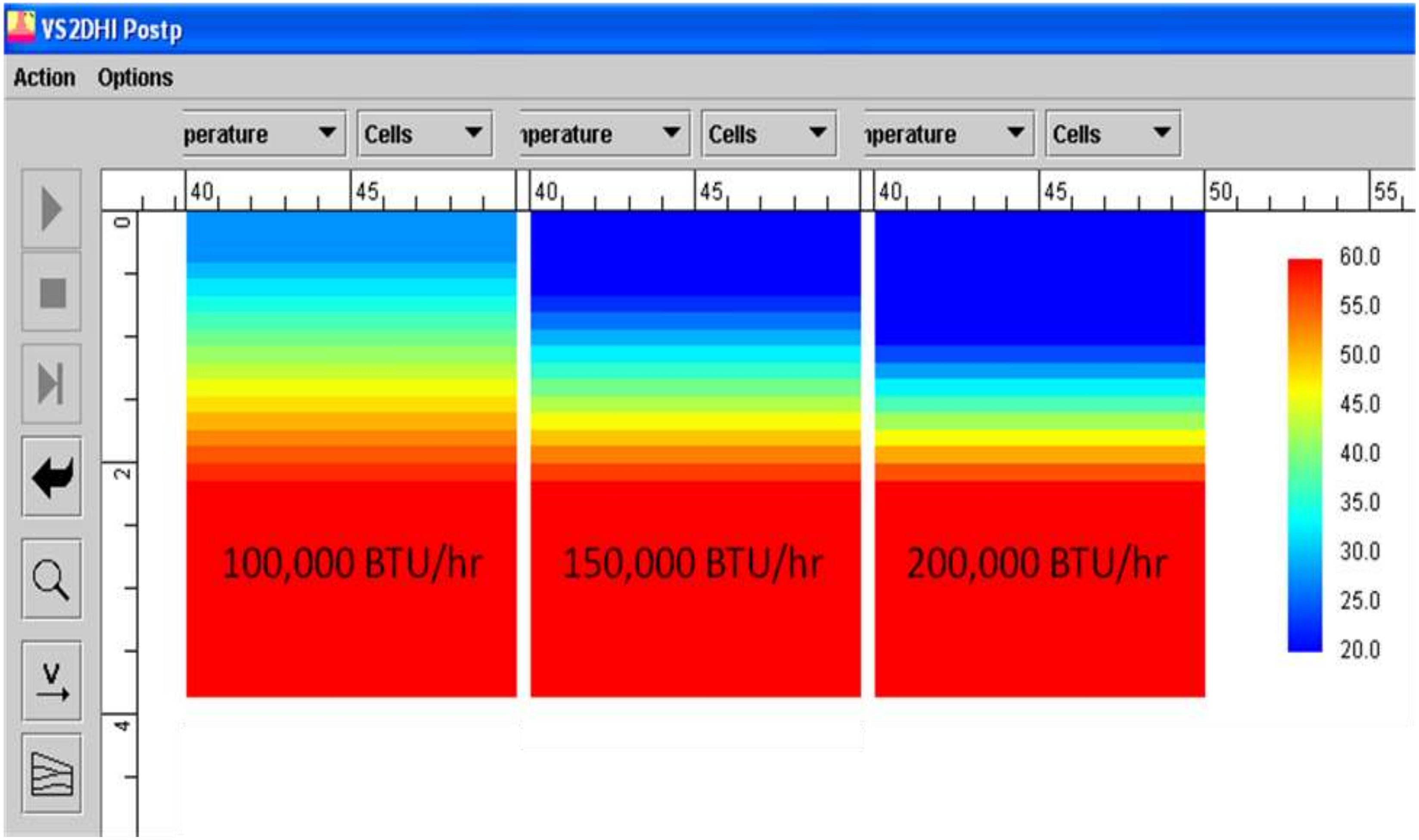


Figure 18. VS2DH Verification of Floor Slab Thermal Calculations

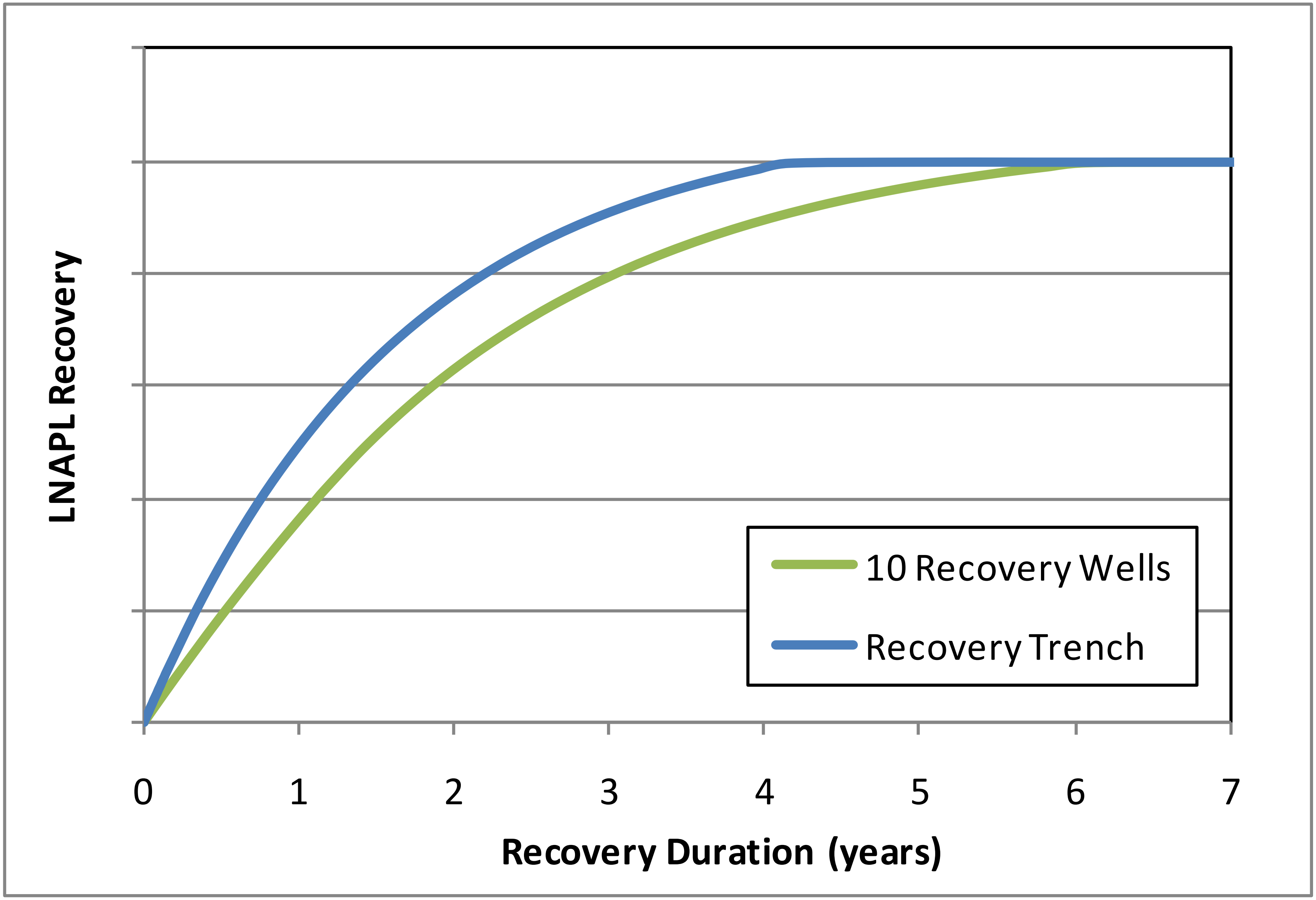
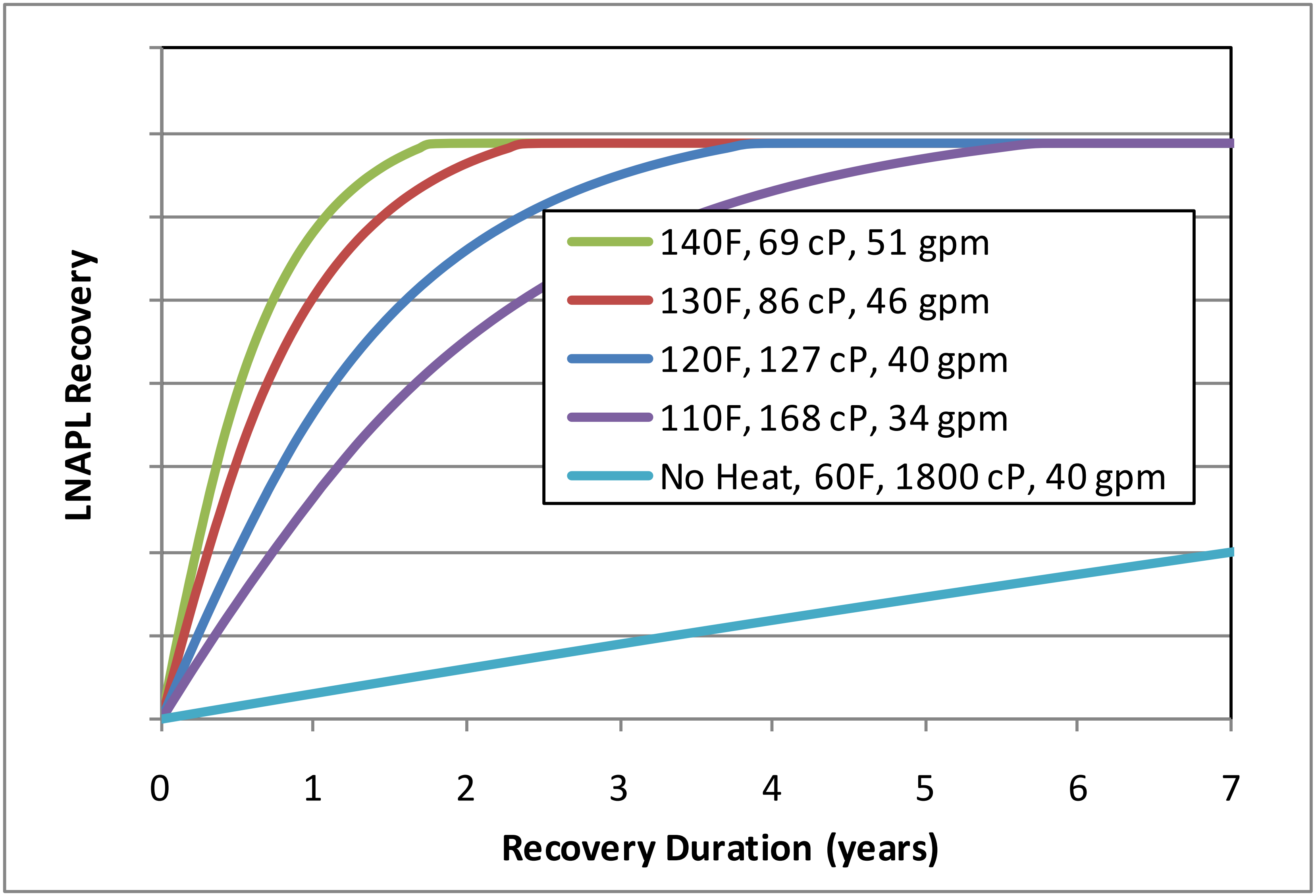


Figure 19. Comparison of Recovery Wells vs. Recovery Trench



Notes: F = subsurface temperature in °F. cP = viscosity in centipoises. gpm = gallons per minute extraction rate from recovery trench.

Figure 20. LDRM Evaluation of Thermal Enhancement

TABLES

HOT WATER FLUSHING DESIGN REPORT
Skykomish School
105 6th Street
Skykomish, Washington

Farallon PN: 683-019

Table 1. Design Quality Objectives for Hot Water Flushing System Design at Skykomish School
Skykomish, Washington

Requirements		Overall Remedy	Major Subsystems				Components							
Design Requirements	Definition	Overall Subsurface Treatment	GW Recirculation and NAPL Recovery	Subsurface Heating	SVE/Subslab Depressurization	Subsurface Sheet Pile Barrier	Injection Wells	Injection Galleries	Groundwater and NAPL Recovery Trench	Water Handling and Treatment System	Hot Water System	SVE Blower/Equip./Well Screen and Vapor Treatment System	Equipment Enclosure	Controls
Functional	The overall purpose of the portion of the system.	Reduce the amount of petroleum beneath the school to the extent technically possible, with the goal of removing separate phase mobile or volatile liquid petroleum components or nonaqueous phase liquid (NAPL).	Provide gradient toward the east side of the school for NAPL recovery along Sixth Street and at southeast and northeast corners of school building.	Provide subsurface heating to reduce NAPL viscosity, reduce NAPL residual saturation, and enhance removal of separate phase mobile petroleum and NAPL.	Remove volatile petroleum constituents and prevent vapor intrusion into occupied space or outdoors by maintaining a negative soil gas pressure in the subsurface and using vapor barriers as required. Provide mechanism for removal of heat from directly below building slab.	Provide hydraulic control and prevent the migration of contaminated groundwater or NAPL.	Provide for directed subsurface flow of injected treated groundwater (heated and unheated).	Provide for infiltration of treated groundwater to capillary fringe and to improve lateral distribution of hot water flushing across treatment zone.	Provide gradient and flow path for removal of groundwater and separate phase mobile petroleum components or nonaqueous phase liquid (NAPL). Provide hydraulic control within sheet pile barrier. Provide separate removal of NAPL and groundwater from sumps within recovery trench.	Treatment of extracted groundwater will be accomplished by the existing treatment system. Pretreatment at HWF system required to reduce temperature. Provide integrated control interface/interlocks of HWF system with treatment system.	Provide subsurface heating by hot water injection. Provide precise control over heating/cooling, including mechanism to recycle heat in recovered groundwater into injection water and mechanism to remove heat from extracted water and inject cool water to allow accelerated cooling.	Extract soil gas and heat from the subsurface and treat extracted hydrocarbons in soil gas prior to discharge. System to provide for subslab soil gas depressurization.	Provide controlled environment for elimination of ambient noise from and protection of treatment equipment, and to provide security to prevent unauthorized access. Must meet snow load requirements as well as shed snow in a manner to accommodate removal of shed snow using heavy equipment.	Acquire data from instruments and control system operations through program algorithms. Provide operators with supervisory control.
Reliability	The ability of a system or component to perform its required functions under stated conditions for a specified period of time	Reliability provided by aggressive technology approach (hot water) to achieve functional requirements within project time frames. Consideration of system components will include an expected operational duration of 3 to 5 years.	Conservative design to achieve a high level of reliability.	Conservative design to achieve a high level of reliability.	Conservative design to achieve a high level of reliability. Backup power required.	Conservative design to achieve a high level of reliability by sealing sheetpile joints and keying into low permeable material at the toe of the sheet piles.	Conservative design to achieve a high level of reliability.	Conservative design to achieve a high level of reliability.	Conservative design to achieve a high level of reliability. Trench design allows quicker and more efficient recovery of NAPL from the site.	Conservative design to achieve a high level of reliability. Backup power on controls and potentially selected equipment.	Conservative design to achieve a high level of reliability. Backup power on controls and potentially selected equipment.	Conservative design to achieve a high level of reliability. Backup power on controls and SVE equipment.	Standard building code requirements.	Backup power to controls system.
Performance	Stated operational goals	Treatment area footprint consists of school building plus 20 feet. Vertical interval of treatment is focused on impacted NAPL and smear zones. Achieve heating goals within summer-only operational approach.	50 GPM flow throughput capability includes factor of safety on flow rates to account for subsurface variability. Leak testing with zero-tolerance for leaks. Separate groundwater and NAPL recovery to increase NAPl removal efficiency and minimize groundwater treatment requirements.	Target max. 140°F average temperature in target treatment zone. For summer treatment approach, reach target temperature within each summer operational period. Temperatures can be reduced by injection of cold water, below 75°F, to prevent potential for heat impacts outside treatment zone.	SVE system sized to 500 SCFM, including factor of safety. Must handle extraction of potential soil gases. Provide measurable soil vacuum below slab floor to achieve a negative pressure below the floor slab.	Toe of barrier will be keyed into the low permeable silt layer and the joints of the sheet pile will be sealed to prevent leakage.	Anticipated injection rate of 40 GPM total, wells designed for max. of 50 GPM total and 10 GPM max per well. Gravity injection expected, adhere to max. pressure at injection screen of 4 psi. Stainless steel wire wrapped well screen. Carbon steel well casing. Casing will be grouted to prevent annulus short circuiting.	Two galleries, one inside school and one outside school on east side of building. Injection up to max. of 30 GPM for each gallery. Gravity injection expected, adhere to max. pressure at injection screen of 1 psi. CPVC well screen and casing.	Total groundwater extraction rate 50 GPM max. and 25 GPM min. 150 °F max. exposure temperature. Steel recovery screen and casing for recovery sumps within trench. Vapor seal at well vault. Surface lift groundwater pumping and NAPL belt skimmer.	Treatment provided at existing treatment facility. Piping engineered for thermal expansion. NAPL presence in recovered groundwater minimal, with groundwater pumping inlet below water surface in recovery sumps. Water storage/treatment capacity not required. Interface controls with existing treatment facility.	Provide 2.1 MM Btu/hr (approx 63 BHP) heating output. Heat exchanger for recovery/recycling of heat in extracted groundwater. Maximum injection water temperature of 160°F. Boiler package including hot water heat exchanger shall be an integrated system engineered and provided by a qualified supplier. Remediation piping and other equipment connected to the integrated package shall be engineered for thermal expansion and rated up to 200°F at 60 PSI pressure.	500 SCFM at 20 in. wc. at well screen. Treat extracted soil gas from 87 PPM TPH(g) to 1,346 ug/m3 APH prior to discharge. Engineered for thermal expansion. Requires condensate knockout and gas cooling to handle water saturated gas stream at up to 140°F upstream of condenser. Well screen and casing will be constructed of PVC.	Doors large enough to accommodate placement/removal of equipment. Fully enclosed by fencing and locked/secure. Boiler to be housed in a separate trailer enclosed within secure fenced area. Area to south of enclosure expected to require grading or possibly retaining wall to allow backhoe access for snow removal. (limited excavation of enclosure area to be conducted by site contractor)	Instruments shall meet physical/chemical compatibility requirements, measurement ranges, and I/O configurations. Control requirements include: (1) integration with existing treatment facility, (2) selected treatment equipment component control (i.e. level control, etc.), (3) integration of independent-controlled components (i.e. SVE, boiler package, etc.) and existing treatment system interlocks. Measurement includes (1) recovery and discharge flow rates, (2) temperatures and pressures, etc.
Interchangeability	Requirements of system components to serve more than one function.	None.	None.	None.	None.	Containment and hydraulic control.	None.	None.	All groundwater and NAPL recovery equipment interchangeable between wells.	Not interchangeable.	Not interchangeable.	Interchangeable carbon beds.	Not interchangeable.	Maximize use of like instruments to facilitate interchangeability.
Safety/Security	Safety considerations for authorized workers and general public	Limit access to system components to authorized personnel and ensure training and protective measures are in place.	Specified for system components.	Specified for System Components.	Specified for system components.	Safety/security buffer zone will be required during installation and removal of sheet pile.	Locked subgrade vaults to prevent unauthorized access.	Locked subgrade vaults to prevent unauthorized access.	Locked subgrade vaults to prevent unauthorized access.	Temporary building structure (enclosure) is needed to maintain security and prevent unauthorized access.	Enclosure is needed to maintain security and prevent unauthorized access.	Enclosure is needed to maintain security and prevent unauthorized access. Locked subgrade vaults to prevent unauthorized access. Insulation on exposed SVE well piping.	Secure/locked enclosure to prevent unauthorized access to equipment. Appropriate safety signage.	Alarm/shutdown conditions programmed into logic. Personnel notification by remote communication.
Environmental	Requirements related to potential impacts to areas, objects and people outside the treatment zone.	Acceptable temperature, vapor, and sound impacts on school and surrounding areas.	Prevent groundwater mounding to level of school slab or ground surface.	Exterior surface of system components exposed to non-project personnel limited to 100°F.	Meet vapor discharge requirements of 1,346 ug/m^3 APH at perimeter of equipment compound. Provide acceptable sound levels. Cap unpaved (grassy) areas outside school within containment. Cap crawl space areas within building exposed to soil.	Barrier to allow for utility crossing.	Hi level float switch in vaults to prevent overflow.	Hi level float switch in vaults to prevent overflow.	Provide acceptable sound level at residence near extraction wells. High level float switch in vaults to prevent overflow. Splashdown-rated (NEMA 4) rating for electrical equipment in vaults.	Acceptable noise level outside of enclosure. Enclosure required to provided heated environment to prevent freezing of equipment.	Acceptable noise level outside of enclosure. Enclosure required to provided heated environment to prevent freezing of equipment.	Acceptable noise level at residence. Enclosure required to provided heated environment to prevent freezing of equipment.	R-28 or better insulation. Enclosure requires heated environment to prevent freezing of equipment. Ventilated for summer. Acceptable noise level at residence.	Controls may require location in HVAC controlled environment, depending on hardware selected.
Operations Monitoring Needs	Identifies measurements needed to verify performance with respect to design.	Measure NAPL and vapor recovery.	Measure water levels, drawdown and mounding, and NAPL recovery.	Measure subsurface temperatures.	Soil vacuum monitoring, SVE off gas monitoring.	Piezometers to be installed for monitoring of water levels on either side of the barrier to evaluate water balance and flow hydraulics.	Monitor injection pressure, flow rate, and temperature.	Monitor injection pressure, flow rate, and temperature.	Drawdown, NAPL levels, temperature at well head, operating sound levels at ground surface.	Process monitoring to include supervisory control and data acquisition (SCADA).	Process monitoring to include supervisory control and data acquisition (SCADA).	Process monitoring to include supervisory control and data acquisition (SCADA). SVE well head vacuum and flow. Sub-slab soil vacuum beneath school.	Enclosure temperature measurement.	Data acquisition as part of SCADA determined as follows: (1) data critical to safe real-time control of system operation, (2) data supportive of efficiency and reliability in system operations, (3) data supportive of interpretation of results.

Table 2
LDRM Input Parameters
Hot Water Flushing Design Report
Skykomish School
Skykomish, Washington
Farallon PN: 683-019

LDRM Input Parameter	Parameter Value	Data Source
Soil heterogeneity	One layer	Site data
Vertical gradient (-)	0	Assumed
K (feet per day)	160	Site data
Relative Permeability Model	Burdine	Assumed
Smear correction	Off	Assumed[1]
Maximum MW LNAPL thickness (feet)	0.3	Assumed
Water table depth (feet bgs)	10	Site data
LNAPL density (g/cc)	0.925	2009 LNAPL testing
LNAPL viscosity (cP)	69 to 168[2]	2009 LNAPL testing
Air/water surface tension (dynes/cm)	62	API 2006[3]
Air/LNAPL surface tension (dynes/cm)	21	API 2006[3]
LNAPL/water surface tension (dynes/cm)	12	API 2006[3]
LNAPL Residual Saturation Model	Constant	Assumed
Porosity (-)	0.25	Assumed from Site data
Van Genuchten "N" (-)	2.2	Carsel & Parrish 1988, IN EEL 2001
Van Genuchten "a" (/foot)	4.7	Carsel & Parrish 1988, IN EEL 2001
Irreducible water saturation (-)	0.05	Carsel & Parrish 1988
Residual LNAPL saturation (-)	0.1	Carsel & Parrish 1988

NOTES:

[1]Smear correction was not applied because hot water flush system is not anticipated to draw down the water table throughout most of the treatment zone.

[2]The range of viscosity values evaluated are based on measured viscosity from 2009 light nonaqueous-phase liquid (LNAPL) sample at temperatures ranging from 110 to 140 °F.

[3]Literature interfacial tension values measured at ambient temperature for LNAPLs with similar viscosity and density were reduced based on elevated surface temperature to be encountered during field implementation of hot water flushing.

bgs = below ground surface
cP = centipoise
CM = centimeter
F = Fahrenheit
g/cc = grams per cm3
K = hydraulic conductivity
MW = monitoring well

Table 3 – Potential Impacts of HWF System Installation

Category	Potential Impact	Design Mitigation
Construction	School building use during the summer of 2012	There will be disruption in the school during placement of the SVE trenches and hot water injection galleries. This activity will involve cutting the concrete floor and excavating shallow trenches for the both the injection of water and the removal of soil vapor. The soil surface will be sealed and the concrete patched and returned to match existing conditions. Care will be taken to mask off and protect other parts of the school during this construction to minimize impacts caused by dust etc. This design assumes that this contraction will take place in the summer of 2012, while the school is vacated.
	Noise	There are a number of construction activities that have the potential to cause noise, such as; installation of sheet pile, drilling and excavating. In most cases noise can be managed by establishing a work zone where personnel not associated with the work will not be allowed during these activities. Other considerations such as work pauses due to coordination with school personnel can be evaluated during the project. This construction work is also anticipated to be completed during the summer of 2012 while school is vacated.
	Open Excavations	Open excavations will be fenced and secured. Excavations will be marked with warning signage.
	Interruptions in utilities	There will be temporary interruptions in the utilities that go to the school. These utilities will be located prior to construction. Arrangements will be made to relocate and provide temporary connections as required to provide service. Both overhead and underground utilities will be affected.
	Traffic	The barrier wall construction along Sixth Street and Railroad Avenue will require partial road closures. Provisions for traffic rerouting will be provided to allow for access to the School and properties to the west.
	Dust	Dust will be generated by excavation activities and by trench installation within the school building. Dust associated with excavation will be mitigated by water spray as has been successfully been done during past excavation work in Skykomish. Dust impacts during trench installation within the school will be controlled by partitioning off work areas to prevent dust migration, and by using wet cutting techniques to remove concrete. This work will be performed while the school is vacant.

Category	Potential Impact	Design Mitigation
Operation and Maintenance	Heating of grounds surrounding the school	The grounds around the school are not likely to be affected by the heating operation. Design calculations indicate increase in ground surface temperature will be minimal due to heat removed by SVE.
	Heating of the school	There is a potential for measurable increases in school floor slab temperature during heat injection. This was observed in the heat transfer modeling that was performed. By installing a more robust SVE system, heat energy can be pulled off and the temperature of the slab regulated. Design calculations indicate increase in slab surface temperature will be minimal due to heat removed by SVE. Temperature sensors will be installed below the school slab and the temperature below the slab recorded. Startup testing will be used to determine acceptable operating temperatures.
	Potential leaks in piping	The piping material specified for transmission of fluids will be over designed to prevent leakage. The piping will be designed for operational pressures of up to 150 psi. System operational pressures will only range up to 20 psi. Screened areas where active injection will take place will have pressure transducers in place to maintain water levels in the trenches below the school.
	Noise	The noise levels during O&M are not anticipated to be significant. The equipment will be housed south of the school in sound insulated enclosures. There will be some pumping equipment in well vaults near the school. In each case there is expected to be minimal to no noise levels above ambient conditions.

APPENDIX A
DESIGN DRAWINGS

HOT WATER FLUSHING DESIGN REPORT
Skykomish School
105 6th Street
Skykomish, Washington

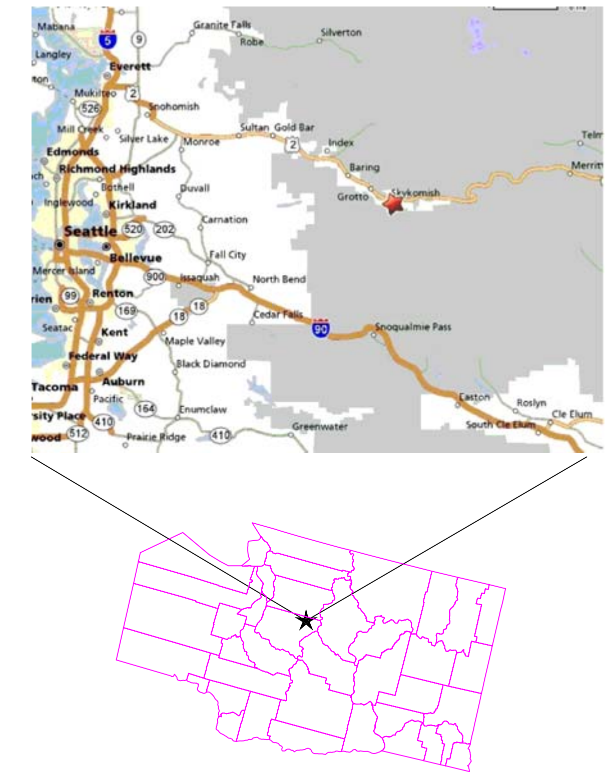
Farallon PN: 683-019

NWDZ REMEDIATION
FORMER MAINTENANCE
AND FUELING FACILITY
SKYKOMISH, WASHINGTON

SUBMITTED TO:
THE BNSF RAILWAY COMPANY
2454 OCCIDENTAL AVE. S. SUITE #1A
SEATTLE, WASHINGTON
(206) 625-6298

PREPARED BY:
AQUIFER SOLUTIONS, INC.
29025-A UPPER BEAR CREEK RD.
EVERGREEN, CO 80439
(303) 679-3143

VICINITY MAP



KING COUNTY, WASHINGTON

Aquifer Solutions, Inc.
www.aquifersolutions.com

HOT WATER FLUSHING SYSTEM
SKYKOMISH SCHOOL

DRAFT - NOT FOR CONSTRUCTION

SHEET	SHEET TITLE		SHEET	SHEET TITLE		SHEET	SHEET TITLE	
T-100:	COVER SHEET	REV. 0 6/6/2011	:		REV.			
T-101:	LEGEND	REV. 0 6/6/2011						
C-100:	SITE PLAN WITH UTILITIES	REV. 0 6/6/2011						
C-101:	HOT WATER FLUSHING SYSTEM LAYOUT	REV. 0 6/6/2011						
C-102:	SOIL VAPOR EXTRACTION SYSTEM LAYOUT	REV. 0 6/6/2011						
C-103:	TEMPORARY SURFACE CAP	REV. 0 6/6/2011						
C-104:	CROSS-SECTIONS	REV. 0 6/6/2011						
C-105:	RECOVERY TRENCH CROSS-SECTION	REV. 0 6/6/2011						
P-100:	PROCESS LEGEND	REV. 0 6/6/2011						
P-104:	PROCESS FLOW DIAGRAM, SHEET 1, HOT WATER FLUSHING SYS.	REV. 0 6/6/2011						
P-105:	PROCESS FLOW DIAGRAM, SHEET 2, HOT WATER FLUSHING SYS.	REV. 0 6/6/2011						
P-106:	PROCESS FLOW DIAGRAM, SHEET 3, HOT WATER FLUSHING SYS.	REV. 0 6/6/2011						
P-107:	PROCESS FLOW DIAGRAM, SHEET 4, HOT WATER FLUSHING SYS.	REV. 0 6/6/2011						
						CURRENT DATE	6/6/2011	

LEGEND:

SURFACE FEATURES:

- EXISTING BUILDING
- RELOCATED BUILDING
- RAILROAD TRACK
- EXISTING CURB/PAVEMENT/SIDEWALK
- EXISTING GRADE CONTOUR 5' INTERVAL
- EXISTING GRADE CONTOUR 1' INTERVAL
- BNSF PROPERTY LINE
- PROPERTY LINE
- EXISTING FENCE
- PROPOSED TEMPORARY CONSTRUCTION FENCE WITH SILT FENCE
- EXCAVATION LIMIT
- WETLANDS BOUNDARY
- RIVER/CREEK EDGE OF WATER
- PROPOSED EXCAVATION ELEVATION CONTOUR 5' INTERVAL
- PROPOSED EXCAVATION ELEVATION CONTOUR 1' INTERVAL
- EXISTING SHEET PILE
- EXISTING HYDRAULIC CONTROL CONTAINMENT (HCC) WALL
- EXISTING MECHANICALLY STABILIZED EARTH (MSE) WALL
- PROPOSED MECHANICALLY STABILIZED EARTH (MSE) WALL
- JERSEY BARRIER
- GUARD RAIL
- TRAFFIC ROUTE/OPEN ROADWAYS
- SOIL HANDLING AREA

SYMBOLS:

- MONITORING WELL
- SURVEY CONTROL POINT
- MARKER LOCATION
- GROUNDWATER TREATMENT SYSTEM RECOVERY WELL
- GROUNDWATER TREATMENT SYSTEM INJECTION WELL
- SP-3 2008 SHEET PILE LOCATION
- MSE-03 2008 MSE WALL LOCATION
- EL-15 EXCAVATION LIMIT CONTROL POINT
- 252 EXCAVATION CONTROL POINT
- EXISTING TREE

UTILITY FEATURES:

- FIRE DEPARTMENT CONNECTION
- FIRE HYDRANT
- WATER METER
- WATER VALVE
- HOSE BIB
- ELECTRIC METER
- GAS VALVE
- OFC OIL FILLER CAP
- STORM DRAIN MANHOLE
- CATCH BASIN
- SEPTIC SYSTEM/ SANITARY SEWER MANHOLE
- CO SEPTIC SYSTEM CLEANOUT
- Vent Pipe SEPTIC SYSTEM VENT
- UTILITY POLE
- UTILITY POLE GUIDE WIRE
- UTILITY POLE W/LIGHT
- ELECTRIC MANHOLE
- TRB TELEPHONE RISER BOX
- JUNCTION BOX
- EXISTING OVERHEAD TELEPHONE UTILITY
- W EXISTING WATER UTILITY
- W TEMPORARY WATER UTILITY BYPASS
- EXISTING GAS UTILITY
- OHP EXISTING ELECTRIC OVERHEAD UTILITY
- EXISTING ELECTRIC UNDERGROUND UTILITY
- UP EXISTING UNDERGROUND ELECTRIC POWER UTILITY
- JUT EXISTING JOINT UTILITY TRENCH
- SD EXISTING STORM DRAIN
- EXISTING SANITARY SEWER
- SIDE SEWER
- OHC OVERHEAD CABLE
- UGC UNDERGROUND CABLE
- BURIED FIBER OPTIC
- INTEGRATED UNMANNED TRAFFIC SIGNAL
- Septic Vault BELOW GROUND STRUCTURE
- PROPANE GAS TANK
- BOLLARD
- S SETTLEMENT MONITORING POINT

SUBSURFACE BARRIER

- CONTAINMENT WALL KEYED INTO SILT LAYER
- TREATED GROUNDWATER INFILTRATION GALLERY
- INJ TREATED GROUNDWATER INJECTION WELL
- GROUNDWATER AND LNAPL RECOVERY TRENCH
- HORIZONTAL SVE GALLERY
- UNDERGROUND TREATED GROUNDWATER PIPING
- UNDERGROUND SVE PIPING
- UNDERGROUND GROUNDWATER EXTRACTION PIPING
- TC/PZ THERMOCOUPLE PROBE / PEIZOMETER
- LSHH HIGH–HIGH LEVEL SWITCH UNDER SLAB
- EXISTING MONITORING WELL
- SGP SOIL GAS PROBE

ABBREVIATIONS:

- FMC- FORMER MALONEY CREEK
- HCC- HYDRAULIC CONTROL CONTAINMENT
- MSE- MECHANICALLY STABILIZED EARTH
- NWDZ- NORTH WEST DEVELOPED ZONE

HORIZONTAL & VERTICAL CONTROL

1. HORIZONTAL DATUM: NAD 83/91
2. VERTICAL DATUM: NAVD 88
3. BENCHMARK: KING COUNTY MONUMENT STAMPED "1995 GPS 8823" WITH THE PUBLISHED ELEVATION OF 931.73. (CP #117 ON C-100.)

NOTES

1. SITE PLAN IS BASED ON 2007 SURVEY DATA PROVIDED BY TRUE NORTH LAND SURVEYING, INC., DATED 12/10/2007.
2. PROPERTIES AND AREAS THAT WERE NOT INCLUDED IN THE SURVEY ARE NOT SHOWN.
3. ALL DISTANCES ARE U.S. SURVEY FEET.

BMPs PER STORMWATER MANAGEMENT MANUAL FOR WESTERN WASHINGTON

- BMP C101 - PRESERVING NATURAL VEGETATION
- BMP C103 - HIGH VISIBILITY FENCE
- BMP C106 - WHEEL WASH/DECONTAMINATION PAD
- BMP C140 - DUST CONTROL
- BMP C220 - COVER CATCH BASINS
- BMP C233 - SILT FENCE
- BMP C250 - CONSTRUCTION WATER TREATMENT

WILSON STONE CLAYTON · STATE OF WASHINGTON · 46282 · REGISTERED · PROFESSIONAL ENGINEER

NO	DRWN	DATE	REVISION	CHKD	DATE	APPVD	DATE
0	JHT	6/6/2011	DESIGN REPORT MAY 2011	DG	5/9/2011	WSC	5/9/2011
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BURLINGTON NORTHERN
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SKYKOMISH, WASHINGTON

DATE: 6/6/2011
PROJ. NO.: 1081

LEGEND
HOT WATER FLUSHING SYSTEM
NWDZ REMEDIATION

DRAWING NUMBER: T-101
SHEET NUMBER:
REVISION 0

NOTES:

1. LOCATIONS OF BUILDINGS, UTILITIES AND OTHER FEATURES SUPPLIED BY AECOM.
2. FOR LEGEND PLEASE SEE DRAWING T-101.
3. UTILITY LOCATIONS ARE APPROXIMATE. CONTRACTOR SHALL PERFORM PUBLIC AND PRIVATE UTILITY LOCATING PRIOR TO ANY EXCAVATION.
4. EXCAVATION EAST AND SOUTH OF SCHOOL PERFORMED IN 2010 IS INDICATED AS HATCHED.

WILSON STONE CLAYTON — STATE OF WASHINGTON — 46282 — REGISTERED PROFESSIONAL ENGINEER

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PROJ. NO.: 1081

DATE: 6/6/2011

SITE PLAN WITH UTILITIES

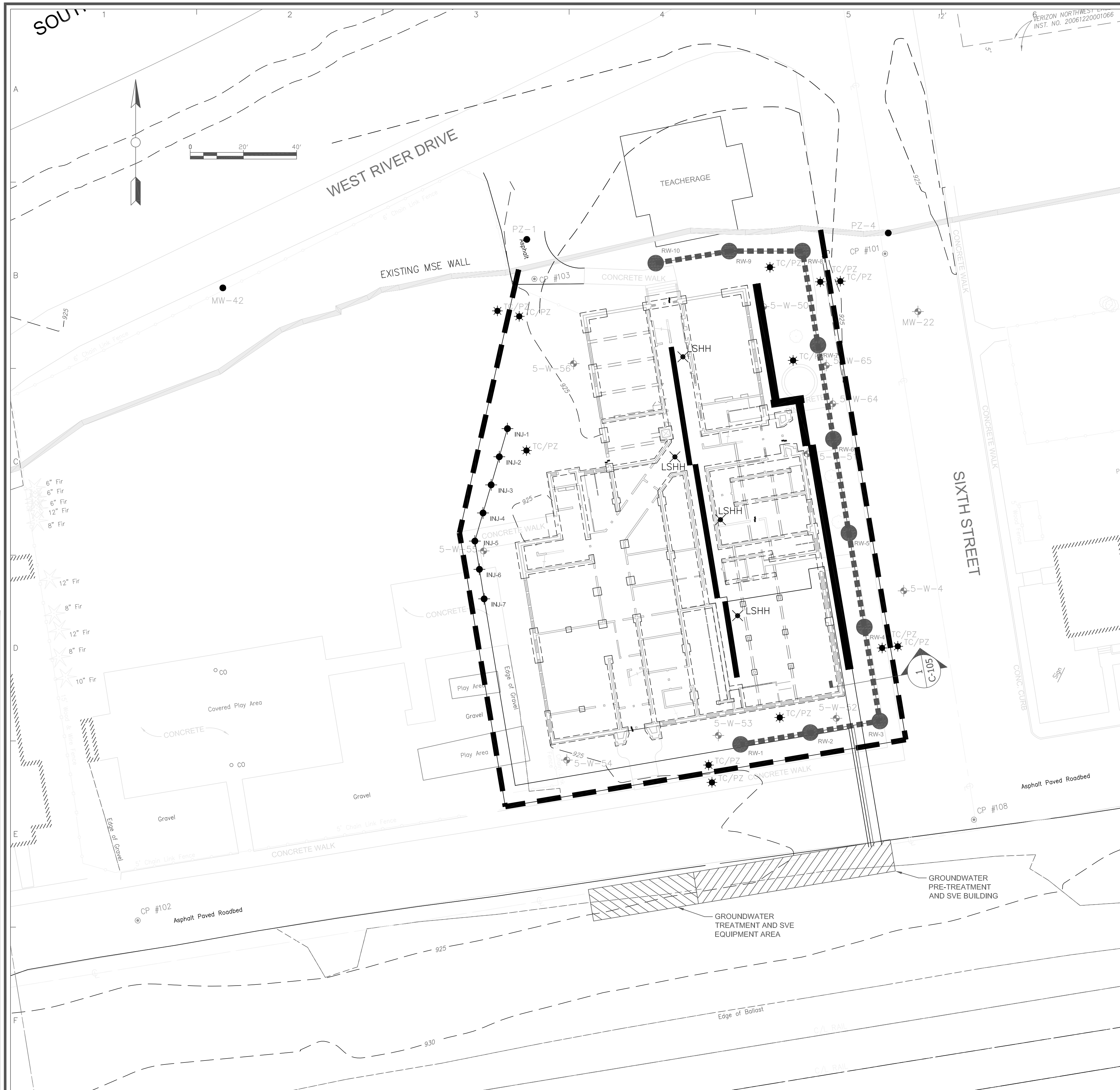
SKYKOMISH SCHOOL

NWDZ REMEDIATION

DRAWING NUMBER: C-100

SHEET NUMBER:

REVISION 0



NOTES:

1. LOCATIONS OF BUILDINGS, UTILITIES AND OTHER FEATURES SUPPLIED BY AECOM.
2. FOR LEGEND PLEASE SEE DRAWING T-101.
3. TWELVE THERMOCOUPLE/ PIEZOMETER (TC/PZ) AND PIEZOMETER (PZ) WELLS WILL BE INSTALLED IN THE APPROXIMATE LOCATIONS SHOWN. THE ENGINEER WILL SPECIFY, PROCURE AND INSTALL THE THERMOCOUPLES ON THE EXTERIOR OF THE PIEZOMETER CASINGS. CONTRACTOR SHALL COMPLETE TC/PZS AND PZS WITH A FLUSH-MOUNTED, BOLTED WELL COVER USING TAMPER-RESISTANT BOLTS.
4. HIGH LEVEL SENSOR HOUSINGS WILL BE INSTALLED IN THE LOCATIONS IDENTIFIED. THESE HOUSINGS SHALL BE INSTALLED IN THE SVE TRENCHES WHERE POSSIBLE. THE HIGH LEVEL HOUSINGS SHALL CONSIST OF A 24 INCH LONG PIECE OF 2-INCH WELL PIPE WITH A BOTTOM PLUG. THE HIGH LEVEL SENSOR SHALL BE COMPLETED WITH A FLUSH MOUNTED BOLTED WELL COVER. THE ENGINEER WILL SPECIFY, PROVIDE AND INSTALL THE HIGH LEVEL SENSOR. THE CONTRACTOR SHALL RUN THE SENSOR WIRES TO THE TEMPORARY EQUIPMENT ENCLOSURE LOCATED SOUTH OF THE SCHOOL. WHERE A TRENCH IS NOT ALREADY PRESENT TO RUN THE WIRE, THE CONTRACTOR SHALL SAW CUT THE CONCRETE AND PLACE THE WIRE IN THE SAW CUT AND CAULK THE SAW CUT WITH FLEXIBLE CONCRETE CAULKING.

LEGEND:

- SHEET PILE CONTAINMENT WALL KEYED INTO SILT LAYER AT APPROX. EL 895 FT. WALL IS LOCATED A MINIMUM OF 20 FT FROM SCHOOL BUILDING FOOTINGS. WALL WILL INTERSECT THE EXISTING MSE WALL ON THE NORTH SIDE OF SCHOOL.
- INJ-1 TREATED GROUNDWATER INJECTION WELL.
- 3-FT WIDE TREATED GROUNDWATER INFILTRATION GALLERY.
- RW-1 15-FT DEEP GROUNDWATER AND LNAPL RECOVERY TRENCH, WITH TEN, 4-FT DIAMETER, 15-FT DEEP RECOVERY SUMPS CONTAINING GROUNDWATER EXTRACTION PUMPS AND LNAPL REMOVAL BELT SKIMMERS.
- TC/PZ THERMOCOUPLE PROBE / PEIZOMETER
- LSHH HIGH-HIGH LEVEL SWITCH UNDER SLAB

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SKYKOMISH, WASHINGTON

DATE: 6/6/2011

PROJ. NO.: 1081

HOT WATER FLUSHING SYSTEM LAYOUT

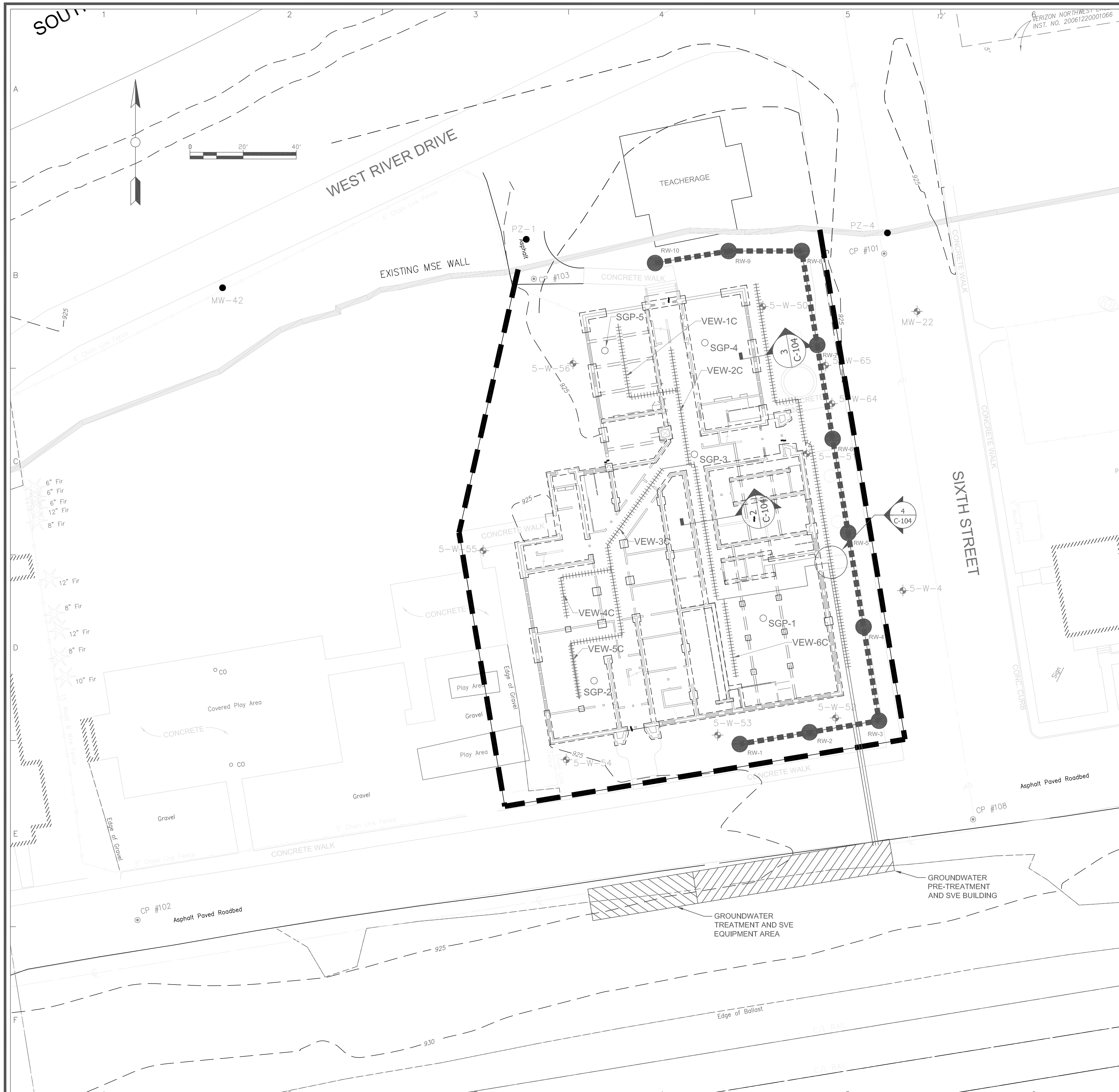
SKYKOMISH SCHOOL

NWDZ REMEDIATION

DRAWING NUMBER: C-101

SHEET NUMBER:

REVISION 0



NOTES:

1. LOCATIONS OF BUILDINGS, UTILITIES AND OTHER FEATURES SUPPLIED BY AECOM.
2. FOR LEGEND PLEASE SEE DRAWING T-101.
3. FIVE SOIL GAS PROBES (SGP) WILL BE INSTALLED BY CORE-DRILLING THROUGH THE CONCRETE FLOOR, AND INSTALLING A FARALLON VOC MONITORING PROBE. LOCATIONS SHOWN ARE APPROXIMATE. THE SGP WILL ALLOW THE ENGINEER TO OBTAIN IN PLACE SOIL VACUUM READINGS AND OBTAIN SOIL VAPOR SAMPLES IF NECESSARY. SHALLOW THERMOCOUPLES WILL ALSO BE INSTALLED JUST BELOW THE FLOOR SLAB AT EACH SGP LOCATION.
4. CAULK ALL FIRST FLOOR CONSTRUCTION JOINTS AND FLOOR PENETRATIONS.
5. IN AREAS OF FIRST FLOOR NOT COVERED BY SLAB (BENEATH STAIRS) INSTALL 20-MIL HDPE VAPOR BARRIER AND SEAL TO WALLS WITH APPROVED SEALANT METHOD.

LEGEND:

SHEET PILE CONTAINMENT WALL.

HORIZONTAL SOIL VAPOR EXTRACTION (SVE) GALLERY. GALLERY LOCATIONS AND NUMBER ARE SUBJECT TO FURTHER REFINEMENT.

SGP-1 SOIL GAS PROBE / THEROMOCOUPLE

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SKYKOMISH, WASHINGTON

PROJ. NO.: 1081
DATE: 6/6/2011

SOIL VAPOR EXTRACTION SYSTEM LAYOUT
SKYKOMISH SCHOOL
NWDZ REMEDIATION

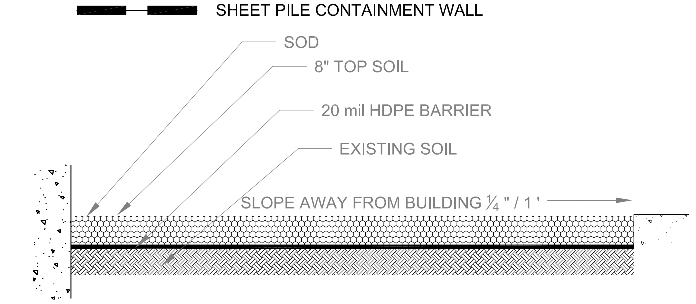
DRAWING NUMBER: C-102
SHEET NUMBER:
REVISION 0

NOTES:

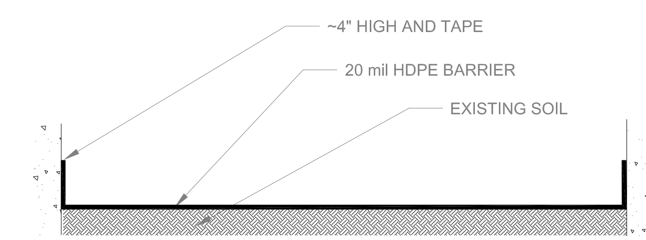
1. CONTRACTOR SHALL PLACE TEMPORARY SURFACE CAP IN UNPAVED AREAS SHOWN. THESE LOCATIONS ASSUME THAT THE CONCRETE WALKS REMAIN IN PLACE. IF THE CONCRETE WALKS ARE REMOVED FOR EXCAVATION AND NOT REPLACED PRIOR TO INITIATION OF TREATMENT, THE TEMPORARY SURFACE CAP SHALL BE PLACED IN THOSE AREAS UNTIL THE CONCRETE WALKS ARE RESTORED.
2. NOTE THAT INTERIOR TEMPORARY SURFACE CAP IS REQUIRED UNDER THE NORTH AND EAST ENTRY STEPS. ACCESS TO THE SOIL SURFACE UNDER THE STEPS IS FROM THE BUILDING INTERIOR. AFTER COMPLETION OF TREATMENT, THE CAPPING UNDER THE STEPS MAY REMAIN IN PLACE.
3. SURFACE FEATURES WITHIN THE CAP AREA WILL BE REMOVED PRIOR TO CAPPING. ANY SURFACE FEATURES THAT ARE TO REMAIN SHALL BE SEALED TO HDPE BARRIER BY METHOD APPROVED BY THE ENGINEER.
4. ACCESS TO MONITORING WELLS, INJECTION WELLS, RECOVERY TRENCHS, PIEZOMETERS, THERMOCOUPLES AND OTHER HWF FEATURES SHALL BE MAINTAINED.
5. AFTER REMEDIATION, CONTRACTOR SHALL REMOVE CAP EXTERIOR TO BUILDING AND RESTORE SURFACE CONSISTENT WITH SURROUNDING CONDITIONS. TREES REMOVED SHALL BE REPLACED IN-KIND.

TEMPORARY SURFACE CAP

SHEET PILE CONTAINMENT WALL



5 EXTERIOR TEMPORARY SURFACE CAP
Not to Scale



6 INTERIOR TEMPORARY SURFACE CAP
Not to Scale

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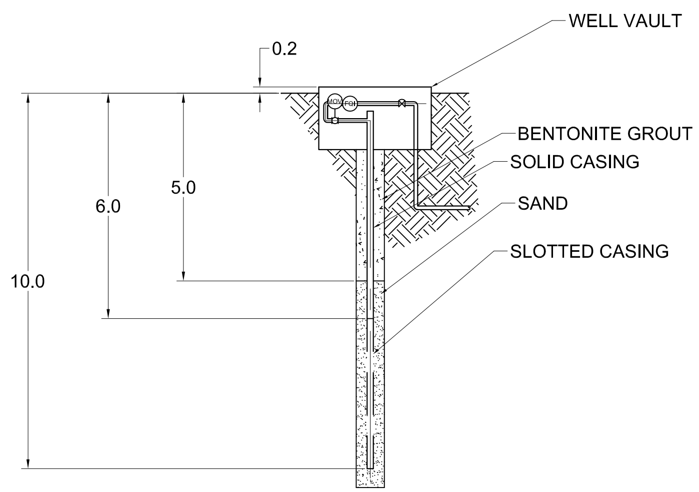
PROJ. NO.: 1081
DATE: 6/6/2011

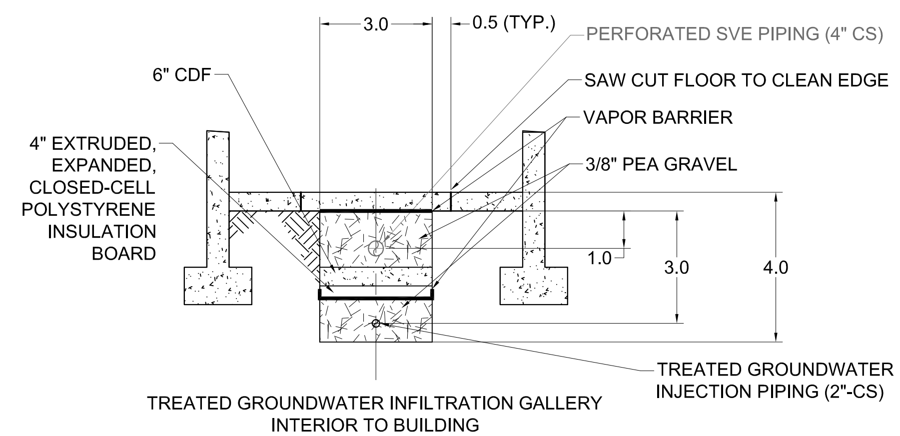
TEMPORARY SURFACE CAP
HOT WATER FLUSHING
SKYKOMISH SCHOOL

NWDZ REMEDIATION

DRAWING NUMBER:
C-103
SHEET NUMBER:
REVISION 0



TREATED GROUNDWATER INJECTION WELL (TYPICAL OF 7)



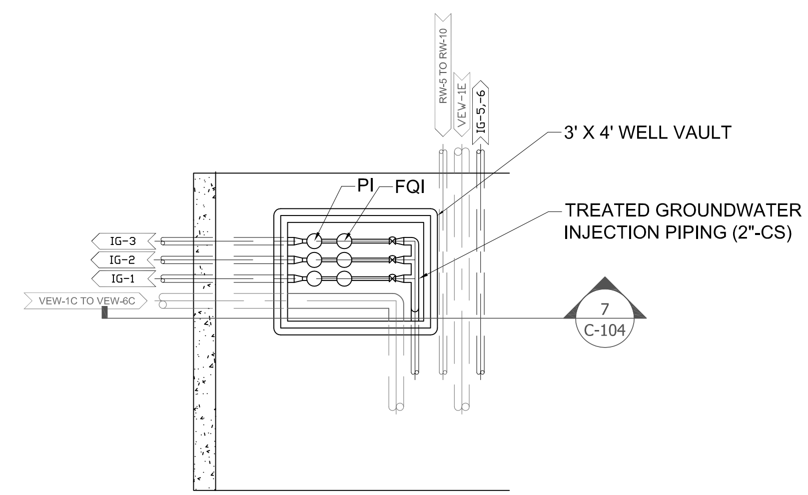
TREATED GROUNDWATER INFILTRATION GALLERY INTERIOR TO BUILDING

2 TREATED GROUNDWATER INFILTRATION AND SVE GALLERY CROSS-SECTION

1" = 2.5'

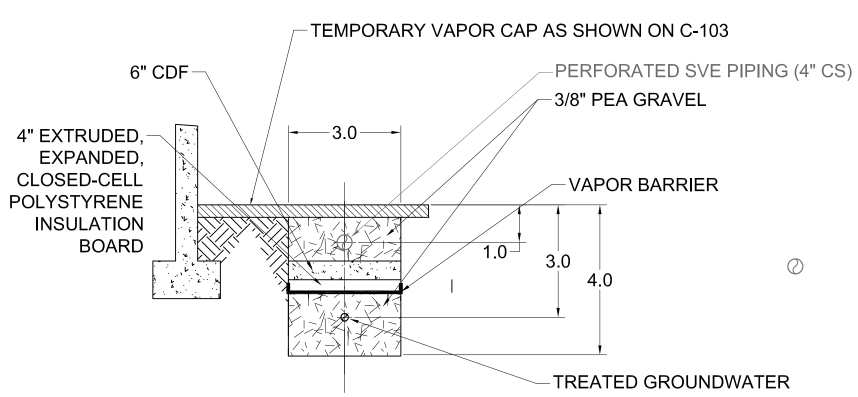
NOTES:

1. FOR LEGEND PLEASE SEE DRAWING T-101.
2. CDF - CONTROLLED DENSITY FILL
3. CS - CARBON STEEL
4. PI - PRESSURE INDICATOR
5. MOV - MOTOR OPERATED VALVE



4 TREATED GROUNDWATER INFILTRATION AND SVE WELL BOX

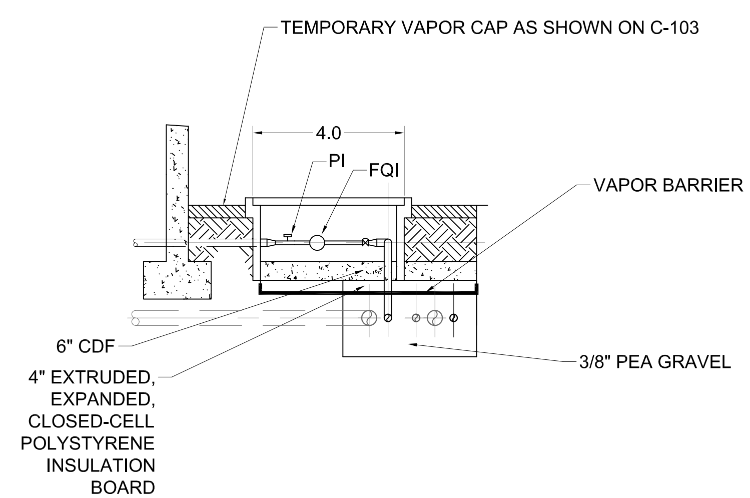
1" = 2.5'



TREATED GROUNDWATER INFILTRATION GALLERY EXTERIOR TO BUILDING

3 TREATED GROUNDWATER INFILTRATION AND SVE GALLERY CROSS-SECTION

1" = 2.5'



7 TREATED GROUNDWATER INFILTRATION AND SVE WELL BOX

1" = 2.5'

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PROJ. NO.: 1081

DATE: 6/6/2011

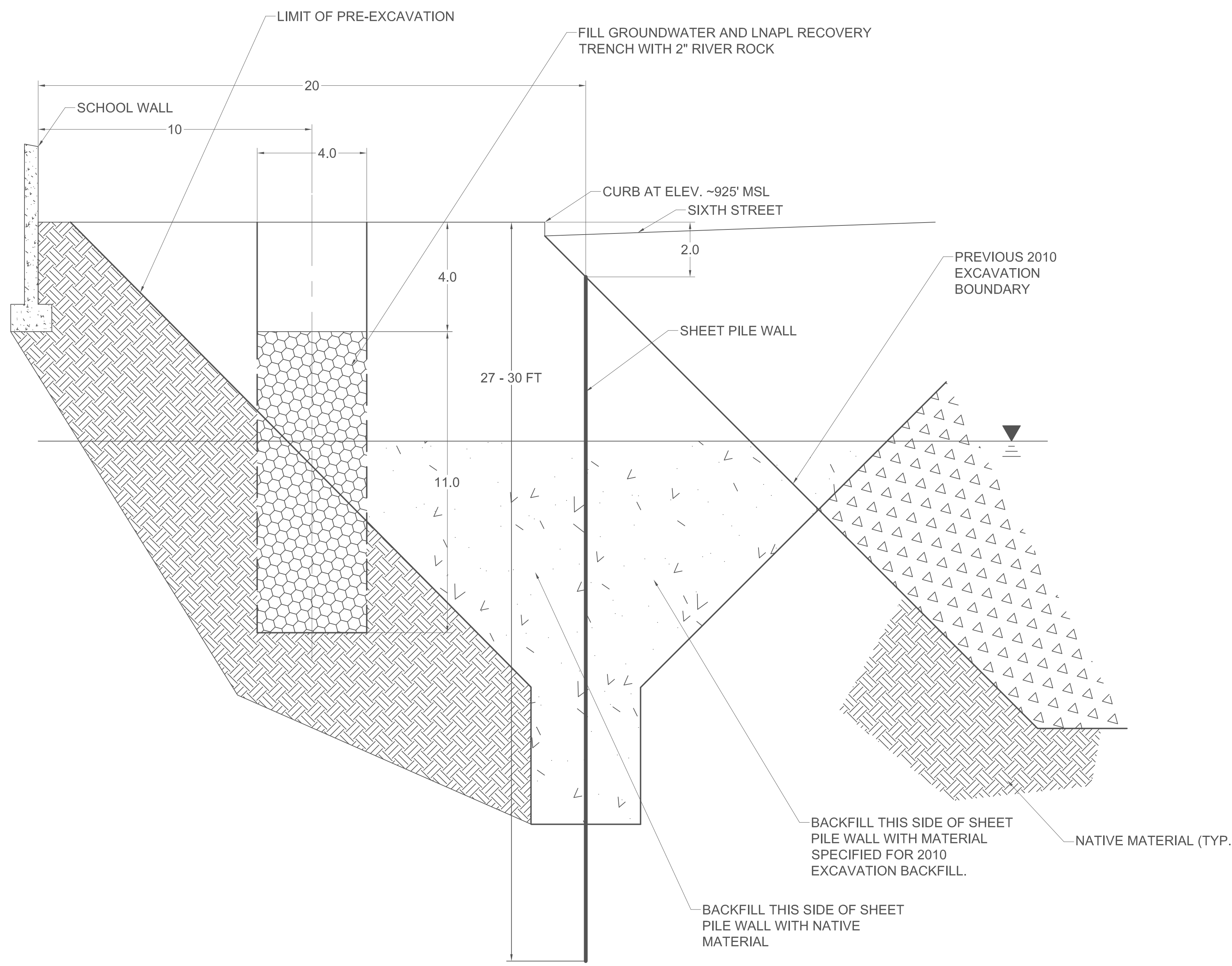
HOT WATER FLUSHING CROSS-SECTIONS SKYKOMISH SCHOOL

NWDZ REMEDIATION

DRAWING NUMBER: C-104

SHEET NUMBER:

REVISION 0



1 GROUNDWATER AND LNAPL RECOVERY TRENCH CROSS-SECTION

1" = 2.5'

NOTES:

1. LOCATIONS OF BUILDINGS, UTILITIES AND OTHER FEATURES SUPPLIED BY AECOM.
2. FOR LEGEND PLEASE SEE DRAWING T-101.
3. DIMENSIONS IN FEET.
4. SHEET PILE WILL EXTEND TO AND BE KEYED INTO THE SILT LAYER. APPROXIMATE DEPTH IS 27 TO 30 FEET BELOW GRADE
5. SHEET PILE ALIGNMENT MAY NEED TO BE PRE-EXCAVATED TO REMOVE LARGE BOULDERS AND COBBLES. TO THE EXTENT POSSIBLE THE PRE-EXCAVATION WILL BE PERFORMED WITH A TRENCH BOX TO MINIMIZE THE SURFACE FOOTPRINT OF THE EXCAVATION.
6. SHOULD REFUSAL OCCUR PRIOR TO DRIVING THE SHEET PILE TO TARGET DEPTH THE AREA BELOW THE SHEET PILE SHALL BE GROUT SEALED WITH A PRESSURE GROUT.
7. SEAL BETWEEN THE MSE WALL AND THE SHEET PILE WITH PRESSURE GROUTING.
8. ALL SHEET PILE WILL BE CUT DOWN TO 2-FEET BELOW GRADE AND THE SURFACE RESTORED.
9. UTILITIES THAT ARE ENCOUNTERED WILL BE TEMPORARILY REMOVED AND RESTORED OR RELOCATED AND REPLACED ONCE THE SHEET PILE WALL HAS BEEN INSTALLED.
10. SHEET PILE JOINTS WILL BE CLEARED WITH HIGH PRESSURE WATER AND GROUTED WITH A BENTONITE/PORTLAND CEMENT GROUT TO SEAL THE JOINTS.
11. CONSTRUCTION SEQUENCE:
    A. INSTALL SHEET PILES
    B. BACKFILL TO WATER TABLE AT ~ 8 FT BGS.
    C. EXCAVATE RECOVERY TRENCH TO A DEPTH OF 15 FT BGS.
    D. INSTALL RECOVERY SUMPS AS SHOWN ON DRAWING C-101.
    E. COMPLETE BACKFILL TO GRADE.
12. BARRIER WALL ALIGNMENT WILL BE FIELD SURVEYED PRIOR TO INSTALLATION AND MAY BE ADJUSTED TO AVOID SITE FACILITIES OR OBSTACLES.

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SKYKOMISH, WASHINGTON

PROJ. NO.: 1081

DATE: 6/6/2011

HOT WATER FLUSHING
RECOVERY TRENCH
CROSS-SECTIONS
SKYKOMISH SCHOOL

NWDZ REMEDIATION

DRAWING NUMBER:
C-105

SHEET NUMBER:

REVISION 0

PROCESS STREAM IN TABLE (A)

MAIN PROCESS PIPING

OTHER PROCESS PIPING

CENTRIFUGAL PUMP

BLOWER

POSITIVE-DISPLACEMENT ROTORY BLOWER

BELT SKIMMER WITH DRUM

STRAINER

HEAT EXCHANGER

CHEMICAL METERING PUMP

PIPING REDUCER

AIR-AIR HEAT EXCHANGER

LINE DESIGNATIONS:
3"-CS-I = 3-in. NOMINAL PIPE SIZE(NPS), Sch. 40 CARBON STEEL, INSULATED
CPVC40 = SCH. 40 CPVC
CPVC80 = SCH. 80 CPVC
PVC80 = Sch. 80 PVC
NI = NOT INSULATED

NOTES:
EW GROUNDWATER EXTRACTION WELL
INJ TREATED GROUNDWATER INJECTION WELL

SYSTEM DESIGNATIONS
100 - EXTRACTION WATER
200 - SVE
300 - BOILER FUEL

VALVE LEGEND

- BALL VALVE, NORMALLY OPEN
- BALL VALVE, NORMALLY CLOSED
- BUTTERFLY VALVE
- CHECK VALVE
- DIAPHRAM VALVE
- GATE VALVE, NORMALLY OPEN
- GATE VALVE, NORMALLY CLOSED
- GLOBE VALVE, NORMALLY OPEN
- GLOBE VALVE, NORMALLY CLOSED
- PRESSURE REDUCING VALVE
- PRESSURE RELIEF VALVE
- VACUUM RELIEF VALVE
- VENT VALVE
- AIR-OPERATED GLOBE VALVE
- MOV — MOTOR-OPERATED BALL VALVE
- MOV — MOTOR-OPERATED GLOBE VALVE
- SV — SOLENOID VALVE

INSTRUMENT IDENTIFICATION

DESIGNATION	MEANING	DESIGNATION	MEANING
FCV	FLOW CONTROL VALVE	LSHH	LEVEL SWITCH, HIGH-HIGH
FE	FLOW ELEMENT	LSL	LEVEL SWITCH, LOW
FI	FLOW INDICATOR	LT	LEVEL TRANSMITTER
FIQ	FLOW INDICATING TOTALIZER	PAH	PRESSURE ALARM, HIGH
FIR	FLOW INDICATING RECORDER	PAHH	PRESSURE ALARM, HIGH-HIGH
FT	FLOW TRANSMITTER	PI	PRESSURE (OR VACUUM) INDICATOR
HS	HAND SWITCH	PIC	PRESSURE INDICATING CONTROLLER
KC	TIMER	PT	PRESSURE TRANSMITTER
LAL	LEVEL ALARM, LOW	TAH	TEMPERATURE ALARM, HIGH
LC	LEVEL CONTROLLER	TAHH	TEMPERATURE ALARM, HIGH
LCV	LEVEL CONTROL VALVE	TI	TEMPERATURE INDICATOR
LI	LEVEL INDICATOR	TT	TEMPERATURE TRANSMITTER
LIC	LEVEL INDICATING CONTROLLER	VFD	VARIABLE FREQUENCY DRIVE
LIR	LEVEL INDICATING RECORDER	YA	EVENT ALARM
LSH	LEVEL SWITCH, HIGH		

FIELD-MOUNTED DISCRETE INSTRUMENT

PANEL-MOUNTED DISCRETE INSTRUMENT

PANEL-MOUNTED SHARED DISPLAY OR CONTROL

PLC FUNCTION

ELECTRICAL SIGNAL

DIGITAL SIGNAL

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29025-A Upper Bear Creek Rd.
Evergreen, CO 80439

BURLINGTON NORTHERN
FORMER MAINTENANCE AND
FUELING FACILITY
SKYKOMISH, WASHINGTON

DATE: 6/6/2011

PROJ. NO.: 1081

PROCESS LEGEND
HOT WATER FLUSHING SYSTEM
SKYKOMISH SCHOOL

NWDZ REMEDIATION

DRAWING NUMBER: P-100

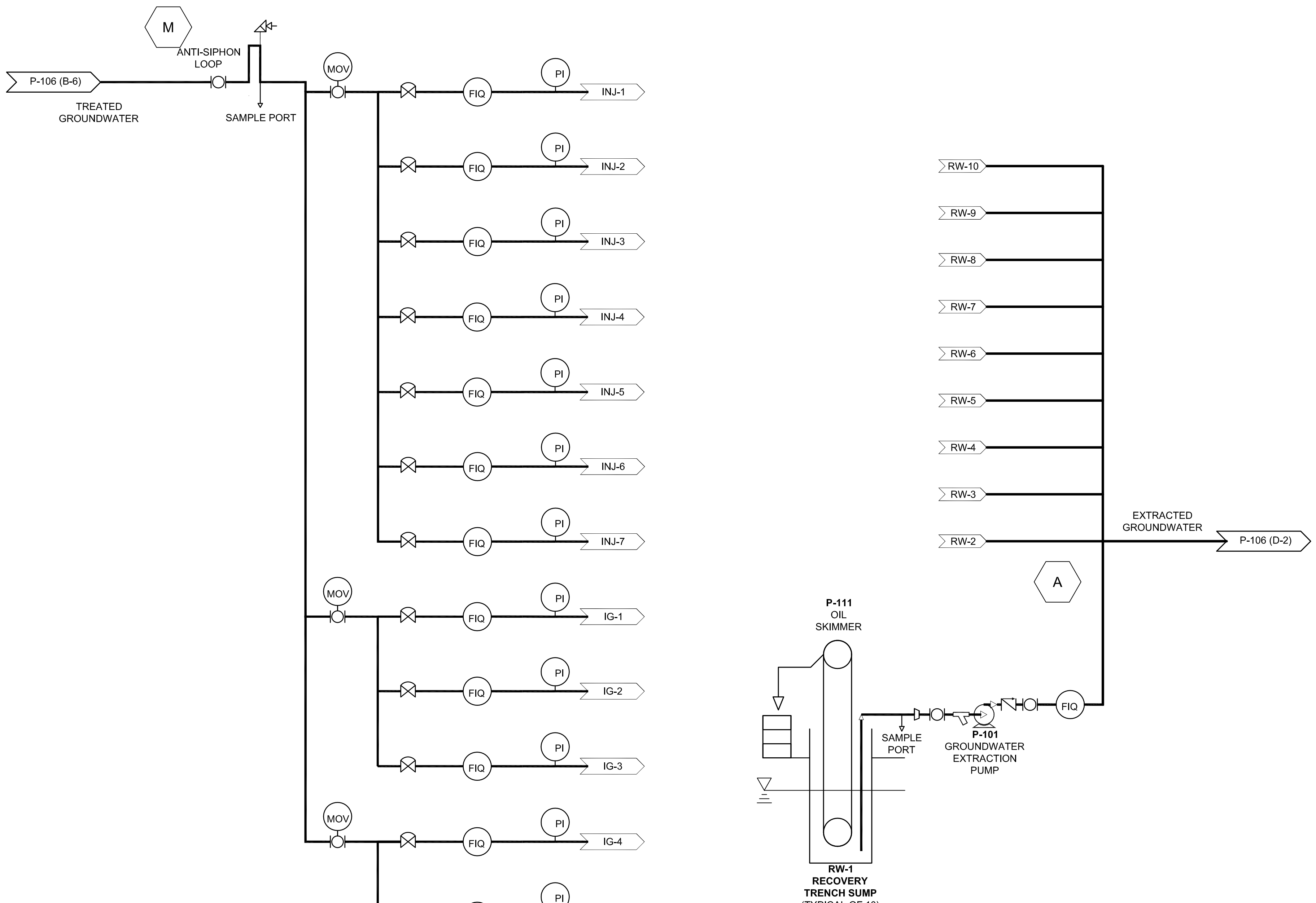
SHEET NUMBER:

REVISION 0

NOTES:

1. LATER = VALUE TO BE DETERMINED IN LATER STAGES OF DESIGN.
2. FOR LEGEND, PLEASE SEE DRAWING P-100.

INJ- TREATED GROUNDWATER INJECTION WELL
IG- TREATED GROUNDWATER INJECTION GALLERY
RW- GROUNDWATER AND LNAPL RECOVERY SUMP



EQUIPMENT SUMMARY

- **P-101 TO P-110**, GROUNDWATER EXTRACTION PUMP, 5 GPM, TEXP MOTOR
- **P-111 TO P-120**, OIL SKIMMER, XXX GPH, YY HP, VAC, PHASE, FLA, TEXP MOTOR

PROCESS FLOWS

STREAM	FLUID	STATE	FLOW RATE	TEMPERATURE	PRESSURE
A	EXTRACTED GROUNDWATER	LIQUID	UP TO 10 GPM EACH, AVERAGE OF 5 GPM EACH	53°F TO 160°F	LATER (NOTE1)
M	TREATED GROUNDWATER	LIQUID	UP TO 50 GPM	50°F TO 160°F	LATER

WILSON STONE CLAYTON
STATE OF WASHINGTON
46282
REGISTERED
PROFESSIONAL ENGINEER

NO	DRWN	DATE	REVISION	CHKD	DATE	APPVD	DATE
0	JHT	6/6/2011	DESIGN REPORT MAY 2011	DG	5/9/2011	WSC	5/9/2011
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SKYKOMISH, WASHINGTON

DATE: 6/6/2011

PROJ. NO.: 1081

PROCESS FLOW DIAGRAM
SHEET 1
HOT WATER FLUSHING SYS.
SKYKOMISH SCHOOL

NWDZ REMEDIATION

DRAWING NUMBER: P-104

SHEET NUMBER:

REVISION 0

NOTES:

1. LATER = VALUE TO BE DETERMINED IN LATER STAGES OF DESIGN.
2. FOR LEGEND, PLEASE SEE DRAWING P-100.
3. SYSTEM OPERATION IS EXPECTED TO BE 24 HOURS PER DAY, 7 DAYS PER WEEK WHEN SCHOOL IS NOT IN SESSION.

VEW SOIL VAPOR EXTRACTION GALLERY
E - GALLERY EAST OF SCHOOL BUILDING
C - GALLERY IN CENTER OF SCHOOL BUILDING

PROCESS FLOWS

STREAM	FLUID	STATE	FLOW RATE	TEMPERATURE	PRESSURE	RELATIVE HUMIDITY
E	EXTRACTED SOIL GAS	GAS	500 SCFM	53°F TO 160°F	LATER (NOTE1)	100%

WILSON STONE CLAYTON
STATE OF WASHINGTON
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PROFESSIONAL ENGINEER

NO	DRWN	DATE	REVISION	CHKD	DATE	APPVD	DATE
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PROJ. NO.: 1081
DATE: 6/6/2011

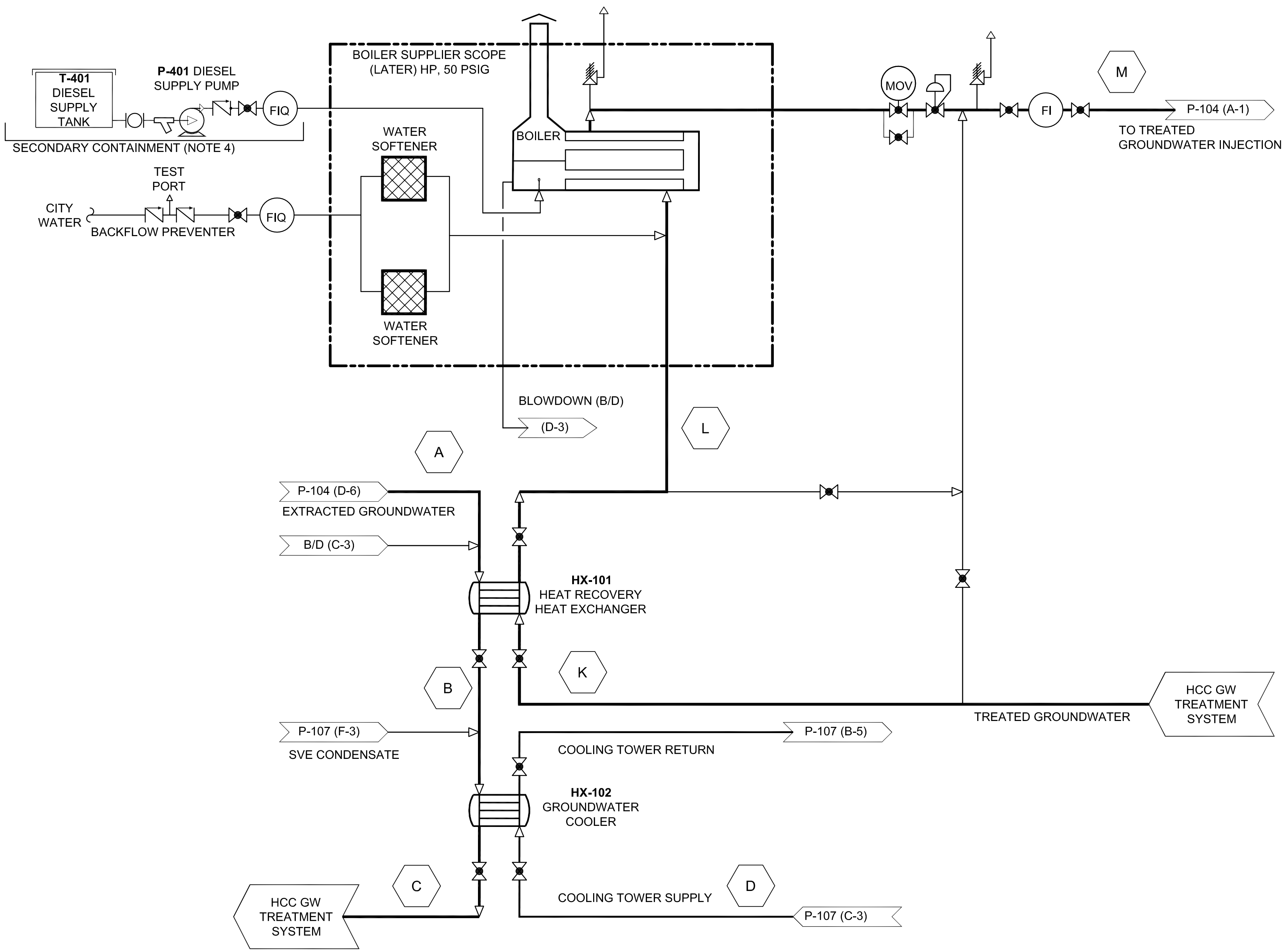
PROCESS FLOW DIAGRAM
SHEET 2
HOT WATER FLUSHING SYS.
SKYKOMISH SCHOOL

NWDZ REMEDIATION

DRAWING NUMBER: P-105

SHEET NUMBER:

REVISION 0



NOTES:

1. LATER = VALUE TO BE DETERMINED IN LATER STAGES OF DESIGN.

EQUIPMENT SUMMARY

- **PACKAGE BOILER**, HOT WATER, FIRE TUBE, (LATER) HP, 480 VAC, 3 PHASE, (LATER) AMPS
- **HX-101**, HEAT RECOVERY HEAT EXCHANGER, (LATER) BTU/HR
- **HX-102**, GROUNDWATER COOLER, (LATER) BTU/HR

PROCESS FLOWS

STREAM	FLUID	STATE	FLOW RATE	TEMPERATURE	PRESSURE
A	EXTRACTED GROUNDWATER	LIQUID	UP TO 50 GPM	53°F TO 160°F	LATER (NOTE1)
B	EXTRACTED GROUNDWATER	LIQUID	UP TO 50 GPM	53°F TO 100°F	LATER
C	EXTRACTED GROUNDWATER	LIQUID	UP TO 50 GPM	55°F TO 70°F	LATER
D	COOLING WATER	LIQUID	LATER	LATER	LATER
K	TREATED GROUNDWATER	LIQUID	UP TO 50 GPM	55°F TO 60°F	LATER
L	TREATED GROUNDWATER	LIQUID	UP TO 50 GPM	UP TO 150°F	LATER
M	HEATED, TREATED GROUNDWATER	LIQUID	UP TO 50 GPM	UP TO 160°F	LATER

WILSON STONE CLAYTON
STATE OF WASHINGTON
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PROFESSIONAL ENGINEER

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DATE: 6/6/2011

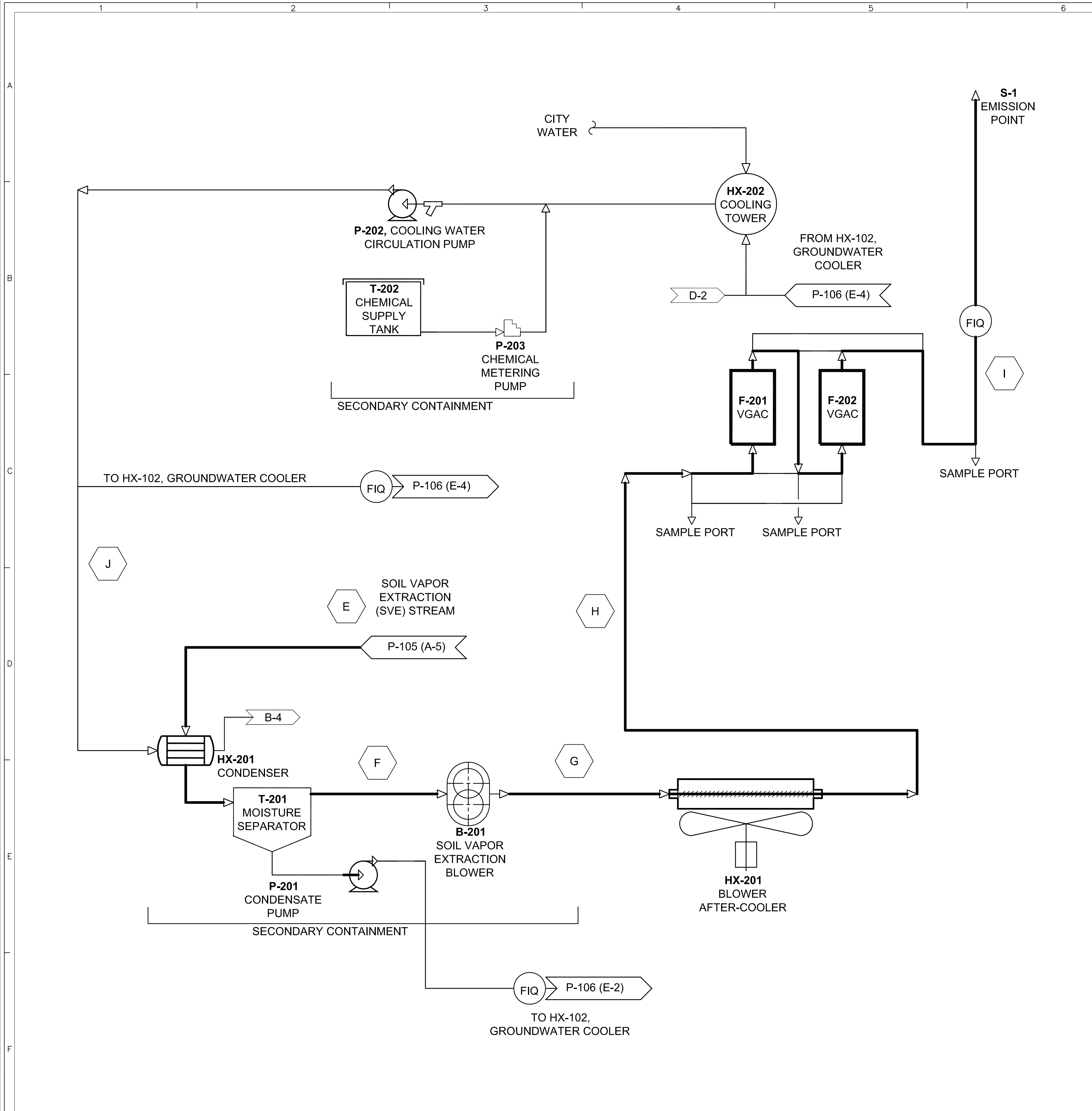
PROCESS FLOW DIAGRAM
SHEET 3
HOT WATER FLUSHING SYS.
SKYKOMISH SCHOOL

NWDZ REMEDIATION

DRAWING NUMBER: P-106

SHEET NUMBER:

REVISION 0



NOTES:

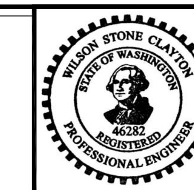
1. WATER TEMPERATURE EXITING T-101 IS EXPECTED TO BE A MAXIMUM OF100°F AT AN AMBIENT AIR TEMPERATURE OF 70°F.
2. SYSTEM OPERATION IS EXPECTED TO BE 24 HOURS PER DAY, 7 DAYS PER WEEK WHEN SCHOOL IS NOT IN SESSION.

EQUIPMENT SUMMARY

- **B-201**, SOIL VAPOR EXTRACTION BLOWER, POSITIVE DISPLACEMENT BLOWER, XX SCFM @ YY IN. WC SUCTION, __-HP, 460 VAC, 3 ϕ, __ AMPS, TEXP MOTOR
- **F-201**, VAPOR-PHASE GRANULAR ACTIVATED CARBON, 1,200 LB OF COCONUT-SHELL CARBON
- **F-202**, VAPOR-PHASE GRANULAR ACTIVATED CARBON, 1,200 LB OF COCONUT-SHELL CARBON
- **HX-201**, CONDENSER
- **HX-201**, BLOWER AFTER-COOLER
- **HX-201**, COOLING TOWER
- **P-201**, CONDENSATE PUMP, 5 GPM
- **P-202**, COOLING WATER CIRCULATION PUMP
- **P-203**, CHEMICAL METERING PUMP
- **T-201**, MOISTURE SEPARATOR
- **T-202**, CHEMICAL SUPPLY TANK

PROCESS FLOWS

STREAM	FLUID	STATE	FLOW RATE	TEMPERATURE	PRESSURE	RELATIVE HUMIDITY
E	EXTRACTED SOIL GAS	GAS	500 SCFM	53°F TO 160°F	LATER (NOTE1)	100%
F	EXTRACTED SOIL GAS	GAS	500 SCFM	LATER	LATER	100%
G	TREATED SOIL GAS	GAS	500 SCFM	LATER	LATER	<50%
H	EXTRACTED SOIL GAS	GAS	500 SCFM	<120°F	LATER	<50%
I	TREATED SOIL GAS	GAS	500 SCFM	<120°F	0 PSIG	<50%
J	COOLING WATER	LIQUID	LATER	LATER	LATER	N/A



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PROCESS FLOW DIAGRAM
SHEET 4
HOT WATER FLUSHING SYS.
SKYKOMISH SCHOOL

NWDZ REMEDIATION

DRAWING NUMBER: P-107

SHEET NUMBER:

REVISION 0