Humboldt Bay Municipal Water District

Feasibility Study

Construction of a Secondary Pipeline Across the Mad River to Supply Water to Fieldbrook and Blue Lake

April 2016

Executive Summary

Introduction

The Humboldt Bay Municipal Water District (HBMWD or District) currently supplies domestic water to the Fieldbrook-Glendale Community Services District (FGCSD) and the City of Blue Lake (Blue Lake). The water supply pipeline to these communities crosses the Mad River via a 14-inch ductile iron pipeline attached to a North Coast Railroad Authority (NCRA) bridge (see Figure 1 for location). The bridge has not been used or maintained by the railroad for many years, and if it fails, it would likely damage the District's pipeline and interrupt the sole domestic water service to FGCSD and Blue Lake. An inspection of the NCRA bridge was completed by Winzler & Kelly in December 2007, and the bridge was found to be in substandard condition and near the end of its functional life (see Appendix A for this report). Because of these issues, the District is assessing alternatives to the existing crossing to supply domestic water across the Mad River to the communities of Fieldbrook, Glendale, and Blue Lake.

Based on previous studies of potential solutions to this problem, two alternatives were selected for consideration in this analysis:

- Alternative 1 – Horizontal Directional Drilling Under the River
- Alternative 2 – Suspended Waterline Over the River

A recently completed geotechnical study was required to refine the feasibility and cost of both of these alternatives. This geotechnical study, along with recent environmental and cultural resource investigations and updated estimates of probable construction costs, allowed for an analysis of the advantages and disadvantages of both alternatives and the selection of a final recommended alternative. Both alternatives are in close proximity to the existing crossing on the railroad bridge. Roscoe and Associates performed a cultural resources investigation in the spring of 2014 and determined that significant archaeological resources are present within the project area (see Figure 2 and Figure 3 for the cultural site extents). The alternatives were developed so that impacts to this area would be avoided.

Environmental Investigations

Several environmental investigations have been recently completed for this project in support of the preparation of the National Environmental Protection Act (NEPA) and California Environmental Quality Act (CEQA) permitting requirements for the final project and to feed into this final Feasibility Study for the selection of the final preferred alternative. These reports were submitted under previous covers and include:

1. *A Cultural Resources Investigation of the Mad River Pipeline Crossing for the HBMWD*, Roscoe and Associates, September 2014.
2. *Blue Lake/Fieldbrook-Glendale CSD Pipeline Mad River Crossing, Biological Evaluation*, GHD, September 2014.
3. *Blue Lake/Fieldbrook-Glendale CSD Pipeline Mad River Crossing, Wetland Delineation*, GHD, September 2014.
4. *Hazardous Materials Corridor Study, HBMWD, City of Blue Lake/Fieldbrook-Glendale CSD Pipeline Mad River Crossing,* GHD, Sept 2014.
5. *Addendum to Roscoe and Rich (2014)–Archaeological testing at the Area of Potential Effect for the Mad River Pipeline Crossing Project*, Feb. 2, 2015

The biological, wetland, and hazardous material investigations did not reveal any rare plant species or wetlands that would be directly impacted by either alternative. The vegetation on the majority of the project site is riparian vegetation, and either alternative would need to address and permit impacts to this vegetation with the appropriate regulatory agencies. Work within the river channel, which would be required if Alternative 2 (Suspended Waterline) was implemented, would require extensive permitting and mitigation measures with several regulatory agencies.

The largest site constraint identified during the environmental investigations was the expansion of a previously identified cultural resource site to areas within the project site. Potential impacts to this site heavily influenced the feasibility of the evaluated alternatives. The outlines of the cultural resource site are shown on associated Figures within this Report.

Geotechnical Investigation

Crawford & Associates (CAInc) conducted a geotechnical study at the Mad River crossing site in 2015 and generated an associated Geotechnical Report (Appendix D).

The main findings of the preliminary geotechnical investigation include the following:

- The four exploratory borings that were drilled (two on each side of the river) each encountered similar soil and rock layers. A few feet of fill materials from the old railroad ballast were underlain by 2 to 12 feet of terrace alluvium deposits consisting of stiff to very stiff clay, sandy clay, and dense clayey sand with varying amounts of gravel up to 30-40%. Below the terrace deposits, there were 3 to 6 feet of residual soil from advanced weathering of the bedrock below. Beneath the residual soil were 5 to 12 feet of weathered meta-argillite bedrock, followed by fresh bedrock to the maximum depth of each boring.
- Fault mapping from the California Geological Survey and United States Geological Survey indicate that the potential for fault rupture at the project site is generally low. However, there is an Earthquake Fault Zone to the south of the project site, and there is potential that there is an active thrust fault crossing the site.
- Liquefaction potential is considered to be generally low due to the cohesive nature of the soils at the banks.
- There is potential for seismic slope instability along the existing channel banks due to the steep banks and high seismic ground motions. This hazard will require further consideration during the final design process.
- Both the aerial crossing and HDD options appeared to be viable alternatives.

HDD Alternative

Bennett Trenchless Engineering (BTE) investigated the feasibility of multiple trenchless methods for installing a pipeline underneath the Mad River. It was determined that HDD is the sole feasible, practical, and cost-efficient method for completing a trenchless crossing for this project. HDD is a trenchless construction method in which a pipe is installed along an arcing drill path, beginning and ending at entry and exit pits, respectively, and passing under the conflicting feature (in this case, the Mad River). A drill rig is set up on the entry side and drills a pilot bore to the exit point. The pilot bore is then reamed in one or more passes to the size required for pullback of the prefabricated pipe string that is laid out on the exit side. After reaming is complete, the pipe is pulled into the bore, preferably in one continuous operation.

A bentonite-based drilling fluid is used in the HDD process to aid in excavation of the soil, carry the cuttings from the bit back to the drill rig, provide hydrostatic support to the otherwise unsupported borehole, and to cool and lubricate the drill pipe and tooling during drilling. The risk of inadvertent fluid returns (hydrofractures or frac-outs) is an important consideration for HDD projects. This typically occurs when excess drilling fluid pressures cause fluid to escape the bore and surface through granular soils, cracks in cohesive soils, or along other natural or man-made conduits. Drilling fluid is generally a non-toxic mixture of water and bentonite clay; however, spills are viewed as an environmental risk.

According to the preliminary Geotechnical Report, depth to fresh bedrock ranges from approximately 15 to 33 feet. Because an HDD alternative would be constructed approximately 15 to 30 feet below the bottom of the river channel, it would be constructed almost entirely within fresh bedrock. Because this bore is anticipated to be drilled completely within fresh bedrock, frac-out risk is anticipated to be low, unless significant open joints, fractures, or faulting is encountered.

A conceptual HDD bore plan view is shown in Figure 2, and a conceptual HDD bore profile is shown in Figure 3.

HDD Right of way Requirements

Right of way agreements for the HDD alternative would be required for the parcels as given in Table ES.1.

Table ES.1: Alternative 1 Right of way Parcels

AP Number	Owner	Easement Type
516-241-026	NCRA	Construction
504-131-004	GR Sundberg	Construction and Permanent

HDD Environmental Considerations

Several considerations regarding permitting and agency coordination would be required for the construction of the HDD alternative:

- The NEPA process will need to be finalized to meet the funding requirements of the Hazard Mitigation Grant through the Federal Emergency Management Agency (FEMA). Minor amendments to the biological survey will need to be conducted to cover the area on the west side of the river that will need to be cleared. The Cultural Resources study may also need to be amended to include a field survey of the area to be cleared for the drilling equipment.
- The CEQA process (likely a Mitigated Negative Declaration) will need to be completed. The amendments conducted for the NEPA process will also be used for the CEQA analysis. Nesting surveys would likely also be required.
- A State Lands Commission lease and associated permitting requirements may be necessary
- California Department of Fish and Wildlife (CDFW) consultation will likely be required for the necessary vegetation clearing for the drill rig.
- CDFW, United States Army Corps of Engineers (USACE), and the Regional Water Quality Control Board (RWQCB) will all likely need to be consulted due to the possibility of frac-out of the drilling fluid under the Mad River and the performance of the drilling below the ordinary high water level.

- A Humboldt County encroachment permit will be required for the work in proximity to Warren Creek Road. If the Sundbergs, who own the property on the east side of the river, are not amenable to the pipe being laid out on their property, an encroachment permit would also be required from the County for laying out the pipe along Glendale Drive.
- A grading permit and SWPPP will also likely be required from the County.

HDD Opinion of Probable Project Cost

The total opinion of probable construction cost for the HDD alternative is $1,832,000. The total opinion of probable project cost including a final geotechnical investigation, surveying, land/right of way acquisition, final design, permitting, and construction management is $2,773,000.

HDD Maintenance and Resilience

This alternative would require very little ongoing maintenance. Because the pipe would be in bedrock and would be approximately 20 feet below the Mad River, there would be no risk of a flood or river bed scour affecting the pipeline. The lifetime of the pipe is expected to be at least 50+ years and could potentially be much longer. The pipeline could be damaged during an earthquake, but HDPE pipe is relatively flexible, and short of a rupture directly across the pipe, it is felt it would survive. Given the pipe’s embedment in the bedrock, it would likely not be impacted during any flood event.

Suspended Waterline Crossing Alternative

This alternative consists of an aerial crossing with a 14-inch diameter ductile iron pipe spanning the width of the river for a distance of approximately 560 feet. The new pipe would tie in to the existing pipe on each side of the river. A conceptual plan view of this alternative is shown on Figure 4, and a profile view is shown on Figure 3. A steel tower with concrete footings and potentially steel piles would be built on each side of the river above the floodplain elevation. From each of the top corners of the tower, 2-inch galvanized steel cables will span across the river to the opposite tower. From these cables, in a suspension bridge style, 5/8-inch diameter cables will hang down and support the ductile iron pipe at 20-foot intervals over the river. Cables will also extend from the towers away from the river on each side to buried concrete dead man anchors that would be approximately 80 cubic yards in volume. To avoid impacts to the identified cultural site, the dead man anchors on the southwest side of the river will be located west of the cultural site, approximately 110 feet from the steel tower.

Some work would have to occur from the river bars of the Mad River channel, including the placement of the steel cable and hangers and assembly and suspension of the flanged ductile iron waterline.

Access will be required on each side of the river for construction of the suspended crossing. Figure 4 shows the potential access routes and the vegetation clearing that will be required for access. Construction equipment will be able to travel on the railroad grade (previously disturbed) through the cultural site without any mitigation measures being required. At the end of the railroad grade, it will be necessary for construction equipment to encroach upon the cultural site. However, disturbance to the cultural site can be mitigated by staking down rubber mats that will be present throughout the duration of the project. At a minimum, a cultural resource monitor will need to be present overseeing the work on the west side of the river during all excavation activities. Based on final recommendations from the archaeologists, the entire area that would be disturbed may have to be fully excavated and any artifacts recovered and logged prior to the construction work being performed.

In addition, this alternative would also require access to be created to the channel for a crane and hoists to complete the placement of hangers and waterline on the tensioned cable. Construction access would include the creation of access points to the river and temporary access roads on the river bar.

Suspended Waterline Crossing Right of way Requirements

Right of way agreements for the suspended waterline alternative would be required for the parcels as given in Table ES.2.

Table ES.2: Alternative 2 Right of way Parcels

AP Number	Owner	Easement Type
516-241-024	Susmilch	Construction and Permanent
504-131-004	GR Sundberg	Construction and Permanent

Suspended Waterline Crossing Environmental Considerations

Following is a summary of the environmental requirements that would likely need to be met for the suspended crossing alternative:

- All of the permit requirements given for Alternative 1, however, it is unlikely that any additional biological work would have to be completed to finalize the NEPA/CEQA documents for Alternative 2, while this would likely be required for Alternative 1.
- Consultations will have to be conducted with the Tribes once the final construction plans are prepared to outline the potential disturbed areas in proximity to the cultural resources site, and final mitigation measures must be agreed upon prior to the performance of the work.
- Additional permits that would be required for this alternative that would not be required for the HDD alternative likely include a 1600 permit from CDFW, a 404 permit from USACE, and a 401 permit from the State Water Resources Control Board (SWRCB) to allow for river bar access that is required for the construction of the suspended crossing alternative. Given that the Mad River is a salmonid bearing stream, there will likely be multiple mitigation measures required to help ensure no take of endangered fish species.

The potential constraints and mitigation measures required to prevent impacts to the cultural resource site and the Mad River from the construction of this alternative are major considerations for this Alternative. The other great unknown for the aerial alternative is whether, and if so, how the visual impacts to the existing historic trestle structure can be mitigated. It is unclear if or how this would affect the final NEPA and CEQA analysis of the project, and it could conceivably hold up final approval.

Suspended Waterline Crossing Opinion of Probable Project Cost

The total opinion of probable construction cost for the suspended waterline alternative is $1,811,000. The total opinion of probable project cost including a final geotechnical investigation, surveying, land/right of way acquisition, final design, permitting, archaeological monitoring, and construction management is $2,918,000. This alternative will also require ongoing yearly maintenance, and the total present worth cost for this alternative was estimated to be $3,072,000.

Suspended Waterline Crossing Maintenance and Resilience

Anticipated maintenance of this crossing would include inspecting the coatings on the structure at regular intervals and performing periodic touch up to the structure coatings and the pipeline coating. The bridge would be designed to meet applicable seismic requirements and would be much more resilient to an earthquake event than the existing NCRA bridge; however, it still could be damaged during a large earthquake event. The tower footings would be placed outside of the floodplain, so it is unlikely that a flood event would cause damage. However, with its proximity to the existing trestle, damage of the existing trestle during a flood event could damage the new crossing as well. With appropriate maintenance, this suspended crossing would likely have a minimum lifetime of 50+ years. Because of its above ground exposure, this alternative would be more susceptible to vandalism or potential terrorism than the HDD alternative.

Apparent Best Project

Given the above considerations, it is recommended that the District proceed with the HDD alternative for the construction of a new pipeline across the Mad River. The initial estimated capital cost between the two alternatives ($2,773,000 for HDD and $2,918,000 for aerial) is so close as to be a minimal factor in the decision. The ongoing maintenance costs associated with the aerial crossing increases the overall present worth cost of this alternative to $3,072,000, which is a factor in this decision. However, the main reason the HDD alternative is recommended is because of reduced environmental risks to the cultural resource site, the Mad River, and the visual impacts to the existing Historic trestle.

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1. Introduction

The Humboldt Bay Municipal Water District (HBMWD or District) currently supplies domestic water to the Fieldbrook-Glendale Community Services District (FGCSD) and the City of Blue Lake (Blue Lake). The water supply pipeline to these communities crosses the Mad River via a 14-inch ductile iron pipeline attached to a North Coast Railroad Authority (NCRA) bridge (see Figure 1 for location). The bridge has not been used or maintained by the railroad for many years, and if it fails, it would likely damage the District's pipeline and interrupt the sole domestic water service to FGCSD and Blue Lake. An inspection of the NCRA bridge was completed by Winzler & Kelly in December 2007, and the bridge was found to be in substandard condition and near the end of its functional life (see Appendix A for this report). The report also identified that the main sources of vulnerability to the bridge are an earthquake or potential damage to the footings during a flood. Because of these issues, the District is assessing alternatives to the existing crossing to supply domestic water across the Mad River to the communities of Fieldbrook, Glendale, and Blue Lake.

1.1 Previous Investigations

1.1.1 Emergency Aerial Crossing Feasibility

The District has previously investigated the feasibility of an emergency aerial crossing using a temporary pipeline (see Appendix B for this report). Multiple crossing locations were evaluated. The study found that a temporary pipeline was impracticable; however, it states that a permanent, cable-supported pipeline is a feasible option to consider.

1.1.2 Winzler & Kelly 2009 Feasibility Study

In 2009, the District engaged Winzler & Kelly to undertake a feasibility study for constructing a redundant pipeline across the Mad River to supply water to FGCSD and Blue Lake (see Appendix C for this report). Five alternatives were analyzed in this study:

1. Alternative 1 – Concrete Encased Pipeline Under the River
2. Alternative 1A – Concrete Encased Pipeline Under the River with a Tie to the Collector 5 Discharge
3. Alternative 2 – Trenchless Method Under the River (Microtunneling)
4. Alternative 3 – Suspended Waterline Over the River
5. Alternative 4 – Improvement of the Existing Railroad Bridge Crossing

Each of the above alternatives was analyzed with respect to constructability, right of way requirements, environmental permitting considerations, and cost. The study generated an opinion of probable cost for each alternative. The suspended waterline crossing alternative had the lowest apparent project cost ($1,550,000). This alternative; however, would likely also have a significant ongoing maintenance cost. The maintenance cost was estimated at $5,000 per year, assuming minor painting annually and major painting every five years. A 50-year lifetime and 8% interest rate were assumed to determine a present worth cost for the maintenance, which calculates to be $61,200, for a total present worth cost for this alternative of approximately $1,611,200. This total present worth cost was still less than the cost for the other alternatives that were analyzed. The report recommended that the District include a suspended crossing in their Capital Improvement Program and begin planning for funding this alternative.

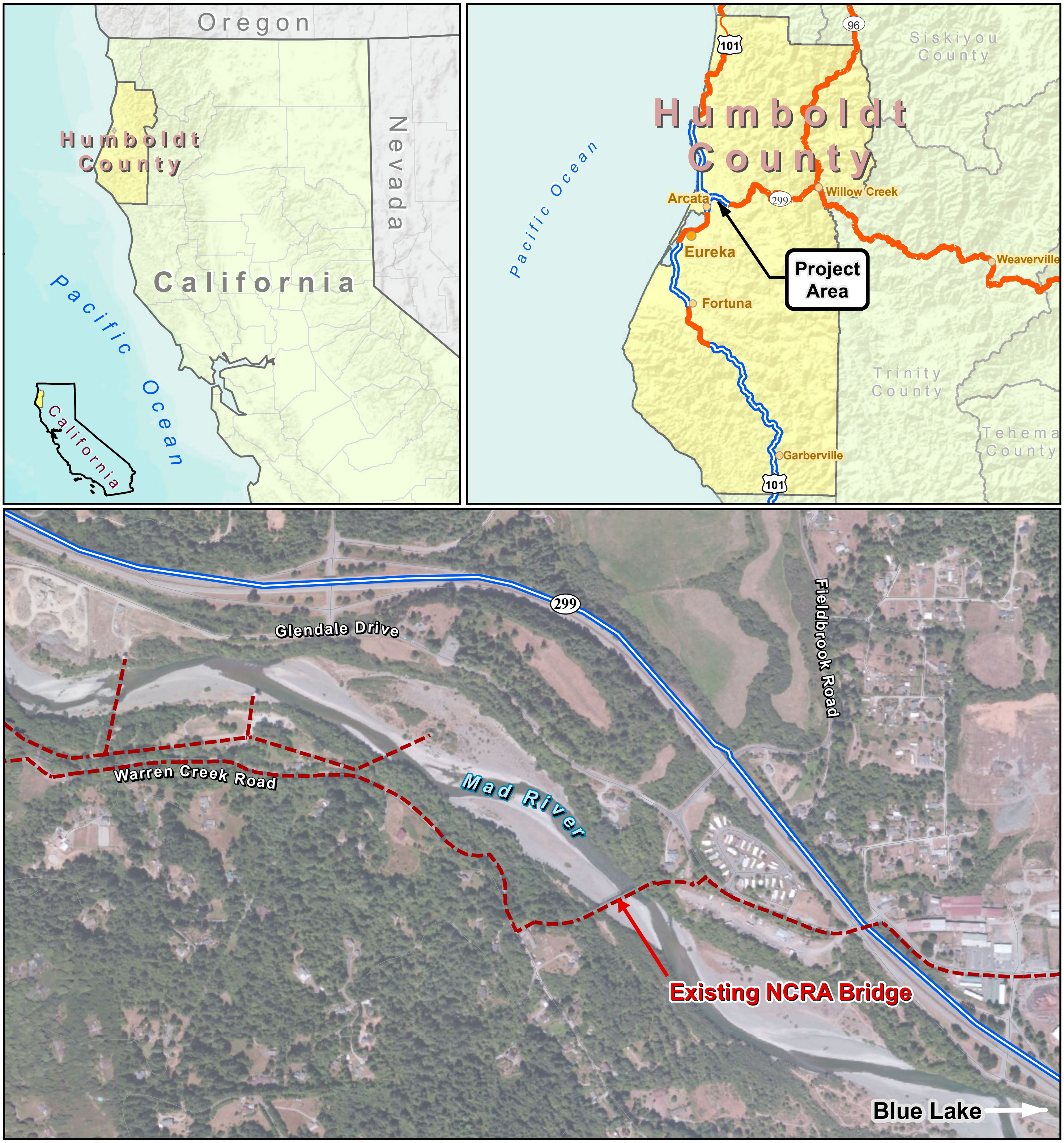
In the 2009 report, a trenchless alternative consisting of microtunneling under the river was considered, and the estimated cost for this alternative was calculated to be $4,218,000. However, it was difficult to obtain an accurate cost for this alternative or the feasibility and cost of a horizontal directional drilling alternative without accurate geotechnical information for the project area. Given the uncertainties with the subsurface conditions, the costs estimated were considered to be conservative.

1.2 Purpose of this Report

There was very limited geotechnical data available when the 2009 Feasibility Study was completed, making it difficult to assess the feasibility and cost of trenchless alternatives. Crawford & Associates, Inc. (CAInc) recently conducted a geotechnical study at the Mad River crossing site and generated an associated Geotechnical Report (Appendix D). Bennett Trenchless Engineers (BTE) used the information presented in the Geotechnical Report to assist in the development of a Trenchless Feasibility Report (Appendix E).

The findings of the recent Geotechnical Report and Trenchless Feasibility Report have been utilized in this 2016 Feasibility Study to re-examine the pipeline alternatives for a replacement HBMWD water main crossing of the Mad River to continue water service to the communities of Glendale, Fieldbrook, and Blue Lake. Specifically, this report re-evaluates the estimated construction costs for the suspended water line and trenchless construction alternatives. It also revisits and updates the considerations for constructability, right of way requirements, and environmental permitting for these alternatives to determine the apparent best alternative for achieving the District’s goal of constructing a new pipeline that can continue to provide water to the above communities. The design of the selected alternative is also developed to a sufficient extent to develop a detailed project description to allow the required National Environmental Policy Act (NEPA) and California Environmental Quality Act (CEQA) documents to be completed.

It should be noted that going through the Envision process was considered for this project. Envision provides a rating system and planning guide for considering sustainability in infrastructure projects. Envision evaluates infrastructure projects and grades them based on how they perform in a variety of categories. There are 60 sustainability criteria that are organized into five categories: Quality of Life, Leadership, Resource Allocation, Natural World, and Climate and Risk. Sustainability ratings are established through a performance evaluation that gives points for achievement within each sustainability criterion. While an analysis of this type was considered, it was determined that the majority of the Envision categories that would apply to this project would be so similar for either alternative that a comparison would not be meaningful. Instead, it was decided that this report would analyze only those categories that would substantially differ for the two alternatives under consideration (e.g. cost, constructability, right of way requirements, environmental permitting requirements, cultural resource impacts, etc.).



HBMWD Water Mains

Limited Access Highway

Highway

Local Roads

Paper Size ANSI A

0 300 600 900 1,200 1,500

Feet

Map Projection: Mercator Auxiliary Sphere
Horizontal Datum: WGS 1984
Grid: WGS 1984 Web Mercator Auxiliary Sphere

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GHD

Humboldt Bay Municipal Water District
Blue Lake/Fieldbrook Mad River Crossing

Job Number	8411162
Revision	1
Date	02 Mar 2016

Project Vicinity and Location Map Figure 1

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718 Third Street Eureka, CA 95501 **T** 707 443 8326 **F** 707 444 8330 **E** eureka@ghd.com **W** www.ghd.com

Data source: ESRI: Street Map USA, County of Humboldt: local roads; HBMWD GIS: pipelines. Created by:gldavidson

2. Alternatives Analysis

Two alternatives were considered in this analysis for providing a redundant pipeline to supply water to FGCSD and the City of Blue Lake:

- Alternative 1 – Horizontal Directional Drilling Under the River
- Alternative 2 – Suspended Waterline Over the River

The 2009 Feasibility Study recommended that a suspended pipeline crossing be included in the District's Capital Improvement Program, as it had the lowest present worth cost of all the alternatives that were analyzed, while the permitting requirements were determined to be similar to those of the other alternatives. A horizontal directional drilling (HDD) alternative was mentioned in the 2009 report but was determined to be infeasible due to the assumed presence of unconsolidated gravels down to 80 feet of depth. However, the CAInc Geotechnical Report refutes this assumption (see Section 2.1.2 for a discussion on the subsurface exploration performed by CAInc). Furthermore, HDD technology has continued to advance since the Feasibility Study was written in 2009, making HDD a feasible alternative for a greater range of projects. Given this information, the HDD alternative is re-evaluated in this 2016 Feasibility Study.

The two alternatives in this study were evaluated on the basis of constructability, right of way requirements, environmental permit considerations, and construction cost. Both alternatives are in close proximity to the existing crossing on the railroad bridge. These alternatives are conceptual, and detailed engineering design would need to be performed on the final selected alternative. A more detailed geotechnical investigation will also be required prior to the final design of the selected alternative. However, the selected alternative is developed sufficiently to allow for the completion of the required NEPA/CEQA documents.

Each alternative analysis includes an assessment of:

- The constructability of the alternative, including a description of the potential difficulties associated with constructing the various project components.
- The right of way needs for the alternative. This analysis includes a review of the ownership of the parcels in the vicinity of the proposed alternatives, the identification of the parcels on which additional easements would be required, and review of the encroachment permits and temporary construction easements anticipated to be needed.
- The environmental permitting requirements, including a review of the agencies that may exert permit authority on the construction of the alternative and the associated permits that would be required, as well as potential permitting difficulties that may be encountered.
- The potential NEPA/CEQA compliance documentation of each alternative. NEPA will have to be completed by FEMA on the final selected project alternative to meet the funding requirement of the Hazard Mitigation Grant. CEQA will also have to be performed by the District on the selected alternative.
    - Roscoe and Associates performed a cultural resources investigation in the spring of 2014 and determined that significant archaeological resources are present within the project area (see Figure 2 and Figure 3 for the cultural site extents). This 2016 Feasibility Study discusses the methods for avoiding impacts to this area for each alternative.

- A budgetary level of the opinion of probable cost for each alternative. The costs presented are based on the preliminary anticipated layouts and details. Costs for the various project components are based on unit prices from projects recently bid and estimates from contractors who specialize in the specific types of work included in the alternative. Land/right of way acquisition, surveying, engineering design, permitting, and construction management costs were calculated as a percentage of the construction costs, and the cost for the geotechnical investigation that will be required for each alternative was estimated based on the cost for geotechnical services on similar projects.

2.1 Findings of Preliminary Geotechnical Investigation

As mentioned previously, as part of this study CAInc conducted a geotechnical investigation and produced a Geotechnical Report (Appendix D) summarizing their findings. The report provides a preliminary geotechnical assessment for the proposed aerial pipeline crossing and HDD alternatives. The relevant findings presented in the report are summarized in this section.

2.1.1 Geology

The site is located in the central belt of the Franciscan Formation consisting of Early Tertiary to Late Cretaceous mélange and Late Cretaceous to Late Jurassic meta-sediments. The project site is located within the Mad River Fault Zone, and an unnamed branch of the fault zone crosses the project site near the northeast bank. The regional geology is shown on Figure 2 of the Geotechnical Report, and fault locations are shown on Figure 3 of the Geotechnical Report. A geologic reconnaissance performed on October 21, 2015 noted bedrock outcrops in the river channel and along the river banks near the existing bridge abutments.

2.1.2 Subsurface Exploration

CAInc observed and logged four exploratory borings in October 2015 (Figure 1 of the Geotechnical Report). Two were drilled on the northeast end of the river (borings B1 and B2), and two were drilled on the southwest end (borings B3 and B4). Boring depth ranged from 15.5 to 35 feet below ground surface (bgs), and all borings were drilled on or near the railroad right of way. The existing cultural resources site on the southwest side of the project site was protected from impacts during the geotechnical investigation through the use of rubber tracked equipment and plywood sheeting placed over the cultural resource site where it was crossed. No physical drilling was conducted within the boundaries of the cultural resource site, and an Archaeologist, Jamie Roscoe oversaw all drilling activities conducted on the southwest side of the river (see Report in Appendix D).

Fill related to the former railroad was encountered in the first 2.5 to 3.5 feet at each boring. Sediment below the fill is terrace alluvium composed of stiff lean clay and sand with varying amounts of gravel and trace cobbles. The sand and gravel encountered in the alluvium is rounded to subrounded and is composed of a variety of different rocks and minerals.

At the banks, the alluvial sediments are underlain by dense, in-situ residual soils derived from the underlying bedrock. These soils retain the appearance and structure of the deeper source bedrock, but with heavy staining and discoloration. These soils are dense lean clay with varying amounts of angular to subangular sand and gravel.

On the northeast side, the bottom of the alluvium is 8 feet bgs in B1 and 16 feet bgs in B2. The in-situ residual soil extends to 12 feet bgs in B1 and 18 feet bgs in B2. On the southwest side, the alluvium ends at 15.5 feet bgs in B3 and 3.2 feet bgs in B4. The bottom of the residual soil is 23 feet bgs in B3 and 9 feet bgs in B4. On each side, the soil is thickest near the river and thins farther back into the terrace.

The residual soils transition to weathered rock and, at the bottom of the borings, into fresh, hard bedrock. An interpreted subsurface profile is shown on Figure 4 in the Geotechnical Report. Free groundwater was not encountered in the borings.

2.1.3 Soil Corrosion Potential

Laboratory tests were run to determine corrosion potential. Based on the results of the tests, the only concern is that the pH of the soil (5.40) is slightly below what Caltrans considers to be a corrosive pH (5.5), meaning that the soils could potentially be corrosive to steel.

2.1.4 Seismicity

Active Faulting

Fault mapping from the California Geological Survey (CGS) and United States Geological Survey (USGS) indicate that the potential for fault rupture at the project site is generally low. However, there is an Earthquake Fault Zone (EFZ) to the south of the project site that aligns with a fault that crosses the site, suggesting that the two faults could be connected. Therefore, there is potential that the thrust fault crossing the site could be considered “active.” Further study would be required if this hazard is considered significant. The significance of this potential hazard will be determined in the final geotechnical study that will be conducted as a part of the final design.

Seismic Design Parameters

CAInc provided California Building Code (CBC) seismic design parameters based on location parameters developed by the USGS as well as the information obtained from the exploratory borings. These design parameters are given in Table 1 of the Geotechnical Report.

Liquefaction

Due to the generally cohesive nature of the soils at the banks, liquefaction potential is considered to be generally low. Liquefaction potential will be further evaluated during a subsequent geotechnical study that will be conducted as part of the final design phase of the project.

Seismic Settlement

Ground shaking during a seismic event can cause densification of granular soil above the water table, which can result in settlement of the ground surface. Based on the preliminary data, some seismic settlement may occur within loose portions of the alluvium along the banks. However, settlement is expected to be relatively minor within the stiff, cohesive soils encountered in the borings.

Seismic Slope Instability

The potential for seismic slope instability along the existing channel banks, including lateral spreading, may be relatively high due to the steep banks and high seismic ground motions. This hazard will require further consideration in design and construction and will be analyzed in the final geotechnical evaluation.

2.1.5 Conclusions from the Geotechnical Report

Based on the findings of the preliminary geotechnical investigation, both the aerial crossing and the HDD options appeared to be viable alternatives. Specific recommendations from the Geotechnical Report with regard to each alternative are discussed in Sections 2.2.3 and 2.3.3, respectively.

2.2 Alternative 1 – Directional Drilling Under the River

2.2.1 General Description

The Bennett Trenchless Engineering (BTE) report investigated the feasibility of multiple trenchless methods for installing a pipeline underneath the Mad River. The methods analyzed include jack and bore, open-shield pipe jacking, pipe ramming, earth pressure balance pipejacking, microtunneling, and HDD. It was determined that among these alternatives, HDD is the sole feasible, practical, and cost-efficient method for completing a trenchless crossing under the Mad River. Other trenchless methods were either determined to be impractical, or would not be cost competitive with HDD. Given the results of the BTE report, Alternative 1 of this 2016 Feasibility Study includes the placement of a new pipeline underneath the Mad River via HDD (see Figure 2 for a conceptual plan view of the HDD bore). The pipeline would tie in to the existing 14-inch transmission main on the west side of the river, east of Warren Creek Road. An entrance pit would be constructed near this location and used to directional drill under the river. The drilling bore would terminate on the east side of the river, just southwest of Glendale Drive on the property of GR Sundberg. The new pipeline would tie-in to the existing 14-inch transmission main near this location.

2.2.2 HDD Conceptual Design and Construction

The BTE Trenchless Feasibility Report (Appendix E) describes the preliminary HDD design and construction considerations, which are summarized in this section.

HDD Construction

HDD is a trenchless construction method in which a pipe is installed along an arcing drill path, beginning and ending at entry and exit pits, respectively, and passing under the conflicting feature (in this case, the Mad River). A drill rig is set up on the entry side and drills a pilot bore to the exit point. The pilot bore is then reamed in one or more passes to the size required for pullback of the prefabricated pipe string. After reaming is complete, the pipe is pulled into the bore, preferably in one continuous operation.

HDD success is largely dependent on the subsurface properties in the area. As detailed in Section 2.1.2 the soils in the vicinity of the crossing on the west side of the river consist of approximately 2.5-3.5 feet of fill, underlain by alluvium (stiff lean clay and sand with varying amounts of gravel and trace cobbles), residual in-situ soils (dense lean clay with varying amounts of sand and gravel, derived from the deeper source bedrock), weathered rock, and fresh bedrock. The soils on each side of the river are thickest near the river and thin out farther back into the terrace. Depth to fresh bedrock ranges from approximately 15 to 33 feet (see Figure 4 of Appendix D for an interpreted subsurface profile). Because an HDD alternative would be constructed approximately 15 to 30 feet below the bottom of the river channel, it would be constructed almost entirely within fresh bedrock.

HDD can be used in most soil conditions, as well as solid rock, so long as the proper tooling is used. HDD can also be used for installing pipelines below the water table. While large quantities of cobbles and gravel (greater than approximately 15%) can cause issues with HDD due to loss of drilling fluid and collapse of the borehole, special design features such as conductor casing can be used to accomplish bores through these materials if these soils are near the surface and less than 30 feet thick.

HDD rigs are generally classified into three sizes: small, medium, and large. The staging area required and construction duration increases as rig size increases, increasing overall cost.

A bentonite-based drilling fluid is used in the HDD process to aid in excavation of the soil, carry the cuttings from the bit back to the drill rig, provide hydrostatic support to the otherwise unsupported borehole, and to cool and lubricate the drill pipe and tooling during drilling. The returned drilling fluid is sent through a solids separation plant with a system of vibrating screens and hydrocyclones that remove the majority of the soil from the slurry. Clean drilling fluid is sent back to the bit. Drilling fluid recovery pits are commonly excavated at each end of the bore. The pits are usually 3-6 feet wide, 6-12 feet long, and 2-4 feet deep. The risk of inadvertent fluid returns (hydrofractures or frac-outs) is an important consideration for HDD projects. This typically occurs when excess drilling fluid pressures cause fluid to escape the bore and surface through granular soils, cracks in cohesive soils, or along other natural or man-made conduits. Drilling fluid is generally a non-toxic mixture of water and bentonite clay; however, spills are viewed as an environmental risk.

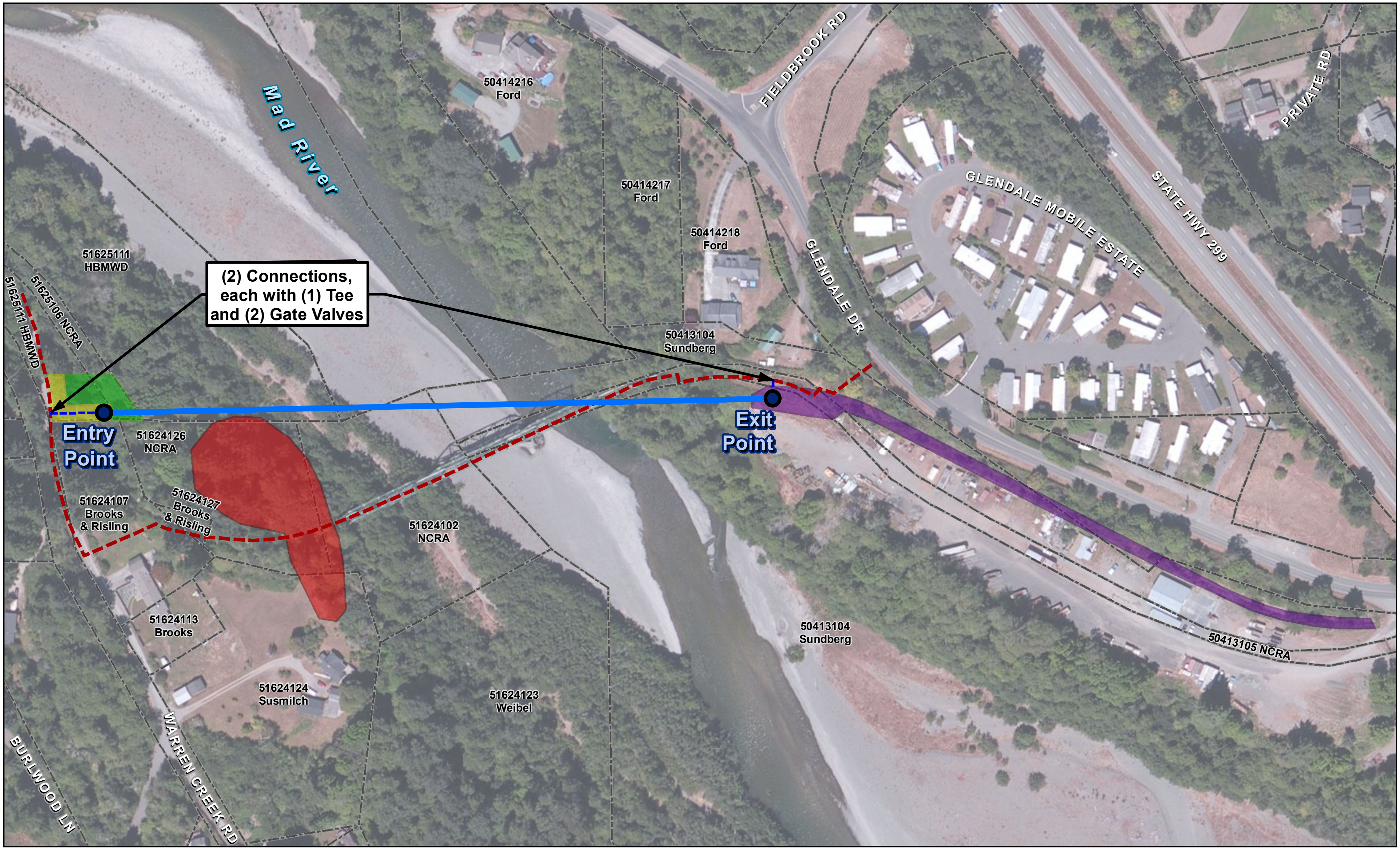
Conceptual Bore Design

The conceptual bore design was developed based on the capabilities and limitations of HDD, the required pipe diameter, mitigation of frac-out risks, and other site constraints. A conceptual HDD bore plan view is shown in Figure 2, and a conceptual HDD bore profile is shown in Figure 3. The plan bore alignment is 1,125 feet long. The proposed entry point is located on the west side of the river, approximately 90 feet east of Warren Creek Road, 600 feet north of the intersection with Burlwood Lane. The bore will terminate at the west end of the GR Sundberg equipment yard, crossing diagonally under the existing NCRA bridge. The conceptual alignment was designed to maintain a minimum of 20 feet of clearance beneath the Mad River channel at all points.

The entry location was chosen to minimize bore length while still maintaining adequate depth beneath the river channel. This location also allows for a short connection length to the existing transmission main and allows for construction access off of Warren Creek Road without affecting nearby private properties. The entry location also avoids disruptions to the identified cultural site.

The exit location was also selected to minimize bore length, maintain adequate depth, and allow for a short connection to the existing transmission main. The location on the edge of the Sundberg site will also minimize disruption to Sundberg’s property.

Because this bore is anticipated to be drilled completely within fresh bedrock, frac-out risk is anticipated to be low, unless significant open joints, fractures, or faulting is encountered. The clearance of 20 feet from the channel bottom was chosen to reduce the risk of inadvertent drilling fluid returns through existing pathways in the rock, and to avoid potential historic flow channels that have been infilled with alluvial cobbles, gravel, and sand. More detailed investigation of the rock profile within the river channel, likely using geophysical methods, will be required as a part of the final geotechnical investigation if the HDD alternative is carried forward into design.



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Feet

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

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- Cultural Site
- Work Area (Undergrowth Removal)
- Pipe Fabrication and Layout Area
- Rig and Separation Plant Area (Completely Cleared)
- Conceptual HDD Alignment
- Existing 14" Water Line
- New Trenched Water Line
- Entry and Exit Points
- Parcels (with APN & Owner)

Humboldt Bay Municipal Water District
BLFG CSD Pipeline Crossing

Job Number	8411162
Revision	A
Date	02 Mar 2016

Conceptual HDD Bore Plan

Figure 2

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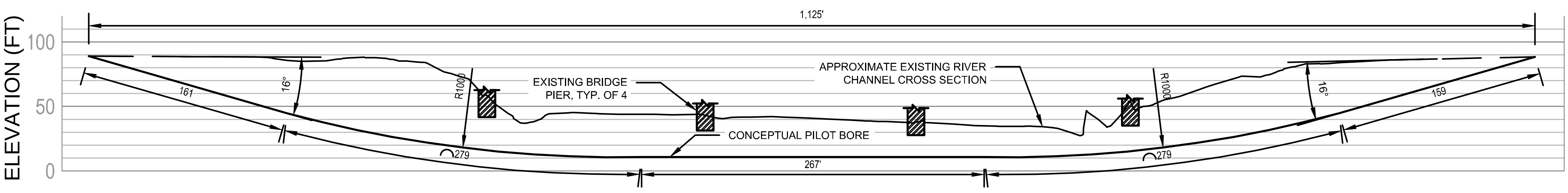
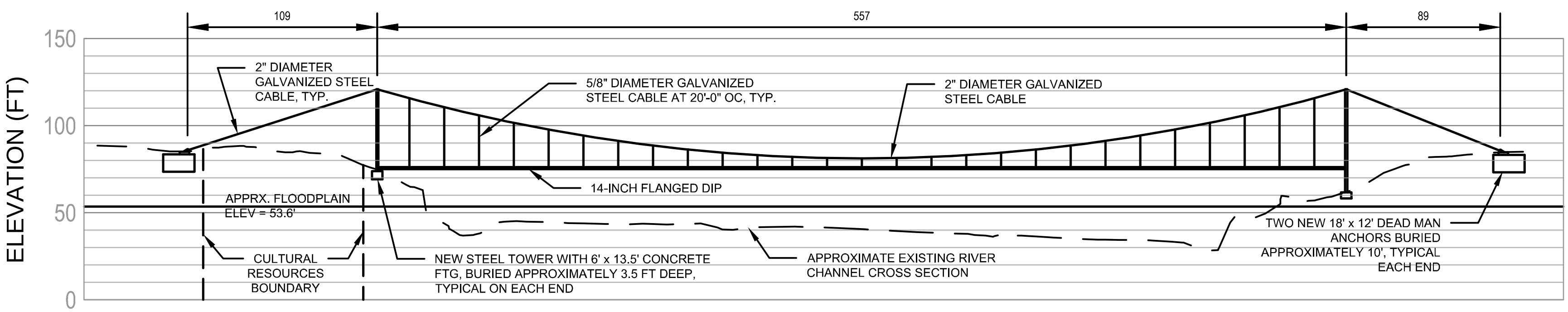
718 Third Street Eureka CA 95501 USA T 707 443 8326 F 707 444 8330 E eureka@ghd.com W www.ghd.com



1 **HDD PROFILE**
SCALE: 1" = 120'



2 **SUSPENDED CROSSING PROFILE**
SCALE: 1" = 100'

Humboldt Bay Municipal Water District
Blue Lake/Fieldbrook Mad River Crossing

HDD and Suspended Crossing Profiles

Job Number | 8411162
Revision | A
Date | 03/02/2016

Figure 3

718 Third Street, Eureka CA USA 95501 **T** 1 707 443 8326 **F** 1 707444 8330 **E** eureka@ghd.com **W** www.ghd.com

Plot Date: 29 March 2016 - 3:03 PM Cad File No: G:\Legacy\Projects\01055 HBMWD\8411162 HBMWD-BLFG CSD PipelineCross-Phs 1\06-CAD\Sheets\8411162-Mad_River_Crossing.dwg

Staging Area

A medium HDD rig will likely be required due to the diameter, length, and subsurface conditions of the proposed HDD crossing. The required staging area for a rig of this size is typically 10,000 square feet at the entry side of the bore. This allows for staging of the drill rig, other pieces of ancillary equipment (e.g. backhoe, boom truck), drill pipe, bentonite, drilling fluid pumps, fluid storage tanks, a solids separation plant, tool trailers, and other equipment. The work area shape can be flexible for the majority of the equipment. However, the drill rig, backhoe/boom truck, and drill pipe storage must be located in an area that is approximately 75 feet long and 30 feet wide and aligned directly behind the entry point, and this area must be completely clear. The separation plant also needs a clear area that is approximately 40 feet long and 30 feet wide. The pipe laydown area on the exit side is usually 20 to 50 feet wide and needs to be equal to the length of the pipe. Figure 2 shows an approximation of the area that would need to be completely cleared to accommodate the rig and separation plant, as well as the rest of the work area that would require undergrowth removal. This figure also shows the proposed pipe fabrication and layout area on the east side of the Mad River.

An HDD bore could be advanced in either direction for this project. The Sundberg equipment yard on the east side of the river provides considerable area for either pipe fabrication and layout or the drill rig setup. Undergrowth and some trees would have to be cleared on the west side to accommodate either work area. If the exit point were located on the west side, a long, narrow area would need to be cleared to allow for pipe fabrication and layout. The overall impacts to the forested area west of the river would be similar with either option. One of the private landowners on the west side has requested that the project avoid creating a pathway for public access from Warren Creek Road to the river near his property. Because clearing of a long, narrow pipe laydown area may create the impression that a trail has been created for river access, the entry point has been preliminarily located on the west side.

Pipe Material

Steel, HDPE, fusible PVC (FPVC), and ductile iron (DI) are the most common pipe materials used for HDD projects, with HDPE and steel being the most widely used. However, FPVC is a product that was developed relatively recently, and it has been gaining popularity in HDD jobs. Due to concerns regarding corrosion resistance, HDPE and FPVC pipe are the most likely candidates for pipe materials to be used for the Mad River crossing. For a nominal 14-inch inside diameter (ID), the outside diameter (OD) for FPVC would be 15.3 inches, while the OD for HDPE would be 18 inches.

Pullback and Pipe Stress Analysis

BTE conducted a preliminary pullback and pipe stress analysis to analyze pipe material options and pipe wall stiffness requirements. Results of the load analysis are presented in Tables 2-4 of the Trenchless Feasibility Report. The analysis indicates that the anticipated loads required and stresses imposed during HDD installation will require the use of either 14-inch nominal (15.3-inch OD) DR 18 DIPS FPVC pipe or 18-inch OD DR 9 IPS HDPE pipe.

Hydrofracture Analysis

As mentioned, the potential for inadvertent drilling fluid returns (hydrofractures or frac-outs) to the ground surface is a serious concern for any HDD crossing. BTE performed a preliminary analysis of the hydrofracture risks for the project. The analysis showed that the risk of hydrofracture is low for the majority of the crossing length. Because the depth of cover decreases near the exit point, the hydrofracture risk is elevated shortly before the exit point. This is a typical risk for all HDD bores and can be mitigated through common measures including specifying that the contractor have equipment and tools on-site for rapid containment and clean-up of inadvertent fluid returns. A detailed Surface Spill and Hydrofracture Contingency Plan is also typically developed.

2.2.3 HDD Recommendations from the Geotechnical Report

Based on the preliminary geotechnical data and geologic mapping within the channel, it appears that conditions are suitable for a horizontal directional drilling (HDD) alternative. CAInc estimates bedrock at depths of about 15 feet or less across the channel, as shown on Figure 4 of the Geotechnical Report. The depth to rock will need to be confirmed with future investigations as some areas of the Mad River channel (e.g., Ranney Collector areas) are known to have gravel depths to about 100 feet, although these are located a few thousand feet from the project site. While it appears that rock is relatively shallow across the channel, the potential for deeper backfilled channels of sand/gravel will need to be considered if this alternative is advanced. This will likely be determined by geophysical methods during the final geotechnical evaluation.

For preliminary assessment, it appears that an HDD pipeline can be completed within competent rock with about 30 feet of cover. Areas of weak rock (e.g., shear/fault zones) and fractures can cause binding of drill tools and fracking of drill mud, and the presence of cobbles and clean gravel can cause loss of drill fluid and collapse of the HDD borehole. These conditions will require further consideration in design/construction. Caving soils in the upper 10-20 feet at the entry and exit points can generally be controlled by driving conductor casing.

The potential for fault rupture and strong ground motions will also require consideration for this alternative. While the site is not within a mapped EFZ for fault rupture hazard, the mapped late-Quaternary thrust fault near the northeast side of the channel should be considered at least potentially active. This feature may require specific design mitigation, such as flexible connections and/or emergency shut-off valves.

2.2.4 Right of way

Parcel data is shown in conjunction with the conceptual HDD design on Figure 2. The HDD entry point would be on parcel 516-251-011, which is owned by the District. This District-owned parcel borders an NCRA parcel (516-241-026), and a portion of this parcel would be cleared (undergrowth only) to create a work area. A construction easement would be needed on this NCRA parcel. From the entry point, a pipe will be trenched and will connect to the existing water transmission line, all of which will take place on this same District-owned parcel. The directional drilled pipeline will remain on/under District property until it reaches the western river bank, at which point it crosses under the Mad River channel (for which a lease is likely required from the State Lands Commission). On the eastern end of the crossing, the pipeline will be under parcel 504-131-004 (owned by GR Sundberg), until it reaches the exit point that is on this same parcel. From the exit point, pipe will be trenched through a small stretch of Sundberg's property to get to the tie-in at the existing transmission main where the District already has an easement in place. A construction easement will need to be obtained from Sundberg for the use of their parcel for the laydown of the pipe for assembly, and a permanent easement for the small section where the pipe travels from the corner of their parcel, back into the District's existing right-of-way. Although it likely will not be difficult to obtain the construction easement from the Sundbergs, based on previous conversations, it is also possible that a portion of the public right-of-way along Glendale Drive could be used to laydown the pipe for assembly.

The following table lists the parcel numbers and owners of each parcel for which easements or access agreements would be required.

Table 1: Right of way Parcels for Alternative 1 (HDD)

AP Number	Owner	Easement Type
516-241-026	NCRA	Construction
504-131-004	GR Sundberg	Construction and Permanent

2.2.5 Environmental Permitting Considerations

Several permits and agency coordination would be required for the construction of the HDD alternative; however, Humboldt County zoning and building ordinances do not apply to water transmission facilities, so building permits would not be required.

NEPA

The National Environmental Policy Act (NEPA) process will need to be finalized for this project to meet the funding requirements of the Hazard Mitigation Grant through the Federal Emergency Management Agency (FEMA). FEMA is the lead agency for this process and has started the NEPA process; however, the NEPA process cannot be finalized until a final alternative is selected and a final project description developed. This Study will develop that description and allow for completion of the NEPA document.

Several studies needed to complete the NEPA process have already been completed including a biological survey and wetland assessment, as well as the Cultural Resources Study. These existing studies will largely cover the proposed HDD project, however, minor amendments to the biological survey will need to be conducted to cover the area on the west side of the river that will need to be cleared for the drilling equipment. Based on the previous biological studies, it is unlikely that there are rare or endangered plants located in this area, however, that will need to be confirmed.

Under the HDD alternative, there would be no impacts to the cultural site as currently mapped, which would make the NEPA/CEQA assessment for this alternative more straight forward as well as the final construction. However, the Cultural Resources Study will likely also have to be amended to include a field survey of the area to be cleared for the drilling equipment, to confirm that this area is outside the identified cultural resource site.

CEQA

The District will be the lead agency for the CEQA process. The appropriate CEQA process would likely be a Mitigated Negative Declaration (MND) as there would likely be no significant impacts from this project after the implementation of mitigation measures. The previous studies conducted for the NEPA analysis will also be utilized for the CEQA MND. The amendments conducted for the biological and cultural resources field surveys for the NEPA analysis will also be used to conduct the CEQA analysis.

State Lands Commission

When California became a state in 1850, it acquired approximately four million acres of land underlying the State's navigable and tidal waterways. Known as sovereign lands, these lands include the beds of California's navigable rivers, lakes and streams, and tidal and submerged lands along the State's more than 1,100 miles of coastline and offshore islands from the mean high tide line to three nautical miles offshore.

The State Lands Commission (Commission) holds the State's sovereign lands for the benefit of all the people of the State, subject to the Public Trust for water related commerce, navigation, fisheries, recreation, open space and other recognized Public Trust uses. The Commission maintains a multiple use management policy to assure the greatest possible public benefit is derived from these lands. The Commission will consider numerous factors in determining whether a proposed use of the State's land is appropriate, including, but not limited to, consistency with the Public Trust under which the Commission holds the State's sovereign lands.

The issuance by the Commission of any lease, permit or other entitlement for use of State lands is reviewed for compliance with the provisions of CEQA. No proposed project will be considered by the Commission until the requirements of CEQA have been satisfied. Additionally, if the application involves lands found to contain "Significant Environmental Values" within the meaning of PRC Section 6370 et seq., consistency of the proposed use with the identified values must also be determined through the CEQA review process. Pursuant to its regulations, the Commission may not issue a lease for use of "Significant Lands" if such proposed use is detrimental to the identified values. It is highly unlikely that a pipeline under the Mad River in this location would be considered detrimental to the identified values.

A lease may be required for the pipeline below the Mad River. The first step is to confirm that the project falls within the jurisdiction of the State Lands Commission. If the project is within the agency's jurisdiction and if the project progresses to design and permit acquisition, a letter requesting Commission review will be required. The letter would include a project description, USGS map location, and an aerial photograph. Also required would be an application for a General Lease right of way, photographs of the site, copies of the applications sent to other permitting agencies, maps, and a minimum expense deposit. This project would consist of transaction type D (public agency lease/permit). The fees associated with this permitting requirement would include a $25 application fee and a minimum expense deposit for processing of $3,000.

California Department of Fish and Wildlife, Regional Water Quality Control Board and Army Corps of Engineers

There are no wetlands identified in the proposed project area, and the areas that will be temporarily impacted are outside the streambed of the Mad River, so a 1600 Streambed Alteration Agreement from the California Department of Fish and Wildlife (CDFW), U.S. Army Corps of Engineers (USACE) 404 permit and a Regional Water Quality Control Board (RWQCB) 401 permit would likely not be required. However, the vegetation clearing required for the drill rig on the west side of the river would likely, at a minimum, require consultation with CDFW. Mitigation measures would also likely be required and would be included in the CEQA MND including performing nesting surveys prior to construction and setting buffers around any identified nests.

There is also the possibility of frac-out of the drilling fluid under the Mad River and the performance of the drilling below the ordinary high water level. CDFW, the USACE and the RWQCB will all likely have to be consulted on the proposed project and may require permits for the work.

County Permits

The work in proximity to Warren Creek Road on the west side of the river will definitely require a County encroachment permit. If a construction easement is also not able to be obtained from the Sundbergs for the layout of the pipe on the east side of the project, it is also possible that the pipe can be laid out along Glendale Drive. This would, however, also require an encroachment permit from the County. It is also likely that a grading permit and stormwater water pollution prevention plan (SWPPP) would be required from the County. The overall grading would be less than an acre and would therefore not trigger the National Pollution Discharge Elimination (NPDES) permit requirements from the State Water Resources Control Board.

Summary of Environmental Requirements

Following is a summary of the environmental requirements mentioned above that would likely need to be met for the HDD alternative:

- The NEPA process will need to be finalized to meet the funding requirements of the Hazard Mitigation Grant through FEMA. Minor amendments to the biological survey will need to be conducted to cover the area on the west side of the river that will need to be cleared. The Cultural Resources study may also need to be amended to include a field survey of the area to be cleared for the drilling equipment.
- The CEQA process (likely a MND) will need to be completed. The amendments conducted for the NEPA process will also be used for the CEQA analysis. Nesting surveys would likely also be required.
- A State Lands lease and associated permitting requirements may be necessary
- CDFW consultation will likely be required for the necessary vegetation clearing for the drill rig
- CDFW, USACE, and the RWQCB will all likely need to be consulted due to the possibility of frac-out of the drilling fluid under the Mad River and the performance of the drilling below the ordinary high water level
- A County encroachment permit will be required for the work in proximity to Warren Creek Road. If the Sundbergs are not amenable to the pipe being laid out on their property, an encroachment permit would also be required from the County for laying out the pipe along Glendale Drive.
- A grading permit and SWPPP will also likely be required from the County.

2.2.6 Project Cost

The anticipated costs for this project are presented in Table 2. The opinion of probable construction cost for this alternative is $1,832,000, and the estimated total project cost is $2,773,000.

Table 2: Opinion of Probable Cost for Alternative 1 (HDD)

Item No.	Description	Unit	Quantity	Unit Cost	Total
1	Mobilization/Demobilization	LS	1	$180,000	$180,000
2	Clearing and Grubbing	LS	1	$40,000	$40,000
3	Erosion and Sediment Control	LS	1	$30,000	$30,000
4	Revegetation	LS	1	$35,000	$35,000
5	Temporary Construction Access Improvements	LS	1	$50,000	$50,000
6	Horizontal Directional Drill 18-inch Outside Diameter HDPE Transmission Main[1]	LS	1	$970,000	$970,000
7	Connect to (E) 14-inch Transmission Main	EA	2	$22,000	$44,000
8	14-inch Gate Valve with Vault	EA	4	$5,000	$20,000
9	Air/Vacuum Relief Valve with Vault	EA	2	$10,000	$20,000
10	Blowoff Assembly with Vault	EA	1	$20,000	$20,000
				Construction Subtotal	$1,409,000
				Contingency (30%)	$423,000
				Opinion of Probable Construction Cost	**$1,832,000**
				Geotechnical Investigation	$80,000
				Survey and Land/ROW Acquisition (10%)	$183,000
				Engineering Design (12%)	$220,000
				Environmental Permitting (10%)	$183,000
				Construction Management (15%)	$275,000
				Final Design and Construction Management Total	**$941,000**
				Opinion of Probable Project Cost:	**$2,773,000**

[1]Includes HDD equipment; pilot bore and reaming; delivery, fabrication, and testing of pipe.

2.2.7 Maintenance and Resilience

This alternative would require very little ongoing maintenance. HDPE pipe is relatively ductile and would be resilient to an earthquake event. Furthermore, acceleration generated from earthquakes is typically dampened within bedrock, which is where the pipe would be. Per the Geotechnical Report, fault mapping from the CGS and USGS indicate that the potential for fault rupture at the project site is generally low. However, there is an EFZ to the south of the project site that aligns with a fault that crosses the site, suggesting that the two faults could be connected. Therefore, there is potential that the thrust fault crossing the site could be considered “active.” As the Geotechnical Report stated, “Further study would be required if this hazard is considered significant.” If there is a fault across the site and it were to rupture, it would likely damage or destroy the pipe. Depending on the offset to the pipe, a new smaller pipe could potentially be used to line the old pipe to continue water service to the communities; however, a completely new pipe would have to be installed to return service to its pre-existing capacity. If this fault were to rupture, there would likely be extensive damage to all of the water infrastructure in the area.

Because the pipe would be in bedrock and would be approximately 20 feet below the Mad River, there would be no risk of a flood or river bed scour affecting the pipeline. The lifetime of the pipe is expected to be at least 50 years, and could potentially be much longer.

2.3 Alternative 2 – Suspended Waterline Crossing

2.3.1 General Description

This alternative was first described in a letter to Barry Van Sickle completed by Winzler & Kelly on June 23, 2006 (Appendix B). This alternative consists of an aerial crossing with a 14-inch diameter ductile iron pipe spanning the width of the river for a distance of approximately 560 feet. The new pipe would tie-in to the existing pipe on each side of the river.

2.3.2 Suspended Crossing Conceptual Design and Construction

A conceptual plan view of this alternative is shown in Figure 4, and a profile view is shown in Figure 3. A steel tower with concrete footings and steel piles would be built on each side of the river above the floodplain elevation (approximately 53.6 feet elevation). The towers will be approximately 50 feet tall and 25 feet wide with 12-inch diameter steel columns. From each of the top corners of the tower, 2-inch galvanized steel cables will span across the river to the opposite tower. From these cables, in a suspension bridge style, 5/8-inch diameter cables will hang down and support the ductile iron pipe at 20-foot intervals over the river. On the east side of the river, the cables will also extend from the tower away from the river approximately 90 feet to the ground elevation, and each cable will be secured to a concrete dead man anchor structure. The dead man will consist of approximately 80 cubic yards of concrete buried in the ground. Dead man anchor structures will be similarly used on the west side of the river. To avoid impacts to the identified cultural site, the dead man anchors on the southwest side of the river will be located west of the cultural resources site, approximately 110 feet from the steel towers.

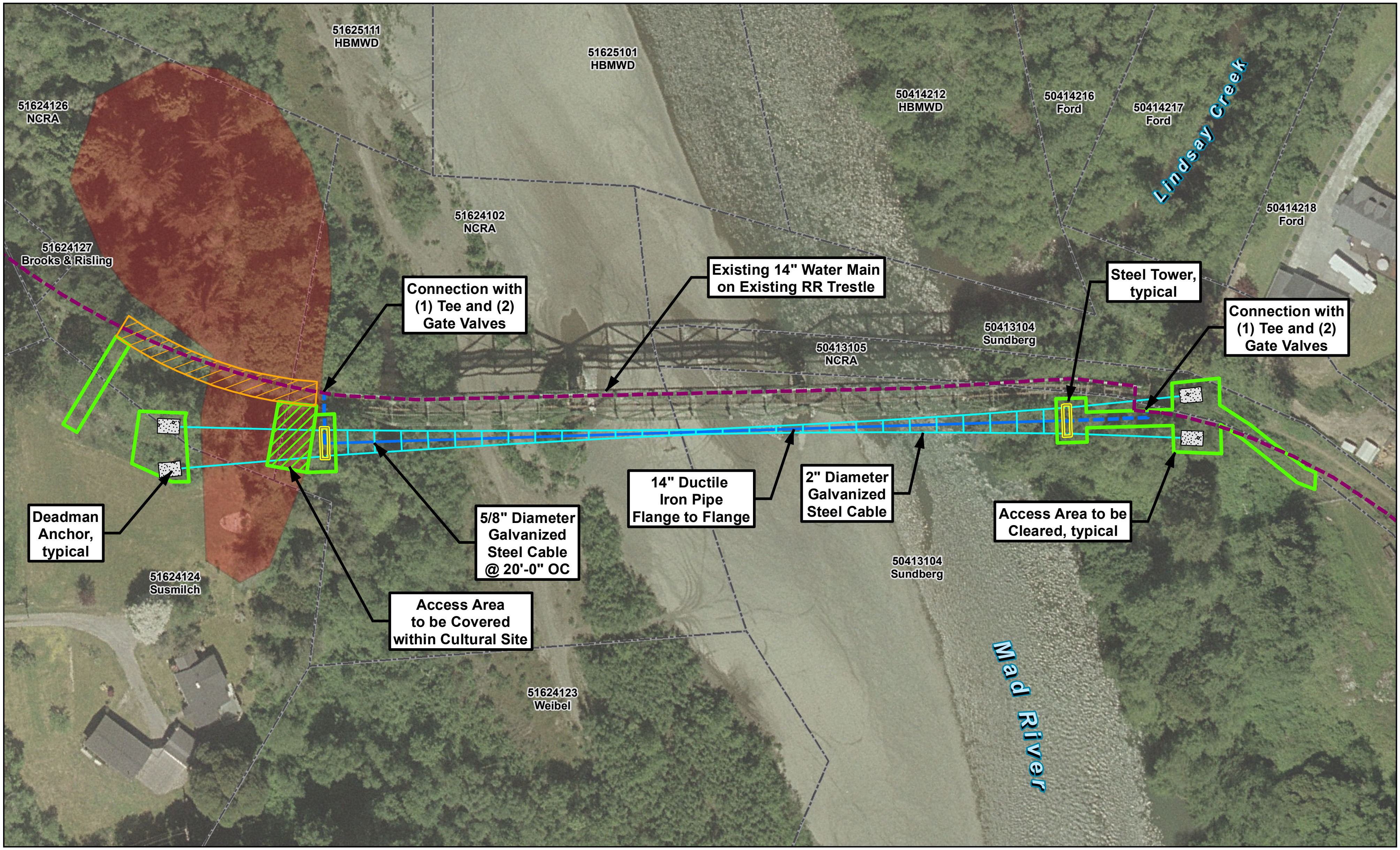
Construction of the suspended waterline would include steel fabrication for the towers and cast in place concrete placement for the anchorage system. Work outside of the channel would include fabrication and erection of the steel suspension cable, including temporary rigging within the channel and tensioning of the cable prior to placement. Work that would have to occur from the river bars of the Mad River channel would include the placement of the steel cable and hangers, and assembly and suspension of the flanged ductile iron waterline.

Access will be required on each side of the river for construction of the suspended crossing. Figure 4 shows the potential access routes and the vegetation clearing that will be required for access. On the west side of the river, vegetation will need to be cleared for the construction of the dead man anchors. Disturbance in this area will not encroach upon the cultural site. Vegetation and trees will also need to be cleared for construction of the steel tower. To access the steel tower location, a path will be cleared to the west of the dead man anchors. This path will lead to the existing railroad grade, which is a generally cleared out corridor that leads east to the existing NCRA bridge and has been identified during the Cultural Resource survey to be previously disturbed. Construction equipment will be able to travel on the railroad grade through the cultural site without any mitigation measures being required. At the end of the railroad grade, it will be necessary for construction equipment to encroach upon the cultural site. However, disturbance to the cultural site can be mitigated by staking down rubber mats that will be present throughout the duration of the project. The construction equipment will be able to travel on the rubber mats without disturbing the cultural site. Minor pruning of branches and potential removal of some smaller trees will be required for the installation of the galvanized steel cables that connect to the dead man anchors, as well as for the steel cables that support the suspended pipe.

On the east side of the river, an access area will need to be cleared up to the locations of the dead man anchors and steel tower. Adequate clearing will also need to occur around each of these areas to provide enough space for construction. Minor pruning will also need to occur on this side to allow for unobstructed pathways for the galvanized steel cables. Mitigation for these construction activities will include pre-construction surveys for nesting birds and establishment of buffer strips for any identified nests.

This alternative would also require access to be created to the channel for a crane and hoists to complete the placement of hangers and waterline on the tensioned cable. Construction access would include the creation of access points to the river and temporary access roads on the river bar. Access could be created from the west side of the river on the District property near Collector 4 and would require two temporary bridges to access the location of the waterline. Alternatively, a construction easement could be obtained across private property north of the proposed crossing along an existing river access and would require only one temporary river crossing. Temporary bridges would have to be large enough to support the crane rig needed to lift the ductile iron pipe sections to be attached to the cable. The access roads on the river bar would likely require little more than minor grading to establish them and to remove them after construction. All of these activities will require a CDFW Streambed Alteration Agreement (1600).

The design would need to account for the loading of the cable during construction of the suspended pipeline and filling of the pipeline with water. This may require assembly of more than one section of pipeline so the cable could be loaded in a balanced fashion.



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0 25 50 75 100

Feet

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

N

- Cultural Site
- Parcels (with APN & Owner)
- Access Area to be Cleared
- Steel Tower
- Access Area to be Covered within Cultural Site
- Deadman
- Railroad Grade (pre-disturbed area)
- Existing 14" Transmission Main
- Flanged 14" Ductile Iron Pipe
- New Trenched Water Line
- Galv. Steel Cable

GHD

Humboldt Bay Municipal Water District
Blue Lake/Fieldbrook Mad River Crossing

Job Number 8411162
Revision A
Date 02 Mar 2016

Conceptual Suspended Crossing Plan

Figure 4

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718 Third Street Eureka CA 95501 USA T 707 443 8326 F 707 444 8330 E eureka@ghd.com W www.ghd.com

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2.3.3 Suspended Crossing Recommendations from the Geotechnical Report

The CAInc Geotechnical Report concludes that a suspended crossing is a viable option for this project, and it offers the following comments and recommendations for this alternative.

Foundation support for the abutment towers is generally available at both banks within undisturbed native soils. Limitations on the soil bearing include total/differential settlement and security with respect to the steep bank slopes. Particular concern is directed to the southwest abutment where the preliminary tower location is near the edge of the steep bank. A shallow footing at this location will need to maintain a minimum horizontal setback from the bank and/or slope protection for adequate security and mitigation of seismic slope instability and lateral spreading. These limitations will require further analysis during project design.

Higher soil bearing, and increased security, is available for tower footings established within the underlying residual soil unit. This unit, however, is at depths of 15+ feet in borings B-2 and B-3 (northeast and southwest banks, respectively) and may be deeper for tower locations positioned close to the banks. Alternatively, foundation support can be achieved by means of drilled or driven piles with penetrations into the weathered bedrock below depths of approximately 18 feet (northeast abutment) and 23 feet (southwest abutment). Cast-in-drilled-hole (CIDH) piles would appear to be appropriate at these locations, as would steel H-piles driven to rock.

Reaction for the anchor cables can be achieved by concrete dead man anchors buried into native stiff clay soils behind the abutment towers. For preliminary design, lateral resistance using a coefficient of friction of 0.35 and passive earth pressure of 250 pounds per square foot (psf) per foot of embedment depth appears generally available within undisturbed soils. The upper 3-5 feet should be neglected in determination of passive earth pressure due to the presence of old fill and soil disturbance.The Geotechnical Report discusses that at the southwest abutment, the archaeological site boundary may preclude construction of dead man anchors. It recommends that drilled soil anchors appear to be a suitable alternative. However, it appears to be feasible to construct dead man anchors to the west of the cultural site. If this alternative is progressed into final design, the use of soil anchors should be considered as a backup option to dead man anchors should the construction of dead man anchors be precluded.

2.3.4 Right of way

Parcel data is shown in conjunction with the conceptual suspended crossing design on Figure 4. The right of way for this alternative would not be significantly different than the existing right of way agreements for the railroad trestle crossing. The agreements would need to be modified to include the construction of the cable suspension towers on each bank. Furthermore, a construction easement and a permanent easement would be required from Susmilch on the west side of the river for construction access and for the installation of dead man anchors on the Susmilch property. Table 3 lists the parcel numbers and owners of each parcel for which easements or access agreements would be required. A construction easement and permanent easment would also be required for the Sundberg parcel on the east side of the river for the installation of the dead man anchors, as well as for installation of the trenched pipe up to the existing District right of way within the NCRA right of way.

Table 3: Right of way Parcels for Alternative 2 (Suspended Waterline Crossing)

AP Number	Owner	Easement Type
516-241-024	Susmilch	Construction and Permanent
504-131-004	GR Sundberg	Construction and Permanent

2.3.5 Environmental Permitting Considerations

All of the permits that would be required for Alternative 1 would also be required for Alternative 2. However, while work will be required near the banks of the river for Alternative 1, work within the actual river channel will be required for Alternative 2. Access to the river bar will be necessary for a crane and hoists to complete the installation of the cable hangers and pipe. This will require the construction of access points to the river and temporary access roads and bridges on the river bar. While the grading that would be required on the river bar would be relatively minor, the river bar work requirements would make the necessary permits likely more difficult to obtain for Alternative 2 than for Alternative 1. Additional permits that would be required for this alternative that would not be required for the HDD alternative likely include a 1600 permit from CDFW, a 404 permit from USACE, and a 401 permit from the SWRCB to allow for river bar access that is required for the construction of the suspended crossing alternative.

In addition to considering the tree and vegetation removal that would be required, the CEQA analysis for this alternative would also have to consider the visual impacts of the aerial crossing structure. The existing NCRA railroad is a historical structure, including the railroad grade and the existing trestle. The visual impacts of a new aerial crossing next to the existing trestle would need to be assessed in the NEPA and CEQA documents.

Additional mitigation measure to avoid impacts to the existing cultural resource site would also have to be established in the NEPA and CEQA documents. Although active excavation activities for this alternative would not be performed within the boundaries of the cultural resource site, the site would have to be driven over to install the footings for the towers on the west side of the river. This would be mitigated by installing rubber mats over the cultural resource site. The excavation for the tower footings and the deadman anchors would also be performed immediately adjacent to the cultural resource site, and a cultural resource monitor would likely have to be present during all of these activities to monitor for resources. This will increase construction costs and likely slow down construction. If the excavation unearthed cultural resources, it would also mean that the work would have to be halted until the resources are catalogued and removed.

Summary of Environmental Requirements

Following is a summary of the environmental requirements mentioned above that would likely need to be met for the suspended crossing alternative:

- All of the permit requirements given for Alternative 1 in Section 2.2.5, however, it is unlikely that any additional biological or cultural resource studies would have to be completed to finalize the NEPA/CEQA documents for Alternative 2, while this would likely be required for Alternative 1
- Additional permits that would be required for this alternative that would not be required for the HDD alternative likely include a 1600 permit from CDFW, a 404 permit from USACE, and a 401 permit from the SWRCB to allow for river bar access that is required for the construction of the suspended crossing alternative

2.3.6 Project Cost

Table 4 presents the opinion of probable cost for the construction of this alternative. In addition to construction costs and soft costs (e.g. geotechnical investigation, engineering design, etc.), there would be an annual maintenance cost associated with painting the bridge. The ongoing maintenance cost for this alternative is estimated at $6,000 per year, assuming a minor painting annually and a major painting every five years. Assuming a 50-year lifetime and a discount rate of 3%, the present worth of the $6,000 per year maintenance cost is $154,000. The total estimated present worth cost for this alternative is $3,072,000.

Table 4: Opinion of Probable Cost for Alternative 2 (Suspended Waterline Crossing)

Item No.	Description	Unit	Quantity	Unit Cost	Total
1	Mobilization and Demobilization	LS	1	$70,000	$70,000
2	Clearing and Grubbing	LS	1	$35,000	$35,000
3	Erosion and Sediment Control	LS	1	$25,000	$25,000
4	Revegetation	LS	1	$30,000	$30,000
5	Temporary Construction Access Improvements (River Bar)	LS	1	$70,000	$70,000
6	Structure Excavation	LS	1	$40,000	$40,000
7	Structural Concrete (Deadman, Concrete Footings)	CY	400	$700	$280,000
8	Furnish and Install Steel Piles (towers)	EA	8	$18,750	$150,000
9	West Tower	LS	1	$110,000	$110,000
10	East Tower	LS	1	$110,000	$110,000
11	Furnish and Install Galvanized Steel Cable and Hangers	LS	1	$200,000	$200,000
12	Furnish and Install 14-inch DIP Water Line (Crane Set)	LF	560	$320	$179,000
13	Connect to (E) 14-inch Transmission Main	EA	2	$22,000	$44,000
14	14-inch Gate Valve with Vault	EA	4	$5,000	$20,000
15	Air/Vacuum Relief Valve with Vault	EA	1	$10,000	$10,000
16	Blowoff Assembly with Vault	EA	1	$20,000	$20,000
				Construction Subtotal	$1,393,000
				Contingency (30%)	$418,000
				Opinion of Probable Construction Cost	**$1,811,000**
				Geotechnical Investigation	$80,000
				Survey and Land/ROW Acquisition (10%)	$181,000
				Engineering Design (15%)	$272,000
				Environmental Permitting (15%)	$272,000
				Archaeological Monitoring	$30,000
				Construction Management (15%)	$272,000
				Final Design and Construction Management Total	**$1,107,000**
				Opinion of Probable Project Cost	**$2,918,000**
				Maintenance Cost per Year (Minor Painting every Year, Major Painting every Five Years)	$6,000
				Present Worth Maintenance Cost (50-year Lifetime, 3% Interest Rate)	**$154,000**
				Total Opinion of Present Worth Cost	**$3,072,000**

2.3.7 Maintenance and Resilience

Anticipated maintenance of this crossing would include inspection of the coatings on the structure at regular intervals and performing periodic touch up to the structure coatings and the pipeline coating. The bridge would be designed to meet applicable seismic requirements, and would be much more resilient to an earthquake event than the existing NCRA bridge. The tower footings would be placed outside of the floodplain, so it is unlikely that a flood event would cause damage under this alternative. With appropriate maintenance, this suspended crossing would likely have a minimum lifetime of 50+ years. Because of its above ground exposure, this alternative would be more susceptible to vandalism than the HDD alternative.

2.3.8 Collaboration with Humboldt County Trails

There have previously been discussions with Humboldt County (County) regarding the rehabilitation of the existing NCRA bridge to make it accessible to pedestrians, thereby enhancing rail-to-trail opportunities in the area. However, in a separate analysis, the County came to the conclusion that it would be more cost effective to build a new bridge than it would be to retrofit the existing bridge (the same conclusion Winzler & Kelly came to in the 2009 Feasibility Study). There have also been discussions regarding collaboration between the County and the District to make the new bridge accessible to pedestrians if this alternative is moved forward. The District and its customers informed the County that it did not have sufficient resources to make the proposed pipeline structure compatible with public pedestrian traffic, however, if the County could obtain the additional funds to make the structure pedestrian friendly, the District would consider that option. At the time, the County concluded that they did not have the funds to partner with the District to construct a bridge that would be accessible to pedestrians.

3. Summary & Recommendations

Two alternatives were analyzed for constructing a second pipeline across the Mad River to provide potable water to the FGCSD and Blue Lake in the event of failure of the existing NCRA trestle crossing. Alternative 1 consists of HDD for the placement of a new pipe under the Mad River, and Alternative 2 consists of constructing a suspended waterline crossing over the Mad River.

A third alternative not discussed in the body of this report is the Do Nothing alternative. If the trestle fails, which it will eventually do at some unknown date, then this alternative will leave FGCSD and Blue Lake without water for an indeterminate amount of time. When the trestle fails, it will likely occur during a large flood or earthquake event, when the District and the surrounding communities will also be dealing with multiple other issues.

This section provides a summary of the benefits and drawbacks of each alternative, a recommendation on the best apparent alternative, and a Project Description of the recommended alternative for use in the final NEPA/CEQA documents.

3.1 Comparison of Alternatives

Each alternative was analyzed with respect to constructability, right of way requirements, environmental permitting considerations, and cost. A summary of the analysis is given as follows.

3.1.1 Constructability

HDD

Given the preliminary information provided in the BTE report and the CAInc report, HDD appears to be a viable alternative for this project. The success of HDD is largely dependent on the subsurface properties in the area. HDD can be used in most soil conditions, including solid rock. However, large quantities of cobbles and gravel can cause issues with HDD due to loss of drilling fluid and collapse of the borehole. The conceptual HDD design was developed to stay within bedrock for the majority of the bore; however, a more in-depth geotechnical analysis will need to be performed if this alternative is moved forward into final design to get a firmer idea of the subsurface profile. Given the potential for encountering unconsolidated gravels in the middle of the bore, there is potential for unforeseeable construction issues with the HDD alternative including collapsing of the bore and inadvertent drilling fluid returns. A detailed geophysical exploration prior to the final design/construction would help alleviate this risk by determining a more accurate subsurface profile.

The HDD conceptual design has been developed so that the identified cultural site on the west side of the river can be completely avoided. However, an amended Cultural Resources survey will likely be required as a field survey of the area to be cleared on the west side of river was not included in the original field survey. This will consist of a fairly minor additional field survey of the area by a qualified archaeologist and a letter amendment to the original report. Assuming no additional cultural resources are found in this area, the final construction of the HDD alternative would likely not require a Cultural Resource Monitor during construction.

There is adequate area on each side of the river for staging of all of the equipment required for HDD construction, as well as area for fabrication and layout of the pipe. Right of way requirements are discussed below.

Because the majority of the bore will be within bedrock, the potential for hydrofracture is low. There is an elevated hydrofracture risk near the exit point as the depth of cover decreases. However, this is a typical risk for all HDD projects and can be mitigated through standard measures.

Suspended Crossing

Given the preliminary information provided in the CAInc report, a suspended crossing appears to be a viable alternative for this project. Access will be required on each bank of the river, as well as within the river channel. On the west side of the river, the presence of the cultural site will make it difficult to access the steel tower location; however, disturbance to the cultural site can be avoided with the use of rubber mats.

The cultural site also makes it so that the western abutment will be located near the edge of a steep bank. A minimum setback from the bank would need to be maintained to mitigate seismic slope instability and lateral spreading. This limitation would require further analysis during final design. Shallow footings could be possible at each abutment; however, higher soil bearing and increased security is available for tower footings established within the residual soil unit that underlies the terrace alluvium. Because this unit is at depths of 15+ feet at the eastern and western banks, it is assumed that drilled or driven piles will be used that penetrate into the weathered bedrock. A more detailed geotechnical report will have to be conducted prior to the final design of this alternative.

3.1.2 Right of way Requirements

HDD

This alternative would require a construction easement from NCRA and an encroachment permit from Humboldt County for the undergrowth removal and site access necessary for the HDD work area on the west side of the river. A construction easement and a permanent easement would also be required from Sundberg on the east side of the river at the proposed HDD exit location.

Suspended Crossing

For this alternative, the existing right of way agreements with the NCRA would need to be modified to include the construction of the cable suspension towers on each bank. A construction easement and a permanent easement would also be required for the Susmilch parcel for the construction of dead man anchors on the west side. A construction easement and permanent easement would also be required for the Sundberg parcel on the east side of the river for the installation of the dead man anchors, as well as for installation of the trenched pipe up to the existing District right of way within the NCRA right of way.

3.1.3 Environmental Permitting Considerations

HDD

Both NEPA and CEQA would have to be completed for this alternative. An additional biological survey would have to be completed of the area that would be cleared for the drilling equipment. This area would also require an expanded field survey for the Cultural Resource study, and the study would have to be amended with the findings. Assuming that neither of these studies find any issues that could not be mitigated, they would be rather minor efforts. It is likely that mitigation measures consisting of survey for nesting birds and the establishment of buffer areas for any identified nests would be established in the MND.

County encroachment and grading permits would be required for this option, as well as likely a lease from the State Lands Commission. Consultations will also have to be conducted with the CDFW with regard to the area to be cleared for the drilling equipment on the west side of the river. Consultations will also have to be conducted with the USACE, the RWQCB and CDFW concerning the passage of the pipe under the river and to address potential frac-out issues.

Suspended Crossing

The NEPA and CEQA process would need to be completed for this alternative as well. However, it is unlikely that any additional biological or cultural resource studies would have to be completed to finalize these documents. Mitigation measures in the MND would likely consist of nesting surveys prior to construction and establishment of buffers. It would also require rubber pads to be placed over the cultural resource site at those points where it would be crossed, as well as a cultural resource monitor to be onsite during all excavation activities on the west side of the river.

The other main mitigation measure/area of concern for this alternative in the NEPA/CEQA analysis would be whether mitigation measures would be required for any visual impacts of a new aerial crossing next to the existing railroad trestle, which is listed on the historic register.

All of the permits required for the HDD alternative would likely also be required for the suspended crossing alternative. In addition, a 1600 permit would also be required from CDFW and potentially a

404 permit from the USACE and 401 permit from the SWRCB to allow for river bar access required for the construction of the suspended crossing alternative.

3.1.4 Cost and Maintenance

HDD

The total opinion of probable project cost for the HDD alternative is $2,773,000. This alternative would require very little ongoing maintenance.

Suspended Crossing

The total opinion of probable project cost for the suspended crossing alternative is $3,072,000. This includes considerations for maintenance, which was assumed to consist of a minor painting ever year and a major painting every five years. The estimated maintenance cost of $6,000 per year was brought to a present worth of $154,000 assuming a 50-year project life and a 3% interest rate. Because of its above ground exposure, this alternative would be more susceptible to vandalism and terrorist threats than the HDD alternative.

3.1.5 Resilience

Both alternatives are expected to have 50+ years of life barring any major catastrophic event. The HDPE pipe used in the HDD option should be fairly resilient to a normal earthquake event. The aerial crossing would also be designed to current earthquake codes and should also be resistant to a normal earthquake. However the geotechnical report also stated that it is possible that an “active” fault runs though the project area. If this fault were to rupture through the project, it would likely put both alternatives out of service. The aerial crossing alternative would likely be easier to repair and put back into service after such an event. The HDD alternative might be able to be relined with a new smaller pipe, depending on the resulting off-set of the fault. This would likely take weeks to months to return water service to the communities of Blue Lake and Fieldbrook-Glendale. This holds true for other unexpected failures of the HDPE pipe as well. Although the pipe is expected to last 50+ years, if it did fail for whatever reason, it would be much more difficult to repair and place back into service.

On the other hand, the HDD alternative would likely not be exposed to flood events at all as it is buried well under the riverbed. The aerial crossing would also be located outside the floodplain and would not be vulnerable to normal flood events. The main reason that the aerial crossing is located upsteam of the old trestle is to attempt to prevent damage to the new crossing if the existing trestle fails during a flood event. However, there is still the potential for the existing trestle to fail during a large event, and damage the new aerial crossing when it fails.

3.1.6 Other Criteria

Some of the other considerations for the two alternatives include:

- The HDD alternative would be much less susceptible to vandalism or tampering with than the aerial crossing. However, vandalism that has damaged the pipe or appurtenances has not been a problem for the District for the existing crossing.
- There would be the potential for the aerial crossing to be retrofitted to allow it to be used as a pedestrian crossing and extension of the proposed Annie-Mary Trail. The District does not have rate payer money to spend on making the crossing pedestrian friendly; however the County had previously expressed interest in utilizing the District crossing for an extension of

the trail. The County currently does not have available funding and may never have the necessary funding. The use of the crossing for pedestrians also opens up the District to additional liability and potential vandalism of their pipe and crossing.

- Both alternatives have the potential for increased construction costs due to changed site conditions. Additional geotechnical explorations are required for both alternatives, and these investigations will help ameliorate these risks; however, the risks will not be able to be eliminated completely. The HDD alternative may encounter differing underground conditions than anticipated resulting in additional time/effort/money for construction. The aerial crossing will require working in the Mad River Channel and excavating immediately adjacent to the cultural resource site. Any time work is conducted in a river channel, the permitting and regulatory oversight and constraints are increased, and rightly so, but if there are any upsets, such as a blown hydraulic line on a piece of equipment, the delays and costs increase substantially. If cultural resources are unearthed during the excavations next to the identified cultural resource site, the project will have to stop while the artifacts are recovered, resulting in additional standby time and cost.
- The hydraulic profile of both alternatives is very similar and related energy use over the lifetime of the project will be effectively the same. Daily reliability and operational effectiveness is also too similar to differentiate the alternatives.

3.2 Apparent Best Project

Given the above considerations, it is recommended that the District proceed with the HDD alternative for the construction of a new pipeline across the Mad River. The initial project cost between the two alternatives ($2,773,000 for HDD and $2,918,000 for aerial) is so close as to be a minimal factor in the decision. The ongoing maintenance costs associated with the aerial crossing, increases the overall present worth cost of this alternative to $3,072,000, which is a distinct factor in this decision. However, the main reason the HDD alternative is recommended is because of reduced environmental risks. The HDD project is located completely outside the identified cultural resource site. Although an amended field survey will need to be conducted to ensure the proposed drill rig area on the west side is indeed outside the footprint of the cultural site, there is a substantially reduced risk of impacting any cultural resources or construction being delayed due to unearthing cultural resources for this alternative. The construction of the HDD alternative will be completely outside the channel and riparian zone of the Mad River

The aerial crossing is also hampered by the need to work in the existing channel to construct it. This will require extensive additional permitting from the CDFW, the USACE, and the RWQCB. These permits and their constraints could increase the bid amount for this alternative beyond what is estimated in this Study and also lead to delays and additional costs.

The other great unknown for the aerial alternative is whether, and if so, how the visual impacts to the existing historic trestle structure can be mitigated. The existing railroad is listed on the historic register, and although this trestle was built much later than other portions of the line, it is included in the register. The trestle is located on a stretch of the river that is secluded and not easily accessible for public viewing, but it could be argued that the new crossing would impact the existing structure visually. It is unclear if or how this would affect the final NEPA and CEQA analysis of the project, and could conceivably hold up final approval.

3.2.1 Project Description

This project will consist of the installation of a new 14-inch interior diameter pipeline underneath the Mad River via HDD (see Figure 2 for a plan view of the HDD bore and Figure 3 for a profile view). The pipe material will either be High Density Polyethylene (HDPE, 18-inch outside diameter) or Fusible Polyvinyl Chloride (FPVC, 15.3-inch outside diameter). This new pipeline will replace the existing 14-inch water main currently located on a railroad trestle that is aging and becoming undermined, and will continue water service to the communities of Blue Lake, Fieldbrook, and Glendale. The pipeline will tie-in to the existing 14-inch transmission main on the west side of the river, east of Warren Creek Road and on the east side of the river, just west of Glendale Drive.

HDD is a trenchless construction method in which a pipe is installed along an arcing drill path, beginning and ending at entry and exit pits, respectively, and passing under the conflicting feature (in this case, the Mad River). A drill rig is set up on the entry side (in this case the west side of the river) and drills a pilot bore to the exit point. The pilot bore is then reamed in one or more passes to the size required for pullback of the prefabricated pipe string. After reaming is complete, the pipe is pulled into the bore, preferably in one continuous operation. The pilot bore will be installed from the west side of the river and an entrance pit will be constructed on a District-owned parcel (APN 516-025-111), approximately 90 feet east of Warren Creek Road, 600 feet north of the intersection with Burlwood Lane. The drilling bore will terminate on the east side of the river, just southwest of Glendale Drive on the property of GR Sundberg (APN 504-131-004), and an exit pit will be constructed at this location. The new pipe will be assembled (fused) and laid out on the Sundberg property, which should allow the pipe to be pulled back in one continuous pull. The new pipeline will then be tied into the existing 14-inch transmission main on each side of the river, which will require standard open trenching for the installation of the pipe to the tie-in location on each side.

A bentonite-based drilling fluid is used in the HDD process to aid in excavation of the soil, carry the cuttings from the bit back to the drill rig, provide hydrostatic support to the otherwise unsupported borehole, and to cool and lubricate the drill pipe and tooling during drilling. The returned drilling fluid is sent through a solids separation plant with a system of vibrating screens and hydrocyclones that remove the majority of the soil from the slurry. Clean drilling fluid is sent back to the bit. Drilling fluid recovery pits are commonly excavated at each end of the bore. The pits are usually 3-6 feet wide, 6-12 feet long, and 2-4 feet deep. The risk of inadvertent fluid returns (hydrofractures or frac-outs) is an important consideration for HDD projects. This typically occurs when excess drilling fluid pressures cause fluid to escape the bore and surface through granular soils, cracks in cohesive soils, or along other natural or man-made conduits. Drilling fluid is generally a non-toxic mixture of water and bentonite clay; however, spills are viewed as an environmental risk.

Conceptual Bore Design

The conceptual bore design was developed based on the capabilities and limitations of HDD, the required pipe diameter, mitigation of frac-out risks, and other site constraints. The plan bore alignment is 1,125 feet long. The conceptual alignment was designed to maintain a minimum of 20 feet of clearance beneath the Mad River channel at all points.

The entry location was chosen to minimize bore length while still maintaining adequate depth beneath the river channel. This location also allows for a short connection length to the existing transmission main and allows for construction access off of Warren Creek Road without affecting nearby private properties. The entry location also avoids disruptions to the identified cultural site.

The exit location was also selected to minimize bore length, maintain adequate depth, and allow for a short connection to the existing transmission main. The location on the edge of the Sundberg site will also minimize disruption to Sundberg's property.

Because this bore is anticipated to be drilled completely within fresh bedrock, frac-out risk is anticipated to be low, unless significant open joints, fractures, or faulting is encountered. The clearance of 20 feet from the channel bottom was chosen to reduce the risk of inadvertent drilling fluid returns through existing pathways in the rock, and to avoid potential historic flow channels that have been infilled with alluvial cobbles, gravel, and sand.

Staging Area

A medium HDD rig will likely be required due to the diameter, length, and subsurface conditions of the proposed HDD crossing. The required staging area for a rig of this size is approximately 10,000 square feet at the entry side of the bore. This allows for staging of the drill rig, other pieces of ancillary equipment (e.g. backhoe, boom truck), drill pipe, bentonite, drilling fluid pumps, fluid storage tanks, a solids separation plant, tool trailers, and other equipment. The drill rig, backhoe/boom truck, and drill pipe storage will be located in an area that is approximately 75 feet long and 30 feet wide and aligned directly behind the entry point, and this area must be completely clear. The separation plant will also require a clear area that is approximately 40 feet long and 30 feet wide. The pipe laydown area on the exit side will be 20 to 50 feet wide and equal to the length of the pipe (approximately 1,125 feet). Figure 2 shows an approximation of the area that will need to be completely cleared to accommodate the rig and separation plant, as well as the rest of the work area that will require undergrowth removal. This figure also shows the pipe fabrication and layout area on the east side of the Mad River.

Hydrofracture Analysis

The potential for inadvertent drilling fluid returns to the ground surface is a serious concern for any HDD crossing. A preliminary analysis of the hydrofracture risks for the project has been performed. The analysis showed that the risk of hydrofracture is low for the majority of the crossing length. Because the depth of cover decreases near the exit point, the hydrofracture risk is elevated shortly before the exit point. This is a typical risk for all HDD bores and can be mitigated through common measures including specifying that the contractor have equipment and tools on-site for rapid containment and clean-up of inadvertent fluid returns. A detailed Surface Spill and Hydrofracture Contingency Plan will also be developed. A more detailed geotechnical/geophysical analysis will also be completed as part of the final design to help obtain a more detailed picture of the subsurface stratigraphy and determine whether there are any granular soils, cracks in the bedrock soils, or other natural or man-made conduits that could serve as preferential pathways for frack-out.

Connections to Existing Water Main and Disinfection/Flushing of the New Pipe

A connection to the existing water main will take place on each side of the river. The existing main will be cut open, and a tee will be installed on the existing main to connect the new pipe to the existing pipe. Two isolation valves will be installed at the tee at each connection so that both the existing line and the new line can be isolated. Because the existing main will be cut open for this work, a portion of the line will need to be drained at each connection location for the connection work to be completed. On the west side, it is anticipated that approximately 600 linear feet of the 14-inch line will need to be drained (approximately 4,800 gallons of water). The drained water will be directed to the approximately 10,000-square-foot HDD staging area. Hay bales will be set up around the perimeter of this staging area to facilitate percolation of the water into the subsurface. A similar approach will be taken on the east side of the river at the Sundberg property, where approximately 365 linear feet of pipe are anticipated to be drained (approximately 2,900 gallons of water).

After the new pipe is installed, it will need to be disinfected with highly-chlorinated water and subsequently flushed. A percolation basin as described above will also be used for the dechlorination of disinfection water that is flushed out of the water line. Standard construction Best Management Practices (BMPs) will be used for the above work, and all of the water handling and disposal requirements as set forth in the District's General NPDES Permit will be followed.

Appendices

Appendix A – Inspection of NCRA Railroad Bridge Across Mad River (Winzler & Kelly, 2008)

Ref: 101055-07010-11010

February 8, 2008

Barry Van Sickle
Superintendent
Humboldt Bay Municipal Water District
P.O. Box 95
Eureka, CA 95502

Re: Inspection of NCRA Railroad Bridge Across Mad River
Agreement No. 54Rt-1 – Focused Engineering Study

Dear Barry:

Per our proposal dated 8/2/2007 and Agreement No. 54Rt-1, we are pleased to provide you with this report on our inspection and limited analysis of the NCRA Railroad Bridge. An inspection of the NCRA Railroad Bridge which carries the domestic water line that serves the Fieldbrook Community Service District and the City of Blue Lake over the Mad River was completed by Winzler & Kelly in December 2007. This report serves as a focused engineering study to provide information for the maintenance and repairs of the District's infrastructure and facilities as described in the HBMWD Infrastructure and Capital Improvement Program. The purpose of the inspection was solely for the purpose of inspecting current conditions of the bridge and support system that is related to the District's facilities and pipeline. The bridge appears to be built in 1930's or 1940's and has not had any known maintenance completed recently.
To facilitate this inspection, HBMWD staff placed a 4' wide plywood walking surface across Span 1 on the west side and across the trestle on the east side allowing a visual inspection from roadbed level of the bridge to be completed. In addition, separate inspections were made of the under side of the bridge and Pier 4 from a boat. Finally, a review of the 1973 Fieldbrook Community Service District construction drawings for this project and the "Annie and Mary Rail-trail Feasibility Study Engineering Evaluation of Trestles, Bridge and Corridor Bed" by the Redwood Community Action Agency was completed.

OBSERVATIONS OF CONDITIONS

Pipeline

We were able to inspect the pipeline along Span 1 of the bridge and on the east side of the trestle. The pipeline is a 14" diameter steel pipe supported on Grinell Fig. 171 pipe supports at 27.5' on center. It appears in good condition with no obvious missing or damaged components and the paint is in adequate condition.

Trusses
The bridge has 3 truss spans that are 15' each. The trusses were initially designed to support train loading, so are over designed for this present load. The paint is in adequate condition; however, there is rust in locations where water builds up during wet conditions. It should also be noted that due to the age of the bridge it is likely that the existing coating system contains traceable amounts of lead in the paint. The bottom X-bracing is composed of a double angle and the joint between the two has significant rust. There is also rust on other horizontal surfaces and joints as is expected. At this time it does not appear that the rust has compromised the capacity of the trusses.

Pins and Rockers
The trusses are supported on pins on their west ends and rockers on their east ends. We were able to inspect the pin on Span 1 and the rocker on Span 3 from road level. Each appeared in good condition without significant rust or missing parts. The rocker was in its fully expanded position which was unusual considering it was a cool day. This is probably due to movement of Pier 3. It means that there is an unknown and possibly excessive load carried to the anchor bolts. The design of the pins and rockers are typical of the period in which the bridge was built. This design has proved non-ductile and vulnerable in earthquakes, so all highway bridges have been retrofitted with backup cables. If the water line remains on the bridge long term, a seismic study and probable retrofit similar to highway bridges will be required.

Piers
The piers are composed of barbell shaped towers sitting on massive rectangular footings. The towers show no evidence of problems. The piers are hard to evaluate since it is unclear how deep they go and what they rest on. Piers 1 and 4 are on the banks and appear fine. At first glance it appears the Pier 3 base is near the gravel surface, but closer examination shows that this is just a construction joint, where one tremmi pour rests on a longer tremmi pour. Both Pier 2 and 3 have four deep scour pools on their east side. Using a survey rod we measured the depth and following how far down the footing concrete extends. At the northeast corner of Pier 2 the rod reached the bottom of the footing and went underneath it. On Pier 3 the pier extended to the bottom of the scour pool. On the northeast corner of Pier 3, a void in the pier revealed what appears to be a timber pile indicating the possibility these piers may be pile supported. The scour pool on Pier 3 extends around the front of the pier where we were unable to determine the depth of concrete, scour depth, or origin of the block. Visually Pier 3 appears to have a slight tilt to the east. It is unknown if this is an illusion, whether it was formed this way or if it indicates settlement. The location of the rocker on Pier 4 indicates some eastward movement on the top of Pier 3.

The piers survived the major floods of 1955 and 1964 without incident. However, we do not know if repairs were done after these floods or if the channel has degraded since then. Overall a visual inspection of the piers proved inconclusive without discovering or eliminating undermining as a major deficiency. Drill holes or test excavations may prove as inconclusive as my visual inspection.

Trestle

The west approach to the bridge consists of a single wooden bent trestle. The District's pipeline does not cross the west trestle and comes from below grade adjacent to the west approach on to the bridge. See attached Figure 1. There is a timber trestle composed of 7 pile bents on the east approach of the bridge. The pipeline is supported on the north cantilever ends of the 12x12 timber pile caps. We were able to visually inspect the diagonal braces and the piles and could probe the pile cap with a screwdriver as well as visually inspect. The following is a summary of the condition of the trestle:

Bent 1 has a rotted pile cap. The northernmost pile is rotted and spaces at the top end of the diagonal brace are missing, leaving a loose bolt.
Bent 2 has rotted diagonal braces.
Bent 3 has a rotted diagonal. Members on top of the pile cap trap trash and water which will eventually lead to rot.
Bent 4 does not support the pipe.
Bent 5 has a rotted pile cap and rotted diagonal.
Bent 6 has a rotted diagonal. I was unable to inspect the cap due to blackberry vines.
Bent 7 has rot on the cap.

Recommendations

1. The condition of the trestle on the east approach is substandard and should be addressed immediately to protect the pipeline. It is our opinion that with the level of rot noted, it is not recommended to replace individual members as the damage is probably more extensive than our inspection reveals. Members that are presently sound are probably near the end of their life and may have rot soon. The 14'0 steel pipeline spans 27.5' between the supports on the main bridge, and per calculation is capable of spanning up to 60' between supports. As such, the pipeline should be able to carry itself without vertical support from the trestle if we provide it with post supports at two locations along this stretch. The trestle and the bend in the line should be adequate to carry lateral loads. In order to make a final recommendation for a repair we will need to complete further additional analysis to refine the design. It is recommended that HBMWD proceed with the design of this temporary support and complete the repairs immediately.

2. As previously discussed highway bridges that are similar in design have been retrofitted to current standards to resist seismic forces. Based on our limited inspection it is our opinion that the main source of vulnerability to the bridge is earthquake and potential

damage at the footings due to a flood. If the Pipeline will remain on the bridge a seismic study should be completed to assess the actual condition and potential required retrofits of the bridge to protect the Pipeline.

3. The District's pipeline crossing the NCRA railroad bridge is the only source of potable water for the Fieldbrook CSD and the City of Blue Lake. We recommend that further analysis be completed evaluating an alternative for crossing the Mad River. Based on our recommendation to make temporary repairs and assuming no retrofits are completed to the bridge, we recommend that a project to provide an alternate Mad River crossing should be planned at the 10 year level for the District's CIP.

If you have any further questions, please don't hesitate to call me.

Sincerely,
WINZLER & KELLY

Stephen Peacock, P.E.
Structural Engineer

Alex Culick, P.E.
Associate Engineer

lcf

Attachments

RUST ON DOUBLE ANGLE LATERAL BRACING

TYPICAL MINOR RUST ON TRUSS

ROCKER ON PIER 4 IN FULLY EXPANDED POSITION

PIN ON PIER 1

FOOTING PIER 2 AT SCOUR POOL

FOOTING PIER 3 FROM UPSTREAM LOOKING AT SCOUR POOL IN RIVER CHANNEL

FOOTING PIER 3 WEST SIDE SHOWING EROSION OF TREMMI POURED CONCRETE

FOOTING PIER 3 FROM DOWNSTREAM LOOKING SOUTH

FOOTING PIER 3 FROM RIVER. NOTE ROD SHOWING PIER AND WATER DEPTH AND EXPOSED PILE AT PIER CORNER.

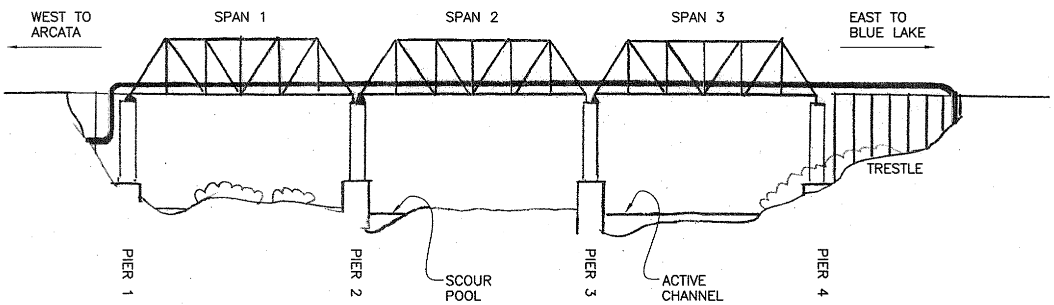
DETAIL OF EMBEDDED PILE ON NORTH END OF PIER 3

TRESTLE AT EAST END LOOKING EAST

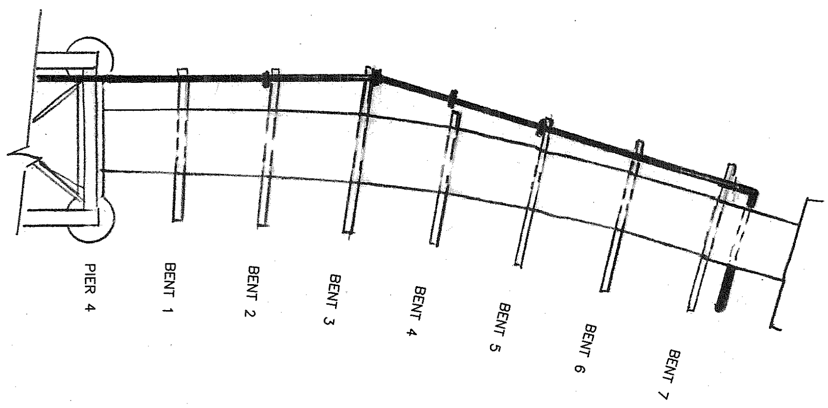
TRESTLE AT EAST END LOOKING WEST

BENT 1 SHOWING ROTTED CAP PILE AND BRACE

BENT 5 SHOWING SCREWDRIVER SUNK INTO ROTTED PILE CAP



1 PROFILE LOOKING NORTH



2 PLAN VIEW OF TRESTLE

REGISTERED PROFESSIONAL ENGINEER
STEPHEN P. PEACOCK
No. S3204
Exp.
STRUCTURAL
STATE OF CALIFORNIA

WINZLER & KELLY
CONSULTING ENGINEERS
633 THIRD STREET
EUREKA, CA 95501-0417
PH (707) 443-8326
FAX (707) 444-8330

DES SPP	BAR IS ONE INCH ON ORIGINAL DRAWING 0 1" IF NOT ONE INCH ON THIS SHEET, ADJUST SCALE ACCORDINGLY	DRN SOG
SUPV SPP		CHK SPP

H.B.M.W.D.

STRUCTURAL
NCRA RAILROAD TRESTLE
MADRIVER

JOB NUMBER 01055-07010
SHEET 1 OF 1

S-1

P:\2005 & Beyond\01055 Humboldt Bay Municipal Water District\01055-072\008\NCRA RailroadTrestle-MadRiver\CAD 01055-07-010\dwg\S-1.DWG

Appendix B – Emergency Pipeline Crossing Feasibility (Winzler & Kelly, 2006)

Ref: 01055-05031-11010

June 23, 2006

Barry Van Sickle
HBMWD
7270 West End Road
Arcata, CA 95521

Re: Emergency Pipeline Crossing – Agreement No. 54-478

Dear Barry:

Per your request and our Agreement No. 54-478, we are pleased to provide you with this letter report describing the development of a conceptual design for an aerial pipeline crossing over the Mad River in two locations. The first would be located near the District's pipeline serving FCSD and Blue Lake. The second location would be near the MCSD pipeline and would be for the purpose of providing MCSD an emergency supply of water in the event their pipeline under the Mad River fails or service is interrupted at that location. Per the Scope of Work the services are:

1. Investigate the feasibility of an aerial crossing utilizing a temporary pipeline. We will do a search of the internet and attempt to locate other projects where an aerial crossing was installed utilizing a temporary pipe. Issues we will research include pipe type and installation details such as roller fittings for attachment to a cable for an aerial crossing.

2. Based on the findings of Task 1 we will complete a conceptual design for an aerial crossing. It is assumed that the aerial pipeline for both crossings will be similar in design, and the locations will be in the near vicinity of the above identified locations, where installation of a crossing may be suitable. Conceptual design will be for an aerial crossing utilizing a temporary pipeline. However, if a temporary pipeline is determined to be infeasible, we will complete a conceptual design for an aerial crossing with a permanent pipeline. The conceptual design will include conceptual piping connections design based on the identified potential locations. Specifics of design such as final size, height and length of crossing will be developed during the design phase of the project. No civil design is planned for the conceptual design.

3. Review and determine permitting requirements for installing a permanent cable and/or pipeline across the river, installation of supporting structures and feasibility of obtaining the permits.

Feasibility Study

The original concept of the aerial crossing utilized a tower at either side of the river with a cable spanning between the towers. During an emergency, a flexible pipeline would be hung from this cable and pulled across to the opposite side of the river. The pipeline would require support, designed as a clevis type hanger, at repeating intervals, the full length of the crossing. When not needed, the pipeline could be retracted back across the river and stored at an offsite location and utilized for other purposes as required.

The feasibility study of this aerial crossing demonstrated this concept to be impracticable. The Super Aqueduct pipe, from Angus Flexible Pipelines, was found as a possible temporary pipeline. It is available up to 12" diameter and is rated for potable water. We contacted a representative of the company and described the concept detailed above. The representative was not aware of any similar projects and also informed us that this pipe was designed to have continuous support from below, and that the "hanging" concept of our design would not be feasible. Additionally, he noted that the Super Aqueduct pipe was not durable like a fire hose, or other heavy-duty water pipe and is not suitable to be dragged across the ground. For this reason, even if a structure was designed to give continuous support to the pipe, it could be damaged during the pulling process across the river.

We also researched the internet and contacted other water districts, for any possible temporary aerial crossings similar in concept and were unsuccessful at finding a similar project. One possible concept is to use rigid pipe, and design it to retract in an accordion type fashion similar to ship-to-ship fueling in the marine industry and military applications. However, with the long span of approximately 460 feet, the amount of pipe in its retracted form would be excessively large and possibly non-transportable.

Conceptual Design

Based on the findings of the feasibility study described above, it was determined that a temporary pipeline was impracticable. Per the scope of work task #2, we continued with a conceptual design of an aerial crossing utilizing a permanent pipe, assuming the structures for both pipelines will be similar in design.

The locations of the new structures will be in the near vicinity the District's pipeline on the railroad trestle serving FCSD and Blue Lake and near the MCSD pipeline. Please find attached sheets C-01 and C-02 for the proposed locations. Also shown are the conceptual piping connections to the existing water lines.

The conceptual design of the aerial crossing consists of a 12" diameter flanged ductile iron pipe, spanning the width of the river. In both locations, this distance is approximately 460 feet. At either side of the river, above the flood plane elevation, a steel tower with a concrete footing will be built. The tower will be approximately 28 feet tall and 20 feet wide, with 12 inch diameter steep pipe columns at each end. From each of the top corners of the tower, a 1 ¾ inch galvanized steel cable will span across the river to the opposite tower. The cables will also extend backwards, away from the river approximately 50 feet, to the ground elevation, and secure to a "dead man", or anchor structure. The dead man will consist of approximately 1,600 cubic feet of concrete buried in the ground. From these cables, in a suspension bridge type style, 3/8-inch diameter cables will hang down and support the ductile iron pipe at 20-foot intervals over the river. Please see attached sheets C-03 and C-04 for details of the conceptual plan.

Environmental Compliance

We contacted the various agencies that exert permit authority over projects in and around stream channels under particular circumstances. Our findings are summarized below:

1. **CEQA**: The District will be the lead agency for CEQA. The appropriate CEQA process would be Negative Declaration provided that there would be no significant impact after considering mitigation measures. Potential impacts include removal of riparian vegetation, damage to cultural resources, river channel modification, and aesthetics. **County and city zoning and building ordinances do not apply to water transmission facilities.**
2. **State Lands Commission**: A lease will likely be required for a permanent structure over the level of ordinary high water of the Mad River. If the project progresses to design and permit acquisition, a letter requesting State Lands review will be required. The letter should include a project description; USGS map location, and aerial photograph.
3. **Corps of Engineers**: A permit under Section 404 will be required if foundations are placed within the level of ordinary high water of the Mad River. A Nationwide Permit for utility lines would probably be appropriate. No Section 404 permit is required for overhead structures. (A permit could be required for overhead structures under Section 10, but that jurisdiction extends only 1.4 miles above the mouth of the Mad River, which is well downstream of the project.)
4. **Regional Water Quality Control Board**: If a Corps permit is required under Section 404, then a Water Quality Certification will be needed from the RWQCB.
5. **Department of Fish and Game Streambed Agreement**: If any materials will be placed in the stream channel or riparian vegetation will be cut, a permit will be required, as usual. Otherwise, a permit would not be required for overhead structures above the channel.
6. **National Marine Fisheries Service**: If a Corps permit is required, the Corps will consult with NMFS under Section 7. Otherwise, NMFS would be willing to provide technical assistance by reviewing the project for potential effects on species listed as threatened or

endangered. The HCP etc. could be amended, if appropriate and necessary, with substantial effort.

7. **U.S. Fish and Wildlife Service**: As with NMFS, if a Corps permit is required, the Corps will consult with the FWS under Section 7. Otherwise, the FWS should be advised of the project so that they may provide technical assistance by reviewing the project for potential effects on species listed as threatened or endangered, specifically the Bald Eagle.
8. **Federal Aviation Administration**: The FAA has a notification requirement for facilities that could affect airport airspace. It seems unlikely that the aerial crossings would have any bearing on airport airspace or aviation safety in general. There is an aerial crossing over the Mad River nearby at each location so a new aerial pipeline crossing will not be a new obstruction in the air space. If the project progresses to design and permit acquisition, it may be prudent to submit project information to FAA for a determination.

Based on our research and the conceptual plans developed if the District chooses to proceed with an emergency crossing a permanent cable supported pipeline is a feasible option to consider. A temporary pipeline that is installed in the case of an emergency is not a feasible alternative due to the length of the crossing. In addition, if the emergency crossing is put to use, it may be relied upon for a significant amount of time until the permanent crossing(s) is repaired and returned to service. In this case a ductile iron pipe will be reliable and be able to withstand the elements for an indeterminate amount of time.

If you have any questions, please don’t hesitate to call me.

Sincerely,
WINZLER & KELLY

Alex Culick, P.E.
Associate Engineer

lcf

c: Carol Rische, HBMWD
Tom Marking, MCSD

Appendix C – Feasibility Study of Alternatives to Construct Secondary Pipelines Across the Mad River (Winzler & Kelly, 2009)

01055-07016.11003

FEASIBILITY STUDY OF ALTERNATIVES TO CONSTRUCT SECONDARY PIPELINES ACROSS THE MAD RIVER TO SUPPLY WATER TO FIELDBROOK AND BLUE LAKE

May 2009

Prepared for:
Humboldt Bay Municipal Water District
828 Seventh Street
Eureka, CA 95501
(707) 443-5018

Prepared by:
WINZLER & KELLY
633 Third Street
Eureka, CA 95501
(707) 443-8326

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Tables **Page**

1.0 INTRODUCTION

Humboldt Bay Municipal Water District (HBMWD) currently supplies domestic water to the Fieldbrook Community Services District and the City of Blue Lake. The water supply pipeline to those communities crosses the Mad River via a 14-inch ductile iron pipeline attached to a North Coast Railroad Authority (NCRA) bridge. The bridge has not been used or maintained for many years, and if it fails, it could damage the District's pipeline and interrupt the sole domestic water service to Fieldbrook and Blue Lake. An inspection of the NCRA bridge was completed by Winzler & Kelly in December 2007, and it found the condition of the bridge to be substandard and near the end of its functional life (see Appendix B for Report). The report also identified that the main sources of vulnerability to the bridge are an earthquake or potential damage to the footings during a flood. Because of these issues the District is exploring alternatives to supply domestic water across the Mad River to the communities of Fieldbrook and Blue Lake.

The District has previously investigated the feasibility of an emergency aerial crossing utilizing a temporary pipeline (see Appendix C for Report). Multiple crossing locations were evaluated. The previous study found that a temporary pipeline was impracticable; however, it states that a permanent cable supported pipeline is a feasible option to consider. This Alternatives Analysis draws upon the findings of the emergency aerial crossing report and examines the other alternatives to review their constructability, permitting and other requirements, and develops planning level construction cost estimates for each feasible alternative.

2.0 ALTERNATIVES ANALYSIS

Five alternatives were considered that could provide a secondary pipeline to supply water to Fieldbrook and the City of Blue Lake. The alternatives considered included alternatives within the channel, under the channel, suspended over the channel and on the existing crossing structure. The five alternatives considered are the following:

1. Alternative 1 – Concrete Encased Pipeline Under the River
2. Alternative 1A – Concrete Encased Pipeline Under the River With a Tie to the Collector Five Discharge
3. Alternative 2 – Trenchless Methods Under the River
4. Alternative 3 – Suspended Waterline Over the River
5. Alternative 4 – Improvement of the Existing Railroad Bridge Crossing

The five alternatives were evaluated on the basis of constructability, right of way requirements, environmental permit considerations and cost. Figure 1, Appendix A, shows an aerial photo with the location of each of the five alternatives. All of the five alternatives are located in the area between Collector Four and the area immediately upstream of the existing crossing on the railroad bridge.

These alternatives are conceptual and detailed engineering design would need to be performed on the selected alternative. The final design of any of these alternatives could vary significantly depending on the subsurface geological characteristics encountered, which can only be determined by a geotechnical investigation. These investigations were not completed for this analysis, but would also need to be completed prior to the final design of the selected alternative.

Each alternative analysis includes a review of:

- The constructability of the alternative, including a description of the potential difficulties associated with constructing the various project components.

- The right of way needs for the alternative. This analysis includes a review of the ownership of the parcels in the vicinity of the proposed alternatives, the identification of the parcels on which additional easements would be required, and review of the encroachment permits and temporary construction easements anticipated to be needed.

- A review of the environmental permitting requirements. Including a review of the agencies that may exert permit authority on the construction of the alternative and the associated permits that would be required, as well as a review of the level of analysis that will be required to satisfy the California Environmental Quality Act (CEQA). For the purposes of this alternative analysis it is assumed that the alternatives would not be federally funded, and therefore, requirements necessary to satisfy the National Environmental Policy Act (NEPA) are not included in this analysis.

- A budget level of the opinion of probable cost. The costs presented are based on the preliminary anticipated layouts and details. Costs for the various project components are based on unit prices from projects recently bid, and estimates from contractors who specialize in the specific types of work included in the alternative. Engineering design, permitting and construction management were calculated as a percentage of the construction costs, and the cost for the geotechnical investigation was estimated based on the cost for geotechnical services on similar projects.

2.1 Alternative 1 – Concrete Encased Pipeline Under the River

2.1.1 Description

Alternative 1 includes the placement of a new 24-inch ductile iron pipeline within the river gravels, approximately 825 feet downstream of the existing railroad bridge crossing. The pipeline would run from the existing 14-inch transmission main located on Warren Creek Road, 200 feet down the river bank to the river channel, approximately 500 feet across the channel, 250 feet up the opposite bank to Glendale Drive, then along Glendale Drive approximately 1,000 feet to the existing 14-inch transmission line on the east side of the railroad bridge crossing. (see Figure 1, Appendix A)

The location for this crossing was selected to simplify water diversion, and so the waterline is located in an area less vulnerable to the erosive forces of the channel. In order to complete the trenching of the pipeline across the river, a water diversion would be necessary to divert the water around the trench excavation. At the current trestle location there is a relatively narrow channel cross section where higher velocities would be anticipated and where bedrock is exposed on each side of the channel. This location is ideal for a bridge, but not for trenching a waterline as it would be more difficult to divert the river in such a narrow location, and the new pipeline would be both difficult to place and vulnerable to erosion if located on top of the bedrock at the banks. The proposed location of this alternative is just downstream where there is a wide bar where the river could be more easily diverted. The diversion would likely be accomplished by the use of water bladders and shallow trenching on the surface of the river bar to create a second channel (which currently exists as a high flow channel) on the east side of the river. This would allow the pipeline trench to be completed in two sections; half on the east side when the river is flowing in the current low flow channel, and the other half of the trench on the west side during which the river would be diverted to the east channel.

The piping within the channel would be 24-inch ductile iron pipe with restrained fittings in a reinforced concrete encasement. The crossing would be between 10 and 15 feet below the existing river channel and would be supported by steel pile driven to a depth of approximately 40 feet below ground surface. This type of crossing was used for the raw water supply line from Collector 5 and has resisted the erosive forces of the river; therefore it is assumed that a similar construction method would be suitable for the new water transmission line crossing in the same vicinity. Figure 2 in Appendix A shows a typical section of the concrete encased pipe and a cross section from the original plans for the installation of the raw water line to Collector 5.

Differences between the new pipeline placement and previous construction include using ductile iron instead of steel pipe to reduce cost, and increasing the pipe diameter from 14-inch diameter to 24 inch to allow for additional capacity in the future.

The piping outside of the channel, including the piping on the bank and within the roadway, will be 14-inch diameter Class 160 PVC pipe, which is equivalent to the existing piping that it would tie into. The pipeline within the bank and roadway sections would likely be placed by open trench construction methods. A short section of ductile iron pipe placed on support brackets would also be required for the bridge crossing over Lindsay Creek on Glendale Drive.

Temporary construction access roads would also be necessary for the construction of this alternative as discussed in the following section.

2.1.2 Constructability Issues

Diverting the river, dewatering the trench excavation, and construction access pose the most significant constructability issues for this alternative.

The diversion of the river through the use of water bladders and trench would be relatively straight forward, although it would be time consuming to permit and install. It would also limit the construction window of the project to the late summer and fall, when flows on the river are at a minimum and salmon are not spawning. Water bladders could be placed on the upstream end of the bar immediately above the proposed trench location. A trench would then be installed to divert the river to the existing high water channel on the east side of the river. Additional grading may also be required to maintain a gradient throughout the diversion.

Dewatering the trench would be difficult due to the subsurface flow of water within the river gravels even with the river diverted. It is likely that at the depth of the planned trench (10-15 feet bgs) a groundwater gradient would flow toward the trench excavation. To remove the water from the trench, constant pumping would be required from the trench and from dewatering well points installed around the trench. This effort would require the installation of wells, the use of pumps and additional labor to maintain the pumps during construction, as well as treatment of the water to reduce turbidity prior to returning it to the river.

Construction access would require the creation of access points to the river, and temporary access roads on the river bar. The most likely access point on the west side of the river would be from the District property near Collector 4. The access road would require a temporary bridge or culvert across the river upstream of Collector 4 to allow construction equipment to reach the gravel bar where the crossing would be located. Temporary bridges would have to be large enough to support the crane rig needed to drive the piles for the pipeline supports. The access roads on the river bar would likely require little more than minor grading to establish them and to remove them after construction. A second access point would also have to be established from Glendale Drive to allow construction of the pipeline from the river to Glendale Drive.

2.1.3 Right of Way Needs

This alternative would require relatively little additional right of way as it would be primarily located on District Property and property within the channel owned by the State Lands Commission. Routing pipelines through the County roads right of way would require a County Encroachment permit. Figure 3 in Appendix A shows the proposed alternatives with the parcel lines and parcel owners. The following table lists the parcel numbers and owners of parcels not already owned by HBMWD that may need easements or access agreements.

Table 1. Alternative 1 - Right of Way Parcels

AP Number	Street Address	Owner
504-142-016-000	1777 Sutter Road	Ford, Lance N. and Ronda L.
County Road	Glendale Drive	Humboldt County

2.1.4 Environmental Permitting Requirements

The following identifies permits and agency coordination that would be required for the In-Stream Crossing alternative.

CEQA: The District will be the lead agency for CEQA. The appropriate CEQA process would likely be a Mitigated Negative Declaration provided that there would be no significant impact after considering mitigation measures. Potential impacts include removal of riparian vegetation, river channel modification, and possible damage to cultural resources. County and city zoning and building ordinances do not apply to water transmission facilities and building permits would not be required.

State Lands Commission: When California became a state in 1850, it acquired approximately four million acres of land underlying the State's navigable and tidal waterways. Known as sovereign lands, these lands include the beds of California's navigable rivers, lakes and streams, as well as the State's tide and submerged lands along the State's more that 1,100 miles of coastline and offshore islands from the mean high tide line to three nautical miles offshore.

The State Lands Commission holds the State's sovereign lands for the benefit of all the people of the State, subject to the Public Trust for water related commerce, navigation, fisheries, recreation, open space and other recognized Public Trust uses. The Commission maintains a multiple use management policy to assure the greatest possible public benefit is derived from these lands. The Commission will consider numerous factors in determining whether a proposed use of the State's land is appropriate, including, but not limited to, consistency with the Public Trust under which the Commission holds the State's sovereign lands.

The issuance by the Commission of any lease, permit or other entitlement for use of State lands is reviewed for compliance with the provisions of the California Environmental Quality Act (CEQA). No proposed project will be considered by the Commission until the requirements of the CEQA have been satisfied. Additionally, if the application involves lands found to contain "Significant Environmental Values" within the meaning of PRC Section 6370 et seq., consistency of the proposed use with the identified values must also be determined through the CEQA review process. Pursuant to its regulations, the Commission may not issue a lease for use of "Significant Lands" if such proposed use is detrimental to the identified values.

Most leases or other entitlements for use of State lands may require approvals from other Federal, State or local agencies. On many proposed projects the Commission is the Lead Agency under CEQA (the public agency with the principal responsibility for carrying out or approving a project) and is therefore responsible for preparing the environmental documentation appropriate to each project. In this case, the District would likely be the lead agency for the CEQA process.

A lease will likely be required for the pipeline below the Mad River. The first step is to confirm that the project falls within the jurisdiction of the State Lands Commission. If the project is within the agency's jurisdiction and if the project progresses to design and permit acquisition, a letter requesting State Lands' review will be required. The letter would include a project description; USGS map location, and aerial photograph. Also required would be an application for a General Lease ROW, photographs of the site, copies of the applications sent to other permitting agencies, and complete project description, maps, and a minimum expense deposit. This project would consist of transaction type D (public agency

Lease/Permit). The fees associated with this permitting requirement would include a $25.00 application fee and a minimum expense deposit for processing of $3000.00.

Corps of Engineers: A permit under Section 404 will be required. A Nationwide Permit for utility lines would probably be appropriate.

Regional Water Quality Control Board: A Water Quality Certification (Section 401 Permit) will be required from the RWQCB.

Department of Fish and Game Streambed Agreement: A 1600 Streambed Alteration Agreement will be required from the Department of Fish and Game.

National Marine Fisheries Service: The Corps will consult with NMFS under Section 7 as part of the 404 permit process.

U.S. Fish and Wildlife Service: As with NMFS, if a Corps permit is required, the Corps will consult with the FWS under Section 7 as part of the 404 permit process. The FWS will provide technical assistance by reviewing the project for potential effects on species listed as threatened or endangered.

2.1.5 Construction Cost

Table 2 below presents the opinion of probable costs for the construction of this alternative. The opinion of probable costs for this alternative is $2,350,000.

Table 2. Opinion of Probable Cost for Alternative Concrete Encased Pipeline Downstream of the Existing Railroad Bridge Crossing					
Item No	**Item Description**	**Quantity**	**Unit**	**Unit Cost**	**Total**
1	Mobilization and Demobilization	1	LS	$70,000	$70,000
2	Clearing and Grubbing	1	LS	$20,000	$20,000
3	Erosion and Sediment Control	1	LS	$50,000	$50,000
4	Temporary Construction Access (Construction Entrance, Temporary River Crossings)	1	LS	$60,000	$60,000
5	Control of Water and River Bypass	1	LS	$200,000	$200,000
6	Excavation and Backfill for Pipeline in Channel	9600	CY	$5.0	$48,000
7	Furnish and Install Steel Piles	30	EA	$5,400	$162,000
8	Furnish and Install 24-Inch Ductile Iron Water Line in Channel	500	LF	$280	$140,000
9	Structural Concrete (Concrete Pipe Encasement in Channel, Pre-Cast)	260	CY	$1,500	$390,000
10	Furnish and Install 14-Inch PVC Water Line Outside of Channel	1460	LF	$160	$233,600
11	Revegetation and Landscaping of Disturbed Area	1	LS	$20,000	$20,000
12	Tie into Existing Pipeline	2	EA	$20,000	$40,000
				Subtotal:	$1,433,600
				Estimating Contingency @ 30%:	$430,000
				OPINION OF PROBABLE CONSTRUCTION COST :	**$1,863,600**
				Geotechnical Investigation :	$40,000
				Engineering Design @ 10%:	$180,000
				Environmental Permitting @ 5%:	$90,000
				Construction Management @ 10%:	$180,000
				FINAL DESIGN AND CONSTRUCTION MANAGEMENT TOTAL:	**$490,000**
				OPINION OF PROBABLE PROJECT COST:	**$2,350,000**

2.1.6 Anticipated Operation and Maintenance

This alternative would require little or no ongoing operation or maintenance.

2.2 Alternative 1-A - Concrete Encased Pipeline with Tie to Collector 5 Raw Water Transmission Line

2.2.1 Description

Alternative 1A includes the placement of a new 24-inch ductile iron pipeline within the river gravels approximately 1,700 feet downstream of the existing railroad bridge crossing. This alternative would utilize the existing 24-inch raw water supply line at Collector 5, converting it into a domestic supply line, thus minimizing the necessary in-channel diversion and concrete work. The proposed pipeline would run under the channel from Collector 5 to the north bank, approximately 350 feet, then another 100 feet across the bank and up to Glendale Drive. The new pipeline would then run along Glendale Drive for approximately 2,300 feet to where it would tie into the existing 14-inch transmission line on the east side of the railroad bridge crossing.

The location for this alternative was chosen to facilitate the connection to Collector 5. The raw water line leaving Collector 5 that goes to the surface water treatment facility would have to be cut and capped adjacent to Warren Creek Road, and tied to the existing 14-inch water transmission main. The raw water supply line at Collector 5 would then have to be cut and capped near Collector 5, and the new concrete encased line would tie into the Collector 5 raw water supply line and continued across the river and up the bank and tie into the existing pipe at Glendale Drive.

Collector 5 is located out of the low flow channel, so diverting the river for this alternative would not be necessary. Dewatering of the trench excavation would still be required for the placement of the concrete encased water line on the east side of Collector 5.

As with Alternative 1, the piping within the channel would be 24-inch ductile iron pipe with flanged or restrained fittings in a reinforced concrete encasement. The crossing would also be between 10 and 15 feet below the existing river channel and would be supported by steel piles driven to a depth of approximately 40 feet. The piping outside of the active channel, including the piping on the bank and within the roadway, will be 14-inch diameter Class 160 PVC pipe, of the same diameter as the existing piping that it would tie to on each side of the river. The pipeline within the bank and roadway sections would likely be placed by open trench construction methods. A short section of ductile iron pipe placed on support brackets would also be required for the bridge crossing over Lindsay Creek on Glendale Drive.

Temporary construction access roads would also be necessary for the construction of this alternative, similar to those described for Alternative 1.

One of the limitations of this alternative is that the condition of the existing pipeline from Collector 5 is unknown. Prior to the design or construction of this alternative, the condition of the pipe should be assessed, likely by exposing the pipe and physically evaluating it. This will add costs to the design phase, and if after the pipe is evaluated, the condition is found to be compromised, one of the other alternatives would have to be implemented.

2.2.2 Constructability Issues

The construction of this alternative would be much less complicated as diversion of the river would not be necessary. Dewatering the trench within the channel would still require a significant dewatering effort with the same issues described for Alternative 1. Similarly, the constructability issues related to the construction access would be similar to those described for Alternative 1.

2.2.3 Right of Way

Like Alternative 1, this alternative is primarily located on District Property and property within the channel owned by the State Lands Commission. Two easements would have to be obtained from the property owners listed in Table 3. Outside of the channel the pipeline would cross some of the adjacent properties. Routing pipelines through the County roads right of way would require a County Encroachment permit.

Table 3. Alternative 1A - Right of Way Parcels

AP Number	Street Address	Owner
504-142-013-000	2244 Garden Bar Rd	Timmons, Carleton
County Road	Glendale Drive	Humboldt County

2.2.4 Environmental Permitting Requirements

The environmental permits required for Alternative 1A would be the same as those required for Alternative 1; however, it is likely that the mitigations measures required would be significantly less because there would be no water diversion for this alternative.

2.2.5 Construction Cost

Table 4 below presents the opinion of probable costs for the construction of this alternative. The opinion of probable costs for this alternative is $1,990,000.

Table 4. Opinion of Probable Cost for Alternative 1A Concrete Encased Pipeline with Tie to Collector 5 Discharge					
Item No	**Item Description**	**Quantity**	**Unit**	**Unit Cost**	**Total**
1	Mobilization and Demobilization	1	LS	$60,000	$60,000
2	Clearing and Grubbing	1	LS	$10,000	$10,000
3	Erosion and Sediment Control	1	LS	$20,000	$20,000
4	Temporary Construction Access (Construction Entrance, Temporary River Crossings)	1	LS	$50,000	$50,000
5	Control of Water	1	LS	$85,000	$85,000
6	Excavation for Pipeline in Channel	5,590	CY	$5	$27,950
7	Furnish and Install Steel Piles	20	EA	$5,400	$108,000
8	Furnish and Install 24-Inch Ductile Iron Water Line in Channel	350	LF	$290	$101,500
9	Structural Concrete (Concrete Pipe Encasement in Channel, Pre-Cast)	185	CY	$1,500	$277,500
10	Furnish and Install 14-Inch PVC Water Line in Roadway	2,524	LF	$160	$403,880
11	Tie to Existing Piping at Collector 5	1	LS	$20,000	$20,000
12	Tie to Existing Raw Water Line at Warren Creek Road	1	LS	$10,000	$10,000
12	Revegetation and Landscaping of Disturbed Area	1	LS	$10,000	$10,000
Subtotal:					$1,183,830
Estimating Contingency @ 30%:					$355,000
OPINION OF PROBABLE CONSTRUCTION COST :					**$1,538,830**
Geotechnical Investigation :					$30,000
Engineering Design @ 12%:					$185,000
Environmental Permitting @ 5%:					$80,000
Construction Management @ 10%:					$155,000
FINAL DESIGN AND CONSTRUCTION MANAGEMENT TOTAL:					**$450,000**
OPINION OF PROBABLE PROJECT COST:					**$1,990,000**

2.2.6 Anticipated Operation and Maintenance

This alternative would require little or no ongoing operation or maintenance.

2.3 Alternative 2 – Trenchless Method under Channel

2.3.1 Description

This alternative includes a pipeline that runs from the existing 14-inch transmission main located on Warren Creek Road, 400 feet along the access road to the existing parking lot to the south of Collector 4, where a 24-foot square, 40-foot deep water tight entrance pit would be located. The entrance pit will be used to microtunnel a new 36-inch diameter steel casing pipe with a new 24-inch HDPE carrier pipe under the river channel to a 24-foot square, approximately 60-foot deep, water tight exit pit on the northeast side of the Mad River, in an open area adjacent to Glendale Drive. From the exit pit, a new 14-inch Class 160 PVC waterline would be extended under Glendale Drive approximately 2,800 feet to where it would tie into the existing 14-inch transmission line on the east side of the railroad bridge crossing. A short section of ductile iron pipe placed on support brackets would also be required for the bridge crossing over Lindsay Creek on Glendale Drive.

2.3.2 Constructability Issues

Microtunneling is a process that uses a remotely controlled Microtunnel Boring Machine (MTBM) combined with the pipe jacking technique to directly install pipelines underground in a single pass. A cutting head attached to a rigid pipe section is jacked in a forward direction, while the material that is being cut flows back through the pipe sections being installed. Microtunneling is ideal in a situation such as a river crossing within unstable gravels, as the hole being created is mechanically stabilized. This process avoids the need to have long stretches of open trench for pipe laying. Microtunneling is currently the most accurate trenchless pipeline installation method and can be economically competitive with direct burial when depths exceed twenty feet or when faced with unstable soil conditions and work below the groundwater level. These conditions increase the risk of surface settlement during a direct burial or conventional tunnel installation.

The beginning and ending points for this alternative were located in areas that are conducive to constructing the entrance and exit pits. These pits will take up significant area and are required to be constructed to the depth of the planned waterline crossing, ten to twenty feet below the river surface. The ground surface elevations at the chosen locations are closer to the river level (approximately 20 feet above) than in the vicinity of the railroad crossing (approximately 60 feet above). This would simplify the construction of entrance and exit pits as they would not have to be as deep, and they would be in an area that is more accessible to equipment. Additionally, pre-cast concrete caissons or sheet piling are typically used for entrance pits for a project of this size, and construction of these pits would be more difficult near the existing railroad bridge crossing where there are 60-foot high bedrock banks.

Microtunneling equipment is susceptible to changes in gravel and rock size throughout a bore, and unanticipated rock or boulders can clog the rock rakes and other mechanisms behind the cutting head used to convey the cut material back to the entrance pits. This can create costly delays and repairs during construction. The construction costs of microtunneling reflects these uncertainties.

2.3.3 Right of Way

This alternative would have significantly less impact on properties along the pipeline alignment; however, right of way is still required. As with the previous alternatives, this alternative is primarily located on District Property and property within the channel owned by the State Lands Commission. Outside of the channel the pipeline would cross the adjacent properties not owned by the District. Routing pipelines through the County roads right of way would require a County Encroachment permit. The following table lists the parcel numbers and owners of each parcel that may need easements or access agreements.

Table 5. Alternative 2 - Right of Way Parcels

AP Number	Street Address	Owner
County Road	Glendale Drive	Humboldt County

2.3.4 Environmental Permitting Considerations

The permitting for this alternative would require contacting the same agencies as with the in-channel alternatives as described in Section 2.2. While these permit requirements would need to be satisfied, the permitting process would likely be easier because this alternative does not require a channel diversion or work in the active channel.

2.3.5 Construction Cost

Table 6 below presents the opinion of probable costs for the construction of this alternative. The opinion of probable costs for this alternative is $4,220,000.

Table 6. Opinion of Probable Cost For Alternative 2 Microtunneling under Channel					
Item No	**Item Description**	**Quantity**	**Unit**	**Unit Cost**	**Total**
1	Mobilization and Demobilization	1	LS	$230,000	$230,000
2	Clearing and Grubbing	1	LS	$10,000	$10,000
3	Erosion and Sediment Control	1	LS	$20,000	$20,000
4	Temporary Construction Access Improvements	1	LS	$10,000	$10,000
5	20' -40 ' Deep Water Tight Entrance and Exit Pits (24'x24')	2	EA	$200,000	$400,000
6	36-Inch Steel Casing Pipe	1100	LF	$1,000	$1,100,000
7	24-Inch HDPE Carrier Pipe	1100	LF	$200	$220,000
8	Furnish and Install 14-Inch PVC Water Line Outside of Channel	3190	LF	$160	$510,400
9	Revegetation and Landscaping of Disturbed Area	1	LS	$8,000	$8,000
10	Tie into Existing Pipeline	2	EA	$20,000	$40,000
				Subtotal:	$2,548,400
				Estimating Contingency @ 30%:	$765,000
				OPINION OF PROBABLE CONSTRUCTION COST :	**$3,313,000**
				Geotechnical Investigation :	$80,000
				Engineering Design @ 10%:	$330,000
				Environmental Permitting @ 5%:	$165,000
				Construction Management @ 10%:	$330,000
				FINAL DESIGN AND CONSTRUCTION MANAGEMENT TOTAL:	**$905,000**
				OPINION OF PROBABLE PROJECT COST:	**$4,218,000**

2.3.6 Anticipated Operation and Maintenance

This alternative would require little or no ongoing operation or maintenance.

2.4 Alternative 3 –Suspended Waterline Crossing

2.4.1 Description

This Alternative was first described in a letter to Barry Van Sickle completed by Winzler & Kelly on June 23, 2006. A copy of this letter is included in Appendix C. This alternative consists of an aerial crossing with a 14-inch diameter flanged ductile iron pipe spanning the width of the river for a distance of approximately 460 feet. A steel tower with concrete footings will be built at either side of the river, above the flood plane elevation. The towers will be approximately 28 feet tall and 20 feet wide, with 12-inch diameter steep pipe columns. From each of the top corners of the tower, a 1¾-inch galvanized steel cable will span across the river to the opposite tower. The cables will extend backwards, away from the river approximately 50 feet, to the ground elevation, and will be secured to a “dead man” or anchor structure. The dead man will consist of approximately 1,600 cubic feet of concrete buried in the ground. From these cables, in a suspension bridge type style, 3/8-inch diameter cables will hang down and support the ductile iron pipe at 20-foot intervals over the river. Figure 3 from the report contained in Appendix C provides a schematic of the proposed crossing.

This alternative would also require access to be created to the channel for a crane and hoist to the waterline and hangers on the tensioned cable. Construction access would require the creation of access points to the river, and temporary access roads on the river bar.

2.4.2 Constructability Issues

Construction of the suspended waterline would include steel fabrication for the towers and cast in place concrete placement for the anchorage system. Work outside of the channel would include fabrication and erection of the steel suspension cable, including temporary rigging within the channel and tensioning of the cable prior to placement. Work that would have to occur within the channel would include the placement of the steel cable and hangers, and assembly and suspension of the flanged ductile iron waterline.

This alternative would require access to be created to the channel for a crane and hoists to complete the placement of the waterline and hangers on the tensioned cable. Construction access would include the creation of access points to the river, and temporary access roads on the river bar. Access could be created from the west side of the river on the District property near Collector 4 and would require two temporary bridges to access the location of the waterline. Alternatively, a construction easement could be obtained across private property north of the proposed crossing along an existing river access, and would require only one temporary river crossing. Temporary bridges would have to be large enough to support the crane rig needed to lift the ductile iron pipe sections to be attached to the cable. As with the access for Alternative 1, the access roads on the river bar would likely require little more than minor grading to establish them and to remove them after construction.

The design would need to account for the loading of the cable during construction of the suspended pipeline and filling of the pipeline with water. This may require assembly of more than one section of pipeline so the cable could be loaded in a balanced fashion.

2.4.3 Right of Way

The right of way for this alternative would not be significantly different than the existing right of way agreements for the railroad trestle crossing. The agreements would need to be modified to include the construction of the cable suspension towers on either bank. The following table lists the parcel numbers and owners of each parcel that may need easements or access agreements.

Table 7. Alternative 3 - Right of Way Parcels		
AP Number	**Street Address**	**Owner**
516-241-002-000		North Coast Railroad Authority
504-131-004-000	1150 Vista Dr	Sundburg, Garth & Linda

2.4.4 Environmental Permitting Considerations

The permitting requirements for this Alternative would be similar to those described for the previous alternatives. The CEQA analyses for this alternative would also have to consider the visual impacts of the aerial crossing structure. The footings for the towers would likely be constructed near the ordinary high water levels and therefore 404, 401 and 1600 permits would all likely be required.

In addition, the Federal Aviation Administration should also be contacted. The FAA has a notification requirement for facilities that could affect airport airspace. It seems unlikely that the aerial crossings would have any bearing on airport airspace or aviation safety in general. The aerial crossing would be located near the existing railroad trestle so it will not be a new obstruction in the air space. However, it may be prudent to submit project information to FAA for a determination.

2.4.5 Construction Cost

Table 8 below presents the opinion of probable costs for the construction of this alternative. The opinion of probable costs for this alternative is $1,550,000.

Table 8. Opinion of Probable Cost for Alternative 3 Suspended Waterline Crossing					
Item No	**Item Description**	**Quantity**	**Unit**	**Unit Cost**	**Total**
1	Mobilization and Demobilization	1	LS	$60,000	$60,000
2	Clearing and Grubbing	1	LS	$10,000	$10,000
3	Erosion and Sediment Control	1	LS	$20,000	$20,000
4	Temporary Construction Access Improvements (River Bar)	1	LS	$60,000	$60,000
5	Excavation for Bridge Tower footings	170	CY	$200	$34,000
6	Structural Concrete (Deadman, Concrete Footings)	170	CY	$1,500	$255,000
7	Furnish and Install Steel Piles	10	EA	$5,400	$54,000
8	Steel Tower	2	EA	$60,000	$120,000
9	Furnish and Install Galvanized Steel Cable and Hangers	1	LS	$100,000	$100,000
10	Furnish and Install 14-Inch Ductile Iron Water Line (Crane Set)	780	LF	$210	$163,800
11	Revegetation	1	LS	$10,000	$10,000
12	Tie into Existing Pipeline	2	EA	$20,000	$40,000
				Subtotal:	$926,800
				Estimating Contingency @ 30%:	$278,000
				OPINION OF PROBABLE CONSTRUCTION COST :	**$1,204,800**
				Geotechnical Investigation :	$40,000
				Engineering Design @ 10%:	$120,000
				Environmental Permitting @ 5%:	$60,000
				Construction Management @ 10%:	$120,000
				FINAL DESIGN AND CONSTRUCTION MANAGEMENT TOTAL:	**$340,000**
				OPINION OF PROBABLE PROJECT COST:	**$1,544,800**

2.4.6 Anticipated Operation and Maintenance

Anticipated operation and maintenance of this crossing would include inspection of the coatings on the structure at regular intervals and performing periodic touch up to the structure coatings and the pipeline coating.

2.5 Alternative 4 – Improve Existing Railroad Bridge Pipeline Crossing

2.5.1 Description

This alternative consists of retrofitting the existing bridge crossing to provide a stabilized crossing for the water transmission line across the Mad River. The existing structure was originally constructed as a railroad crossing in the late 1930's or 1940's and is therefore over-designed to serve solely as a support for a water line crossing, which is the only current use of the structure. The bridge is constructed of steel beams and trusses and was evaluated by Winzler & Kelly in 2007 under *Agreement No. 54Rt-1 – Focused Engineering Study* (see Appendix B). That study found that the bridge is likely susceptible to failure during an earthquake or major flood and recommended a repair to the pipeline supports on the north end of the bridge, a seismic study and retrofit if the pipeline was to remain on the bridge, and this study to review alternative pipeline crossings to replace the bridge.

This alternative would improve the structure for long term use as a water line crossing and would include stabilizing the two mid-river piers, replacing the structural components of the wooden trestle approaches and restraining the deck trusses to resist seismic forces. Stabilizing the mid-river piers would include the reinforcement of the piers by installing five H piles on each side of both piers. A 24-inch by 48-inch deep pile cap would then be installed on the new piles and tied to the piers with prestressed anchors.

Replacing the structural components of the wooden trestle approaches would include replacing the deteriorated members (cross braces, bent caps) with new wooden members. Only the structural members necessary to support the waterline would be replaced.

Seismic restraint of the railroad bridge deck to the existing concrete piers would involve placing concrete blocking at the top of the existing pier, and tying the deck to the new blocking with steel cables. The concrete blocking would then be tied to the existing piers by doweling into the existing structure.

This alternative would require access to the channel for a crane and hoists to complete the placement of the piles and for equipment to place the cast-in place pile caps. Construction access would include the creation of access points to the river, and temporary access roads on the river bar as described for Alternative 3.

This alternative would also require the District to begin to perform preventative maintenance on the bridge. In the first year this would entail extensive scraping and repainting of the bridge. Given the age of the bridge, the existing paint is likely lead based paint, which would have to be remediated. This will consist of establishing engineering controls to capture the paint as it is being removed, clearing the paint down to metal and repainting the entire structure. This will add a considerable cost in the first year, as well as ongoing maintenance costs, likely considerably higher than the other alternatives.

2.5.2 Constructability Issues

Construction of this alternative includes relatively common construction methods including cast in place concrete, timber construction, pile driving and earthwork. The fact that the work is in close proximity to the existing structure would make it more difficult to execute. The challenges of working in the channel would be similar to those presented in the previous alternatives.

2.5.3 Right of Way

The right of way issues for this alternative are similar to the ones for the cable suspended pipeline outlined in the previous section and the right of way parcels are the same as are listed in Table 7.

A significant disadvantage of this alternative is that the District does not own the bridge, and since this alternative would involve actual retrofitting of the NCRA bridge, agreements would have to be negotiated with the Railroad Authority to obtain permission to perform this work. Agreements would also have to be made outlining who would be performing the on-going maintenance on the bridge. The District would also be expending their and their rate payer's funds to improve someone else's asset.

2.5.4 Environmental Permitting Considerations

The permitting for this alternative would require contacting the same agencies as described for Alternative 1. The permitting process would likely be easier than with Alternative 1, since diversion of the River would not be required; however, work would still be performed in the channel. The State Lands Commission may or may not have to be consulted. The easier permit requirements would likely be more than offset by the additional work required in dealing with the North Coast Railway Authority to obtain agreements for this work. Additional permits would be required from the Air Board for addressing the lead based paint removal.

2.5.5 Construction Cost

Table 9 below presents the opinion of probable costs for the construction of this alternative. The opinion of probable costs for this alternative is $1,870,000.

Table 9. Opinion of Probable Cost for Alternative 4 Improve Existing Railroad Bridge Pipeline Crossing					
Item No	**Item Description**	**Quantity**	**Unit**	**Unit Cost**	**Total**
1	Mobilization and Demobilization	1	LS	$50,000	$50,000
2	Clearing and Grubbing	1	LS	$10,000	$10,000
3	Remove Lead Based Paint	17,400	SF	$20	$350,000
4	Repaint Bridge	17,400	SF	$8	$140,000
5	Erosion and Sediment Control	1	LS	$10,000	$10,000
6	Temporary Construction Access Improvements (River Bar)	1	LS	$80,000	$80,000
7	Excavation for Footings in Channel	1	LS	$50,000	$50,000
8	Structural Reinforcement of Approach Structures (Lumber)	1	LS	$100,00	$100,000
9	Seismic Restraint of Bridge (Cables Restraints and Blocking)	8	EA	$20,000	$160,000
10	Furnish and Install Steel Piles with Tie to Footing	20	EA	$6,000	$120,000
11	Structural Concrete (Concrete Footings)	40	CY	$1,500	$60,000
12	Fencing and Re-vegetation	1	LS	$5,000	$5,000
				Subtotal:	$1,135,000
				Estimating Contingency @ 30%:	$340,500
				OPINION OF PROBABLE CONSTRUCTION COST :	**$1,475,500**
				Geotechnical Investigation :	$20,000
				Engineering Design @ 10%:	$145,000
				Environmental Permitting	$80,000
				Construction Management @ 10%:	$145,000
				FINAL DESIGN AND CONSTRUCTION MANAGEMENT TOTAL:	**$390,000**
				OPINION OF PROBABLE PROJECT COST:	**$1,865,500**
* Note: The annual costs for repainting and maintaining the bridge are not included in the cost estimate for this alternative and should be considered.					

2.5.6 Anticipated Operation and Maintenance

This alternative presents two unique challenges including: the improvement of a structure not owned by the District, and the potential long term maintenance of the structure. The North Coast Railroad Authority (NCRA) currently owns and manages the railroad bridge. Any improvements would require an agreement from the NCRA, and agreements obtain on who would be performing ongoing maintenance. Since the NCRA is not currently performing any maintenance on the bridge, it is unlikely that they would be very interesting in signing any agreements stating that they would be performing on-going maintenance at some established interval. As stated previously, the execution of this alternative would also mean that the District would be expending their and their rate payer's funds to improve someone else's asset, and potentially undertaking the responsibility of performing on-going maintenance on someone else's asset. Recent discussions within the County regarding the rail-banking of the railroad line that includes the bridge suggest that a new management entity may be formed to take responsibility for this line in the future; however, it is unknown when or if this would happen.

The existing structure is currently painted with lead-based paint. Future maintenance of this structure would require periodic touch-up of the deteriorated areas and re-painting of the entire structure. The touch-up and re-coating of the bridge would require containment and disposal of the lead paint scraped off and would have a significant cost. The annual costs for re-coating are not included in the cost estimate for this alternative and should be considered.

2.6 Alternatives Considered but Not Evaluated

Directional drilling a new 24-inch waterline beneath the channel of the Mad River, in between Collector Four and Collector Five was also reviewed as an alternative; however, it was not considered due to the anticipated presence of unconsolidated gravels at the site. Based on field geological evaluations completed for previous projects, it is assumed that gravels in this general vicinity are approximately 80 feet deep with bedrock below.

Directional drilling is completed by boring a pilot hole, reaming out the hole to the desired size by completing multiple passes with a cutting head to enlarge the hole, and then pulling the pipe through the enlarged hole. There is no mechanical support of the hole between passes of the cutting heads. If directional drilling were to be attempted for this project, the drilling would have to be at least 80 feet deep in bedrock rather than in the river gravels so that the holes being drilled and enlarged would not collapse. Directional drilling could be complete through the bedrock; however, an approximate radius of 800 feet would be the maximum curvature that could be attained with a rod large enough to install a 24-inch pipe, which would require the entrance and exit pits to be approximately 3,500 feet from the center of the bore, and beyond project limits considered suitable for this project.

3.0 SUMMARY & RECOMMENDATIONS

Several alternatives were reviewed for constructing a new pipeline across the Mad River to provide potable water to the communities of Fieldbrook and Blue Lake in the event of the failure of the existing NCRA trestle crossing. Table 10 summarizes the alternatives and associated opinion of probable construction cost.

Table 10. Summary of Opinion of Probable Construction Cost for Alternatives 1-4		
Alternative	**Alternative**	**Estimated Construction Cost**
1	Concrete Encased Pipeline Downstream of the Existing Railroad Bridge Crossing	$2,350,000
1A	Concrete Encased Pipeline with Tie to Collector 5 Discharge	$1,990,000
2	Microtunneling under Channel	$4,220,000
3	Suspended Waterline Crossing	$1,550,000
4	Improve Existing Railroad Bridge Pipeline Crossing *	$1,870,000
* Note: The annual costs for repainting and maintaining the bridge are not included in the cost estimate for this alternative and should be considered.		

A fifth alternative not discussed in the body of this report is the Do Nothing alternative. If the trestle fails, which it will eventually do at some unknown date, this alternative will leave Blue Lake and Fieldbrook without water for an indeterminate amount of time. Chances are that the trestle will fail during a flood or earthquake event, when the District and the surrounding communities are also dealing with multiple other issues.

Alternative 3, the installation of a suspended waterline crossing, has the lowest apparent construction cost. This alternative and Alternative 4 would likely have the highest on-going maintenance costs associated with them, however the aerial crossing annual maintenance would likely be considerably less than the existing trestle just given their relative ages and the extensive trestle work on the existing bridge. It is estimate that the ongoing maintenance cost for the aerial crossing would likely be on the order of $5,000 per year. This assumes minor painting yearly with a major painting every 5 years. Assuming a 50 year life time, and an interest rate of 8%, the Present Worth of the $5,000/year maintenance cost is $61,200, for a total present worth for this alternative of approximately $1,605,200. This is still less than the construction cost for any of the other alternatives.

It is recommended that Alternative 3, a suspended crossing be included in the District’s Capital Improvement Program, and the District begin planning for funding this alternative.

Appendix A
Figures

Legend

Alternative - 1	Butterfly Valve
Alternative - 1A	Gate Valve
Alternative - 2	Domestic Transmission Main
Alternative - 3	Blow Off Valve
Alternative - 4	AirRelease Valve
	CVCombination Valve

0 250 500 1,000 Feet

N E S W

ALTERNATIVES OVERVIEW

Figure 1

ALTERNATIVES TO SUPPLY SECONDARY PIPELINES

Essex facility, Project # 010550716

WINZLER & KELLY

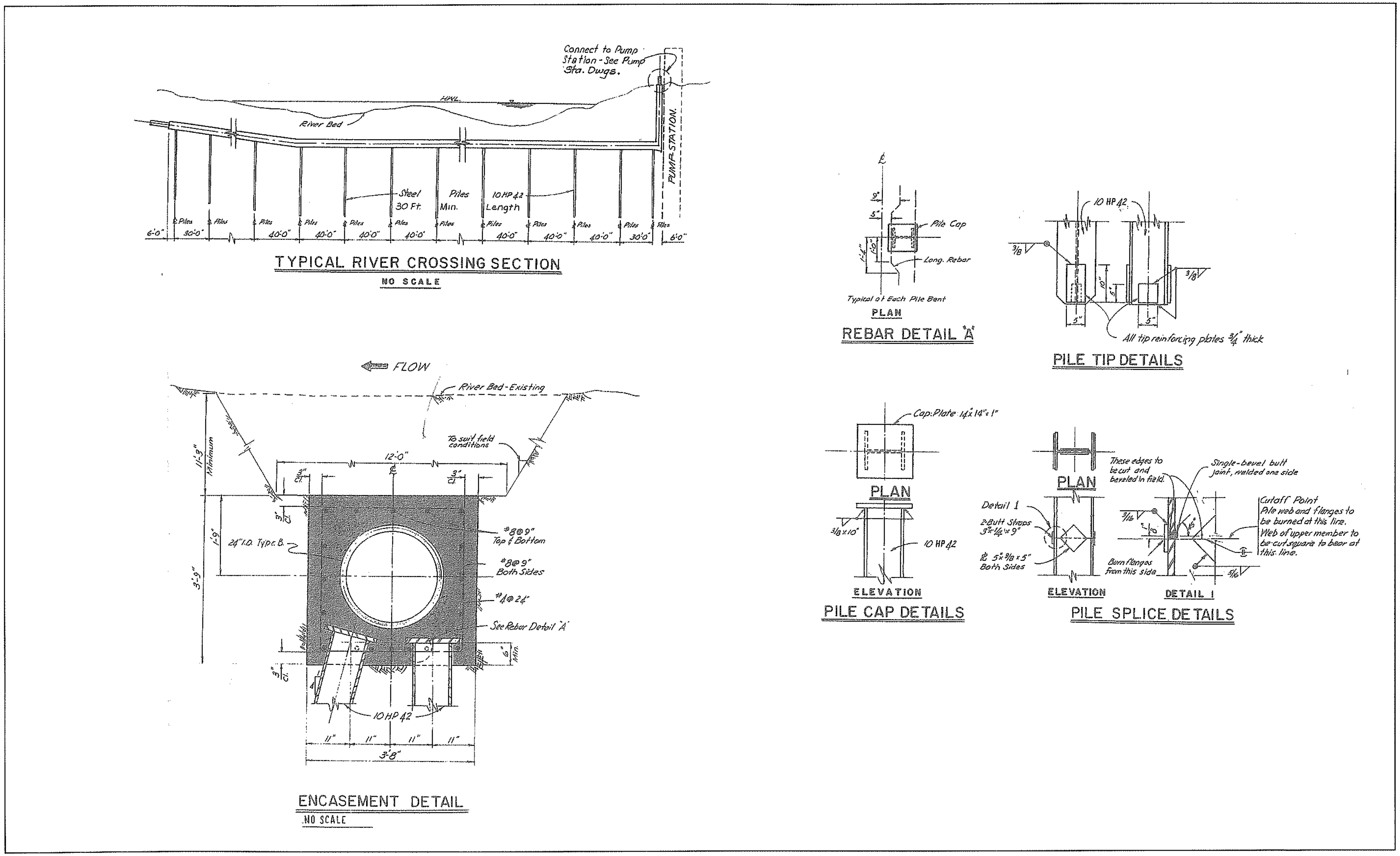
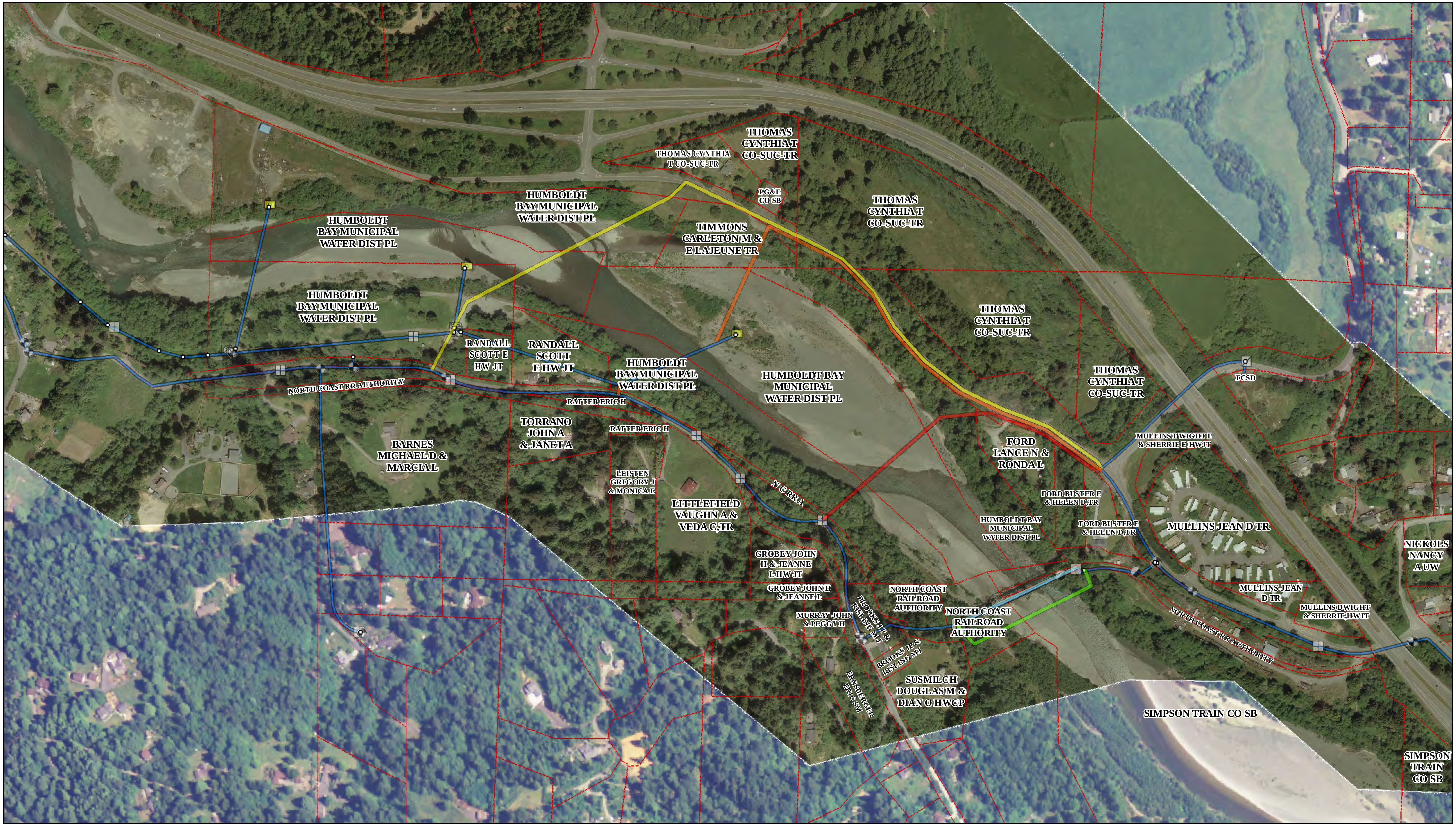


Figure 2. River Crossing Section.



0 200 400 800 Feet

Legend

- Alternative - 1
- Alternative - 1A
- Alternative - 2
- Alternative - 3
- Alternative - 4
- Butterfly Valve
- Gate Valve
- Domestic Transmission Main
- Blow Off Valve
- AirRelease Valve
- CVCombination Valve
- Parcels

AREA PARCELS
Figure 3
ALTERNATIVES TO SUPPLY SECONDARY PIPELINES

Essex facility, Project # 010550716

WINZLER & KELLY

Appendix B
Inspection Report, February 2008

Appendix C
Emergency Pipeline Crossing Report, June 2006

Appendix D – Preliminary Geotechnical Report (Crawford & Associates, 2015) and letter report from Jamie Roscoe to GHD on "Archaeological Monitoring during geotechnical testing within the Mad River Pipeline Area of Potential Effect, California"

PRELIMINARY GEOTECHNICAL REPORT

Humboldt Bay Municipal Water District
Water Transmission Pipeline Replacement Over Mad River
Blue Lake and Fieldbrook-Glendale Community Services District

Humboldt County, California

Prepared by:

Crawford & Associates, Inc.
4220 Rocklin Road, Suite 1
Rocklin, CA 95677

December 2015

Prepared for:

GHD Inc.
718 3rd Street
Eureka, CA 95501

File No. 15-245.1
December 9, 2015

Mr. Patrick Kaspari
GHD Inc.
718 3rd Street
Eureka, CA 95501

Subject: **PRELIMINARY GEOTECHNICAL REPORT**
Humboldt Bay Municipal Water District
Water Transmission Pipeline Replacement over Mad River
Humboldt County, California

Dear Mr. Kaspari,

Crawford & Associates, Inc. (CAInc) is pleased to submit this Preliminary Geotechnical Report for the Humboldt Bay Municipal Water District water pipeline project. CAInc prepared this report in accordance with the GHD task order signed by CAInc on September 25, 2015. This report fulfills the tasks presented in CAInc's Proposal for Geotechnical Engineering Services dated February 27, 2015.

Thank you for selecting CAInc to be on your design team. Please call if you have questions or require additional information.

Sincerely,

Crawford & Associates, Inc.,

Nate Majerus
Senior Project Geologist

Rick Sowers, P.E., C.E.G.
Principal

REGISTERED PROFESSIONAL ENGINEER
RICHARD D. SOWERS
No. 38788
Exp. 3/31/17
CIVIL
STATE OF CALIFORNIA

REGISTERED GEOLOGIST
RICHARD D. SOWERS
No. 1104
CERTIFIED ENGINEERING GEOLOGIST
STATE OF CALIFORNIA

Corporate Office: 4030 S. Land Park Drive, Suite C • Sacramento, CA 95822 • (916) 455-4225
Modesto: 1165 Scenic Drive, Suite B • Modesto, CA 95350 • (209) 312-7668
Pleasanton: 6200 Stoneridge Mall Road, Suite 330 • Pleasanton, CA 94588 • (925) 401-3515
Rocklin: 4220 Rocklin Road, Suite 1 • Rocklin, CA 95677 • (916) 455-4225
Ukiah: 100 North Pine • Ukiah, CA 95482 • (707) 240-4400

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1 INTRODUCTION

1.1 Purpose

Crawford & Associates, Inc. (CAInc) prepared this Preliminary Geotechnical Report to fulfill the tasks presented in CAInc's Proposal for Geotechnical Engineering Services date February 27, 2015, and agreed to in the Task Order Agreement signed September 25, 2015. This report provides preliminary (Phase-1) geotechnical assessment for a proposed new aerial pipeline crossing and includes an initial assessment for a horizontal directional drilling (HDD) alternative. Additional (Phase-2) investigation is required for either the aerial or HDD alternative as part of final design.

1.2 Scope of Services

To prepare this report, CAInc completed the following tasks:

1. Project Coordination and Preparation – Met with the design team to discuss the project design needs, reviewed existing geotechnical data and published geologic maps, and conducted a site visit to view site characteristics and borehole locations.
2. Geologic Reconnaissance – Located and sampled bedrock outcroppings near the project location and correlated that data with borehole data collected for this study and previously by Humboldt Bay Municipal Water District (HBMWD).
3. Subsurface Exploration - Drilled and sampled four boreholes at the project site, two on each side of the Mad River.
4. Laboratory Testing – Conducted laboratory tests on selected samples, including moisture content, dry density, sieve analysis, plasticity index, and corrosivity.
5. Preliminary Geotechnical Report – Performed preliminary engineering analysis of the data to develop the conclusions presented in this report.

1.3 Project and Site Description

The project site is located along the banks of the Mad River approximately two miles upstream from Arcata, CA. Access to the southwest edge of the river is through a private residence located at 845 Warren Creek Road, Arcata. Access to the northeastern edge of the river is through an equipment yard operated by GR Sundberg, Inc. located at 1220 Glendale Drive, McKinleyville. A vicinity and project location map is attached as Figure 1.

The project will replace an existing 14" ductile iron pipe where it presently crosses the Mad River attached to a 1930's era North Coast Railroad Authority (NCRA) steel-truss bridge. The bridge is vulnerable to damage or failure during an earthquake or severe flood. The pipeline is the main water supply to the communities of Blue Lake, Fieldbrook and Glendale.

A preliminary plan by GHD (dated 10/27/2015) shows a new aerial crossing spanning the Mad River for a distance of approximately 540 ft. The new crossing is immediately upstream (southeast) of the existing bridge with new suspension towers located on each bank at approximate elevation 60 feet (northeast bank) and 70 feet (southwest bank). Channel bottom is about elevation 35 feet. The towers will be anchored by either a concrete "deadman" or drilled soil anchors located behind each tower. Cultural studies by Roscoe & Rich (2014) show the area directly behind the existing/proposed southwest abutment towers is within the boundary of archaeological site CA-HUM-931.

Alternatively, the pipeline may be installed under the river by horizontal directional drilling (HDD) methods. The key geotechnical issues for this alternative include the depth of channel bedload (sand/gravel), character of the underlying bedrock, potential for frac-outs, and caving soils at the entry/exit points. For this alternative, the entry point would likely be at the northeast side (from Sundberg yard) and the exit point at the southwest bank, outside the boundary of archaeological site CA-HUM-931.

2 GEOLOGIC SETTING

The site is located within the Coast Range geomorphic province, characterized by strong northwest trending ridges and valleys. More specifically, the site is located in the central belt of the Franciscan Formation consisting of Early Tertiary to Late Cretaceous mélange and Late Cretaceous to Late Jurassic meta-sediments.

The sediments within the Mad River are mapped as Quaternary-age alluvial channel deposits. Quaternary terrace deposits are located along the top of both banks. Bedrock in the area is mapped as Late Cretaceous to Late Jurassic arkosic and lithic meta-sandstone and meta-argillite that depositionally overlie chert. These meta-sedimentary rocks are unnamed and are distinguished by their topographic expression and degree of fracture.

The project site is located within the Mad River Fault Zone, defined by a series of subparallel low angle thrust faults that strike to the northwest. Several of these faults have shown displacement during the Holocene Epoch (last 11,700 years). An unnamed branch of the fault zone crosses the project site near the northeast bank.

The regional geology is shown on Figure 2 and fault locations on Figure 3.

3 GEOLOGIC RECONNAISSANCE

Our geologic reconnaissance on October 21, 2015 of the river channel and both banks noted bedrock outcrops in the river channel and along the river banks near the existing bridge abutments.

Along the northeast side of the river, meta-argillite outcrops were found approximately 75 yards upstream from the current bridge. These outcrops were very hard, needing heavy blows from a sledge hammer to remove hand samples. The exposed surfaces and fracture faces were slightly weathered with discoloration and oxidation ranging from light orange-yellow to dark reddish-brown. Meta-argillite outcrops were also observed along the northeast channel just below and slightly upstream from the bridge abutment; the rock at these locations is fresh and massive with some quartz veins and could only be chipped with a sledge hammer.

The southwest bank had fewer, and more weathered, outcrops. The largest outcrop was approximately 1500 feet upstream from the bridge in a cut bank next to the river channel. That outcrop was moderately hard and slightly to moderately weathered meta-argillite. A separate outcrop was observed approximately 300 feet downstream from the bridge along steps dug in the hillside for a hiking trail. This outcrop was intensely weathered (to a residual soil) that maintained a steep slope but crumbled when hit with a hammer.

The final outcrop was fresh, fine grained meta-sandstone observed in the middle of the channel just upstream from the northeast pier. This outcrop is very hard and is approximately 120 feet west of the meta-argillite outcrops at the northeastern bank. The difference in rock types suggest that either the meta-sedimentary beds are tilted in the region or the unnamed thrust fault is located between these outcrops.

Photos of the outcrops are attached in Appendix A.

4 SUBSURFACE EXPLORATION

CAInc observed and logged four exploratory borings at the site ranging in depth between 15.5 and 35 feet below ground surface (bgs). Two borings were drilled near the northeast bridge abutment on October 19, 2015, and two borings were drilled near the southwest abutment on October 20, 2015. All four borings were drilled on or near the old railroad right-of-way. Special care was taken to avoid disturbance to the archeological site. The approximate boring locations are shown on Figure 1; photos of the drill rig and boring locations are shown in Appendix A.

4.1 Alluvium and In-Situ Residual Soil

All four borings encountered backfill at the surface related to the former railroad. The backfill ranges in thickness from 2.5 feet to 3.5 feet. The fill is moderately stiff lean clay with some gravels that were the old railroad ballast. The ballast is most prevalent on the southwestern side of the river.

The sediment below the fill is terrace alluvium composed of stiff lean clay and sand with varying amounts of gravel and trace cobbles. The sand and gravel encountered in the alluvium is rounded to subrounded and is composed of a variety of different rocks and minerals. Alluvium comprised of coarse sand and gravel is present within the active channel and represents channel bedload.

At the banks, the alluvial sediments are underlain by dense, in-situ residual soils derived from the underlying bedrock. These soils retain the appearance and structure of the deeper source bedrock, but with heavy staining and discoloration. These soils are dense lean clay with varying amounts of angular to subangular sand and gravel. The coarser materials are composed of resistant portions of the source rock, including quartz from younger joint infilling.

On the northeast side of the river, the bottom of the alluvium is 8 feet bgs in B1 and 16 feet bgs in B2. The in-situ residual soil extends to 12 feet bgs in B1 and 18 feet bgs in B2. The southwest side shows a similar profile, with the alluvium ending at 15.5 feet bgs in B3 and 3.2 feet bgs in B4. The bottom of the residual soil is 23 feet bgs in B3 and 9 bgs feet in B4. The soils on both sides of the river is thickest near the river and thins farther back into the terrace.

A cross-section showing the interpreted subsurface profile is in Figure 4. The detailed boring logs are attached as Appendix B.

4.2 Bedrock

The residual soils transition to weathered rock and, at the bottom of the borings, into fresh, hard bedrock. The weathered rock is a dark gray color with some staining on joint surfaces. This rock was broken into clayey gravel with sand by the drilling and sampling process, but an increase in blow counts, increased difficulty of drilling, and hard angular rock fragments define the rock.

The bedrock observed in the four borings was meta-argillite, which corresponds with the mapped geology of the region and the outcrops observed near the borings. An interpreted subsurface profile is shown on Figure 4. The detailed boring logs are attached as Appendix B.

4.3 Groundwater

Free groundwater was not encountered in the borings completed for this investigation (October 2015). Groundwater levels can vary depending on rainfall, seasonal changes, and surface water levels of the Mad River. For this site, we expect groundwater is seasonally perched within the granular sediment deposits overlying the weathered rock. Groundwater within the rock unit is likely restricted to fracture and shear zones.

5 LABORATORY TEST RESULTS

We completed the following laboratory tests on representative soil samples obtained from the exploratory borings:

- Moisture Content - Dry Density (ASTM D2216 / D2937)
- Particle Size Analysis (ASTM D422)
- Atterberg Limits (ASTM D4318)
- Sulfate/Chloride Content (CTM 417/422)
- pH/Minimum Resistivity (CTM 643)

The index tests were performed to verify the field soil classifications. The corrosivity tests were performed to evaluate the soil corrosion potential, discussed further below. The complete laboratory test results are presented in Appendix C.

6 SOIL CORROSION POTENTIAL

We performed two suites of corrosion tests for this project. For reference, Caltrans considers a site to be corrosive if the chloride concentration is 500 ppm or greater, sulfate concentration is 2000 ppm or greater, soil pH is 5.5 or less, or minimum resistivity is 1000 ohm-cm or less. Corrosion testing yielded maximum chlorides of 24.8 ppm, maximum sulfates of 54.8 ppm, minimum pH of 5.05 and minimum soil resistivity of 2,140 ohm-cm. Based on these results, the only concern is that the pH of the soil is slightly lower than the Caltrans guideline and could be corrosive to steel.

7 SEISMICITY

7.1 Active Faulting

The project site is within the Mad River Fault Zone, a 10 kilometer wide series of northwest striking, low angle thrust faults. The 2010 California Geological Survey (CGS) Fault Activity Map (www.quake.ca.gov) shows these faults to show evidence of displacement during the Holocene period (last 11,700 years). The CGS mapping does not show any of these faults crossing the project site; however, The United States Geological Survey (USGS) Earthquake Hazards Program Fault Map (earthquake.usgs.gov) shows an unnamed branch of the Mad River Fault Zone crossing the project site parallel to the river. This fault crosses under the current bridge near the northeast abutment and truncates just southeast of the project site (see Figure 3).

The CGS Special Studies Zones map (maps.conservation.ca.gov) of the Arcata North Quadrangle shows portions of the Mad River Fault Zone within an Earthquake Fault Zone (EFZ) for fault rupture hazard. The site is not included within a mapped zone. The two closest EFZs terminates approximately 1.4 miles northwest and 1.1 miles south of the site. This would indicate that the potential for fault rupture is generally low. However, the EFZ to the south aligns with the fault that crosses the site, suggesting that the two faults could be connected. Therefore, there is potential that the thrust fault as mapped by the USGS could be considered "active". Further study would be required if this hazard is considered significant.

7.2 Seismic Design Parameters

The California Geological Survey, Probabilistic Seismic Hazards Mapping Ground Motion Page (www.conservation.ca.gov) indicates a maximum peak horizontal ground acceleration (PGA) on the order of 0.61g for a seismic event with a 10% probability of exceedance in 50 years (design basis earthquake).

Based on our exploratory borings, we provide the California Building Code (CBC) design parameters below. Table 1 shows the 2013 California Building Code and ASCE 7-10 seismic design parameters for the site. CAInc determined the values using a site latitude of 40.900°N and longitude of 124.028°W with the Earthquake Ground Motion Parameters - Version 5.1.0 developed by the United States Geological Survey.

Table 1: Seismic Design Parameters

Site Class	C
S_s – Acceleration Parameter	3.003 g
S_1 – Acceleration Parameter	1.173 g
F_a – Site Coefficient	1.0
F_v – Site Coefficient	1.3
S_{MS} – Adjusted MCE* Spectral Response Acceleration Parameter	3.003 g
S_{M1} – Adjusted MCE* Spectral Response Acceleration Parameter	1.525 g
S_{DS} – Design Spectral Acceleration Parameter	2.002 g
S_{D1} – Design Spectral Acceleration Parameter	1.016 g
T_L – Long-Period Transition Period**	8 seconds

* Maximum Considered Earthquake
** Figure 22-12, ASCE 7-10

7.3 Liquefaction

Liquefaction can occur when loose to medium dense, granular, saturated soils (generally within 50 feet of the surface) are subjected to ground shaking. Due to the generally cohesive nature of the soils at the banks, we consider the potential for liquefaction to be generally low. This will be further evaluated during the design phases of the project.

7.4 Seismic Settlement

During a seismic event, ground shaking can cause densification of granular soil above the water table that can result in settlement of the ground surface. Based on our preliminary data, some seismic settlement may occur within loose portions of the alluvium along the banks. However, settlement is expected to be relatively minor within the stiff, cohesive soils encountered in the borings.

1.1 Seismic Slope Instability

The potential for seismic slope instability along the existing channel banks, including lateral spreading, may be relatively high due to the steep banks and high seismic ground motions. This hazard will require further consideration in design and construction.

8 CONCLUSIONS AND RECOMMENDATIONS

Based on the findings of this preliminary geotechnical investigation, both the aerial crossing and the HDD options appear to be viable. Our preliminary recommendations are discussed below. Additional geotechnical study, including field investigation and testing, is necessary for final design. For the HDD option, test borings in the channel are necessary to verify the suitability of this option and to develop design/construction criteria. The locations and depths of these borings will depend on further details developed during the design phases for the project.

8.1 Aerial Crossing

Foundation support for the abutment towers is generally available at both banks within undisturbed native soils. For preliminary design, reinforced concrete footings, established below the old railroad grade fill and at least 5 feet into the stiff clay terrace soils, can use allowable soil bearing capacities on the order of 2000-3000 psf. Limitations on the soil bearing include total/differential settlement and security with respect to the steep bank slopes. Particular concern is directed to the southwest abutment where the preliminary tower location is near the edge of the steep bank; a shallow footing at this location will need to maintain a minimum horizontal setback from the bank and/or slope protection for adequate security and mitigation of seismic slope instability and lateral spreading. These limitations will require further analysis during project design.

Higher soil bearing, and increased security, is available for tower footings established within the underlying residual soil unit. This unit, however, is at depths of 15+ feet in borings B-2 and B-3 (northeast and southwest banks, respectively) and may be deeper for tower locations positioned close to the banks. Alternatively, foundation support can be achieved by means of drilled or driven piles with penetrating into the weathered bedrock below depths of approximately 18 (northeast abutment) and 23 feet (southwest abutment). Cast-in-drilled-hole (CIDH) piles would appear to be appropriate at these locations, as would steel H-piles driven to rock.

Reaction for the anchor cables can be achieved by concrete “deadman” anchors buried into native stiff clay soils behind the abutment towers. For preliminary design, lateral resistance using a coefficient of friction of 0.35 and passive earth pressure of 250 psf per foot of embedment depth appears generally available within undisturbed soils. The upper 3-5 feet should be neglected in determination of passive earth pressure due to the presence of old fill and soil disturbance.

At the southwest abutment, the archaeological site boundary may preclude construction of a deadman anchor and drilled soil anchors appear to be a suitable alternative. For preliminary design, anchors about 6 inches in diameter can achieve ultimate bond stresses estimated at about 25-50 psi between grouted section (bond length) and the residual soil and/or weathered rock. Assuming a minimum bond length of 25 feet for tiebacks drilled at 15-20° from horizontal, ultimate design loads on the order of 120 kips can be used for preliminary design.

8.2 HDD Alternative

Based on our preliminary data and geologic mapping within the channel, it appears that conditions are suitable for a horizontal directional drilling (HDD) alternative. We estimate bedrock at depths of about 15 feet or less across the channel, as shown on Figure 4. The depth to rock will need to be confirmed with future investigations as some areas of the Mad River channel (e.g., Raney Collector areas) are known to have gravel depths to about 100 feet -- although these are located a few thousand feet from the project site. While it appears that rock is relatively shallow across the channel, the potential for deeper backfilled channels of sand/gravel will need to be considered if this alternative is advanced.

For preliminary assessment, it appears that a HDD pipeline can be completed within competent rock with about 30 feet of cover. Areas of weak rock (e.g., shear/fault zones) and fractures can cause binding of drill tools and fracking of drill mud, and the presence of cobbles and clean gravel can cause loss of drill fluid and collapse of the HDD borehole. These conditions will require further consideration in design/construction. Caving soils in the upper 10-20 feet at the entry and exit points can generally be controlled by driving conductor casing.

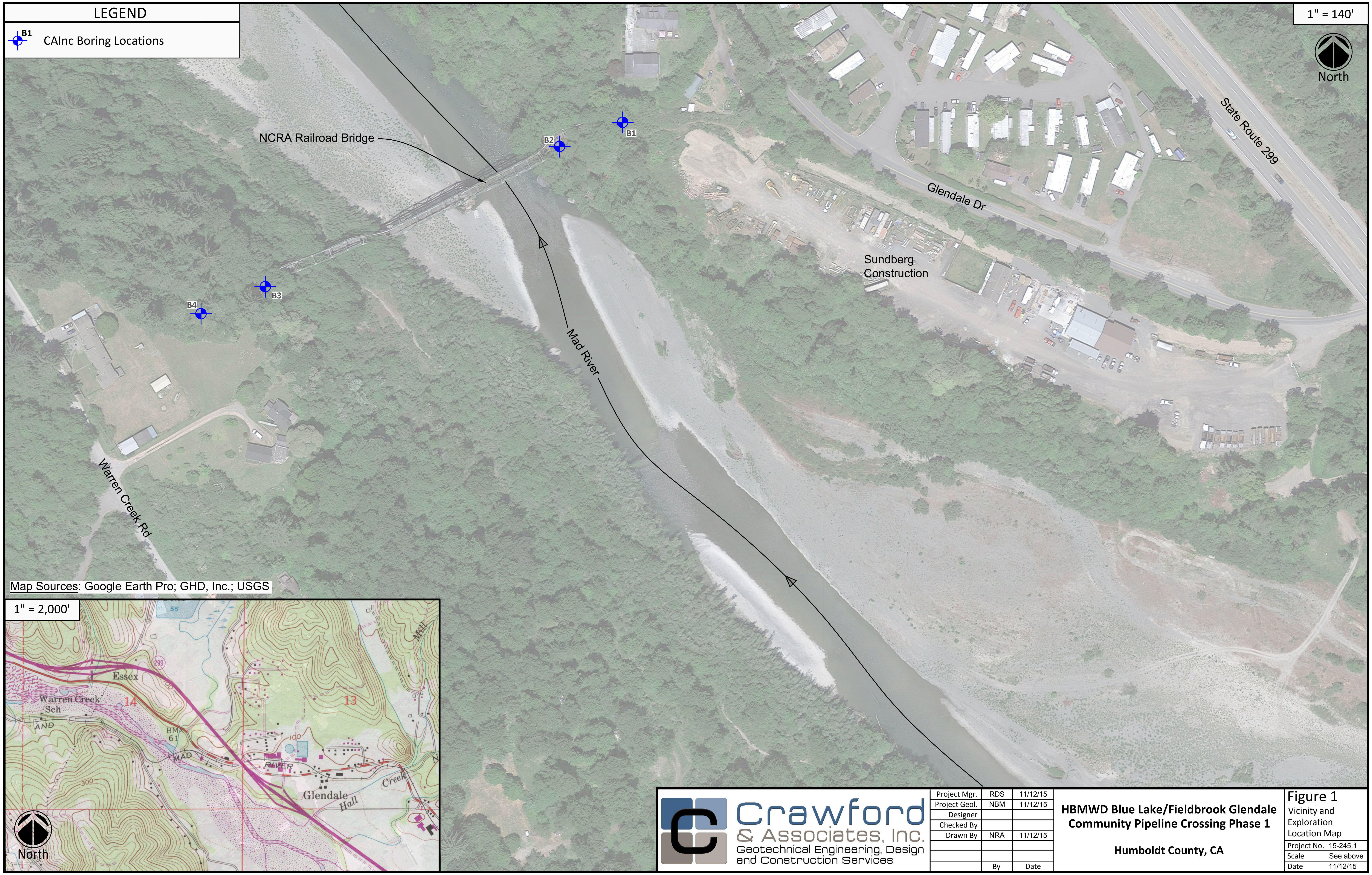
The potential for fault rupture and strong ground motions will also require consideration for this alternative. While the site is not within a mapped EFZ for fault rupture hazard, the mapped late-Quaternary thrust fault near the northeast side of the channel should be considered at least potentially active. This feature may require specific design mitigation, such as flexible connections and/or emergency shut-off valves.

9 LIMITATIONS

This report is intended for GHD Inc. and the design team to use during preliminary design and is based on our initial subsurface exploration, geologic mapping and review of available documents and published mapping. Our scope did not include evaluation of on-site hazardous materials. Final design will require further investigation and analysis based on the selected pipeline alternative and design details. Geotechnical recommendations for final design will be provided in the final Geotechnical Report.

CAInc performed these services in accordance with generally accepted geotechnical engineering principles and practices currently used in this area. Do not use or rely on this report for different locations or improvements without the written consent of CAInc.

FIGURES



Crawford & Associates, Inc.
Geotechnical Engineering, Design and Construction Services

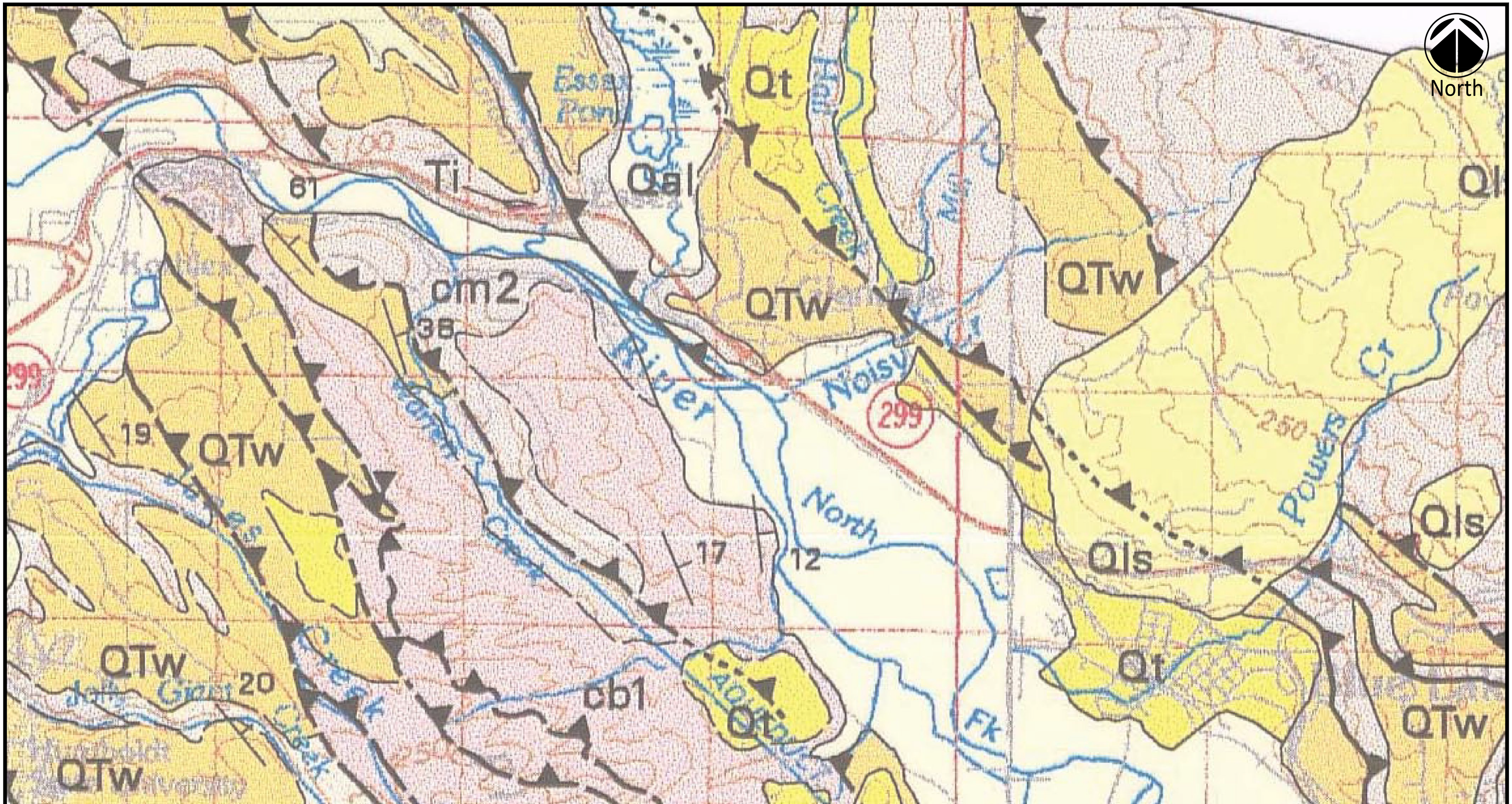
	By	Date
Project Mgr.	RDS	11/12/15
Project Geol.	NBM	11/12/15
Designer		
Checked By		
Drawn By	NRA	11/12/15

HBMWD Blue Lake/Fieldbrook Glendale Community Pipeline Crossing Phase 1

Humboldt County, CA

Figure 1
Vicinity and Exploration Location Map

Project No. 15-245.1
Scale: See above
Date: 11/12/15



LEGEND

Qal	Alluvial deposits (Holocene and late Pleistocene)
Qt	Undifferentiated nonmarine terrace deposits (Holocene and Pleistocene)
QTw	Marine and nonmarine overlap deposits (late Pleistocene to middle Miocene)
Ti	Volcanic rocks of Fickle Hill (Oligocene)
cb1	Broken metasedimentary formation (Cretaceous to Jurassic)
cm2	Metasedimentary melange (Cretaceous to Jurassic)
?	Thrust fault
10	Strike and dip of bedding

Project Mgr.	RDS	11/12/15
Project Geol.	NBM	11/12/15
Designer		
Checked By		
Drawn By	NRA	11/12/15
	By	Date

Geologic Map Source: R.J. McLaughlin et al, 2000, Geology of the Cape Mendocino, Eureka, Garberville, and Southwestern part of the Hayfork, 7.5 minute Quadrangles.

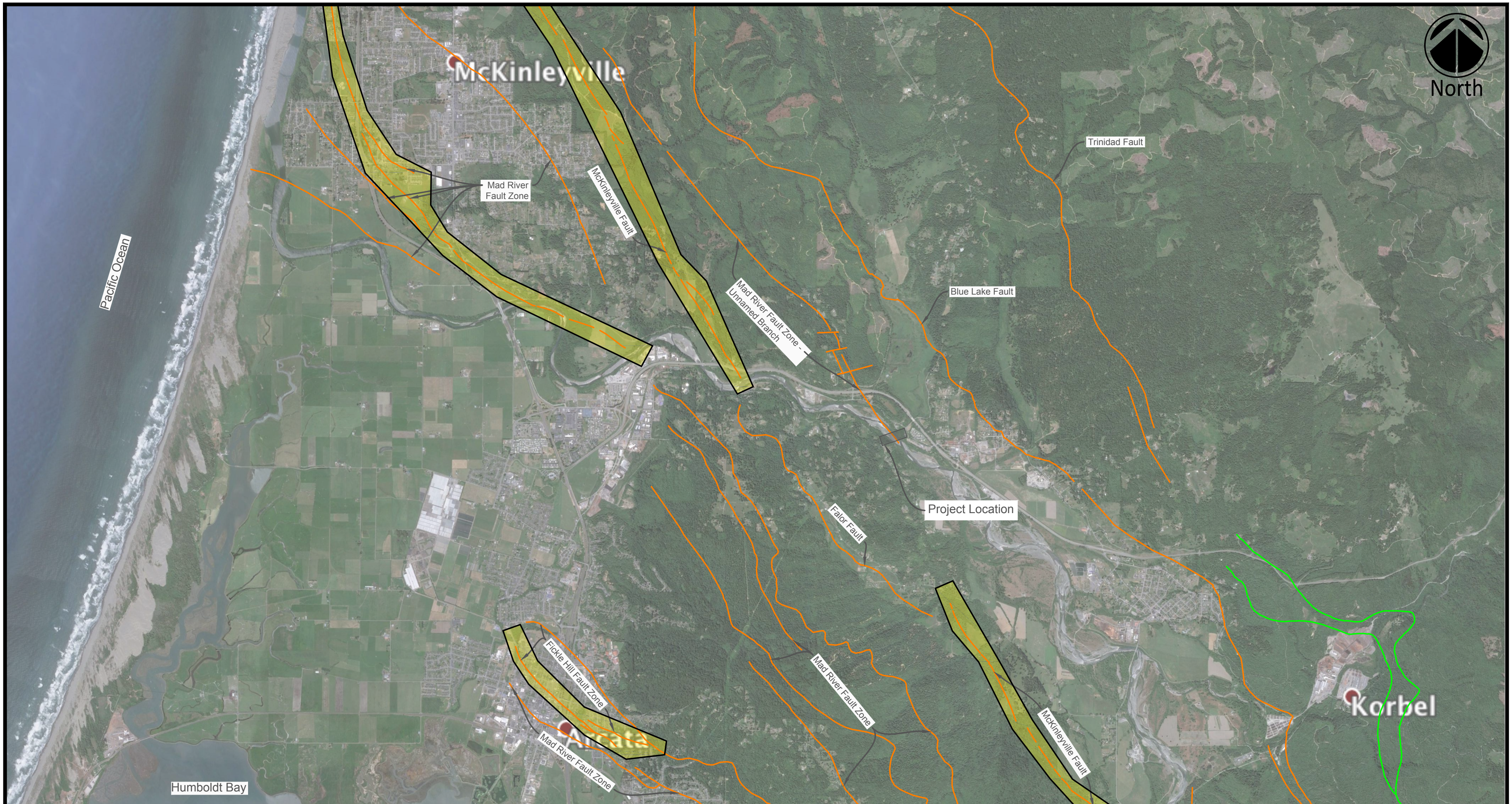
Crawford & Associates, Inc.
Geotechnical Engineering, Design and Construction Services

HBMWD Blue Lake/Fieldbrook Glendale Community Pipeline Crossing Phase 1

Humboldt County, CA

Figure 2
Geology Map

Project No.	15-245.1
Scale	1":3,000'
Date	11/12/15



LEGEND

Quaternary Fault (Age)	Location
<15,000 years	Observed
<130,000 years	Approximated
	Alquist-Priolo Zone

Project Mgr.	RDS	11/12/15
Project Geol.	NBM	11/12/15
Designer		
Checked By		
Drawn By	NRA	11/12/15
	By	Date

Fault Map Source: Google Earth Pro with USGS Fault Location Overlay

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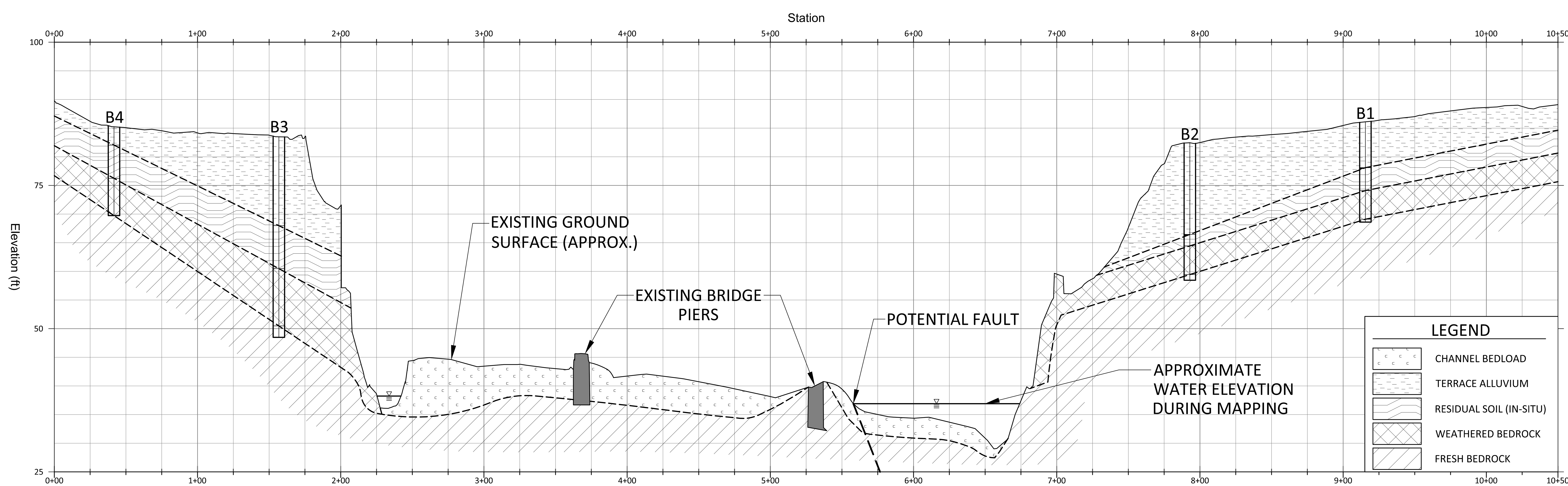
HBMWD Blue Lake/Fieldbrook Glendale Community Pipeline Crossing Phase 1

Humboldt County, CA

Figure 3
Fault Activity Map

Project No.	15-245.1
Scale	1":5,000'
Date	11/12/15



Profile of Cross Section

SCALE
HORZ: 1" = 40'
VERT: 1" = 10'

DATE: | REVISION: | BY:

VERIFY SCALE
BAR REPRESENTS THREE INCHES ON ORIGINAL

USE OF THIS DOCUMENT, INCLUDING THE INCORPORATED DESIGNS, IS AN INSTRUMENT OF SERVICE FOR THIS PROJECT AND SHALL NOT BE USED FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF CRAWFORD & ASSOCIATES INC.

CLIENT: GHD, INC.
LOCATION: APN: 50413105 & 51624102
GLENDALE, HUMBOLDT COUNTY, CA

Crawford & Associates, Inc.
Geotechnical Engineering, Design and Construction Services
4030 S. Land Park Drive, Suite C
Sacramento, CA 95822

DRAWING: GEOLOGIC CROSS-SECTION
PROJECT: HBMWD PIPELINE CROSSING – PHASE 1

Date: NOV 2015
Scale: AS SHOWN
Drawn: RH
Checked: NM
Reviewed: RS
Job No. 15-245.1

Figure 4

Xrefs: X-cltrl_extents_bndry_stateplane.DWG; X-BORDER-34X22.dwg
Path: S:\AutoCAD Civil 3D\Projects\15-245.1-Mad River Crossing\Drawings\Crawford\15-245 Mad River Crossing.dwg Plot Date: Dec 08, 2015 at 10:46am

APPENDIX A

Photographs


LEGEND
B1 CAInc Boring Locations
CAInc Picture Locations (directional)
CAInc Picture Locations (ground)
North
14, 15
13
12
B1
B2
B3
B4
1, 3, 10
2, 11
4
5
6
8
9
18
19
20
21
22
23
24
25
26
Map Sources: Google Earth Pro
Crawford & Associates, Inc.
Geotechnical Engineering, Design and Construction Services
Project Mgr. RDS 11/12/15
Project Geol. NBM 11/12/15
Designer
Checked By
Drawn By NRA 11/12/15
By
Date
HBMWD Blue Lake/Fieldbrook Glendale Community Pipeline Crossing Phase 1
Humboldt County, CA
Appendix A
Photograph Locations
Project No. 15-245.1
Scale 1":140'
Date 11/12/15

Picture 1: Archeological site as seen from parking area at NW corner of property located at 845 Warren Creek Road, Arcata, CA. The orange flags mark utilities.

Picture 2: Archeological site as seen from B3 looking towards parking area.

Picture 3: Mobilization of the drill rig across archeological site prior to drilling using particle board as mats.

Picture 4: Looking west along old railroad grade from B3 location towards B4 location prior to drilling.

Picture 5: Drill rig set augering B3 in railroad grade just west of bridge abutment.

Picture 6: Drill rig augering B4 in railroad grade looking east towards bridge.

Picture 7: Heavily weathered argillite in sample barrel. Sample is from B3 at a depth of 22.5 feet to 23.5 feet.

Picture 8: Area of B3 after borehole completion, grouting, and site cleanup. The flag on the stake shows where the boring was located.

Picture 9: Area of B4 after borehole completion, backfill, and site cleanup. The flag on the stake shows where the boring was located.

Picture 10: Demobilization of the drill rig across the archeological site using plywood as mats.

Picture 11: Archeological site after demobilization of the drill rig.

Picture 12: Drill rig being set up at B1 on old railroad grade just off of parking area at NW end of property at 1220 Glendale Drive, McKinleyville, CA.

Picture 13: Blue flags marking alignment of water pipeline at east side of river. Pipeline is 3.8 feet deep at closes flag in picture. Drill rig at B1 is out of frame to left.

Picture 14: Additional marking alignment of pipeline at east side of river close to bridge.

Picture 15: Drill rig being set up at B2. Boring site was at the abutment of the bridge that collapsed in 1896.

Picture 16: Weathered argillite samples from B2. The brown rock at the top was shallower than 18 feet, and the gray rock at the bottom was from below 18 feet.

Picture 17: Weathered argillite (gray) and residual soil (brown) from B2 in the sample barrel. Samples shown are from 16.5 feet to 18.5 feet.

Picture 18: Outcrop of meta-argillite seen just below parking area at east side of the river south of the bridge.

Picture 19: Additional outcrop of meta-argillite on east side of the river south of bridge.

Picture 20: River level outcrop of meta-argillite along west side of river.

Picture 21: View downriver from where previous picture was take. Bridge is approximately 1200 feet away.

Picture 22: High grade meta-argillite outcrops at east abutment of bridge.

Picture 23: Close-up view of high grade meta-argillite outcrop from previous picture.

Picture 24: Outcrop of meta-sandstone at bent of bridge. Picture is looking downstream.

Picture 25: Close up view of meta-sandstone outcrop near bent. White marks on rock at bottom-left of picture is from blows from a sledge-hammer.

Picture 26: Steps cut in heavily weathered argillite along hiking trail downstream from the west bridge abutment.

APPENDIX B

Boring Logs

UNIFIED SOIL CLASSIFICATION (ASTM D 2487-06)

MATERIAL TYPES	CRITERIA FOR ASSIGNING SOIL GROUP NAMES			GRAPHIC SYMBOL	GROUP SYMBOL	SOIL GROUP NAMES
COARSE-GRAINED SOILS >50% RETAINED ON NO. 200 SIEVE	**GRAVELS** >50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	CLEAN GRAVELS <5% FINES	$Cu \geq 4$ AND $1 \leq Cc \leq 3$		**GW**	WELL-GRADED GRAVEL
			Cu < 4 AND/OR 1 > Cc > 3		**GP**	POORLY-GRADED GRAVEL
		GRAVELS WITH FINES >12% FINES	FINES CLASSIFY AS ML OR MH		**GM**	SILTY GRAVEL
			FINES CLASSIFY AS CL OR CH		**GC**	CLAYEY GRAVEL
	SANDS <50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	CLEAN SANDS <5% FINES	$Cu \geq 6$ AND $1 \leq Cc \leq 3$		**SW**	WELL-GRADED SAND
			Cu < 6 AND/OR 1 > Cc > 3		**SP**	POORLY-GRADED SAND
		SANDS WITH FINES >12% FINES	FINES CLASSIFY AS ML OR MH		**SM**	SILTY SAND
			FINES CLASSIFY AS CL OR CH		**SC**	CLAYEY SAND
FINE-GRAINED SOILS >50% PASSING NO. 200 SIEVE	**SILTS AND CLAYS** LIQUID LIMIT <50	INORGANIC	PI>7 AND PLOTS ON OR ABOVE "A" LINE		**CL**	LEAN CLAY
			PI>4 AND PLOTS BELOW "A" LINE		**ML**	SILT
		ORGANIC	LL (oven dried)<0.75/LL (not dried)		**OL**	ORGANIC CLAY OR SILT
	SILTS AND CLAYS LIQUID LIMIT >50	INORGANIC	PI PLOTS ON OR ABOVE "A" LINE		**CH**	FAT CLAY
			PI PLOTS BELOW "A" LINE		**MH**	ELASTIC SILT
		ORGANIC	LL (oven dried)<0.75/LL (not dried)		**OH**	ORGANIC CLAY OR SILT
HIGHLY ORGANIC SOILS		PRIMARILY ORGANIC MATTER, DARK COLOR, ORGANIC ODOR			**PT**	PEAT

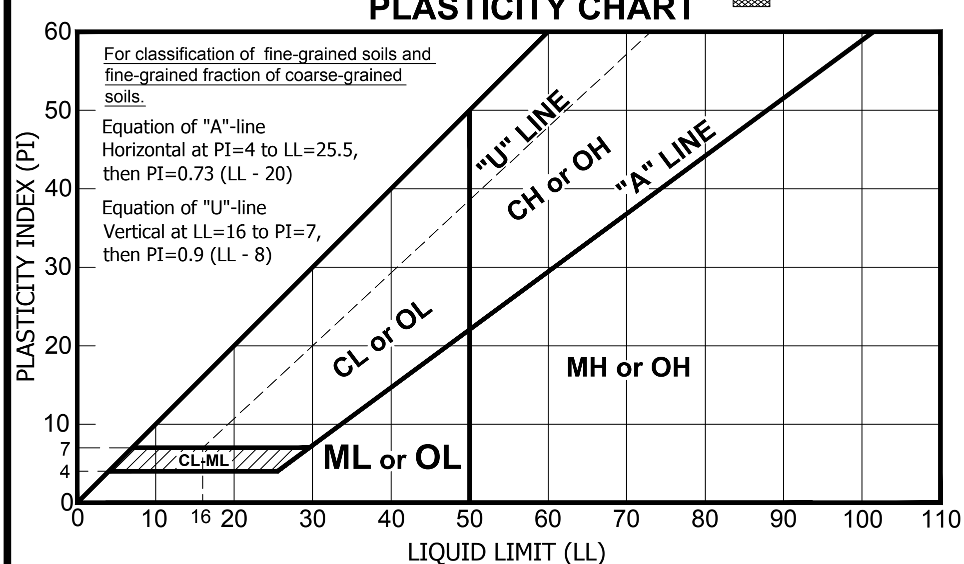
NOTE: $Cu = D_{60}/D_{10}$

$Cc = (D_{30})^2 / D_{10} \times D_{60}$

BLOW COUNT

The number of blows of a 140-lb. hammer falling 30-inches required to drive the sampler the last 12-inches of an 18-inch drive. The notation 50/0.4 indicates 4-inches of penetration achieved in 50 blows.

PLASTICITY CHART



SAMPLE TYPES

- Auger or backhoe cuttings
- Shelby tube
- Standard Penetration (SPT)
- Bulk Sample
- Modified California 2"
- California Standard 2.5"
- Rock core

ADDITIONAL TESTS

C	- Consolidation
CP	- Compaction Curve
CR	- Corrosivity Testing
CU	- Consolidated Undrained Triaxial
DS	- Direct Shear
EI	- Expansion Index
P	- Permeability
PA	- Partical Size Analysis
PI	- Plasticity Index
PP	- Pocket Penetrometer
R	- R-Value
SE	- Sand Equivalent
SG	- Specific Gravity
SL	- Shrinkage Limit
SW	- Swell Potential
TV	- Pocket Torvane Shear Test
UC	- Unconfined Compression
UU	- Unconsolidated Undrained Triaxial

GROUND WATER LEVELS

- Later water level after drilling
- Water level at time of drilling

Crawford & Associates, Inc.
Geotechnical Engineering, Design and Construction Services

BORING LOG / TEST PIT LEGEND AND SOIL DESCRIPTIONS

CALTRANS SOIL & ROCK LOGGING MANUAL (2010)

LEGEND OF ROCK MATERIALS
IGNEOUS ROCK
SEDIMENTARY ROCK
METAMORPHIC ROCK

PERCENT CORE RECOVERY (REC) & ROCK QUALITY DESIGNATION (RQD)

$$REC = \frac{\sum \text{LENGTH OF THE RECOVERED CORE PIECES (INCHES)}}{\text{TOTAL LENGTH OF CORE RUN (INCHES)}} \times 100\%$$

$$RQD = \frac{\sum \text{LENGTH OF INTACT CORE PIECES} \geq 4 \text{ INCHES}}{\text{TOTAL LENGTH OF CORE RUN (INCHES)}} \times 100\%$$

BEDDING SPACING

DESCRIPTION	THICKNESS / SPACING
MASSIVE	GREATER THAN 10'
VERY THICKLY BEDDED	3' - 10'
THICKLY BEDDED	1' - 3'
MODERATELY BEDDED	4" - 1'
THINLY BEDDED	1" - 4"
VERY THINLY BEDDED	¼" - 1"
LAMINATED	LESS THAN ¼"

FRACTURE DENSITY

DESCRIPTION	OBSERVED FRACTURE DENSITY
UNFRACTURED	NO FRACTURES.
VERY SLIGHTLY FRACTURE	CORE LENGTHS GREATER THAN 3 ft.
SLIGHTLY FRACTURED	CORE LENGTHS MOSTLY FROM 1 TO 3 ft.
MODERATELY FRACTURED	CORE LENGTHS MOSTLY FROM 4 INCHES TO 1 ft.
INTENSELY FRACTURED	CORE LENGTHS MOSTLY FROM 1 TO 4 INCHES.
VERY INTENSELY FRACTURED	MOSTLY CHIPS AND FRAGMENTS.

ROCK HARDNESS

DESCRIPTION	CRITERIA
EXTREMELY HARD	CANNOT BE SCRATCHED WITH A POCKETKNIFE OR SHARP PICK. CAN ONLY BE CHIPPED WITH REPEATED HEAVY HAMMER BLOWS
VERY HARD	CANNOT BE SCRATCHED WITH A POCKETKNIFE OR SHARP PICK. BREAKS WITH REPEATED HEAVY HAMMER BLOWS.
HARD	CAN BE SCRATCHED WITH A POCKETKNIFE OR SHARP PICK WITH DIFFICULTY (HEAVY PRESSURE). BREAKS WITH HEAVY HAMMER BLOWS.
MODERATELY HARD	CAN BE SCRATCHED WITH POCKETKNIFE OR SHARP PICK WITH LIGHT OR MODERATE PRESSURE. BREAKS WITH MODERATE HAMMER BLOWS.
MODERATELY SOFT	CAN BE GROOVED 1/16 INCH DEEP WITH A POCKETKNIFE OR SHARP PICK WITH MODERATE OR HEAVY PRESSURE. BREAKS WITH LIGHT HAMMER BLOW OR HEAVY MANUAL PRESSURE.
SOFT	CAN BE GROOVED OR GOUGED EASILY BY A POCKETKNIFE OR SHARP PICK WITH LIGHT PRESSURE, CAN BE SCRATCHED WITH FINGERNAIL. BREAKS WITH LIGHT TO MODERATE MANUAL PRESSURE.
VERY SOFT	CAN BE READILY INDENTED, GROOVED OR GOUGED WITH FINGERNAIL, OR CARVED WITH A POCKETKNIFE. BREAKS WITH LIGHT MANUAL PRESSURE.

WEATHERING DESCRIPTORS FOR INTACT ROCK

DESCRIPTION	CHEMICAL WEATHERING-DISCOLORATION AND/OR OXIDATION		GENERAL CHARACTERISTICS
	BODY OF ROCK	FRACTURE SURFACES	
FRESH	NO DISCOLORATION, NOT OXIDIZED.	NO DISCOLORATION OR OXIDATION.	HAMMER RINGS WHEN CYRSTALLINE ROCKS ARE STRUCK.
SLIGHTLY WEATHERED	DISCOLORATION OR OXIDATION IS LIMITED TO SURFACE OR, OR SHORT DISTANCE FROM, FRACTURES; SOME FELDSPAR CRYSTALS ARE DULL.	MINOR TO COMPLETE DISCOLORATION OR OXIDATION OF MOST SURFACES.	HAMMER RINGS WHEN CRYSTALLINE ROCKS ARE STRUCK. BODY OF ROCK NOT WEAKENED.
MODERATELY WEATHERED	DISCOLORATION OR OXIDATION EXTENDS FROM FRACTURES USUALLY THROUGHOUT; Fe-Mg MINERALS ARE "RUSTY," FELDSPAR CRYSTALS ARE "CLOUDY."	ALL FRACTURE SURFACES ARE DISCOLORED OR OXIDIZED.	HAMMER DOES NOT RING WHEN ROCK IS STRUCK. BODY OF ROCK IS SLIGHTLY WEAKENED.
INTENSELY WEATHERED	DISCOLORATION OR OXIDATION THROUGHOUT; ALL FELDSPARS AND Fe-Mg MINERALS ARE ALTERED TO CLAY TO SOME EXTENT; OR CHEMICAL ALTERATION PRODUCES IN-SITU DISAGGREGATION, SEE GRAIN BOUNDARY CONDITIONS.	ALL FRACTURE SURFACES ARE DISCOLORED OR OXIDIZED, SURFACES FRIABLE.	DULL SOUND WHEN STRUCK WITH HAMMER, USUALLY CAN BE BROKEN WITH MODERATE TO HEAVY MANUAL PRESSURE OR BY LIGHT HAMMER BLOW WITHOUT REFERENCE TO PLANES OF WEAKNESS SUCH AS INCIPIENT OR HAIRLINE FRACTURES, OR VEINLETS. ROCK IS SIGNIFICANTLY WEAKENED.
DECOMPOSED	DISCOLORED OR OXIDIZED THROUGHOUT, BUT RESISTANT MINERALS SUCH AS QUARTZ MAY BE UNALTERED; ALL FELDSPAR AND Fe-Mg MINERALS ARE COMPLETELY ALTERED TO CLAY.		CAN BE GRANULATED BY HAND. RESISTANT MINERALS SUCH AS QUARTZ MAY BE PRESENT AS "STRINGERS" OR "DIKES."

LOG OF BORING B1

PROJECT NO: 15-245.1	BEGIN DATE: 10/20/2015	DRILLING CONTRACTOR: Geo-Ex Subsurface
PROJECT: HBMWD Pipeline Crossing	COMPLETION DATE: 10/20/2015	DRILLING METHOD: Hollow-Stem Auger
LOCATION: East Side of Mad River	SURFACE ELEVATION: 86.09(ft)	DRILL RIG: CME 45c
CLIENT: GHD	SURFACE CONDITION:	HAMMER TYPE: Autohammer (140lbs, 30" drop)
LOGGED BY: NBM	WATER DEPTH: Dry During Drilling	SAMPLER TYPE & SIZE: SPT/CalMod/Bulk
DEPTH OF BORING: 17.5(ft)	READING TAKEN:	BOREHOLE DIAMETER: 4"
	HAMMER EFFICIENCY: 75.2%	BACKFILL METHOD: Native Soil Backfill

FIELD									LABORATORY					
DEPTH (ft)	SAMPLE	SAMPLE NO	BLOWS PER 6 IN.	BLOWS PER FOOT	POCKET PEN. (TSF)	GRAPHIC LOG	DESCRIPTION	RECOVERY(%)	PLASTIC LIMIT	LIQUID LIMIT	MOISTURE (%)	DRY DENSITY (PCF)	% PASSING 200 SIEVE	REMARKS
0–1							Lean CLAY (CL); 7.5YR 4/4 (brown), dry, medium stiff, trace fine gravel, trace woody organics.							Fill from old railroad bed
1–3	Bulk	1												
3–4.5	SPT	2	11 18 21	39			CLAYEY SAND with GRAVEL (SC); 7.5YR 4/4 (brown), dry, stiff, 20-30% fine to medium rounded to subrounded gravel, 30-40% fine to coarse sand (low on medium), occasional coarse gravel to cobble; gravels are basalt, quartzite, quartz, chlorite, feldspars.		19	28	9.1 10.6	131.1 111.7		PI
5–6	Bulk	3											33	Hit quartzite cobble (approximately 6"), hard and fresh
8–9.5	SPT	4	6 19 19	38			Lean CLAY (CL); 10YR 4/2 (dark grayish brown), dry to moist, stiff, trace coarse sand/ fine gravel. CLAYEY SAND with GRAVEL (SC); 10YR 4/2 (dark grayish brown) with 10YR 2/1 (black) infilling (thin) in some residual fractures,stiff, shows structure of source rock.		16	33				In-situ residual soil PI
9.5–10	Bulk	5											31	
12–13.5	SPT	6	18 24 33	57			METAMORPHIC ROCK, Meta-Argillite, 10YR 3/1 (very dark gray), dry to moist, moderately to slightly weathered, moderately soft to moderately hard.							Bedrock, rock appears to be massive but fractures and shears easily during drilling/sampling
14–15.5		7	12 8 9	17			METAMORPHIC ROCK, Meta-Argillite, Moderately soft.							Shear zone
16–17		8	11 12 50/5"	62/11										
17–17.5	Bulk	9					METAMORPHIC ROCK, Meta-Argillite, Hard to moderately hard, fresh rock.							

Bottom of borehole at 17.5 ft bgs

ELEVATION (ft)	DEPTH (ft)
	1
84	2
	3
82	4
	5
80	6
	7
78	8
	9
76	10
	11
74	12
	13
72	14
	15
70	16
	17
68	18
	19
66	20
	21
64	22
	23
62	24

LOG OF BORING B2

PROJECT NO: 15-245.1
PROJECT: HBMWD Pipeline Crossing
LOCATION: East Side of Mad River
CLIENT: GHD
LOGGED BY: NBM
DEPTH OF BORING: 24(ft)

BEGIN DATE: 10/20/2015
COMPLETION DATE: 10/20/2015
SURFACE ELEVATION: 82.44(ft)
SURFACE CONDITION:
WATER DEPTH: Dry During Drilling
READING TAKEN:
HAMMER EFFICIENCY: 75.2%

DRILLING CONTRACTOR: Geo-Ex Subsurface
DRILLING METHOD: Hollow-Stem Auger
DRILL RIG: CME 45c
HAMMER TYPE: Autohammer (140lbs, 30" drop)
SAMPLER TYPE & SIZE: SPT/CalMod/Bulk
BOREHOLE DIAMETER: 4"
BACKFILL METHOD: Native Soil Backfill

ELEVATION (ft)	DEPTH (ft)	SAMPLE NO	BLOWS PER 6 IN.	BLOWS PER FOOT	POCKET PEN. (TSF)	DESCRIPTION	RECOVERY(%)	PLASTIC LIMIT	LIQUID LIMIT	MOISTURE (%)	DRY DENSITY (PCF)	% PASSING 200 SIEVE	REMARKS
	0–2					Lean CLAY (CL); 7.5YR 4/4 (brown), dry, moderately stiff, trace gravel, trace woody organics.							Backfill from old railroad bed
80	2–4	1	7 4 4	8		SANDY lean CLAY (CL); 7.5YR 4/4 (brown), dry, stiff, minor orangish yellow staining, 30% fine to medium subrounded gravel, 10% fine to coarse sand.							
78	4											58	
76	5–7	2											
74	7–9	3	5 7 8	15		GRAVELLY lean CLAY with SAND (CL); 7.5 YR 4/4 (brown), dry, stiff, up to 40% fine to coarse rounded to subrounded gravel, 20% fine to coarse sand, majority of gravel is quartzite.		19	32	16.7	101.4		PI
72	9–12					SANDY lean CLAY (CL); 7.5YR 4/4 (brown), dry, stiff, minor orangish yellow staining, 30% fine to medium subrounded gravel, 10% fine to coarse sand.							
70	12–14	4	10 14 14	28		Lean CLAY with GRAVEL (CL); 10YR 3/2 (very dark grayish brown), dry, stiff, 10-20% fine to medium gravel, 10% fine sand.							
68	14–15	5											
66	15–16	6	7 13 17	30									Dense below 15', difficult drilling
	16–18	7	9 12 13	25		Lean CLAY (CL); 10YR 4/2 (dark grayish brown) with 2.5YR 3/3 (dark reddish brown) staining on retained fracture faces (tight joints/fractures), dry to moist, stiff.							In-situ residual soil
64	18–22	8	15 16 26	42		METAMORPHIC ROCK, Meta-Argillite, some 2.5 YR 3/3 (dark reddish brown) staining, 10YR 5/1 (gray) with some 2.5YR 3/3 (dark reddish brown) and minor decomposed to 2.5 YR 5/6 (light oliver brown), moderately to slightly weathered, moderately soft to soft.		24	41	8.7	131.1	22	Bedrock; PI
60	22–23	9	22 24 50/5"	74/11									
58	23–24					METAMORPHIC ROCK, Meta-Argillite, 10YR 5/1 (gray), fresh, moderately hard to hard.							
	24					Bottom of borehole at 24.0 ft bgs							

Crawford & Associates, Inc.
Geotechnical Engineering, Design and Construction Services

Crawford & Associates, Inc.
4030 S Land Park Drive, Ste. C
Sacramento, CA 95822
(916) 455 4225

PROJECT NUMBER: 15-245.1
PROJECT: HBMWD Pipeline Crossing
BORING: B2
ENTRY BY: NBM
CHECKED BY: RDS

LOG OF BORING B3

PROJECT NO: 15-245.1	BEGIN DATE: 10/19/2015	DRILLING CONTRACTOR: Geo-Ex Subsurface
PROJECT: HBMWD Pipeline Crossing	COMPLETION DATE: 10/19/2015	DRILLING METHOD: Hollow-Stem Auger
LOCATION: West Side of Mad River	SURFACE ELEVATION: 83.47(ft)	DRILL RIG: CME 45c
CLIENT: GHD	SURFACE CONDITION:	HAMMER TYPE: Autohammer (140lbs, 30" drop)
LOGGED BY: NBM	WATER DEPTH: Dry During Drilling	SAMPLER TYPE & SIZE: SPT/CalMod/Bulk
DEPTH OF BORING: 35(ft)	READING TAKEN:	BOREHOLE DIAMETER: 4"
	HAMMER EFFICIENCY: 75.2%	BACKFILL METHOD: Tremmie Grouted

ELEVATION (ft)	DEPTH (ft)	SAMPLE NO	BLOWS PER 6 IN.	BLOWS PER FOOT	POCKET PEN. (TSF)	DESCRIPTION	RECOVERY(%)	PLASTIC LIMIT	LIQUID LIMIT	MOISTURE (%)	DRY DENSITY (PCF)	% PASSING 200 SIEVE	REMARKS
	0					Lean CLAY (CL); 5YR 4/4 (reddish brown), dry, moderately stiff, 10% sand.							Backfill from old railroad bed
81	2												
	3.5					SANDY lean CLAY (CL); 10YR 4/6 (dark yellowish brown), dry, stiff, trace to 5% fine subrounded gravel, 30% fine sand, minor woody organics.							
79	4	1	4 5 6	11									
77	6												
75	8	2						23	41	12.7		63	PI
	9	3	8 17 21	38									Microcrystaline quartz cobble, hard, fresh, 6", 5GY 6/2 (light grayish green)
73	10					Lean CLAY (CL); 10YR 4/6 (dark yellowish brown), dry, stiff, 10% fine sand, some 2-5mm dark brown to black bands.							
71	12	4						20	44			89	PI
69	14	5	13 37 46	83									
	15.5					GRAVELLY lean CLAY with SAND (CL); 10YR 4/3 (brown), dry to moist, very stiff, 10-20% fine to medium angular gravel (residual rock, 10YR 5/2 grayish brown), dense.							In-situ residual soil
67	16	6						21	47			63	PI
	17	7	42 50/5"	50/5									
65	18												Switch to rotary drilling, difficult drilling for auger, approximately 25% hard rock in soil
63	20	8											
61	22												
	22.5	9	30 50/5"	50/5									
	23.2					METAMORPHIC ROCK, Meta-Argillite, 7.5YR 4/3 (brown) with 7.5 YR 2.5/2 (very dark brown) staining in fractures, moderately weathered, moderately hard.							Bedrock
59	24												

ELEVATION (ft)	DEPTH (ft)	SAMPLE	SAMPLE NO	BLOWS PER 6 IN.	BLOWS PER FOOT	POCKET PEN. (TSF)	GRAPHIC LOG	DESCRIPTION	RECOVERY(%)	PLASTIC LIMIT	LIQUID LIMIT	MOISTURE (%)	DRY DENSITY (PCF)	% PASSING 200 SIEVE	REMARKS
	25–27.5		10					METAMORPHIC ROCK *(continued)*.							
	27.5–28.5		11	23 50/5"	50/5			METAMORPHIC ROCK, Meta-Argillite, 7.5YR 4/3 (brown), discoloration in fractures more orangish, overall slightly less weathered than above, moderately weathered, moderately hard to hard.							
	30–32.5		12					METAMORPHIC ROCK, Meta-Argillite, 10YR 4/1 (dark gray), slightly weathered to fresh, moderately hard to hard.							
	32.5–33.5		13	15 50/5"	50/5			METAMORPHIC ROCK, Meta-Argillite, 10YR 4/1 (dark gray), fresh, hard.							

Bottom of borehole at 35.0 ft bgs

Elevation scale: 57, 55, 53, 51, 49, 47, 45, 43, 41, 39, 37, 35, 33, 31, 29
Depth scale: 26–55

LOG OF BORING B4

PROJECT NO: 15-245.1
PROJECT: HBMWD Pipeline Crossing
LOCATION: West Side of Mad River
CLIENT: GHD
LOGGED BY: NBM
DEPTH OF BORING: 15.5(ft)

BEGIN DATE: 10/19/2015
COMPLETION DATE: 10/19/2015
SURFACE ELEVATION: 85.22(ft)
SURFACE CONDITION:
WATER DEPTH: Dry During Drilling
READING TAKEN:
HAMMER EFFICIENCY: 75.2%

DRILLING CONTRACTOR: Geo-Ex Subsurface
DRILLING METHOD: Hollow-Stem Auger
DRILL RIG: CME 45c
HAMMER TYPE: Autohammer (140lbs, 30" drop)
SAMPLER TYPE & SIZE: SPT/CalMod/Bulk
BOREHOLE DIAMETER: 4"
BACKFILL METHOD: Native Soil Backfill

ELEVATION (ft)	DEPTH (ft)
	1
83	2
	3
81	4
	5
79	6
	7
77	8
	9
75	10
	11
73	12
	13
71	14
	15
69	16
	17
67	18
	19
65	20
	21
63	22
	23
61	24

SAMPLE NO	BLOWS PER 6 IN.	BLOWS PER FOOT	POCKET PEN. (TSF)	DESCRIPTION	RECOVERY(%)	PLASTIC LIMIT	LIQUID LIMIT	MOISTURE (%)	DRY DENSITY (PCF)	% PASSING 200 SIEVE	REMARKS
				GRAVELLY lean CLAY (CL); 5YR 4/4 (reddish brown), dry, moderately stiff, 25% fine to medium gravel, 10% sand.							Backfill from old railroad bed to 3.2 feet, gravel is ballast
				Lean CLAY (CL); 5YR 4/4 (reddish brown), dry, stiff, trace sand.							
1	17 32 37	69		CLAYEY SAND with GRAVEL (SC); Mottled color (brown, reddish brown, dark brown, grayish brown), dry, very stiff, dense.		24	29	10.6	122.8	17 14	In-situ residual soil PI
				CLAYEY SAND with GRAVEL (SC); 10YR 4/6 (dark yellowish brown), dry, stiff, black staining on retained fracture/joint faces, retained structure from source rock.							
				Lean CLAY with SAND (CL); 10YR 4/1 (dark gray), dry to moist, stiff.							Same color as bedrock but still residual soil
2	4 7 11	18		Lean CLAY with SAND (CL); 10YR 3/4 (dark yellowish brown), dry to moist, stiff, dense, rock structure retained.							
3				METAMORPHIC ROCK, Meta-Argillite, 10YR 4/1 (dark gray), becomes harder with depth, starts at moderately hard and slightly weathered, rock is fresh and hard at 15.5 feet.							Bedrock
4	11 25 27	52									
5				Bottom of borehole at 15.5 ft bgs							

APPENDIX C

Laboratory Test Results

Crawford & Associates, Inc.
Geotechnical Engineering, Design and Construction Services

Project Name: HBMWD Pipeline Crossing
CAInc File No: 15-245.1
Date: 11/23/15
Technician: KKL

MOISTURE-DENSITY TESTS - D2216

	1	2	3	4	5
Sample No.	B1	B1	B2	B2	B3 (4/4)
USCS Symbol	CL	Rock	CL	Rock	CL
Depth (ft.)	4-4.5	9-9.5	8-8.5	19.5-20	8-9
Sample Length (in.)	5.124	4.890	4.629	5.650	
Diameter (in.)	2.388	2.414	2.411	2.425	
Sample Volume (ft^3)	0.01328	0.01295	0.01223	0.01510	
Total Mass Soil+Tube (g)	983.2	1096.3	862.4	1196.3	
Mass of Tube (g)	239.1	256.2	206.2	219.6	
Tare No.	C17	C12	B10	2	C12
Tare (g)	13.9	13.9	13.7	127.6	13.9
Wet Soil + Tare (g)	55.6	78.9	48.0	536.5	67.9
Dry Soil + Tare (g)	51.6	73.5	43.1	503.7	61.8
Dry Soil (g)	37.7	59.6	29.4	376.1	47.9
Water (g)	4.0	5.4	4.9	32.8	6.1
Moisture (%)	**10.6**	**9.1**	**16.7**	**8.7**	**12.7**
Dry Density (pcf)	**111.7**	**131.1**	**101.4**	**131.1**	

Crawford & Associates, Inc.
Geotechnical Engineering, Design and Construction Services

Project Name: HBMWD Pipeline Crossing
CAInc File No: 15-245.1
Date: 11/23/15
Technician: KKL

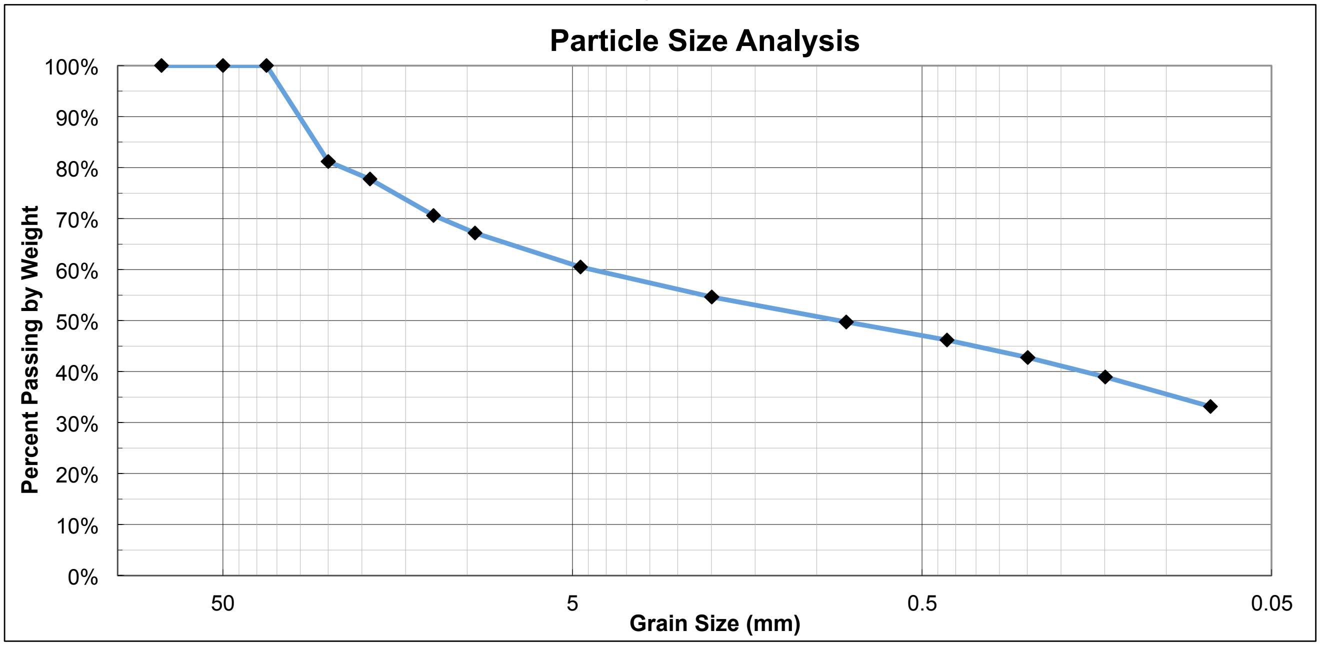
MOISTURE-DENSITY TESTS - D2216

	1	2	3	4	5
Sample No.	B4				
USCS Symbol	Rock				
Depth (ft.)	4-4.5				
Sample Length (in.)	4.839				
Diameter (in.)	2.407				
Sample Volume (ft^3)	0.01274				
Total Mass Soil+Tube (g)	1036.6				
Mass of Tube (g)	251.0				
Tare No.	C20				
Tare (g)	13.6				
Wet Soil + Tare (g)	47.3				
Dry Soil + Tare (g)	44.0				
Dry Soil (g)	30.5				
Water (g)	3.2				
Moisture (%)	**10.6**				
Dry Density (pcf)	**122.8**				

Crawford & Associates, Inc.
Geotechnical Engineering, Design and Construction Services

Project Name: HBMWD Pipeline Crossing
CAInc File No: 15-245.1
Date: 11/13/15
Technician: KKL
Sample ID: B1 (1/2)
Depth: 5-6'
USCS Classification: Clayey GRAVEL with SAND

Grain Size Analysis - ASTM 6913



% Cobble	% Gravel		% Sand			% Fines
	Coarse	Fine	Coarse	Medium	Fine	Silt/Clay
	22	17	6	8	13	
0	**40**		**27**			**33**

		Sieve #	Opening mm	Cummulative Mass Retained	% Passing %
Cobbles		**3"**	75	0.00	100%
Gravel	Coarse	**2"**	50	0.00	100%
		1-1/2"	37.5	0.00	100%
		1"	25.0	113.30	81%
		3/4"	19.0	134.40	78%
	Fine	**1/2"**	12.5	177.00	71%
		3/8"	9.50	198.10	67%
		#4	4.75	238.30	61%
Sand	Coarse	**#10**	2.00	273.80	55%
	Medium	**#20**	0.825	303.30	50%
		#40	0.425	324.70	46%
	Fine	**#60**	0.250	345.30	43%
		#100	0.150	368.40	39%
		#200	0.075	403.40	33%

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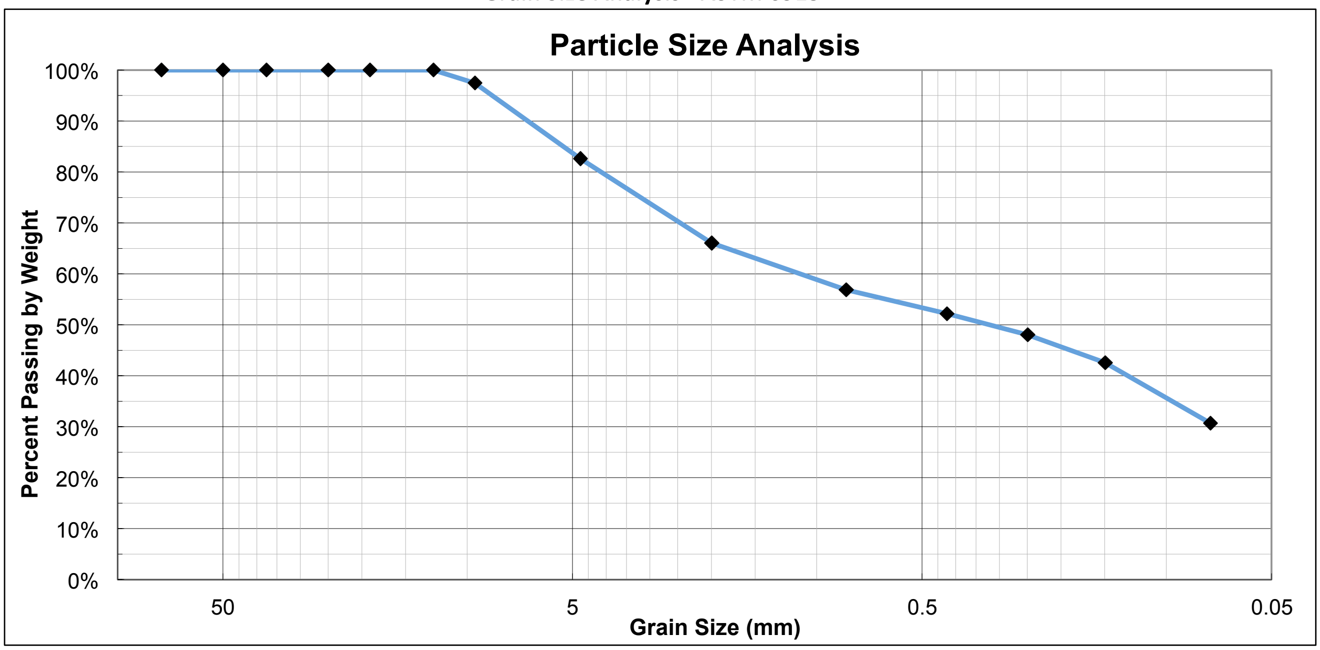
and Construction Services

Project Name: HBMWD Pipeline Crossing
CAInc File No: 15-245.1
Date: 11/12/15
Technician: KKL
Sample ID: B1
Depth: 9.5-10'
USCS Classification: Clayey SAND with GRAVEL

Grain Size Analysis - ASTM 6913



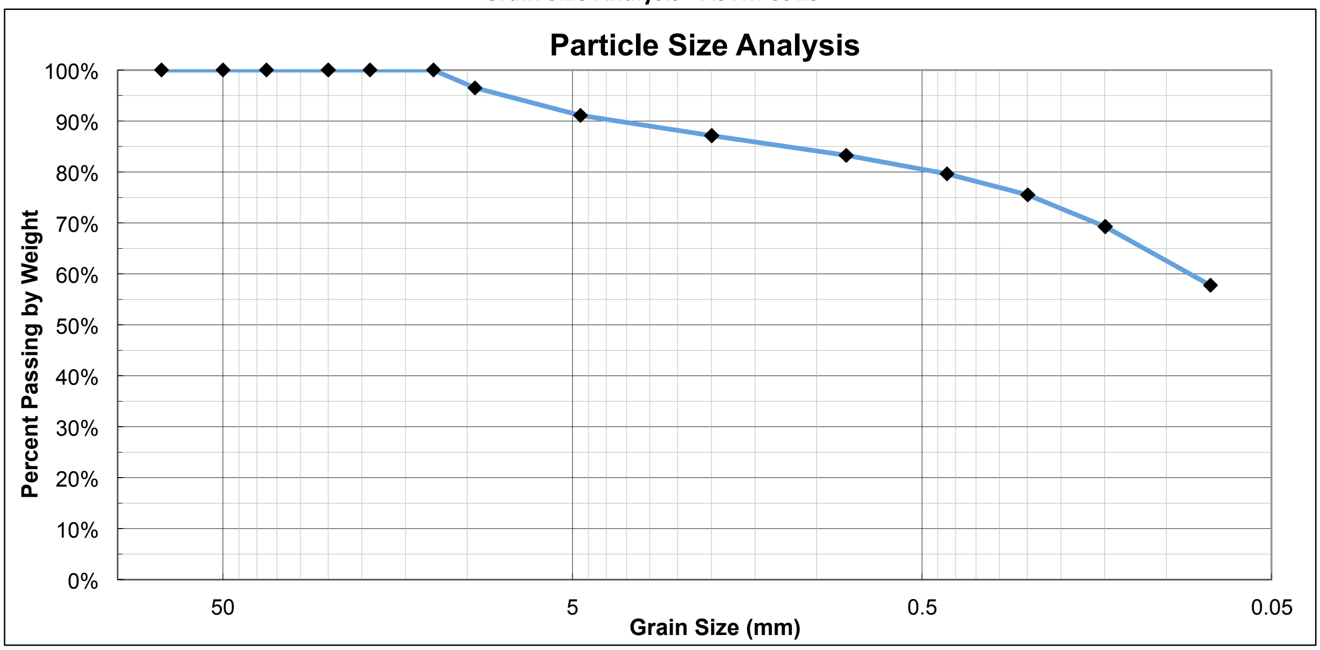
% Cobble	% Gravel		% Sand			% Fines
	Coarse	Fine	Coarse	Medium	Fine	Silt/Clay
	0	17	17	14	21	
0	**17**		**52**			**31**

		Sieve #	Opening mm	Cummulative Mass Retained	% Passing %
Cobbles		**3"**	75	0.00	100%
Gravel	Coarse	**2"**	50	0.00	100%
		1-1/2"	37.5	0.00	100%
		1"	25.0	0.00	100%
		3/4"	19.0	0.00	100%
	Fine	**1/2"**	12.5	0.00	100%
		3/8"	9.50	5.10	97%
		#4	4.75	34.70	83%
Sand	Coarse	**#10**	2.00	67.80	66%
	Medium	**#20**	0.825	86.10	57%
		#40	0.425	95.40	52%
	Fine	**#60**	0.250	103.70	48%
		#100	0.150	114.60	43%
		#200	0.075	138.30	31%

Crawford & Associates, Inc.
Geotechnical Engineering, Design and Construction Services

Project Name: HBMWD Pipeline Crossing
CAInc File No: 15-245.1
Date: 11/12/15
Technician: KKL
Sample ID: B2 (1/2)
Depth: 4-7'
USCS Classification: Sandy lean CLAY

Grain Size Analysis - ASTM 6913



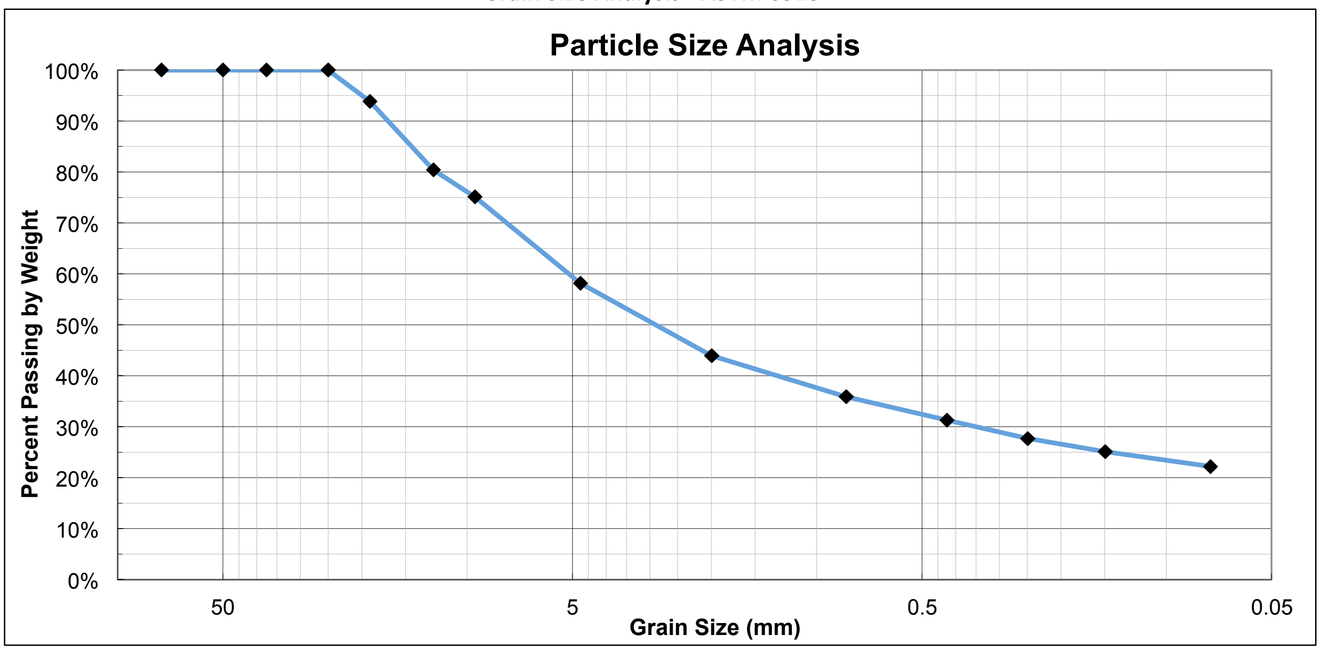
% Cobble	% Gravel		% Sand			% Fines
	Coarse	Fine	Coarse	Medium	Fine	Silt/Clay
	0	9	4	7	22	
0	**9**		**33**			**58**

		Sieve #	Opening mm	Cummulative Mass Retained	% Passing %
Cobbles		**3"**	75	0.00	100%
Gravel	Coarse	**2"**	50	0.00	100%
		1-1/2"	37.5	0.00	100%
		1"	25.0	0.00	100%
		3/4"	19.0	0.00	100%
	Fine	**1/2"**	12.5	0.00	100%
		3/8"	9.50	9.50	97%
		#4	4.75	24.20	91%
Sand	Coarse	**#10**	2.00	35.10	87%
	Medium	**#20**	0.825	45.60	83%
		#40	0.425	55.50	80%
	Fine	**#60**	0.250	66.80	76%
		#100	0.150	83.80	69%
		#200	0.075	115.20	58%

Crawford & Associates, Inc.
Geotechnical Engineering, Design and Construction Services

Project Name: HBMWD Pipeline Crossing
CAInc File No: 15-245.1
Date: 11/13/15
Technician: KKL
Sample ID: B2
Depth: 19.5-20'
USCS Classification: Clayey GRAVEL with SAND

Grain Size Analysis - ASTM 6913



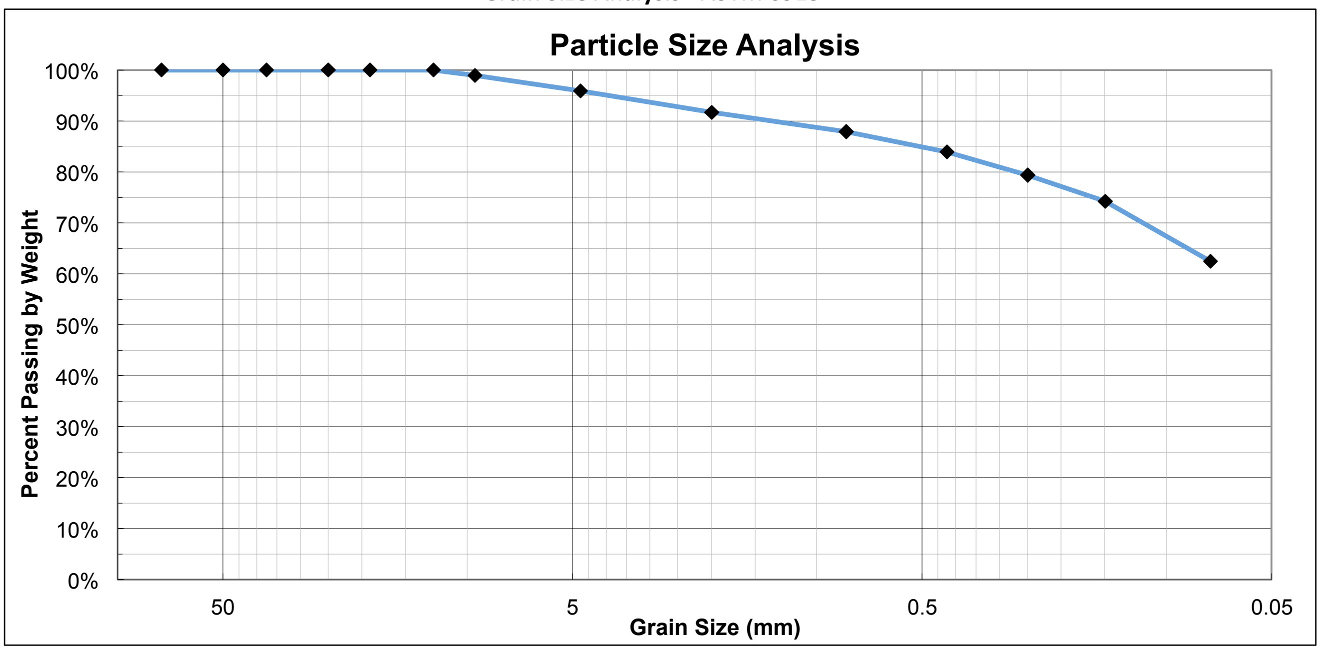
% Cobble	% Gravel		% Sand			% Fines
	Coarse	Fine	Coarse	Medium	Fine	Silt/Clay
	6	36	14	13	9	
0	**42**		**36**			**22**

		Sieve #	Opening mm	Cummulative Mass Retained	% Passing %
Cobbles		**3"**	75	0.00	100%
Gravel	Coarse	**2"**	50	0.00	100%
		1-1/2"	37.5	0.00	100%
		1"	25.0	0.00	100%
		3/4"	19.0	23.10	94%
	Fine	**1/2"**	12.5	73.70	80%
		3/8"	9.50	93.60	75%
		#4	4.75	157.30	58%
Sand	Coarse	**#10**	2.00	210.90	44%
	Medium	**#20**	0.825	241.10	36%
		#40	0.425	258.40	31%
	Fine	**#60**	0.250	271.80	28%
		#100	0.150	281.60	25%
		#200	0.075	292.60	22%

Crawford & Associates, Inc.
Geotechnical Engineering, Design and Construction Services

Project Name: HBMWD Pipeline Crossing
CAInc File No: 15-245.1
Date: 11/23/15
Technician: KKL
Sample ID: B3 (1/4)
Depth: 8-9'
USCS Classification: Sandy lean CLAY

Grain Size Analysis - ASTM 6913



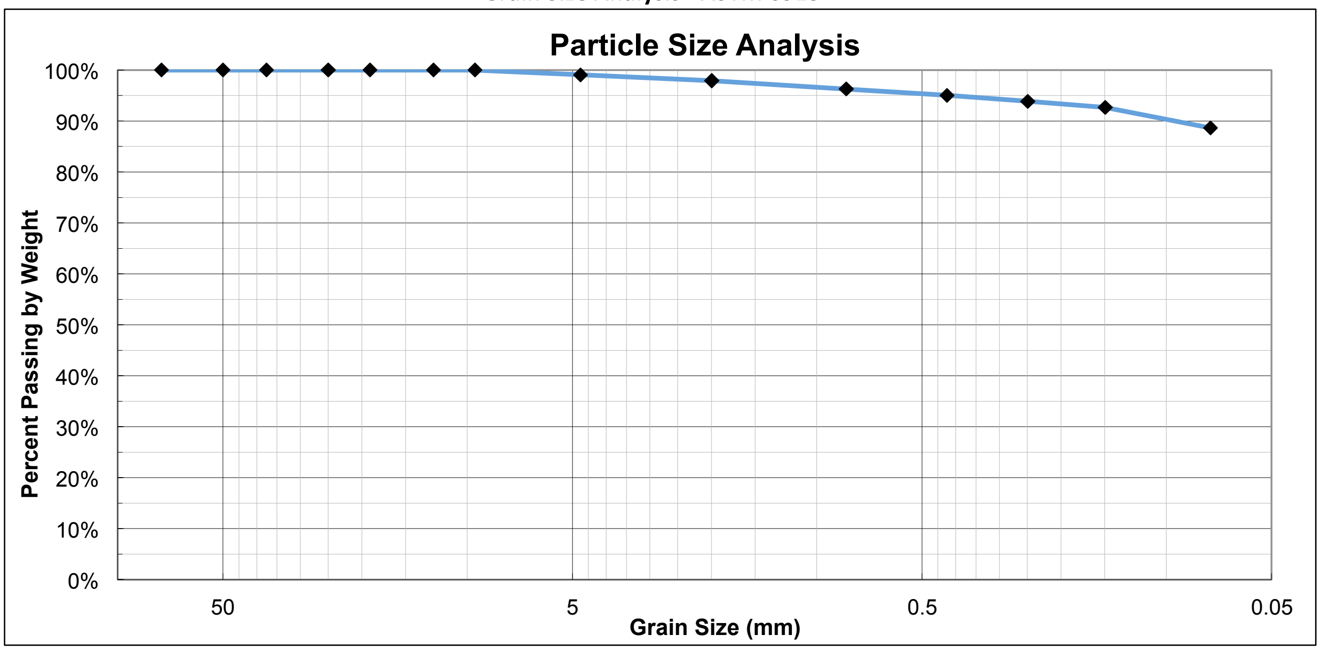
% Cobble	% Gravel		% Sand			% Fines
	Coarse	Fine	Coarse	Medium	Fine	Silt/Clay
	0	4	4	8	21	
0	**4**		**33**			**63**

		Sieve #	Opening mm	Cummulative Mass Retained	% Passing %
Cobbles		**3"**	75	0.00	100%
Gravel	Coarse	**2"**	50	0.00	100%
		1-1/2"	37.5	0.00	100%
		1"	25.0	0.00	100%
		3/4"	19.0	0.00	100%
	Fine	**1/2"**	12.5	0.00	100%
		3/8"	9.50	2.20	99%
		#4	4.75	8.50	96%
Sand	Coarse	**#10**	2.00	17.30	92%
	Medium	**#20**	0.825	25.30	88%
		#40	0.425	33.60	84%
	Fine	**#60**	0.250	43.10	79%
		#100	0.150	53.80	74%
		#200	0.075	78.40	63%

Crawford & Associates, Inc.
Geotechnical Engineering, Design and Construction Services

Project Name: HBMWD Pipeline Crossing
CAInc File No: 15-245.1
Date: 11/17/15
Technician: KKL
Sample ID: B3 (1/2)
Depth: 12-13'
USCS Classification: Lean CLAY

Grain Size Analysis - ASTM 6913



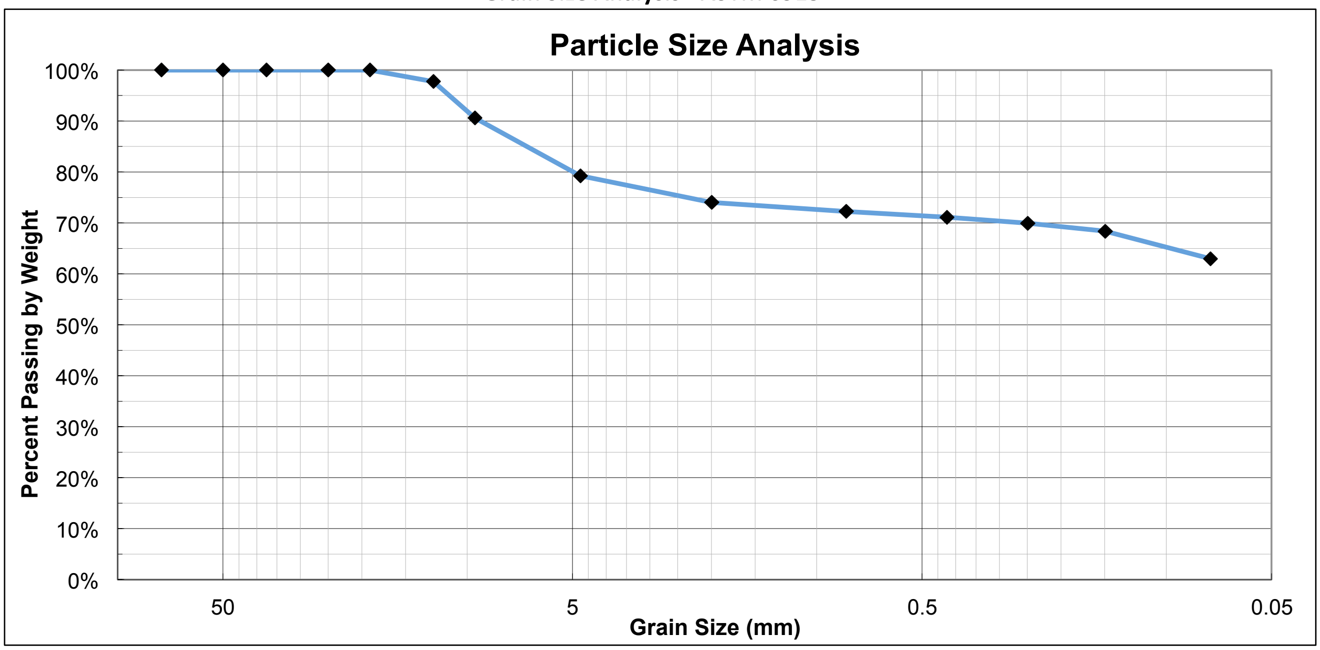
% Cobble	% Gravel		% Sand			% Fines
	Coarse	Fine	Coarse	Medium	Fine	Silt/Clay
	0	1	1	3	6	
0	**1**		**10**			**89**

		Sieve #	Opening mm	Cummulative Mass Retained	% Passing %
Cobbles		**3"**	75	0.00	100%
Gravel	Coarse	**2"**	50	0.00	100%
		1-1/2"	37.5	0.00	100%
		1"	25.0	0.00	100%
		3/4"	19.0	0.00	100%
	Fine	**1/2"**	12.5	0.00	100%
		3/8"	9.50	0.00	100%
		#4	4.75	1.80	99%
Sand	Coarse	**#10**	2.00	4.10	98%
	Medium	**#20**	0.825	7.30	96%
		#40	0.425	9.60	95%
	Fine	**#60**	0.250	11.90	94%
		#100	0.150	14.30	93%
		#200	0.075	22.10	89%

Crawford & Associates, Inc.
Geotechnical Engineering, Design and Construction Services

Project Name: HBMWD Pipeline Crossing
CAInc File No: 15-245.1
Date: 11/23/15
Technician: KKL
Sample ID: B3 (1/3)
Depth: 16-17'
USCS Classification: Gravelly lean CLAY with SAND

Grain Size Analysis - ASTM 6913



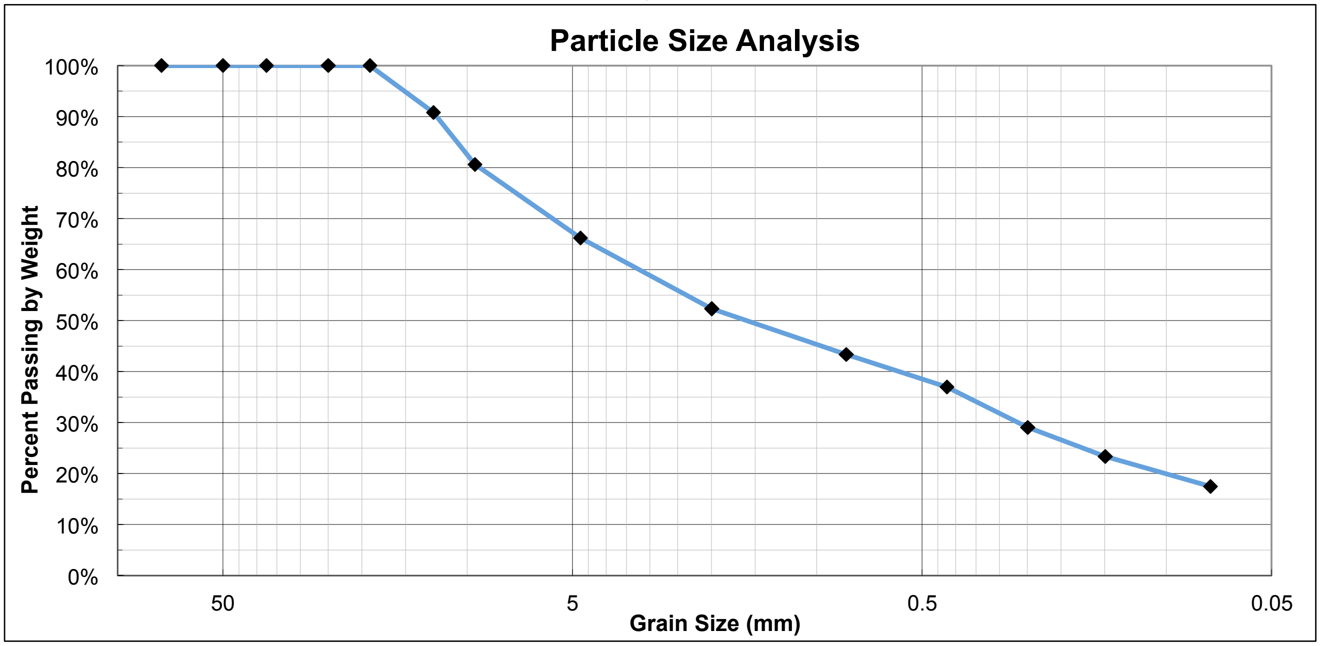
% Cobble	% Gravel		% Sand			% Fines
	Coarse	Fine	Coarse	Medium	Fine	Silt/Clay
	0	21	5	3	8	
0	21		16			63

		Sieve #	Opening mm	Cummulative Mass Retained	% Passing %
Cobbles		3"	75	0.00	100%
Gravel	Coarse	2"	50	0.00	100%
		1-1/2"	37.5	0.00	100%
		1"	25.0	0.00	100%
		3/4"	19.0	0.00	100%
	Fine	1/2"	12.5	6.80	98%
		3/8"	9.50	28.60	91%
		#4	4.75	63.00	79%
Sand	Coarse	#10	2.00	78.90	74%
	Medium	#20	0.825	84.30	72%
		#40	0.425	87.70	71%
	Fine	#60	0.250	91.30	70%
		#100	0.150	96.00	68%
		#200	0.075	112.40	63%

Crawford & Associates, Inc.
Geotechnical Engineering, Design and Construction Services

Project Name: HBMWD Pipeline Crossing
CAInc File No: 15-245.1
Date: 11/23/15
Technician: KKL
Sample ID: B4
Depth: 3-3.5'
USCS Classification: Clayey SAND with GRAVEL

Grain Size Analysis - ASTM 6913



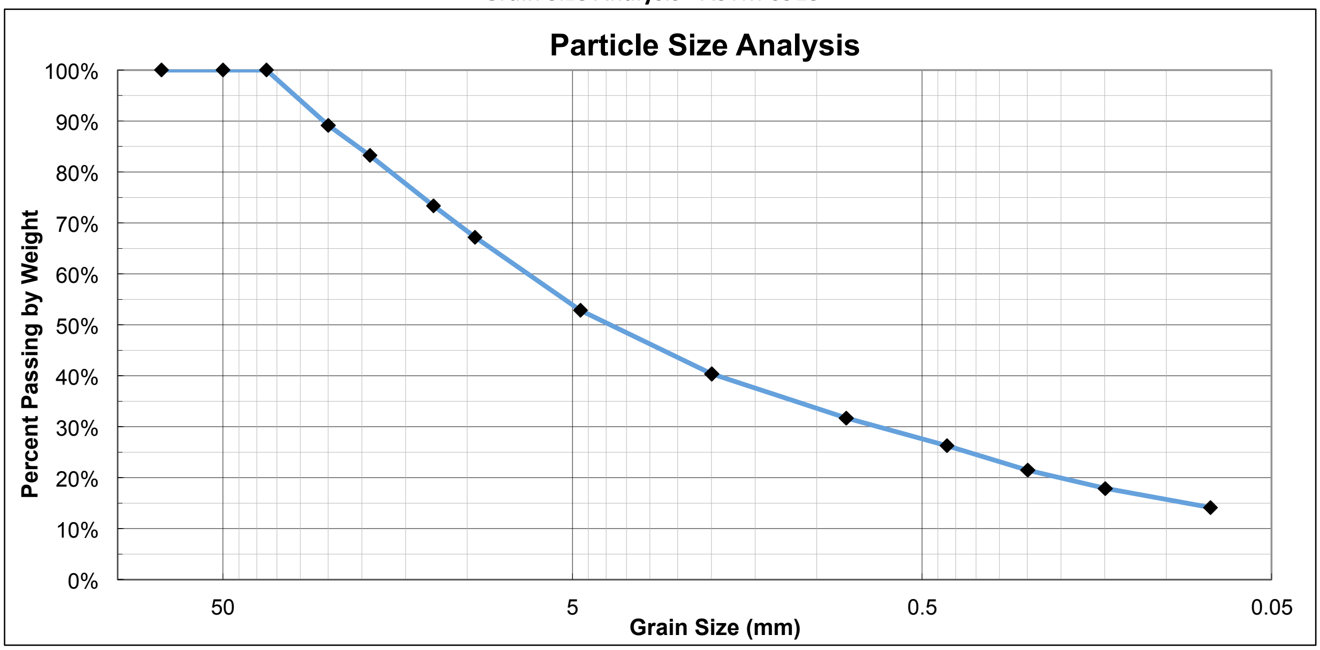
% Cobble	% Gravel		% Sand			% Fines
	Coarse	Fine	Coarse	Medium	Fine	Silt/Clay
	0	34	14	15	20	
0	**34**		**49**			**17**

		Sieve #	Opening mm	Cummulative Mass Retained	% Passing %
Cobbles		**3"**	75	0.00	100%
Gravel	Coarse	**2"**	50	0.00	100%
		1-1/2"	37.5	0.00	100%
		1"	25.0	0.00	100%
		3/4"	19.0	0.00	100%
	Fine	**1/2"**	12.5	14.00	91%
		3/8"	9.50	29.50	81%
		#4	4.75	51.50	66%
Sand	Coarse	**#10**	2.00	72.70	52%
	Medium	**#20**	0.825	86.40	43%
		#40	0.425	96.20	37%
	Fine	**#60**	0.250	108.20	29%
		#100	0.150	116.90	23%
		#200	0.075	125.90	17%

Crawford & Associates, Inc.
Geotechnical Engineering, Design and Construction Services

Project Name: HBMWD Pipeline Crossing
CAInc File No: 15-245.1
Date: 11/17/15
Technician: KKL
Sample ID: B4
Depth: 3.5-4'
USCS Classification: Clayey GRAVEL with SAND

Grain Size Analysis - ASTM 6913



% Cobble	% Gravel		% Sand			% Fines
	Coarse	Fine	Coarse	Medium	Fine	Silt/Clay
	17	30	13	14	12	
0	**47**		**39**			**14**

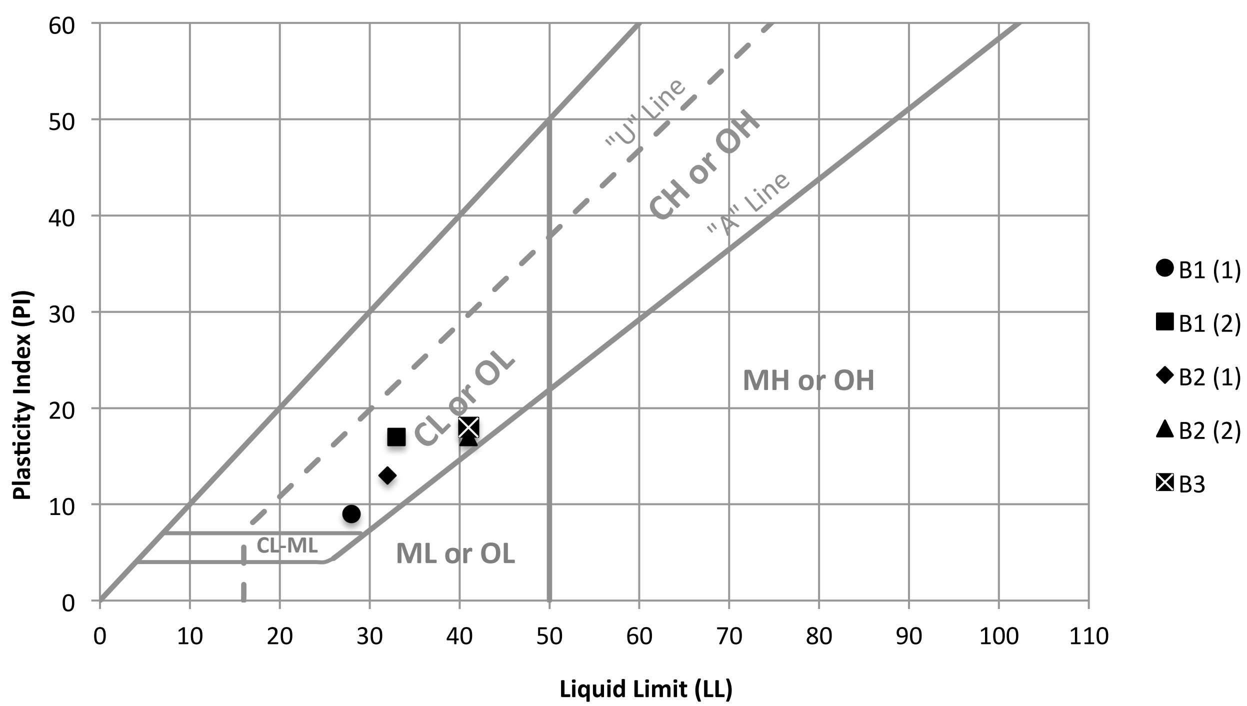
		Sieve #	Opening mm	Cummulative Mass Retained	% Passing %
Cobbles		**3"**	75	0.00	100%
Gravel	Coarse	**2"**	50	0.00	100%
		1-1/2"	37.5	0.00	100%
		1"	25.0	51.40	89%
		3/4"	19.0	79.60	83%
	Fine	**1/2"**	12.5	126.40	73%
		3/8"	9.50	155.50	67%
		#4	4.75	223.80	53%
Sand	Coarse	**#10**	2.00	282.90	40%
	Medium	**#20**	0.825	324.00	32%
		#40	0.425	349.90	26%
	Fine	**#60**	0.250	372.70	22%
		#100	0.150	389.60	18%
		#200	0.075	407.50	14%

Crawford & Associates, Inc.
Geotechnical Engineering, Design and Construction Services

Project Name: HBMWD Pipeline Crossing
CAInc File No: 15-245.1
Date: 11/17/15
Technician: KKL

Plastic Index - ASTM D4318

Sample ID	Depth (ft)	Plastic Limit	Liquid Limit	PI
B1 (1)	3.5-4	19	28	9
B1 (2)	9-9.5	16	33	17
B2 (1)	8.5-9	19	32	13
B2 (2)	19.5-20	24	41	17
B3	8-9.0	23	41	18



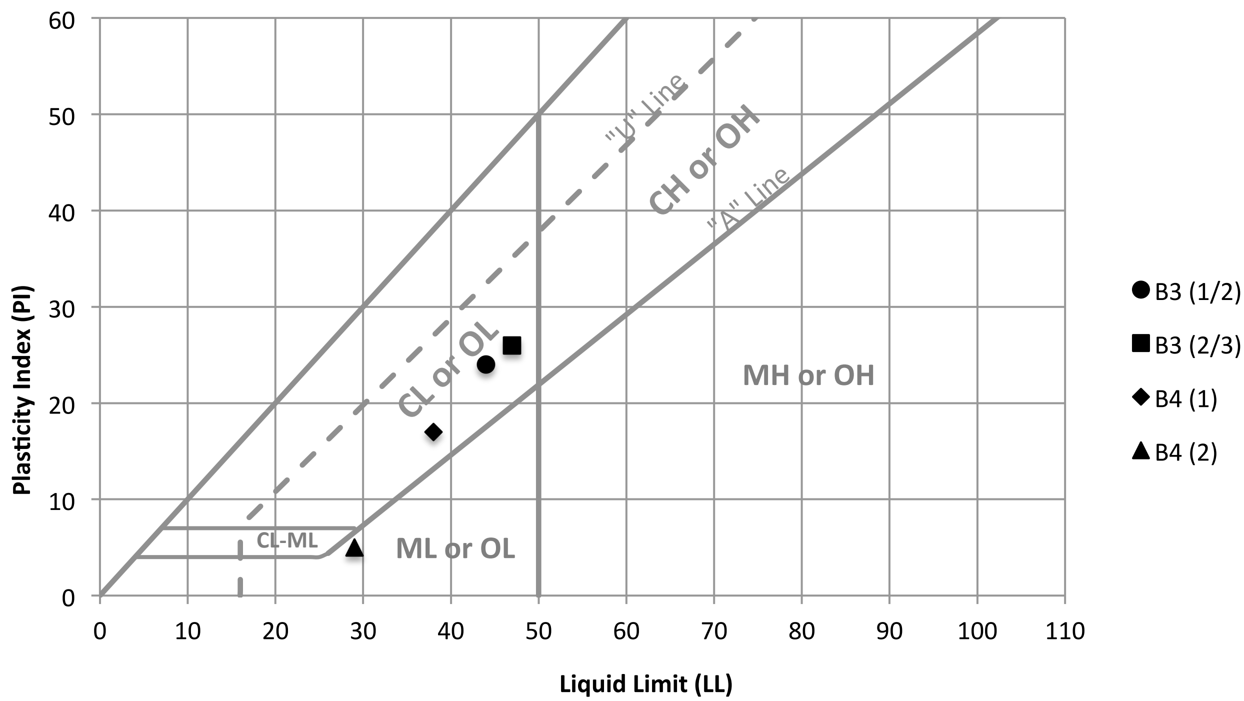
Plasticity Chart

Crawford & Associates, Inc.
Geotechnical Engineering, Design and Construction Services

Project Name: HBMWD Pipeline Crossing
CAInc File No: 15-245.1
Date: 11/17/15
Technician: KKL

Plastic Index - ASTM D4318

Sample ID	Depth (ft)	Plastic Limit	Liquid Limit	PI
B3 (1/2)	12-13.0	20	44	24
B3 (2/3)	16-17.0	21	47	26
B4 (1)	3-3.5	21	38	17
B4 (2)	4-4.5	24	29	5



Plasticity Chart

Sunland Analytical
11419 Sunrise Gold Cir.#10
Rancho Cordova, CA 95742
(916) 852-8557

Date Reported 11/11/15
Date Submitted 11/04/15

To: Nate Majerus
Crawford & Associates, Inc.
4030 S.Land Park Dr. Ste C
Sacramento, CA, 95822

From: Gene Oliphant, Ph.D. \ Randy Horney
General Manager \ Lab Manager

The reported analysis was requested for the following:
Location : PROJECT-15-245.1 Site ID: B1 AT 5-6FT 2/2
Thank you for your business.

* For future reference to this analysis please use SUN # 70795 - 147731

EVALUATION FOR SOIL CORROSION

Soil pH	5.40		
Minimum Resistivity	9.11	ohm-cm (x1000)	
Chloride	14.2 ppm	0.0014	%
Sulfate-S	21.1 ppm	0.0021	%

METHODS:
pH and Min.Resistivity CA DOT Test #643 Mod.(Sm.Cell)
Sulfate CA DOT Test #417, Chloride CA DOT Test #422

Sunland Analytical
11419 Sunrise Gold Cir.#10
Rancho Cordova, CA 95742
(916) 852-8557

Date Reported 11/11/15
Date Submitted 11/04/15

To: Nate Majerus
Crawford & Associates, Inc.
4030 S.Land Park Dr. Ste C
Sacramento, CA, 95822

From: Gene Oliphant, Ph.D. \ Randy Horney
General Manager \ Lab Manager

The reported analysis was requested for the following:
Location : PROJECT-15-245.1 Site ID: B1 AT 8.5-9FT
Thank you for your business.

* For future reference to this analysis please use SUN # 70795 - 147732

EVALUATION FOR SOIL CORROSION

Soil pH	7.40			
Minimum Resistivity	2.14	ohm-cm (x1000)		
Chloride	7.9	ppm	0.0008	%
Sulfate-S	4.3	ppm	0.0004	%

METHODS:
pH and Min.Resistivity CA DOT Test #643 Mod.(Sm.Cell)
Sulfate CA DOT Test #417, Chloride CA DOT Test #422

Sunland Analytical
11419 Sunrise Gold Cir.#10
Rancho Cordova, CA 95742
(916) 852-8557

Date Reported 11/11/15
Date Submitted 11/04/15

To: Nate Majerus
Crawford & Associates, Inc.
4030 S.Land Park Dr. Ste C
Sacramento, CA, 95822

From: Gene Oliphant, Ph.D. \ Randy Horney
General Manager \ Lab Manager

The reported analysis was requested for the following:
Location : PROJECT-15-245.1 Site ID: B2 AT 4-7FT
Thank you for your business.

* For future reference to this analysis please use SUN # 70795 - 147733

EVALUATION FOR SOIL CORROSION

Soil pH	5.22			
Minimum Resistivity	7.77		ohm-cm (x1000)	
Chloride	15.5	ppm	0.0016	%
Sulfate-S	4.4	ppm	0.0004	%

METHODS:
pH and Min.Resistivity CA DOT Test #643 Mod.(Sm.Cell)
Sulfate CA DOT Test #417, Chloride CA DOT Test #422

Sunland Analytical
11419 Sunrise Gold Cir.#10
Rancho Cordova, CA 95742
(916) 852-8557

Date Reported 11/11/15
Date Submitted 11/04/15

To: Nate Majerus
Crawford & Associates, Inc.
4030 S.Land Park Dr. Ste C
Sacramento, CA, 95822

From: Gene Oliphant, Ph.D. \ Randy Horney
General Manager \ Lab Manager

The reported analysis was requested for the following:
Location : PROJECT-15-245.1 Site ID: B2 AT 16-16.5FT
Thank you for your business.

* For future reference to this analysis please use SUN # 70795 - 147734

EVALUATION FOR SOIL CORROSION

Soil pH	5.49	
Minimum Resistivity	6.70	ohm-cm (x1000)
Chloride	9.1 ppm	0.0009 %
Sulfate-S	36.1 ppm	0.0036 %

METHODS:
pH and Min.Resistivity CA DOT Test #643 Mod.(Sm.Cell)
Sulfate CA DOT Test #417, Chloride CA DOT Test #422

Sunland Analytical
11419 Sunrise Gold Cir.#10
Rancho Cordova, CA 95742
(916) 852-8557

Date Reported 11/11/15
Date Submitted 11/04/15

To: Nate Majerus
Crawford & Associates, Inc.
4030 S.Land Park Dr. Ste C
Sacramento, CA, 95822

From: Gene Oliphant, Ph.D. \ Randy Horney
General Manager \ Lab Manager

The reported analysis was requested for the following:
Location : PROJECT-15-245.1 Site ID: B3 AT 8-9FT
Thank you for your business.

* For future reference to this analysis please use SUN # 70795 - 147735

EVALUATION FOR SOIL CORROSION

Soil pH	5.05	
Minimum Resistivity	12.33	ohm-cm (x1000)
Chloride	16.0 ppm	0.0016 %
Sulfate-S	7.2 ppm	0.0007 %

METHODS:
pH and Min.Resistivity CA DOT Test #643 Mod.(Sm.Cell)
Sulfate CA DOT Test #417, Chloride CA DOT Test #422

Sunland Analytical
11419 Sunrise Gold Cir.#10
Rancho Cordova, CA 95742
(916) 852-8557

Date Reported 11/11/15
Date Submitted 11/04/15

To: Nate Majerus
Crawford & Associates, Inc.
4030 S.Land Park Dr. Ste C
Sacramento, CA, 95822

From: Gene Oliphant, Ph.D. \ Randy Horney
General Manager \ Lab Manager

The reported analysis was requested for the following:
Location : PROJECT-15-245.1 Site ID: B3 AT 12-13FT
Thank you for your business.

* For future reference to this analysis please use SUN # 70795 - 147736

EVALUATION FOR SOIL CORROSION

Soil pH	5.05			
Minimum Resistivity	5.90	ohm-cm (x1000)		
Chloride	12.8	ppm	0.0013	%
Sulfate-S	4.8	ppm	0.0005	%

METHODS:
pH and Min.Resistivity CA DOT Test #643 Mod.(Sm.Cell)
Sulfate CA DOT Test #417, Chloride CA DOT Test #422

Sunland Analytical
11419 Sunrise Gold Cir.#10
Rancho Cordova, CA 95742
(916) 852-8557

Date Reported 11/11/15
Date Submitted 11/04/15

To: Nate Majerus
Crawford & Associates, Inc.
4030 S.Land Park Dr. Ste C
Sacramento, CA, 95822

From: Gene Oliphant, Ph.D. \ Randy Horney
General Manager \ Lab Manager

The reported analysis was requested for the following:
Location : PROJECT-15-245.1 Site ID: B3 AT 16-17FT
Thank you for your business.

* For future reference to this analysis please use SUN # 70795 - 147737

EVALUATION FOR SOIL CORROSION

Soil pH	5.33			
Minimum Resistivity	4.96	ohm-cm (x1000)		
Chloride	24.8	ppm	0.0025	%
Sulfate-S	8.7	ppm	0.0009	%

METHODS:
pH and Min.Resistivity CA DOT Test #643 Mod.(Sm.Cell)
Sulfate CA DOT Test #417, Chloride CA DOT Test #422

Sunland Analytical
11419 Sunrise Gold Cir.#10
Rancho Cordova, CA 95742
(916) 852-8557

Date Reported 11/11/15
Date Submitted 11/04/15

To: Nate Majerus
Crawford & Associates, Inc.
4030 S.Land Park Dr. Ste C
Sacramento, CA, 95822

From: Gene Oliphant, Ph.D. \ Randy Horney
General Manager \ Lab Manager

The reported analysis was requested for the following:
Location : PROJECT-15-245.1 Site ID: B4 AT 8-9.5FT
Thank you for your business.

* For future reference to this analysis please use SUN # 70795 - 147738

EVALUATION FOR SOIL CORROSION

Soil pH	5.65	
Minimum Resistivity	2.95	ohm-cm (x1000)
Chloride	19.2 ppm	0.0019 %
Sulfate-S	54.8 ppm	0.0055 %

METHODS:
pH and Min.Resistivity CA DOT Test #643 Mod.(Sm.Cell)
Sulfate CA DOT Test #417, Chloride CA DOT Test #422

James Roscoe, M.A.
Roscoe and Associates
Cultural Resources Consultants
3781 Brookwood Drive
Bayside, CA 95524

Date: October 26, 2015

Pat Kaspari
Project Manager, GHD
718 3rd Street
Eureka, CA 95501

RE: Archaeological Monitoring during geotechnical testing within the Mad River Pipeline Area of Potential Effect, California.

Dear Mr. Kaspari,

On October 20 and 21, 2015, James Roscoe of Roscoe and Associates (RA), conducted archaeological monitoring during geotechnical testing within the boundaries of CA-HUM 931, a Wiyot habitation site located within a portion of the Area of Potential Effect for the proposed Mad River Pipeline Crossing Project. This monitoring was conducted in consultation with Thomas Torma, Tribal Historic Preservation Officer (THPO) for the Wiyot Tribe, Janet Eidsness, THPO, for the Blue Lake Rancheria, and Erika Cooper, THPO, for the Bear River Band of the Rohnerville Rancheria.

The geotechnical drill holes were to be drilled within the grade of the abandoned Annie and Mary Railroad which runs through the boundaries of CA-HUM-931. Previous test excavations by RA had determined that the railroad grade had been cut through the archaeological deposit associated with CA-HUM-931 into the sterile clay subsoil below.

Archaeological monitoring was recommended by RA and the three Wiyot area tribes so that any buried cultural materials that might be unearthed during the geotechnical testing would be quickly identified and the appropriate actions taken to ensure protection of significant cultural artifacts or features. Pat Kaspari, Project Manager for GHD, coordinated the geotechnical work and archaeological monitoring with Crawford and Associates-Geological Consultants, Geo Ex. - drill rig contractors, Roscoe and Associates, and the Wiyot Tribe, Blue Lake Rancheria, and the Bear River Band of the Rohnerville Rancheria in a timely and professional manner.

On October 20 and 21, 2015, the rubber tracked drill rig was walked over a route previously brushed out to the railroad grade (Photo1). Two bore holes were excavated and 2.5 inch wide auger samples were brought up (Photo 2). Soil samples were collected and notes for soil logs were taken by Nate Majerus, Senior Geologist for Crawford and Associates. The boring core samples were examined for the presence of buried archaeological materials with negative results (Photo 3).

Test Hole 1 was drilled approximately 20 feet from the end of the Mad River Railroad Bridge and Test Hole 2 was drilled approximately 30 feet to the west of Test Hole 1, also within the railroad grade. Test Hole 1was excavated to a depth of 35 feet before ending at solid native bedrock. The top 8 inches was imported fill and ballast turning into reddish orange clay subsoil of medium plasticity. Test Hole 2 was excavated through approximately 10 inches of imported fill and ballast which was layered on top of a reddish orange clay subsoil of medium plasticity which ended at native bedrock at a depth of 15.5 feet. The drill rig was entered and exited across a portion of CA-HUM-931 to the location of drill holes 1 and 2 using sheets of plywood to protect the archaeological deposit from possible impacts caused by the passage of the tracked drill rig (Photo 4).

No significant, buried cultural resources were observed within the borings or during the passage of the drill rig.

Sincerely,

James Roscoe

James Roscoe, M.A.

Photo 1. Cleared path allowing access over a portion CA-HUM-931.

Photo 2. Coring at Test Hole 1.

Photo 3. Core sample from Test Hole 1.

Photo 4. Walking drill rig on top of protective layer of plywood.

Appendix E – Trenchless Feasibility Report (Bennett Trenchless Engineers, 2016)

TECHNICAL MEMORANDUM

BENNETT trenchless engineers

950 Glenn Drive, Suite 115
Folsom, CA 95630
Ph 916.294.0095

Date: February 1, 2016

To: Patrick Kaspari, PE
Senior Project Manager

Prepared By: Matthew Wallin, PE
Kate Wallin

REGISTERED PROFESSIONAL ENGINEER MATTHEW SCOTT WALLIN No. C 65002 Exp. 6-30-17 CIVIL STATE OF CALIFORNIA

HUMBOLDT BAY MUNICIPAL WATER DISTRICT

BLFG CSD Water Transmission Pipeline Replacement – Mad River Crossing

TRENCHLESS FEASIBILITY REPORT

1. Description of Project and Scope of Work

Humboldt Bay Municipal Water District's (HBMWD; District) Blue Lake and Fieldbrook–Glendale (BLFG) Community Services District (CSD) Water Transmission Main Replacement Project consists of the abandonment and replacement of the District's existing 14-inch water main crossing of the Mad River. This pipeline provides the main water supply to the Blue Lake, Fieldbrook, and Glendale communities. The existing pipeline crosses above the river on a disused North Coast Railroad Authority (NCRA) bridge that is in deteriorating condition and is no longer maintained by NCRA. HBMWD is currently working with GHD in the early stages of the project to replace the vulnerable existing crossing. Two options are being investigated for constructing a new crossing: a new pipe bridge, or a new trenchless installation beneath the river. Bennett Trenchless Engineers (BTE) has been retained by GHD to as a subconsultant to evaluate the feasibility and planning-level construction cost for the trenchless crossing alternative.

This Trenchless Feasibility Report describes the trenchless construction feasibility issues considered for the BLFG CSD Water Main Replacement across the Mad River. A preferred trenchless construction method and alignment are recommended, based on evaluation of technical feasibility, relative construction risks, impacts to the surrounding areas and site features, and relative cost. Hydrofracture and pipe stress analyses were conducted for the recommended trenchless alternative to ensure the conceptual alignment presented is constructible.

2. Site Conditions

2.1. Surface Conditions

As shown in Figure 1, the existing pipeline crossing of the Mad River and the proposed replacement crossing are located approximately 3.6 miles northeast of Arcata, CA, just south of Highway 299 on the west edge of the community of Glendale.

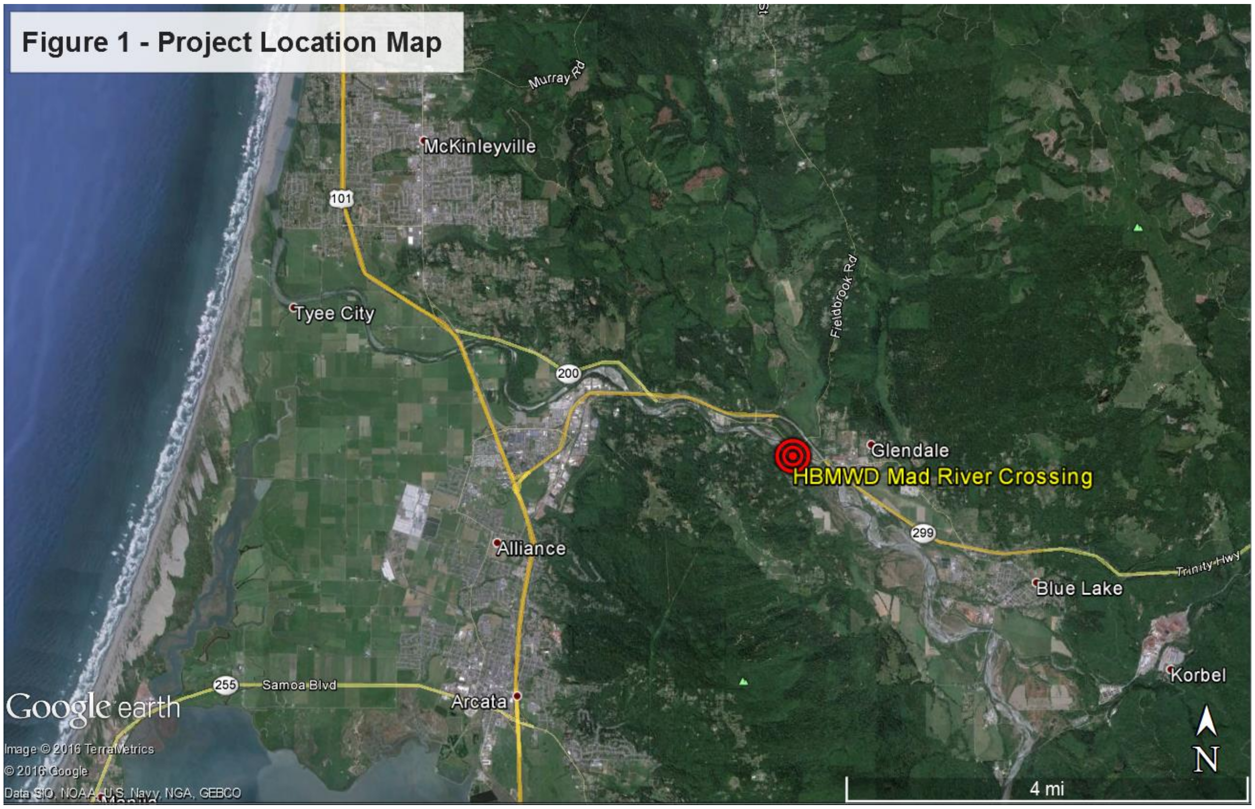


Figure 1 - Project Location Map

The existing waterline begins at HBMWD's pumping station located along West End Road in Arcata, and then flows east along West End Road before turning onto Warren Creek Road and continuing approximately 4,000 feet. As shown in Figure 2, the water line then turns east off the road, crosses a private residential parcel, and then crosses the Mad River attached to the existing NCRA bridge. After crossing the river, the pipeline follows the abandoned railroad grade adjacent to property owned by GR Sundberg, Inc. that is currently used as an equipment yard for their contracting business. Finally, the pipeline turns northeast and connects to distribution lines running in both directions along Glendale Drive, approximately 450 feet southeast of the intersection with Fieldbrook Road in McKinleyville.

The site topography at the river crossing consists of relatively flat terraces on both sides with a deep channel and steep banks. The elevation on both sides of the river is approximately 85 to 90 feet, with the majority of the river bed at elevation 35. The deepest elevation of the main channel at the crossing location is approximately elevation 29 to 30.

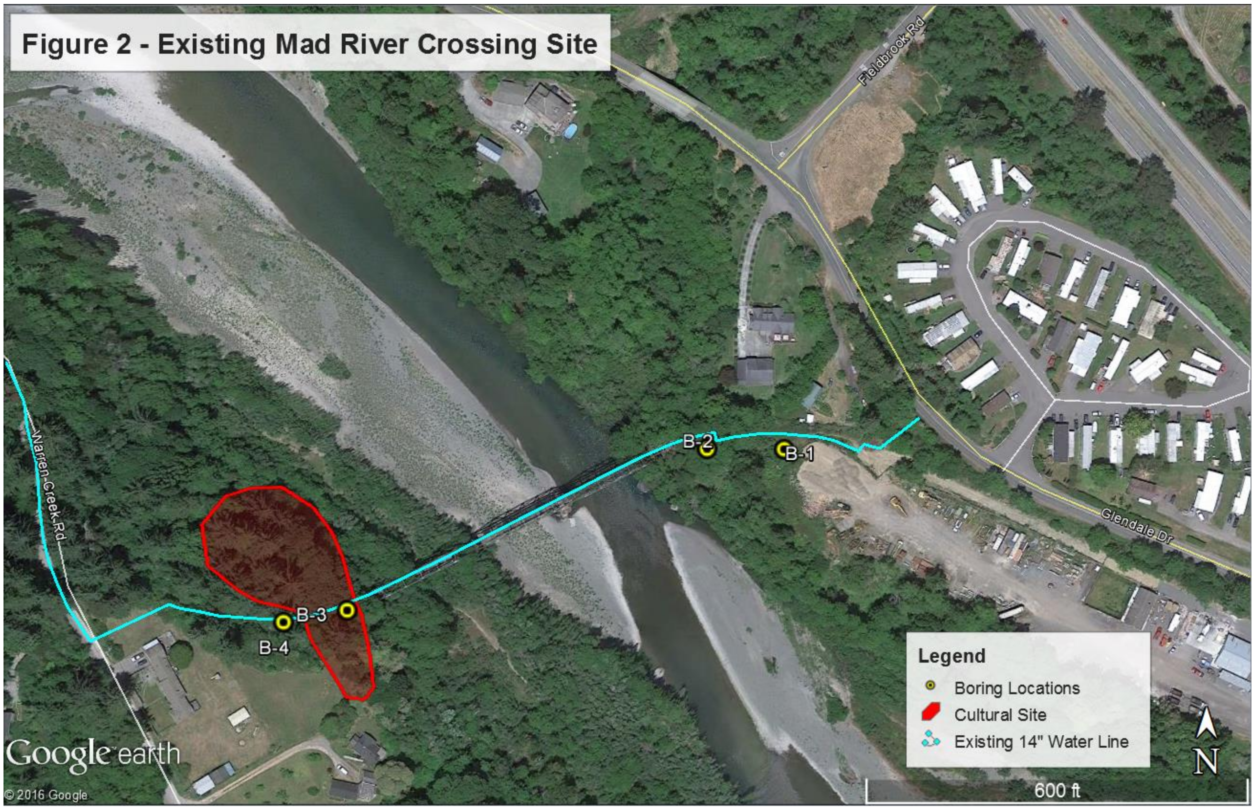


Figure 2 - Existing Mad River Crossing Site

The northeastern side of the proposed crossing is located at the far western end of GR Sundberg's large equipment yard. The site has been recently graded flat, is free of vegetation, and currently does not have any equipment stored nearby. However, the reason for the recent grading is unknown and GR Sundberg may have plans to develop the area in some way. The area between the equipment yard and the north end of the NCRA bridge has some undergrowth and small trees. Additionally, there are telecom and electrical lines that cross the river on the NCRA bridge and then run overhead along the western boundary of the Sundberg equipment yard.

The southwestern side of the proposed crossing is located approximately 500 feet north of the intersection of Warren Creek Road and Burlwood Lane in a wooded area. The southern and western sides of the project site are bounded by two private residential parcels. As the pipeline comes off of the NCRA bridge, it follows the abandoned railroad grade which is currently overgrown with low vegetation and small trees. The surrounding area to the east and north is fully forested with mature trees and undergrowth. The telecom line that crosses the NCRA bridge continues underground to the west from the end of the bridge to Warren Creek Road.

During the initial investigation stages of the project, a large cultural site was discovered along the west bank of the river. The approximate limits of the site are shown in red in Figure 2. It is important that the replacement project limit disruption to the near surface soil within the cultural site limits.

2.2. Subsurface Conditions

The geotechnical investigation for the Mad River crossing was performed by Crawford & Associates, Inc. (CAInc). Four geotechnical borings were completed along the proposed crossing alignment, two on each bank of the river. Boring logs and the results of laboratory testing have been provided by CAInc for the preparation of this trenchless feasibility analysis. The locations of the borings are shown in Figure 2, as B-1 through B-4, from east to west.

Each of the four borings encountered similar soil and rock layers. In areas formerly occupied by the NCRA rail line, a few feet of fill materials consisting of clayey soil with significant gravel from the rail ballast were encountered at the surface. Below the fill, the borings encountered 2 to 12 feet of terrace alluvium deposits consisting of stiff to very stiff clay, sandy clay, and dense clayey sand with varying amounts of gravel up to 30-40%. Beneath the terrace deposits, the borings encountered 3 to 6 feet of residual soil from advanced weathering of the bedrock below. The residual soil exhibited similar properties of stiff to very stiff clay, sandy clay, and dense clayey sand with varying gravel portions. Finally, each of the borings encountered 5 to 12 feet of weathered meta-argillite bedrock, followed by fresh bedrock to the maximum depths explored. The terrace alluvium was thickest in Borings B-2 and B-3, immediately adjacent to the river banks, while the remaining soil layers showed relatively consistent thickness, with the lithographic contacts sloping toward the river on each side. The contact with weathered bedrock also sloped toward the river on each side. Rock contact elevations were 75 and 77 feet in Borings B-1 and B-4, respectively, approximately 180 feet from each river bank. Rock contact elevations in Borings B-2 and B-3 were 64 and 61 feet, respectively, approximately 100 feet from each bank. A profile of the soil and rock layers encountered is included in the Preliminary Geotechnical Report prepared by CAInc, dated December 2015. It has not been included in this report as any trenchless crossing alternative will need to be constructed approximately 15 to 30 feet below the bottom of the river channel and will therefore be constructed almost entirely within the fresh bedrock.

Groundwater was not encountered in any of the borings. However, the deepest boring only reached elevation 48 feet. It is assumed that groundwater would be encountered near the surface water elevation of the river at approximately 35 feet.

3. Trenchless Construction Method

Trenchless construction methods such as auger boring (sometimes referred to as bore and jack), open-shield pipejacking, and pipe ramming are open-faced methods where the excavation face is not sealed against groundwater and unstable soil conditions. These methods are not suitable for construction in saturated conditions such as river crossings due to the risk of flooding within the tunnel. There are several trenchless construction methods suitable for installing a pipeline beneath a river including earth pressure balance (EPB) pipejacking, microtunneling, and horizontal directional drilling (HDD). Due to the anticipated solid rock conditions combined with the required length of the crossing (at least 700 feet) the use of microtunneling or earth pressure balance pipe jacking would be challenging due to the risk of tooling wear while excavating the rock. Additionally, the depth of a microtunneled or EPB pipejacking crossing (at least 60 feet below the terraces) would require very expensive shaft excavations preventing these methods from being cost competitive with HDD. Finally, microtunneling or EPB pipejacking equipment capable of tunneling in rock would be a minimum of 48 inches in diameter to allow for the proper tooling to be used at the excavation face. The water line would then be installed within the oversized steel casing pipe installed by the microtunnel or EPB equipment. This two-step installation process would further exacerbate the issues with cost competitiveness. These factors leave HDD as the sole feasible, practical, and cost efficient method for completing the Mad River trenchless crossing.

3.1. Horizontal Directional Drilling

Horizontal directional drilling (HDD) is a trenchless construction method whereby a pipe is installed along an arcing drill path, beginning and ending at the ground surface, and passing under the conflicting feature in between. As illustrated in Figure 3a, a drill rig is set up on one side of the crossing and commences drilling a pilot bore to the exit point. The alignment typically begins with an 8- to 16-degree declined tangent section that extends into a vertical curve with a radius typically between 500 and 5,000 feet, depending on pipe diameter, pipe material, and required geometry. After passing beneath the obstacle, the alignment will rise to the surface at a typical inclined angle of 5 to 16 degrees.

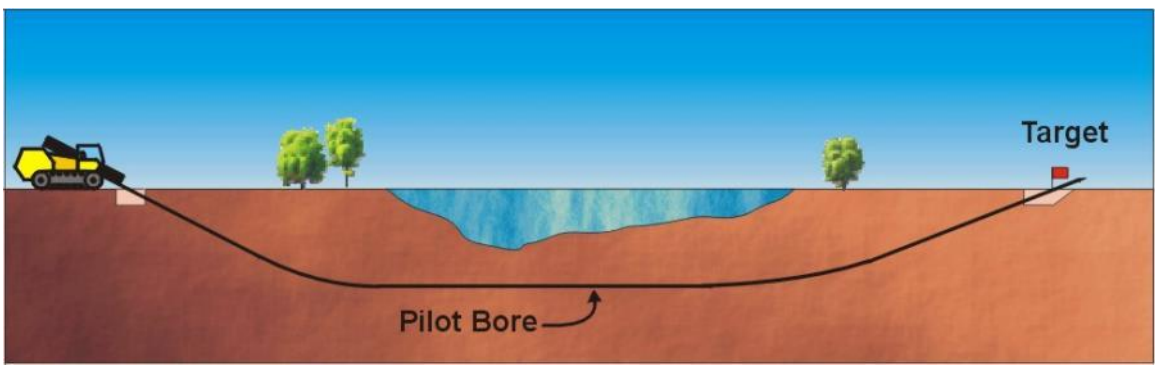


Figure 3a: Pilot Bore of HDD Operation

The pilot bore is then reamed in one or more passes to obtain the required diameter needed for pullback of the prefabricated pipe string. Once reaming is complete, the drill pipe is connected to the product pipe with a swivel and pulling head at the exit side of the alignment, and pulled into place, preferably in one continuous operation, as illustrated in Figure 3b.

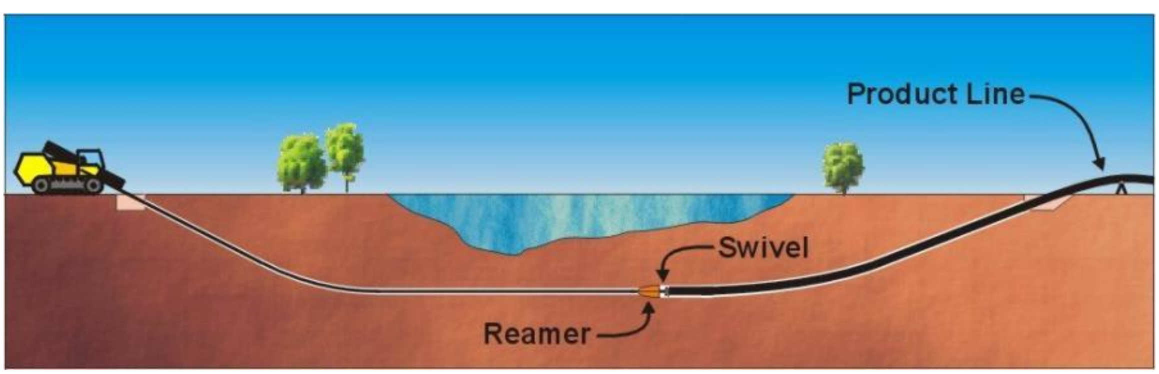


Figure 3b: Pullback of Product Pipe in HDD

During the pilot bore, steering is accomplished using an angled bit and rotating drill pipe. To advance the bore in a straight line, the bit is rotated and advanced simultaneously. To steer, the operator aligns the angled face of the bit in the desired direction and advances the drill stem without rotating. As the bit is advanced, ground resistance develops against the angled bit and deflects the bore in the desired direction.

Guidance of the system for a typical crossing of this length is accomplished by the use of a downhole wireline steering tool located in a non-magnetic drill pipe, immediately behind the bit. This tool measures the pitch, clock face position, and magnetic azimuth of the bit and sends the data back to the surface to the drill rig operator. The position of the bit is calculated after each successive drill pipe has been pushed using the pipe length, average pitch, and average azimuth angle reported for each reach. Accuracy of the basic downhole wireline system can be improved with the use of an energized surface coil such as the TruTracker or ParaTrack system. These systems create a magnetic field at the ground surface that can be detected and interpreted by the downhole tool to triangulate the position of the drill head. An 8- to 10-gauge copper wire coil must be laid on the surface around the bore path. The corners and any bends of the coil are then surveyed prior to drilling so that the induced magnetic field can be predicted. Achievable line and grade tolerances for a typical HDD installation in favorable ground conditions using a downhole steering tool and surface coil are on the order of plus or minus 1 to 10 feet over the length of the bore, assuming good practices.

HDD can be used in most soil conditions and solid rock, when the proper tooling is used. Additionally, it can be used to install pipelines below the water table. Large quantities (more than 15-30%) of cobbles and permeable gravel soils can cause problems with HDD installations due to loss of drilling fluid and collapse of the borehole. Individual larger boulders can obstruct progress. However, special design features such as conductor casing can be used to accomplish bores through these soils if the thickness of the problem soils is limited to less than approximately 30 vertical feet, near the surface.

HDD is capable of installing cables and pipes ranging from 2 inches to over 48 inches in diameter, and individual bores greater than 10,000 feet long have been completed. The equipment is typically categorized into three sizes: small, medium, and large rigs. The cost, staging area required, and construction duration increases as bore length, diameter, and rig size increase. Small HDD rigs are generally used for product pipes up to approximately 8 inches in diameter, or bundles of smaller 2- to 4-inch pipes. Medium size rigs can install single or bundles of pipes up to approximately 18 inches in diameter and large rigs are used for larger pipes up to approximately 60 inches, or for very long bores that have high torque and pullback forces. The average required staging area for each of the size classes is 1,500, 10,000, and up to 30,000 square feet, respectively.

The HDD process uses a bentonite-based drilling fluid to aid in excavation of the soil, to carry the cuttings from the bit back to the drill rig, to provide hydrostatic support to the otherwise unsupported borehole, and to cool and lubricate the drill pipe and tooling during drilling. For medium and large-sized installations, the returned drilling fluid is collected and sent through a solids separation plant consisting of a system of vibrating screens and hydrocyclones which remove the majority of the native soil from the slurry. The clean drilling fluid is then recycled and sent back down to the bit. While HDD operations are surface-launched and do not typically required any shored excavations, drilling fluid recovery pits are typically excavated at each end of the bore. These pits are typically approximately 3 to 6 feet wide, 6 to 12 feet long, and 2 to 4 feet deep.

Because of the large quantities of drilling fluid used, an important consideration for HDD projects is the risk of inadvertent fluid returns (often referred to as hydrofractures or frac-outs). Inadvertent fluid returns can occur when excess drilling fluid pressures cause fluid to escape the bore and surface through granular soils, cracks in cohesive soils, or along other natural or man-made conduits. While the drilling fluid is generally a non-toxic mixture of water and bentonite clay, drilling fluid spills are often viewed as an environmental risk. Therefore, it is important to design HDD projects to reduce the risks of inadvertent returns.

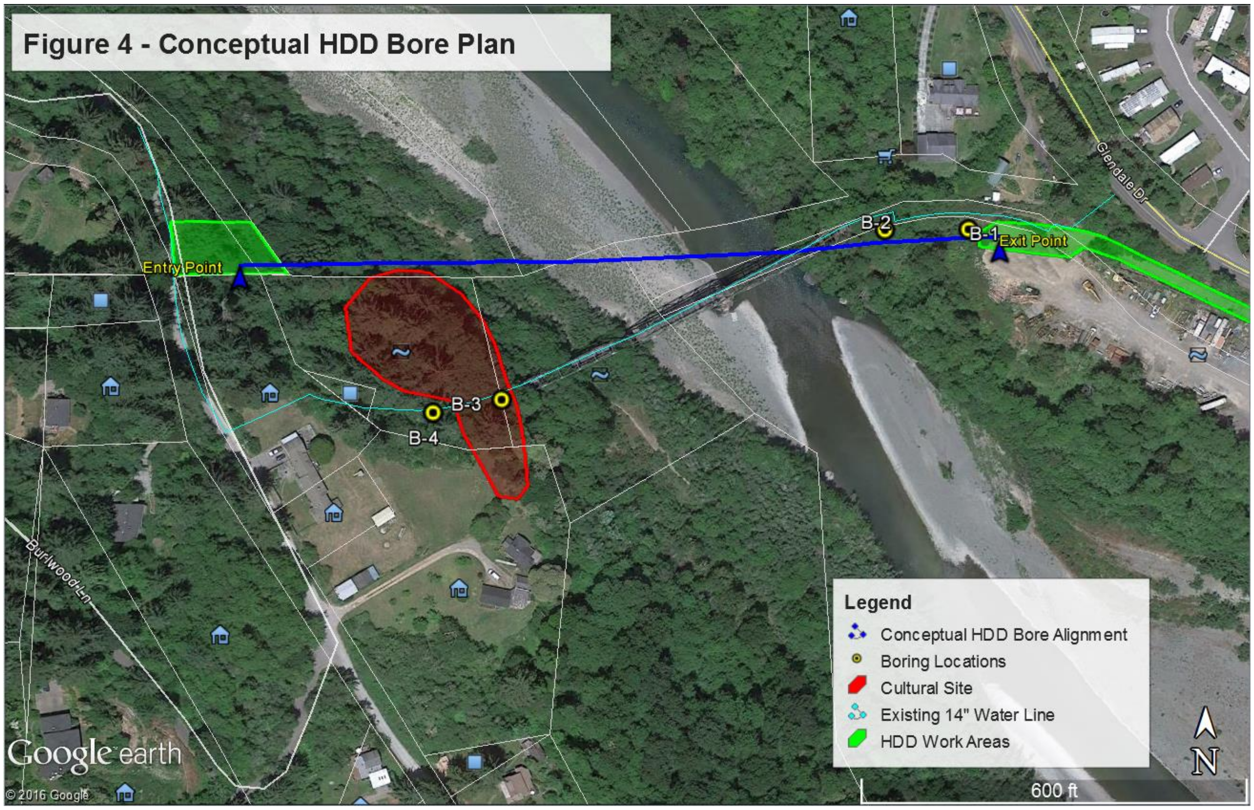
4. Alignment Description and Work Area Considerations

4.1. Bore Alignment Description

As described in the previous section, horizontal directional drilling is the most feasible and cost-effective trenchless construction method available for completing the Mad River crossing. Figures 4 and 5 illustrate our conceptual bore alignment and profile for the trenchless crossing alternative. The bore design was developed based on the capabilities and limitations of the HDD method, the required pipe diameter, mitigation of potential hydrofracture risks to the river channel, and the other site constraints. The conceptual bore alignment is 1,125 feet long, measured horizontally between the entry and exit points. It is 1,145 feet long measured along the curved vertical profile. The proposed entry point is located at Station 0+00, approximately 90 feet east of Warren Creek Road, 600 feet north of the intersection with Burlwood Lane. The bore will continue almost due east to the west end of the GR Sundberg equipment yard, crossing diagonally beneath the NCRA bridge near the east bank of the river. The conceptual bore has been designed to pass a minimum of 20 feet beneath the channel of the Mad River at all points along the profile. (It should be noted that the currently available site survey does not cover the western half of the proposed bore. We have done our best to extrapolate the available contour data to approximate the topography along the bore. If the HDD crossing alternative is advanced into design, the conceptual bore alignment may have to be modified to fit site specific data.) The entry and exit angles for the conceptual bore are both 16 degrees. Both vertical curves have a radius of 1,000 feet and the lowest elevation of the proposed bore alignment is 5 feet.

The west end point of the bore was chosen to keep the bore as short as possible, while still attaining adequate depth beneath the river. It was also chosen to allow for a short connection length to the existing water line, to keep the bore within HBMWD property, and to allow for construction access directly off of Warren Creek Road without affecting either of the nearby private properties. Finally, the bore was sited to avoid disruptions to the identified cultural site.

The east end point was similarly chosen to minimize the bore length, but maintain adequate depth. It was also chosen to allow for a short connection to the existing line, and to minimize disruption to the Sundberg's property.



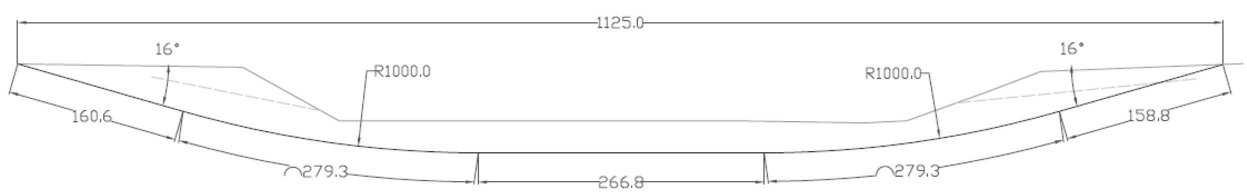


Figure 5 – Conceptual HDD Bore Profile

Typically, the depth of an HDD bore for a river crossing is chosen to mitigate the risk of hydrofracture (or inadvertent fluid returns) into the river channel during construction. Because this bore is anticipated to be constructed completely within the bedrock, risk of hydrofracture is anticipated to be low, unless significant open joints, fractures, or faulting is encountered. In this case, the depth of the bore was set at 20 feet below the channel bottom to reduce the risk of drilling fluid returns through existing pathways in the rock mass, and to avoid possible historic flow channels that have been infilled with alluvial sand, gravel, and cobbles. If an HDD solution is carried forward into design, further investigations will be necessary to investigate the rock profile within the river channel, likely using geophysical methods. The depth of the bore alignment could be increased to a minimum of 30 feet if necessary.

4.2. Staging Area Considerations

Due to the diameter, length, and ground conditions of the proposed HDD crossing, a medium HDD rig will likely be required. The typical required staging area for this size rig is approximately 10,000 square feet at the entry side of the bore. The work area is necessary to support not only the drill rig, but several pieces of ancillary equipment, including a backhoe or boom truck, drill pipe and bentonite storage, drilling fluid pumps, fluid storage tanks, a solids separation plant, tool trailers, and other support equipment for the drilling operations. The exact shape of the work area can be flexible for most of the equipment, and certain pieces, such as the separation plant, do not have to be located immediately adjacent to the entry point. However, the drill rig, backhoe or boom truck, and drill pipe storage must be located in an area approximately 30 feet wide by 75 feet long, aligned directly behind the entry point, that is completely clear. Additionally, the separation plant needs to have a clear area measuring approximately 30 feet wide and 40 feet long.

The required layout area for the exit side, or pipe side, of the bore is equal to the length of the pipe to be installed, by approximately 20 to 50 feet wide. Ideally, the pipe is completely assembled prior to pullback and installed without stopping to weld/fuse pipe. Interruptions during pullback increase the risk of bore collapse and/or the pipe becoming stuck within the bore. For this project, an intermediate pipe fuse/weld would not be extremely risky as the bore should be stable in the bedrock, reducing the risk of restrictions in the bore that may develop during a stoppage.

For the Mad River crossing, an HDD bore could be advanced in either direction. The Sundberg equipment yard on the east side provides substantial layout area for either the drill rig setup or pipe fabrication and layout. On the west side, undergrowth and some trees would have to be cleared to allow for either work area. If the entry point were located on the west side, a large, roughly rectangular work area would be needed measuring approximately 10,000 square feet. Approximately 3,500 square feet would need to be completely cleared for the drill rig, drill pipe storage and handling, and the separation plant. The remaining area could likely retain any mature trees, with the equipment stored below the canopy.

If the exit point were located on the west side, a long, narrow work area would have to be cleared to allow for pipe fabrication and layout prior to pullback. If the entire pipe were fabricated in one piece, the work area would measure approximately 20 feet wide by 1,200 feet long. An intermediate weld could reduce the required area to approximately 25 feet wide by 600 feet long. The majority of this work area would not have to be completely cleared, however one clear location measuring approximately 30 feet wide by 50 feet long would be necessary for setting up the fusion machine and pipe handling equipment.

While the details of the two options are different, the overall impacts to forested area west of the river appear to be similar. For the purposes of this feasibility analysis, we have recommended that the drill rig entry site be located on the west side. This recommendation is primarily based on a request by one of the private landowners that the project avoid creating a pathway for public access from Warren Creek Road to the river near his property. Clearing of a long, narrow work area for pipe layout may create the impression that a trail has been created for river access.

Figure 6 shows, in more detail, the proposed entry point work area on the west side of the river. The area is yellow shows the approximate limits of the area that would need to be completely cleared. The remaining area in green would only require undergrowth removal.

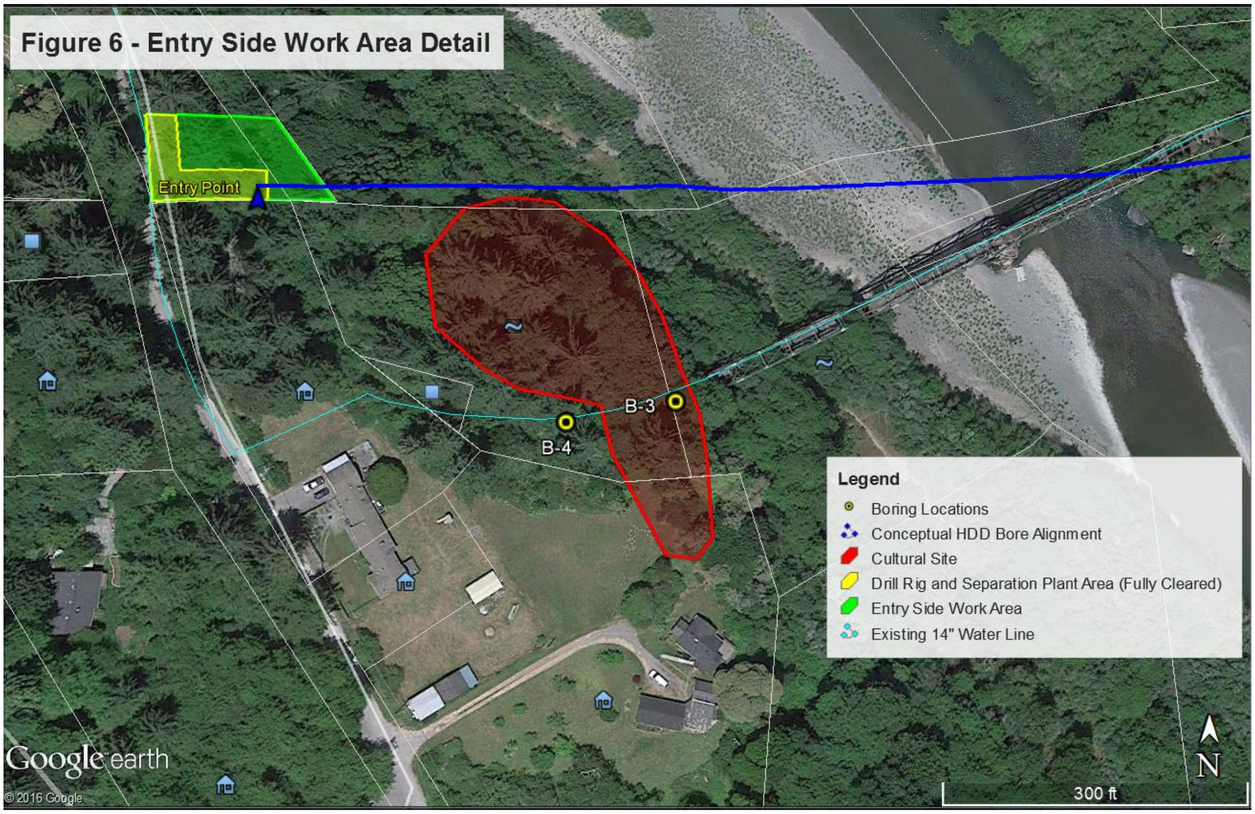
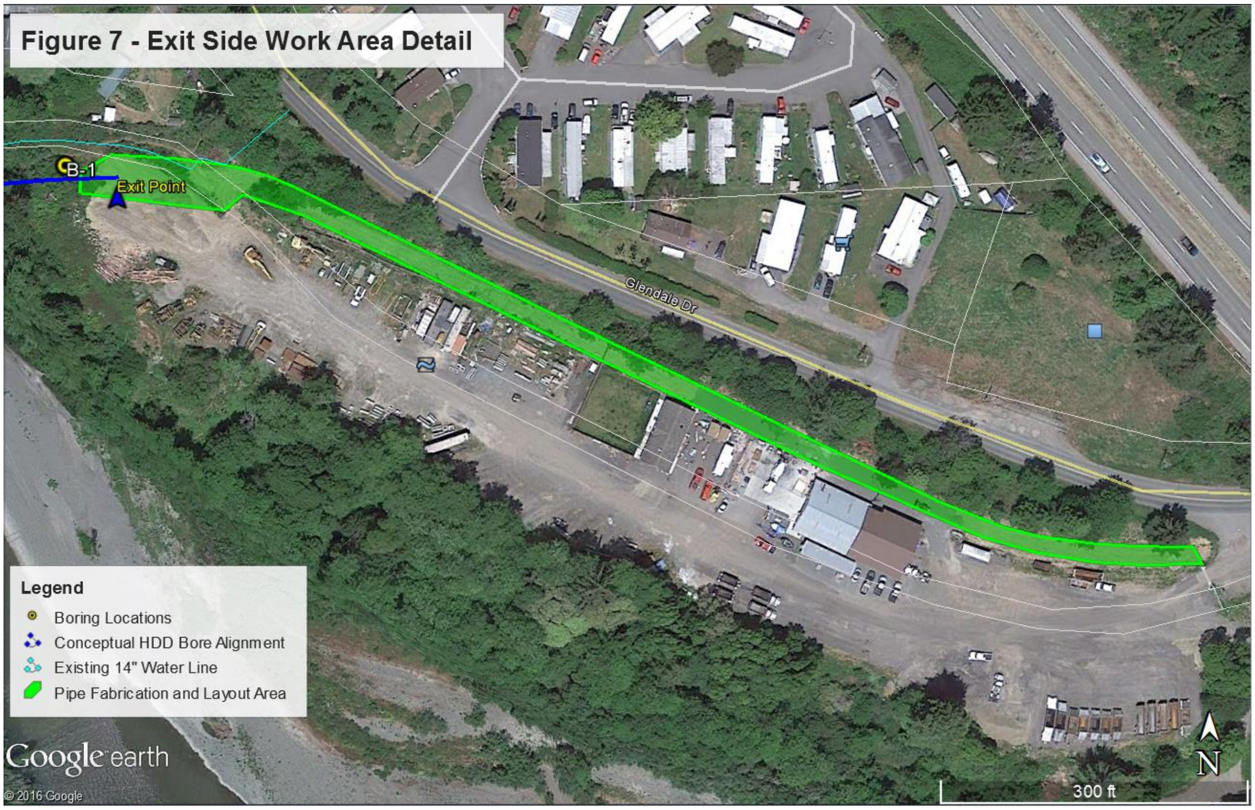


Figure 7 illustrates the proposed pipe fabrication and layout area on the east side of the river. The full length of pipe could be fabricated and laid out for pullback along an open, 20-foot wide corridor behind (north) the GR Sundberg equipment storage and workshop areas. This option is expected to minimize disruption to Sundberg's operations during the HDD construction. However, if this option is not favorable to Sundberg, there are two alternative possibilities. One option would be to string the pipe through Sundberg's main access drive, in front (south) of the buildings. The final option would be to continue routing the pipe east, through the row of trees along Glendale Drive, and then run the pipe along the south shoulder of the road, within the public right-of-way. This option may require closing a portion of the south edge of the road, but we believe that two-way traffic could be maintained on Glendale Drive with narrowed lanes.



5. Design Considerations

5.1. Pipe Material Considerations

The most common pipe materials used with HDD are steel, HDPE, fusible PVC (FPVC), and ductile iron (DI). Of these four, HDPE and steel are by far the most commonly used. Fusible PVC is a product that was developed relatively recently, but the material has been gaining recognition and popularity in the HDD market and many HDD projects have been successfully completed using FPVC.

Corrosion resistance is a concern for most projects. Unlined and uncoated steel and ductile iron pipe could be subject to corrosion both inside and out. In certain applications steel and DI pipe can be lined and coated with mortar, coal tar, or various epoxies to prevent corrosion. However, for small-diameter HDD installations, linings used with steel pipe cannot be patched after sections are welded together. For DI pipe used in water applications cement mortar is available as a lining alternative. Coatings used with either steel or DI may also be damaged during pullback due to abrasion from the rock in the bore walls. It is assumed that any coatings considered would have to be robust enough to survive pullback, be protected by another sacrificial coating, or be used in combination with an additional cathodic protection scheme. Due to the difficulties related to corrosion protection, steel is not considered practical for use as the carrier pipe for this project. DI may be may be a feasible option, but further analysis regarding corrosion risks would need to be performed. HDPE and FPVC are advantageous materials for many pipeline applications as they are inert to corrosion.

Another consideration for pipe material is outside diameter (OD). Steel, HDPE, and FPVC joints are connected using butt-welding methods that result in a uniform external diameter. The relative tensile strengths of the pipe materials dictate that for a nominal 14-inch diameter ID, the OD will be smallest for steel (~15 inches), slightly larger for FPVC (15.3 inches), and largest for HDPE (18 inches). Ductile iron pipe uses a raised bell and spigot joint system where the maximum diameter at the bell is approximately 4 inches larger (19.3-inch OD) than the main pipe barrel (15.3-inch OD). The larger pipe materials require the excavation of a larger bore diameter. This increases drilling time and thus bid cost, especially for a bore drilled in rock.

Based on the considerations presented above, HDPE and FPVC pipe are the most likely carrier pipe materials to be used for the Mad River crossing. If the HDD option is carried forward to design, a more thorough analysis of DI as a potential pipe material could be conducted. The analyses presented in the following sections address the use of HDPE or FPVC as the carrier pipe for the water line.

6. Pullback and Pipe Stress Analysis

To analyze the pipe material options and pipe wall stiffness requirements, we have conducted preliminary pullback and pipe stress analyses.

The pullback calculations have been performed based on a combination of the methods laid out in the Plastics Pipe Institute's Handbook of Polyethylene Pipe, and J.D. Hair and Associates' 1995 engineering design guide entitled "Installation of Pipelines by Horizontal Directional Drilling". These methods estimate the loads that the pipeline will experience as it is pulled into the bore and analyze the combined tensile and bending stresses, as well as buckling failure potential of the pipe resulting from these loads. The loads are estimated by calculating the expected frictional drag due to the friction between the pipe and the wall of the bore, the fluidic drag as the pipe is pulled through the drilling fluid in the bore, the effects of the weight of the pipe, and the additional force arising from capstan effect as the flexible pipe string is pulled through bends in the bore. The analysis of the fluidic drag component of these calculations is based on an approach described by Duyvestyn, 2009.

The pipe parameter values assumed for the calculations are shown in Table 1. The drilling fluid was assumed to have a mud weight of 11 lb. /gal, yield point of 25 lb. /100ft^2, and plastic viscosity of 100 centipoise.

We have assumed that the pipes will be empty as they enter the bore during installation. For plastic pipe it is desirable, and sometimes necessary, for the pipe to be full of water during pullback to reduce the buoyant uplift forces, thereby reducing the friction between the pipe and the borehole. The water is also helps to resist the external hydrostatic pressure from the drilling fluid which could lead to an unconstrained buckling failure of the pipe. We have run the analysis with the pipes empty to produce a conservative result. If the HDD option is carried forward to design, a more thorough analysis can be performed that may allow for slightly thinner pipe wall to be used. We have also assumed that the pipe will be supported by rollers and/or cranes during installation.

Table 1 - Assumed Pipe Input Parameter Values for Pipe Stress and Pullback Calculations		
	HDPE 18" IPS	**FPVC 14" DIPS**
OD	18.0"	15.3"
ID	13.76"	13.5"
Bore Diameter	27"	24"
DR	9	18
Pipe Weight	43.8 lb/ft	25.0 lb/ft
Modulus of Elasticity	63,000 psi	400,000 psi
Yield Strength	3,200 psi	7,000 psi
Poisson's Ratio	0.45	0.38
Allowable Tensile Strength	1,150 psi (12 hour load duration)	2,800 psi

The results of the pullback load analyses are summarized in Table 2. Observations from previous projects indicate that startup loads can be higher than steady state loads. To account for this we have applied a factor of 1.25 to the steady state pull loads to account for static friction and gelling of the drilling fluid that can be observed when resuming after pull stoppages.

Table 2 - Pullback Load Analysis for HDD Installation (Startup Loads, 1.25x Steady State)		
Location	**Startup Loads for HDPE Pipe (pounds)**	**Startup Loads for FPVC Pipe (pounds)**
Entry Point	9,800	5,600
End of Straight Tangent/Beginning of First Vertical Curve	21,650	17,000
End of First Vertical Curve/Beginning of Horizontal Section	41,300	29,000
End of Horizontal Section/Beginning of Second Vertical Curve	52,000	40,200
End of Second Vertical Curve/Beginning of Straight Tangent	63,400	48,100
Exit Point	63,900	49,400
Maximum Allowable Pull Load (FS = 2.5)	**115,600**	**108,000**

For both pipe analysis cases, stresses resulting from the pullback force, and additional tensile stress resulting from the pipe bending through the vertical curves, were analyzed at potentially critical points along the bore and compared to the recommended allowable stress. The results of the pullback force and pipe stress analyses are summarized in Tables 3 and 4. The safe pull stress values for HDPE and FPVC pipe incorporate a manufacturer-recommended factor of safety of 2.5. Therefore, if the ratio of the combined calculated stress to the safe pull stress is equal to or less than 1.0 it is considered an acceptable level of stress. The most critical combined stress location in the bore typically occurs at the end of the exit side vertical curve.

Additionally, unconstrained buckling stresses resulting from the heavy drilling fluid outside the pipes have been compared against the critical buckling stress of the pipe to determine the risk of buckling failure. For the buckling analysis, the ASTM design standard recommends a minimum factor of safety of 2 as the safe limit.

Table 3 - Pipe Stress/Buckling Analyses for HDD Installation of HDPE Pipe Using Startup Loads

18-inch OD DR 9		
	Combined Stress Ratio	**Installation Buckling Stress Factor of Safety**
Entry Point	0.08	-
End of Straight Tangent/Beginning of First Vertical Curve	0.19	5.8
End of First Vertical Curve/Beginning of Horizontal Section	0.40	3.3
End of Horizontal Section/Beginning of Second Vertical Curve	0.45	3.3
End of Second Vertical Curve/Beginning of Straight Tangent	0.59	5.0
Exit Point	0.55	-

Table 4 - Pipe Stress/Buckling Analyses for HDD Installation of FPVC Pipe Using Startup Loads

15.3-inch OD DR 18		
	Combined Stress Ratio	**Installation Buckling Stress Factor of Safety**
Entry Point	0.05	-
End of Straight Tangent/Beginning of First Vertical Curve	0.16	3.3
End of First Vertical Curve/Beginning of Horizontal Section	0.38	2.2
End of Horizontal Section/Beginning of Second Vertical Curve	0.37	2.2
End of Second Vertical Curve/Beginning of Straight Tangent	0.56	2.8
Exit Point	0.46	-

The results of our pullback analysis indicate that the anticipated loads required and the stresses imposed during the HDD installation will require the use of either 18-inch OD DR 9 IPS HDPE pipe, or 14-inch nominal (15.3” OD) DR 18 DIPS FPVC pipe.

7. Hydrofracture Analysis

Hydrofracture, or inadvertent drilling fluid returns, to the ground surface is a serious concern for any HDD crossing. A preliminary analysis of the hydrofracture risks for this project has been performed, as detailed below.

The hydrofracture calculations are based on the Delft Cavity Expansion Model, (Bennett and Wallin, 2008, Staheli, et. al., 1998; Delft Geotechnics, 1997; Luger and Hergarden, 1988). The cavity expansion model provides a rational method to calculate the maximum allowable drilling fluid pressure that the soil can withstand before plastic yield or hydrofracture occurs, at any point along a bore. The maximum allowable pressure is the safe upper bound value of allowable drilling fluid pressures for the HDD bore, and is dependent on depth of earth cover and the soil characteristics. The calculations assume homogeneous soil properties within each layer, and do not take into account pre-existing preferential seepage paths to the ground surface.

The minimum required pressure to return the soil cuttings back to the surface was evaluated using the Bingham Plastic Model and assuming laminar flow conditions. The laminar flow approach generates a conservative result since the conditions will more likely be a combination of laminar and turbulent flow. The minimum required pressure is dependent on the length, depth, and diameter of the bore, as well as the drilling fluid properties. We have assumed good drilling practices by the Contractor in our selection of drilling fluid properties.

Locations where the minimum required pressure exceeds the maximum allowable pressure have elevated risk of hydrofracture. The risk of hydrofracture was only analyzed for the drilling of the pilot bore because this step of the HDD process has the highest risk of hydrofracture due to the small diameter of the bore and the relatively large diameter of the drill pipe, as well as the single flow path available for drilling fluid returns.

The results when using this method for analyzing hydrofracture risk are primarily dependent on the geotechnical conditions and the bore geometry. Representative average geotechnical parameter values were selected based on review of geotechnical borings provided by Crawford & Associates (December 2015). The engineering properties of the alluvial terrace deposits and the residual soil were similar enough to model them as one layer. The fresh, hard bedrock will likely exhibit sufficient strength to resist any reasonable fluid pressure from the HDD operation. Therefore, to obtain a conservative result, the ground conditions for the bore were modeled as a two layer system consisting of stiff to very stiff sandy lean clay with gravel overlying weathered, soft meta-argillite bedrock. The soil parameters used in the analysis are shown in Table 5 below. Groundwater was assumed to be at the river elevation of 35 feet. The results of the evaluation of hydrofracture risk for the proposed geometry of the pilot bore are shown in Figure 8.

Table 5 – Soil and Rock Properties Used in Hydrofracture Analysis		
	Stiff to Very Stiff Sandy Clay with Gravel	**Weathered, Soft Meta-Argillite Bedrock**
Cohesion (c)	1,000 psf	5,000 psf
Soil Friction Angle (ϕ)	0	0
Shear Modulus (G)	60,000 psf	200,000 psf
Soil Unit Weight (γ)	125 pcf	135 pcf

Figure 8 is a plot of the ground surface and bore profile in feet of elevation, (right hand y-axis) and the maximum allowable pressure and minimum required pressure in psi (left hand y-axis), against horizontal stationing on the x-axis. The maximum allowable pressure that the soil can withstand before plastic yield (fracturing) occurs increases with increasing depth of cover. The lowest allowable pressures are seen near the entry and exit points and under low points, such as the bottom of the river. The minimum required pressure to return the drilling fluid to the entry point increases as the distance from the entry point increases and as the depth of the bore increases. Critical locations, where risk of hydrofracture is elevated, occur where the minimum required drilling fluid pressure (P_{min}) exceeds the maximum allowable pressure (P_{max}).

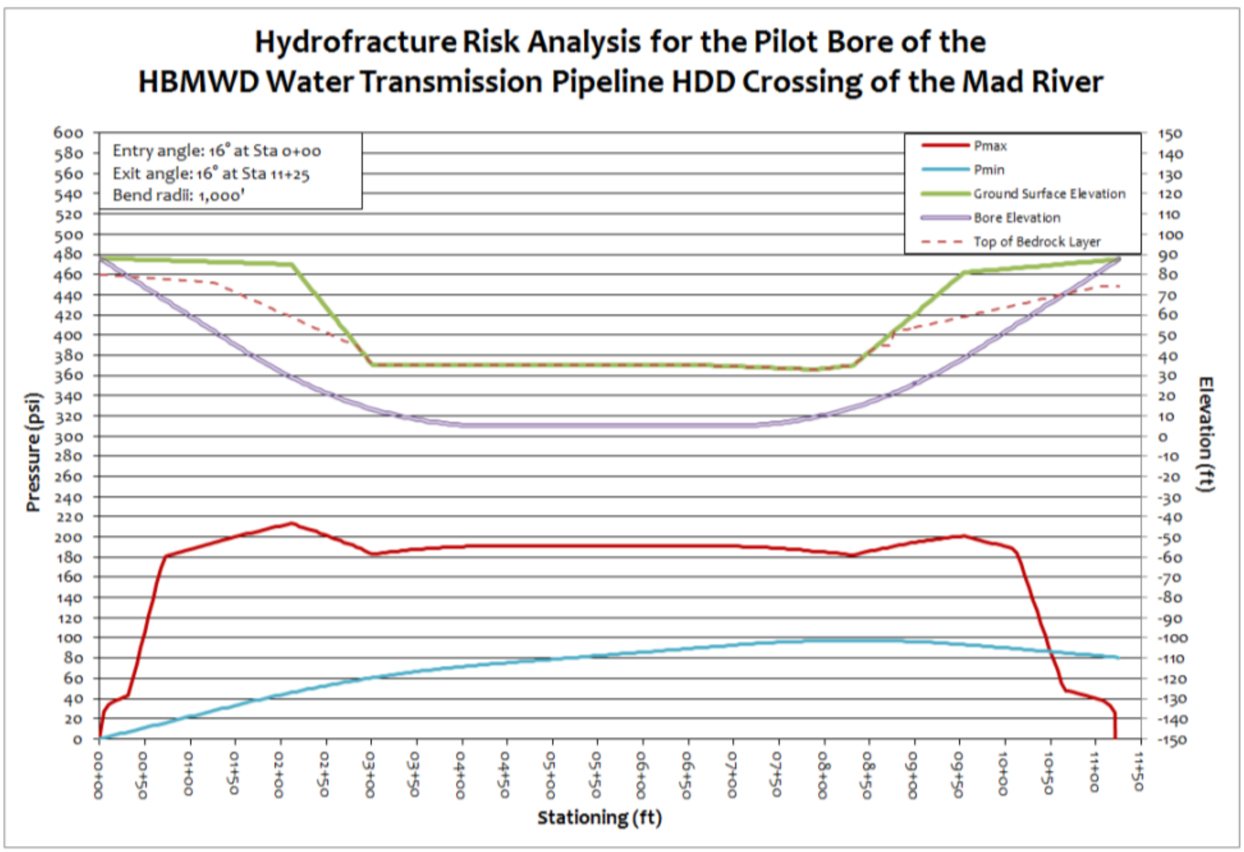


Figure 8: Evaluation of Hydrofracture Risks - Comparison of Maximum Allowable and Minimum Required Drilling Fluid Pressures for the Pilot Bore of the Mad River Crossing

The most important result shown in Figure 8 is that the risk of hydrofracture is low for the majority of the crossing length. Because the depth of cover decreases toward the exit point, there is an elevated risk of hydrofracture shortly before the exit point, starting at approximate

Station 10+40. This risk is typical for all HDD bores and can be mitigated through common measures including specifying that the drilling contractor have tools and equipment on-site for rapid containment and clean-up of any inadvertent fluid returns. Typically a detailed Surface Spill and Hydrofracture Contingency Plan will be developed for the project that describes the planned response in the event of an inadvertent drilling fluid return.

It is important to note that the actual risk of hydrofracture during construction is dependent on contractor means and methods and actual ground conditions along and above the bore. The results of these analyses are applicable to HDD work performed using industry good practices and within the parameters assumed in the analysis.

8. Construction Cost and Schedule Considerations

A preliminary design-level cost and schedule estimate has been prepared for the HDD alternative for the Mad River crossing using the pipe material and diameter configurations discussed in the previous sections. The cost and schedule estimates are based on historic bids for similar projects and our own experience with previous HDD projects. The work items covered in the estimates include: mobilization and setup of the HDD drilling equipment; completion of the pilot bore and reaming to final bore diameter; delivery, fabrication, and testing of the product pipes; installation of the product pipe; grouting both ends of the bore; and demobilization of the drilling equipment. The cost and schedule estimates do not include preparation of the work area on the west side of the crossing. The cost and schedule estimates also do not include tie-ins of the trenchless pipe to open cut sections, installation of any valves or other appurtenances, or site restoration. The costs presented include a 30% markup for contractor overhead, profit, insurance, bonds, and escalation, as well as a 30% preliminary design-level contingency. Table 6 presents the estimated cost and duration for the conceptual alignment. The costs include the HDPE or FPVC pipe material and fusion of the pipe. Construction durations are based on 10-hour shifts, worked six days per week.

Table 6: Summary of HDD Cost and Schedule Estimate

Carrier Pipe	18” OD DR 9 IPS HDPE
Bore Length	1,125’
Bore Diameter	27”
Total Raw Cost	$744,000
Bid Cost with 30% Contractor Markups†	$967,000
Planning Cost with 30% Design Contingency	$1,257,000
Cost per Foot	~ $1,100/ft
Estimated Construction Duration	36 shifts

** Estimates do not include costs and durations for tie-ins, valves, and surface restoration.*
†Costs include 30% additional for taxes, markups, overhead, profit, insurance, bond, escalation.

9. Recommended Trenchless Design

- After review of the project criteria and the preliminary geotechnical report, a field inspection of the site conditions, and both hydrofracture and pipe stress analyses, we find that horizontal directional drilling (HDD) is a feasible trenchless construction alternative for completing a replacement of the HBMWD BLFG CSD Water Transmission Pipeline crossing of the Mad River. Alternative trenchless methods such as auger boring, pipe ramming, open-shield pipejacking, and microtunneling are either not technically feasible, or are not cost-competitive for this project.

- We recommend a bore alignment that extends from a point approximately 600 feet north of the intersection of Warren Creek Road and Burlwood Lane, and 90 feet east of the road, to the northwestern corner of GR Sundberg's equipment yard, approximately 450 feet southeast of the intersection of Glendale Drive and Fieldbrook Road, as shown in Figure 4 of this report.

- We recommend a bore profile of approximately 1,125 feet in length, with a minimum of 20 feet of vertical earth cover at all points along the bore, as shown in Figure 5 of this report. The conceptual bore profile reaches a minimum elevation of 5 feet.

- We recommend that the bore be advance from west to east, with the entry point and drill rig located off of Warren Creek Road (see Figure 6), and pipe fabrication and layout located along the north boundary of GR Sundberg's equipment yard (Figure 7). If obtaining temporary construction easement from GR Sundberg were unfavorable, it would likely be feasible to lay out the pipe along the south shoulder of Glendale Drive. It would also be feasible to reverse the bore direction and drill from east to west.

- An HDD crossing will require clearing undergrowth and some mature trees in the forested area on the west side of the river to allow for either rig setup or pipe fabrication. An area of approximately 3,500 to 4,000 square feet would need to be completely cleared of trees and brush. An additional 5,000 to 6,000 square feet would need to be cleared of undergrowth and small trees, but mature trees could be retained.

- The results of pipe stress analyses indicate that a replacement pipeline installed by HDD could be completed with either 18-inch OD IPS DR 9 HDPE pipe or 14-inch nominal (15.3" OD) DIPS DR 18 FPVC pipe.

- The results of a hydrofracture risk analysis indicate that there is a low probability of hydrofracture for the majority of the conceptual bore. It is likely that drilling fluid will come to the surface over the last 75 feet of the bore alignment near the exit point. This is typical for most HDD crossing and can be handled with simple containment measures.

- We estimate that the HDD crossing of the Mad River, as described in this report, would cost approximately $1.26M (~ $1,100/ft) to construct and would take approximately 36 working days to complete. These construction cost and duration estimates include all HDD operations to advance the bore, and to install and test the pipeline crossing beneath the river. They do not include preparation of the forested site on the west side of the river or any tie-in work to the existing water line after HDD installation is complete.

- If the HDD alternative were selected as the preferred method for completing the Mad River pipeline replacement, we recommend that further survey and geotechnical work be conducted. Survey data would need to be obtained covering the bore alignment and planned work areas. The survey should also include detailed data on mature trees on the west side of the river so that the HDD work area could be developed to minimize the removal of mature trees. The final geotechnical investigation should include at least one boring on each side of the river, including coring of the bedrock to at least elevation 0 feet. Additionally, the design team should consider using geophysical methods to investigate the bedrock contact elevation across the river channel to mitigate the risk of encountering a deep historic river channel infilled with gravel and cobbles.

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GHD Inc

718 Third Street

Eureka CA 95501

T: 1 707 443 8326   F: 1 707 444 8330   E: eureka@ghd.com

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		Name	Signature	Name	Signature	Date
1	Nathan Stevens	Patrick Kaspari				

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