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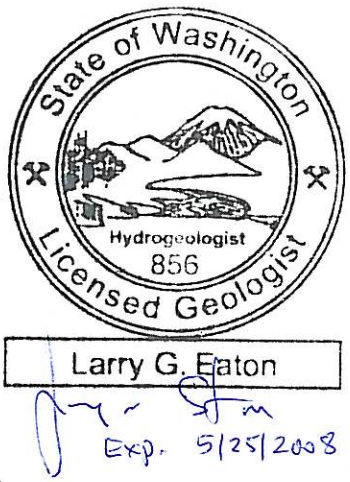

Memorandum

To: Jeff Cameron, PE – City of Longview, Washington

From: Larry Eaton, RG, LHG – GSI Water Solutions, Inc.
Ken Trotman, RG, LHG – GSI Water Solutions, Inc.
Dr. Dimitri Vlassopoulos – S.S. Papadopulos & Associates, Inc.

Date: December 14, 2007

Re: City of Longview Proposed New Wellfield, Mint Farm Area, Longview, Washington – A Second Opinion

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The purpose of this memorandum is to present a summary of GSI Water Solutions' (GSI) review of the City of Longview's (City) Weber Avenue test well report that was prepared by Robinson, Noble & Saltbush, Inc. (R&N) as part of the proposed Mint Farm groundwater wellfield project. Our scope of work for this project included addressing the following key elements:

- Is the groundwater system (aquifer) in the Mint Farm area productive enough to support a 20 million gallon per day (mgd) wellfield, and if so is it sustainable?
- Are there any native groundwater quality concerns and if so are they treatable?
- What are the issues with obtaining new groundwater rights for the proposed wellfield?
- What are the issues related to siting the wellfield in an industrial area?

This memorandum addresses each of these key elements in a peer review format, using available data provided to us by the City. Our findings are presented below. A brief background outlining why the City is contemplating a new wellfield also is presented.

Background and Current Conditions

Currently, the City water supply is from a surface water intake on the Cowlitz River. The City has a nearly 60-year-old raw water treatment plant that is in need of repair and updating, and in need of expansion to meet future growth demands. The river

intake pumps fail frequently, and flocculation/residual basins and drying beds require frequent cleaning because of sediment loading from the river (includes sediment and ash from the Mt. St. Helens eruption area). Sedimentation problems in the river have and will continue to impact Cowlitz River water supplies. In addition, the existing river intake does not meet current regulations for protecting fish. Rehabilitating the existing water treatment plant and expanding it to meet future demands, and constructing a new intake upriver were estimated to cost more than $66 million, according to City staff. However, the issue of sediment loading on the Cowlitz River still would be a major hurdle, even with a new intake and new water treatment plant.

For the reasons outlined above, the City staff has considered alternative water supply options for the City that include:

1. Developing a new 20-mgd groundwater supply wellfield and a new water treatment plant in the Mint Farm area.
2. Developing an intake on the Columbia River, upgradient of industrial outfalls and constructing a new water treatment plant near the intake or elsewhere in the City, depending on available land.

The new groundwater wellfield option has received the most interest from City staff and is the focus of this memorandum. The other option, of using the Columbia River, and the concept of using a collector well system (infiltration gallery) also are discussed briefly in this memorandum, with the understanding that advancing these options would require additional work. The merits and drawbacks of these options are presented below.

Groundwater Evaluation

As requested by the City, GSI reviewed the report entitled "*Draft, Construction and Testing Report, Weber Avenue Monitoring Well, Longview, Washington, January 2007*"prepared by R&N. The purpose of our review was to assess whether the results from the test well work support a 20-mgd groundwater wellfield in the Mint Farm area. We also reviewed another report prepared by R&N entitled "*Construction and Testing Mint Farm Generation Station Well 2, Longview, Washington, June 28, 2002*" and several other hydrogeologic reports prepared by R&N for the City of Kelso and the Port of Longview.

R&N's Weber Avenue test well report concluded that a single 20-inch-diameter well could yield up to 3,000 gallons per minute (gpm), which means that five large-diameter (20-inch) production wells would be required in the Mint Farm area to achieve the goal of developing a 20-mgd wellfield.

Figure 1 presents a base map of the Longview area and shows the location of a cross section line (A-A'). Figure 2 presents a generalized cross section through the Mint Farm area based on well logs provided by R&N and well logs obtained from the Washington State Department of Ecology (Ecology). The cross section extends across the Columbia River to the Oregon side, just west of Rainier, Oregon. The general subsurface conditions in the Mint Farm area consist of a valley eroded into the underlying bedrock and filled in with sediments by the Columbia River over time. Specifically, clayey silt

that thickens to the south toward the Columbia River is present from the ground surface to varying depths as shown in Figure 2. It is not known for sure, but it is anticipated that the Columbia River also is underlain by silt with clay. South of the Columbia River, the thickness of the silt horizon is less compared to the area north of the river (see Figure 2). These low permeability soils are underlain by silty sand north of the river, but this unit does not appear to be present south of the river. The target aquifer is a sand and gravel unit overlying bedrock. Low permeability shales and sandstones comprise the bedrock in the area. The static water level (potentiometric surface) is at or near the ground surface for the sand and gravel aquifer, which shows it is under pressure (confined). The transmissivity of the sand and gravel aquifer, which is a measure of how easily the aquifer will transmit water, was estimated at roughly 1 million gallons per day per foot of drawdown (gpd/ft) for the Weber Avenue test well and an order of magnitude higher for Mint Farm Generator Plant wells. These transmissivity values are high and essentially mean that a properly constructed water supply well will have high yield. The sustainability of that yield depends on the extent of the aquifer -- does it cover a large area and is it influenced by positive (supply of water like a river) or negative (no or low flow areas) boundaries? For example, wells completed in the Camas, Washington, area have similar values for transmissivity and these city wells easily yield more than 1,000 gpm. The hydraulic response observed in the short-term aquifer test of the Mint Farm Generator Plant wells also showed that the sand and gravel aquifer is confined (2×10^{-4} storativity), which means water is released from storage as a result of change in head caused by a pressure response and the compaction of the aquifer. The pump test data also show a hydraulic connection between the sand and gravel aquifer and the Columbia River (positive boundary).

GSI completed a preliminary assessment of the proposed spacing of the production wells for the Mint Farm wellfield to assess interference between the wells. Based on aquifer test data presented by R&N in the Weber Avenue test well report, the proposed spacing of 200 feet between wells would result in approximately 30 feet of additional drawdown at each well (a conservative assumption because we did not take into account the influence of the Columbia River). This amount of interference is not excessive given the available drawdown in the wells and, in our opinion, would not affect the sustainable (safe) yield of the new production wells, assuming the wells are properly designed. As such, based on (1) aquifer test data presented (aquifer transmissivity and storativity), (2) assuming the extent of the sand and gravel aquifer is extensive, (3) the positive boundary of the Columbia River, and (4) further taking into account interference between wells, we conclude that the estimated yield of 3,000 gpm per well is achievable and that the Mint Farm area easily can support a 20-mgd wellfield.

In summary, we agree with R&N that a properly designed wellfield and properly designed production wells completed in the target sand and gravel aquifer easily should meet the production goal of 20 mgd for the City. If the City decides to move forward with a Mint Farm wellfied, we recommend that the City consider installing six production wells, to provide redundancy to the wellfield system.

Water Quality

Water quality data were obtained from the Weber Avenue test well and included testing native groundwater for a suite of geochemical constituents, metals, and volatile organic compounds (VOC). Water quality data for the Weber Test well and water quality data for other wells sampled in the area by R&N are summarized in Table 1 (presented at the end of this memorandum). VOC compounds were not detected in the groundwater sample collected from the Weber Avenue well. Water quality samples collected as part of the Mint Farm Generator Plant project were not tested for VOCs.

Iron and manganese were detected in the groundwater sample collected from the Weber Avenue well at concentrations above the federal secondary maximum contaminant level (SMCL). The SMCLs are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. The U.S. Environmental Protection Agency (EPA) recommends secondary standards to water system providers, but does not require systems to comply. Iron and manganese were detected in the groundwater sample collected from the Weber Avenue well at concentrations of 0.97 milligram per liter (mg/L) and 0.622 mg/L, respectively. The SMCLs for iron and manganese are 0.3 mg/L and 0.05 mg/L, respectively. However, the iron concentration for the groundwater sample obtained from the Weber Avenue well is much less than what has been detected in other wells in the area (see Figure 3). Likewise, the concentration for manganese detected in groundwater sampled from the Weber Avenue well was less than what has been detected in groundwater from other local wells (see Figure 4). Iron and manganese, however, are sufficiently above the SMCL level to require treatment before delivery of groundwater to City customers. It is important to note that the groundwater sample collected from the Weber Avenue well was not laboratory filtered or field filtered, thus the concentration for iron and/or manganese represents a total value and the dissolved concentration for these constituents may be less. Additional sampling would be needed to evaluate the dissolved concentration for these constituents. We understand, however, that Ecology typically requires total concentrations for compliance purposes.

Arsenic was detected at a concentration of 13.2 micrograms per liter (µg/L), which is slightly higher than the newly established federal maximum contaminant level (MCL) of 10 µg/L. Figure 5 presents arsenic data for the Weber Avenue groundwater sample as well as arsenic concentrations present in groundwater samples collected from other wells near the City. The dissolved concentration, like iron and manganese, is not known for arsenic.

Based on discussions with Dr. Dimitri Vlassopoulos and water treatment engineers that we commonly work with on water resource projects, treating for iron, manganese, and arsenic is relatively straightforward and would include a combination of filtration and oxidation. We understand that the City is considering microfiltration with oxidation as the primary treatment method for a new water supply plant. The City, we also understand, plans to commission a preliminary treatment study that will include batch testing the groundwater to evaluate the chemistry of the iron and manganese in the water (is it in a dissolved, ferric, or colloidal state?) to determine the best treatment process for a new groundwater treatment plant. We further understand that the

treatment procedure for iron and manganese would remove the low-level arsenic present in the groundwater through the oxidation process. The preliminary treatment study also would include evaluating the total organic matter (it was detected in the Mint Farm Generator Plant well at 1.2 mg/L, but was not tested for at the Weber Avenue well) in native groundwater to determine if it would affect treatment processes.

Lastly, taste and odor testing was not performed on groundwater samples collected in the past. We were told by City staff that taste and odor were issues when the City used native groundwater as a supply source in the 1940s. Most likely, other than disinfection, the native groundwater from these older wells was not treated before it was delivered to customers. Because native groundwater is high in iron and manganese, this would explain the reason for the complaints. We anticipate that the new water treatment plant would eliminate taste and odor issues. With that said, early-stage batch testing for the water treatment plant could include a taste and odor evaluation using local residents to help allay some of these concerns.

Groundwater Rights

Our evaluation did not include a water rights audit of the City's existing surface water rights and/or groundwater rights. However, based on discussions with City staff working closely with the Washington Department of Ecology (Ecology), we understand that Ecology is supportive of converting the City's surface water right on the Cowlitz River to a groundwater right. A transfer, which would be a change in place of use, would be required, but City staff believes there is a low probability that this would not be approved by Ecology. The primary driver for Ecology is to reduce the take on the Cowlitz River to preserve in-stream flows for fish.

The Columbia River in the Longview area is open to further appropriations, which means that the City could apply for a new surface water right on the Columbia River. The water rights on the Cowlitz River could be transferred downstream to the Columbia River to facilitate a new permit, or the City could use the Cowlitz River water rights elsewhere (e.g., a wellfield) and still obtain a new surface water right on the Columbia River. Our understanding it that it would take approximately 1 year, or possibly less, if the City elected to pay for the review, to obtain a new surface water right on the Columbia River near Longview.

Lastly, if the City were to pursue a new groundwater right in Oregon (near the City of Rainier) and use that water in Washington (as outlined in the Collector Well [Oregon] Option), there is precedence to support that type of use. For example, in Oregon there are withdrawal points (groundwater extraction points) where the place of use is out of state—Washington and Idaho. However, additional work is needed to fully review this type of use with Ecology and the Oregon Water Resources Department, which we would recommend if the City were to advance the concept of using a collector well in Oregon to supply water to the City (see subsequent sections).

Wellfield Siting Issue

The proposed Mint Farm wellfield site would be located in an industrial part of the City, as shown in Figure 6. The location of the proposed wellfield and surrounding

industries and potential contaminant source areas identified in an Environmental Data Resources, Inc. (EDR), standard environmental risk management report also are shown in Figure 6. However, the siting information shown in Figure 6 does not reflect a detailed contaminant source inventory search, but is based on records provided to us by the City and input from City staff.

The key siting issue is that the proposed wellfield would be located in a known industrial area that very likely will continue to be an industrial area for the foreseeable future. This fact raises key questions:

1. What, if any, releases of contaminants occurred in the area in the past and what were the types of releases? Most importantly, if a release occurred, was it a solvent that is denser than water and was the release significant enough to affect the deeper sand and gravel aquifer (i.e., volume of the release)? If a contaminant plump is present in the area, how would pumping at the Mint Farm wellfield affect its migration?

2. What is the risk of a potential future release? How can that risk be monitored? What would be the impact of the release to the wellfield?

3. Can institutional controls be put into place in an industrial area to mitigate the potential for a release that could affect the source aquifer without impairing economic growth in the immediate area?

The overall conceptual model is that there is an upward vertical gradient from the deeper aquifer to the shallow aquifers. Also, there is a direct connection between the deep aquifer and the Columbia River, based on aquifer test data presented by R&N. We do not have data to determine if pumping from the sand and gravel aquifer would result in a response in shallow wells in the area, but most likely it would because there is no impervious clay layer separating the sand and gravel aquifer and the shallow aquifers hosted in the finer overlying sediments. Based on the high water levels measured in the Weber Avenue well, there appears to be an upward hydraulic gradient between the sand and gravel aquifer and the overlying shallow aquifer. Although this gradient would limit downward migration of dissolved-phase contaminants through the aquifer, dense nonaqueous phase liquids (DNAPL) at sufficient volumes have the potential to migrate downward to the sand and gravel aquifer. Chlorinated solvents, for example, have a relatively high specific density and likely would migrate downward regardless of an upward hydraulic gradient (depending on the magnitude of the upward hydraulic gradient). In general, industrial facilities have decreased their use of chlorinated solvents; however, discovery of chlorinated solvent groundwater plumes from historic releases are not uncommon occurrences in industrial areas. With that said, a future release of dense solvents, of sufficient volume at the surface, could affect the sand and gravel aquifer at depth in time. With pumping at the wellfield (20 mgd peaking), the potentiometric surface of the deeper aquifer also would reduce the overall vertical gradient. In summary, it is our opinion that the overlying sediments are not an impervious barrier to the potential migration of contaminants downward to the deeper sand and gravel aquifer. A release of solvents or similar dense contaminants at the surface would not result in an immediate impact to the deeper aquifer, but in time it could affect the sand and gravel aquifer, assuming the release (1) consists of denser than

water contaminants, (2) is of sufficient quantity, and (3) is not immediately remediated at the spill site.

To illustrate the area of influence for the proposed 20-mgd Mint Farm wellfield, a simplified two-dimensional groundwater analytical model of the wellfield was developed using WinFlow® by Environmental Simulation. Figures 7 and 8 present capture zone models for the proposed wellfield. The difference between the size and shape of the two capture zone models is based on the groundwater gradient (slope of the groundwater table toward the river), which can vary depending on the seasonal stage of the Columbia River. In addition, water level data for the wells used are not surveyed, which added uncertainty to the groundwater gradient and further supported modeling with two gradients. These capture zones also show the potential time it would take for a particle of water to travel to the wellfield. The Washington wellhead protection program requires that the 1-, 5- and 10-year time-of-travel zones be defined around a municipal groundwater source. Overall, the capture zones identify the area that would contribute water to the wells. It is important, however, to point out that this is a simplified model and does not take into account other stresses related to pumping of nearby wells (e.g., Chinook Ventures and/or Weyerhaeuser) or other hydrogeologic complexities, such as changes in the aquifer's lateral permeability. As such, if a wellhead protection plan were developed for the wellfield it may be advantageous to develop a groundwater model that is able to take into account other changes in hydrogeologic conditions related to time and space.

Within the capture zone, some key industries stand out:

1. ***Chinook Ventures and Alcoa.*** Ecology recently issued a cleanup order for this site. The order requested Chinook Ventures and Alcoa to complete a remedial investigation and feasibility study to address soil and groundwater contamination. The site historically has been an aluminum smelting and casting facility. Data show groundwater is contaminated with fluoride and cyanide.

2. ***Prudential Steel and Flexible Foam.*** Prudential Steel, a steel tubular manufacturing and distribution facility that was owned by the Canadian firm Maverick Tub Corporation, previously occupied the site. The plant was a RCRA large-quantity generator (1,000 kilograms or more of hazardous waste per month). The nature of the waste is unknown at this time, and we are unsure if the fabrication facility used any solvents. Prudential Steel was shut down in 2001, and subsequently the site was taken over by Flexible Foam, which makes foam products for a variety of commercial applications. The type and quantities of chemicals used at the plant are unknown, however, the air discharge permit lists VOCs. We are unsure if there is a connection between the air emission of VOCs and the use of these chemicals in raw form in the plant.

3. ***Longview Auto Wrecking.*** This site has been listed by Ecology with confirmed releases of petroleum products (which will not sink in groundwater).

4. ***Weyerhaeuser CO HG Chlor Alk Site (No. 6).*** This site is listed by Ecology and is under an independent cleanup action. Confirmed releases of metals and cyanide are reported in the EDR report for this site.

5. ***Toyocom Devices of America, Inc.*** Information for this site was obtained from an Ecology fact sheet on Toyocom's state waste discharge permit. Toyocom makes synthetic quartz crystals for the electronics industry on an 8.5-acre site at the Mint Farm Industrial Park. The crystal growing process uses natural quartz as seed crystals and a 4 percent solution of sodium hydroxide/lithium hydroxide solution. These components are heated and pressurized in an autoclave for a 3-month period. The new crystals are rinsed and the remaining sodium hydroxide solution is neutralized and pre-treated before discharge to the City's wastewater system. Ecology determined that this facility stores chemicals that have the potential to cause water pollution if released; therefore, the facility has developed a spill plan to prevent accidental release. A preliminary review of Ecology's Web site indicated that a contaminant release has not been reported for the site.

Other facilities in the Mint Farm Industrial Park area include Solvay Interox, JM Huber Chemical Division, and Oljuni LLC. This short list is not an exhaustive review of the past environmental practices in the area that may pose a risk to the proposed wellfield. We understand that the City plans to complete a more detailed environmental due diligence audit of the Mint Farm area that will focus on areas within the capture zone developed as part of this investigation.

Wellfield Siting Summary

Concerns about siting the City's sole drinking water source in a wellfield that is within a known historical industrial area are well founded, but not insurmountable. It is not clear from reviewed data whether contamination occurred in the past or if the deeper aquifer has been affected. Likewise, there are definite hurdles to developing a wellhead protection plan and managing that plan in an industrial area, not to mention public perception of siting a wellfield within an industrial area. However, many cities manage these hurdles and risks. For example, the City of Portland's backup groundwater wellfield is located in an industrial part of the city and known contamination has been detected in the wellfield. In summary, if the City decides to develop the Mint Farm groundwater wellfield, the following recommendations, at a minimum, are made:

1. Complete a due diligence of past environmental practices in the area to attempt to define the nature and extent of groundwater contamination in the capture zone of the proposed Mint Farm wellfield and determine whether known contamination poses a significant risk to the proposed groundwater wellfield. Determine if there was a past release of contaminants, especially chlorinated solvents, and how much was released.

2. Develop a wellhead protection program (as required by Ecology) that balances the need to protect the City's wellfield investment, but at the same time does not overtly impair economic growth in the Mint Farm area. This effort might include developing a more accurate groundwater model of the area with defined capture zones. More importantly, the wellhead protection program would need to have an outreach program; community participation and the key to its success would be buy-in and cooperation from industry in the area.

3. Assuming no real significant risks are found during the contaminant source inventory, install a network of shallow and deep monitoring wells that are routinely monitored by the City to act as an early warning system in event a release occurs that is not otherwise detected.

4. Develop an emergency cleanup plan in the event of a future release in the capture zone and make sure existing industries as well as future industries are part of the plan. This plan would include routinely sampling/monitoring strategically installed and located sentinel wells to detect a release before it affected the wellfield.

5. As a final backup, develop a plan to bring online a wellhead remediation system in the event the deeper aquifer is unexpectedly affected with contaminants. For example, the design of the wellfield and treatment plant should include a footprint for a future treatment system. A funding mechanism for the build-out of a future treatment system (e.g., air stripping) also should be considered.

Alternative Option Analysis

In addition to reviewing the feasibility of developing a wellfield in the Mint Farm area, GSI, at the City's request, also took a brief look at other alternative water supply options (see Table 2). Each of these options assumes that a new water treatment plant would be constructed, so each focuses on the water source. The following matrix presents the options, with some of the obvious pros and cons for each option. A discussion of the Collector Well Option, which may not have been presented previously, is discussed in more detail below.

Collector Well

As an alternative to conventional vertical wells, a radial collector well consists of a large-diameter caisson (vertical reinforced concrete shaft) with horizontal lateral well screens projecting out into the aquifer (often beneath a river) to collect and pre-filter the groundwater (see Figure 9). Typically installed in transmissive shallow alluvial aquifers (much like what is present in Rainier) in close proximity to a dependable water source (Columbia River), these wells take advantage of the natural filtering process and sometimes are referred to as riverbank filtration (RBF) systems. The pre-treatment by natural filtration can help to simplify the final treatment process. These systems are under the direct influence of surface water and must meet Ecology treatment goals for groundwater under the direct influence of surface water. The City of St. Helens and the Port of St. Helens each have collector wells; the Port of Kalama has studied the feasibility of a collector well with favorable results.

Table 2. Source Water Option Analysis
City of Longview

Option	Pros	Cons
Mint Farm Wellfield	• Aquifer is suitable for 20-mgd system. • Iron and manganese present, but based on testing, better than other wells and treatable. • Water supply system in one area. • Permitting issues would be fairly straightforward.	• Past contamination unknown. • Challenges to manage a wellhead protection program in a growing industrial area. • Wellfield vulnerable to future releases. Single source issue. • Potential negative public perception related to developing a municipal wellfield in an industrial area.
New Cowlitz River Intake	• City and customers comfortable with source. • Improved raw water quality with new intake. • Contaminants usually pass quickly.	• Cowlitz River would continue to plague treatment plant with sediment, silt, and highly turbid water. • Single source issue. • Likely would be required to meet fish protection regulations. • Reduced future flows of river could affect intake and/or supply.
Columbia River Intake	• Less vulnerability to low river flows during peak times. • Columbia River water may be less turbid and have less sediment loading than water from the Cowlitz River. • Contaminants usually pass quickly.	• Public perception that Columbia River is contaminated. • Single source issue • Would have to permit and construct river intake and would be required to meet fish protection regulations. • Would have to obtain a new surface water right (possibly could transfer existing Cowlitz River rights to Columbia River).

Option	Pros	Cons
Collector Well (Washington)	The sand and gravel aquifer present along the Columbia River in the Longview area, based on available data, is too deep for a collector well (more than 150 feet below ground surface) and possibly these sands and gravels may not be **directly** connected to the river. We understand the sediments along the Cowlitz River are poorly sorted, variable, and less productive, and, for these reasons, we understand that collector wells are not feasible. City staff members confirmed that they have discussed a collector well idea along the Cowlitz River with Collector Wells International, and Ranney Method Western Corporation did a study in 1977 (GSI was unable to review this report).	
Collector Well (Oregon)	• Collector well alleviates developing a wellfield in an industrial area. • Aquifer appears suitable, but more work needed. • Current water right on Cowlitz River can be preserved or traded for in-stream credits. • Collector wells along Columbia River have been successful, albeit, treatment for iron and manganese necessary, but technically achievable.	• Collector well produces from a shallow aquifer, thus zone of protection still would be required. • The City would need jurisdictional control assistance for a collector well in Oregon, which would require cooperation from the City of Rainier. • Single source issue. • May have higher iron and manganese (Port of Kelso issue) than Mint Farm wells. • Perception of Columbia River water quality and vulnerability. • Water right obtainable, but will require more work. • Longer pipeline route/expense and coordination needed with Washington and Oregon Departments of Transportation for bridge crossing. Bridge may not be able to support the load of a two 24-inch water lines for 20 mgd. Water lines for 10 mgd may be feasible, but would require additional engineering analysis, according to the Washington Department of Transportation. • Vulnerable if bridge fails – earthquake/barge damage. • Two locations of operation raise operational issues and costs.

Option	Pros	Cons
		Boring a pipeline under the Columbia River is very expensive ($8 million).
Collector Well (Oregon with Wellfield Development)	• Same advantages as Collector Well (Oregon), and: • Wells would provide peaking capacity and emergency backup if the transmission main failed on the bridge. • Perception of only one source vulnerability reduced.	• Same disadvantages as Collector Well (Oregon) and: • Two systems would have to be maintained – collector well and groundwater well system. • Again the bridge may not be able to support even one 24-inch pipe line. • Boring beneath the Columbia River is very expensive ($8 million or more).

Summary

Based on data reviewed for the Weber Avenue well it is our opinion that the target sand and gravel aquifer should easily meet the production capacity goal of 20 mgd. This assumes that the production wells for the Mint Farm wellfield are properly designed and constructed. Limited interference between wells hosted in a wellfield in the Mint Farm area would not reduce the overall wellfield's capacity goal. Six production wells would meet the 20-mgd capacity goal, with one well providing redundancy. Native groundwater quality exceeds the SMCLs for iron and manganese, and arsenic was detected at a concentration slightly greater than the federal MCL. Iron, manganese, and arsenic levels can be reduced with a combination of filtration and oxidation, which is the City's preferred treatment alternative for a new supply source. Obtaining new groundwater rights for the Mint Farm wellfield, we understand, is not a fatal flaw for the wellfield project.

The key issue surrounding the Mint Farm wellfield is its siting in a known industrial area of the City. Past environmental practices need to be clearly understood, based on best available data, to assess if a risk currently is unacceptable for siting the wellfield in the Mint Farm area. In addition, assuming the wellfield is developed, a wellhead protection program that includes the cooperation of local and future industries needs to be implemented. A long-term monitoring program using sentinel wells would need to be part of the routine operation of the wellfield. Besides overcoming the public perception of siting a municipal wellfield in an industrial area, the challenge also would be to provide institutional controls in the City's wellhead protection program that balance protecting the wellfield and the City's investment while at the same time not impairing economic growth in the immediate area.

The City is fortunate in that it has multiple options to develop a new water supply source for its customers that include the Cowlitz River, the Columbia River, the Mint Farm native groundwater wellfield, and a collector well along the Columbia River.

Many communities throughout the Northwest have far fewer options to meet their current and future water supply demands. However, with that said, each of these options has pros and cons, and each of these options would be costly to develop. The following is a brief summary of the options, as outlined in this memorandum:

- **Mint Farm Wellfield**: The proposed wellfield easily can supply the City with the target goal of 20 mgd, but managing the potential environmental risks of this site would be challenging.
- **New Cowlitz River Intake:** Although this option is familiar to the City, it most likely would be plagued with sedimentation and turbidity issues in the future, similar to the issues the City has with the current intake.
- **Columbia River Intake:** This option may be pretty straightforward, but would be a challenge from a public relations perception because many individuals believe the Columbia River is or will become polluted.
- **Collector Well (Oregon):** Assuming the collector well option is feasible, this option would require the City to site the water supply system on the Oregon side of the Columbia River, which poses jurisdictional issues and operational challenges. Water conveyance piping would need to be installed across the Columbia River. Boring a pipeline beneath the river is very expensive ($8 million). Alternatively, the Lewis and Clark Bridge could be used to support the pipeline. Water supply at 20 mgd probably would not be feasible because of load issues. However, pipeline loads associated with 10 mgd may be feasible, depending on the results of an engineering analysis.
- **Collector Well (Oregon) with Wellfield Development:** This combined option, which includes developing a limited wellfield in the Mint Farm area, provides redundancy and emergency supply if the main water line is disrupted. However, this option would increase development costs and would not alleviate all of the hurdles outlined for the Collector Well (Oregon) option.

Please do not hesitate to call us at 503-239-8799 with questions about this memorandum.

Sincerely,

for

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GSI Water Solutions, Inc.

Ken Trotman, LHG, RG
GSI Water Solutions, Inc.

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Table 1.
Water Qyality Data
Mint Farm Wellfield Project
City of Longview

Class	Analyte	Unit	Regulatory Criteria	Regulatory Standard	Kelso Test Well[1] 6/17/1999	Kelso Test Well[1] 10/11/1999	Well 4 Sample #1[2] 5/31/2001	Well 4 Sample #2[2] 6/1/2001	Well 4 Sample #3[2] 6/1/2001	Well 1[2] 6/1/2001	Well 2 Mint Farm[3] 4/25/2002	Weber Ave Test Well[4] 1/19/2007
Field Parameter												
	pH	pH	SMCL	6.5-8.5	6.7	7.2	NA	NA	NA	NA	7.62	NA
	Conductivity	µs/cm		None	639	475	390	401	405	557	NA	295
	Temperature	degC		None	NA	NA	NA	NA	NA	NA	19.5	NA
	Turbidity	NTU	MCL	1	190	190	140	140	150	40	1	3.8
Geochemistry												
	Bicarbonate(as CaCO3)	mg/L		None	364	344	NA	NA	NA	NA	NA	NA
	Calcium	mg/L		None	84	83	NA	NA	NA	NA	22.4	31.2
	Carbonate	mg/L		None	0	0	NA	NA	NA	NA	NA	NA
	Carbon Dioxide	mg/L		None	NA	NA	NA	NA	NA	NA	95	NA
	Chloride	mg/L	SMCL	250	4	3	5	5	5	28	6	10.6
	Hardness	mg/L	SMCL	250	304	300	164	168	184	224	NA	116
	Magnesium	mg/L		None	23	22	NA	NA	NA	NA	6.39	8.9
	Nitrate-N	mg/L	MCL	10	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.1 U	0.1 U
	Nitrite-N	mg/L	MCL	1	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	NA	0.1 U
	Total Nitrate/Nitrite	mg/L	MCL	10	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	0.1 U
	Potassium	mg/L		None	4.7	5.4	NA	NA	NA	NA	3.8	4.73
	Silica	mg/L		None	64	90	NA	NA	NA	NA	119	NA
	Sodium	mg/L	RL	20	20	20	13	14	14	22	7.2	14.5
	Sulfate	mg/L	SMCL	250	1 U	1 U	1 U	1	3	1 U	10 U	0.2 U
	Total Alkalinity	mg/L		None	NA	NA	NA	NA	NA	NA	103	NA
	Total Dissolved Solids	mg/L	SMCL	500	335	381	231	243	245	317	170	182
	Total Organic Carbon	mg/L		None	NA	NA	NA	NA	NA	NA	1.2	NA
	Total Suspended Solids	mg/L		None	NA	NA	NA	NA	NA	NA	4 U	NA
Metals and Trace elements												
	Aluminum	mg/L	SMCL	0.05-0.2	NA	NA	NA	NA	NA	NA	NA	0.0133
	Antimony	mg/L	MCL	0.006	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	NA	0.00005 U
	Arsenic	mg/L	MTCA	0.005	*0.01* U	0.017	*0.01* U	0.01	0.01	0.01	NA	0.0132
	Barium	mg/L	MCL	2	0.1 U	0.1 U	0.1 U	0.1	0.1	0.1	0.014	0.0284
	Beryllium	mg/L	MCL	0.004	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	NA	0.00002 U
	Boron	mg/L		None	NA	NA	NA	NA	NA	NA	NA	0.05 U
	Cadmium	mg/L	MCL, MTCA	0.005	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	NA	0.00005 U
	Chromium	mg/L	MTCA	0.05	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	NA	0.0003
	Cobalt	mg/L		None	NA	NA	NA	NA	NA	NA	NA	0.00024
	Copper	mg/L	AL	1.3	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	NA	0.01 U
	Iron	mg/L	SMCL	0.3	16.7	12.3	16.6	18.2	19.2	4.23	0.551	0.97
	Lead	mg/L	AL, MTCA	0.015	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	NA	0.00057
	Manganese	mg/L	SMCL	0.05	1.5	1.29	1.51	1.58	1.65	1.36	0.372	0.622
	Mercury	mg/L	MCL, MTCA	0.002	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	NA	0.0002 U
	Molybdenum	mg/L		None	NA	NA	NA	NA	NA	NA	NA	0.00133
	Nickel	mg/L	MCL	0.1	0.04 U	0.04 U	0.01 U	0.04 U	0.04 U	0.04 U	NA	0.0021
	Selenium	mg/L	MCL	0.05	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	NA	0.001 U
	Silver	mg/L	SMCL	0.1	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	NA	0.00002 U
	Strontium	mg/L		None	NA	NA	NA	NA	NA	NA	NA	0.14
	Thallium	mg/L	MCL	0.002	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U	NA	0.00002 U
	Tin	mg/L		None	NA	NA	NA	NA	NA	NA	NA	0.0001 U
	Vanadium	mg/L		None	NA	NA	NA	NA	NA	NA	NA	0.0004
	Zinc	mg/L	SMCL	5	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	NA	0.0142
Miscellaneous												
	Color	ACU	SMCL	15	20	150	5 U	5	5	5 U	5 U	5 U
	Cyanide	mg/L	MCL	0.2	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	NA	0.00001 U
	Flouride	mg/L	MCL	4	0.3	0.2	0.2	0.2	0.2 U	0.3	NA	0.0002 U
	Orthophosphate	mg/L		None	NA	NA	NA	NA	NA	NA	NA	0.3
	Reactive Silica	mg/L		None	NA	NA	NA	NA	NA	NA	53.8	NA
	Total Phosporus	mg/L		None	NA	NA	NA	NA	NA	NA	0.627	NA
Volatile Organic Compounds												
	1,1,1,2-Tetrachloroethane	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	1,1,1-Trichloroethane	µg/L	MCL, MTCA	200	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	1,1,2,2-Tetrachloroethane	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	1,1,2-Trichloroethane	µg/L	MCL	5	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	1,1-Dichloroethane	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	1,1-Dichloroethene	µg/L		None	NA	NA	NA	NA	NA	NA	NA	0.5 U
	1,1-Dichloroethylene	µg/L	MCL	7	0.5 U	NA	NA	NA	0.5 U	NA	NA	NA
	1,1-Dichloropropene	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	1,2,3-Trichlorobenzene	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	1,2,3-Trichloropropane	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	1,2,4-Trichlorobenzene	µg/L	MCL	70	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	1,2,4-Trimethylbenzene	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	1,2-Dichlorobenzene	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	1,2-Dichloroethane	µg/L	MCL, MTCA	5	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	1,2-Dichloropropane	µg/L	MCL	5	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	1,3,5 Trimethylbenzene	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	1,3-Dichlorobenzene	µg/L		None	NA	NA	NA	NA	NA	NA	NA	0.5 U
	1,3-Dichloropropane	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	1,3-Dichloropropene	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	NA
	1,4-Dichlorobenzene	µg/L	MCL	75	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	2,2-Dichloropropane	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	2-Chlorotoluene	µg/L		None	NA	NA	NA	NA	NA	NA	NA	0.5 U
	4-Chlorotoluene	µg/L		None	NA	NA	NA	NA	NA	NA	NA	0.5 U
	Benzene	µg/L	MCL, MTCA	5	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	Bromobenzene	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	Bromochloromethane	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	Bromodichloromethane	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	Bromoform	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	Bromomethane	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	Carbon Tetrachloride	µg/L	MCL	5	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	Chlorobenzene	µg/L	MCL	100	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	Chloroethane	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	Chloroform	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	Chloromethane	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	cis-1,2-Dichloroethylene	µg/L	MCL	70	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	cis-1,3-Dichloropropene	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	DBCP	µg/L	MCL	0.2	*0.5* U	NA	NA	NA	*0.5* U	NA	NA	*0.5* U
	Dibromochloromethane	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	Dibromomethane	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	Dichlorobenzene	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	NA
	Dichlorodifluoromethane	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	EDB	µg/L	MTCA	0.01	*0.5* U	NA	NA	NA	*0.5* U	NA	NA	*0.5* U
	Ethylbenzene	µg/L	MCL, MTCA	700	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	Hexachlorobutadiene	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	Isopropylbenzene	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	M,P Xylenes	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	M-Dichlorobenzene	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	NA
	Methylene Chloride	µg/L	MTCA	5	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	MTBE	µg/L	MTCA	20	NA	NA	NA	NA	0.5 U	NA	NA	0.5 U
	Naphthalene	µg/L	MTCA	160	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	N-Bulylbenzene	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	N-Propylbenzene	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	O-Chlorotoluene	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	NA
	O-Xylene	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	P-Chlorotoluene	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	NA
	P-Isopropyltoluene	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	Sec-Butylbenzene	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	Styrene	µg/L	MCL	100	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	tert-Butylbenzene	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	Tetrachloroethylene	µg/L	MCL, MTCA	5	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	Toluene	µg/L	MCL, MTCA	1000	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	Total Xylens	µg/L	MTCA	1000	0.5 U	NA	NA	NA	0.5 U	NA	NA	NA
	trans-1,2-Dichloroethylene	µg/L	MCL	100	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	trans-1,3-Dichloropropene	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	Trichloroethene	µg/L		None	NA	NA	NA	NA	NA	NA	NA	0.5 U
	Trichloroethylene	µg/L	MCL, MTCA	5	0.5 U	NA	NA	NA	0.5 U	NA	NA	NA
	Trichlorofluoromethane	µg/L		None	0.5 U	NA	NA	NA	0.5 U	NA	NA	0.5 U
	Vinyl Chloride	µg/L	MTCA	0.2	*0.5* U	NA	NA	NA	*0.5* U	NA	NA	*0.5* U

Notes;

[1] Data Source; City of Kelso Test Well Drilling and Construction, November 2000, Robinson & Noble, Inc.
[2] Data Source; Port of Longview Industrial Park Well 4 Construction and Testing, June 2001, Robinson & Noble, Inc.
[3] Data Source; Construction and Testing; Mint Farm Generation Station Well 2 Longview, Washington, June 28 2002, Robinson & Noble, Inc.
[4] Data Source; Draft Construction and Testing Report Weber Avenue Monitoring Well Longview, Washington, January 2007
AL = EPA Action Level.
MCL = Maximum Contaminant Level.
NA = Not Analyzed.
RL = EPA Recommended Level.
SMCL = Secondary Maximum Contaminant Level.
U = Analyte not detected at indicated detection limit.
ug/Kg = Micrograms per kilogram.
mg/Kg = Milligrams per kilogram.
bold = concentration exceeds regulatory.
Italic = laboratory reporting limit exceeds regulatory.

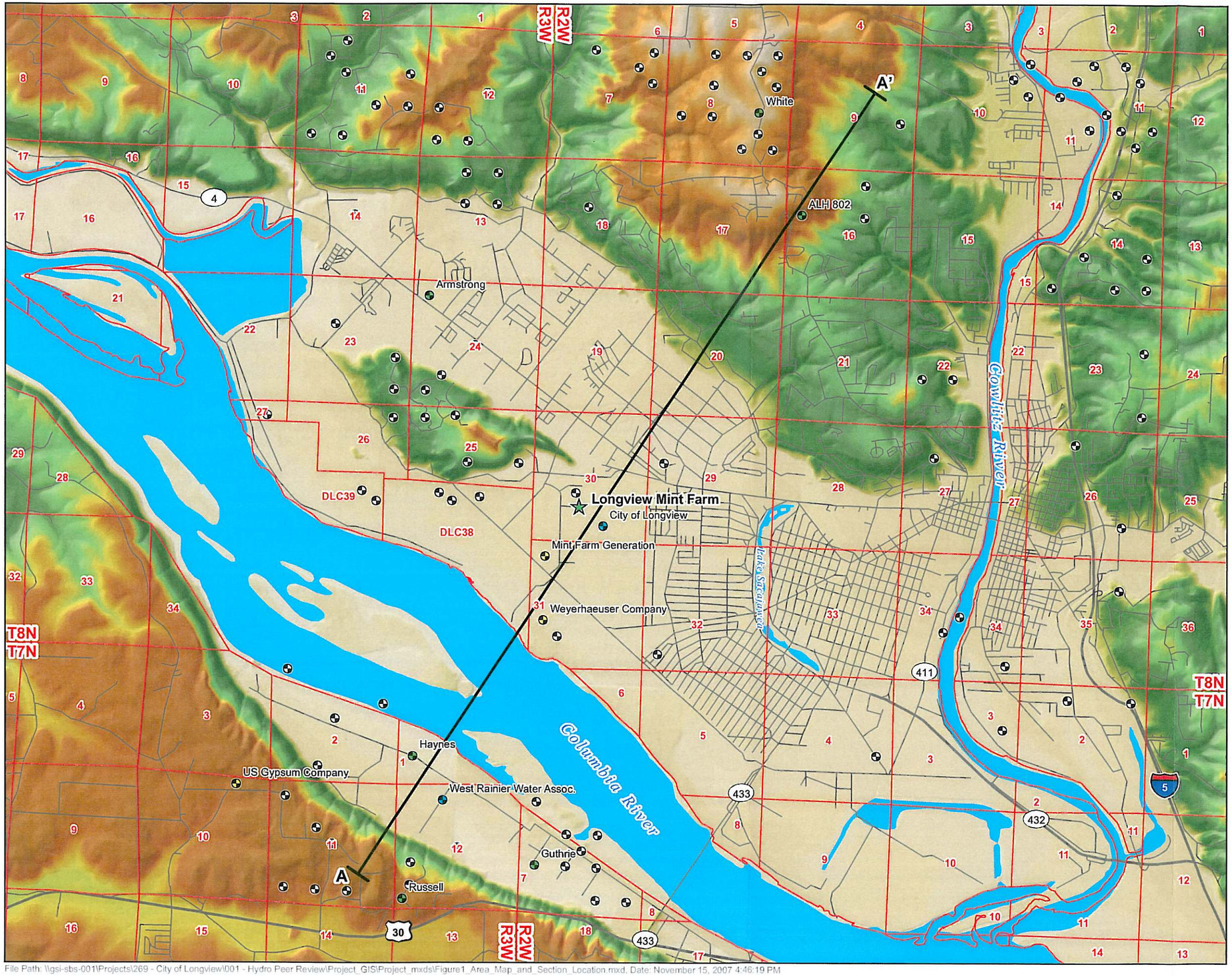

FIGURE 1

Area Map and Section Location

City of Longview

LEGEND

- Geologic Cross Section
- Longview Mint Farm

Existing Water Wells

- Domestic Well
- Industrial Well
- Municipal Well
- Other Water Well
- Freeways and Highways
- Roads
- Waterbodies

Elevation

High : 1350 ft

Low : 0 ft

N

Scale

1:48,000

0 2000 4000 6000 8000

Feet

MAP NOTES:

Projection: Washington State Plane South Zone
Datum: North American Datum of 1983
Date: November 15, 2007
Data Sources: EDR, ESRI, USGS, Washington Department of Ecology

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A
Southwest

A'
Northeast

Looking Northwest

US Gypsum
Russell

DTW = 137' bgs on 3/12/01

Basalt

TD = 342 ft
Q = 7.7 gpm
SC = 0.037 gpm/ft

TD = 602 ft

West Rainier Water Association

DTW = 1' bgs on 3/22/86

TD = 130 ft
Q = 100 gpm

Haynes

DTW = 1' bgs on 7/7/97

TD = 79 ft
Q = 100 gpm
SC = 1.35 gpm/ft

Columbia River
Stage = 3.3 ft amsl

Weyerhauser

DTW = 20' bgs on 3/8/74

Silt with Clay

TD = 202 ft
Q > 650 gpm
SC = 282 gpm/ft

Mint Farm

DTW = 0.7' bgs on 4/24/02

Gravel

TD = 352 ft
Q > 1,400 gpm
SC = 242 gpm/ft

City of Longview

DTW = +1' ags on 1/5/07

Sandy Silt

TD = 397 ft

Armstrong

DTW = 4' bgs on 10/31/03

TD = 170 ft
Q > 50 gpm
SC > 1.7 gpm/ft

Shale and Sandstone

Shale and Siltstone
Bedrock

Buck

DTW = 69.7' bgs on 2/7/07

TD = 181 ft
Q = 10 gpm

Clay

White

DTW = 90' bgs on 6/19/86

TD = 402 ft
Q = 5.7 gpm
SC = 0.02 gpm/ft

Elevation (ft amsl)

800
600
400
200
0
-200
-400
-600
-800

0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
16,000
18,000
20,000
22,000
24,000
26,000
28,000
30,000
32,000
34,000
36,000
38,000

Distance from A (ft)

LEGEND

- Perforated Interval
- Screened Interval
- Static Water Level (and date)

TD = Total depth
DTW = Depth to water
gpm = Gallons per minute
SC = Specific Capacity
ft asl = Feet above sea level
bgs = Below ground surface
ags = Above ground surface

- Clay
- Silt with Clay
- Sandy Silt
- Gravel
- Basalt
- Shale and Siltstone/Sandstone Bedrock

200 ft
0
2,000 ft

Vertical Exaggeration = 10x

GSI Water Solutions, Inc.

Figure 2
Geologic Cross Section
City of Longview

Mint Farm Wellfield Project
City of Longview

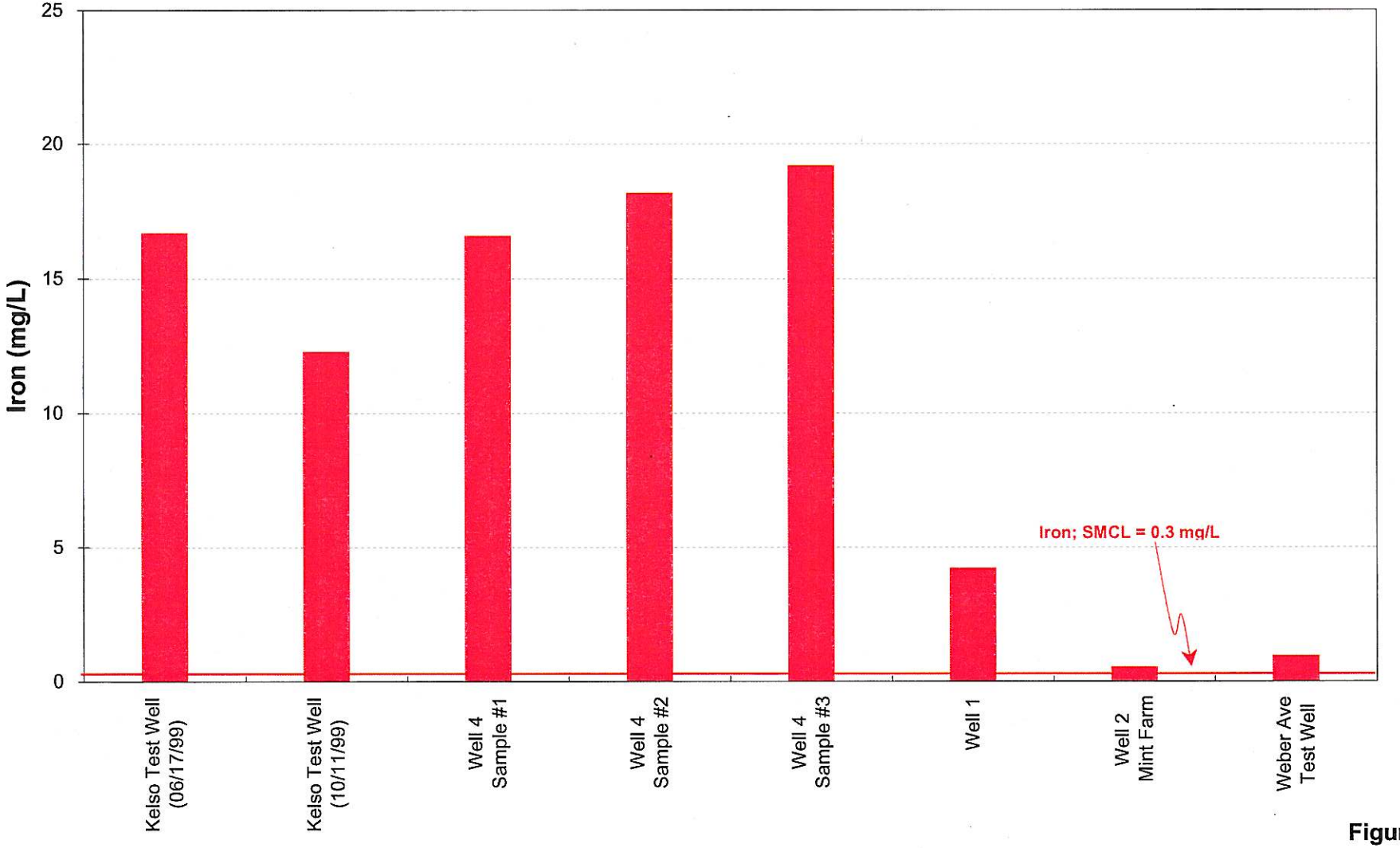

Figure 3
Groundwater Chemistry
Iron
City of Longview

Water quality data_edit.xlsWater quality data_edit.xls

Mint Farm Wellfield Project
City of Longview

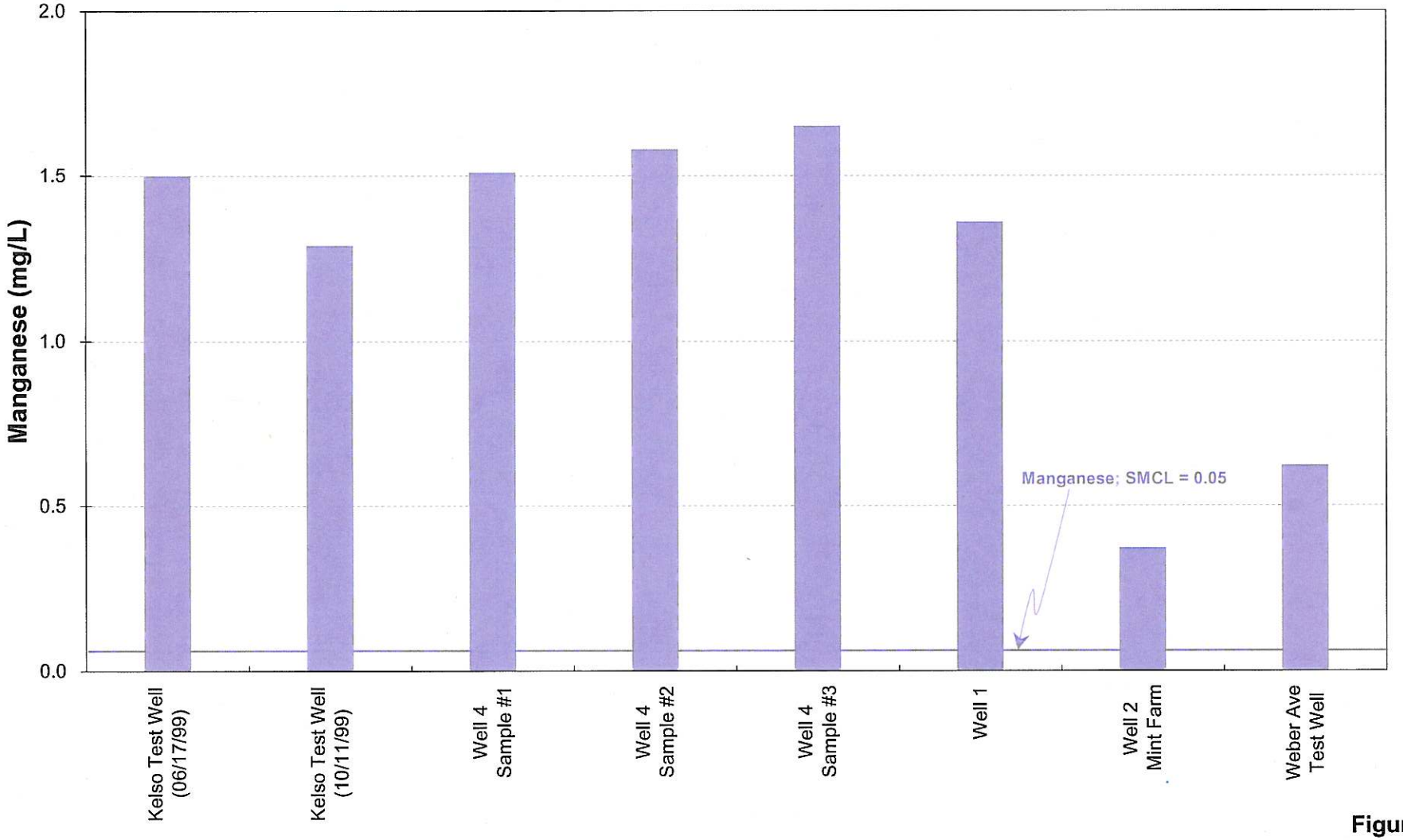

Figure 4
Groundwater Chemistry
Manganese
City of Longview

Water quality data_edit.xlsWater quality data_edit.xls

Mint Farm Wellfield Project
City of Longview

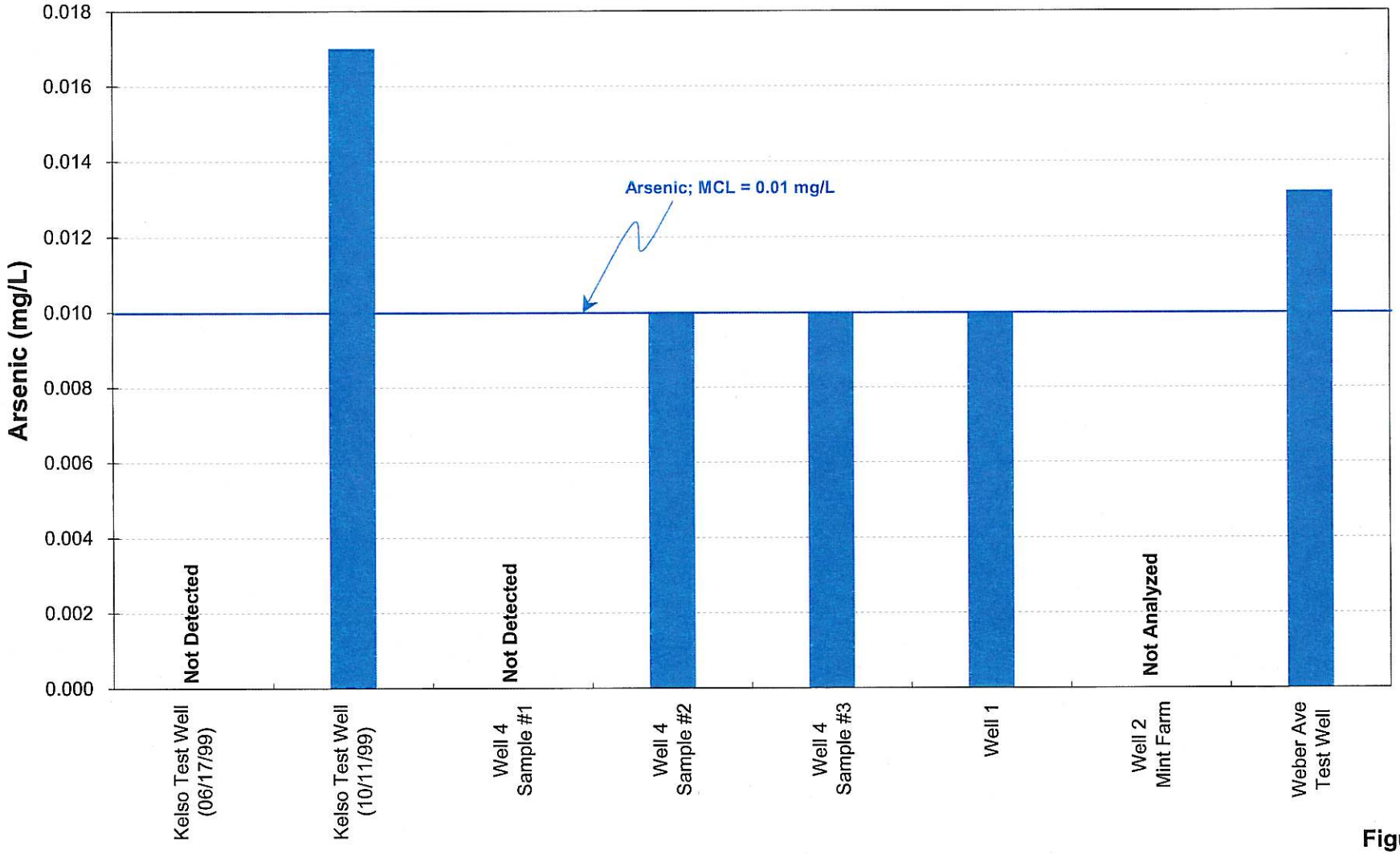

Figure 5
Groundwater Chemistry
Arsenic
City of Longview

Water quality data_edit.xlsWater quality data_edit.xls

FIGURE 6

Potentially Contaminated Sites

City of Longview

LEGEND

- Longview Mint Farm
- EDR Data Locations
- Tax Lots
- Highways and Roads
- Waterbodies

N

Scale
1:15,840

0 0.125 0.25 0.375 0.5
Miles

MAP NOTES:
Projection: Washington State Plane South Zone
Datum: North American Datum of 1983
Date: November 14, 2007
Data Sources: EDR, City of Longview, Aerial photo taken in July of 2006 by USDA

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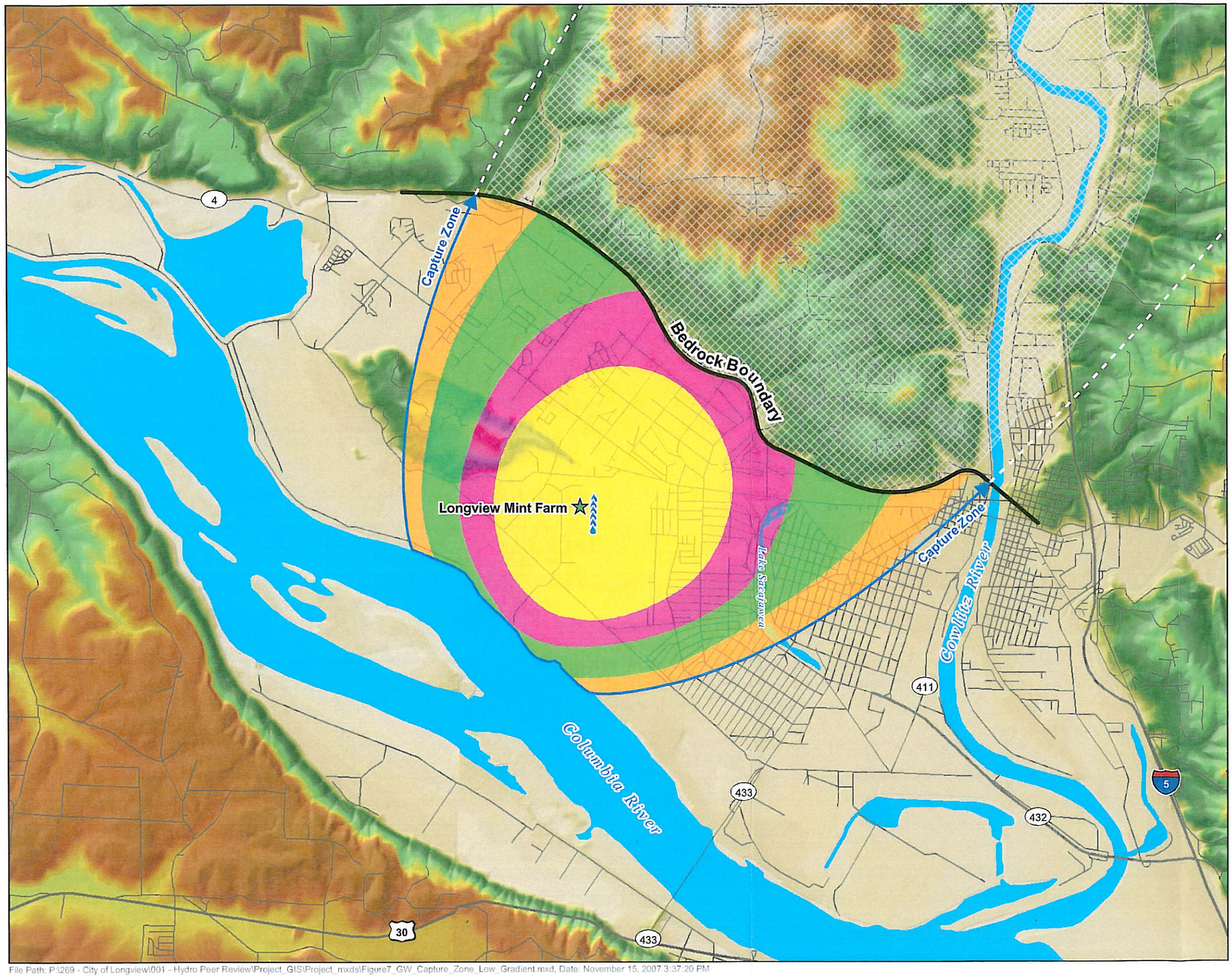

FIGURE 7

Estimated Capture Zone and Time of Travel (gradient = 0.0005)

City of Longview

LEGEND

Particle Time of Travel

- 10 year
- 5 year
- 2 year
- 1 year
- Bedrock
- Proposed Wells
- Longview Mint Farm
- Freeways and Highways
- Roads
- Waterbodies

Elevation

- High : 1350 ft
- Low : 0 ft

N

Scale
1:48,000

0 2000 4000 6000 8000
Feet

MAP NOTES:
Projection: Washington State Plane South Zone
Datum: North American Datum of 1983
Date: November 15, 2007
Data Sources: EDR, ESRI, USGS, City of Longview

GSI Water Solutions, Inc.

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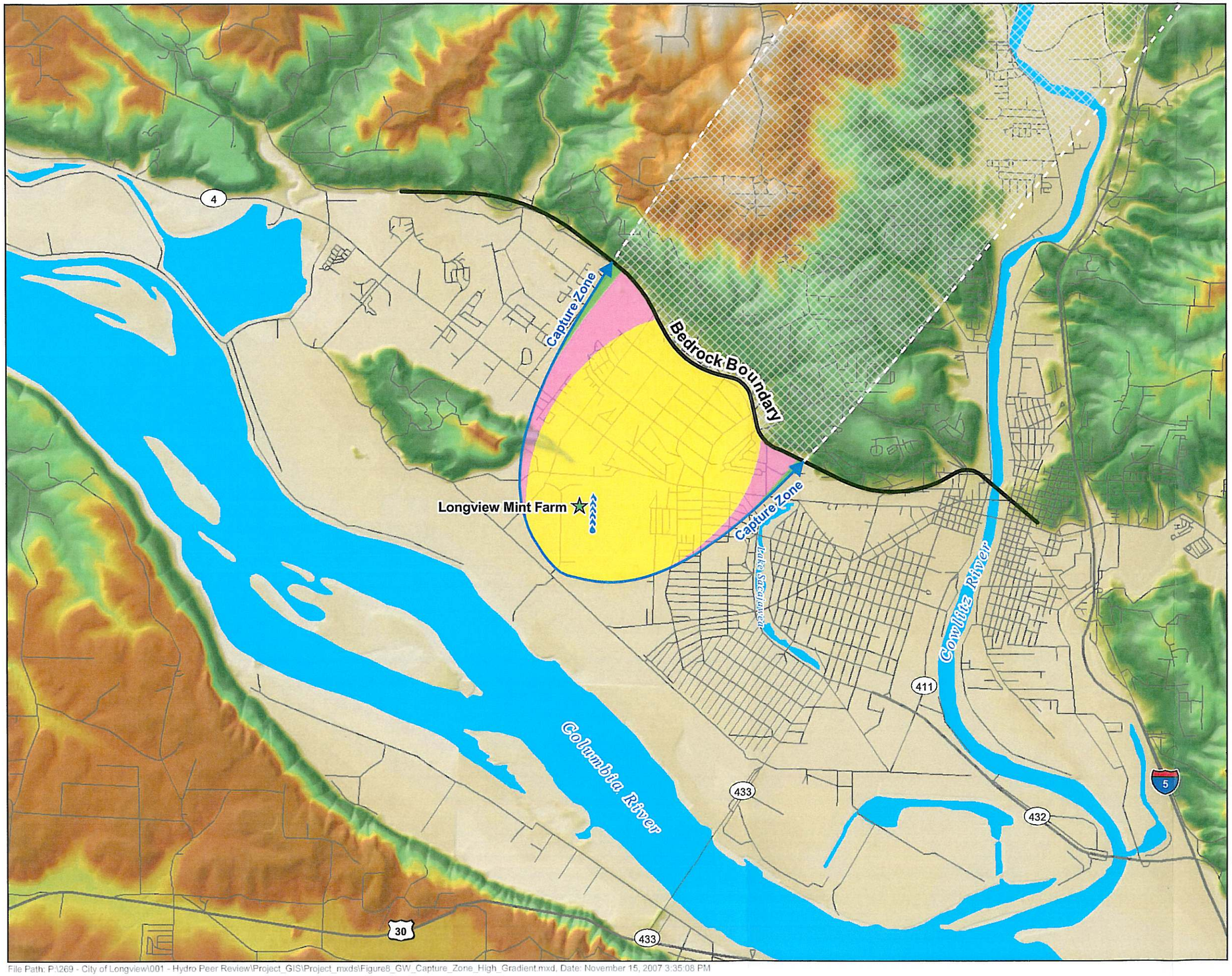


FIGURE 8

Estimated Capture Zone and Time of Travel (gradient = 0.0013)

City of Longview

LEGEND

Particle Time of Travel

- 5 year
- 2 year
- 1 year
- Bedrock
- Proposed Wells
- Longview Mint Farm
- Freeways and Highways
- Roads
- Waterbodies

Elevation

- High : 1350 ft
- Low : 0 ft

N

Scale

1:48,000

0 2000 4000 6000 8000

Feet

MAP NOTES:

Projection: Washington State Plane South Zone
Datum: North American Datum of 1983
Date: November 15, 2007
Data Sources: EDR, ESRI, USGS, City of Longview

GSI Water Solutions, Inc.

File Path: P:\269 - City of Longview\001 - Hydro Peer Review\Project_GIS\Project_mxds\Figure8_GW_Capture_Zone_High_Gradient.mxd, Date: November 15, 2007 3:35:08 PM

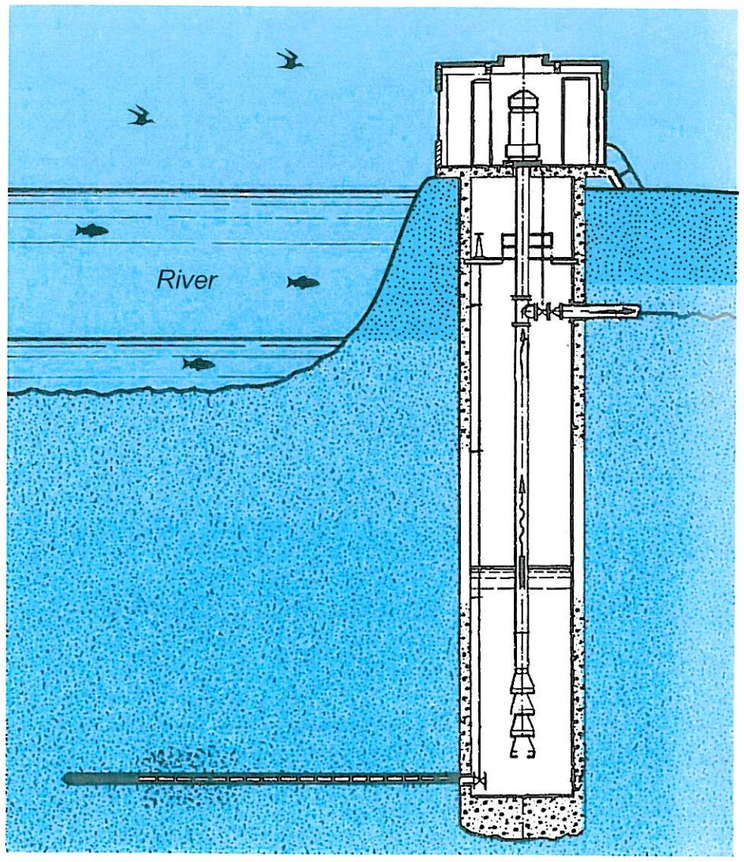
FIGURE 9

Typical Collector Well System

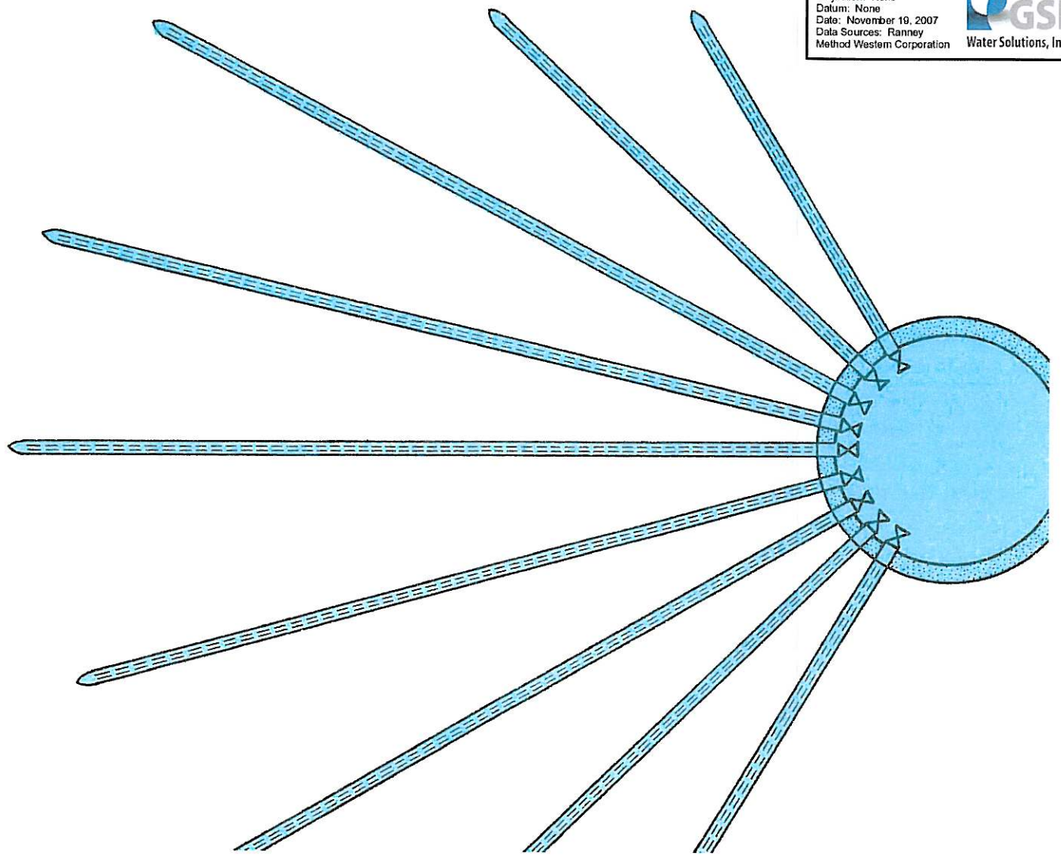
City of Longview

MAP NOTES:
Projection: None
Datum: None
Date: November 19, 2007
Data Sources: Ranney Method Western Corporation

GSI Water Solutions, Inc.



PROFILE



PLAN

Ref: "Supplying Water for Municipal and Industrial Use" brochure, Ranney Method Western Corporation