BergerABAM

Water System Resiliency Study

Submitted to

City of Manzanita
Department of Public Works
Manzanita, Oregon

Submitted by

BergerABAM
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Portland, OR 97232

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January 2018

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WATER SYSTEM RESILIENCY STUDY

City of Manzanita

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1.0 BACKGROUND AND NEED

The City of Manzanita recently obtained a study grant through the Oregon Health Authority's Sustainable Infrastructure Planning Project program to evaluate the seismic resiliency of their water system. The state of Oregon has made resiliency planning a high priority because of the potential for a Cascadia Subduction Zone (CSZ) event. Resiliency planning is particularly important for Oregon's coastal communities because of the risks associated with their geographic location. Those risk include ground accelerations (shaking), tsunami, and landslides/liquefaction. See Figure 1-1 which depicts the plate movement of the Cascadia subduction zone.

The intent of this study is to evaluate Manzanita's existing water system with respect to a possible CSZ event. Specific elements of the study include evaluations of the water supply sources, water transmission, storage, and distribution. From this evaluation, system vulnerabilities were identified. Recommendations were then developed that are believed to address those vulnerabilities and hence increase the City's water system resiliency.

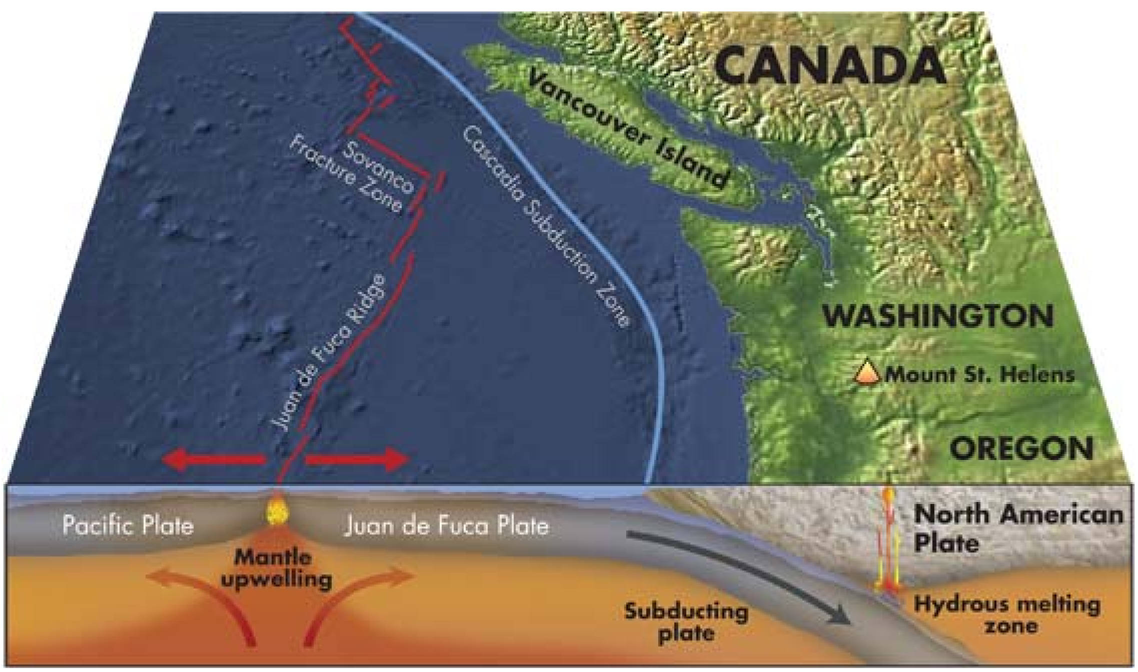


Figure 1-1. Cascadia Subduction Zone (CSZ)

2.0 APPLICABLE RESILIENCY GUIDANCE AND BEST PRACTICES

There are two primary guidance documents that have been developed to aid Oregon communities with hazard assessment and resiliency planning. The Tillamook County Multi-Jurisdictional Natural Hazards Mitigation Plan contains assessments specifically for the City of Manzanita and surrounding areas. The Oregon Resiliency Plan (ORP) is a statewide assessment that focuses solely on the impacts and planning needed for a CSZ event.

Tillamook County Multi-Jurisdictional Natural Hazards Mitigation Plan

This comprehensive plan assesses the probability of hazard occurrence and local vulnerabilities and establishes goals, objectives, and strategies for natural hazard mitigation. It identifies resources for implementing the mitigation strategies and also establishes processes, procedures, and responsibilities for periodically reviewing the plan. The scope of this plan is broader than the Oregon Resiliency Plan by addressing all significant natural hazards present in Tillamook County to include coastal erosion, earthquakes, floods, landslides, severe weather, tsunamis, volcanic ashfall, and wildfires.

Oregon Resiliency Plan (ORP)

This document is a result of Oregon legislation that required development of a plan that would help Oregon communities survive and bounce back from a magnitude 9.0 Cascadia earthquake and tsunami. It summarizes the science of Cascadia subduction zone earthquakes and estimates their impacts, then provides detailed analysis of the current vulnerability of buildings, the business community, transportation, energy, communications, and water/wastewater systems. The plan defines performance targets for each of these subjects and provides recommendations with a goal to meet resilience targets over the next 50 years.

3.0 EXISTING CONDITIONS

Location and Geology

The City of Manzanita is located in Tillamook County on the northwest Oregon coast. It is located north of the City of Tillamook and south of Cannon Beach. Neahkahnie Mountain lies just to the north. There are some smaller communities adjacent to Manzanita such as the City of Wheeler to the south and City of Nehalem to the east. The Nehalem River and Bay are a significant geographic presence to the southeast, as is the Tillamook State Forest to the east.

The City itself extends along the beach from north to south, and then expands to the west in the northern section. Several residents, and some businesses and government buildings, are situated on a hill that rises from the beach line up to an elevation of approximately 200 feet.

Figure 3-1. Coastline photo of Manzanita

Much of Manzanita sits upon old, stable sand dunes and marine terraces. The soils consist primarily of loamy fine sand with intermittent pockets of other types of soils such as Brallier peat with some iron cementation.

3.1 Community

The City is primarily a residential and tourist-oriented community with a population of about 600. There is, however, a high percentage of seasonally occupied housing units (approximately 65 percent). As a result, the population at any given time is significantly greater than the permanent resident population. Seventy percent of resident occupations are white-collar oriented. There is little workforce dependence on the marine environment, farming, or forestry. The population has a high median age and a large percentage of retired residents. Many of the local businesses cater to this population and to the tourism. Population growth is projected to be low; however, some housing development is occurring.

Manzanita shares its water system with some nearby communities. The City of Wheeler has a population of approximately 420 people and Route 53 Water Inc. has approximately 89 residents. An emergency water connection (normally closed) is shared with the City of Nehalem, which has a population of 271. Water is also supplied to Tideland Water District and Neahkahnie. See Figure 3-2 for a view of surrounding communities.

Figure 3-2. Aerial photo of surrounding area

3.2 Existing Water System

The City's water system strategy has evolved over the last two decades as they have managed changing water sources and water quality issues. Some significant improvements have been completed such as construction of two groundwater wells, a high-density polyethylene (HDPE) transmission main, replacement of distribution lines, and improvements to reservoir hydraulics. See Appendix A, Exhibit 2, for a regional water system map.

Water Supply

The City has two available sources of supply. In 2003, two groundwater wells were constructed adjacent to Foss Road, approximately 6-miles to the southeast. The wells are dependable and provide high water quality. Each well is currently rated for 500 gallons per minute (gpm), with a maximum production of 750 gpm when in duplex operation. The City has a water right of up to 1,400 gpm and capacity to build additional groundwater wells if needed. The wellfield site is shown in Figure 3-3.

The second source of supply is the surface water source from Anderson Creek. The diversion structures are located northeast of the City in the Tillamook Forest approximately 3 miles from City limits. The City, however, is no longer using this source and does not consider this a viable option going into the future. There is not enough stream volume for an adequate and consistent supply. Additionally, the diversions and asbestos-cement transmission lines are in disrepair. Repairing the diversions and transmission main would cost several million dollars. The transmission main alignment is also in high-risk landslide zones and access is very limited.

Figure 3-3. Groundwater well site

Transmission Line

Along with the construction of the new groundwater wells, the City constructed approximately 8-miles of 8-inch and 10-inch HDPE transmission main between the wells and the water treatment plant. Many of the significant water crossings were bored underneath the rivers. There are inter-ties with the City of Wheeler, Route 53 Water Inc., and Tideland Water District.

Reservoir Storage

The City has three reservoirs of varying size and age. They are located in the same general area of Manzanita at the northern limits. Reservoir No. 1 was built of welded steel in 1979 and has a capacity of 500,000 gallons. This reservoir was recoated in 2003. Reservoir No. 2 was built of concrete in 1960 and has a capacity of 250,000 gallons. It sits adjacent to Reservoir No. 1. Reservoir No. 3, constructed of glass-fused, bolted steel, was built in 1997 and has a capacity of 1.6 million gallons. The reservoir has experienced some settlement requiring repairs to the bolted panels. This largest reservoir sits below the elevation of the others and is on a separate parcel to the northeast.

Water Distribution

The City has been making improvements to its water distribution system. Some older asbestos cement lines and undersized lines have been replaced in conjunction with other ongoing projects such as roadway improvements. There are still a number of older lines that can be replaced and upsized to improve reliability and flow. The distribution system is split into two pressure zones. The high pressure zone is fed directly from Reservoir No. 1 through a booster pump. This zone serves the higher elevation area on the north side of Manzanita. The lower pressure zone is primarily served by Reservoir No. 3.

4.0 CASCADIA SUBDUCTION ZONE RISK FACTORS

There are several factors to consider when conducting a water system resiliency analysis. Factors include ground accelerations (shaking), tsunami, landslides, and liquefaction. Being located in this coastal geographic location means that all of these factors pose a threat to the water system and to the recovery effort.

Ground Accelerations

The ground accelerations (shaking) from the earthquake can have a damaging effect on the water system. Any component that is not in serviceable condition or is not restrained may pull away at joints and connections. Non-ductile or brittle piping may fracture. This type of damage can occur throughout the system including groundwater wells, pumps, transmission line, well houses and buildings, and distribution pipe. Reservoirs are particularly vulnerable to shaking as it causes sloshing inside the reservoir. This leads to buckling or separation from the foundation.

Tsunami Inundation

The tsunami inundation zones are shown on the Oregon Department of Geology and Mineral Industries (DOGAMI) maps (see Figure 4-1 and appendix A). A significant portion of the City is within the varying levels of the tsunami inundation zone. The yellow shaded areas represent tsunami limits based on the largest CSZ event. The purple shaded areas represent limits of smaller seismic events. The impacts of a tsunami can be devastating for infrastructure within the affected zone. Although many of the water system assets are buried, ground subsidence is anticipated to occur in the 3 to 5 foot range, which can cause the pipeline to shift and shear. Portions of the system that are aboveground will likely be destroyed. The debris and damage left behind will make access and repair very challenging.

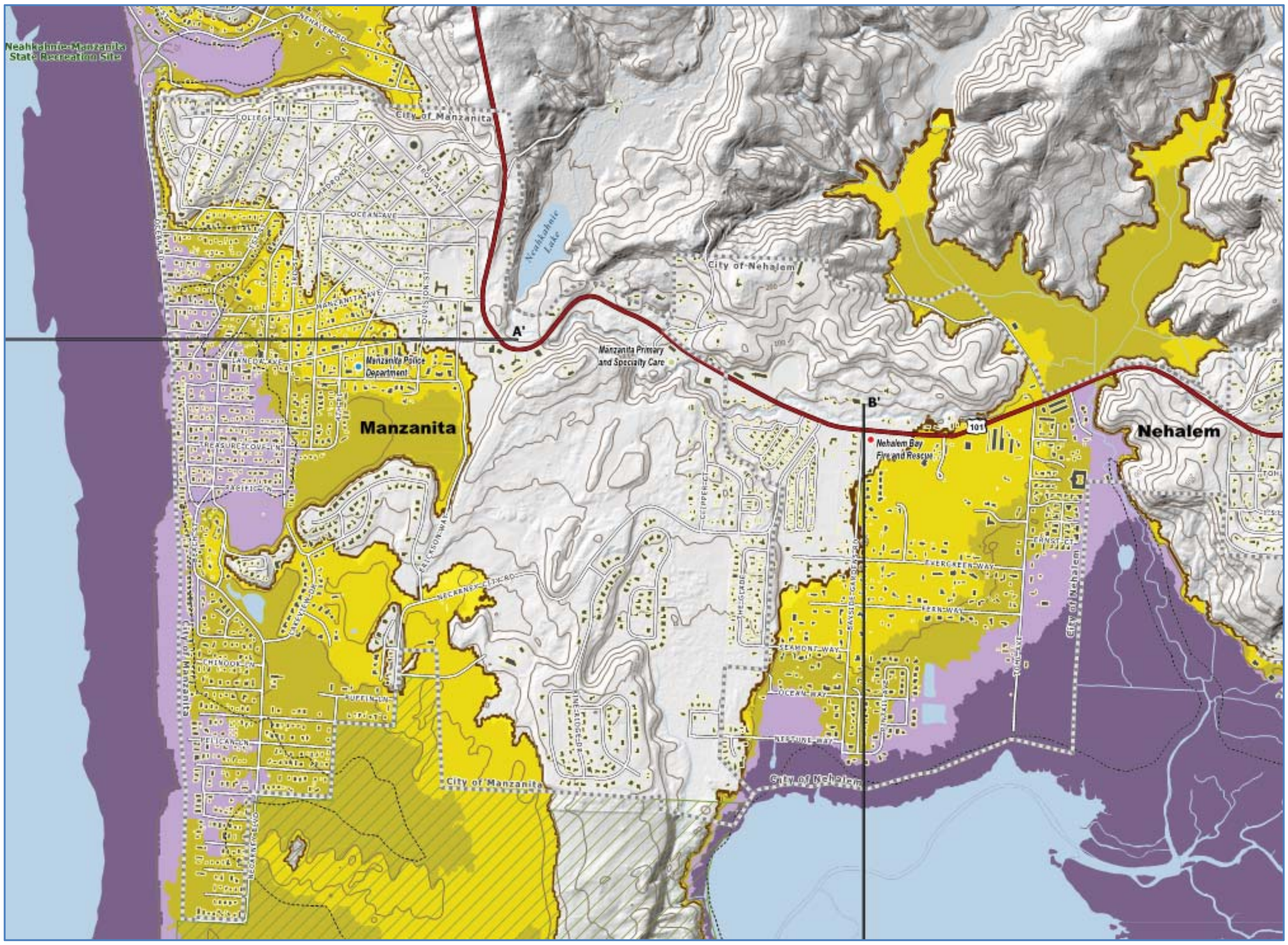


Figure 4-1. DOGAMI map of Manzanita and vicinity

Landslides or Liquefaction

The coastal area, particularly the Tillamook State Forest, is highly vulnerable to landslides and liquefaction. Liquefaction occurs when shaking causes a temporary increase in ground water pressure and a loss of soil bearing capacity. This can cause structures such as reservoirs to settle and pipe connections to shear. Much of Manzanita is located on sandy material and therefore subject to settlement. There are many slopes adjacent to the City limits, or along the transmission alignment, that pose high risks for landslide damage. Figure 4-2 shows hatched areas on the north side of the City where historical landslides have occurred, and are likely to reoccur. Figure 5-1 shows landslide risks in the surrounding areas that include the transmission main alignment.

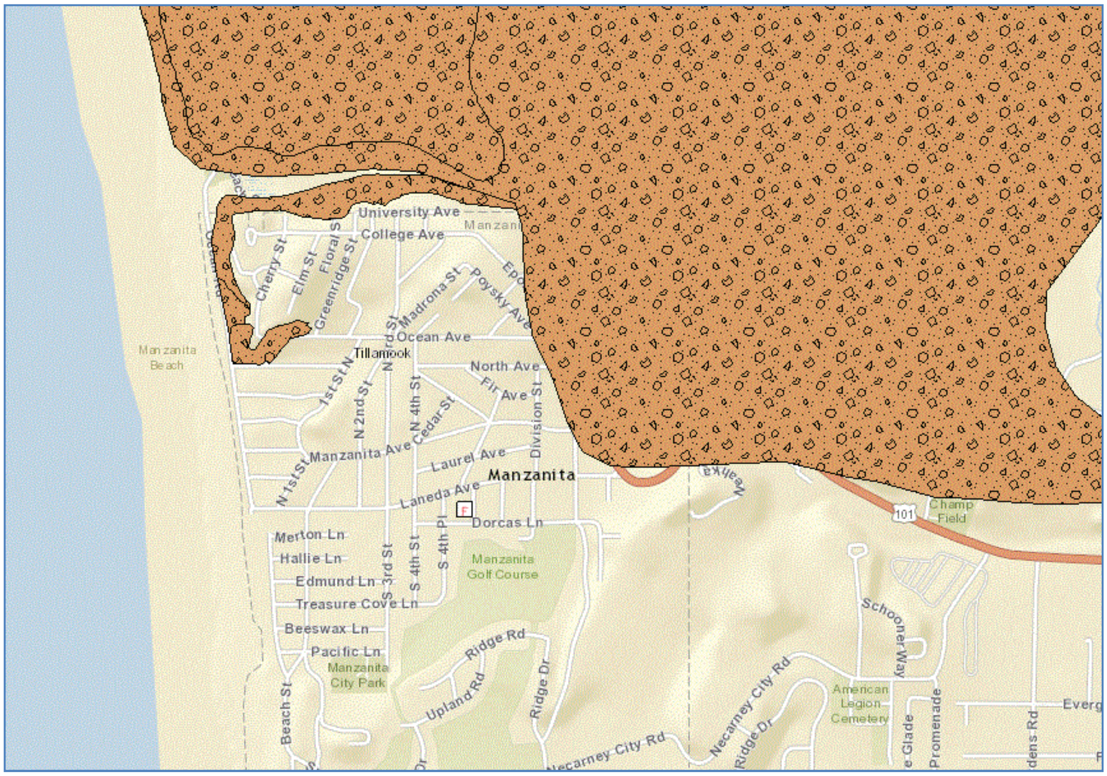


Figure 4-2. Landslide risk areas to the north

5.0 WATER SYSTEM VULNERABILITIES

Each aspect of the City's water system was evaluated with respect to the risk factors presented by the CSZ event. In some cases, a more intermediate level seismic event was considered.

Water Supply Source

The primary water source are the two groundwater wells located southeast of the City along Foss Road. The wells and well house were recently constructed and in good condition. This location is above the tsunami inundation zone and is not expected to be damaged by a tsunami. Primary risks for the wells are the potential landslides on the adjacent slopes, which could result in deep soil deposits over the well production site. Ground accelerations or ground subsidence has the potential to damage the wells and associated distribution lines. See Figure 5-1 which shows high landslide risk levels around the well site and along the transmission main alignment.

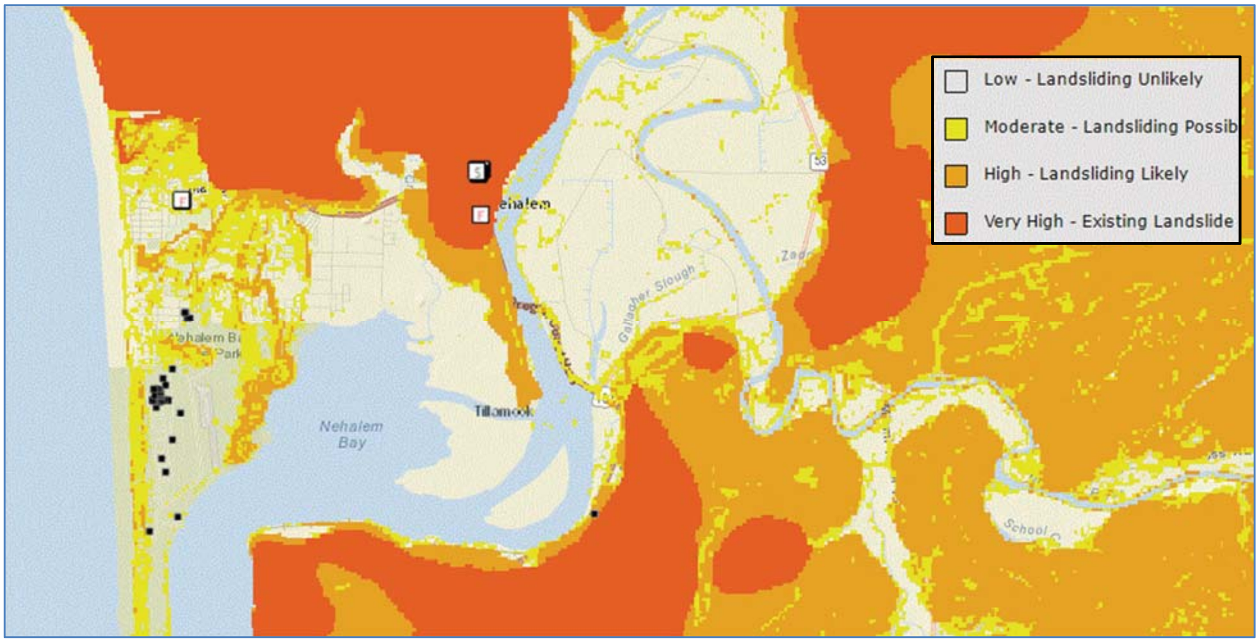


Figure 5-1 Landslide risk areas (broader area)

A significant vulnerability for the City is the lack of an alternative water supply source that can serve as backup for the groundwater wells. Because of the vulnerability of the well locations and the transmission main alignment, it is anticipated that this water supply source will be disabled for a long period of time following a CSZ event.

Water Transmission Main

There are numerous locations along the transmission main alignment vulnerable to a CSZ event. Landslide and tsunami inundation risk follow the majority of the transmission main. Foss Road is particularly susceptible to landslides due to the steep terrain. As the line turns west onto Necanicum Highway, it enters the tsunami inundation zone. Once the pipe turns northwest onto Highway 101, it enters a more vulnerable area within the tsunami inundation zone (designated by the purple shading), and continues in this zone until it crosses the Nehalem River. Based on the DOGAMI mapping, this section of the transmission main is vulnerable to a small and medium tsunami event. For a larger seismic event, these sections of the water transmission are likely to be irreparably damaged.

The water treatment plant (WTP) was constructed in 2003 and has some seismic resiliency per applicable building code requirements. Because the treatment aspect of the plant is currently inactive, this facility is not as critical as others. It is, however, an important part of the water supply chain because all transmission water must travel through the plant prior to reaching the reservoirs. The CSZ event could damage the building and interior piping.

Reservoir Storage
The three existing reservoirs pose a range of vulnerabilities for the water system. Each reservoir is different in terms of age, size, and location. The reservoirs were evaluated individually and as an interconnected group. See Figure 5-3 for an aerial view of the reservoir site. The aerial view is somewhat askew as a result of showing approximate slopes and grades in this area.

Figure 5-2. Aerial view of reservoir site

Reservoir No. 1 (Welded Steel, 500,000 gallons)
Because this reservoir was constructed in 1979, there was very little consideration for seismic resistance. The Oregon Resiliency Plan predicts that reservoirs built in this time frame will most likely fail and release all stored water. The reservoir as-built drawings were reviewed as a part of this study to discern whether a structural retrofit is advisable. The structural review revealed that although the risk of lifting off the foundation is lower, the relatively thin steel wall panels (0.5 inch) would buckle and fail during the CSZ event.

Reservoir No. 2 (Concrete, 250,000 gallons)
This reservoir was constructed in 1960. The Oregon Resiliency Plan predicts that reservoirs built in this time frame are very likely to fail and to release their contents. This reservoir also adds to the complexity of the site distribution piping, which creates more opportunity for damage.

Reservoir No. 3 (Glass-fused Bolted Steel, 1.5 million gallons)
This reservoir was constructed in 1997. The Oregon Resiliency Plan predicts that reservoirs built in this time frame will most likely suffer some damage, but may not release the stored contents. This reservoir, however, has a fatal flaw in terms of its site location. It is located adjacent to a steep slope with a high likelihood for landslide or slope failure. The City has previously observed movement around the reservoir, both immediately after it was built and more recently with pavement cracking in Epoh Avenue. The movement in Epoh Avenue was evaluated by a geotechnical engineer and documented in a report (see Appendix B).

Although further geotechnical review and investigation is recommended, it is possible that slope failure and associated ground movement will cause catastrophic failure of Reservoir No. 3. The tsunami inundation zone is also mapped to reach the toe of this slope, which could accelerate failure. The reservoir also poses a life safety risk to the residents near the toe of the slope.

Figure 5-3. Reservoir No. 3 near the steep slope

BergerABAM also evaluated the hydraulic elevations related to this reservoir, as there was some concern that the amount of accessible water storage may be restricted because of system hydraulics. The inlet and outlet water lines were profiled in comparison to the reservoir storage height, and it was confirmed that all contents of this reservoir would be accessible via gravity outflow.

Reservoir Site

Because the City is built primarily on sandy soils, the reservoirs may be subject to liquefaction and ground movement. Reservoir No. 3 is at the greatest risk for catastrophic failure because of the proximity to the steep slope. A smaller seismic event may be all that is necessary to trigger slope failure. The other two reservoirs have a much greater setback from the slope, but they are also likely to fail because of a lack of lateral reinforcing and ground subsidence.

The complex network of piping, connections, and valving between the three reservoirs creates additional vulnerability for water storage (see Figure 5-5). Even if the reservoir structure survives, the contents will likely spill as a result of sheared pipe connections or joint separations. Losing water storage diminishes the City's capacity for first-response and recovery actions such as fighting fires and providing potable water for residents and critical facilities.

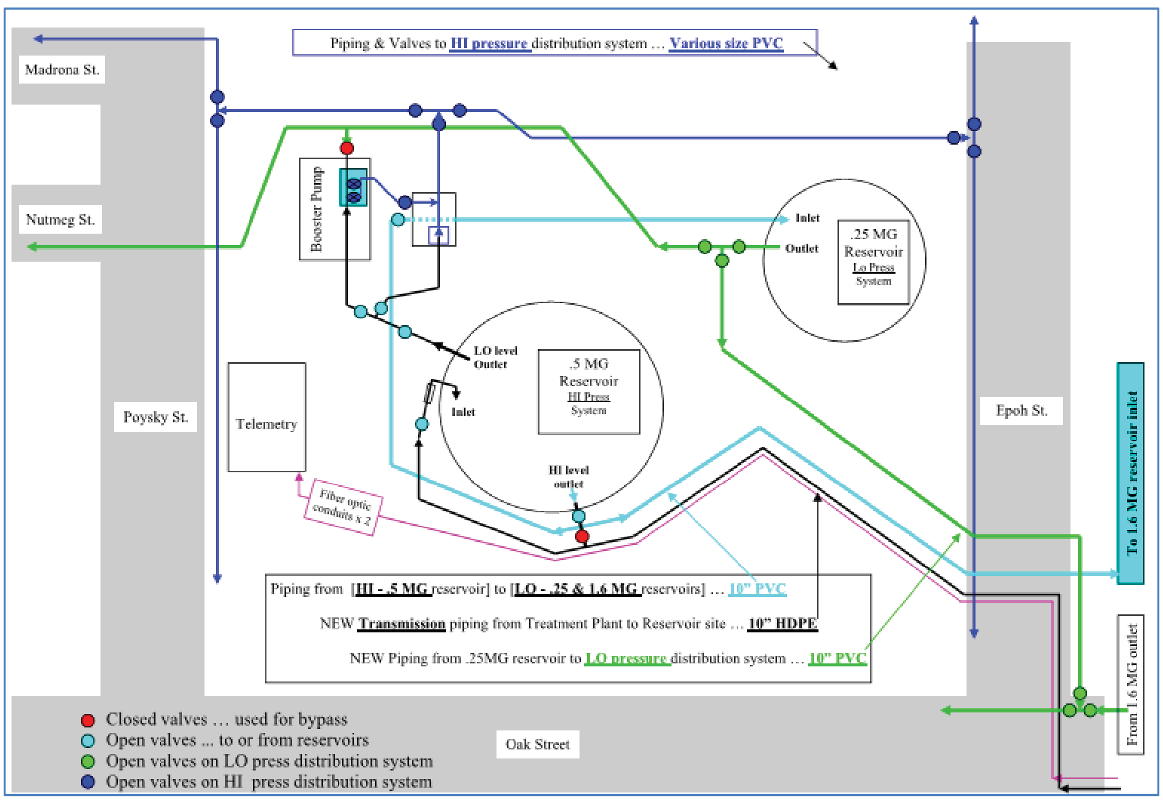


Figure 5-4. Pipe network at reservoir site

Water Distribution System

Vulnerabilities in the distribution system stem from older, non-ductile, pipe materials such as asbestos-cement and cast iron pipe, and unrestrained joints/connections. Although some progress replacing older water mains has been made, there remains a significant amount of vulnerable distribution pipe. Damage to the distribution system will likely cause bleed out of reservoir storage.

Water System Information Management System
The City does not currently have a water system information management system in place. These systems are typically based upon a Geographic Information System (GIS) platform that ties utility information to local mapping. Such a system will allow water system operators to record, catalogue, analyze, and manage all critical information relating to the system. Most importantly, all water system components can be accurately located and described with respect to operations and maintenance needs. Not having a GIS system creates vulnerability with respect to effective emergency response. If the operator cannot accurately and efficiently locate critical water system components (i.e. valves, interties, pipelines) then the emergency response effort may be hindered.

6.0 RECOMMENDATIONS

There are several actions the City can take to increase the seismic resiliency of the water system. The Oregon Resiliency Plan recommends that communities focus on improving the backbone of their water system. It states the following:

> *"The backbone water system would be capable of supplying key community needs, including fire suppression, health and emergency response, and community drinking water distribution points, while damage to the larger system is being addressed."*

The backbone of the water system generally consists of those facilities that provide key needs as described above. For Manzanita, it includes the groundwater wells, primary transmission main, reservoirs, and key distribution lines. The goal for recovery of the backbone system after the CSZ event is shown in Appendix A, Exhibit 4. As a reference, time to achieve 50 to 60 percent operability is three to seven days for transmission mains, booster pumps, and reservoirs; three to seven days for fire suppression at key locations; and two to four weeks for wells and water supply to critical facilities. See Exhibit 1 in Appendix A for a map of water system recommendations.

Water Supply Source
It is critical for the City to establish another water supply source that has a higher probability for recovery. Based on discussions with the City, this initiative is already in progress. The City is planning to build a test well near the existing WTP, which is outside of the tsunami inundation zone. The well would be close enough to the WTP and transmission main that repairing any damage between the well and other facilities becomes more feasible. The proposed third well is expected to produce about 80 gpm. This new well would be considered surface water and would require filtration and treatment at the existing WTP. Some minor WTP modifications would be required.

If considering improvements that could increase resiliency for a smaller seismic event, then additional groundwater wells can be constructed at the existing well site. These wells would serve as backup to the existing wells, and increase the probability that at least one well would remain serviceable. This improvement is unlikely to increase resiliency for the maximum CSV event.

Transmission Main

Even though much of the transmission main is likely to be irreparably damaged within the tsunami inundation zone, there are improvements that can be made outside of the zone to increase water system resiliency. Those improvements include:

- Provide a pressure sustaining valve at the City limits, next to the Fire Rescue Station, to prevent system bleed out from tsunami damage.
- Provide a bypass line around the WTP in the case of WTP building collapse, or to backfeed the transmission main.
- Provide an emergency connection (normally closed) to the distribution system that will serve to bypass the reservoirs if they have failed. Connect at Manzanita Avenue and replace the water main branch in the street.
- Provide an emergency water connection to the other critical facilities along the transmission main alignment such as the Fire Rescue Station.

If considering improvements that could increase resiliency for a smaller seismic event, then the following also represent resiliency opportunities:

- Bury the pipeline where it is aboveground. See appendix A, Exhibit 1 for aboveground locations. See Figure 6-1 for the aboveground pedestrian bridge crossing.
- Provide flow control valves or automated valves that will prevent bleed out of the system at key connections and locations. Connections needing bleed out protection include Zaddock Creek and Tideland Water District.

Figure 6-1. Aboveground crossing of transmission main

Reservoir Storage

Because the existing groundwater wells and transmission line are vulnerable in the CSZ event, reservoir storage becomes the primary focus for resiliency and recovery. The following improvements are recommended:

- In concert with thorough geotechnical review, build two new reservoirs to replace the existing three reservoirs on the site of Reservoirs No. 1 and No. 2.
    - ❖ Design new reservoirs with seismically resilient foundations and structural design.
    - ❖ Provide seismic connections at inlets and outlets.
    - ❖ Install automated valving to prevent the potential for bleed out in the case that the transmission lines or distribution is severed.
    - ❖ Ensure adequate storage sizing for extended reliance on emergency water use.

If not wanting to replace the reservoirs, and considering a smaller seismic event, the following improvements can be considered:

- Structurally reinforce Reservoir No. 1 by stiffening walls, steel interior columns, and new anchorage into a fortified ring foundation.
- Provide seismic connections at the inlet and outlet of each reservoir.
- Take Reservoir No. 2 offline and isolate from the system.

- Provide protection from bleed out at strategic locations by installing pressure sustaining valves.

Distribution System

It is important to protect the reservoir storage from bleeding out through damaged locations in the distribution system. This will require pressure sustaining valves near the reservoirs and at strategic locations in the distribution system. It is also important to continue upgrading the distribution with more resilient water pipe even though most of the distribution system is not part of the backbone. Replacement of older, non-ductile lines—particularly asbestos cement or cast iron—is recommended. If the distribution system is more resilient, then the recovery period is reduced.

Water System Information Management System

Building a GIS mapping platform for the water system, and potentially other infrastructure systems, can greatly enhance the City's ability to understand, plan, and respond to emergency situations. Current and future employees can be thoroughly trained with regard to the location and function of all critical water system components. Operations and maintenance data pertaining to emergency response can be stored and tagged to specific valves, interties, or pipeline segments. This will allow for a much more expedient and focused response when needed.

7.0 SUMMARY OF RECOMMENDATIONS AND FUNDING

Recommended project improvements have been organized in the tables below. Reference Exhibit 1 in Appendix A, which shows general locations of these improvements. A resiliency value has been estimated for each improvement as either low, medium, or high. This estimate refers to the perceived increase in resiliency associated with completion of that improvement. An order-of-magnitude cost estimate has been provided for each improvement.

Table 7-1. Water Supply Source Improvements

Project	Resiliency Value	Cost Range
Establishment of third well and WTP upgrades	High	$250K
Two backup wells at current well site	Low	$350K

Table 7-2. Water Transmission/Distribution

Project	Resiliency Value	Cost Range
Bleed out control vault at City limits	High	$100K
Bypass and flow control at WTP	Medium	$150K
Reservoir bypass connection and water main	Medium	$100K
Emergency connection to fire and rescue	Medium	$50K
Bleed out control at Zaddock Creek	Medium	$50K
Bleed out control at Tidelands Water District	Medium	$100k
Replace connection with City of Nehalem	Medium	$100k

Bury trans. main at pedestrian bridge crossing	Low	$200K
Bury trans. main at bridge crossing (101/53)	Low	$250K

Table 7-3. Reservoir Storage

Project	Resiliency Value	Cost Range
Build two 1-million gallon reservoirs	High	$3,500K
Bleed out flow control vaults (4) at reservoirs	Medium	$400K
Structurally reinforce Reservoir #1	Medium	$500K
Seismic connections at three reservoirs	Medium	$150K
Decommission Reservoir #2	Medium	$25K

Table 7-4. Water System Information Management System

Project	Resiliency Value	Cost Range
Build GIS System for Water Infrastructure	High	$31K

Replacement of older water distribution mains will also add to water system resiliency. An average cost factor for replacement of water mains is $125 per linear foot.

7.1 Project Funding

There are several funding opportunities for these projects; many geared for seismic resiliency and emergency planning.

Oregon Office of Emergency Management (OEM) – Provides several grant opportunities to local governments to assist in preparedness and mitigation activities. Two specific programs are the Emergency Management Performance Grant and the Hazard Mitigation Assistance program, funded through the Federal Emergency Management Agency (FEMA). Within the Hazard Mitigation Assistance program, there is also a Pre-Disaster Mitigation Grant.

FEMA Earthquake State Assistance Program – This program is developed to reduce the risks of life and property from future earthquakes through the establishment and maintenance of an effective earthquake risk reduction program.

Water and Wastewater Financing Program – This is a program funded by the state of Oregon through the Infrastructure Finance Authority. This program funds reasonable costs for construction of drinking water systems. Grants are available up to $750,000 depending on financial review.

There are several other financing programs to consider such as Oregon's Water Resource Department (WRD) funds, the Department of Environmental Quality's Clean Water Revolving Loan Fund, and the U.S. Department of Agriculture.

8.0 CONCLUSION

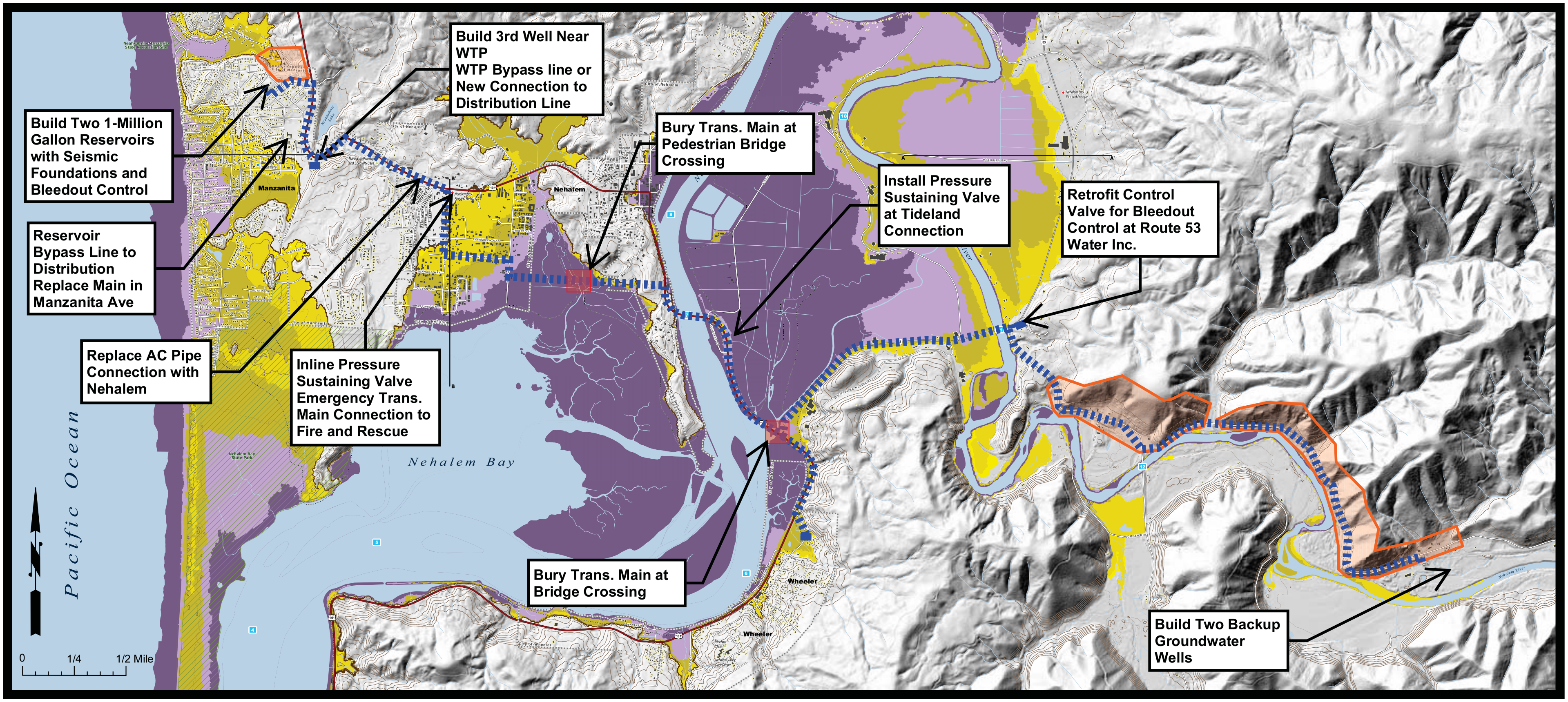
Planning for the Cascadia Subduction Zone seismic event can be a daunting task given the risk factors associated with coastal locations. However, there are several meaningful projects the City can undertake to improve water system resiliency. These projects can be prioritized over a longer time period depending on level of importance and funding opportunities. By incorporating these projects into the water masterplan and/or the capital facilities plan, the City is then prepared to seek funding and grant opportunities. BergerABAM can assist the City in the research and coordination of those funding opportunities.

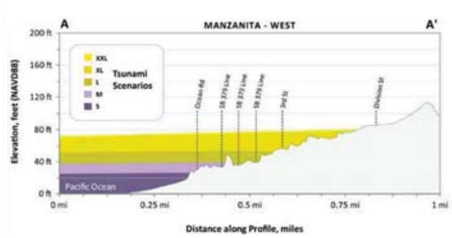
As discussed throughout the report, it is recommended that the City focus on those projects with the highest resiliency return. Those projects relating to an alternate water supply and to reservoir storage are believed to provide the greatest value. An alternate water supply in a secure location increases the probability that water can be supplied in a much shorter timeframe following the CSV event. Replacement of the reservoirs increases the probability that there will be water storage to fight fires and provide emergency water for residents.

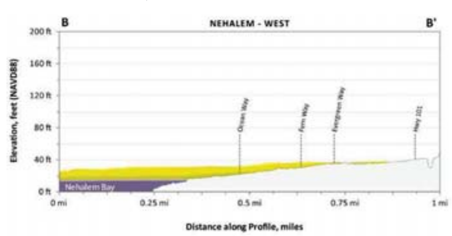
If there are any question or comments about the content of this report, please contact Dan Johnston at anytime at phone number 503/872-4121.

City of Manzanita
Water System Resiliency Study
Manzanita, Oregon

Appendix A
Exhibits







lip t)	Maximum Slip Range (ft)	Time to Accumulate Slip (yrs)	Earthquake Magnitude
?	118 to 144	1,200	~9.1
?	115 to 144	1,050 to 1,200	~9.1
)	72 to 98	650 to 800	~9.0
)	46 to 62	425 to 525	~8.9
;	30 to 36	300	~8.7
one			

- Urban Growth Boundary
- Building Footprint
- Simulated Gauge Station
- Profile Location
- Senate Bill 379 Line
- State Park
- Elevation Contour (25 ft intervals up to 200 ft)
- Landslide Hazard Area
- Existing Transmission Main
- Fire Station
- Police Station
- School
- Hospital/Urgent Care Clinic
- U.S. Highway
- State Highway
- Improved Road
- Above-Ground Bridge Crossing Hazard

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January 2018

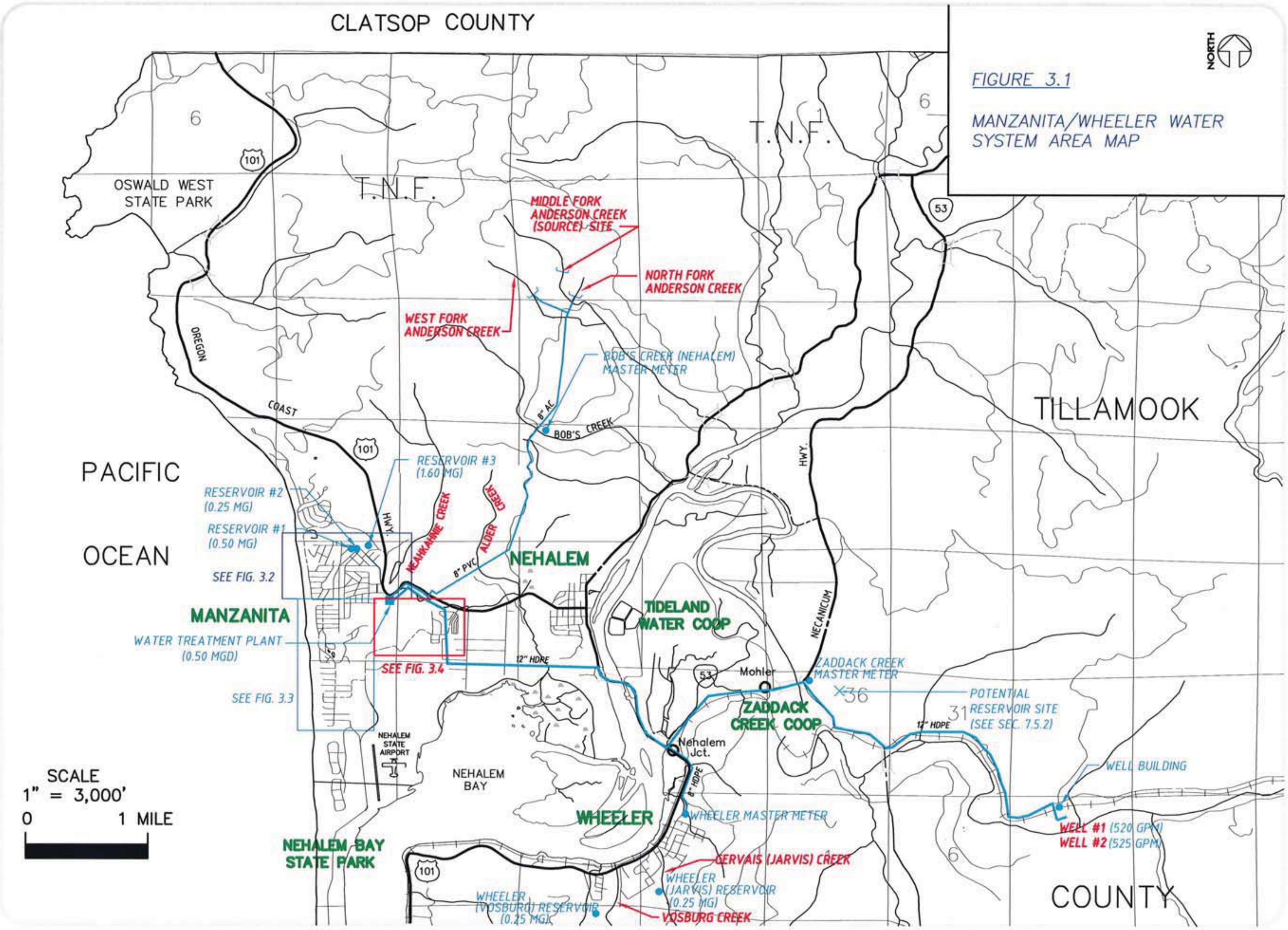
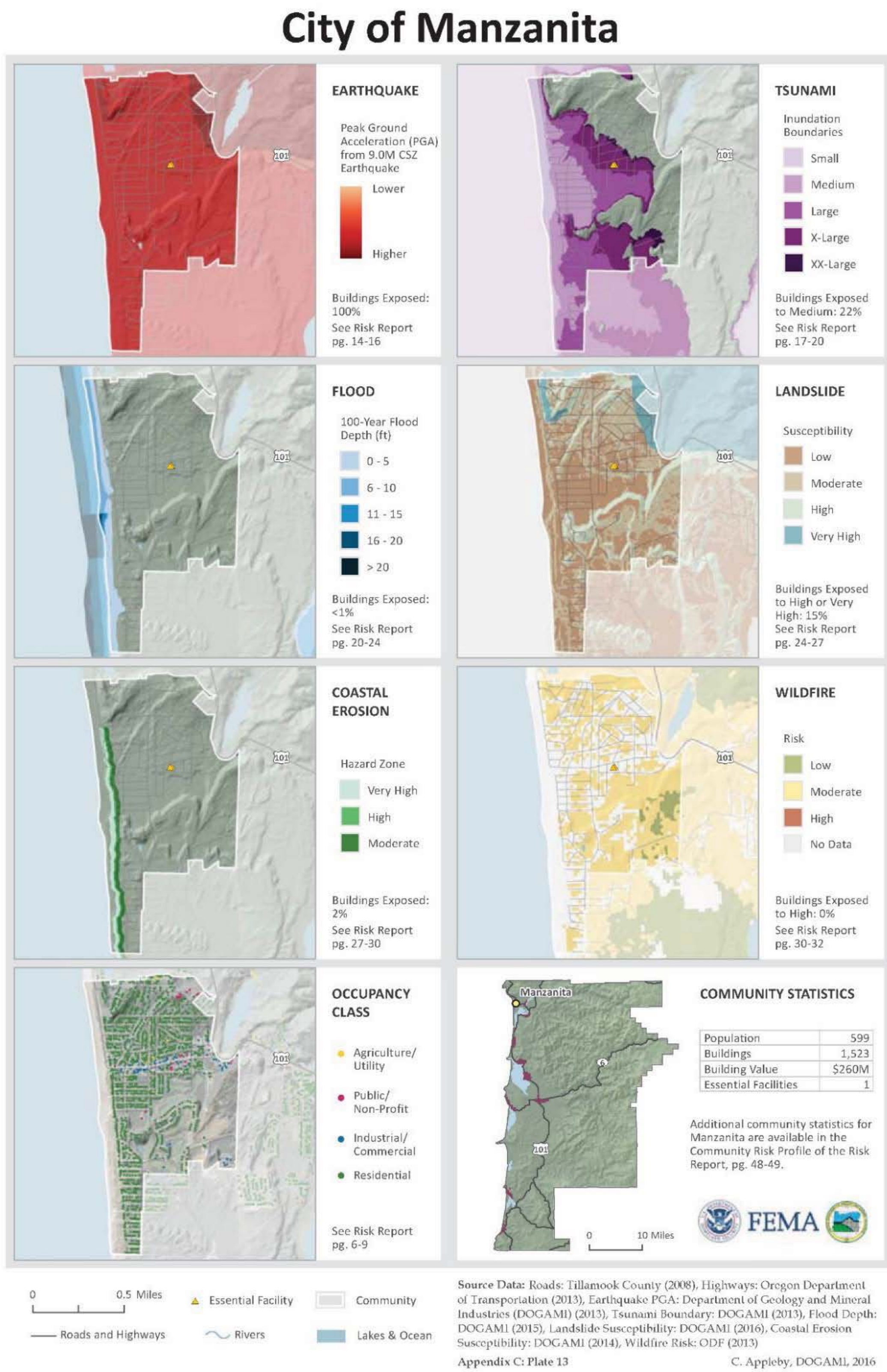


FIGURE 3.1
MANZANITA/WHEELER WATER SYSTEM AREA MAP
NORTH
CLATSOP COUNTY
TILLAMOOK COUNTY
PACIFIC OCEAN
OSWALD WEST STATE PARK
T.N.F.
T.N.F.
6
6
6
101
101
101
53
53
OREGON COAST HWY.
NECANICUM HWY.
MIDDLE FORK ANDERSON CREEK (SOURCE) SITE
NORTH FORK ANDERSON CREEK
WEST FORK ANDERSON CREEK
BOB'S CREEK (NEHALEM) MASTER METER
BOB'S CREEK
8" AC
8" PVC
RESERVOIR #3 (1.60 MG)
RESERVOIR #2 (0.25 MG)
RESERVOIR #1 (0.50 MG)
SEE FIG. 3.2
NEAHKAHNIE CREEK
ALDER CREEK
NEHALEM
MANZANITA
WATER TREATMENT PLANT (0.50 MGD)
SEE FIG. 3.4
SEE FIG. 3.3
12" HDPE
TIDELAND WATER COOP
Mohler
ZADDACK CREEK MASTER METER
ZADDACK CREEK COOP
POTENTIAL RESERVOIR SITE (SEE SEC. 7.5.2)
12" HDPE
WELL BUILDING
WELL #1 (520 GPM)
WELL #2 (525 GPM)
Nehalem Jct.
8" HDPE
NEHALEM STATE AIRPORT
NEHALEM BAY
WHEELER
WHEELER MASTER METER
NEHALEM BAY STATE PARK
GERVAIS (JARVIS) CREEK
WHEELER (JARVIS) RESERVOIR (0.25 MG)
WHEELER (VOSBURG) RESERVOIR (0.25 MG)
VOSBURG CREEK
SCALE
1" = 3,000'
0
1 MILE

Figure 116. Multi-Hazard Community Map Set: City of Manzanita



Source: DOGAMI (2016)

KEY TO THE TABLE

TARGET TIMEFRAME FOR RECOVERY:

Desired time to restore component to 80–90% operational	G
Desired time to restore component to 50–60% operational	Y
Desired time to restore component to 20–30% operational	R
Current State (90% operational)	✕

TARGET STATES OF RECOVERY: WATER & WASTEWATER SECTOR (COAST)											
	Event occurs	**0–24 hours**	**1–3 days**	**3–7 days**	**1–2 weeks**	**2 weeks – 1 month**	**1–3 months**	**3–6 months**	**6 months–1 year**	**1–3 years**	**3 + years**
Domestic Water Supply											
Potable water available at supply source (WTP, wells, impoundment)				R		Y		G		X	
Main transmission facilities, pipes, pump stations, and reservoirs (backbone) operational			R	Y	G					X	
Water supply to critical facilities available				R		Y		G		X	
Water for fire suppression—at key supply points			R		Y			G		X	
Water for fire suppression—at fire hydrants						R	Y	G		X	
Water available at community distribution centers/points				R	Y	G	X				
Distribution system operational					R		Y	G			X

(To be continued on next page)

City of Manzanita
Water System Resiliency Study
Manzanita, Oregon

Appendix B
Geotechnical Report

Geotech Solutions Inc.

August 18, 2017 *otak-17-1-consult*

OTAK; kyle.ayers@otak.com

GEOTECHNICAL ENGINEERING SERVICES - Road Slide Reconnaissance
Epoh and College Avenues - Manzanita, OR

This letter summarizes our reconnaissance services for the roadway slide near the water tank on Epoh Avenue in Manzanita, Oregon. You and the City stated that the road movement has occurred over many years and months, has accelerated this year, but does not appear to be rapidly progressing or causing a major safety issue at this time. If that occurs we should be contacted for emergency approaches. The purpose of our services for this phase was to complete a slope reconnaissance and provide qualitative approaches to stabilization, with a scope of work for investigation and more in depth stabilization design parameters if requested. Our scope of work included the following:

- Complete a site reconnaissance of the existing slope conditions, taking clinometer readings of site slopes and observing soil exposures and slope conditions.
- Provide qualitative recommendations for slope repair approaches, and prepare a scope of work for geotechnical parameters for slope repair investigation and design parameters for design by others if requested.
- Summarize our observations and recommendations in a letter report.

SITE CONDITONS

Surface Conditions

We completed a site reconnaissance on August 9, 2017. We observed the asphalt concrete roadway surface and abutting features, and traversed the upper portion of the slope below the guardrail. The primary affected roadway area on Epoh Avenue is located roughly 180 feet NW of the NW edge of the water tank, beginning near the 428 Epoh address driveway, and extends through the radius of the roadway just past the manhole. The cracked and deformed pavement is on the downhill half of the roadway from the centerline, and is roughly 130 feet long. Cracks are up to roughly ¾" wide and are deflected up to 6 inches downhill in aggregate, in a series of longitudinal offset cracks. Much of the cracking is limited to the downhill ¼ of the roadway, with the larger deflections nearer the edge of pavement. A guardrail has been noted as tilting outward over time to its present state. Cracking was noted by the City to have grown this year, particularly after winter rainfall. Lesser cracking is present upslope of the primary area, and dissipates prior to the tank area and around the radius.

The City stated no utilities are located in this downhill half of the roadway, and stated the manhole near the centerline is connected to the south. Old discharge lines from the water tank were stated as not routed in the roadway, and not under use.

The slope below the roadway is inclined at roughly 1.5H:1V in the upper 20-25 vertical feet with brush and small trees present, and below that includes mature conifer growth on roughly 2H:1V slopes on an overall slope roughly 120 feet high.

1112 7th Street, Oregon City, OR 97045 *ph 503.657.3487 fax 503.722.9946*

Subsurface Conditions

We completed two drive probes to depths of up to 5 feet on the slope below the roadway, and observed exposed soils above the roadway. Driving resistance indicated loose conditions in the observed poorly graded fine sand. The upper hillside surface below the roadway is likely comprised of fill placed for roadway construction. Conditions uphill of the roadway were loose to medium dense, and this likely represents the native sand condition.

CONCLUSIONS AND RECOMMENDATIONS

Loose sand fill will maintain slopes near the angle of repose in unsaturated conditions with no cohesion. That is likely near 30 degrees for this sand. The upper slopes are steeper than this. Capillary tension, root involvement, bedding, and aging can result in slopes temporarily holding higher angles. Medium dense sand will hold even steeper angles, particularly if deposited and bedded/laminated with a dip opposite the slope (such as the lee side of dunes). The angle of repose on the native loose to medium dense sand is likely near 32 degrees. The lower slopes are generally flatter than this.

It is our opinion that the upper slope is composed of sand fill downhill from the centerline, and is likely creeping downslope toward equilibrium with its angle of repose, particularly in wet or dry conditions or if heavy vibration was induced. This condition has led to the pavement deformation and cracking. This will likely continue over the long term to a slope edge projected to be near the centerline.

If the present deformation and rates are unsuitable, we recommend reconstructing the downhill half of the roadway in the affected area (approx. 130 foot length) to reduce deformation and cracking. There are two levels of repair described for this herein - Options 1 and 2. The first is more intensive/costly and designed to arrest more movement and limit cracking over the long term (sans earthquake conditions). Both are intended to limit individual crack sizes and offsets, but will likely result in cracking near the centerline over time. Option 3 would simply be to accept the deformation but attempt to reduce seasonal impacts from runoff. Option 4 is only a short term measure that may help until another Option can be completed.

Total upper slope repair is not included herein, and would require more stability analyses, and likely a short wall with pile support at the guardrail combined with Option 1. We can provide a scope for evaluating that level of repair on request.

For each of the following options we recommend roadway runoff be prevented onto the downhill slope, such as with an extruded asphalt concrete curb at pavements edge, with proper runoff routing south on College Avenue.

Option 1

This would involve removal of pavement and 4 feet of roadbed from the centerline to the downhill pavement edge and reconstructing a reinforced crushed rock fill roadbed that extends to the guardrail, and deepening guardrail post depths to 6 feet. After removal, a non-woven geosynthetic could be placed, for separation, such as a Propex Geotex 801 or equivalent. Then a layer of geogrid, such as a Propex Gridpro BXP12 or equivalent, could be placed at the base and every one foot (except the top) to grade, with crushed rock structural fill infill. The grids should be wrapped back over the overlying rock (in a form of loop) and extend back 4 feet toward the centerline tapering down to within 4 inches of itself at the end. This is to aid in retaining the rock should it become exposed. The rock should

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consist of 1-1/2 “- 0 well graded angular clean crushed rock with less than 6% fines, which can also serve as road base. The desired asphalt concrete thickness could then be placed. Future excavation through the grid would damage this repair and that in Option 2.

Option 2
This option would cost less than Option 1 but result in more cracking over time. This option includes removing the top two feet of roadbed on the downhill half of the road, placing geogrid at the base and wrapping it back over to the centerline, then covering it with one foot of the preceding crushed rock and repaving.

Option 3
Mill and regrade and/or repave the roadway with an inverted crown and route the runoff away from the affected area south on College Avenue to suitable discharge, without adding more than a few inches of fill to the downhill edge

Option 4
This is intended to be short term only. Crack seal the roadway and install an extruded asphalt curb.

LIMITATIONS AND OBSERVATION DURING CONSTRUCTION

We have prepared the preceding information for use by OTAK and the City of Manzanita and members of their design and construction teams for the subject slide only. Recommendations for more geotechnical parameters can be provided as addenda to our agreement. The information herein can be used for bidding or estimating purposes, but should not be construed as a warranty of subsurface conditions. We have made observations only at the aforementioned locations, and only at the stated depths. These observations do not reflect soil types, strata thicknesses, water levels or seepage that may exist between observations or at other areas of the site. We should be consulted to review final design and specifications in order to see that our recommendations are suitably followed. If any changes are made to the anticipated locations, loads, configurations, or construction timing, our recommendations may not be applicable, and we should be consulted. The preceding recommendations should be considered preliminary, as actual soil conditions may vary. In order for our recommendations to be final, we must be retained to review final plans, to observe actual subsurface conditions encountered, and to observe pile, grid, and rock fill installation. Our observations will allow us to adapt to actual conditions and to update our recommendations if needed.

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We appreciate the opportunity to work with you on this project and look forward to our continued involvement. Please contact us if you have any questions.

Sincerely,

Don Rondema, MS, PE, GE
Principal

Attachments: Site Location, Site photo

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N

NOT TO SCALE

BASE PHOTO FROM GOOGLE EARTH 2016 AERIAL

Geotech Solutions Inc.

SITE PLAN

otak-17-1-consult


photo provided by OTAK