

**DRAFT MEMO**

DATE: March 1, 2010

TO: Glenn Boettcher, Maintenance Director, City of Mercer Island

FROM: Kathy Goetz Troost, LG, University of Washington; Burt Clothier, LHG, Robinson, Noble & Saltbush, Inc.; Greg Hill, PE, Roth Hill LLC

**RE: SEISMIC STABILITY/VULNERABILITY OF NEW GROUNDWATER WELL, MERCER ISLAND**

This memo summarizes the most important factors related to the seismic stability and vulnerability of the new groundwater well and pump system (well system) in the City of Mercer Island (City). This memo was prepared in response to a request from Mr. Glenn Boettcher of the City.

The well system was over-designed with respect to seismic hazards with the knowledge that these components need to withstand a Seattle fault earthquake and provide emergency water to the island following such an earthquake. A Seattle fault earthquake is defined as a shallow earthquake of Magnitude 6.7 with fault rupture at the ground surface (ground rupture of 14 miles). The peak ground acceleration on Mercer Island is modeled at 0.70 g (EERI and WMD-EMD, June 2005).

Many factors can impact the seismic stability and vulnerability of the new well system, and these are grouped into two categories for ease of discussion. The factors in the “natural environment” are the conditions and geologic hazards that need to be mitigated by the built environment.

Natural Environment

Geologic Setting  
Ground Rupture  
Ground Shaking  
Aquifer Changes

Built Environment

Well Design  
Pump Design  
Pump Facility  
Piping/Connections Design

We address the natural environment first, then the built environment, and how the design of the well system addresses the potential impacts from the natural environment.

**Natural Environment**

*Geologic Setting. The new groundwater well is located on the crest of the island within dry gravelly sand deposits; therefore settlement and liquefaction are not expected to be concerns during earthquake shaking.*

The surficial geologic unit surrounding the well and pump facility is Vashon recessional outwash, a glacially derived, medium dense, gravelly sand deposit. This rests on a very

dense sandy deposit known as Vashon advance outwash and on Vashon till a very dense gravelly silty sand deposit. Groundwater is known to be relatively deep here. The surficial geologic units at the Pump facility are not saturated. Some granular fill may be present locally across the site.

*Ground Rupture. The well site is located within the active Seattle fault zone but not on an active fault strand. Therefore it is highly unlikely that the well system would be negatively impacted by direct surface rupture from an earthquake.*

The well sits between two known active strands of the Seattle fault as identified by Liberty and Pratt (2009) and Stephenson, et al (2007). At the ground surface, the closest active strand is approximately 1600 feet to the south, and dips downward to the north at approximately 45 degrees. The fault plane passes below the well at approximately 1600 feet. The closest known active strand to the north is 1750 feet away at the ground surface and dips 45 degrees down to the south. The fault plane passes below the well at approximately 1750 feet. Backthrusts from either of these fault strands, if present, could intersect the well. Such backthrusts are not known or suspected to exist on Mercer Island at this time. No evidence of faulting was encountered in the boring drilled for the well.

*Ground Shaking and amplification. The types of deposits present beneath the well site would not amplify the shaking, i.e. intensify or lengthen the duration of the shaking as would happen in weaker saturated deposits. Potential impacts from ground shaking have been addressed by structural design.*

The well site is located within the active Seattle fault zone and is at high risk to ground shaking should an earthquake occur on a strand of the Seattle fault near or on Mercer Island. Therefore, the structures have been designed to withstand the expected level of shaking from a M 6.7 shallow earthquake. The level of ground shaking can be predicted using the Seattle seismic hazard maps and projecting their values to Mercer Island. For a M 6.7 earthquake, shaking is expected to reach 70% of gravity, for a (Modified Mercalli Intensity) MMI of VIII to IX, and the perceived shaking will be severe to violent. A Seattle fault event is expected to provide the most intense shaking of the 3 types of earthquakes to potentially impact the area. The 2005 estimate of probability of occurrence in 50 years for an earthquake on the Seattle fault is 5% with a recurrence interval of 1000 years (EERI and WA EMD, June 2005).

*Aquifer Changes. The aquifer providing emergency water is thick, composed of sand and gravel, and the well screen is near the middle of the aquifer; therefore it is highly unlikely that earthquake shaking would cause any permanent changes in the aquifer.*

Sometimes shaking can cause very short term, transitory turbidity in well water. The Utility and Emergency Management Departments have policies for checking turbidity immediately following an event prior to releasing water into the supply system. A manual bypass is available to flush the system of silty water should this be needed. This transitory turbidity will correct itself, and it may slightly impact performance for a few hours to a few days. Earthquakes are not known for causing permanent damage to deep aquifers. A literature search was conducted and no record was found of such an account.

## **Built Environment**

*Well Design. During an earthquake, the most stable structures are those that are buried and coupled with the ground; therefore it is highly unlikely that earthquake shaking would cause any damage to the well itself.*

No published reports of bent or collapsed wells were found resulting from earthquake shaking. The emergency supply well will move with the ground during earthquake shaking because the well casings are driven, grouted, and cemented into the ground. The well boring is 570 feet deep and has an 8-inch casing located within a 12 inch casing. The annulus between the casings is open and thus will allow some deflection and movement between the exterior casing and interior casing which should attenuate the impact of any ground motion on the well. The well was drilled to a depth of 570 feet, backfilled with pea gravel to 546 feet, screened with a 0.040 slot stainless steel well screen to 504 feet, then sealed at the top at 497 feet in depth with a packer. Static water level in the deep aquifer is at 368 feet below ground surface, yielding over 100 feet of aquifer over the well pump intake. This contingency would allow the pump to continue to operate in the event that the depths of ground water in the aquifer were impacted as the result of a seismic event.

*Pump Design. During an earthquake, the most stable structures are those that are buried and coupled with the ground; therefore it is highly unlikely that earthquake shaking would cause any damage to the pump design.*

The pump is submersible, all mechanical and electrical components of the pump are located at the bottom of the well. The pump column is connected to the top of well casing by a welded steel flange. All critical well pump column connections are secured by a threaded coupling and an extra welded strap. The pump column is an 8-inch diameter, schedule 40 steel pipe, and it will attenuate earthquake shaking. Stainless steel casing spacers were placed between the pump column and the well casing as additional measures to prevent damage to the pump column and well casing and to keep the pump column stable inside of the casing. The spacers are located approximately 100 feet apart allowing some room for deflection if needed.

*Pump Station Facility. The well facility was “overdesigned” with respect to seismic safety for the foundation and building; therefore it is highly unlikely that earthquake shaking would cause any damage to the pump facility. The facility was designed to meet a seismic event that approximately equates to an event of (M 7.5), which is significantly more stringent than the anticipated event of (M 6.7). It was also designed using an Importance Factor (I) of 1.5, which is the highest factor of safety in seismic design. An Importance Factor of 1.5 is used for any critical facility that needs to be fully operational after a seismic event. Other designs of lower “I” factors might perform well during a design event but may need to be assessed or not be able to be occupied immediately after an event. The facility is a low-profile, light-weight, wood-frame building with shear walls, the most favorable to withstand damage in a seismic event. All electrical cabinets are anchored to the floor of the facility. All mechanical equipment is anchored to the floor of the facility. The piping system and bladder tank are housed within the building.*

To anchor the bladder tank and building to the foundations, longer bolts and a deeper concrete foundation for anchoring than were needed by design, were used.

*Piping/connections design. All below ground connections between the well and pump facility are flexible to allow for shaking, rotation, slip, and settlement; therefore it is highly unlikely that earthquake shaking would cause damage to these essential connections. The entire system uses small diameter pipe and is contained in a compact design, further reducing risk to shaking damage.*

Where necessary, such as at the entrance to the pump facility, seismic fittings were used for connections between rigid piping runs. These fittings allow for 360 degree motion, some slip, some extension, and some settlement, should any occur. The fittings will not allow the pipes to separate or act as a lever on the well casing or building foundation. All piping is anchored to the floor of the facility; the facility is rigid and anchored to its foundation. Over designed stepped footings were designed to account for the location of the building relative to the reservoirs.

## **Summary**

Ground rupture does not appear to be a threat, but ground shaking from earthquakes is a possibility. The potential impacts to the well system are:

1. Transient turbidity. This will be managed by the Utility and Emergency Management Departments via monitoring and maintenance.
2. Damage to the well system. Damage to the well system appears highly unlikely given the extent of the seismic design as summarized above. However, piping connections will be monitored prior to an event and evaluated after an event, given that they are the most vulnerable part of the well system.