Water System Performance – Paso Robles M 6.5 Earthquake of December 22, 2003

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City of Paso Robles

The City of Paso Robles water system consists of 14 wells, 5 pump stations, 2 four million gallon steel tanks, 1 four million gallon open cut lined reservoir with wood roof, and about 148 miles of buried distribution pipe. Typical winter time demand is about 2.5 to 3 million gallons per day; summer time demand reaches 11 to 12 million gallons per day. The population served is about 30,000 people.

Figure 1. Paso Robles Golden Hill Tanks (North Tank on left)

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The earthquake damaged the two steel tanks (Figure 1). Both tanks are at the same site, with the north tank built in 1972, and the south tank built in 2001. The north tank rests on grade; the south tank walls rest on a circumferential reinforced concrete ring beam. Both tanks are unanchored.

The north tank has two inlet-outlets. The normal inlet pipe rises out of the ground adjacent and outside of the tank; is supported to the tank wall, and then dumps water into the top from over the top. The outlet pipe enters the tank under the bottom of the tank, with the center of the outlet about 2 feet inside the tank wall. The north tank has a third outlet pipe that exits the tank side wall, enters the ground, and then leads to the south tank.

The north tank showed evidence of wall uplift of perhaps 2 to 3 inches. This uplift damaged the inlet pipe (pulled apart coupling, Figure 2). This led to flooding outside the tank. The recently-painted bottom plate showed evidence of substantial yielding (cracked paint, Figure 3). The outlet pipe and the steel floor near the pipe showed evidence of high stress (cracked paint), a permanent displacement downwards, suggesting that subsurface had been washed away by a pipe leak (Figure 4). The cross connection pipe was leaking where it entered the ground. The columns supporting the roof appeared to be slightly out-of-plumb. The roof beams and rafters had substantial movement, with perhaps 50% of the rafters moving 6 to 10 inches permanently away from their original position (Figure 5). The bottom course of the tank showed evidence of bowing outwards at about 3 to 8 feet above the foundation, perhaps by an inch or so. No elephant foot buckling was noted at the base of the tank. The external ladder was slightly buckled, likely caused by the bulging of the tank wall that could not be accommodated by the stiffer ladder rails.

Figure 2. North Tank, Inlet Pipe with Pulled Apart Coupling

Figure 3. North Tank, Cracking of Paint on Bottom Base Plate

Figure 4. North Tank, Outlet Near Tank Wall

Figure 5. North Tank, Displaced Roof Rafters

Given the damage, the tank was drained immediately after the earthquake, and remained empty at the time of the inspection (January 12, 2004).

The south tank also showed evidence of wall uplift, although perhaps on the order of an inch. The inlet pipe pulled apart (Figure 6) leading to flooding and erosion near the pipe.

The side-entry pipe leading to the north tank was damaged where it enters the ground (uplift leading to pull apart of a mega-lug joint, Figure 7). The utility staff closed the gate valves on both of these damaged pipes before the entire tank could be drained; and the tank remained in service, using its third outlet pipe. Divers were sent into the tank and reported that there was no observable damage, so the tank has been kept in service.

Figure 6. South Tank, Inlet Part Pulled Apart

Figure 7. South Tank, Uplift Failed this Side Entry Pipe (pull apart joint under the ground)

There was no damage to any of the wells or pump stations or hydropneumatic tanks in the Paso Robles water system. Temporary power outages did not affect water delivery, in that the hillside tanks provided adequate water without the need for replenishment from the wells.

The Paso Robles distribution system uses Cast Iron pipe with primarily leaded joints (about 20% of total inventory) for its older part of town located west of highway 101; Asbestos Cement pipe (about 60% of total inventory) and PVC pipe (about 20% of inventory). The largest diameter transmission pipes are ductile iron. The earthquake caused three leaks in the system, all due to interaction of air-valve assemblies with adjacent concrete boxes; these were rapidly repaired, typically requiring just an hour or so at each location. During the subsequent days, about 7 more leaks were discovered and repaired, all to small diameter (4 inch or smaller) pipe. With the exception of the pulled-apart pipes at the tanks, there were no known pipe breaks.

There was no reported sanding or other waster quality impacts at the wells.

Mobile Home Park South of Paso Robles

There is a mobile home part located adjacent and south of Paso Robles. This park has its own water system, consisting of a well, an at-grade tank located atop a hill, and distribution pipelines.

The 0.15 MG welded steel tank was damaged by the earthquake. The tank suffered an elephant foot buckle, Figure 8. The buckle led to damage of several attached inlet-outlet lines and the overflow pipe. The buckle can be seen in Figure 9, and its outwards displacement (about 3 to 4 inches) impacted an adjacent fence; the elastic rebound of the buckle can be seen as the dent in the fence post is lower than the final position of the buckle. The tank also showed evidence of a small top-course buckle. The attached pipes of the tank were repaired and the tank was returned to service on January 12, 2004.

There were six service line breaks from the underground distribution pipeline to the mobile homes. These service lines are attached to the buried pipeline, and then typically enter through the floor of the mobile home. The reason for these breaks was probably due to the inertial movement of the mobile home structure.

Figure 8. Tank with Elephant Foot Buckle

Figure 9. Buckle and Impacted Fence Post

City of Templeton

The City of Templeton water system includes four tanks, 10 wells, 40 miles of CI, AC, PVC and steel distribution pipe. The water system serves 5,400 people.

One tank is a 1966 bolted steel tank, 0.42 MG. It uplifted, and had elephant foot buckling, suffered sheared bolts, showed evidence of corrosion, and was split at its top. The tank was drawn down and taken out of service.

A second tank was built in 1967 (0.42 MG). This tank used rubber bellows (Super-Flex) for flexibility to attached pipes. This tank suffered no damage, although there was apparent up and down movement of the bellows due to tank wall uplift.

A third tank was built in 1998 (1 MG), designed to AWWA D100, and used EBAA Iron flextend couplings for attached pipelines. The tank was also anchored to a foundation. The tank suffered no apparent damage, but some cell phone antennae attached to the tank were damaged.

A fourth tank (0.86 MG) is a steel tank, designed per AWWA D100. It suffered no damage.

There was no reported damage to the wells or the buried pipelines.

Morro Bay Water System

The City of Morro Bay is located along the Pacific Ocean. It was reported (but not confirmed by this team) that there were a few pipeline breaks, and one of the local distribution tanks suffered a leak.

We observed 4 bolted steel tanks at one location. All four were at grade on concrete foundations, with hard-piped side entry pipes. There was no damage, although there were several very slight leaks at some bolted connections (could have been the case pre-earthquake). The ground level shaking at this site was likely under PGA = 0.10g.

DWR Coastal Aqueduct

The California Department of Water Resources owns and operates the California Coastal Aqueduct. This Aqueduct draws raw water from canal in the Central Valley (no damage), pumps it via four pump stations over the Coastal Hills (no damage), treats it (no damage to the water treatment plant). The pipeline segment traverses the San Andreas fault, where there was observed some slight weeping of water and requiring the tightening of a Dresser coupling; a couple of air valves along the pipeline needed help reseating.

Calpine King City Power Plant

Calpine owns and operates a 150 MWe gas-fired power plant in King City. Ground motions at this site were likely no more than PGA = 0.10g. At the time of the earthquake, the plant was in operation; the plant suffered no damage, and did not trip off line. There are two at-grade welded steel anchored water tanks at this site (each 68,000 gallons). Both suffered no damage. Site water is provided from two wells located about a mile from the plant; neither the well or pipeline suffered any damage. Some sloshing of water in tanks was noted at the plant.

Morro Bay Power Plant

Duke Energy owns and operates a gas-fired power plant in Morro Bay. The plant includes two water tanks. Neither water tank was known to be damaged by the earthquake. At the time of the earthquake, this plant was not operational.

San Ardo Oil Field

The San Ardo experienced light levels of ground shaking in this earthquake. The oil field currently produces about 12,000 barrels of oil per day. The field included more than 20

at-grade welded steel tanks with capacity more than 400,000 gallons, none of which was reported to have leaked or suffered any other damage.

Oil from this field used to be transported to Morro Bay via three pipelines. The alignment traverses the areas with highest levels of ground shaking. These pipelines were taken out of service a few years ago, but are maintained and pressurized with nitrogen (corrosion control) at 15 psi to 20 psi). The pipes are 4", 6" and 10/12" diameter butt welded steel pipelines, typically buried with two or three feet of cover. Immediately after the earthquake, the alignment was overflown, with no observation of damage or landslide across these pipes. Nitrogen pressure was maintained, suggesting no leaks.

Fires

There were no fire ignitions in Paso Robles from this earthquake. It was reported that there were three ignitions in the City of Atascadero, located about 10 miles south of Paso Robles.

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Background

The Paso Robles M 6.5 earthquake occurred at 11:16 am PST, December 22, 2003. It struck in San Luis Obispo County (SLO). County-wide population is 217,000 people (1990 census) with 80,300 households, 90,200 housing units (median value $215,000), 10700 mobile home units.