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MITIGATION OF FAULT RUPTURE HAZARD TO WATER MAINS OF A MAJOR METROPOLITAN IN THE SAN FRANCISCO BAY AREA

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SUMMARY

The City of Hayward is located in an area of high seismic hazard, primarily because the Hayward Fault runs through the center of the city. The Hayward Fault is one of the most active faults in the San Francisco Bay Area, and has an estimated probability of 28% of a major earthquake in the next 30 years. The expected size of such an event is Magnitude 7.0 with fault rupture displacement ranging between 4 to 6 feet (1.2 to 1.8 meters). The City has a number of transmission and distribution water pipelines, with limited displacement and rotational capacity, which will be subject to fault rupture hazard.

The purpose of this work was to improve the reliability of water supply for critical tasks such as fire fighting and providing drinking water following a major earthquake on the Hayward Fault. The project focused on developing cost effective and practical solutions that would result in a reliable supply of water for emergency operations immediately following the earthquake. Because of the uncertainties associated with earthquakes and the need for a highly reliable solution, the proposed mitigation scheme was based on accepting damage at the fault rupture locations and developing strategies and tools that the City could use rapidly in a time of emergency and chaos that typically follows a major natural disaster. To ensure a continued water supply immediately following the earthquake, the approach consisted of a combination of pipeline replacement and developing a scheme to isolate and bypass damaged pipelines.

For the mitigation scheme to be successful, detailed information is needed on the amount and distribution of fault displacements at the fault crossing, uncertainty in the estimates of fault displacement, the number of fault traces within the fault zone, the width of the shear zone at the fault, the impact of long-term fault creep, and the depth and strength of surface sediments overlying the fault. Therefore, prior to developing the mitigation scheme, detailed mapping of the fault was performed through field reconnaissance,

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evaluation of pre-development aerial photographs and an extensive literature search on fault trenching, historic mapping of the fault and geologic and geotechnical investigations within the fault zone.

INTRODUCTION

The City of Hayward lies within the greater San Francisco Bay region, located along the broad boundary between the North American and Pacific tectonic plates. Lateral motion along the plate boundary is expressed as a nearly 50-mile-wide zone of northwest-trending, near-vertical strike-slip faults, with the predominant ones being the San Andreas, Hayward-Rodgers Creek, Calaveras, and San Gregorio faults (Figure 1). The study area included in this project consists of a northwest-southeast trending zone represented by the Hayward Fault, which bisects the City of Hayward. The northernmost extent of the study area is approximately located at the intersection of Mission Boulevard and Grove Way. The southernmost extent of the study area is located just south of Treeview Elementary School near the intersection of Janice Avenue and Faircliff Street. The approximate boundaries of the study area are shown in Figure 2.

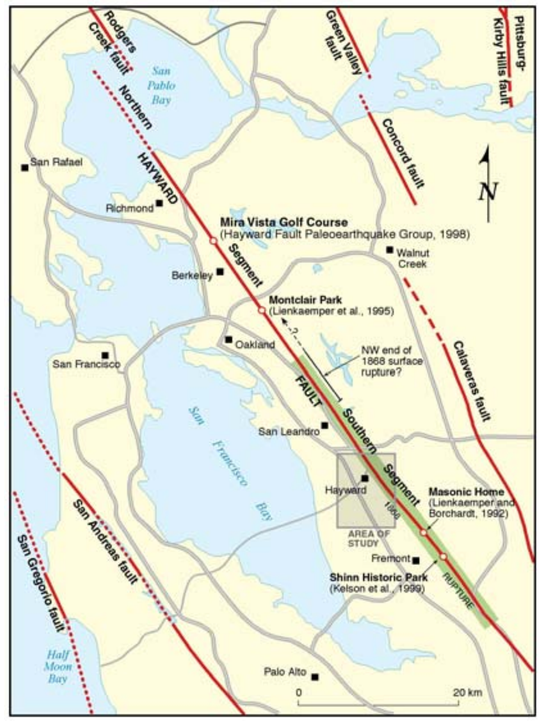


Figure 1: Hayward Fault Regional Map

Within the city limits, the City of Hayward has a total of 46 water pipelines that cross the Hayward Fault. In addition, one of the main pipelines bringing water into the City (the 24-inch Mission Boulevard pipeline), crosses the fault at Nursery Avenue in the City of Fremont, located south of the City of Hayward. Pipelines crossing the Hayward Fault range in size from 4 to 24 inch and consist predominantly of asbestos cement pipes with some cast iron, ductile iron and PVC pipes. All of the pipelines have bell and spigot joints with limited displacement and rotational capacity. As the total fault displacement associated with a large earthquake on the Hayward Fault is expected to be on the order of 4 to 6 feet, significant damage and disruption of water service during the critical hours following the earthquake are considered highly likely. The purpose of this project was to increase the reliability of the water system, specifically with respect to fault rupture hazard. The City of Hayward is also involved in other reliability improvement projects, which are not discussed in this paper.

HAYWARD FAULT

The Hayward Fault borders the eastern margin of the East Bay hills in the eastern San Francisco Bay area, and is a major component of the Hayward-Rodgers Creek fault system. It extends from near Warm Springs, Fremont on the south to San Pablo Bay on the north (Figure 1), with a total fault length of about 60 miles (Lettis [1]). The fault exhibits a long-term slip rate of 9 to 10 mm/yr (Prescott [2]; Lienkaemper [3]; Lienkaemper [4]), which is one of the highest rates of all the faults within the San Francisco Bay region, and thus poses the greatest danger to local communities in the East Bay (WGNCEP [5]).

The fault is divided into northern and southern segments, each approximately 30 miles long (WGCEP [6]). The northern segment of the fault extends from Oakland to San Pablo Bay, and the southern segment, which traverses the City of Hayward, extends from Oakland to Fremont. Segmentation of the fault is based, in part, on the occurrence of the 1868 rupture (M_w ~ 7.0) along the southern Hayward

Fault, as well as the probable timing of past earthquakes on the northern Hayward and Rodgers Creek faults (WGCEP [6]).

Investigations of paleo-earthquake timing at the Tule Pond site in Fremont (Lienkaemper [7]), Shinn Historic Park (Kelson [8]), previous investigations in the City of Fremont by Williams [9] and work done by WGCEP [6] suggest that large earthquakes exhibiting surface rupture have an average recurrence of 150 to over 300 years. Despite the range of estimates, there is general consensus within the scientific community that the Hayward Fault may produce large, damaging earthquakes approximately every two hundred years. Because about 130 years have passed since the most-recent large rupture on the fault, there is general agreement that the fault poses a real and significant hazard to the eastern San Francisco Bay area.

Within the City of Hayward, the Hayward Fault delineates the boundary between flatlands along the San Francisco Bay margin and the western margin of the East Bay Hills. Portions of the City of Hayward east of the Hayward Fault are situated on upland foothills and moderate to steep slopes formed on bedrock of the East Bay Hills. However, most of the City is located west of the Hayward Fault on a broad alluvial plain bordering the eastern margin of the San Francisco Bay.

WATER SYSTEM

The portion of the City of Hayward located east of the Hayward Fault consists of hills that rise to about 1,500 feet above sea level. Because of this change in elevation, the water distribution system within the City is divided into different pressure zones, designated by the elevation of each zone. The majority of the City’s water distribution network is in the flat 250-foot pressure zone located west of the fault, while the hills on the east side of the fault are divided in five pressure zones. Under normal conditions, the primary source of water for the City of Hayward is from the San Francisco Public Utilities Commission (SFPUC) Hetch Hetchy system through the 24-inch Mission and 42-inch Hesperian pipelines. Before entering the City, the Mission line crosses the Hayward Fault at Nursery Avenue in the City of Fremont. Within the City of Hayward, both the Mission and Hesperian lines are located west of the fault and are not subject to fault crossing hazard. Figure 2 and Figure 3 show the distribution schematic for the City of Hayward water system.

Water from the Mission and Hesperian pipelines located in the 250 foot pressure zone is pumped across the Hayward Fault to thirteen storage reservoirs located within the different pressure zones in the hills. The storage capacity provided by the reservoirs is critical for the City. The City also has five wells located along its western margins that can provide additional sources of water.

The water lines crossing the fault consist of four main transmission lines that feed the storage reservoirs and 42 distribution lines for general water supply. The transmission lines include a 24-inch line, a 16-inch line and two 12-inch lines. The distribution lines range in size from 4-inch to 12-inch pipelines. Except for the 24-inch transmission line that run through a park at the fault crossing location, all other transmission and distribution pipelines run beneath city streets together with other utilities. The backfill for pipeline trenches is well compacted and designed to carry full traffic load, thereby providing lateral restraint to the pipelines and making them vulnerable to relative displacement caused by fault rupture.

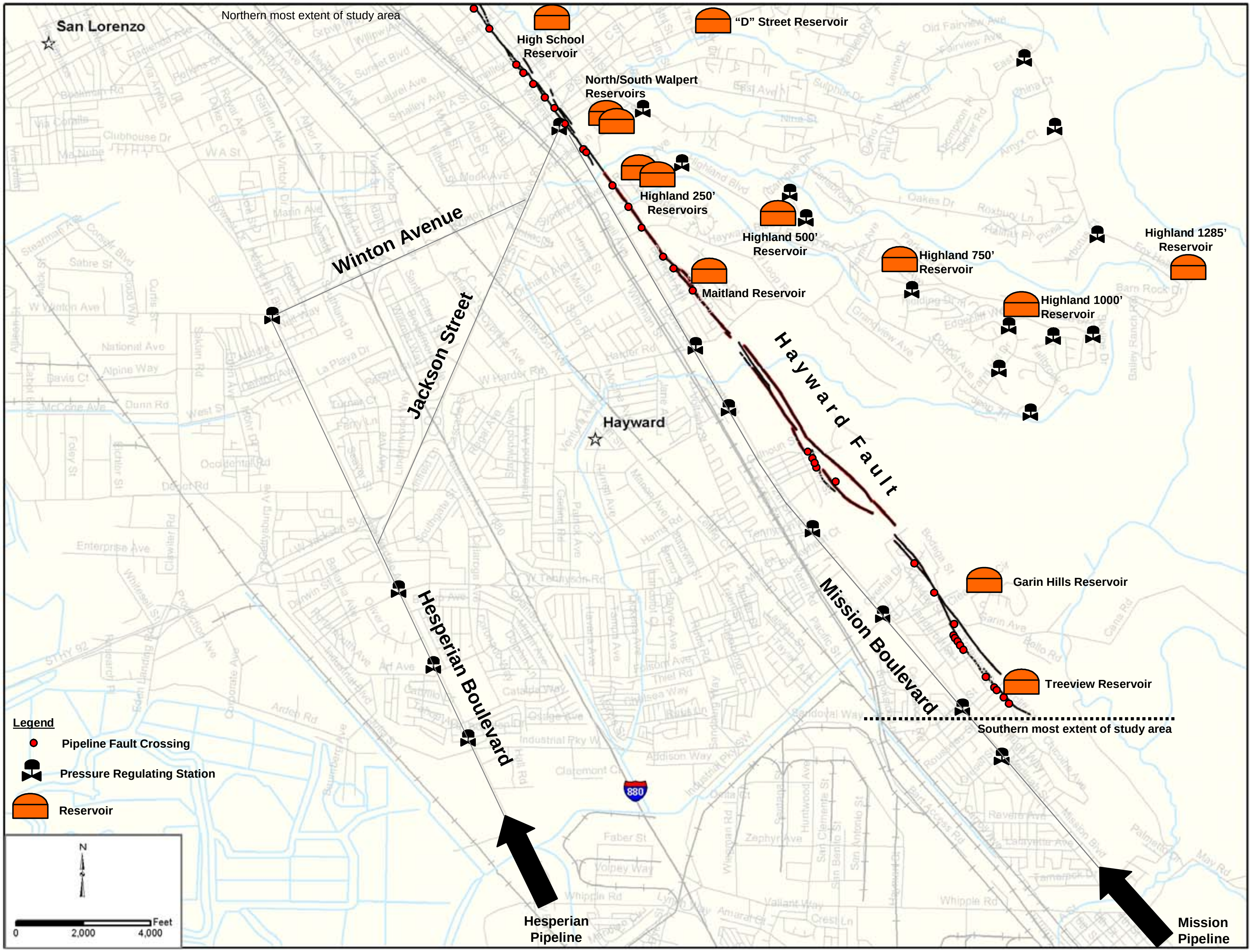


Figure 2: City of Hayward Water System Layout

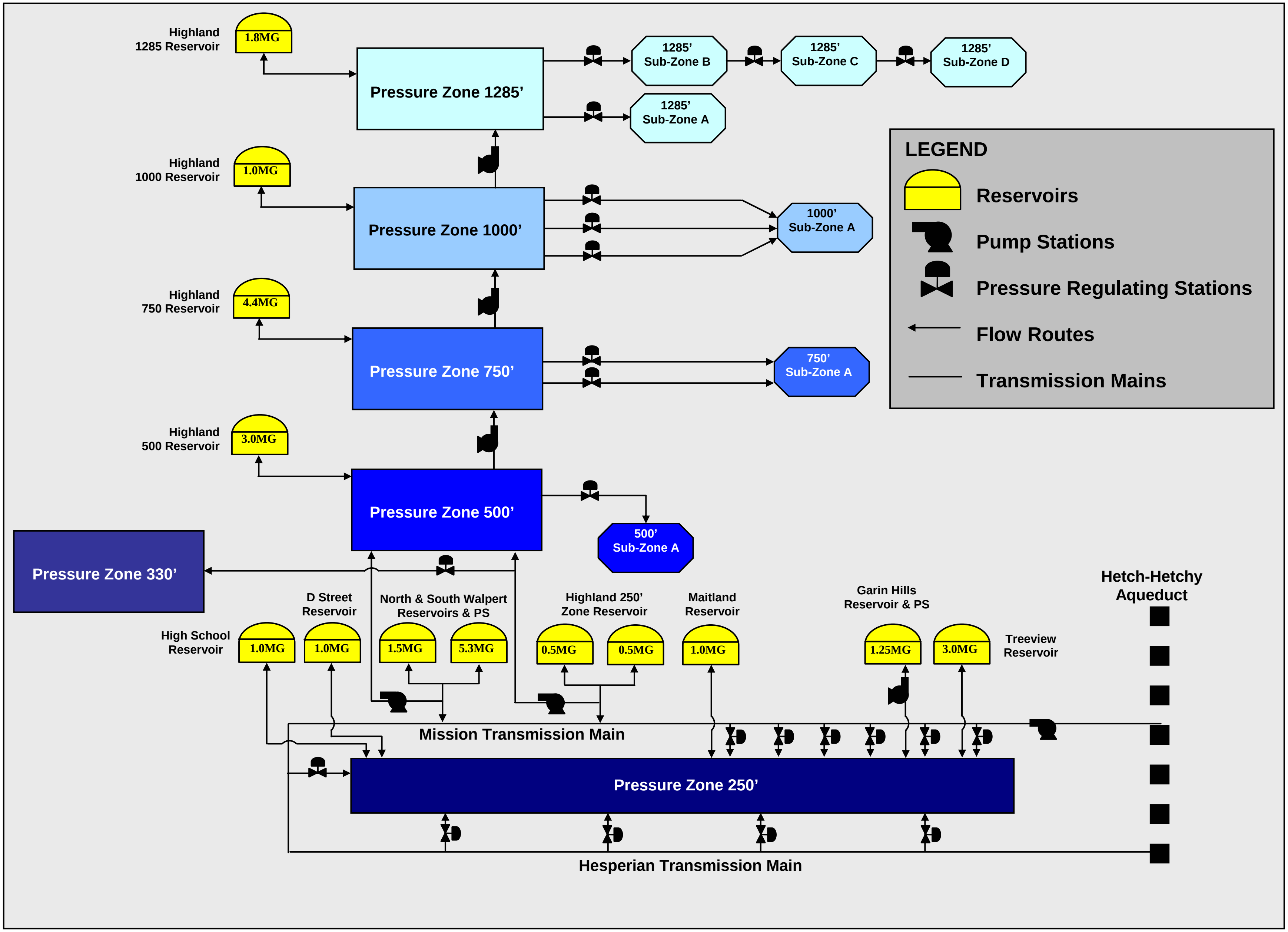


Figure 3: City of Hayward Water System Schematic

APPROACH

The approach used for the project included detailed mapping of the fault so that the location of pipeline fault crossings could be accurately defined. The fault map was incorporated with the City of Hayward water system maps in the ARC/GIS Geographical Information System. A reliable mitigation scheme could be developed both efficiently and reliably because of the accurate spatial representation of the fault relative to the street layout and the water system, which included pipelines, valves and fire hydrants.

Fault Characterization

Within the City, the Hayward Fault has been designated active by California Geological Survey (CGS) (CDMG [10]) under the Alquist-Priolo Fault Zoning Act, State of California legislation designed to mitigate the risk from surface fault-rupture hazard. Because of the regulatory nature of the Act, the CGS mapping is conservative, showing all possible traces of the Hayward Fault, creeping and non-creeping as well as active and potentially active.

Since it was necessary for this project to locate the fault with a high degree of confidence, several other sources of data, in addition to CGS maps, were compiled and analyzed to locate and characterize active creeping and non-creeping traces of the fault. These data sources included mapping by the United States Geological Survey (USGS) of the 1868 surface rupture (Radbruch-Hall [11], [12]) and mapping of actively creeping fault traces through the City (Lienkaemper [13]). Specifically for this project, we also compiled data from over twenty years of detailed geotechnical Alquist-Priolo site investigations.

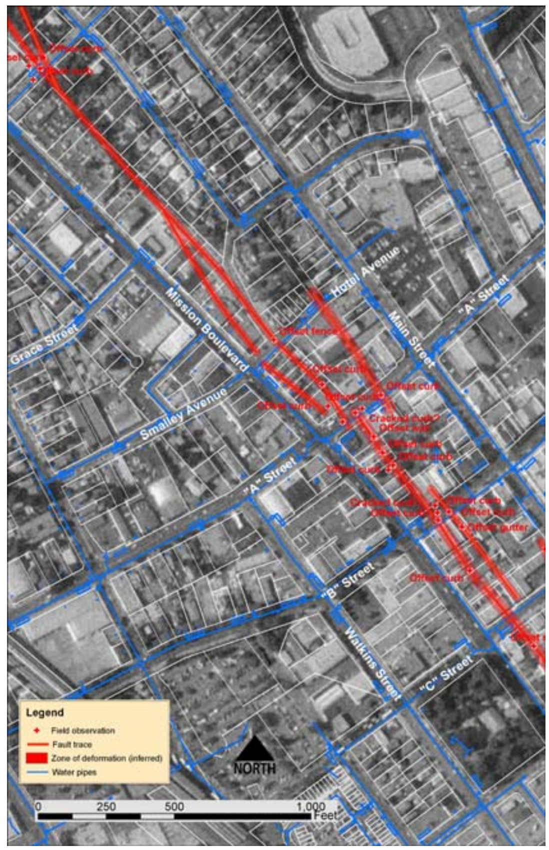


Figure 4: Hayward Fault Mapping

The information obtained on the Hayward Fault was verified and updated through independent mapping of active and potentially active fault traces through detailed field reconnaissance and examination of predevelopment (1930- and 1940-vintage) stereo aerial photographs, an example of which is shown in Figure 4. The fault traces were identified on the basis of distinctive geomorphic landforms such as linear ridge fronts, sag ponds, and observed lineations. In particular, the available information was interpreted to identify the location of single or multiple fault traces likely to rupture at pipeline crossings. Field reviews were made of previously mapped fault traces for evidence of creep as manifested by bowed curbs and cracked pavements as presented in Figure 5. Independent mapping of the fault traces was also necessitated because the CGS and USGS mapping was completed at small scale (1:24,000-scale), which can result in fault trace lines on the map representing a width of about 25 feet on the ground.

For field investigation, a Personal Digital Assistant (PDA) linked with a Geographical Positioning System (GPS) was used for collecting data in the field. Accurate location information of features defining the fault was acquired directly into the PDA from the GPS receiver using specifically designed PDA software. The PDA allowed for direct synchronization of collected information with the Geographical Information System (GIS) database. Data from the PDA was downloaded to the office PC through a "hot

Figure 5: Creep Exhibited by Hayward Fault

sync" with the PDA. Detailed data on the location and geometry of the fault, width of the fault zone, intersection angle between the fault and the pipelines, magnitude of surface fault displacement and presence of surface creep were included in the GIS database. The field setup of the PDA and GPS is shown in Figure 6.

The width of the deformation zone across the fault was estimated as a 50- to 100-foot zone on either side of the identified fault traces. This zone takes into account the uncertainty about the location of the fault trace, and was estimated through detailed surveying of linear features displaced by the surface rupture (e.g., alignments of trees, fence lines, walls, canals). The pipeline mitigation scheme designed for this project assumed that the pipe break could occur anywhere within this zone. The width of the fault zone was considered reasonable because Rockwell [14] indicate that, in addition to the total displacement at the fault due to the primary fault rupture, as much as 15% of the total lateral slip can occur as bending or drag in a 10- to 50-foot-wide zone along the primary fault rupture. Similar amounts of near-fault bending were documented along the San Andreas Fault near Fort Ross in Sonoma County California as a result of the 1906 San Francisco earthquake (Lawson [15]).

Figure 6: PDA/GPS Setup Used for Fault Mapping

Classification of Pipelines

The water system schematic in Figure 2 shows that two main pipelines, the 24-inch Walpert line and the 16-inch Palisade line, serve nine out of the eleven storage reservoirs and the 12-inch lines along Barry Avenue and Garin Avenue serve the remaining two reservoirs. All of the transmission and the distribution lines cross the Hayward Fault just east of Mission Boulevard and are located within the 250 foot pressure zone. Of the 42 distribution lines, approximately half are considered minor: these lines typically terminate at dead end streets, have a limited service or serve areas located within the fault rupture zone. Because all of the fault crossings are located within the same pressure zones, it is possible to plan a bypass system by rerouting water, if needed, without significant effort.

RETROFIT SCHEME

The general street layout within the City of Hayward lies in a grid that is oriented in the northwest-southeast direction, about the same as the strike of the Hayward Fault. The orientation of the City streets relative to the Hayward Fault results in the pipelines, which essentially follow the street layout, crossing the fault at a nearly 90 degree angle. It is very expensive to strengthen the existing pipelines to reliably withstand the fault rupture hazard because of the large number of crossings, and because the pipelines are buried at least five feet below street level with compacted backfill. Various approaches for retrofit of pipelines to withstand fault rupture hazard (Lau [16], Maison [17]) were considered and discarded because of both high cost and difficulty in construction under city streets crowded with other utilities.

It is also important to note that even if a practical pipeline replacement option is identified, it will likely be necessary to replace the pipelines again following the earthquake because of the significant distortion of the pipeline subjected to large displacement caused by fault rupture. The limited practicality of mitigating the impact of fault rupture with pipeline retrofit required that we considered other alternatives that could achieve the level of post-earthquake reliability desired by the City. These alternatives accept pipeline damage but facilitate rapid isolation of damage and restoration of emergency service by relying on shut-off valves to isolate damage and by providing a means to temporarily transport water from one side of the fault to the other. This approach was considered practical and reliable because of the presence of sources of water on both sides of the fault that include storage reservoirs on the east and emergency wells and the Mission and Hesperian pipelines on the west side of the fault.

Transmission Pipelines

Buried pipelines are not subject to large inertia forces because of the confining effect of the surrounding soil. Instead, the pipelines are vulnerable to damage when they are forced to conform to the movements of the surrounding soil. These deformations result at locations where pipelines cross the fault, or in areas of large landslides or zones of high liquefaction with related settlement and lateral spreading. Ground deformations may cause concentration of loading and relative displacement, leading to the development of locally large strains in a buried pipeline. This loading imparts tensile strains and curvature to the pipeline on both sides of the fault and creates a spiral shaped failure surface in the surrounding soil (Audibert and Nyman [18]).

Damage mechanisms for continuous pipelines include tensile failure, local buckling or wrinkling leading to circumferential cracking, buckling of a large length of the pipeline and failure at the welded joints; these mechanisms depend predominantly on the angle of pipeline fault crossing and the strength and quality of welds. If the inclination of the pipeline relative to the fault is such that the fault movement introduces tension rather than compression or bending in the pipeline, and if the joints have sufficient strength to accommodate this load, the pipeline can withstand the fault displacement without rupture and maintain its pressure integrity. However, the pipeline undergoes severe distortion and may require repair or realignment after the earthquake. A welded steel pipeline with sufficient ductility can accommodate relatively large strains if it is in good condition and the girth welds are capable of developing full yielding of the pipe cross-section. High ductility allows for a more uniform distribution of strain and lessens the likelihood of local tearing of the pipe wall. As a result, continuous pipelines under longitudinal tension with joints capable of developing full yield stress of the pipe buried in loose, shallow backfill, which allows the pipeline to more easily displace the surrounding soil, are very likely to withstand large ground deformations. Therefore, retrofit of the four transmission lines and the Mission pipeline fault crossing at Nursery Avenue was considered as an option.

Analytical Assessment

Detailed non-linear finite element analyses of the transmission pipelines were performed using the ANSYS [19] analysis package to evaluate the possibility of replacing the existing lines with new lines that could accommodate the fault rupture displacement.

The finite element analyses utilized a straight pipe plasticity element (PIPE20) and a nonlinear spring element (COMBIN39) of ANSYS to model the pipeline and surrounding soil. PIPE20 is a uniaxial element with tension-compression, bending, and torsion capabilities. It has six degrees of freedom at each node with plastic, creep and swelling capabilities. PIPE20 element is assumed to have "closed ends" so that the axial pressure effect can be modeled. COMBIN39 is a unidirectional element with nonlinear generalized force-deflection capability. It has large displacement capability and can have two or three degrees of freedom at each node.

The finite element models were developed based on a review of the pipeline alignment at the location of each fault crossing. The total length of the pipeline models ranged from 550 feet to 600 feet. For all analyses, the fault displacements were assumed to occur as abrupt offsets of the ground surface. It was also assumed that all replacement pipelines would be constructed of API 5L Grade X65 steel pipe with full-penetration girth welds consistent with quality requirements for high-pressure natural gas service. The results of the analysis showed that the 24-inch Walpert line with a wall thickness of 0.625 inch had a maximum tensile strain of less than 1%, and the 16-inch Palisade line with wall thickness of 0.5 inch had a maximum tensile strain of 2% for 10 feet of imposed displacement. These strains are well within the 4% tensile strain limit for maintaining pressure integrity established for the analytical assessment. Similar analysis of the 24-inch Mission Boulevard pipeline fault crossing at Nursery Avenue was also performed. The analysis showed that an API 5L Grade X65 replacement pipeline with a wall thickness of 0.5 inch would be able to withstand the expected fault displacement. On the other hand, analysis results showed that the Barry Avenue and the Garin Avenue line would sustain unacceptably large strains from the imposed fault displacement. These large strains were a result of the need to have horizontal and vertical bends near the fault crossing.

Design Recommendations

Welded steel pipe such as that used for high-pressure gas lines was selected for the retrofit of the main transmission lines because of the reliable historic performance of such lines under large ground deformations. The design was confirmed through a detailed non-linear finite element analysis. The selection and specification of both pipe and welding for a strain-based design of replacement pipelines included consideration of a number of factors that are typically not used for a conventional stress-based design in various codes and standards. Specifications for the replacement steel pipelines for this project included requirements for pipe yield to tensile strength ratio, weld material strength, pipe and weld toughness, and radiographic inspection and weld acceptance criteria.

Distribution Pipelines

The basic philosophy behind the mitigation strategy for the distribution pipelines was to isolate and bypass pipelines damaged due to fault rupture. The distribution pipelines were divided into two groups: those requiring isolation and those requiring bypass. The lines that terminated into dead end streets or had a limited service area were recommended for isolation by shutting the water supply at the nearest valve located upstream of the fault rupture to prevent bleeding of the system in the critical hours following the earthquake. If the valve was at a significant distance from the fault rupture, it was recommended that a new valve be placed so as to minimize service interruption to parcels outside of the immediate fault rupture zone (50 to 100 feet from the zone of excessive deformation).

The mitigation strategy for the remaining distribution lines was to isolate and bypass the damaged section of the pipelines. Valves upstream and downstream of the fault rupture were identified as isolation valves. To the extent possible, existing valves were identified as isolation valves; however, if the existing valves were at a significant distance from the rupture zone, new isolation valves were recommended.

Detailed information identifying the mitigation scheme, location of isolation valves and the size and location of bypass pipelines was added to a set of the City of Hayward water maps. The intention is that these maps will be available to the City's field crew who can, within a short period of time, isolate the damage so that there is a minimal loss of water. Immediate fire fighting operations can commence on the upstream side of the fault using water from the storage reservoirs and on the downstream side of the fault from water delivered through the Mission and Hesperian aqueducts and the emergency wells.

The City has ongoing projects to retrofit the storage reservoirs, and is also working on other redundant sources of water supply on the west side of the fault. In addition, other initiatives are under way in the Bay Area to improve the reliability of the Hetch Hetchy water system. When implemented, these measures, together with the mitigation scheme to address the fault rupture hazard, will result in reliable water service to the community following a major earthquake on the Hayward Fault.

Once the immediate need for water in the critical hours following the earthquake has passed, the storage reservoirs would be replenished by transporting water across the fault through 5-inch potable water hoses connected to fire hydrants on opposite sides of the fault. The mechanics of this operation were incorporated in an Immediate Response Plan (IRP) that was developed to become part of the City of Hayward's Emergency Response Plan. The required length and the storage site for flexible hose is identified on the IRP maps for each pipeline fault crossing. For ease of operation, it has been recommended that the City maintains hoses in standard lengths of 100 feet and 50 feet at a location that will be accessible to the crew performing temporary restoration of service during the days following the earthquake.

IMMEDIATE RESPONSE PLAN

The purpose of the Water IRP is to restore water service to the City, as soon as practical following an earthquake - primarily for fire fighting purposes and secondarily for domestic consumption. The Water IRP is an emergency measure and is meant to provisionally restore water service before permanent repairs are made to the damaged water lines.

The mitigation scheme under the Water IRP calls for isolating the sections of the water pipelines that are damaged due to large surface fault rupture. Isolation of damage will prevent the loss of water reserves that will be needed for fire fighting immediately following the earthquake. Once the immediate emergency is over, water service to the City is provisionally restored by bypassing the damaged sections of pipelines through 5-inch potable water hose connected to water hydrants on either side of the damaged pipeline.

The Water IRP is a two-step process that includes "Damage Identification and Isolation" as Step 1 and "Provisional Service Restoration" as Step 2. The Water IRP maps identify the isolation valves used to interrupt the uncontrolled release of water from the damaged sections of the pipeline and the bypass hydrants for subsequent service restoration. Sample maps are shown in Figure 7.

The IRP requires that immediately following the earthquake, the City of Hayward Public Works designate an emergency response manager who will form an Initial Reconnaissance Team (IRT). The timing for forming the IRT and its composition will depend upon the time of the occurrence of the earthquake (for example daytime, night time or during a rush hour). Planning for designation of members of the IRT will begin as soon as possible to facilitate rapid formulation of the IRT after the earthquake.

The IRT will be deployed from the City of Hayward's designated Emergency Operations Center (EOC) within the first few hours after the earthquake. It is responsible for locating and isolating damaged sections of the water lines by closing the primary isolation valves identified on the Water IRP maps. The primary isolation valves shown on these maps will shut off water supply along the designated pipelines identified on the maps. If the damage is limited to a few, but not all, of the identified pipelines on the

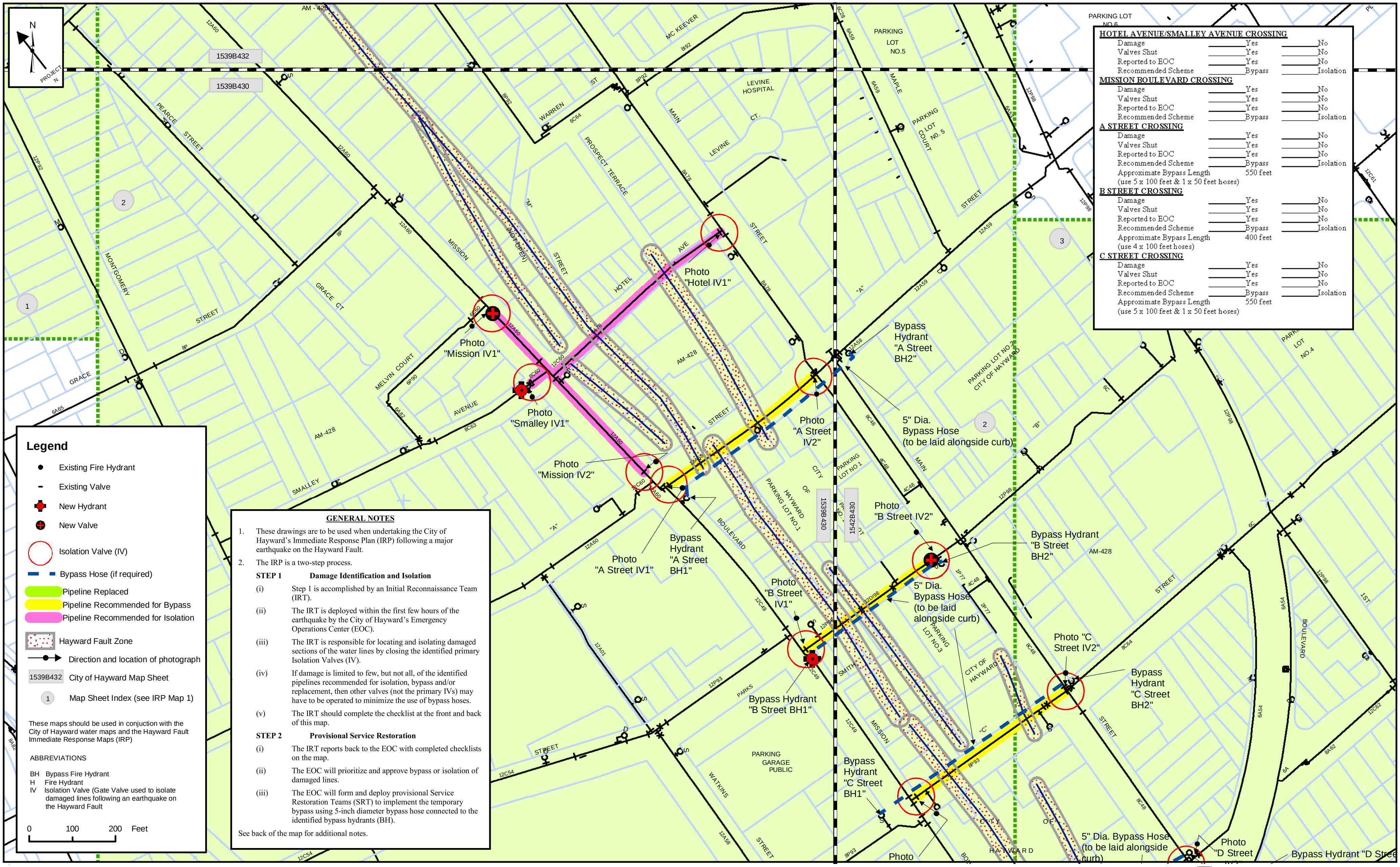
Water IRP maps, then other valves (not the Primary isolation valves) may have to be operated to not shut off water service unnecessarily along the pipelines that were not damaged. The IRT is responsible for noting any conditions such as road closures, debris, damaged bypass hydrants or isolation valves and downed power or gas lines that may hamper the subsequent service restoration through bypass hoses.

Because of the relatively large extent of the area covered by the City of Hayward water system, it has been recommended that the EOC consider forming a number of IRTs. For example, if the City has enough resources, three IRTs are preferable, one each for the northern, the central and the southern sections of the City. Due to the importance of the transmission lines along Walpert Street, Palisade Street, Berry Avenue and Garin Avenue, the IRT responsible for the corresponding section of the city would first review the status of these lines and then the remaining lines within its section. Flexibility in the plan is provided to allow the EOC to adopt a different prioritization sequence of damage identification and isolation based upon the actual circumstances following the earthquake.

Based on the data collected by the IRTs in the field and the recommendations included in the Water IRP maps, the EOC will plan for Step 2, “Provisional Service Restoration,” which includes a decision to bypass the damaged lines or to keep them isolated and the prioritization of the bypass operation. The EOC will then form and deploy Service Restoration Teams (SRT) to perform the bypass operations.

CONCLUSIONS

The City of Hayward is located in an area of high seismic hazard due to the presence of the Hayward Fault that runs through the center of the city. The Hayward Fault has a very high probability of producing an earthquake as large as Magnitude 7.0 with expected fault rupture displacement in the next 30 years. Within the City of Hayward, a number of water pipelines cross the fault and, therefore, have a high likelihood of rupture during a major earthquake of the fault. A cost-effective mitigation strategy against fault rupture hazard was developed to increase the reliability of the system to provide water for critical functions immediately following the earthquake. The proposed mitigation scheme will also provisionally restore service for some time after the earthquake until permanent repairs are made to the system and the existing pipelines realigned to accommodate the fault displacement. The scheme includes recommendations for pipeline design that can withstand the expected fault displacement for the most critical pipelines and a plan for damage isolation and bypass using flexible hose, fire hydrants and standard isolation valves. A detailed immediate response plan was also developed to execute the proposed mitigation recommendations as soon as practical following an earthquake. The City is currently in the process of implementing these recommendations.



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HAYWARD

Water IRP Map B

Figure 7: Water Immediate Response Plan - Typical Sheet (Front)

Water IRP Map B

Inspector's Name_______________________ Date:_______________ Time:_______________

EQUIPMENT/TOOLS CHECKLIST

_____Standard Field (Tools/Safety) Equipment _____Valve Operating Tools _____Debris Removal Tools _____Backup Communication
_____Drinking Water _____Snacks/Food _____Portable Toilet _____Extra Batteries

OBSERVATIONS

Report any observations that may hinder bypass operation or would prevent the bypass operation without first being mitigated.

Location Accessibility (Y/N) Vehicular Access (Y/N) Debris (Y/N) Downed Power Lines (Y/N)
Broken Sewer Lines (Y/N) Gas Leaks (Y/N) Damage to Hydrants (Y/N) Damage to Valves (Y/N)
Road Closures/Alternate Routes ______________________________
Additional Comments (if any) ______________________________

EMERGENCY CONTACTS

EOC ___________(Phone) ___________(Radio) Fire ___________(Phone) ___________(Radio)
Police ___________(Phone) ___________(Radio) PG&E ___________(Phone) ___________(Radio)

GENERAL NOTES

1. Bypass hose location – Emergency Equipment Building at the City Corp Yard, Hayward, CA
2. Traffic Impacts – Isolation valves are located on the street, temporary lane closure required for valve operation.
3. Bypass is a temporary measure, low water flow rate should be expected

Additional Notes and Comments:______________________________

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HAYWARD

Water IRP Map B

Figure 7 continued: Water Immediate Response Plan – Typical Sheet (Back)

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