Capitol Lake Dam Preservation
Project Number: 2016-931

Comprehensive Assessment Report

Presented to:

Washington State Department of
Enterprise Services

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Executive Summary

Scope

Moffatt & Nichol (M&N) was retained by the Washington State Department of Enterprise Services (DES) to perform a waterfront facility inspection and provide a comprehensive assessment of the Capitol Lake Dam located in Olympia, Washington. The Capitol Lake Dam was built between 1949 and 1952 and has therefore been in service for nearly 70 years. The objective of the comprehensive assessment is to document the current condition of the dam, provide repair recommendations, and develop considerations to extend the dam's service life another 50 years. The scope of work included structural, durability, mechanical, electrical, safety, and geotechnical assessments of the dam. A topographic survey of the dam was also conducted and monuments were set to provide a baseline for monitoring horizontal or vertical movement of the earth-fill embankment and the spillway components.

Inspection Findings

The following summarizes the dam assessment findings:

1. The structural components of the dam, including the abutments, pier walls, wingwalls, beams, and deck, are in fair condition. Fair is defined as: all primary structural elements are sound with isolated minor to moderate deterioration observed, and there is no reduction in structural capacity. The observed minor to moderate defects include minor surface corrosion of steel components, hairline concrete cracks, an open corrosion concrete spall on the northeast wingwall, fungal decay of the timber walkway posts above the northwest wingwall, and undermining of the timber walkway bulkhead above the northwest wingwall.
2. The durability assessment found that the chloride ion concentration is above the threshold within the splash zone and corrosion is active at the reinforcing steel; however, the corrosion rate is low. Cracks initiating from the corroding reinforcing steel are expected to propagate to the surface in approximately ten years.
3. The mechanical and electrical components are in fair condition. In other words, widespread minor to moderate deterioration is observed on the mechanical and electrical components, and localized areas of moderate to advanced deterioration are present, but have not yet affected the dam operation. Most of the equipment is aging and exhibits deterioration, coating loss, and corrosion. The dam will continue to function provided a proactive approach is developed for repairing and/or replacing components.
4. The geotechnical evaluation found that the earthen embankment is stable in the static condition. In a seismic event, the subsurface soils are susceptible to liquefaction. If the soil liquefies during a seismic event, infrastructure along 5th Avenue SW may fail, including public utilities, city streets, or the spillway. Overtopping of the dam is possible if the embankment fails. However, lives are not at risk if the reservoir is released. Mitigation measures are available to improve the dam's stability during a seismic event.

Permitting

In-water projects of any kind, ranging from simple repairs to more complex redevelopment activities, must comply with a number of federal, state, and local regulatory laws and permits before construction can begin. At Capitol Lake Dam, permit agencies generally allow work below ordinary high water (OHW) between July 1 through July 31 of any year, unless an extension or exception is granted. This work window can vary depending on the type of work and where on the dam the work is being conducted. Permits for overwater work above OHW are also required; however, the requirements are generally less restrictive.

Recommendations

Given the dam's age combined with the fact that it has not been adversely affected by environmental factors, a major failure is unlikely if existing loading conditions and regular maintenance are sustained. The recommendations, the associated rough order of magnitude opinion of probable cost (ROM OPC), and the relative urgency of the recommendations are provided below.

Item No.	Item Description	Recommended Action	Urgency	ROM OPC
1	Standby Hydraulic System - Gate Attachment	Install chain that allows attachment of the standby ropes to the gate without necessity of diving. Chain should be installed as to not interfere with normal operation of the gate.	High	$37,500
2	Gate Trunnion – Lubrication	Replace and relocate access of all the existing trunnion lubrication ports and tubing.	High	$37,500
3	Standby Hydraulic System - Cylinders	Remove and refurbish or replace the existing hydraulic cylinders.	High	$32,000
4	Electrical Panel and Motor Control Center (MCC) - Conduits	Seal around exterior penetrations, replace all outlet box and conduit body covers.	High	$1,300
5	Electrical Panel and MCC - Receptacle Cover - Shock Hazard	Upgrade to weatherproof cover or eliminate receptacle.	High	$1,300
6	Gate Trunnions – Friction	Take amp meter readings of gate motors to detect over loading of the motor and drive system.	High	$1,700
7	Capitol Lake Controls (METASYS) - Enclosure	Cover holes in door left by prior components to prevent ingress of moisture into panel.	High	$4,300
8	Capitol Lake Controls (METASYS) - Level Sensors	Terminate connections at stilling wells within raceway system.	High	$2,200
9	Fish Gate - Exposed Coupling Cover	Install OSHA compliant machine guard around the couplings near the deck.	High	$12,600
10	Fish Gate - Drive Components	The operator switch for the device can be accessed easily by the public, exposing the device to vandalism or uncontrolled operation of the gate. Place padlocked protective cover to prevent access.	High	$12,600
11	Fish Gate - Wire Rope	Replace the wire ropes.	High	$19,200

Item No.	Item Description	Recommended Action	Urgency	ROM OPC
12	Coupling Guards	The shaft couplings connecting the gate electric motors to the gear reducers should have removable guards installed to be in compliance with OSHA 1917.151 for rotating machinery.	High	$6,500
13	West Gate Motor/Brake	Replace motor/brake unit. Existing motor/brake continues to function but appears to be aging.	High	$15,000
14	Timber Walkway Repairs	Replace posts and repair and protect undermined foundation.	High	$20,000
15	Fencing/Guardrails	Install and repair fencing/guardrails.	High	$5,000
16	Steel Grating Repair	Provide positive connection to concrete surface.	High	$2,500
17	Ladder Repairs	Remove damaged ladder on west abutment; Ladder to catwalk - provide ladder extension and non-slip coating on rungs.	Moderate	$5,000
18	Roof Repairs	Replace control room roof and fall protection anchor point	Moderate	$12,000
19	Exposed Spur Gears and Gear Drive Chain	Replace damaged pinions and realign. Remove, clean and inspect all gearing. Re-lubricate before placing back in service. Replace gear drive chain.	Moderate	$144, 200
20	Gate Position Sensors	Replace potentiometer and limit switches with updated technology	Moderate	$9,800
21	Standby Hydraulic System - Filter	Install pressure gauges before and after the filter to allow pressure drop indication of filter.	Moderate	$12,000
22	Gate Trunnion – Cleaning and Inspection	The gate trunnions should be dismantled, cleaned of marine life and debris and assessed for wear and damage.	Moderate	$64,600
23	Gear Reducers – Breather Cap	Replace old breather caps with new.	Moderate	$200
24	Fish Gate - Exposed Coupling	Remove and inspect. At a minimum replace the elastomeric element.	Moderate	$2,000
25	Repair Radial Gate Seals	Remove and install new gate seals.	Moderate	$115,000

Item No.	Item Description	Recommended Action	Urgency	ROM OPC
26	Standby Hydraulic System - Rigging	Replace corroded wire ropes as necessary.	Low	$10,500
27	Gate Bearing Blocks / Shafts / Couplings	Remove bearings and examine shafts and bearings for wear. Replace damaged seals. Replace bearings as needed. Replace any damaged or corroded bolts and tighten to manufacturer's specifications (if available). Replace or refurbish worn shafts. Clean and repaint shaft. Remove and inspect couplings.	Low	$67,100
28	Gear Reducers – Replace	Take existing gear reducers from service and send to gear rehabilitator for inspection of gear unit internals. Refurbish as necessary. Alternatively replace the unit with new. Replacement with new would reduce the time a gate would be out of service.	Low	$32,300
29	Wingwall - Concrete Spalls	Repair spall per Figure 7.	Low	$9,000
30	Repair Stoplog Cutouts	Remove debris and failed coating and recoat.	Low	$35,000
31	Fishway Beams - Concrete Spalls	Repair spall per Figure 7.	Low	$18,000
32	Recoat Radial Gates	Remove debris and failed coating and recoat.	Low	$180,000
33	Replace Stillwell Hatch	Replace with spring-assisted hatch.	Low	$15,000
34	Concrete Ramp	Remove adjacent tree and repair the concrete ramp.	Low	$6,000
35	Gate Cushions	Replace timber gate cushions.	Low	$10,000
36	Concrete Spillways	Install cathodic protection system to protect the reinforcing steel within the tidal zone and splash zone	Low	$800,000
37	Embankment	Deep soil mixing or jet grouting to improve shear strength and containment of liquefiable soils.	Low	$15,000,000
38	Embankment	Buttressing berm (downstream side) to improve stability.	Low	$1,500,000
39	Embankment	Add drainage to improve stability.	Low	$500,000

1. Introduction

1.1. Objective

Moffatt & Nichol (M&N) was retained by the Washington State Department of Enterprise Services (DES) to perform a waterfront facility inspection and provide a comprehensive assessment of the Capitol Lake Dam located in Olympia, Washington. The objective of the comprehensive assessment is to document the current condition of the dam, provide repair recommendations, and develop considerations to extend the dam's service life another 50 years. The scope of work included structural, durability, mechanical, electrical, safety, and geotechnical assessments of the dam. A topographic survey of the dam was conducted and monuments were set to provide a baseline for monitoring horizontal or vertical movement of the earth-fill embankment and the spillway components. Repair costs based on the observations and laboratory findings are provided for short-term and long-term repair recommendations. The following independent assessment reports and topographic survey were prepared as part of this project:

- **Appendix A - Structural and Safety:** *Capitol Lake Dam Preservation Structural Condition Assessment Report* by M&N, dated March 3, 2017
- **Appendix B - Durability:** *Capitol Lake Dam Preservation Durability Assessment* by Tourney Consulting Group (TCG), dated October 13, 2016
- **Appendix C - Mechanical and Electrical:** *Fifth Avenue Dam Capitol Lake Tide Gates Machinery and Controls Assessment* by Fives Lund LLC (Lund), dated January 30, 2017
- **Appendix D - Geotechnical:** *Geotechnical Engineering Report; Capitol Lake Dam Preservation Assessment* by Terracon Consultants, Inc. (Terracon), dated December 7, 2016
- **Appendix E – Topographic Survey:** *Topographic Survey Capitol Lake Dam* by Pacific Geomatic Services (PGS), dated September 28, 2016

This report summarizes the findings and recommendations provided in the assessment reports listed above, provides permitting considerations, and builds on the observations and findings in the *Capitol Lake Dam Condition Assessment and Life Expectancy* report prepared by Moffatt & Nichol, dated October 31, 2008.

The 2008 M&N report recommended providing a complete service life model of the dam's concrete, conducting a geotechnical assessment, and comparing elevations of key dam components to record drawings. Eight years have passed since observations were made; therefore, the findings of this report are compared to the 2008 M&N report and updated to provide a current summary of findings.

1.2. Dam Description

Capitol Lake Dam is located in Olympia, Washington at the mouth of the Deschutes River where the river empties into Budd Inlet and is managed by DES. The Dam was constructed between 1949 and 1952 and serves to control the water level in Capitol Lake. The recorded dam dimensions are 1,290 feet long and 45 feet high (Ecology, 2015), although the dam's dimensions vary by source. The dam includes a reinforced concrete spillway and an earth-fill dam. The spillway is approximately 82 feet wide and 167 feet long and the earth-fill dam is approximately 800-1120 feet long (depending on the source), 80 feet wide across the top, and 26.5 feet high. The 5th Avenue Southwest roadway crosses over the top of the dam. Figure 1 shows an aerial view of the dam.

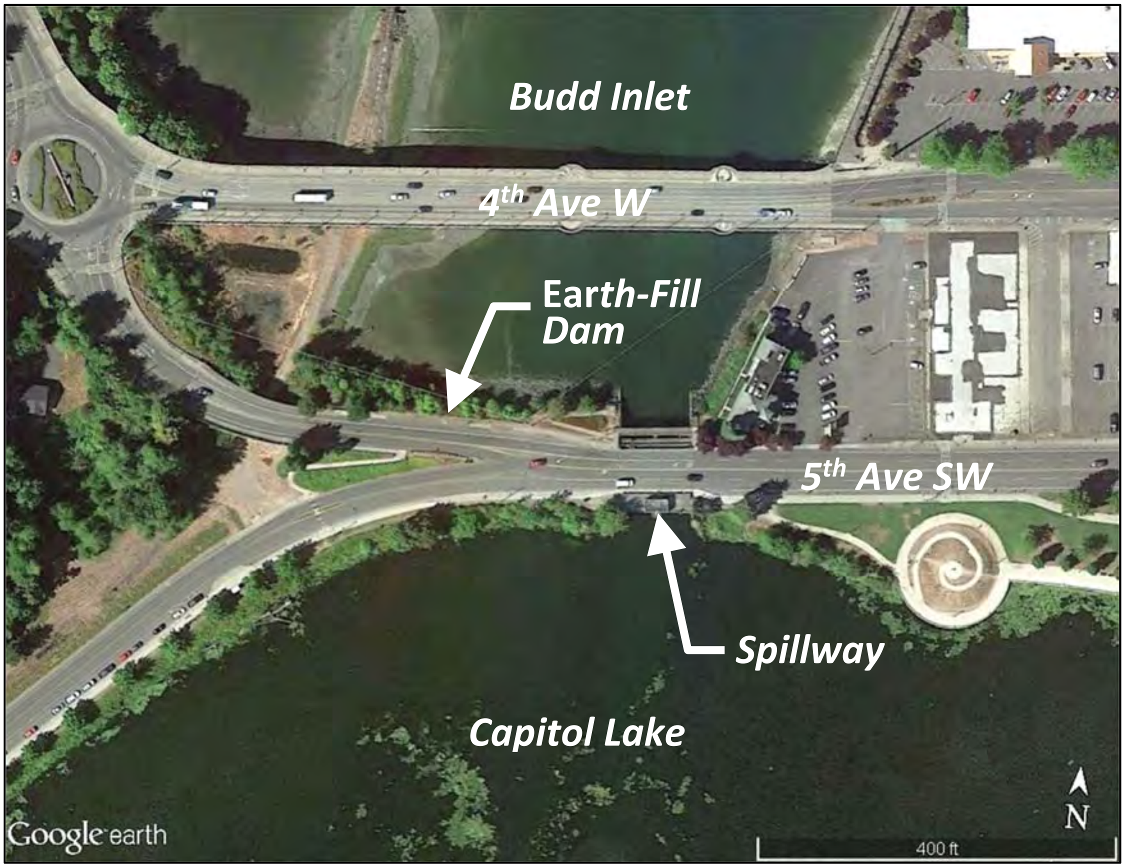

Figure 1: Capitol Lake Dam Aerial (Source: Google Earth)

The spillway includes two flood control discharge channels and a fishway channel constructed with concrete abutments, pier walls, wingwalls, a bottom slab, an ogee crest, and a sill. The west and east flood discharge channels have a minimum clear width of 36 feet and 24 feet, respectively. The fishway channel located at the easterly side of the spillway has a 9-foot 6-inch clear width.

The flood control discharge channels are controlled by radial gates on the south end of the structure. The ogee, located downstream of each radial gate, serves as a bearing pad for the radial gate seals. The ogees slope from the radial gate and transitions into the bottom slab. Timber baffles form a fish ladder in the fishway channel.

The abutments and pier walls support a road deck, timber walkway, public utilities, and control house above. The control house shelters the reduction gears, electric motors, control panel, and miscellaneous appurtenances. Each gate mechanism is operated by a large gearbox driven by an electric motor. Each gearbox drives cable drums that raise and lower the respective gate. An independent hydraulic backup system is incorporated for the west gate.

Upstream and downstream stoplog cutouts are located along the sides of the abutment and pier walls. Stoplogs can be inserted upstream of the dam to dewater the gates. The original design also included a fixed, floating log boom in Capitol Lake upstream of the spillway. The log boom was intended to prevent logs and other debris flowing from the Deschutes River from blocking the spillway channels, however, the log boom was not in place at the time of this inspection.

Three cut-off walls are constructed below the bottom slab to mitigate seepage. The upstream and downstream cut-off walls consist of a single row of steel sheet piling 12 feet and 10 feet in length, respectively. The central cut-off wall consists of a concrete seal-wall lying beneath the main slab and extending up the outside of each side wall to an elevation of 0.00 feet Olympia datum. An underdrain consisting of clean graded sand and gravel extends the length of the spillway just downstream of the central cut-off wall. Bleeder pipes extend from the gravel core upward through the spillway slab.

In 1987, a siphon system was constructed in the vicinity of the dam. The siphon system was installed to convey salt water back to Budd Inlet that had collected in a crater in Capitol Lake. It is believed the crater was formed when there was a regular practice of flooding the lake with marine water to control aquatic plants. The energy from the turbulent marine water flowing into Capitol Lake scoured the lake bottom just upstream of the spillway. The marine water from the flooding procedure would settled to the lowest part of the lake and, in certain conditions the water would become toxic. (Nelson, 1986)

Figure 2 and Figure 3 show a plan view and section view of the dam spillway, respectively.

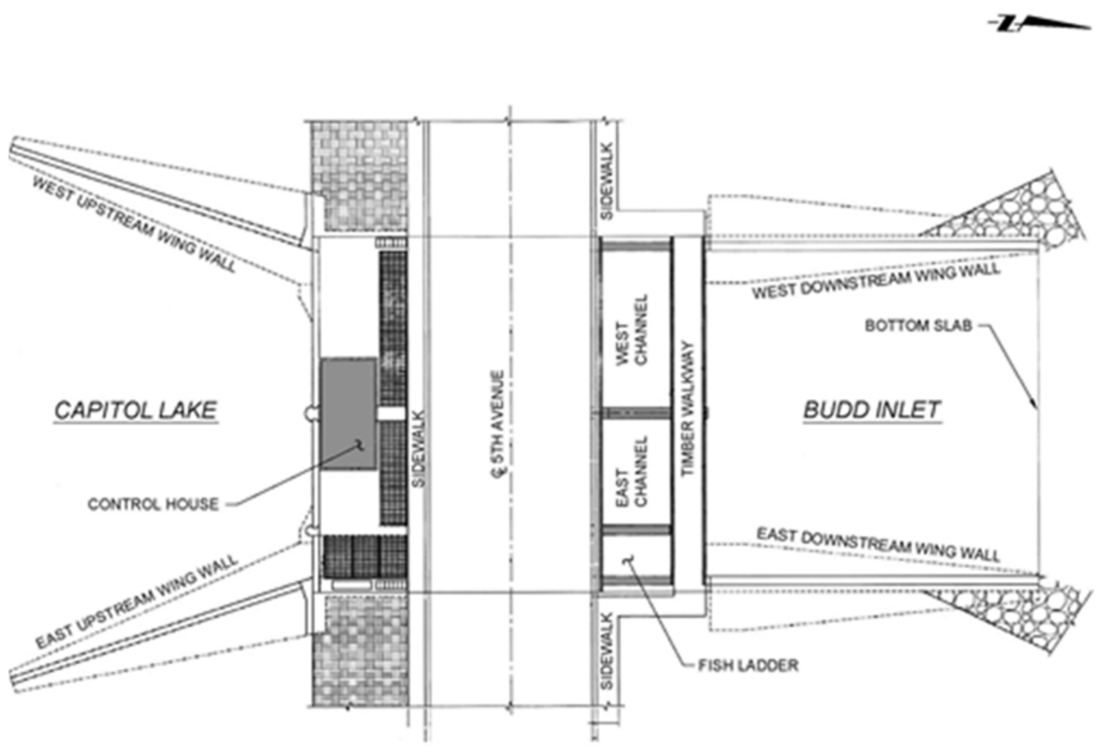

Figure 2: Capitol Lake Dam Spillway Plan View

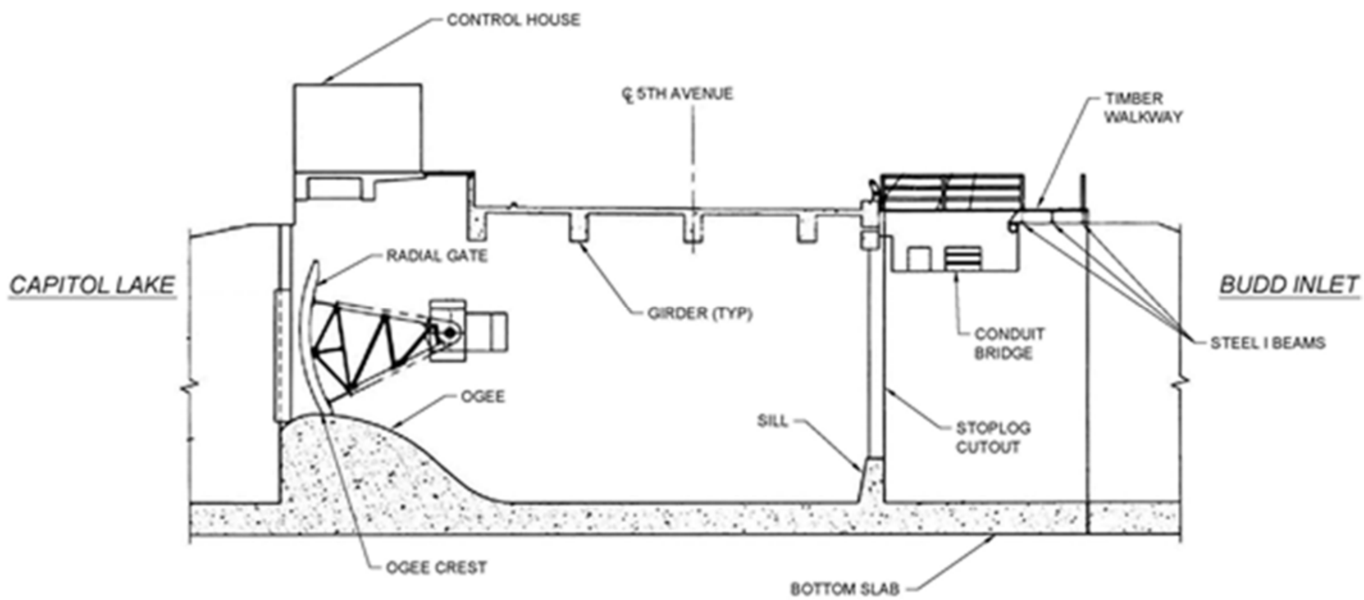

Figure 3: Capitol Lake Dam Spillway Section View, Looking West

The earth-fill dam is described in the original design as being constructed with an impervious earth core material (Kramer, Chin & Mayo (KCM), 1980). Flanking the impervious core, the original design shows a semi-pervious transition soil. Rock armoring lines both the upstream and downstream sides of the earth embankment. Rock armoring also lines the spillway bottom on the Capitol Lake side and surrounds the bottom slab and wing walls on the Budd Inlet side. Figure 4 illustrates the original design of the earth-fill dam.

1. Group 1 Soils, Impervious Earth Core
2. Group 2 Soils, Semipervious Transition Zone
3. 1' Selected Sand & Gravel Filter Blanket
4. Rip-Rip (1 Ton) Slope 2:1@ Spillway Flatten To 3:1
5. 2'-0" Thick Rip-Rap Protection
6. Rip-Rap (1 Ton) Below Elev. -8.0

Elevations shown based on City of Olympia datum.

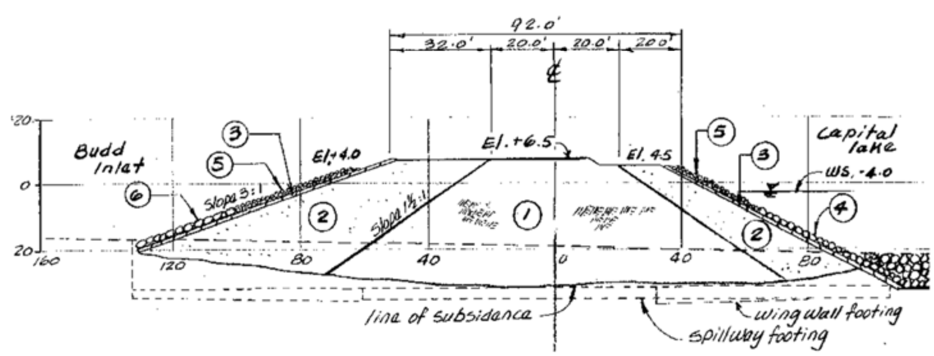

Figure 4: Capitol Lake Dam Earth-Fill Section View, Looking East (Source: KCM, 1980)

Multiple rehabilitation projects have taken place over the life of the dam. The known rehabilitation projects are listed in Table 1. This list only represents the reference information provided by DES and may not be a complete list of dam rehabilitation projects.

Table 1: Completed Rehabilitation Projects

Year	Work Completed
1952	• Original construction complete.
1980	• Gate seals replaced. • Generator installed. • Existing hydraulic backup system pump replaced with motorized pump with valve.
1986	• Crater siphon system installed. • Hoist enclosed gears inspected and serviced. • Gate seals replaced.
1994	• Gates removed and cleaned/repaired. • Gate seals replaced. • Catwalks added.
2015	• Fish ladder weirs replaced/repaired.
2016	• Plastic coated gate hoist wire ropes replaced with stainless steel wire rope.

1.3. Scope of Work and Methodology

1.3.1. Structural

The structural assessment included an above-water and underwater investigation of all accessible structural components of the spillway and included observations of the mudline conditions and utility encasements and hangers. Testing the functionality of the on-site utilities other than the dam's gate controls is not included. The investigation methodology was based on the American Society of Civil Engineers (ASCE) Manuals and Reports on Engineering Practice Number 130, "Waterfront Facilities Inspection and Assessment", 2015 Edition (ASCE 130).

Three basic levels of inspection are used for inspecting facilities. The type and extent of damage/deterioration that can be detected depends on the level of inspection performed. The following general descriptions for Levels I through III comply with ASCE 130. This investigation included Level I and Level II inspection of the spillway below water and Level I and Level III inspection above water. A description of the Level III inspection is included in Paragraph 1.3.2 Concrete Durability.

Level I - Visual or tactile inspection of above-water and underwater components without the removal of marine growth. This level of investigation generally serves as a confirmation of as-built conditions and detects obvious damage or deterioration to the structure.

Level II - Partial marine growth removal of a statistically representative sample – for walls, this is typically cleaning a one square foot area of the wall every 100 linear feet. This level of investigation is intended to detect and identify damage and deterioration that may be hidden by surface biofouling.

Level III - Nondestructive testing (NDT) or partially destructive testing (PDT) of a statistically representative sample. These procedures are conducted to detect any hidden internal damage or deterioration. In this inspection, concrete sampling was performed above water.

Capitol Lake and Budd Inlet are infested with New Zealand Mudsnails. All diving, boating, and inspection activities followed the decontamination protocols provided in the Washington Department of Fish and Wildlife (WDFW) manual titled, *WDFW Invasive Species Management Protocols, dated November 2012* and the DES Standard Operating Procedure (SOP) manual titled *Buildings and Ground Division, Olympia Fifth Avenue Dam Procedure*, dated September 1, 2016.

Detailed descriptions of the structural assessment scope, methodology, findings, recommendations, and photographs of typical conditions are provided in the *Capitol Lake Dam Preservation Structural Condition Assessment Report* prepared by Moffatt & Nichol, dated March 3, 2017, included in Appendix A.

1.3.2. Concrete Durability

The concrete durability assessment included visual observations, extracting concrete samples (Level III investigation), conducting concrete property tests, and predicting future performance of the concrete components. The objective of the concrete durability assessment is to evaluate the remaining useful service life of the dam's concrete. M&N worked with TCG to complete the visual observations and extract concrete samples. TCG conducted the laboratory testing and provided the findings and recommendations.

A summary of the testing theory, field investigation, and chloride ion laboratory testing is described below. A detailed description of the scope, methodology, findings, and recommendations is provided in the *Capitol Lake Dam Preservation Durability Assessment Report* prepared by Tourney Consulting Group, dated November 10, 2016, included in Appendix B. Note that this is just one point in time and conditions can change to become more or less corrosive dependent on temperature, future chloride contents, oxygen contents, and degree of saturation.

Testing Theory

Marine concrete structures commonly remain in good condition for 20 or more years before showing signs of deterioration when constructed properly. The appearance of a structure does not always indicate the true condition of its concrete; therefore, laboratory testing is used to detect deterioration of the concrete matrix. Two deterioration mechanisms that can be tested for in the laboratory are chloride ion intrusion and chemical degradation. It is critical to understand the cause of deterioration when determining repair recommendations because the repair methods for the different concrete deterioration mechanisms are significantly different.

Chloride ion intrusion is a problem with any concrete exposed to salt water or salt spray. Unless sealers are applied, any concrete exposed to chlorides will eventually allow chloride ions to migrate into it. The migration can be slowed down by reducing the permeability of the concrete with various admixtures and pozzolans, but eventually the chloride ions will migrate into the concrete and reach the reinforcing steel. The chloride ions destroy the passive layer that protects reinforcing steel from corrosion and enables the formation of rust. The expanding rust layer develops internal stresses in the concrete matrix initiating cracks. The cracks eventually reach the surface of the concrete member which leads to the concrete cover delaminating from the reinforcing steel and eventually spalling off. This result can be delayed with thicker cover and less permeable concrete, or with the addition of chemical corrosion inhibitors. The laboratory results from the 2008 M&N report suggest corrosion of the reinforcing steel is the most probable mechanism that could compromise the dam's concrete components (M&N, 2008); therefore, this assessment focuses on the possible deterioration from chloride ions.

The common chemical degradation mechanisms include alkali-silica reaction (ASR), sulfate attack, and delayed ettringite formation (DEF). These chemical degradation mechanisms involve volumetric expansion of the concrete matrix caused by chemical reaction byproducts. The expansion creates internal stresses leading to cracks and eventually spalling of the concrete. This form of degradation is tested for using petrographic analysis in the laboratory with concrete cores extracted from the facility. The M&N 2008 assessment included petrographic analysis, and the laboratory results did not indicate chemical degradation of the concrete matrix is a likely deterioration mechanism. Given the dam's age, the probability of the dam undergoing these types of chemical deterioration in the next 50 years is low; therefore, petrographic analysis of the concrete cores is not included in this scope of work. Refer to M&N's 2008 assessment report for additional discussion on chemical degradation.

Site Investigation

The site investigation included resistivity testing, collecting cover depth measurements, conducting half-cell potential measurements, and extracting concrete samples.

Concrete Electrical Resistivity

Concrete electrical resistivity is a measurement to detect how effective concrete is at inhibiting the penetration rate of water, oxygen, carbon dioxide, and chlorides to the reinforcing steel. Concrete electrical resistivity was tested per a modified version of American Society for Testing and Materials (ASTM) Standard C1202 – *Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration*. ASTM C1202 provides a system by which to relate the electrical conductance and resistance of concrete to the mobility of ions. A lower conductance value (lower current) corresponds to decreased ion mobility (higher resistance), or reduced chloride ion penetration. Concrete's resistance to ion mobility can be used to predict the time until the onset of corrosion in reinforced concrete. In the case of low concrete resistivity, or increased current, chloride ions will penetrate the concrete faster and accelerate the onset of corrosion in the reinforcing steel.

Readings were taken within the tidal zone and above because resistivity of concrete can vary depending on the temperature and degree of saturation. An increase in temperature will decrease the resistivity. In other words, an increase in temperature increases ion mobility which results in electric current flow.

Cover Depth Measurements

A cover depth survey was conducted to determine the depth of steel reinforcing in the locations of extracted cores. Ground penetrating radar was used to determine locations and depth of steel reinforcing. Cover depth is an important measurement for evaluating concrete durability because the cover depth affects the time it takes for chloride ions to penetrate to the reinforcing steel. As the cover depth increases, the travel time of chloride ions to the reinforcing steel increases.

Half-Cell Potential Survey

Corrosion of reinforcing steel is an electro-chemical process. The greater the potential, the higher the risk that corrosion is active. Electrochemical testing was completed according to ASTM C876 – *Standard Test Method for Corrosion Potentials of Uncoated Reinforcing Steel in Concrete*. This test consists of drilling and connecting to the reinforcing steel in two locations within the desired testing area in order to test for continuity of the reinforcing steel. Once continuity is confirmed, half-cell measurements can be taken by connecting to the steel reinforcement and placing a reference electrode in circuit to measure the electrical potential. From these electrical potential measurements, an equipotential contour map can be developed to determine locations of active corrosion. The half-cell potential readings are also used to calculate the estimated corrosion rate

Concrete Samples

A total of six 2-inch-diameter, 6-inch-deep cores and twelve 3-inch-deep powder samples were extracted. Samples 1 through 6 correspond to cores and samples 7 through 18 correspond to powder samples. The abutment and pier wall core samples were extracted from near the top of the tidal zone and in the splash zone. The samples extracted from the Budd Inlet side were taken within the west spillway channel assuming a harsher environment is present. The west spillway channel is used less frequently, and therefore, it was assumed the chloride concentrations of the marine water would be higher due to less frequent mixing with the fresh lake water.

Where powder samples were taken, three individual holes were drilled in close proximity to each other. Laboratory testing is conducted in one-inch increments; therefore, the powder generated from drilling each one-inch increment in the same hole were kept separate. The powder generated from each corresponding increment in the three holes was combined to create a better representative sample of concrete in the area. Figure 5 shows where each sample was taken.

Chloride Ion Laboratory Testing

The laboratory testing included testing the extracted concrete cores and powder samples for chloride ion concentration. Acid-soluble chloride concentration profiles of the concrete cores and powders were determined per ASTM C1152 – *Standard Test Method for Acid-Soluble Chloride in Mortar and Concrete*. Testing of concrete cores and powders is conducted in one-inch increments to evaluate the chloride concentration at increasing depth. The cores were cut into one-inch thick disks and pulverized into powder for testing the concrete at six depths. The powders collected in the field are tested at three depths per the collected one-inch increments.

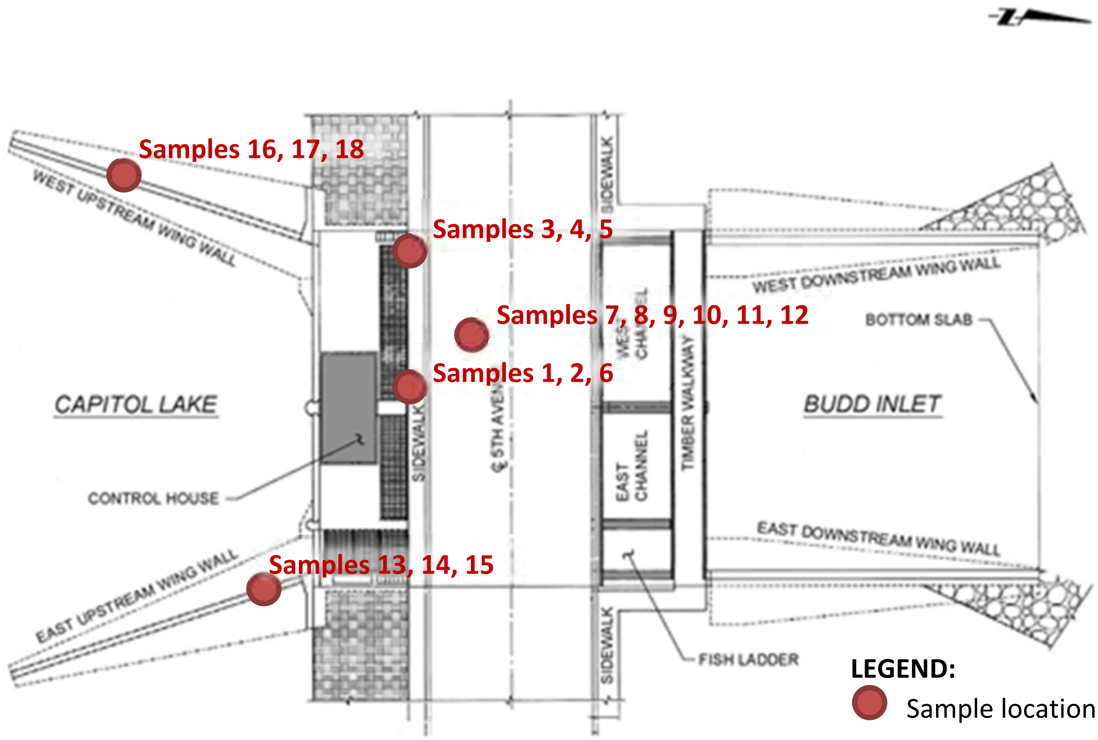

Figure 5: Locations of concrete samples

1.3.3. Mechanical & Electrical

The mechanical and electrical assessment included the dam's tide gates machinery and controls and the siphon system to the extent it was accessible. M&N and Lund met with representatives from DES's operation and maintenance staff who are responsible for the dam. M&N and Lund made observations of the dam's mechanical and electrical functions while the dam was operated. Both flood control discharge channel radial gates and the fishway weir were operated.

A detailed description of the mechanical and electrical assessment scope, methodology, findings, and recommendations is provided in the *Fifth Avenue Dam Capitol Lake Tide Gates Machinery and Controls Assessment* report prepared by Fives Lund, dated January 30, 2017, included in Appendix C.

1.3.4. Safety

The safety assessment included visual observations of the safety features installed and potential areas for improvement to protect DES's maintenance crew and the public. Existing conditions were compared to the applicable sections of the Occupational Safety and Health Administration (OSHA) Standards – 29 CFR Part 1910. This assessment was not conducted to ensure full compliance with OSHA standards. The site observations were conducted by M&N concurrently with the structural investigation.

Detailed descriptions of the safety assessment scope, methodology, findings, recommendations, and photographs of typical conditions are provided in the *Capitol Lake Dam Preservation Structural Condition Assessment* report prepared by Moffatt & Nichol, dated March 3, 2017, included in Appendix A.

1.3.5. Geotechnical

The geotechnical assessment included the earth-fill portion of the dam. The purpose of the assessment is to provide an engineering evaluation of the subsurface soil conditions, apparent dam condition, groundwater conditions, and static and seismic stability of the dam. The assessment included researching existing subsurface information, a visual reconnaissance to look for surficial evidence of distress to the embankment, two borings for subsurface exploration, and geotechnical laboratory testing. The visual reconnaissance generally followed the guidelines presented in the Inspection Guidelines of the Dam Safety Guidelines Part III (DSO 1992).

Detailed descriptions of the geotechnical assessment scope, methodology, findings, and recommendations are provided in the *Geotechnical Engineering Report; Capitol Lake Dam Preservation Assessment* prepared by Terracon, dated December 7, 2016, included in Appendix D.

1.3.6. Topographic Survey

The dam was surveyed by PGS including the earth-fill embankment and the spillway components. PGS used conventional total station data combined with high definition 3D laser scanning to complete the survey and evaluation. PGS compared their findings to the limited available survey information to evaluate settlement since the dam was constructed. PGS also set survey monuments to establish a base for future settlement evaluations of the dam. A plan of the survey and the monument locations is provided in Appendix E.

2. Observation & Findings

2.1. Structural

The structural investigation included observations of the concrete, steel, and timber components. The observations did not involve disassembly of components to expose possible non-readily visible deterioration. The cut-off walls are buried below the bottom slab and were not inspected except for the sheet pile tops on the downstream cut-off wall.

Concrete Components

Concrete components include the abutments, wingwalls, pier walls, ogee crest, the sill, the bottom slab, girders, and deck soffit. The ogee crest, sill, and bottom slab were all observed with one-inch-thick marine growth covering up to 100 percent of the submerged surface areas. Sediment accumulation was observed on the bottom slab up to six inches in depth adjacent to the abutment and pier walls. The accumulated sediment prevented visual inspection of the entire bottom slab, however, where visible the concrete surface exhibited minor to moderate cracking and spalling, primarily along the expansion joint located north of the pier wall. Additional spalling, obscured by sediment accumulation, may be present.

Minor scaling of less than 1/8-inch depth was observed on the vertical and horizontal concrete faces at locations of Level II cleanings. No significant defects were observed on the abutments, pier walls, ogee crest, sills, and bottom slab. One open corrosion spall was observed on the downstream east wingwall.

Hairline cracking and efflorescence was observed on the concrete deck soffit and girders. All four crossbeams in the fishway were observed with moderate closed corrosion spalls along the full length of the soffit.

Steel Components

The steel components include the radial gate, stoplogs, timber walkway support beams, and visible portions of the downstream steel sheet pile cut-off wall. The radial gate and gate arms exhibited coating failure and minor to moderate surface corrosion on the inlet side where the steel is exposed to saltwater. The areas of moderate corrosion and section loss were observed in the splash zone. Leaks were observed in the radial gate seals on the west and east radial gates. The leaks were observed on the west edge of the west gate and at the lower west corner of the east gate.

The easterly steel chain used to connect the standby hydraulic system for the west gate was observed to be disconnected and laying at the base of the radial gate. The chain was immediately removed with the risk of the chain being pinned between gate and ogee if the gate is opened and closed.

The stoplog cutouts were observed with minor to moderate corrosion on the steel embedded surfaces. Section loss of less than 10 percent was noted.

The steel beams supporting the walkway exhibit widespread coating loss and minor corrosion over a majority of the surface area, although section loss is minor and infrequent.

Timber Components

The timber components include the timber walkway and the radial gate cushion. The timber walkway exhibited minor weathering; however, no significant deterioration was observed. The timber walkway is supported in the northeast corner by a concrete retaining wall and timber posts. The timber posts exhibit moderate to major rot and section loss at the interface between the post and the concrete retaining wall. The steel connections at the base are corroded and deformed. The concrete retaining wall supporting the walkway exhibits moderate undermining approximately two inches tall and extending 12 inches under the wall. The westerly radial gate cushion was observed to be crushed and rotted.

Other Appurtenances

The other appurtenances include the non-structural components, site features, and utilities. The northwest side of the dam includes an access ramp to a viewpoint that allows pedestrians to get closer to the water. The lower ramp has a large bump that extends approximately 10 feet horizontally and has a 12-inch vertical differential. The bump is likely caused by roots from the adjacent tree.

Various utilities cross the spillways on the north (outlet) side of the dam. The exterior of the utilities and hangers exhibit minor weathering and corrosion of steel hardware. The concrete duct banks that span the spillways were observed to deflect when loaded; however, no evidence of overstressing was observed. No significant deterioration was observed on the utility hangers or supports.

The dam stillwells are accessed through a utility hatch on the southeast corner of the dam. The lids do not have a spring mechanism to assist with lifting the lid and they exhibit minor corrosion.

Steel grating is used as decking on the elevated platform surrounding the control room. The steel grating exhibits minor corrosion. The grating does not have a positive connection securing the grating to the platform. In one location, the grating protrudes above the deck up to one inch.

The roof of the control room building has a modified bitumen membrane coating. The age of the coating is unknown. The roof exhibits widespread alligator cracking likely caused by extended exposure to ultraviolet radiation. The depth of the cracking is unknown and no active roof leaks were observed.

Riprap and rock armoring was observed along the upstream and downstream edges of the bottom slab and wingwalls. The riprap and armoring varied in size between two and four feet in diameter on the upstream side and up to five feet in diameter on the downstream side. The riprap lining around the channel exhibits minimal areas of voids and is consistent in size and shape.

2.2. Durability

This section summarizes the observations provided in the *Capitol Lake Dam Preservation Durability Assessment* report by Tourney Consulting Group. The durability assessment included extracting concrete samples and conducting laboratory testing to assess the concrete durability. Reinforcing steel was found in two of the six core samples (Samples 2 and 6). Visual observation of steel showed mild signs of corrosion in small isolated areas and no loss in cross-sectional area. The concrete properties assessed include:

- Type of Concrete
- Cover to Reinforcing Steel
- Acid-Soluble Chloride Concentration
- Calculated Reinforcing Steel Corrosion Rate
    - Half-Cell Potential Measurements
    - Electrical Resistivity

A summary of the sample locations, elevation per mean lower low water (MLLW), and findings from the field work and laboratory testing is provided in Table 2. The acid-soluble chloride results are provided in parts per million (PPM).

Two different concrete mix designs were used to construct the dam and were defined as Class A and Class B (SCC, 1948). The Class A concrete was used in thin, heavily reinforced members; for example, the parkway deck, control house deck, and the girders and beams. The Class B concrete was used in all reinforced and mass sections of the structures other than those covered by Class A; for example, the bottom slab, apron, footings, wingwalls, cut-off walls, overflow gravity section, and fishway channel walls.

The concrete cover was found to be relatively consistent within the two concrete class types. The Class B concrete components all had a cover of approximately 4 inches. The Class A concrete components had reduced cover of approximately 2.5 inches and 1.3 inches for the beam and deck soffit, respectively.

The average resistivities were found to be 21.5 kiloohm-centimeters (kΩ-cm) for concrete in the splash zone and 53.4 kΩ-cm for concrete within the upper tidal zone. The half-cell potential readings and resistivity measurements are used to calculate the estimated corrosion rate in micrometers per year (µm/year).

Table 2: Concrete Sample Summary

Sample No.	Dam Component	Elevation (feet MLLW)	Side of Dam	Conc Class	Cover (Inches)	Acid-Soluble Chloride Results (PPM) Depth Increments (Inches)						Corrosion Rate (µm/year)
						0-1	1-2	2-3	3-4	4-5	5-6	
2	West Pier	+9.5	Budd Inlet	B	4	3945	2044	916	246	163	145	-
1	West Pier	+13.5	Budd Inlet	B	4	5258	3800	2607	**802**	221	95	-
6	West Pier	+17.5	Budd Inlet	B	4	476	75	69	71	87	76	4.33
3	West Abutment	+10.2	Budd Inlet	B	4	4617	2421	1540	**924**	418	166	-
4	West Abutment	+12.0	Budd Inlet	B	4	4815	2813	1947	**1753**	**704**	422	1.76
5	West Abutment	+15.8	Budd Inlet	B	4	597	103	55	54	59	59	1.76
7, 8, 9	Beam	+22.0	Budd Inlet	A	2.5	186	49	47	-	-	-	N/A
10, 11, 12	Deck	+24.0	Budd Inlet	A	1.3	70	34	46	-	-	-	N/A
13, 14, 15	East Wing Wall	+23.5	Capitol Lake	B	-	146	106	111	-	-	-	0.89
16, 17, 18	West Wing Wall	+16.5	Capitol Lake	B	-	861	320	167	-	-	-	0.44

2.3. Mechanical & Electrical

This section summarizes the observations provided in the *Fifth Avenue Dam Capitol Lake Tide Gates Machinery and Controls Assessment* report by Fives Lund LLC. The spillway machinery and electrical components continue to function in the marine environment; however, areas of advancing corrosion and wear were observed. No critical areas of concern were noted but the system is showing its age. Both gates were raised and lowered through a full cycle during the site visit. The system was relatively quiet and appeared to run smoothly; no unexpected or loud noises were evident. All limits functioned as expected (normal stop and backup stop). The following summarizes the notable observations of the machinery and electrical components.

The recently replaced spillway stainless steel ropes appear to be in very good condition. The fishway plastic-coated wire rope appears compromised at the waterline with evidence of corrosion. The rope drums, drum shafts, and couplings have surface corrosion where the protective coating has failed. One of the west gate drums has a broken flange, although this does not appear to significantly affect gate operation.

The gears for both gates appear to be in fair condition with general wear and isolated instances of excessive wear or damage. The pinion gear has one gear tooth exhibiting a loss of approximately one quarter of the tooth.

The dam operators reported that some of the grease ports are bent, all are difficult to access, and appear to be blocked because it is difficult or not possible to get grease to flow to the trunnion bearings. Dam operators also noted the gate had opened beyond the limit switch and crushed the timber gate cushion. The limit switch appeared to be functioning properly during the site investigation.

The distribution panel and motor control center occupy a free-standing multi-compartment two section enclosure. Overall the enclosure appears to be in acceptable condition. Surface corrosion is persisting and approaching moderate levels. The enclosed components appear to be in good operating order.

The standby hydraulic cylinders are in poor condition and should be overhauled or replaced soon.

Below the fishway gearbox is a coupling and shaft that extend to an exposed worm gear drive that engages the drum shaft. The coupling beneath the final gearbox is exposed with features that could snag clothing. The flexible elastomeric element of this coupling appears degraded and in need of replacement.

The operational status of the siphon system is unknown; there is no way to physically verify whether the water was siphoning because piping is submerged. DES reported that a recent underwater investigation found that the intake of the 12-inch-diameter siphon pipe was buried in mud and possibly preventing the system from functioning. The reverse flow preventer that serves the siphon pump is leaking water onto the floor and appears to have been doing so for some time as witnessed by the rust stains. This is creating excessive humidity inside of the structure and accelerating the corrosion in the environment. This will have an adverse effect on electrical contacts and equipment and should be remedied.

2.4. Safety

Safety features include the components that allow safe access for the DES maintenance crew and protect the public; only components with notable observations are discussed below.

Two ladders are present on the dam. One ladder provides access from the elevated platform to the catwalk. The other ladder is accessed through the steel grating panels and provides access to the west radial gate bearing in the west spillway channel. The catwalk ladder has a few safety deficiencies:

- The elevated platform opening is an 18-inch-square opening which is less than the OSHA-required 24-inch-square opening.
- The rungs are smooth steel and an anti-slip surface is recommended.
- The ladder rails do not extend above the elevated platform’s deck surface.

The ladder extending from the grated decking into the west spillway channel is broken due to impact from the radial gate and is not safe to use.

The fiberglass catwalk railing exhibits broken or missing rails at three locations. Chain-link fencing is present along the wingwalls and along the walkway. Damage was observed in three locations in the vicinity of the concrete ramp.

OSHA and the International Building Code (IBC) state railing shall be provided at all locations where the vertical difference between surfaces is more than 30 inches. Two locations in the vicinity of the dam are not compliant with this standard. The elevated platform of the control house has a vertical drop of 42-1/2 inches from the platform to the sidewalk and no railing is present. Also, there is a gap in the fence near the northwest wingwall and there is no railing in that gap.

A broken fall-protection anchor point was observed on the control room roof.

2.5. Geotechnical

This section summarizes the observations and findings provided in the *Geotechnical Engineering Report; Capitol Lake Dam Preservation Assessment* report by Terracon Consultants, Inc.

Surface Observations

Most of the top of the dam is paved for 5th Avenue SW, Deschutes Parkway SW, and the sidewalks. Surface cracking, ruts, and holes were not apparent along the crest of the dam. Vegetation along the top of the dam consisted primarily of lawn. Minor erosion was observed on the upstream slope near the dam crest, particularly where paths down to the lake were observed on the west side of the spillway structure. Below the high-tide line, the rip rap appeared to be in good condition. There were no signs of distress from seepage or erosion at the downstream area below the dam.

Subsurface Profile

Based on existing subsurface information and the results of the borings, subsurface conditions on the project site can be generalized as described in

Table 3: Subsurface Profile (Terracon, 2016)

Stratum	Approximate Depth to Bottom of Stratum (feet)	Material Description	Consistency / Density
1 [1,2]	27 to 35	Embankment Fill sandy GRAVEL with silt	Medium dense becoming loose below about 10 feet below ground surface
2 [3]	55	Estuarine Deposits SILT, SAND, and SHELLS – embankment fill gravels may have mixed with silt at contact	Soft to Medium Stiff / Loose
3 [4]	20 to 400	Vashon recessional sand and minor silt	Stiff to Hard

1. Construction records were not available. Based on construction methods typical to the time of construction, it is assumed that fill was placed without moisture and density control. This material is typically variable in composition, consistency, density, moisture, and depth. It was difficult to discern the depth of the contact between native soil and embankment fill due to poor recovery in the samplers.
2. Boring B-1 was terminated in this unit due to borehole caving.
3. Boring B-2 was terminated at this depth in heaving sands.
4. Depth to bottom of stratum is inferred from the geologic map.

Groundwater

Groundwater was observed in boring B-2 at about 12.5 feet below ground surface. Groundwater levels can be expected to vary seasonally and from year to year depending on precipitation, site utilization, and other on- and off-site factors. Groundwater levels will also fluctuate with tide and lake water levels.

2.6. Topographic Survey

The elevations used in the original design reference the City of Olympia datum. Table 4 shows the datum conversions relative to MLLW between the City of Olympia, North American Vertical Datum of 1988 (NAVD 88), MLLW, and National Geodetic Vertical Datum of 1929 (NGVD 29) vertical datums.

Table 4: Datum Conversions

City of Olympia[1] (feet)	NAVD 88[2] (feet)	MLLW (feet)	NGVD 29[3] (feet)
-17.97	-4.03	0.00	-8.35

1. *Per KCM, 1980*
2. *Per the National Oceanic and Atmospheric Administration (NOAA) Tides and Currents website.*
3. *Per NOAA using Mean Sea Level (MSL) as an approximation for NGVD 29.*

The historical elevation data available for comparing the survey is limited. The only elevations available in the references provided by DES are the elevations of various spillway components shown on the 1995 record drawings prepared by ABAM Engineers. Table 5 shows a comparison of the PGS survey to the available historical elevations. Note that the source and accuracy of the historical elevations is unknown; therefore, a difference in the component elevations does not necessarily imply dam movement.

Table 5: Survey Elevation Comparison (PGS, 2016)

Description	1995 Elevation (feet City of Olympia)	2016 Elevation (feet NAVD 88)	Difference (feet)	Δ (feet)
Top of Concrete Spillway	-27.0	-13.5	13.5	0.4
Centerline of 5th Ave	+6.6 +/-	+20.4	13.8	0.1
Top of Concrete Pad	+11.0	+24.2	13.2	0.7
Top of Control House	+21.0	+34.4	13.3	0.6

3. Engineering Evaluation

3.1. Structural

An overall Condition Assessment Rating (CAR) was assigned to the dam as well as to each of the individual components including: abutments, wingwalls, pier walls, spillway components, riprap and rock armoring, girders and deck soffits, radial gates, the walkway, and other appurtenances. The CARs are based on the findings of the field observations. The condition assessment scale includes the following six categories: Good, Satisfactory, Fair, Poor, Serious, and Critical. Descriptions of the six CARs per ASCE 130 are provided in Table 6.

Overall, the dam is rated as “Fair”. All primary structural elements are sound, but minor to moderate defects and deterioration are observed. Localized areas of moderate deterioration are present but do not significantly reduce the structural capacity. Repairs are recommended but the priority of the recommended repairs are low unless noted otherwise.

Table 7 summarizes the CARs for the facility based on component type.

Table 6: Condition Assessment Rating Descriptions (ASCE, 1995)

CAR Rating	Description
"Good"	No visible defects or only minor defects noted. Structural elements may show very minor deterioration, but no overstressing observed. No Repairs are required.
"Satisfactory"	Limited minor to moderate defects or deterioration observed, but no overstressing observed. No repairs are required.
"Fair"	All primary structural elements are sound; but minor to moderate defects or deterioration observed. Localized areas of moderate to advanced deterioration may be present but do not significantly reduce the load bearing capacity of the structure. Repairs are recommended, but the priority of the recommended repairs is low.
"Poor"	Advanced deterioration or overstressing observed on widespread portions of the structure, but does not significantly reduce the load bearing capacity of the structure. Repairs may need to be carried out with moderate urgency.
"Serious"	Advanced deterioration, overstressing or breakage may have significantly affected the load bearing capacity of primary structural components. Local failures are possible, and loading restrictions may be necessary. Repairs may need to be carried out on a high-priority basis with urgency.
"Critical"	Very advanced deterioration, overstressing, or breakage has resulted in localized failure(s) of primary structural components. More widespread failures are possible or likely to occur, and load restrictions should be implemented as necessary. Repairs may need to be carried out on a very high priority basis with strong urgency.

Table 7: Capitol Lake Dam Facility CAR Summary

Component Type	Condition Assessment Rating (CAR)
Abutments, Wingwalls, and Pier Walls	Fair
Spillway Components	Fair
Riprap and Rock Armoring	Good
Girders and Deck Soffits	Fair
Radial Gates	Satisfactory
Walkway	Poor
Other Appurtenances	Fair
OVERALL	**Fair**

The majority of the dam is in fair condition or better. The cracking observed on the abutments, wingwalls, decking, and girders is minor and can be reasonably expected of a loaded concrete member over 65 years old. Nearly all concrete structures undergo some cracking due to shrinkage and flexure and typically the cracks are small and not a cause for concern. Efflorescence is visible in patches along the sides of the abutment and wingwall elements and nearly all the dam's exposed soffits. The presence of the efflorescence is indicative of water seepage through the concrete, which is normal and warrants no concern.

The open corrosion spall on the east downstream wingwall was likely initiated by impact from a boat or other object. Since corrosion of the exposed steel has initiated, the spall will continue to grow unless repaired.

The corrosion cracks on the fishway cross-beam soffits will eventually lead to open corrosion spalls if not repaired. These beams are more susceptible to deterioration from corrosion than the other beams and girders due to being located in the splash zone. Although these beams support fishway gate components that were abandoned in place and no longer used, they are not structurally obsolete and they should be repaired.

The steel grating on the deck surface does not have a positive connection to the concrete deck. Although the individual sections of grating are relatively heavy and unlikely to be displaced, this area is accessible to the public, therefore, we suggest installing a positive connection to prevent tampering or unsafe conditions.

The timber platform above the east downstream wingwall will continue to deteriorate unless measures are taken to remedy the issue. The timber post bases are rotting and the rate of deterioration will increase now that the protective treatment is compromised. The undermined foundation was likely caused by wind-waves coming from the north at high tide. Riprap should be placed on the slope to prevent additional erosion. Repairing the timber posts and protecting the foundation should be completed with moderate urgency.

The seals on the radial gates are in poor condition. Flow through the damaged seals does not yet significantly affect the dam's performance. However, the leaks in the seals compromise the integrity of the surrounding (and still intact) seals by initiating small currents, or flows of water through the openings. The localized points of pressure caused by the ongoing currents make the surrounding seals more susceptible to failure by being torn or becoming separated altogether from the gates near the openings.

The general conditions observed during the inspection are relatively consistent with the conditions reported in the M&N 2008 report. The condition of the wingwalls, abutments, pier walls, ogee crest, and bottom slab have generally remained unchanged. Hairline cracking and efflorescence has remained similar to that observed during the previous inspection. Some spalls on the bottom slab previously noted may have been obscured by accumulated sediment and were not observed, but they are not considered to have an adverse impact on the overall structural condition.

The steel coating loss is more widespread; however, the corrosion of radial gate components has not significantly increased since the previous inspection. Leaks in the radial arm seals are still present and do not appear to have increased in size.

Rock armoring appears to have remained in place and in the same general condition as previously noted.

3.2. Durability

The durability assessment considers the field observations, laboratory findings, and results from M&N's 2008 assessment. This evaluation is focused on the corrosion of the reinforcing steel due to chloride ions penetrating the concrete.

The concrete transport properties tested in 2008 indicate a good quality concrete with low permeability for both classes of concrete (M&N, 2008); meaning the concrete will have a slow rate of chloride ion infiltration. This agrees with the limited number of corrosion-related defects observed during the visual investigation given the age of the structure.

The splash zone is commonly one of the more severe areas of steel corrosion due to the presence of oxygen, moisture, and chlorides. Corrosion of the reinforcing steel is generally minimal below MLLW where components are continuously submerged or embedded in subsoil due to the reduced oxygen levels. Figure 6 illustrates the elevation ranges commonly found to exhibit corrosion. The figure shows the elevation range with the greatest probability of corrosion is in the splash zone above high tide.

Corrosion of reinforcing steel typically occurs when concrete becomes significantly contaminated with chloride ions. If a chloride concentration of 0.05 percent (500 ppm) by weight of concrete or greater is measured at the level of the reinforcement, it is reasonable to assume that corrosion of the reinforcing steel has initiated or will initiate in the near future. The 0.05 percent threshold is a general rule of thumb, indicating a significant level of chloride contamination in the concrete matrix (ASCE, 2015). When the threshold is exceeded, a concrete structure typically exhibits corrosion spalls that are induced by corroded reinforcing steel. Chloride-induced spalling may not be evident for four or ten years from the time the chloride ion concentration reaches the critical point in the concrete.

Samples 1, 3, and 4 were found to have chloride concentrations greater than 500 ppm at or near the depth of reinforcing steel. The elevation range of these samples is between +10 and +13.5 feet MLLW. These elevations are near mean high tide and in the splash zone which correlate to elevations within the highly corrosive environment.

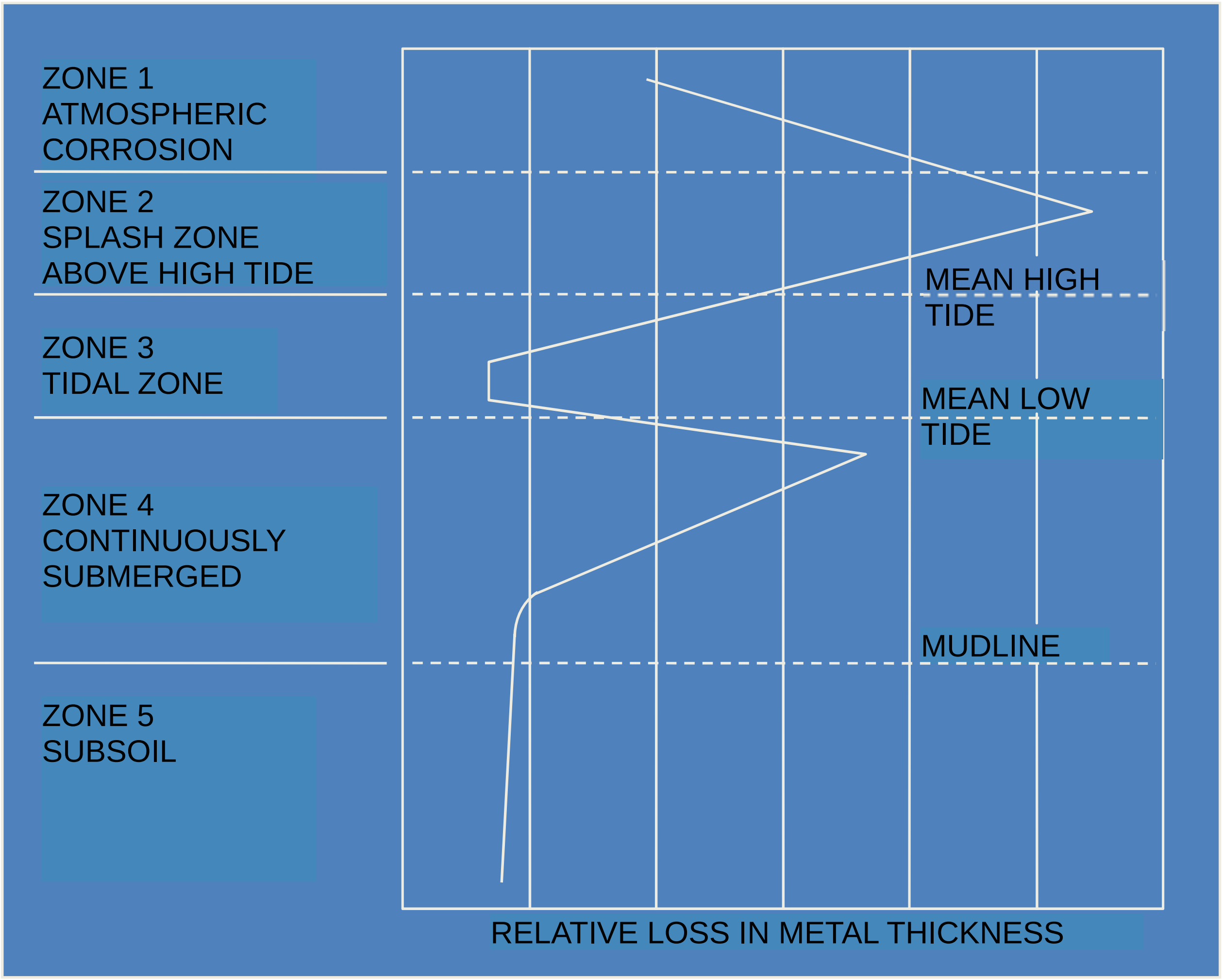

Figure 6: Relative Loss in Metal Thickness at Elevation Ranges

The half-cell potential findings also indicate there is high potential for corrosion within the upper tidal zone and splash zone. There is greater than 90 percent probability there is corrosion activity within these areas. Areas above the splash zone have less potential for corrosion and the estimated corrosion activity is within the range that is either less than 10 percent probability or the probability is uncertain.

Higher levels of chloride concentrations at the reinforcement were found in the Class B concrete even though the concrete cover was consistently greater than the Class A concrete. This is likely because the Class A concrete components are in the upper reaches of the splash zone or the atmospheric zone where the chloride exposure is less than that of the Class B components.

The minor rust spots observed on the reinforcing steel extracted with the concrete samples is to be expected given the chloride content typically found at the reinforcement depth. However, the samples containing the reinforcing steel, Samples 2 and 6, had relatively low chloride concentrations at the level of the reinforcement; therefore, the rust spots may have occurred post-extraction during transport to the laboratory.

The chloride concentrations found in 2008 were converted from ppm weight of cement to ppm weight of concrete to compare the two results. The 2008 findings indicated the chloride concentration was above the threshold at the abutments and pier walls — which agrees with these findings. The comparison also indicates the chloride content at the reinforcement level has increased since 2008.

Even though corrosion may have initiated, the corrosion rate may be low. Therefore, it may take longer than the typical four to ten years for crack propagation and spalling to occur due to the low corrosion rates exhibited in this structure as a result of the use of high-quality, low-permeability concrete, adequate depth of cover for the reinforcing bars, and the size of the reinforcing bars.

3.3. Mechanical and Electrical

This section summarizes the recommendations provided in the *Fifth Avenue Dam Capitol Lake Tide Gates Machinery and Controls Assessment* report by Fives Lund LLC. The tide gate machinery is generally in fair to poor condition due to the advanced age of the components and potential overloads that have occurred over the years. The replacement of aging machinery should be expected to maintain operations. Proper maintenance, testing, and inspections of the gate machinery will prolong the service life of the machinery.

A special assessment by a biologist is recommended for Capitol Lake to determine if the siphon system is still necessary. Assessing the need for the siphon system will justify whether to repair the siphon system. If it is determined the siphon system is still needed, a thoroughly inspection of the system is recommended to determine the required repairs.

Areas where dissimilar metals are in contact should be monitored during maintenance, testing, and inspections to look for evidence of electrochemical degradation. During electrochemical degradation, the less noble metal acts as the anode in a galvanic cell and will corrode. Dissimilar metals can unintentionally be in contact where coatings have failed. For example, the gate lifting ropes were recently replaced with stainless steel ropes that are wound onto a painted steel drum. The dissimilar metals are in contact where the drum paint has failed. The steel drum is less noble than stainless steel rope and may lead to corrosion and section loss of the drum.

The electrical distribution equipment is in fair condition; although it has exceeded its normal life expectancy. With proper maintenance and continued operation, the electrical equipment may continue to operate for an undetermined amount of time. The age and level of degradation of all equipment leads to a higher than normal probability of malfunction.

If the electrical system continues to be exposed to the humidity created from the leaking siphon control system, it will accelerate the deterioration of the electrical system. In general, equipment should be protected from high humidity; covers with holes or that enable moisture to enter the control room should be restored or replaced. Restoring or replacing individual electrical components for equipment of this age may be difficult due to the minimal availability of parts.

If a full redesign of the electrical equipment is considered at any point, DES should be aware of current regulatory design codes, such as the National Fire Protection Agency. The existing control room floor plan may not meet these standards and could require significant improvements to meet current codes.

3.4. Geotechnical

This section summarizes the recommendations provided in the *Geotechnical Engineering Report; Capitol Lake Dam Preservation Assessment* report by Terracon Consultants, Inc. The geotechnical assessment evaluated the dam for stability in the static condition and during a seismic event. The earthquakes from 1949, 1965, and 2001 provided valuable comparisons for how the dam would respond to a seismic event. The modeling results indicate that the dam is stable in the static condition. The calculated factor of safety is approximately 1.3 assuming the water level on the Budd Inlet side of the dam is at MSL. This modeling is consistent with the dam history and visual observations of the dam condition during the site reconnaissance, which did not disclose areas of noticeable dam embankment distress. The most critical static case occurs at an extreme low tide at the downstream toe of the dam. The calculated factor of safety is approximately 1.1 for this case based on interpreting the borings logged in 1948 which show loose to very loose, saturated, silt with variable sand content at the contact between the dam fill and former estuary bottom. It should be noted that if the loose surficial soil at the previous mudline were removed or displaced during original construction of the dam, better soil than assumed in the analyses could be present near the contact of the dam embankment and the mudline. However, the lack of construction records related to the dam construction does not allow alternate interpretations of the ground conditions present at the contact between the dam embankment and the previous mudline.

The evaluation of a seismic event found that the embankment foundation soils are susceptible to liquefaction which could have significant impacts to the Capitol Lake Dam. Liquefaction occurs in soils located below the water table. Loose sands are most susceptible to liquefaction, but non-plastic and low plasticity fine-grained (silt and clay) soils are also susceptible. During strong ground shaking, the soil particles start to densify, but the loading is too rapid for the water to dissipate and the soil particles lose their grain-to-grain contact. As a result, a viscous fluid mass of soil is formed with reduced strength.

The bank failures observed during past earthquakes around Capitol Lake are the result of loose, saturated soils liquefying and losing strength. These previous instances of liquefaction are relatively shallow. If ground shaking is strong enough, liquefaction may occur to considerable depth in susceptible soils.

The findings indicate the embankment foundation soils could liquefy with peak ground acceleration (PGA) values as low 0.30g. PGA is the maximum horizontal value of ground acceleration recorded at a site during the seismic event. A PGA value of 0.30g equates to an earthquake return period of approximately 225 years. More specifically, the loose to medium dense sand layer modeled between the elevations of -25 and -35 feet NGVD 29 could liquefy and lose strength. The factor of safety for this sand layer is less than 1.0 indicating significant embankment displacements (i.e., greater than 1 meter) may occur. The displacements may damage utilities embedded in the embankment, reduce freeboard, or result in overtopping of the dam.

The vegetation on the embankment slopes should be monitored and maintained to avoid heavy vegetation. Heavy vegetation may obscure indications of dam distress and the roots can loosen soils.

Soil layers typically exhibit high variations in soil types and densities. Subsurface conditions throughout the embankment may differ from the two borings taken. Additional standard penetration test (SPT) borings and advancement of cone penetrometer test (CPT) soundings would provide a higher level of confidence in the findings and recommended mitigation measures. Measurement of shear wave velocity values would also aid the assessment of seismic site response.

3.5. Original Design Criteria

Various design criteria from the dam's original construction can be compared to current operating conditions to evaluate the adequacy of the original design criteria. The original design criteria and known current operating conditions are provided in Table 8. Based on the available information, it appears the original hydraulic and hydrologic design assumptions are adequate.

Table 8: Original Design Criteria Comparison

Design Criteria	Design Value (KCM, 1980)	Current Operating Condition
Design Normal Water Surface of Capitol Lake	-4.0 feet Olympia; +14 feet MLLW	-3.5 feet to -4.0 feet
Design Maximum flow at high tide	10,000 cubic feet per second	8,600 cubic feet per second[1]
Design Tidal Range	22.47 feet	14.56 feet[2]

1. *Extreme recorded discharge records of the Deschutes River near Olympia are available from the USGS at the E Street gauge. 8,600 cubic feet per second was recorded on February 9, 1996.*
2. *Per NOAA Station 9446969 at Bud Inlet in Olympia, WA*

4. Permitting

In-water and/or above-water projects of any kind[1], ranging from simple repairs to more complex redevelopment activities, must comply with a number of federal, state, and local laws and regulations before construction can begin. Each regulatory agency has statutory responsibility for certain aspects of environmental protection and for proposed activities to avoid, minimize and/or mitigate for potential adverse environmental impacts that could result during construction or eventual operation of the completed facility/infrastructure. Impacts include those that can affect not only the biological environment, but also the physical environment (the existing shoreline) and human environment (impacts to public access, in-air noise, existing traffic and parking patterns).

The following permits and approvals are anticipated for the majority of repairs and/or improvements, but will vary in level of effort, cost, and time to complete:

- State Environmental Policy Act (SEPA) Review – Exemption anticipated for repairs
- City of Olympia Substantial Shoreline Development Permit (SSDP) – Exemption anticipated for repairs
- WDFW Hydraulic Project Approval (HPA)

[1] Work that extends waterward of the ordinary high water mark (OHWM). The OHWM is commonly estimated as the mean higher high water (MHHW) line which is 14.56 feet MLLW at the Capital Lake Dam (NOAA).

- US Army Corps of Engineers (USACE) Section 10 Permit – A Nationwide Permit (NWP) may be applicable for repairs
- Washington State Department of Ecology (Ecology) Section 401 Water Quality Certification (WQC) (separate permit may not be required if the repairs meet all of the USACE NWP conditions)
- Coordination with the Department of Natural Resources (DNR) on any proposed changes to tideland leases or lease conditions are not anticipated, and, if required, would be the responsibility of DES.
- Local permits as necessary (e.g. local Land Use or Building Permits)

All of the above permits and approvals take time to complete and can impact the final design, schedule, and overall cost of a repair and/or improvement project. Many permits may also include the payment of review fees to the responsible agency (e.g. WDFW, local City permitting department).

Agency review and permitting can take anywhere from three to six months to complete. More complex projects can take upwards of 10 to 12 months to permit depending on the necessary investigations and reviews. For modifications to the existing use and/or structure that result in the potential for short- or long-term impacts (from construction activities or future operations), more detailed analysis is required and avoidance measures and mitigation may be necessary. This can result in the need for field surveys to assess potential impacts on biological resources (macroalgae, eelgrass presence surveys, wetland delineations) and other resources (archaeological).

In-water work windows vary by location and are established to avoid critical fish migration periods. At Capitol Lake Dam, work below the ordinary high water mark (OHWM) must occur from July 1 through July 31 of any year. If work past July 31 becomes necessary, a work window modification may be submitted for review by the applicable resource agency(ies). For example, a past HPA for dam repairs allowed for work to occur from September 1 through October 11 given special fishway closure restrictions.

Any existing USACE NWP currently held or obtained before March 2017, will have an expiration date of March 2017 (with a 1-year extension allowance if work is underway or under contract). Any NWP applied for after March 18, 2017 will have a maximum authorization period of up to March 2022. DES may want to consider submitting one application after March 18, 2017, for one 5-year NWP covering a majority of the repair recommendations that fall in the two- to seven-year range. A similar approach could be completed for the SEPA and SSDP Exemptions. While this type of process could result in timing and cost benefits, delaying submittal of a permit application past March 18, 2017 may result in not obtaining the NWP prior to the opening of the 2017 in-water work window. Consideration of these types of benefits against the possible schedule risks is important.

5. Maintenance & Repair Recommendations

The Capitol Lake Dam should maintain its existing functionality over the next 50 years if an appropriate and aggressive program of inspection and repair is followed and natural disasters or other major events, such as earthquakes, do not occur. Because chloride levels exceeding the 0.05 percent threshold were detected, initial repairs of spalls and cracks and installing a corrosion inhibiting mechanism will be necessary as part of the maintenance program. The replacement of aging machinery should be expected to maintain operations. Proper maintenance, testing, and inspections of the gate machinery will prolong the service life of the machinery. The following subsections provide considerations regarding inspection, spall repair, anti-corrosion measures, and geotechnical mitigation measures.

5.1. Inspection Frequency

Inspections are intended as a form of routine preventative maintenance and should identify the need for repairs as necessary. Preventative maintenance should consider the age of components and repairs relative to the design life of those components and repairs. A list of routine inspections of the machinery and controls is provided in the DES SOP manual (DES, 2016). DES maintenance staff and operators should create and maintain a log of all maintenance and incidents that occur. The log should include a schedule for all maintenance and record the date, technician, what was done, and part number/description of any consumables or lubrication used. The log should also include entries for any unscheduled maintenance and/or repair work done to the system.

ASCE 130 provides guidance on structural inspection intervals based on the material type, condition rating, and environment. Given the overall dam condition of fair, ASCE recommends Routine Inspections every four years. If a Routine Inspection identifies required repairs, a Repair Design Inspection is required to collect the necessary information for designing a repair. Post-Event Inspections should be conducted as necessary following significant, potentially damage-causing events. Each type of inspection is fully defined in ASCE 130, and is summarized below.

Routine Inspections

The primary purpose of a routine inspection is to assess the general overall condition of the structure, assign a condition assessment rating to the portions of the structure, and recommend what future course of action should be taken for the structure, if any. Routine inspections should be performed on a routine, cyclical basis and therefore represent a proactive, rather than reactive, approach to maintenance. During these inspections, previously reported damage should be observed and any discrepancies noted.

Post-Event Inspections

Post-Event Inspections should be conducted after a significant, potentially damage-causing event such as a flood, earthquake, storm, vessel impact, or tsunami. The primary purpose of a post-event inspection is to rapidly assess the structural stability of the structure and determine whether further attention to the structure is necessary as a result of the event. Post-Event Inspections are intended to be relatively rapid, visual or tactile inspections conducted to determine whether the event resulted in any significant damage requiring repairs, load restrictions, or further investigation.

An earthquake, such as the Nisqually Earthquake of 2001, is arguably the most significant type of recurring natural event to affect structures in Olympia. A Post-Event Inspection is recommended to be carried out within a reasonable amount of time following any earthquake or other event that potentially affects the stability or functionality of the Capitol Lake Dam. Adequate time should be allowed between the time the event occurs and the time the inspection takes place to ensure the structure can be safely accessed without concern of post-event occurrences, such as aftershocks in the case of an earthquake.

5.2. Concrete Spall Repair Methods

The suggested repair measures for corrosion cracking and spalling include removing loose and deteriorated concrete and patching with a non-shrink epoxy mortar. Good preparation and installation technique are essential to a long-lived repair. An example of a patching material is SikaRepair® 223. When selecting a repair material, the properties of the selected mortar shall be comparable to the properties of the concrete. Following is a general spall repair procedure and Figure 7 illustrates this procedure.

1. Clean the area and remove all loose material.
2. Saw cut the edge of the area to minimum depth of 1 inch. The concrete should be cut in a rectangular pattern around the damage.
3. Remove concrete until there is 1-inch clear behind the reinforcing bar. Clean all loose material from the surface of the spall and blast or grind to produce a surface roughness with approximately ¼-inch of depth variation. Clean rust from the exposed reinforcing.
4. Discrete anodes or linear anodes should be installed within the patched area. Otherwise, it is common for accelerated deterioration to occur in the existing concrete surrounding the patched area.
5. Dampen the surface of the spall with water. The surface should be saturated, but should not have standing water. Scrub in a thin mixture of the repair mortar.
6. Apply repair mortar in lifts no thicker than manufacturer's recommendations to fill the void.
7. Cure the repair with methods used for typical concrete.

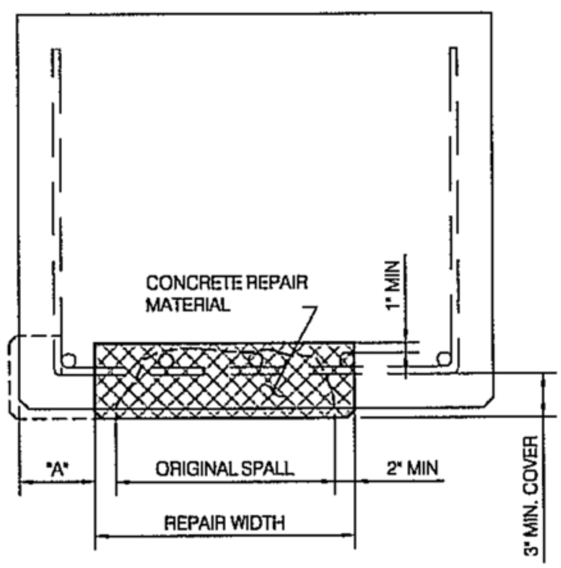

Figure 7. Patch Repair General Section

5.3. Anti-Corrosion Measures

The Capitol Lake Dam has reached an age where even a good concrete mix will start to see some corrosion of the reinforcing without intervention. Intervention will require implementing a chloride inhibiting system, or anti-corrosion mechanism. There are four basic types of anti-corrosion mechanisms: cathodic protection; electrochemical chloride extraction; corrosion inhibitors; and concrete removal.

Cathodic Protection

There are two types of cathodic protection: passive systems and active systems. Both systems prevent new corrosion activity from initiating while simultaneously reducing ongoing corrosion activity.

In many passive cathodic protection systems, galvanic anodes are embedded into the concrete and connected by a wire to the reinforcing steel. The anodes serve as sacrificial units that draw chloride ions away from the reinforcing steel. An example of an embedded anode passive cathodic protection system is Galvashield® CC, by Vector™. Another type of passive system that does not involve embedding units into the concrete is a zinc coating applied to the outside of the structure to act as a sacrificial anode. Passive cathodic protection is one of the most common means of providing corrosion protection to marine structures. Anode installation is a relatively simple process. Maintenance includes regular replacement of the anodes. The typical anode replacement interval is 10 years.

An impressed current system uses anodes connected to an external DC power source, typically a transformer-rectifier connected to AC power. The number of anodes and required power must be designed based on the structure details. Impressed current systems typically have higher initial construction cost; however, the long-term cost is generally lower. Long-term costs are generally limited to rectifier replacement within 15-25 years, regular monitoring, and periodic adjustments. Routine maintenance of active cathodic systems is critical, because malfunctions can be difficult to detect. Examples of impressed current systems include Ebonex® or Vectrode® by Vector™.

Electrochemical chloride extraction

Electrochemical chloride extraction removes chloride ions electrically from contaminated concrete. Chloride ions are extracted by applying a temporary electric field between the reinforcing steel in the concrete and an externally mounted anode mesh. While the ions are being transported out of the concrete, electrolysis at the reinforcement surface produces a high pH environment, returning the reinforcing steel to a passive condition over a period. An example of an electrochemical chloride extraction system is Norcure® Chloride Extraction, by Vector™.

Electrochemical chloride extraction is typically used on highway bridges and other structures that are not normally exposed to chlorides (i.e. exposure only comes from road salts); it is not normally applied to submerged structures or to structures that are in constant contact with chlorides. Consequently, this solution is not likely to be appropriate for the Capitol Lake Dam.

Penetrating Corrosion Inhibitors

Penetrating corrosion inhibitors are a means to halt the ongoing corrosion reaction. This type of system can be painted on the structure's surface, allowing it to migrate through the concrete and protect the passive layer of the reinforcing steel, thus preventing corrosion and spalling. There are several types of penetrating corrosion inhibitors, and different mechanisms have different design lives. An example of a penetrating corrosion inhibitor is Sika FerroGard® 903. Penetrating corrosion inhibitors must be applied in the dry; consequently, it would be difficult to apply this product to all areas of the dam.

Concrete Removal

Using concrete removal as an anti-corrosion mechanism involves significant effort and cost. The contaminated concrete is physically removed from the structure and replaced. The extent of the concrete removal is determined by the depth that chloride contamination is known to exist.

Selected Anti-Corrosion Method

The most suitable corrosion protection solution is determined by evaluating the existing corrosion behavior, cost and availability of each method, acceptable maintenance costs and frequencies, and desired extension of service life. From a permitting standpoint, all of the methods are generally considered acceptable. Based on the findings, an impressed current cathodic protection system is recommended for the concrete walls within the tidal zones and above. The system installation is recommended within the next two to three years before physical damage to the concrete occurs.

5.4. Geotechnical Mitigation Measures

Various mitigation measures can be considered when rehabilitating an existing embankment dam or stabilizing liquefaction-susceptible soils, including: improving the properties of the dam and/or foundation soil, modifying the geometry of the existing dam, or a combination of these methods. The following is a description of potential mitigation methods (Terracon 2016):

- Construct a berm on the downstream side to buttress the dam and improve the embankment's stability.
- Add drains to improve stability by lowering the phreatic surface (reducing soil pore pressure to atmospheric level) and providing relief for earthquake-induced pore pressures.
- Install stone columns to increase the density of loose soils and act as drains to reduce liquefaction potential.
- Conduct deep soil mixing or jet grouting to improve shear strength of the materials and provide containment of liquefiable soils.
- Conduct compaction grouting to densify loose granular soils and reinforce fine-grained soils.

The various mitigation measures are beneficial for different earthquake intensities and therefore, a combination of mitigation measures may be considered. For lower earthquake return periods, the combination of a buttress berm and improved drainage would improve the dam stability. For higher earthquake return periods, the most economically feasible mitigation measure to stabilize the dame is likely deep soil mixing or jet grouting.

5.5. Opinion of Probable Cost and Urgency

This section provides details of the recommendations, the associated urgency, and opinion of probable cost of the recommendations. Table 9 provides the following details for each recommendation:

- Recommended repairs sorted from higher urgency to lower urgency
- Repair urgency
- The reason for the recommendation and/or the potential risks if no action is taken
- Rough order of magnitude opinion of probable costs (ROM OPC)

The suggested urgencies are discretionary and are based on M&N's understanding of dam operations. DES should also assess the listed urgencies considering dam operations, public utilities, and city streets. Impacts downstream of the dam may be considered; however, the Department of Ecology Dam Safety Office has assigned the dam a Hazard Class index of 3, implying there are no lives at risk if the dam were to fail and release the reservoir (Ecology, 2015).

The urgencies consider the estimated remaining service life of the component, possible impacts if no action is taken, and the safety of the public and maintenance staff. The following descriptions explain how urgency is assigned to the various recommendations and the approximate suggested timeline for action.

> *High Urgency* – Immediate action is recommended when public or maintenance staff safety is at risk, imminent failure of a major component is possible, or a critical component that affects dam operations has already failed.
>
> *Moderate Urgency* – Action is required within 1 to 2 years. This applies to components that are still functioning, but there is no estimated remaining service life.
>
> *Low Urgency* – Action is recommended within 3 to 5 years. This applies to components with service life remaining, but deterioration has initiated and no-action within 3 to 5 years will result in significant deterioration. This may also apply to deteriorated secondary components that are not critical to dam operations and deteriorated major components that have a low risk of failure within 3 to 5 years

An opinion of the potential risks associated with not repairing or upgrading components is considered. For this report, risks are generally limited to dam functionality or public and staff safety near the dam. DES should consider a comprehensive risk assessment to identify the broader risks associated with the dam.

The ROM OPC for individual items include the costs for materials, equipment, labor, and engineer design services. The costs for mobilization/demobilization, Washington State sales tax, construction/bidding/design contingency, contractor overhead and profit, environmental permitting, street closure cost, and construction administration are not included. Savings may be realized through performing multiple tasks during a single period of time.

The observations and findings used to develop the ROM OPC have inherent limitations. Therefore, the quantities used in this ROM OPC are approximate; actual conditions could vary greatly due to the limited scope of the inspection and the extent of deterioration that may occur before repairs are conducted.

Table 9: Recommended Action, Urgency, Risk, and Rough Order of Magnitude Opinion of Probable Cost

Item No.	Item Description	Recommended Action	Urgency	Reason for Recommendation / Potential Risk if No Action	ROM OPC
1[2]	Standby Hydraulic System - Gate Attachment	Install chain that allows attachment of the standby ropes to the gate without necessity of diving. Chain should be installed as to not interfere with normal operation of the gate.	High	Existing chains not attached and standby system cannot operate gate; Improvements will increase safety and efficiency during emergency situations	$37,500
2[2]	Gate Trunnion – Lubrication	Replace and relocate access of all the existing trunnion lubrication ports and tubing.	High	Accelerated wear of trunnion and reduced service life; Possibly not able to operate gates	$37,500
3[2]	Standby Hydraulic System - Cylinders	Remove and refurbish or replace the existing hydraulic cylinders.	High	Cylinders have exceeded the service life; Not able to operate dam in an emergency	$32,000
4[2]	Electrical Panel and Motor Control Center (MCC) - Conduits	Seal around exterior penetrations, replace all outlet box and conduit body covers.	High	No action may lead to early corrosion and deterioration of components and reduced service life	$1,300
5[2]	Electrical Panel and MCC - Receptacle Cover - Shock Hazard	Upgrade to weatherproof cover or eliminate receptacle.	High	Public and staff safety	$1,300
6[2]	Gate Trunnions – Friction	Take amp meter readings of gate motors to detect over loading of the motor and drive system.	High	Mitigate increased rate of wear	$1,700
7[2]	Capitol Lake Controls (METASYS) - Enclosure	Cover holes in door left by prior components to prevent ingress of moisture into panel.	High	No action may lead to early corrosion and deterioration of components and reduced service life	$4,300
8[2]	Capitol Lake Controls (METASYS) - Level Sensors	Terminate connections at stilling wells within raceway system.	High	No action may lead to non-functioning sensors; Inadequate dam operations	$2,200

Table 9: Recommended Action, Urgency, Risk, and Rough Order of Magnitude Opinion of Probable Cost

Item No.	Item Description	Recommended Action	Urgency	Reason for Recommendation / Potential Risk if No Action	ROM OPC
9[2]	Fish Gate - Exposed Coupling Cover	Install OSHA compliant machine guard around the couplings near the deck.	High	Public Safety	$12,600
10[2]	Fish Gate - Drive Components	The operator switch for the device can be accessed easily by the public, exposing the device to vandalism or uncontrolled operation of the gate. Place padlocked protective cover to prevent access.	High	Public Safety and dam operations	$12,600
11[2]	Fish Gate - Wire Rope	Replace the wire ropes.	High	No action may lead to sudden failure of fish gate	$19,200
12[2]	Coupling Guards	The shaft couplings connecting the gate electric motors to the gear reducers should have removable guards installed to be in compliance with OSHA 1917.151 for rotating machinery.	High	Maintenance staff safety	$6,500
13[2]	West Gate Motor/Brake	Replace motor/brake unit. Existing motor/brake continues to function but appears to be aging.	High	Risk of not being able to operate west gate during a flood event.	$15,000
14	Timber Walkway Repairs	Replace posts and repair and protect undermined foundation.	High	Public safety	$20,000
15	Fencing/Guardrails	Install and repair fencing/guardrails.	High	Public and maintenance staff safety	$5,000
16	Steel Grating Repair	Provide positive connection to concrete surface.	High	Public safety	$2,500
17	Ladder Repairs	Remove damaged ladder on west abutment; Ladder to catwalk - provide ladder extension and non-slip coating on rungs.	Moderate	Maintenance staff safety	$5,000
18	Roof Repairs	Replace control room roof and fall protection anchor point	Moderate	No action may lead to leaking roof and equipment moisture damage;	$12,000

Table 9: Recommended Action, Urgency, Risk, and Rough Order of Magnitude Opinion of Probable Cost

Item No.	Item Description	Recommended Action	Urgency	Reason for Recommendation / Potential Risk if No Action	ROM OPC
				there is no permanent fall protection anchor point on roof	
19[2]	Exposed Spur Gears and Gear Drive Chain	Replace damaged pinions and realign. Remove, clean and inspect all gearing. Re-lubricate before placing back in service. Replace gear drive chain.	Moderate	No action may lead to early deterioration of components and reduced service life	$144, 200
20[2]	Gate Position Sensors	Replace potentiometer and limit switches with updated technology	Moderate	Improved dam reliability	$9,800
21[2]	Standby Hydraulic System - Filter	Install pressure gauges before and after the filter to allow pressure drop indication of filter.	Moderate	Improved monitoring	$12,000
22[2]	Gate Trunnion – Cleaning and Inspection	The gate trunnions should be dismantled, cleaned of marine life and debris and assessed for wear and damage.	Moderate	Failure would impact ability to prevent flooding	$64,600
23[2]	Gear Reducers – Breather Cap	Replace old breather caps with new.	Moderate	Mitigate increased rate of wear	$200
24[2]	Fish Gate - Exposed Coupling	Remove and inspect. At a minimum replace the elastomeric element.	Moderate	Mitigate increased rate of wear	$2,000
25	Repair Radial Gate Seals	Remove and install new gate seals.	Moderate	Not replacing the seals will increase the rate of deterioration where the seals have already failed.	$115,000
26[2]	Standby Hydraulic System - Rigging	Replace corroded wire ropes as necessary.	Low	Currently under contract to be replaced with Item 1	$10,500

Table 9: Recommended Action, Urgency, Risk, and Rough Order of Magnitude Opinion of Probable Cost

Item No.	Item Description	Recommended Action	Urgency	Reason for Recommendation / Potential Risk if No Action	ROM OPC
27[2]	Gate Bearing Blocks / Shafts / Couplings	Remove bearings and examine shafts and bearings for wear. Replace damaged seals. Replace bearings as needed. Replace any damaged or corroded bolts and tighten to manufacturer's specifications (if available). Replace or refurbish worn shafts. Clean and repaint shaft. Remove and inspect couplings.	Low	Mitigate increased rate of wear	$67,100
28[2]	Gear Reducers – Replace[2]	Take existing gear reducers from service and send to gear rehabilitator for inspection of gear unit internals. Refurbish as necessary. Alternatively replace the unit with new. Replacement with new would reduce the time a gate would be out of service.	Low	Mitigate increased rate of wear	$32,300
29	Wingwall - Concrete Spalls	Repair spall per Figure 7.	Low	Not repairing the spall will lead to an increased rate of deterioration in the vicinity of the spall	$9,000
30	Repair Stoplog Cutouts	Remove debris and failed coating and recoat.	Low	The steel coating is failing, and corrosion has initiated on the unprotected steel. A fresh coating will protect the steel from section loss and eventual replacement.	$35,000
31	Fishway Beams - Concrete Spalls	Repair spall per Figure 7.	Low	Not repairing the spall will lead to an increased rate of deterioration in the vicinity of the spall	$18,000
32	Recoat Radial Gates	Remove debris and failed coating and recoat.	Low	The steel coating is failing, and corrosion has initiated on the unprotected steel. A fresh coating will protect the steel from section loss and eventual replacement.	$180,000

Table 9: Recommended Action, Urgency, Risk, and Rough Order of Magnitude Opinion of Probable Cost

Item No.	Item Description	Recommended Action	Urgency	Reason for Recommendation / Potential Risk if No Action	ROM OPC
33	Replace Stillwell Hatch	Replace with spring-assisted hatch.	Low	Replacement will improve hatch operability	$15,000
34	Concrete Ramp	Remove adjacent tree and repair the concrete ramp.	Low	No action may lead to additional ramp damage	$6,000
35	Gate Cushions	Replace timber gate cushions.	Low	No action may lead to concrete and steel gate impact damage if the gates by pass the limit switch	$10,000
36[3]	Concrete Spillways	Install a cathodic protection system to protect the reinforcing steel within the tidal zone and splash zone	Low	Without cathodic protection, the concrete's remaining service life is 10 years; at that point cracks and spalls will propagate to the surface and the embedded reinforcing steel will exhibit section loss. With cathodic protection, the remaining service life could be designed for 50 years.	$800,000
37[1]	Embankment	Deep soil mixing or jet grouting to improve shear strength and containment of liquefiable soils.	Low	Failure of the earthen embankment during a seismic event	$15,000,000
38[1]	Embankment	Buttressing berm (downstream side) to improve stability.	Low	Failure of the earthen embankment during a seismic event	$1,500,000
39[1]	Embankment	Add drainage to improve stability.	Low	Failure of the earthen embankment during a seismic event	$500,000

1. *Terracon, 2016*
2. *Fives Lund LLC, 2016*
3. *TCG, 2016*

The sum of the recommended repair costs per year is illustrated in Figure 8 with the exception of the recommended embankment improvements. The large magnitude of cost for the embankment repairs relative to the other repair recommendations overpowers the data illustrated by the graph and therefore is not included. The ROM OPCs for low urgency items are spread equally over years three through five. The intent of this figure is to show the magnitude of repair costs to anticipate each year for the next five years. This does not account for unanticipated repair items or preventative maintenance not listed in Table 9.

Figure 8: Estimated repair costs by year

6. Conclusions

The Capitol Lake Dam was built between 1949 and 1952 and has therefore been in service for nearly 70 years. The dam has maintained its structural integrity since its initial construction, and given the dam's age combined with the fact that it has not been adversely affected by environmental factors, a structural failure is unlikely if existing loading conditions and regular maintenance and inspection are sustained. The strength of the dam is further demonstrated by its ability to remain in place during the Nisqually Earthquake of 2001, one of the largest on record in Washington State history. The Nisqually Earthquake measured 6.8 on the Richter Scale, and the epicenter of the seismic activity was approximately 10 miles northeast of Olympia. No major visible structural damage or noticeable settlement was reported following the earthquake.

7. References

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APPENDIX A – Capitol Lake Dam Preservation Structural Condition Assessment Report

Project Name: Capitol Lake Dam Preservation
Project Number: 2016-931

Structural Condition Assessment Report

Presented to:

Washington State Department of Enterprise Services

March 3, 2017

Prepared By

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Executive Summary

Moffatt & Nichol (M&N) was retained by the Washington State Department of Enterprise Services (DES) to perform a waterfront facility inspection and to provide a condition assessment of the Capitol Lake Dam located in Olympia, Washington. The observations noted in the field were analyzed to ascertain a condition assessment rating for the structure and to determine repair recommendations and associated repair costs.

An overall Condition Assessment Rating (CAR) was assigned to the dam as well as to each of the individual components. The CARs are based on the findings of the field observations. The condition assessment scale includes the following six categories: Good, Satisfactory, Fair, Poor, Serious, and Critical. Descriptions of the six CARs are provided in Table 2. Table ES-1 summarizes the CARs for the facility

Table ES-1: Capitol Lake Dam Facility CAR Summary

Component	Condition Assessment Rating (CAR)
Abutments, Wingwalls, and Pier Walls	Fair
Spillway Components	Fair
Riprap and Rock Armoring	Good
Girders and Deck Soffits	Fair
Radial Gates	Satisfactory
Walkway	Poor
Other Appurtenances	Fair
OVERALL	**Fair**
Note: Radial Gate seals were in Poor Condition in 2007	

Repair recommendations are provided and the rough order of magnitude total project cost of those repairs is $550,000. Note that the observations and findings used to develop the costs have inherent limitations and actual repair quantities and costs may be significantly different depending on the condition of those portions of the structure and when the repairs are performed.

1. Introduction

1.1. Objective and Background

Moffatt & Nichol (M&N) was retained by the Washington State Department of Enterprise Services (DES) to perform a waterfront facility inspection and to provide a condition assessment of the Capitol Lake Dam located in Olympia, Washington. The scope of work included above-water and underwater investigations of the dam including the abutments, wingwalls, pier walls, spillway components, rock armoring, concrete girders, radial gates, walkway and other appurtenances. The observations noted in the field were analyzed to ascertain a condition assessment rating for the structure and to determine repair recommendations and associated repair costs.

The Capitol Lake Dam is located at the north end of Capitol Lake in Olympia, WA. The Dam was constructed between 1949 and 1951 and serves to control the water level in Capitol Lake. Concrete abutments, pier walls, and wingwalls establish the two flood control discharge channels and a fish ladder. Additionally, the abutments and pier walls support a road deck and control house above. The flood control channels are controlled by radial gates at the south end of the structure. The spillway consists of a bottom slab, an ogee crest, and sill. The ogee, located downstream of each radial gate, serves as a bearing pad for the radial gate seals. The ogees slope from the radial gate and transition into the bottom slab. Upstream and downstream stoplog cutouts are located along the sides of the abutment and pier walls. Rock armoring lines the channel bottom of the Capitol Lake side of the dam. On the Budd Inlet side of the dam, rock armoring surrounds the bottom slab and wing walls. Figure 1 and Figure 2 show a plan view and section view of the dam, respectively.

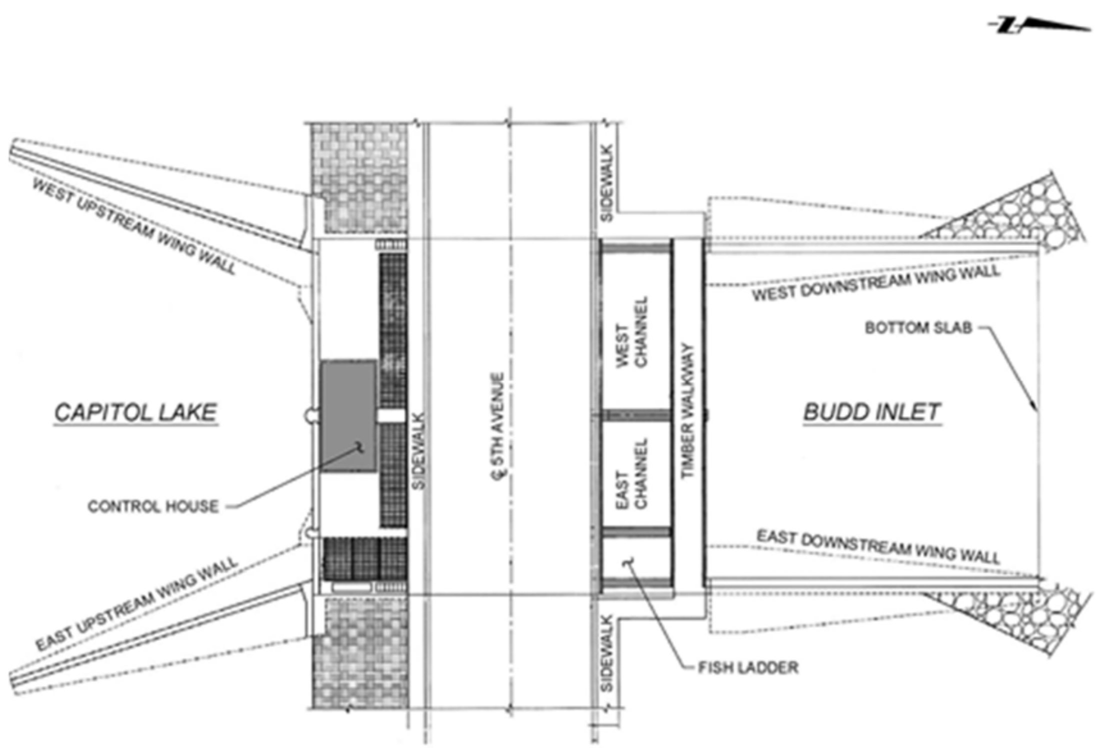


Figure 1: Capitol Lake Dam Plan View

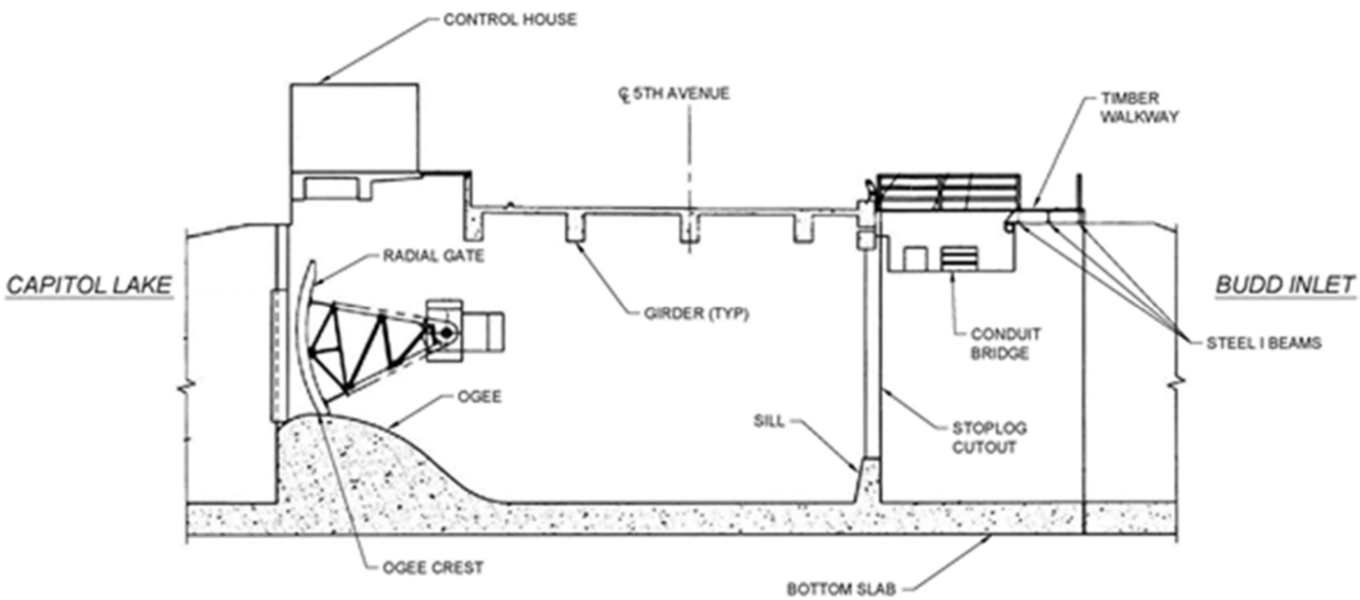


Figure 2: Capitol Lake Dam Section View, Looking West

1.1.1. Previous Inspections

The most recent known inspection of the facility was conducted by M&N in May 2007. M&N's 2007 inspection noted the overall condition of the facility as Fair, with individual components rated between Poor and Good condition. Further discussion of the previous inspection is included in Section 3.

1.2. Inspection Scope of Work and Methodology

The above-water and underwater investigation methodology was based on the American Society of Civil Engineers (ASCE) Manuals and Reports on Engineering Practice Number 130, "Waterfront Facilities Inspection and Assessment", 2015 Edition (ASCE 130). ASCE 130 provides guidance on types of inspections and specific structure considerations depending on objectives, frequency of inspection and the level of damage. The field investigation consisted of a visual inspection of the abutments, pier walls, wingwalls, concrete girders, spillway components, rock armoring, and utilities. Photographs of typical conditions and representative defects are provided in the following sections and additional photographs are provided in Appendix A.

The below-water investigation was conducted on July 28th and 29th, 2016. M&N's engineer-divers performed the investigation with Surface-Supplied Air (SSA) equipment in accordance with OSHA regulations and ADCI standards. The underwater investigation was conducted from shore on the Capitol Lake side of the dam and from a 23-foot aluminum boat on the Budd Inlet side of the dam using a three-person SSA dive crew. Three basic levels of inspection are used for inspecting facilities underwater. The type and extent of damage/deterioration that can be detected depends on the level of inspection performed. The following general descriptions for Levels I through III comply with ASCE 130. This underwater investigation included Level I and Level II inspection of the dam below water and Level I and Level III inspection above water.

Level I - Visual or tactile inspection of components without the removal of marine growth. This level of investigation generally serves as a confirmation of as-built conditions and detects obvious damage or deterioration to the structure.

Level II - Partial marine growth removal of a statistically representative sample – for walls, this is typically cleaning a one square foot area of the wall every 100 linear feet. This level of investigation is intended to detect and identify damage and deterioration that may be hidden by surface biofouling.

Level III - Nondestructive testing (NDT) or partially destructive testing (PDT) of a statistically representative sample. These procedures are conducted to detect any hidden internal damage or deterioration. In this inspection, concrete core sampling was performed above water.

The above-water visual investigation of accessible above-water components was conducted on August 9th and 10th, 2016. The above-water investigation included an inspection of all accessible components by walking along the roadway, walking beneath the structure on catwalks, and accessing the remaining areas from a small boat.

The concrete cores extracted by M&N for the Level III inspection were provided to Tourney Consulting Group (TCG) for testing. The results and recommendations from the concrete core testing are provided in a report titled "Capitol Lake Dam Preservation Durability Assessment" by TCG, dated October 13, 2016.

1.3. Inspection Limitations

Information represented in this report only reflects the observations noted from this inspection. Observations did not involve disassembly of components to expose possible non-readily-visible deterioration. Inspection of mechanical equipment is not included as part of this report. The mechanical equipment assessment is provided in a report titled "Capitol Lake Dam Machinery and Controls Assessment; Capitol Lake Dam Preservation" by Fives Lund LLC, dated January 30, 2017.

1.4. Rating System

Individual components were categorized into six condition ratings based on the observations: not inspected, no damage, minor, moderate, major, and severe. Component rating definitions are shown in Table 1.

Table 1: Component condition rating descriptions

COMPONENT RATING	DESCRIPTION
Not Inspected (NI)	Component was inaccessible or not included in the scope.
No Damage (ND)	Component had a sound material surface.
Minor (MN)	*Timber:* Checks, splits, and gouges less than 0.5 inches wide. *Steel:* Less than 50% of perimeter or circumference affected by corrosion at any elevation or cross-section; loss of thickness up to 15% of nominal thickness at any location. *Concrete:* Mechanical abrasion or impact dents; general cracks up to 1/16-inch wide; occasional corrosion stain or small pop-out corrosion spall.
Moderate (MD)	*Timber:* Checks and splits greater than 0.5 inches wide; diameter loss up to 15%; cross-section area loss up to 25%; corroded hardware; marine borer infestation. *Steel:* Greater than 50% of surface at any elevation/cross-section affected by corrosion; 15% to 30% loss of nominal thickness at any location. *Concrete:* Structural cracks up to 1/16-inch wide; corrosion cracks up to ¼-inch wide; chemical deterioration; random cracks up to 1/16-inch wide; soft concrete and rounding corners up to 1-inch deep; frequent corrosion stain or medium pop-out corrosion spall.
Major (MJ)	*Timber:* Checks and splits through full depth of cross-section; diameter loss 15% to 30%; cross-section loss 25% to 50%; heavily corroded hardware; displacement, misalignments at connections. *Steel:* Partial loss of flange edges or visible reduction of wall thickness; 30% to 50% loss of nominal thickness, any location. *Concrete:* Structural cracks 1/16-inch to ¼-inch wide; partial breakage (spalls); corrosion cracks greater than ¼-inch wide; multiple cracking and disintegration of surface due to chemical deterioration.
Severe (SV)	*Timber:* Diameter loss greater than 30%; cross-section area loss greater than 50%; loss of connections and/or fully non-bearing; partial or complete breakage. *Steel:* Structural bends or buckling, breakage and displacement at supports, loose or lost connections; greater than 50% loss of nominal thickness, any location. *Concrete:* Structural cracks greater than ¼-inch wide; breakage; loss of bearing and displacement at connections; reinforcing steel w/cover loss and greater than 30% diameter loss for any main bar; exposed steel due to chemical deterioration; cross section loss greater than 30% of any component for any reason.

Condition Assessment Ratings (CARs) are based on the findings of the field observations. The condition assessment scale includes the following six categories: Good, Satisfactory, Fair, Poor, Serious, and Critical. Descriptions of the six CARs are provided in Table 2.

Table 2: Condition Assessment Rating Descriptions (ASCE 130)

CAR Rating	Description
"Good"	No visible defects or only minor defects noted. Structural elements may show very minor deterioration, but no overstressing observed. No Repairs are required.
"Satisfactory"	Limited minor to moderate defects or deterioration observed, but no overstressing observed. No repairs are required.
"Fair"	All primary structural elements are sound; but minor to moderate defects or deterioration observed. Localized areas of moderate to advanced deterioration may be present but do not significantly reduce the load bearing capacity of the structure. Repairs are recommended, but the priority of the recommended repairs is low.
"Poor"	Advanced deterioration or overstressing observed on widespread portions of the structure, but does not significantly reduce the load bearing capacity of the structure. Repairs may need to be carried out with moderate urgency.
"Serious"	Advanced deterioration, overstressing or breakage may have significantly affected the load bearing capacity of primary structural components. Local failures are possible, and loading restrictions may be necessary. Repairs may need to be carried out on a high-priority basis with urgency.
"Critical"	Very advanced deterioration, overstressing, or breakage has resulted in localized failure(s) of primary structural components. More widespread failures are possible or likely to occur, and load restrictions should be implemented as necessary. Repairs may need to be carried out on a very high priority basis with strong urgency.

2. Observed Inspection Conditions

The following section is a summary of the observations noted in the field. The observations are separated into the following categories:

- Abutments, wingwalls, and pier walls
- Spillway components
- Riprap and rock armoring
- Girders and deck soffit
- Radial Gates
- Walkway
- Other Appurtenances

Additional photographs of components and observations are provided in Appendix A of this report. A plan view summarizing the observed inspection conditions above and below water is provided in Figure B-1 in Appendix B.

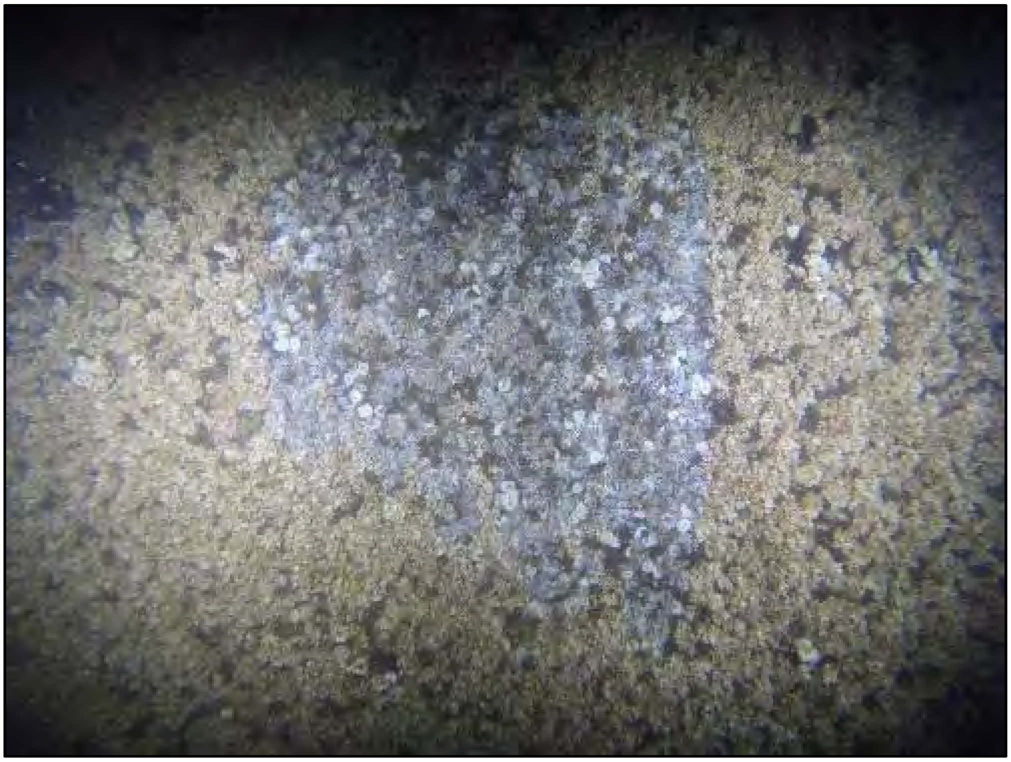
2.1. Abutments, Wingwalls and Pier Walls

The concrete abutments and wingwalls are the eastern- and western-most structural components of the dam that retain the earthen embankment. The pier walls establish the flood control discharge channels and the fish ladder. Two pier walls are located between the abutments. The pier walls support the roadway above and form the discharge channels. Photograph 1 through Photograph 4 show elevation views of the typical wingwall, pier walls, and abutment surface underwater.

Photograph 1: East Downstream Wingwall

Photograph 2: Typical Pier Wall Looking Northeast

Photograph 3: Typical Pier Wall at Fish ladder



Photograph 4: Typical Abutment Surface at Level II Cleaning Location

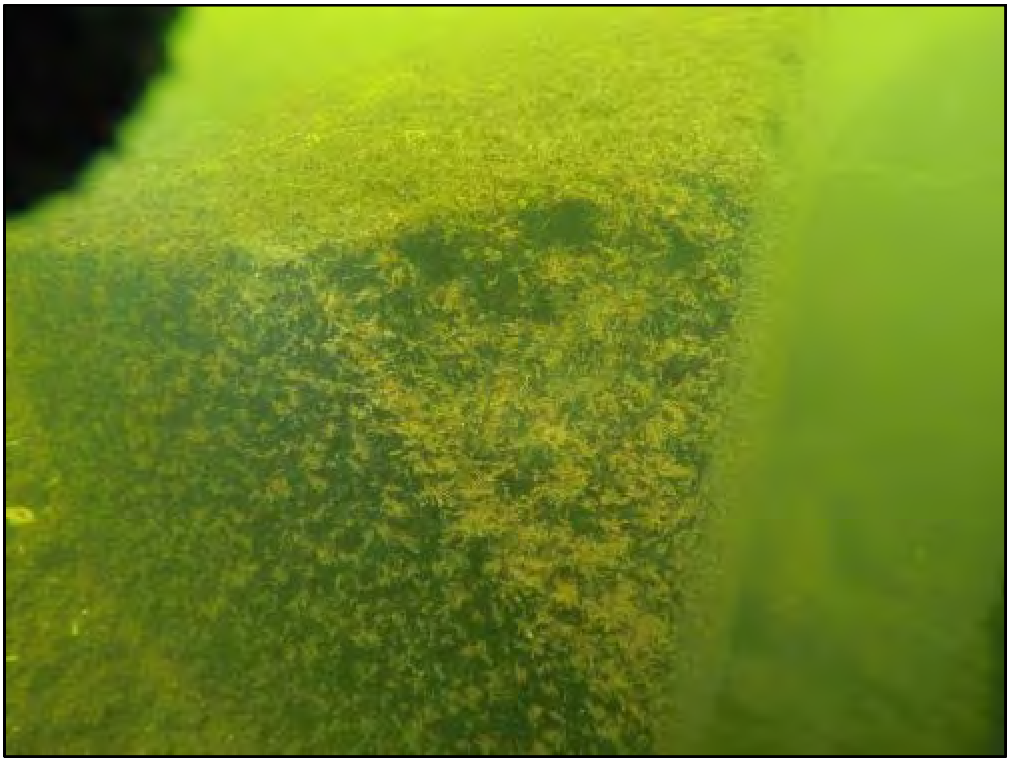
The abutments, wingwalls, and pier walls exhibit minor to moderate deterioration including efflorescence, spalls, and cracking at various locations. Photograph 5 shows an isolated area of efflorescence and an approximately three-foot-long hairline crack observed on the vertical face of the west abutment.

One localized corrosion spall was observed on the east downstream wingwall as shown in Photograph 6. The corrosion spall measures approximately 108 inches long by 8 inches wide. An impact spall was observed underwater on the west upstream wingwall and can be seen in Photograph 7. The spall measures approximately four inches square by two inches deep. Exposed rebar was not observed.

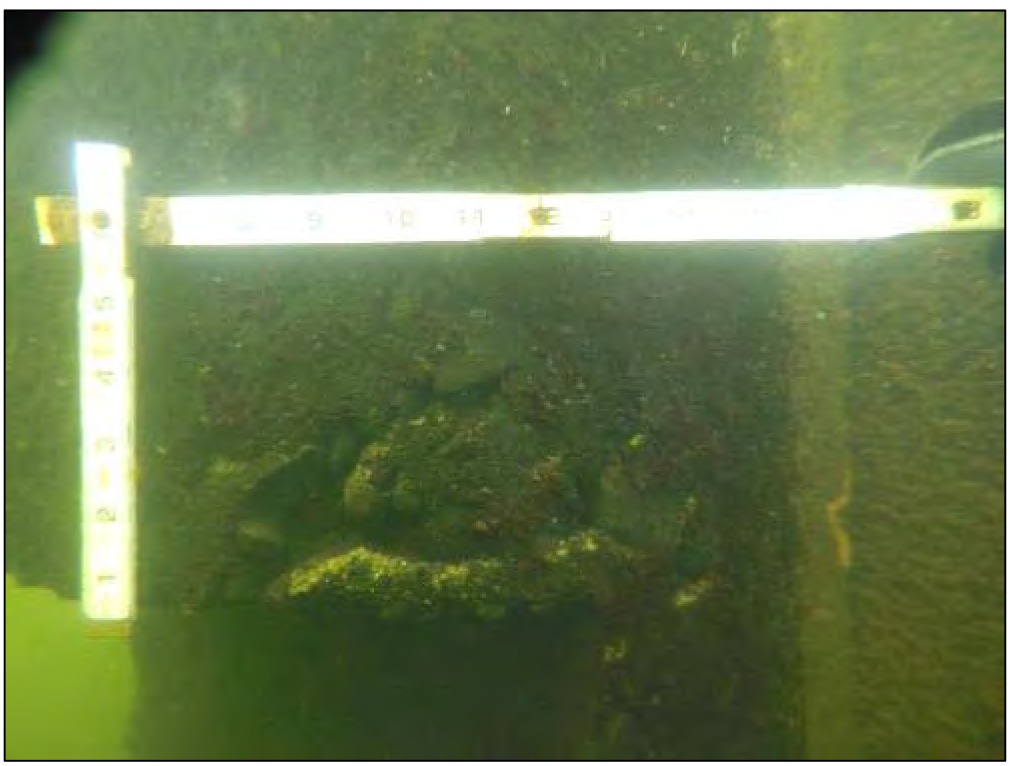
Areas of poorly consolidated concrete were observed on the upstream end of the pier wall between the east and west spillways. The areas observed were less than two square feet in area and appear to be from the original construction of the dam. Photograph 8 shows the area of poorly consolidated concrete on the upstream end of the pier wall.

Photograph 5: Efflorescence on West Abutment

Photograph 6: Open Corrosion Spall on East Downstream Wingwall



Photograph 7: Impact Spall on West Upstream Wingwall



Photograph 8: Poorly Consolidated Concrete on the Upstream End of the Pier Wall Between the East and West Spillway

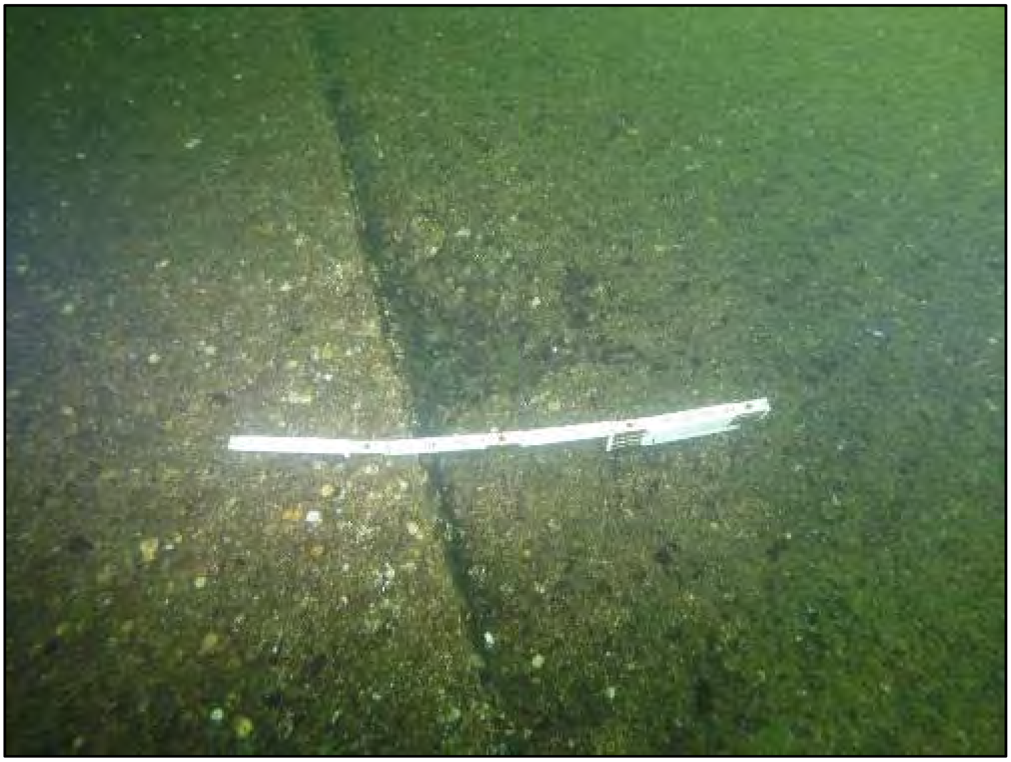
2.2. Spillway Components

Spillway components include the ogee crest, the sill, the bottom slab, and stoplog cutouts. The ogee crest, sill, and bottom slab were all observed with one-inch-thick marine growth covering up to 100-percent of the submerged surface areas as shown in Photograph 9. Minor scaling of less than 1/8-inch depth was observed on the vertical and horizontal concrete faces at locations of Level II cleanings. Sediment accumulation was observed on the bottom slab up to six-inches in depth adjacent to the abutment and pier walls. The accumulated sediment prevented visual inspection of the entire bottom slab, however, where visible the concrete surface exhibited minor to moderate cracking and spalling, primarily along the expansion joint located north of the pier wall as shown in Photograph 10. Additional spalling, obscured by sediment accumulation, may be present.

No significant defects were observed on the ogee crest and sills.

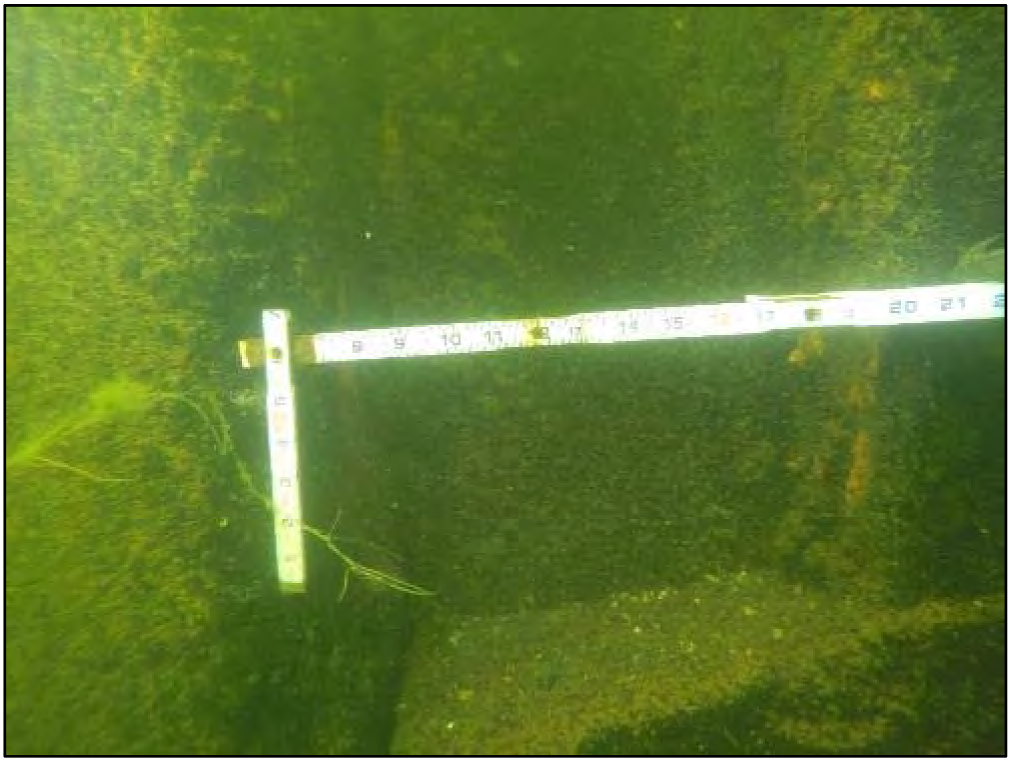
The stoplog cutouts were observed with minor to moderate corrosion on the steel embedded surfaces. Section loss of less than 10-percent was noted. Photograph 11and Photograph 12 show the observed condition of the stoplog cutouts.

Photograph 9: Typical Marine Growth on Concrete Surfaces Underwater



Photograph 10: Spall on Bottom Slab at Expansion Joint

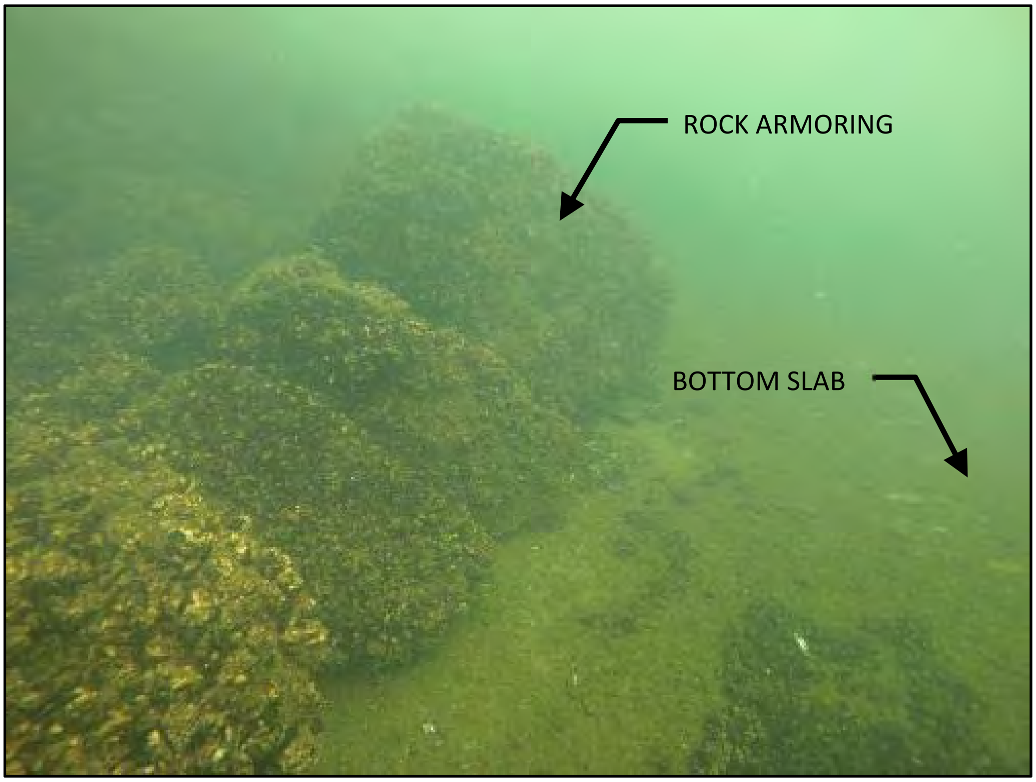
Photograph 11: Stoplog Cutout with Moderate Corrosion



Photograph 12: Typical Stoplog Cutout Underwater on Upstream Side

2.3. Riprap and Rock Armoring

Riprap and rock armoring was observed along the upstream and downstream edges of the bottom slab and wingwalls. The riprap and armoring varied in size between two and four feet in diameter on the upstream side and up to five feet on the downstream side. The riprap lining around the channel exhibits minimal areas of voids and is consistent in size and shape. Photograph 13 and Photograph 14 show typical rock armoring observed on the downstream edge of the structure. The bottom slab is visible on the right side of Photograph 13.



Photograph 13: Typical Rock Armoring along Downstream Edge of Spillway

Photograph 14: Rock Armoring at North Edge of Spillway, Cut Off Steel Sheetpile in Foreground

2.4. Girders and Deck Soffit

Hairline cracking and efflorescence was observed on the concrete deck soffit and girders. The observed general condition of the deck soffit and girders is shown in Photograph 15 and Photograph 16. All four crossbeams in the fishway were observed with moderate closed corrosion spalls along the full length of the soffit. Photograph 17 shows the typical closed corrosion spall observed in the fish ladder.

Photograph 15: Typical Girders and Deck Soffit – West Channel

Photograph 16: Typical Deck Soffit – West Channel

Photograph 17: Typical Closed Corrosion Spall on Fish Channel Crossbeam

2.5. Radial Gates

The radial gates are constructed of steel components and control flow through the flood control channels. Photograph 18 and Photograph 19 show the west radial gate from the lake side and the inlet side, respectively.

Photograph 18: Lake Site of West Radial Gate.

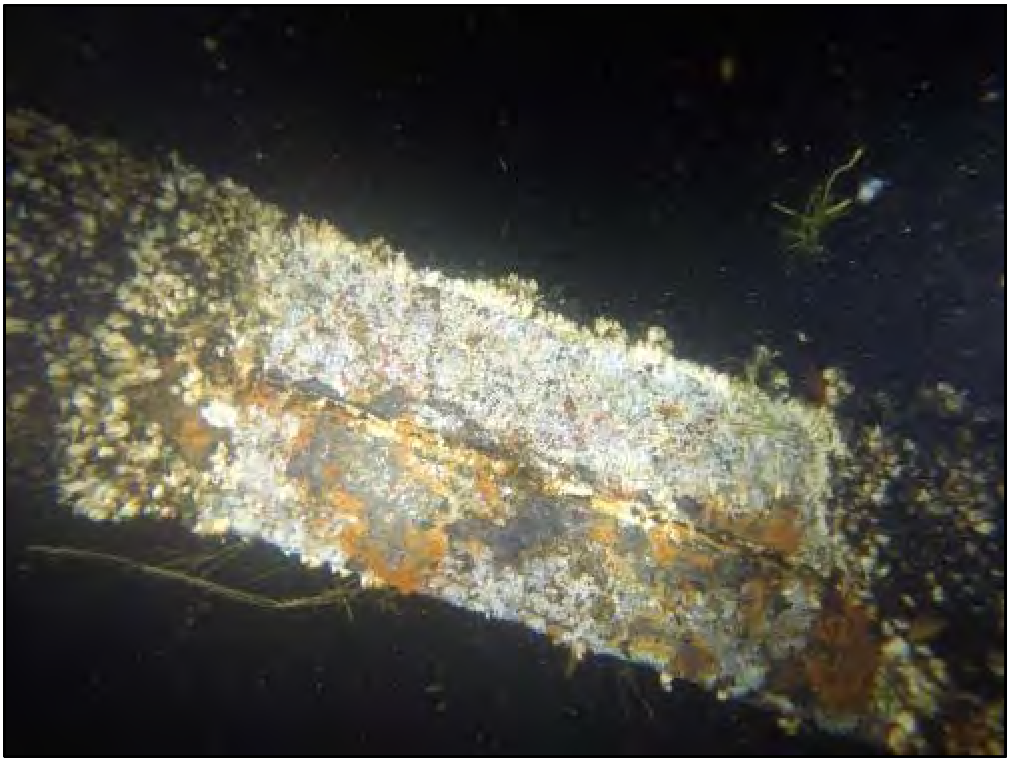
Photograph 19: Inlet Side of West Radial Gate.

Coating failure and minor to moderate surface corrosion on the steel members of the radial gates was observed primarily on the inlet side where the steel is exposed to saltwater. The areas of moderate corrosion and section loss were observed in the splashzone as shown in Photograph 20. Photograph 21 and Photograph 22 show the observed minor corrosion on the steel members in the intertidal zone and underwater, respectively.

Leaks were observed in the radial gate seals on the west and east radial gates. The leaks were observed on west edge of the west gate and at the lower west corner of the east gate.

Photograph 20: Moderate Corrosion on Radial Gate Above Water

Photograph 21: Minor Corrosion on Radial Gate in Intertidal Zone



Photograph 22: Minor Corrosion on Radial Gate Underwater

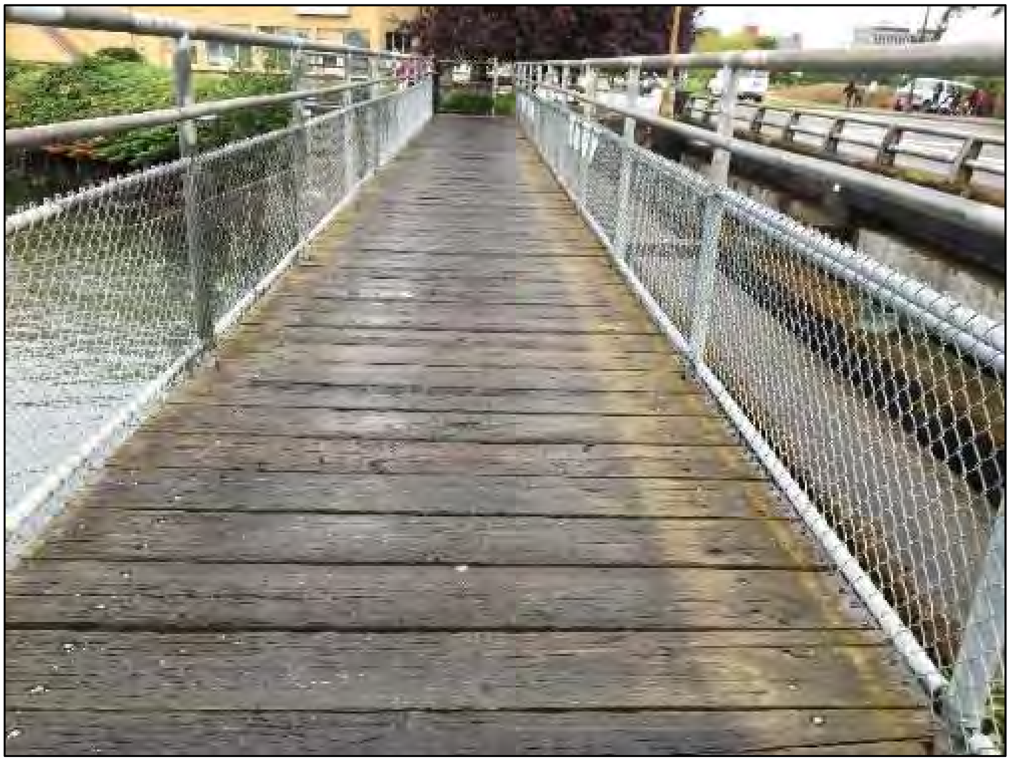
2.6. Walkway

The walkway is composed of steel and timber members. The timber exhibited minor weathering; however, no significant deterioration was observed. The steel beams supporting the walkway exhibit widespread moderate coating loss and moderate corrosion over a majority of the surface area, although section loss is minor and infrequent. Photograph 23 through Photograph 25 show the typical condition of the walkway.

The walkway is supported in the northeast corner by a concrete retaining wall and timber posts. The timber posts exhibit moderate to major rot and section loss at the interface between the post and the concrete retaining wall. The steel connections at the base are corroded and deformed. The concrete retaining wall supporting the walkway exhibits moderate undermining approximately two inches tall that extends 12 inches under the wall. Photograph 26 shows the rotted timber post and corroded steel connection. Photograph 27 shows the undermined retaining wall.

Photograph 23: Elevation of the Walkway, Looking South

Photograph 24: Underside of the Walkway



Photograph 25: Topside of the Walkway, Looking East

Photograph 26: Timber Post Exhibits Rot and Section Loss and the Steel Connection is Corroded and Deformed

Photograph 27: The Concrete Retaining Wall Supporting the Walkway Exhibits Moderate Undermining

2.7. Other Appurtenances

The other appurtenances include the non-structural components, utilities, and safety features of the dam. Safety features include the components that allow safe access for the DES maintenance crew and protect the public; only components with notable observations are discussed below.

The northwest side of the dam includes an access ramp to a viewpoint that allows pedestrians to get closer to the water. The lower ramp has a large bump that extends approximately 10 feet horizontally and has a 12-inch vertical differential. The bump is likely caused by roots from the adjacent tree. Photograph 28 shows the bump in the concrete ramp.

Various utilities cross the spillways on the north side of the dam. This inspection included a visual assessment of the exterior condition and hanger condition. Testing the functionality of the utilities is not included. The exterior of the utilities exhibit minor weathering; however, no notable deterioration was observed. No deterioration was observed on the utility hangers or supports. Photograph 29 shows the typical condition of the utilities.

Photograph 28: The Concrete Ramp Exhibits a Large Bump Extending Approximately 10 Feet and has a Vertical Differential of Approximately 12 Inches.

Photograph 29: Typical Condition of the Utilities Crossing the Dam

The dam stillwells are accessed through a utility hatch on the southeast corner of the dam. The lids do not have a spring mechanism to assist with lifting the lid and they exhibit minor corrosion. Photograph 30 shows the stillwell utility hatch.

Steel grating is used as decking on the elevated platform surrounding the Control Room. The steel grating exhibits minor corrosion. The grating does not have a positive connection securing the grating to the platform. In one location the grating protrudes above the deck up to 1 inch. Photograph 31 shows the typical condition of the steel grating and the uneven surface between the grating and surrounding concrete deck.

Photograph 30: Condition of the Stillwell Hatch Cover

Photograph 31: Typical Condition of the Steel Grating on the Elevated Platform

Two ladders are present on the dam. One ladder provides access from the elevated platform to the catwalk. The other ladder is accessed through one of the steel grating panels and provides access to one of the radial gate arms. The catwalk ladder has a few safety deficiencies:

- 18-inch by 18-inch opening is less than the typical requirement of 24 inches square.
- The rungs are smooth steel are recommended to have an anti-slip surface.
- The ladder rails do not extend above the deck surface.

The ladder extending from the grated decking into the west channel is broken due to impact from the radial gate. Also, the adjacent timber gate cushion is rotten and crushed. Photographs 32 and 33 show the catwalk access ladder. Photograph 34 shows the broken radial gate access ladder and the adjacent crushed timber cushion.

Photograph 32: Condition of the Catwalk Access Ladder

Photograph 33: Catwalk Access Ladder Opening

Photograph 34: Crushed Timber Cushion and Deformed Radial Gate Access Ladder

Various railing components are used throughout the dam to protect DES maintenance staff and the public. The catwalk railing is a fiberglass railing and exhibits broken or missing rails at three locations. Photograph 35 shows a missing top rail on the center portion of the catwalk. Photographs of the other two broken and missing rails are provided in Appendix A.

Photograph 35: Missing Top Rail Near the Center of the Catwalk

Chain-link fencing is present along the wingwalls and along the walkway. Damage was observed in three locations in the vicinity of the concrete ramp.

- A top rail is missing at the pedestrian-gate at the bottom of the ramp (Photograph 36)
- A top rail is missing at the east end of the concrete ramp
- The top rail is disconnected at the west end of the concrete ramp

Additional photographs of damaged fencing is provided in Appendix A.

Railing should be provided at all locations where the vertical difference between surfaces is more than 30 inches per the Occupational Safety and Health Standards (OSHA) and the International Building Code (IBC). Two locations in the vicinity of the dam are not compliant with this standard. The elevated platform of the control house has a vertical drop of 42-1/2 inches from the platform to the sidewalk. Also, there is a gap in the fence near the northwest wingwall. Photograph 37 shows the elevated platform where the railing is recommended and Photograph 38 shows the fence gap near the northwest wingwall.

Photograph 36: Missing Top Rail on the Concrete Ramp

Photograph 37: No Handrail Along the Edge of the Elevated Platform and Steps

Photograph 38: No Fence Between Concrete Ramp and Wingwall Fence

The roof of the dam control room building has a modified bitumen membrane coating. The age of the coating is unknown. The roof membrane exhibits widespread alligator cracking likely caused by extended exposure to ultraviolet radiation. The depth of the cracking is unknown and no active roof leaks were observed. A fall-protection anchor point was observed on the roof. The anchor point appeared to be broken. Photograph 39 shows the alligator cracking of the roof membrane and the broken fall-protection anchor point.

Photograph 39: Alligator Cracking of the Control Room's Roof Membrane and a Failed Fall-Protection Anchor Point

3. Comparison to the Previous Inspection

The general conditions observed during the inspection are relatively consistent with the conditions observed during the 2007 inspection. The condition of the wingwalls, abutments, and pier walls have generally remained unchanged. Hairline cracking and efflorescence has remained similar to that observed during the previous inspection. The condition of the spillway, ogee crest, and bottom slab have generally remained unchanged. Some spalls previously noted may have been obscured by accumulation of sediment and were not observed.

The steel coating loss is more widespread; however, the corrosion of radial gate components has not significantly increased since the previous inspection. Leaks in the radial arm seals are still present, but do not appear to have increased in size.

Rock armoring appears to have remained in place and in the same general condition as previously noted.

4. Conclusions & Recommendations

An overall Condition Assessment Rating (CAR) was assigned to the dam as well as to each of the individual components including: abutments, wingwalls, pier walls, spillway components, riprap and rock armoring, girders and deck soffits, radial gates, the walkway, and other appurtenances. The CARs are based on the findings of the field observations. The condition assessment scale includes the following six categories: Good, Satisfactory, Fair, Poor, Serious, and Critical. Descriptions of the six CARs are provided in Table 2. Table 3 summarizes the CARs for the facility.

The Abutments, Wingwalls, and Pier Walls are rated as "*Fair*". All primary structural elements are sound, but minor to moderate defects and deterioration are observed. Localized areas of moderate deterioration are present, but do not significantly reduce the structural capacity. Repairs are recommended, but the priority of the recommended repairs are low.

The Spillway Components are rated as "*Fair*". All primary structural elements are sound, but minor to moderate defects and deterioration are observed. Localized areas of moderate deterioration are present, but do not significantly reduce the structural capacity. Repairs are recommended, but the priority of the recommended repairs are low.

The Riprap and Rock Armoring is rated as "Good". No visible damage was noted and no repairs are required.

The Girders and Deck Soffit are rated as "*Fair*". All primary structural elements are sound, but minor to moderate defects and deterioration are observed. Localized areas of moderate deterioration are present, but do not significantly reduce the structural capacity. Repairs are recommended, but the priority of the recommended repairs are low.

The Radial Gates are rated as "Satisfactory". Limited minor to moderate defects or deterioration are observed including leaking seals. Repairs are recommended, but are not required.

The Walkway is rated as "*Poor*" because of the advanced deterioration of the timber posts and undermining of the retaining wall. All other primary structural elements are sound, but minor to moderate defects and deterioration are observed. Repairs are recommended with moderate urgency.

Overall, the dam is rated as "Fair". All primary structural elements are sound, but minor to moderate defects and deterioration are observed. Localized areas of moderate deterioration are present but do not significantly reduce the structural capacity. Repairs are recommended, but the priority of the recommended repairs are low.

Table 3: Capitol Lake Dam Facility CAR Summary

	Condition Assessment Rating (CAR)
Abutments, Wingwalls, and Pier Walls	Fair
Spillway Components	Fair
Riprap and Rock Armoring	Good
Girders and Deck Soffits	Fair
Radial Gates	Satisfactory
Walkway	Poor
Other Appurtenances	Fair
OVERALL	**Fair**

Repairs are recommended, but the priority of the recommended repairs is low, unless otherwise noted. A Routine Inspection per ASCE 130 should be performed every five years based on the overall condition of the facility.

4.1. Repair Recommendations

The following subsections describe the recommended repairs and the urgency of the recommended repairs. Repair recommendations listed as low priority should be performed within the next three to five years. Repair recommendations listed as moderate priority should be performed within the next two years.

Abutments, Wingwalls, and Pier Walls

- Repair the concrete spalls observed on the east downstream wingwalls; *low urgency*

Spillway Components

The following repairs are recommended:

- Repair the concrete spalls and cracking along the expansion joint; *low urgency*
- Repair the minor corrosion on the stoplog cutouts; *low urgency*

Riprap and Rock Armoring

- No repairs recommended at this time.

Girders and Deck Soffits

The following repairs are recommended:

- Repair the corrosion spalls observed on the fish ladder crossbeams; *low urgency*

Radial Gates

The following repairs are recommended:

- Recoat the radial gate steel components; *low urgency*
- Repair the radial gate seals; *low urgency*

Walkway

The following repairs are recommended:

- Replace the rotten and deteriorated timber posts and steel connections; *moderate urgency*
- Fill and protect the undermined retaining wall; *moderate urgency*

Other Appurtenances

The following repairs are recommended:

- Replace the stillwell hatch with an aluminum spring-assisted hatch; *low urgency*
- Secure the steel grating to the concrete deck to prevent them from being lifted out of place; *low urgency*
- Replace the deformed radial gate ladder and the two timber gate cushions; *low urgency*
- Provide fencing and handrails where the vertical difference between surfaces is greater than 30 inches and along steps; *moderate urgency*
- Repair the missing and disconnected handrail components*; moderate urgency*
- Provide a non-slip coating on the ladder rungs; *moderate urgency*
- Provide a ladder extension above the deck surface. Safety posts products are available that attach to the ladder rungs and telescope out of the manhole*; moderate urgency*
- Repair the Control Room roof; *moderate urgency*
- Repair the fall-protection anchor point; *moderate urgency*
- Repair the bump in the concrete ramp; *low urgency*

5. Cost Estimate

The rough order of magnitude (ROM) total construction cost for the recommended repairs is approximately $382,000. The ROM construction cost includes contractor overhead and profit, Washington State tax, and a 15 percent contingency. The total project cost includes the construction costs, engineer design services, environmental permitting, and construction administration. A detailed construction cost is included in Table 4.

The observations and findings used to develop the ROM construction costs have inherent limitations as discussed earlier in this report under Section 1.4, Inspection Limitations. Therefore, the quantities used in this ROM construction cost are approximate; actual conditions could vary greatly due to the limited scope of the inspection.

Table 4: Recommended Repairs ROM Construction Cost

	Quantity	Unit	Extended Cost
Abutments, Wingwalls, Piers	1	LS	$6,000
Spillway Components	1	LS	$51,000
Girders and Deck Soffits	1	LS	$11,500
Radial Gates	1	LS	$172,000
Walkway	1	LS	$6,000
Other Appurtenances	1	LS	$28,500
Mob/Demob	10	%	$30,000
Subtotal			**$305,000**
Contingency (15%)			$46,000
Construction Subtotal			**$351,000**
WSST (8.7%)			$31,000
Construction Total			**$382,000**
Design, Permitting, Admin			$168,000
Total Cost			**$550,000**

APPENDIX A – PHOTOGRAPHS

Photograph 40: East Upstream Wingwall

Photograph 41: West Upstream Wingwall

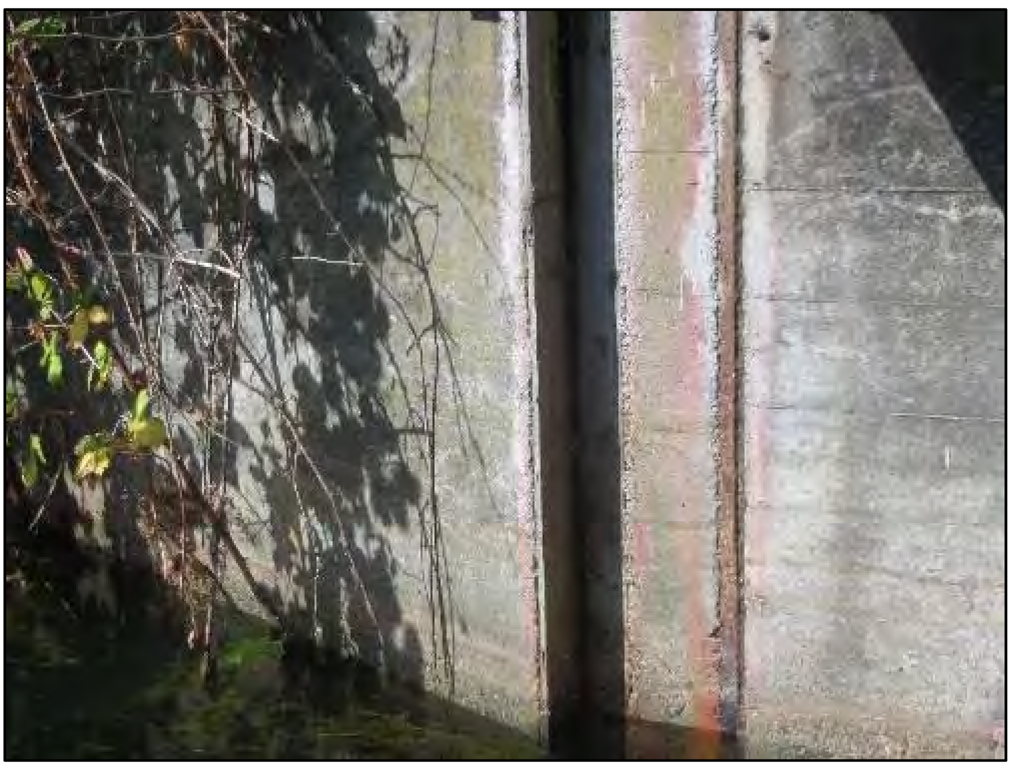
Photograph 42: West Downstream Wingwall

Photograph 43: Typical Abutment Looking Northwest

Photograph 44: Level II Cleaning on West Downstream Wingwall

Photograph 45: Interface of Sill, Stoplog Cutout, and Pier Wall Underwater

Photograph 46: Spall on Bottom Slab at Expansion Joint



Photograph 47: Stoplog Cutout on West Upstream Abutment

Photograph 48: Moderate Corrosion on Stoplog Cutout on Downstream Side

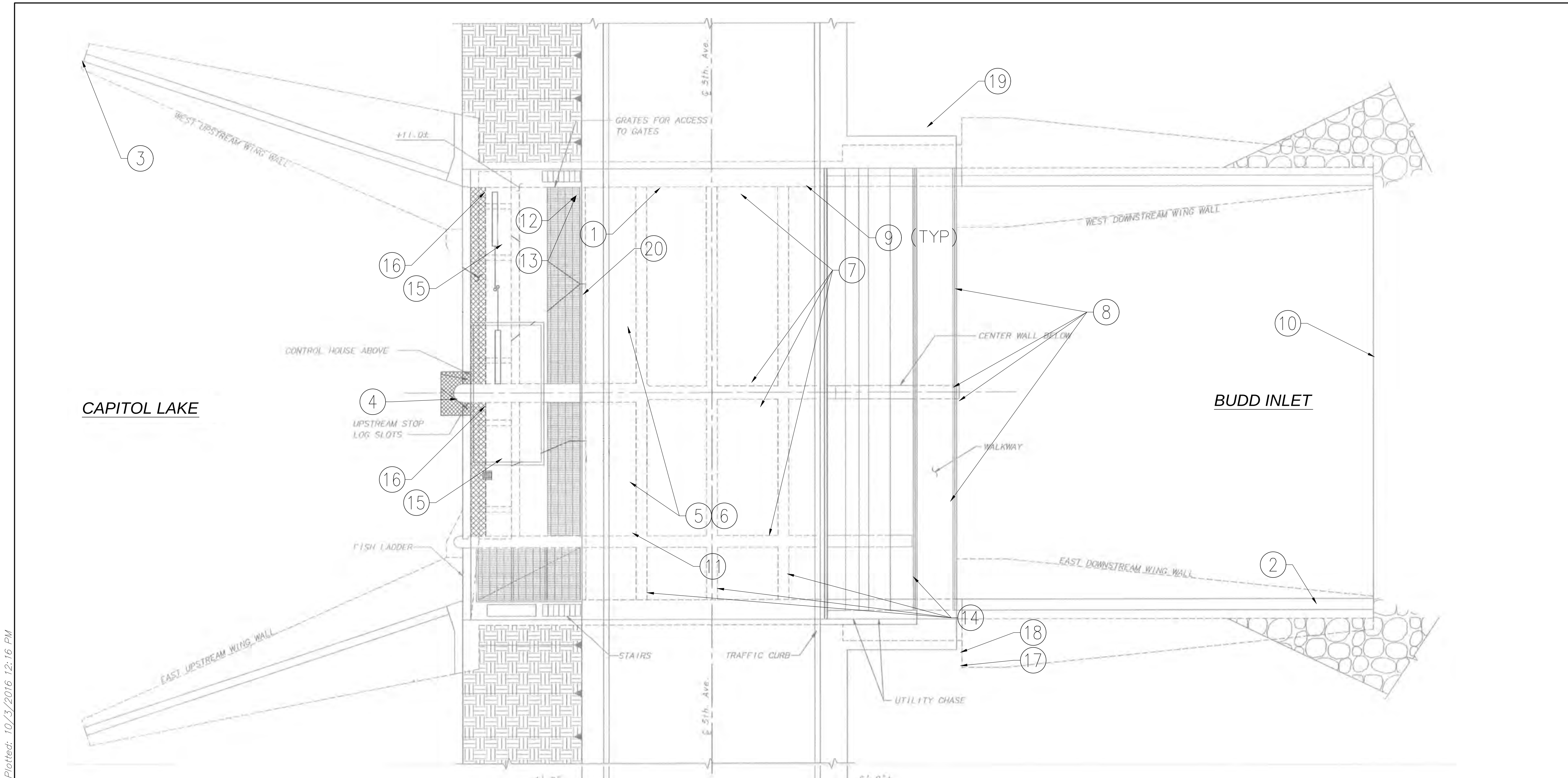
Photograph 49: Missing Top Rail on the Northwest Wingwall Fence

Photograph 50: Disconnected Top Rail at the West end of the Concrete Ramp

Photograph 51: Missing Catwalk Guardrail Elbow on the East Side of the West Spillway

Photograph 52: Missing Catwalk Guardrail Top Rail on the West Side of the West Spillway

APPENDIX B – PLAN VIEW



1 PLAN
FIG-01 SCALE: 1" = 10'

OBSERVED DEFECTS:

1. EFFLORESCENCE AND HAIRLINE CRACKING ON WEST ABUTMENT WALL
2. CORROSION SPALL, RUST STAINING, NO EXPOSED REBAR, ON EAST DOWNSTREAM WINGWALL
3. IMPACT SPALL ON WEST UPSTREAM WINGWALL
4. POORLY CONSOLIDATED CONCRETE ON UPSTREAM END OF PIER WALL
5. MARINE GROWTH UP TO 1-INCH THICK, 100 PERCENT COVERAGE ON SUBMERGED SURFACES OF SPILLWAY
6. MINOR SCALING, LESS THAN 1/8-INCH DEPTH, ON SUBMERGED CONCRETE SURFACES
7. SEDIMENT ACCUMULATION ON BOTTOM SLAB, UP TO 6-INCH DEPTH
8. SPALLING, NO EXPOSED REBAR, NO RUST STAINING ALONG EXPANSION JOINT AT SEVERAL LOCATIONS
9. MINOR TO MODERATE CORROSION ON STOPLOG CUTOUTS.
10. RIPRAP AND ROCK ARMORING UP TO 5-FOOT DIAMETER
11. HAIRLINE CRACKING AND EFFLORESCENCE ON DECK SOFFIT AND GIRDERS
12. DEFORMED LADDER
13. CRUSHED TIMBER GATE CUSHION
14. CORROSION CRACKING ON FISHWAY CHANNEL CROSSBEAMS
15. MODERATE COATING LOSS ON RADIAL GATE COMPONENTS
16. LEAKING RADIAL GATE SEALS
17. WALKWAY TIMBER SUPPORT POSTS ROTTEN AND CONNECTION HARDWARE CORRODED.
18. MODERATE UNDERMINING OF RETAINING WALL, 2-INCHES TALL, 12-INCH PENETRATION
19. UNEVEN CONCRETE PATH
20. MINOR CORROSION OF STEEL GRATING

LEGEND:

(XX) OBSERVED DEFECTS, SEE NOTE XX

CAPITOL LAKE DAM
STRUCTURAL CONDITION ASSESSMENT REPORT

FIGURE B-1 - CONDITION PLAN

moffatt & nichol

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APPENDIX C – COST ESTIMATE

2016 ROM Repair Cost

Item No.	Description	Approx. Quantity[1]	Unit	Order of Magnitude Unit Cost ($)	Order of Magnitude Extended Cost	Extended Cost, Subtotal
	Abutments, Wingwalls, and Pier Walls					**$ 6,000**
	Repair Concrete Spalls	1	LS	$ 6,000	$ 6,000	
	Spillway Components					**$ 51,000**
	Repair Concrete Spalls	1	LS	$ 28,000	$ 28,000	
	Repair Stoplog Cutouts	1	LS	$ 23,000	$ 23,000	
	Girders and Deck Soffits					**$ 11,500**
	Repair Concrete Spalls	1	LS	$ 11,500	$ 11,500	
	Radial Gates					**$ 172,000**
	Recoat Radial Gates	1	LS	$ 115,000	$ 115,000	
	Repair Radial Gate Seals	1	LS	$ 57,000	$ 57,000	
	Timber Walkway					**$ 6,000**
	Timber Walkway Repairs	1	LS	$ 6,000	$ 6,000	
	Other Appurtenances					**$ 28,500**
	Replace Stillwell Hatch	1	LS	$ 9,000	$ 9,000	
	Steel Grating Repair	1	LS	$ 1,500	$ 1,500	
	Ladder Repairs	1	LS	$ 3,000	$ 3,000	
	Install and Repair Fencing/Guardrails	1	LS	$ 3,500	$ 3,500	
	Roof Repairs	1	LS	$ 7,500	$ 7,500	
	Repair Concrete Ramp	1	LS	$ 4,000	$ 4,000	
	Mobilization/Demobilization & General Requirements	10	%		$ 27,500	**$ 30,000**
				Subtotal		**$ 305,000**
				Contingency	15%	46,000
				Construction Subtotal		**$ 351,000**
				Washington State Sales Tax	8.7%	31,000
				Construction Subtotal		**382,000**
				A&E Design Services	30%	114,600
				Environmental Permitting	4%	15,280
				B&G and A/E Construction Support	10%	38,200
				Total Repair Cost		**$ 550,000**

Notes

1 Quantities may vary considerably from those assumed for this estimate, depending on actual conditions when the work is performed.

APPENDIX B – Capitol Lake Dam Preservation Durability Assessment

Capitol Lake Dam Preservation Durability Assessment

Olympia, Washington
DES Project No. 2016-931

Prepared For:

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1. Introduction

TCG conducted a comprehensive field investigation of the Capitol Lake Dam to evaluate the current condition of the concrete above the low water level during a site visit in August of 2016. The investigation included visual observations, concrete sampling, cover survey, resistivity survey, and electrochemical testing. The objective of this assessment is to determine the current condition of the above water concrete, and if necessary, perform a service life analysis to predict future performance using the STADIUM® model, and provide general repair options and recommendations in collaboration with Moffatt & Nichol (M&N). This report includes the analysis and findings of this scope of work.

1.1. Background

The Capitol Lake Dam was constructed between 1949 and 1951 in Olympia, WA. The structure allows the passage of water underneath the 5th Avenue roadway. The purpose is to control the water level of the Capitol Lake and provide flood control for downtown Olympia.

The spillway consists of two flood discharge channels and a fishway channel. The concrete elements include abutments, pier walls, and wing walls which support the beams and deck of 5th Avenue. Reference Figure 1 for an overview of the dam. The concrete is exposed to seawater on the North side from the Budd Inlet, and freshwater on the South side from the Capitol Lake. The concrete elements are exposed to chloride ions from either submerged, tidal, or airborne seawater exposure zones, which may potentially cause concrete degradation over time from reinforcement corrosion.

Figure 1: Overview of Dam from the Budd Inlet Side

2. Historical Document Review

Historical documents related to condition assessments, drawings, repairs, and specifications were provided to TCG. The list of received documents is as follows:

- 09-24-2015 Fish Ladder Emergency Work Summary.pdf
- 92-263 Capitol Lake Tide Gate Repair AS-BUILT - reduced.pdf
- 92-263 Capitol Lake Tide Gate Repair AS-BUILT.pdf
- 92-263 Capitol Lake Tide Gate Repair Plan Set.pdf
- 2008 - Moffatt & Nichol - Capitol Lake Dam Condition Assessment and Life Expectancy Appendix.pdf
- 2008 - Moffatt & Nichol - Capitol Lake Dam Condition Assessment and Life Expectancy.pdf
- 2015-2017 DES Budget.pdf
- 201604041649.pdf
- Capitol Lake Dam Operation for Flood Control - 2001 OCR.PDF
- cSummaryDocs_0630.pdf
- DeschutesBasinTestBoringReportApril1948.pdf
- FIELD REPORT.docx
- GeotechEngineering4th5thAveImprovementsReport_July 1999 - Reduced.pdf
- Heritage Park Survey.dwg
- Heritage Park Survey.pdf
- 1949 Specs.pdf
- 1980 Specs and Plans.pdf
- 1986 Plans and Specs.pdf
- 1994 Plans.pdf
- 1980 Structural Repair Report for Capitol Lake

2.1. Concrete Mix Design

Based on Section 27.12 of the 1949 Project Specifications, concrete mix proportions and material type requirements were defined. Since actual mix designs were not available it has been reasonably assumed that the mixtures met the specification requirements. A summary of the mix designs defined in the 1949 Specifications are displayed in Table 1.

Table 1: Concrete Mix Proportions

Material	Class A		Class B	
	Type	Proportion (lb/yd3)	Type	Proportion (lb/yd3)
Cement	Type II	611	Type II	564
Coarse Aggregate	No. 2	1820	No. 2	1470
Coarse Aggregate	N/A	N/A	No. 3	732
Fine Aggregate		1365		1098
Water		271.2		250.4
W/CM		0.44		0.44
Air %		1.5		1.5

Notes:

1. Class A concrete: Used in thin, heavily reinforced members, for example, railroad, parkway & control house decks & their supporting girders & beams & control house.
2. Class B Concrete: Used in all reinforced and mass sections of the structures other than those covered by Class A, for example, main floor slab, apron, footings, wing walls, cut-off walls, overflow gravity section, fishway channel walls, etc.

2.2. Concrete Transport Properties

Concrete transport properties were provided by the 2008 condition assessment by M&N. The transport properties are used as inputs in the predictive service life model STADIUM®. The ion diffusion coefficient (IDC) and the porosity were tested. The IDC is the diffusion of ion species in cementitious materials (modified ASTM C1202) and porosity is the volume of permeable voids in the concrete (ASTM C642). A summary of the results is presented in Table 2. The results indicate a good quality concrete with low permeability.

Table 2: Concrete Transport Properties

Core Label	Porosity, %	IDC ($x10^{-11}$ m^2/s)
K	9.9	1.1
N	7.6	0.6

Notes:

1. Reference 2008 Assessment by Moffatt & Nichol

2.3. Degradation Mechanisms

The 2008 M&N condition assessment concluded that corrosion due to chloride intrusion is the most probable mechanism that could compromise serviceability of the concrete portions of the Capitol Lake Dam. The test results did not indicate significant chemical deterioration of the concrete matrix, aside from chlorides. The probability of deterioration due to alkali-silica reaction (ASR), sulfate attack, and delayed ettringite formation (DEF) was considered low. Based on these conclusions, our assessment focused on chloride corrosion.

2.4. Repairs

Review of historical documents revealed that no major repairs have been performed on the reinforced concrete elements of the structure. The majority of the repairs conducted over its service life have included repairs to the fish ladder brackets and weirs, the steel radial arm tide gates, and other steel elements.

3. Field Investigation and Testing

3.1. Visual Observations

TCG visually observed the reinforced concrete elements above the water level. The concrete elements overall generally appeared to be in good condition. Figures 2 through 7 illustrate the general condition of the dam concrete elements. Some minor cracking was observed throughout the structure and one select location on the East wing wall on the Budd Inlet side exhibited noticeable cracking with exposed corroding rebar (reference Figure 24).

Figure 2: East Wing Wall – Budd Inlet Side

Figure 3: West Channel Pier Wall

Figure 4: West Channel Abutment Wall

Figure 5: East Channel Deck Soffit and Girders

Figure 6: East Channel Fishway Channel Wall

Figure 7: East Channel Pier Wall

3.2. Concrete Coring and Sampling

During the site investigation TCG conducted a general walkthrough of the structure by noting elements and locations of interest. From these observations TCG and M&N located 6 cores and 12 powder samples to be taken. Extraction of cores and powders were conducted by M&N and the samples were provided to TCG to be tested at our AASHTO/CCRL certified laboratory. Photographs of the cores are provided in the Appendix.

Concrete cores 2 inches in diameter and at least 6 inches in length were provided to TCG. Due to limited access and difficulty of extracting cores, powder samples from the Capitol Lake side and from the beam and deck soffits were collected. Each location consisted of three 1-inch diameter drill holes at 1-inch depth increments, up to 3 inches deep. Three holes in a triangular type pattern were drilled for the purpose of ensuring that one sample depth does not consist predominately of aggregate or paste, but rather provides a representative sample of the concrete in that area. The powder was collected from each hole at the same depth and combined into a single container to be analyzed as one composite sample.

The laboratory testing conducted on the concrete samples consisted of ASTM C1152 acid-soluble chloride testing. The coring and sampling locations are provided in Table 3.

Table 3: Concrete Coring and Sampling Locations

Sample Number	Sample Identification	Sample Type	Date Sampled	Time Sampled	Approx. Distance Above Water Level (ft)	Side of Dam	Location	Acid-Soluble Chloride
1	PM	2" Dia. Core	8/9/2016	4:00 PM	8.5	Budd Inlet	West Channel, Pier Wall, High Tide	√
2	PL	2" Dia. Core	8/9/2016	4:00 PM	4.5	Budd Inlet	West Channel, Pier Wall, Low Tide	√
3	AL	2" Dia. Core	8/9/2016	4:55 PM	5.2	Budd Inlet	West Channel, Abutment Wall, Low Tide	√
4	AM	2" Dia. Core	8/10/2016	9:10 AM	6	Budd Inlet	West Channel, Abutment Wall, High Tide	√
5	AU	2" Dia. Core	8/10/2016	9:55 AM	7.8	Budd Inlet	West Channel Abutment Wall, Above Tide	√
6	PU	2" Dia. Core	8/10/2016	11:10 AM	8.5	Budd Inlet	West Channel, Pier Wall, Above Tide	√
7	Beam Soffit	Powder	8/10/2016	12:00 PM	-	Budd Inlet	West Channel, Beam Soffit, 0-1" Depth	√
8	Beam Soffit	Powder	8/10/2016	12:00 PM	-	Budd Inlet	West Channel, Beam Soffit, 1-2" Depth	√
9	Beam Soffit	Powder	8/10/2016	12:00 PM	-	Budd Inlet	West Channel, Beam Soffit, 2-3" Depth	√
10	Deck Soffit	Powder	8/10/2016	12:00 PM	-	Budd Inlet	West Channel, Deck Soffit, 0-1" Depth	√
11	Deck Soffit	Powder	8/10/2016	12:00 PM	-	Budd Inlet	West Channel, Deck Soffit, 1-2" Depth	√
12	Deck Soffit	Powder	8/10/2016	12:00 PM	-	Budd Inlet	West Channel, Deck Soffit, 2-3" Depth	√
13	East Wing Wall	Powder	8/10/2016	1:00 PM	9	Capitol Lake	East Wing Wall, Top Surface, 0-1" Depth	√
14	East Wing Wall	Powder	8/10/2016	1:00 PM	9	Capitol Lake	East Wing Wall, Top Surface, 1-2" Depth	√
15	East Wing Wall	Powder	8/10/2016	1:00 PM	9	Capitol Lake	East Wing Wall, Top Surface, 2-3" Depth	√
16	West Wing Wall	Powder	8/10/2016	1:00 PM	2	Capitol Lake	West Wing Wall, Top Surface, 0-1" Depth	√
17	West Wing Wall	Powder	8/10/2016	1:00 PM	2	Capitol Lake	West Wing Wall, Top Surface, 1-2" Depth	√
18	West Wing Wall	Powder	8/10/2016	1:00 PM	2	Capitol Lake	West Wing Wall, Top Surface, 2-3" Depth	√

Table Notes – Sample Identification Nomenclature:
First Letter: A = Abutment, P = Pier
Second Letter: U = Upper, M = Middle, L = Lower

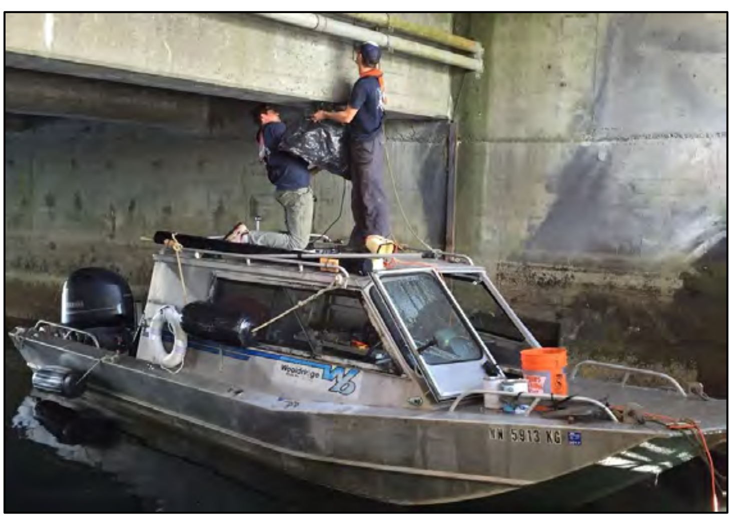

Figure 8: Powder sample collection on beam soffit by M&N

3.3. Cover Survey

TCG conducted a cover survey of the Dam in order to understand the reinforcing depth. The cover survey was completed using a ground penetrating radar (GPR). The GPR device used was a GSSI StructureScan™ Mini HR configured with a 2600 MHz antenna capable of locating rebar at depths of up to 16 inches. The model allows for both 2-D scans, for real time target location, and 3-D scans, for x-ray like imaging. Figures 10 and 11 display select 2-D and 3-D results.

GPR transmits high frequency radio waves into the concrete. The antenna records variations in the reflected return signal due to varying dielectric constants of the buried objects or boundaries. Figure 9 represents the scale used to define the variation in dielectric constants which represent a change in material. The left side of the scale (color black) represents a low dielectric constant and as the colors change from left to right, the value increases. The colors do not represent a specific value but generalize the variations and visually identify changes.

Figure 9: GPR Data Legend

The cover survey focused on the specific field test sites. The cover depths are summarized in Table 4. The GPR measurement will vary slightly based on the concrete's age, material constituents, and internal moisture. The concrete cover was verified in specific locations in order to calibrate the device.

Note that review of the 1949 project specifications stated "All main reinforcement in spillway structure below the deck slab and girders, shall be placed not less than 3 inches from any concrete surface, unless specifically indicated or authorized."

Table 4: Cover Survey Results (Top Layer of Reinforcement Only)

Element	Average Cover, in.	Std. Dev.
Pier Wall	4.0	0.30
Abutment Wall	4.0	0.44
Deck Soffit	1.3	0.07
Beam Soffit	2.5	0.05

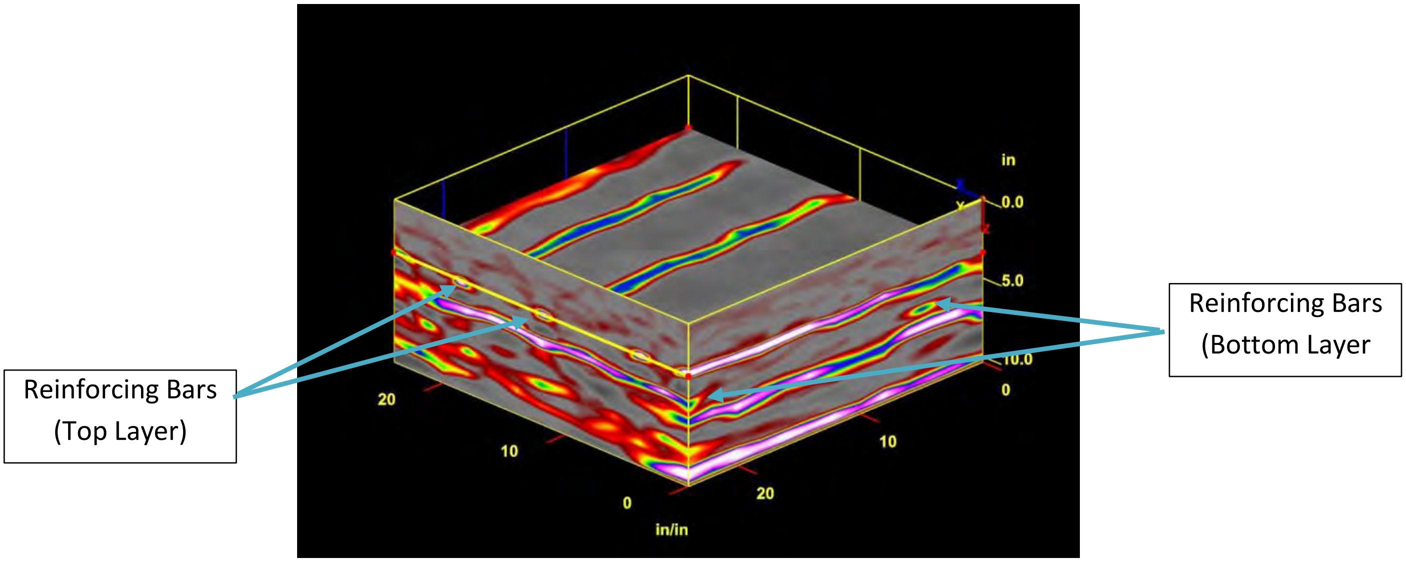

Figure 10: 3-D Image from West Channel Abutment Wall

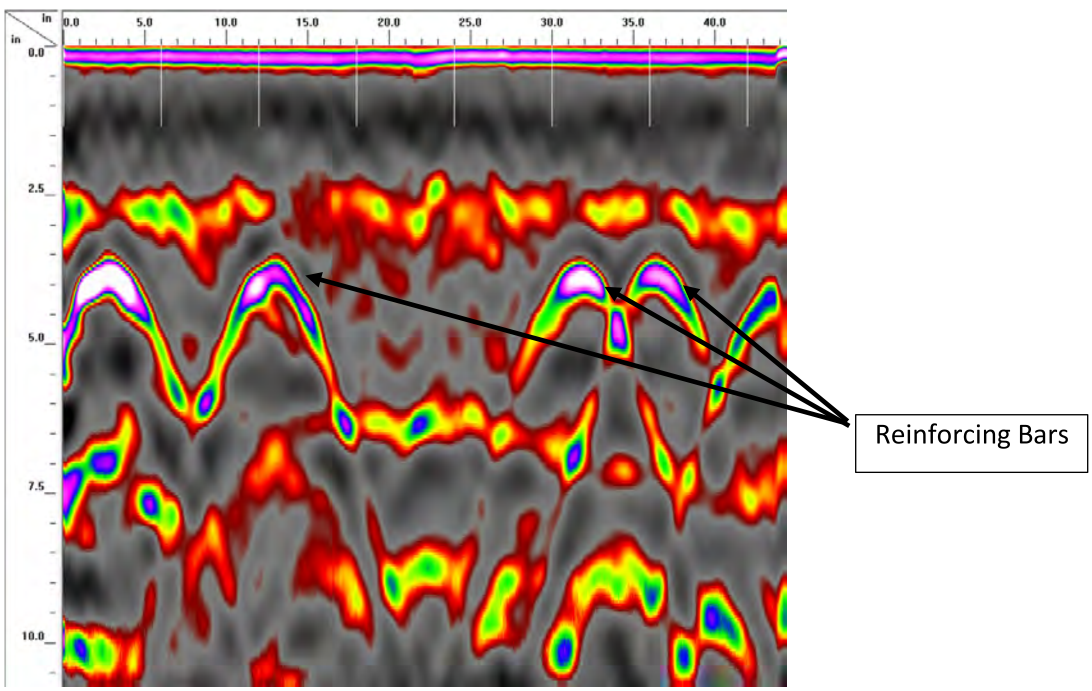

Figure 11: 2-D Image from West Channel Abutment Wall

3.4. Chloride Testing

Chloride testing of samples from each element were used to form a chloride profile. Cores were tested at 6 depths in 1-inch increments, and powders were collected and tested at 3 depths in 1-inch increments. Cores were cut into disks at predetermined depths and then pulverized into powder. The powder was then used to determine the chloride concentration according to ASTM C1152 "Standard Test Method for Acid-Soluble Chloride in Mortar and Concrete". The test results are summarized in Table 5 and plotted in Figures 12 through 15. Test reports are provided in the Appendix.

It is apparent that the chloride contents at the level of reinforcement has increased since the 2008 condition assessment, reference Figures 13 through 15. Note the 2008 assessment tested one depth at the level of rebar. Chlorides appear to be near or above the critical chloride threshold level of black bar for the pier and abutment walls within the tidal zones. A chloride threshold of 500 parts per million (ppm) or 0.05% by weight concrete was assumed. This indicates that corrosion is likely to initiate in the near future or has already been initiated, which seem to agree with the half-cell potential results presented in Section 3.5. The time it takes for corrosion to propagate and cause cracking or spalling at the concrete surface varies and depends on several variables. Literature and research indicate the propagation for black steel typically ranges from 4-10 years. Propagation is discussed further in Section 3.7.

The abutment and pier walls above the tidal zone along with the wing walls on the Capitol Lake side above the water, appear to be well below the chloride threshold for corrosion at the depth of reinforcement.

Table 5: Acid-Soluble Chloride Results

Acid-Soluble Chloride Results								
Sample No.	Sample ID	Location	Depth Increments, inches					
			0-1	1-2	2-3	3-4	4-5	5-6
			0.5	1.5	2.5	3.5	4.5	5.5
			ppm	ppm	ppm	ppm	ppm	ppm
1	PM	Pier Wall-High Tide	5258	3800	2607	802	221	95
2	PL	Pier Wall-Low Tide	3945	2044	916	246	163	145
3	AL	Abutment Wall-Low Tide	4617	2421	1540	924	418	166
4	AM	Abutment Wall-High Tide	4815	2813	1947	1753	704	422
5	AU	Abutment Wall-Above Tide	597	103	55	54	59	59
6	PU	Pier Wall-Above Tide	476	75	69	71	87	76
7,8,9	-	Beam Soffit-Above Tide	186	49	47	-	-	-
10,11,12	-	Deck Soffit-Above Tide	70	34	46	-	-	-
13,14,15	-	East Wing Wall-Above Tide	146	106	111	-	-	-
16,17,18	-	West Wing Wall-Above Tide	861	320	167	-	-	-

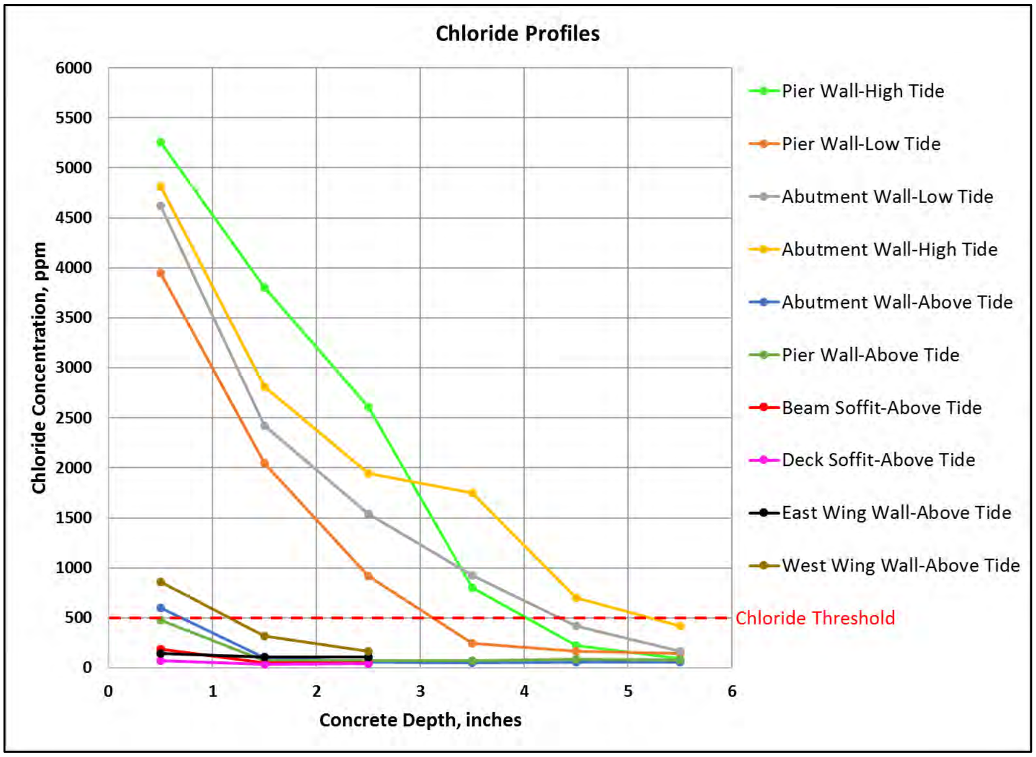

Figure 12: TCG Measured Chloride Profiles

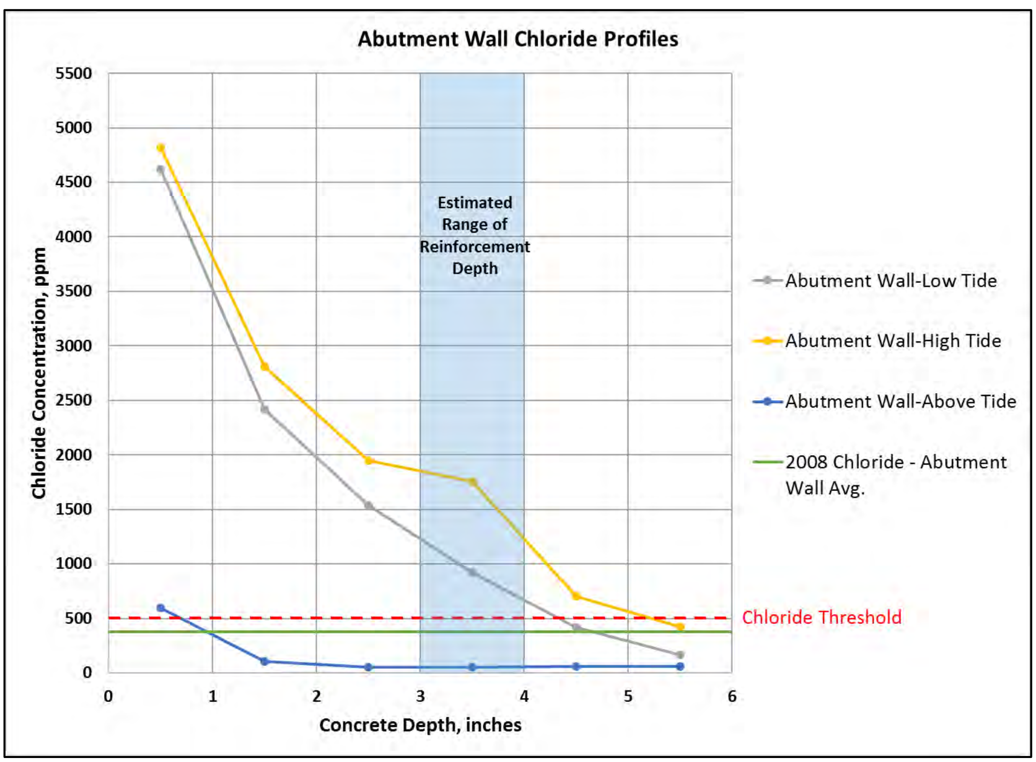

Figure 13: Abutment Wall Chloride – TCG Results vs 2008 Assessment

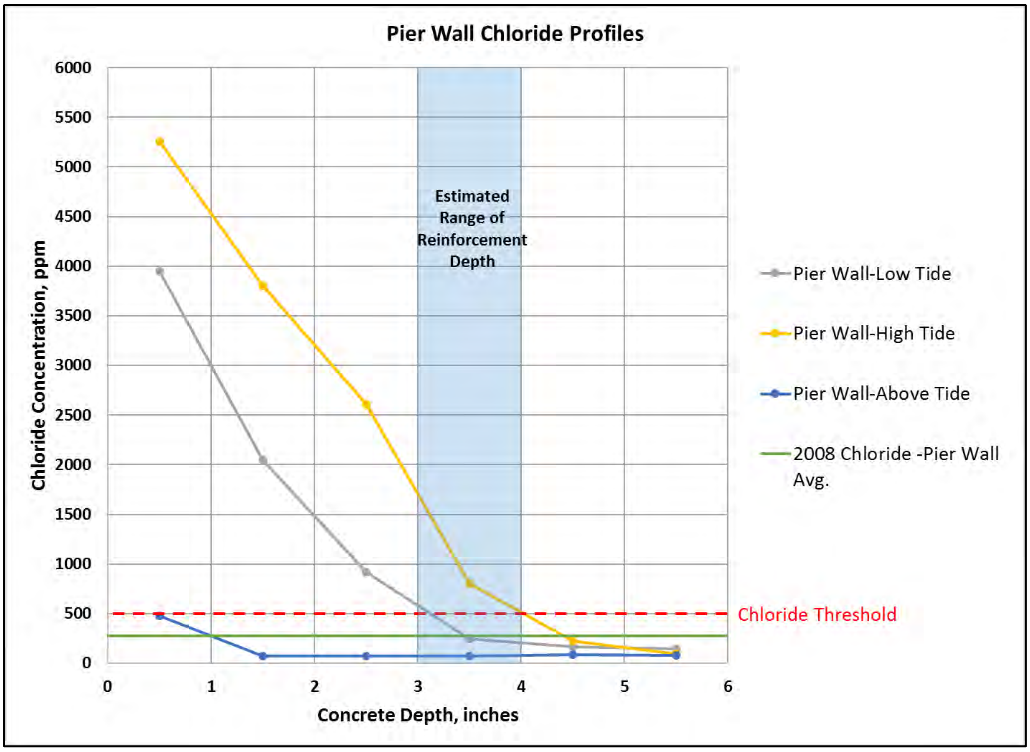

Figure 14: Pier Wall Chloride – TCG Results vs 2008 Assessment

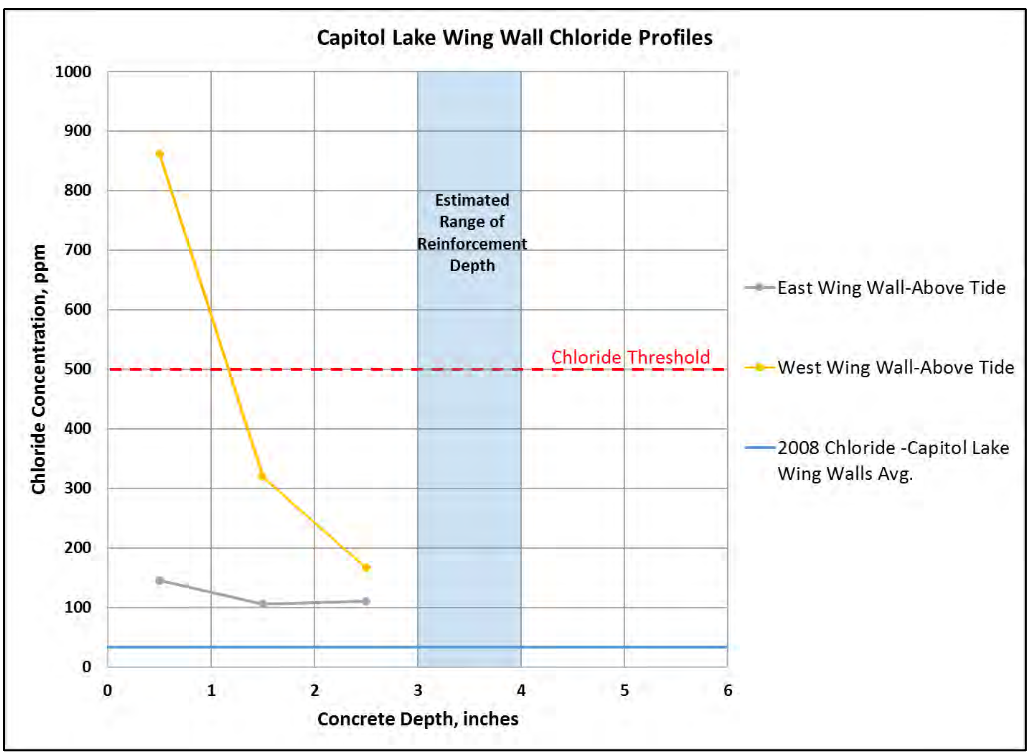

Figure 15: Capitol Lake Wing Wall Chloride – Current Results vs 2008 Assessment

3.5. Half-Cell Potential Survey

During the site investigation electrochemical testing was completed according to ASTM C876 "Standard Test Method for Half-Cell Potentials for Uncoated Reinforcing Steel in concrete". This test consists of drilling and connecting to the reinforcing steel in two locations within the desired testing area in order to test for continuity of the reinforcing steel. The test method is limited by electrical circuitry and requires electrical continuity in the steel reinforcement for relevant interpretations. Once continuity is confirmed, half-cell measurements can be taken by connecting to the steel reinforcement and placing a reference electrode in circuit to measure the electrical potential. In this case, a copper-copper sulfate (Cu-$CuSO_4$) reference electrode was used and placed in contact with the concrete in grid patterns (6" spacing) to measure the potential at multiple locations within an area. An equipotential contour map can then be developed to determine locations of active corrosion, refer to Figures 16 through 22. According to ASTM C876 an electrical potential more negative than -350 mV CSE indicates more than 90% probability for corrosion activity. Table 6 provides the standard probability limits for corrosion activity according to ASTM C876. Figures 23 and 24 display example half-cell survey sites.

Table 6: Standard Limits of Likelihood of Corrosion Occurrence Based on ASTM C876

Half Cell Potential Measurements	Risk of Corrosion Activity
> -0.200 mV CSE	<10%
< -0.200 and > -0.350 mV CSE	Uncertain level of corrosion activity
< -0.350 mV CSE	>90%

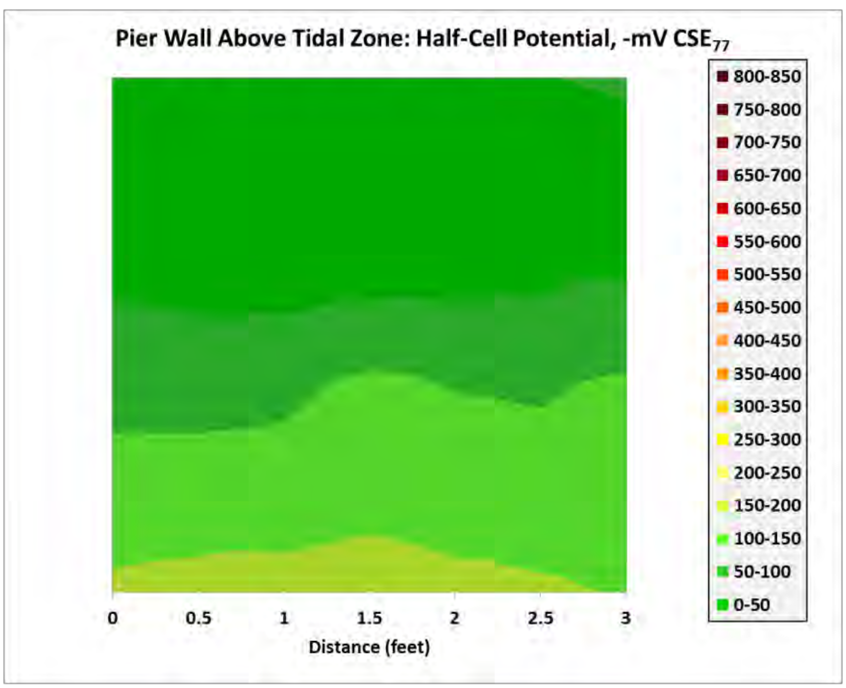

Figure 16: West Channel Pier Wall – Above Tidal Zone – 3' x 3' Grid

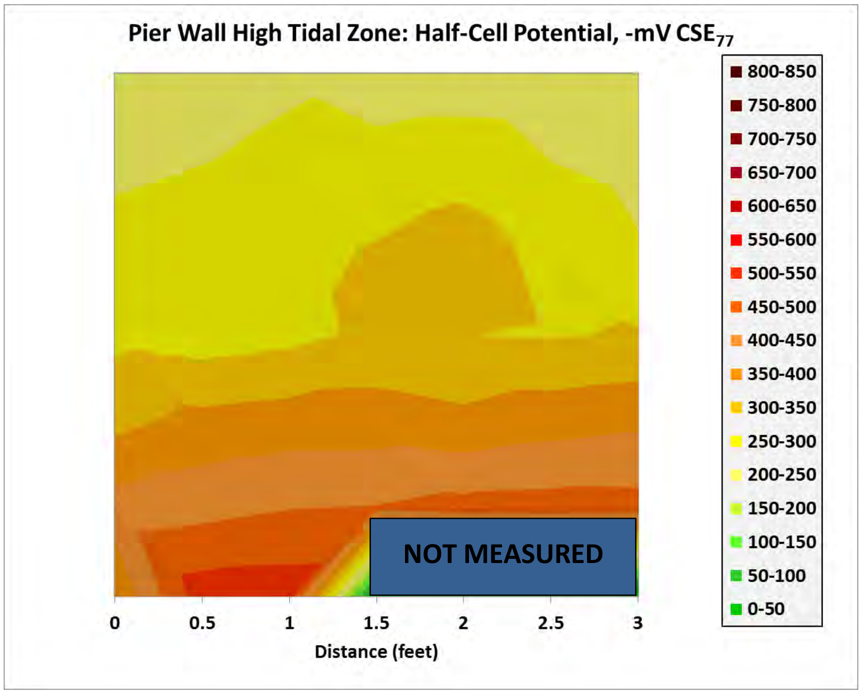

Figure 17: West Channel Pier Wall – High Tidal Zone – 3' x 3' Grid

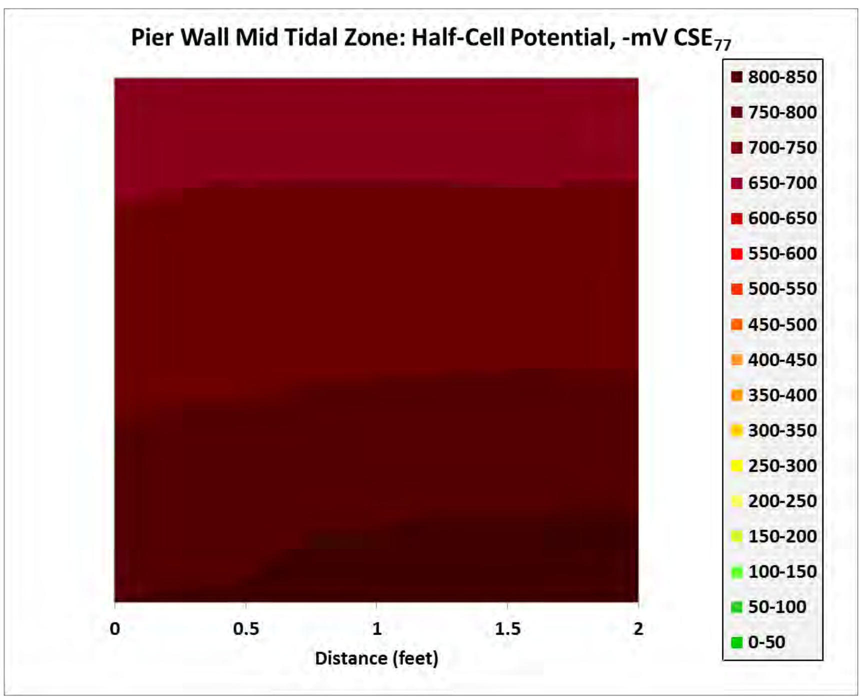

Figure 18: West Channel Pier Wall – Mid Tidal Zone – 2' x 2' Grid

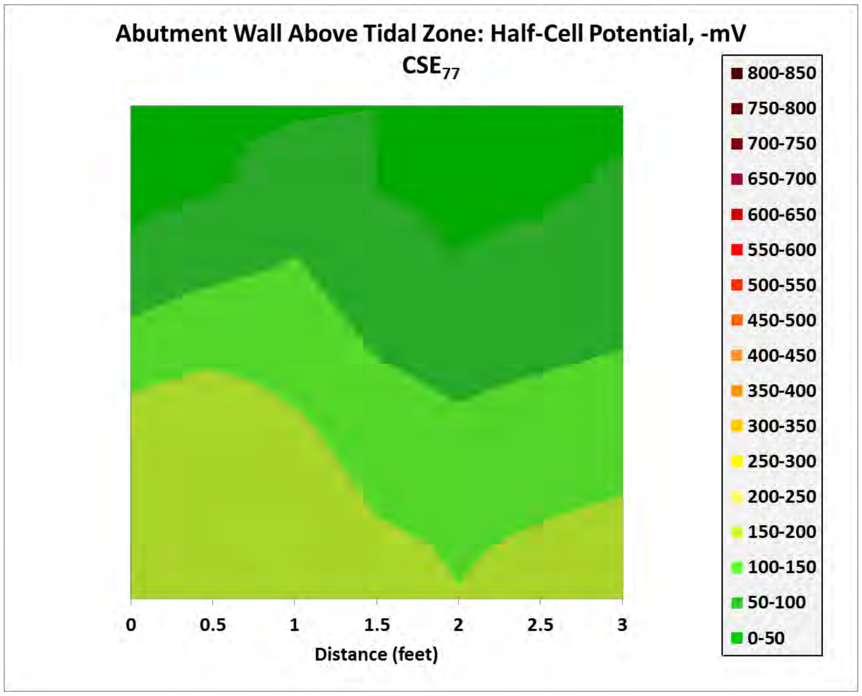

Figure 19: West Channel Abutment Wall – Above Tidal Zone – 3' x 3' Grid

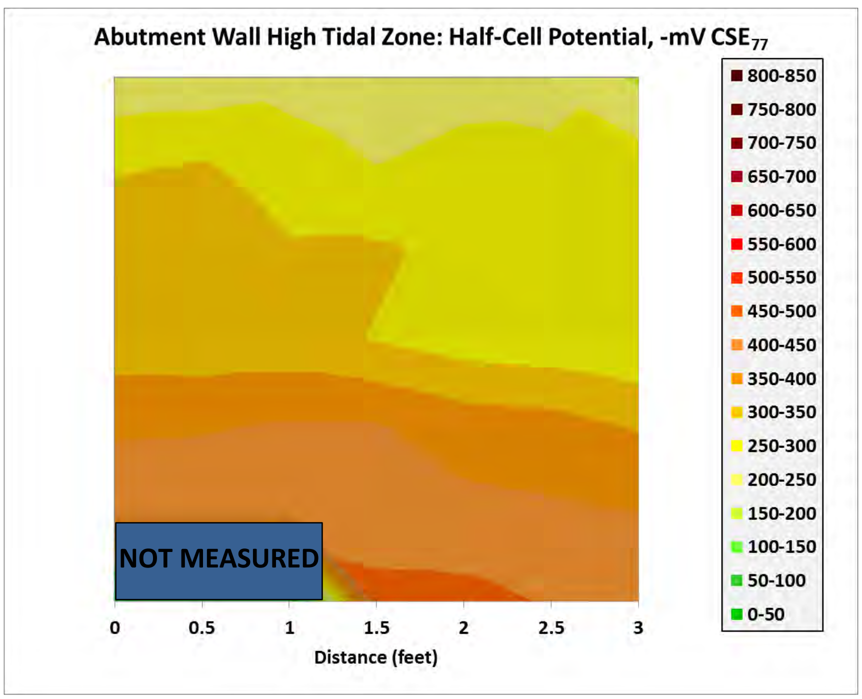

Figure 20: West Channel Abutment Wall – High Tidal Zone – 3' x 3' Grid

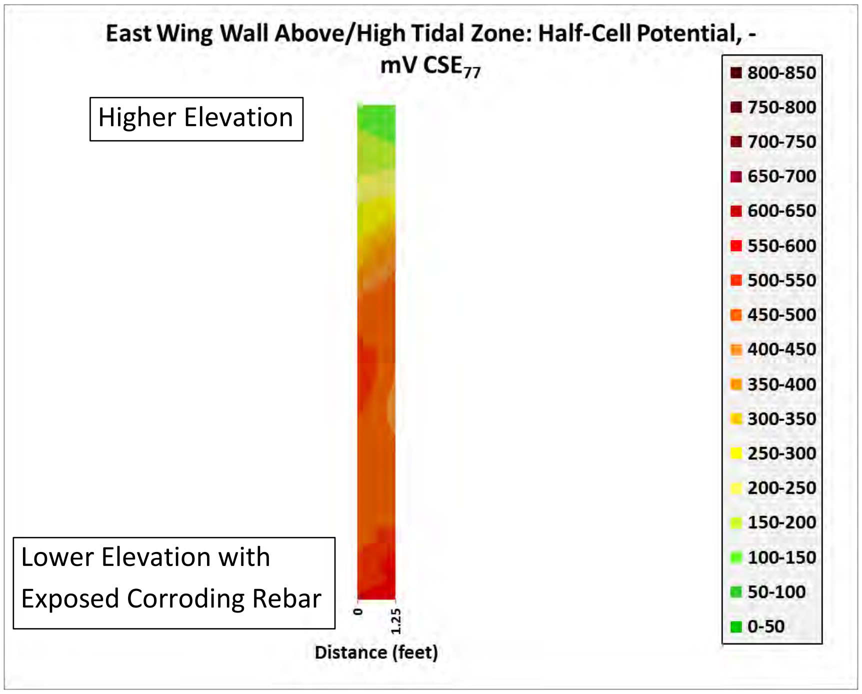

Figure 21: Budd Inlet – East Wing Wall Top Surface – Above/High Tidal Zone – 1.25' x 12.5' Grid – Exposed Rebar Exhibiting Corrosion

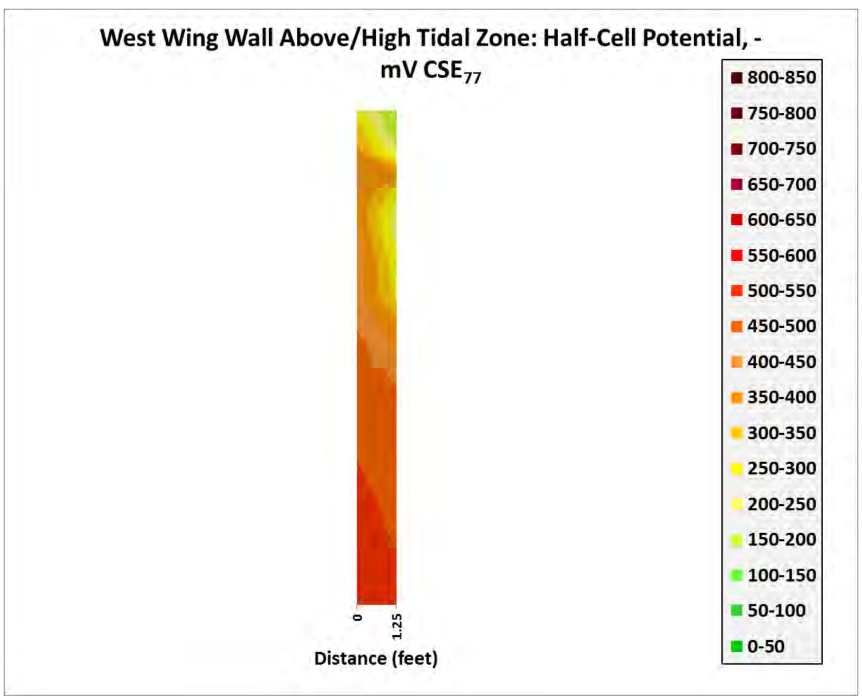

Figure 22: Budd Inlet – West Wing Wall Top Surface – Above/High Tidal Zone – 1.25' x 12' Grid

Figure 23: Half-Cell Potential Survey Site (West Channel Pier Wall – High Tidal Zone)

Figure 24: Half-Cell Potential Survey Site (East Wing Wall With Exposed Corroding Rebar)

The half-cell potential findings indicate there is high potential for corrosion within the tidal zones. There is greater than 90% probability that there is corrosion activity within the specific test areas. Note that rebar was found in two of the six cores (pier wall above tide and at low tide – samples 2 and 6) and did not display significant corrosion. There appeared to be mild signs of rust in small select areas of the steel. Steel shows no loss in cross-sectional area. Some of the rust may be attributed to two days of storage and transport in moist containers. There did appear to be some minor cracking on the structure, most significant was found in the east wing wall, reference Figure 24. It is unclear whether this cracking was caused by corrosion or by an outside force, such as a boat.

Areas above the tidal zone have less potential for corrosion. The corrosion activity is within the range that is either less than 10% probability or the probability is uncertain.

3.6. Concrete Electrical Resistivity

Concrete resistivity directly affects the corrosion rate in that as resistance increases, current decreases. Resistivity of the same concrete can vary depending on the temperature and degree of saturation, therefore readings were taken within the tidal zone and above. The resistivity's were found to be on average 21.5 kΩ-cm for concrete above the tidal zone and average of 53.4 kΩ-cm for concrete within the high tidal zone. The resistivity's are in the range that is associated with good quality concrete.

3.7. Estimated Corrosion Rate Analysis

Corrosion rate was not directly measured in the field, however TCG has calculated the corrosion rate based on half-cell potential readings and resistivity measurements of the concrete. The potential contours are perpendicular to the ionic currents in the concrete. The current can be estimated by dividing the potential difference by the resistance in the concrete between the contours. The resistance is a function of the resistivity of the concrete multiplied by the distance between the contour lines. Thus if the contours are closer together, the resistance is lower and the current is higher. The equation is as follows:

$$i = \Delta V/\rho l$$

where, i is the current density in A/cm^2, ρ is the resistivity in Ω•cm, l is the distance between potential contours in cm, and ΔV is the voltage difference between the contours in volts.

The steel in the more negative contour is the corroding steel. The areas of the most intense corrosion are regions where the most negative contours are surrounded on all sides by a less negative potential. Note that this is just one point in time and conditions can change to become more or less corrosive dependent on temperature, future chloride contents, oxygen contents, and degree of saturation. Table 7 below shows the estimated currents based on the above analysis.

Table 7: Corrosion Calculations

Element	Exposure Location	Potential Corroding Area (mV SCE)	ΔV (V)	l (cm)	Corrosion Rate	
					i(μA/cm^2)	μm/year
East Wing Wall	Above/High Tide	-569	0.05	30.5	0.076	0.89
West Wing Wall	High Tide	-536	0.05	61	0.038	0.44
Pier Wall	High Tide	-521	0.05	7.6	0.37	4.33
Pier Wall	Mid Tide	-832	0.05	15.2	0.15	1.76
Abutment Wall	High Tide	-467	0.05	15.2	0.15	1.76

Calculated currents and corrosion rates appear to be low. Even though corrosion may have initiated, the corrosion rate is low and may take longer than the typical 4-10 years for propagation to occur due to the corrosion rate, concrete type, rebar depth, and size of the rebar.

4. Summary of Findings

During general visual observations no substantial concrete distress or damage was identified. One significant crack on the east wing wall on the Budd Inlet side was found but the root cause of the crack is unknown. Visual observation of steel found in cores showed mild signs of rust in small select areas. Signs are minor and show no loss in cross-sectional area.

The corrosion of steel in concrete requires several conditions to be present. The lack of any of these conditions will prevent corrosion from occurring. These conditions are:

- Anode metal (reinforcing steel);
- Cathode metal and oxidant (reinforcing steel with oxygen present);
- Electrolyte (within concrete capillary pores or if in contact sea water);
- Depassivating ion (e.g. chloride);
- Electrical connection between anode and cathode.

Concrete areas within and above the tidal zone have available oxygen. Moisture and chloride ions are present either through airborne, splash, or direct contact to seawater. Continuity of rebar was checked at each half-cell location and confirmed. All of the conditions exist for corrosion of rebar to occur.

Test results for the deck underside and beams indicate chloride levels significantly below the threshold levels and less than 10% probability that no corrosion is occurring. TCG believes this area is not a concern for corrosion within the next 50 years. Test results indicate chloride concentrations are near or above the critical level for corrosion initiation in the tidal exposure zones. Half-cell potential readings also showed high potential for corrosion in these areas. Therefore, corrosion is likely to have initiated in these specific areas. However, based on our estimated corrosion rate, the time until concrete will crack or spall may be longer than the typical 4-10 years of propagation. The propagation period can vary based on several factors and there is a level of uncertainty in calculating this value.

Since it is likely that corrosion has initiated in certain areas of the structure, service life modeling using the STADIUM® software is unnecessary. The remaining service life of the structure in its current condition mainly depends on the propagation period.

5. Recommendations

It is understood that 50 years of additional service life is needed for the Capitol Lake Dam. TCG would recommend installation of either a galvanic or impressed current cathodic protection (CP) system to address corrosion of the reinforcing steel in the concrete walls within the tidal zone and above. The basic principle of cathodic protection is to use galvanic or impressed currents to electrochemically convert the corroding anodic steel reinforcing to be a non-corroding cathode. The new anode is not structural and is not destructive to the reinforced concrete system.

Galvanic Cathodic Protection

In a galvanic system, sacrificial galvanic anodes are embedded in the concrete and connected to the steel reinforcement. Since the galvanic anodes are a more electrochemically active metal, the anodes continue to corrode instead of the steel rebar consuming the anode material until eventually it must be replaced. The number and mass of anodes must be designed based on the structure details. The pros and cons are as follows:

Pros	Cons
- Low maintenance - Less chance of vandalism since there are no exposed wires or rectifiers. - Power source is not required - Low initial cost	- Depending on reinforcement detailing, large anode masses could be required making it impractical. - The anode has a distinct life and is not renewable (replacement within 25 years). - Metallizing galvanic system is not applicable in a wet/dry environment. - Higher long term cost due to system replacement within 25 years.

Estimated General Cost = \$40 per ft^2
(Materials & installation in a tidal environment)

Estimated Engineering Design Cost = \$10,000

Estimated area of CP = 11,400 ft^2
(Includes abutment, pier & fish ladder wall faces from MLWL to top of element. Note it was assumed one set of anodes in the fish ladder and pier walls can protect both sides of walls.)

Total Estimated Cost = \$932,000
(Materials & installation x2 & engineering design x2 to account for system replacement within 25 years)

Impressed Current Cathodic Protection

An impressed current system uses anodes connected to an external DC power source, typically a transformer-rectifier connected to AC power. The amount of anodes and required power must be designed based on the structure details. The pros and cons are as follows:

Pros	Cons
- Less disruptive installation. - With replacement of rectifier, this system will last the entire 50 years. - Capability of remote monitoring of CP system - Lower long term cost	- Requires monitoring/adjustments periodically. - Requires a power source - Rectifier replacement within 15-25 years - Exposed wiring gives higher chance for vandalism, however access is limited. - Higher initial cost

Estimated General Cost = \$50 per ft^2
(Materials & installation in a tidal environment)

Estimated Engineering Design Cost = \$12,500

Estimated area of CP = 15,816 ft^2
(Includes abutment, pier & fish ladder wall faces from MLWL to top of element. Note the estimate includes both sides of the fish ladder and pier walls)

Total Estimated Cost = \$792,050
(Materials, installation, design)

Note: Costs are relative to typical tidal installations and are estimated for the two abutment faces (including wing walls), fish ladder wall faces and two pier wall faces from the MLWL to the top of the elements. Reinforcement detailing and specific designs of each system will be required to determine actual cost.

Based on our findings and the structural element details, we would recommend installing an impressed current CP system for the concrete walls within the tidal zones and above. We would recommend installing the system within the next 2-3 years before physical damage to the concrete occurs.

Liability and Limitations

This report contains professional opinions and judgments based on the conditions observed during our site visits, testing, and documents that have been provided to us. This report is believed to be accurate within the limitations of the information obtained. TCG reserves the right to modify our recommendations should more data or information become available.

APPENDIX

1. Chloride Test Report

Tourney Consulting Group LLC
3401 Midlink Drive
Kalamazoo MI 49048

Phone (269)-384-9980
Fax (269)-384-9981
www.tourneyconsulting.com

ASTM C 1152 Acid-Soluble Chloride Ion Contents (PPM)

Client: Moffatt & Nichol
600 University Street Suite 610
Seattle, WA 98101
Attention: Bryon Haley

Date Cored: 8/9 & 8/10/16
Date Received: 8/15/2016
Date Tested: 8/18 & 8/24/16
Date Reported: 8/24/2016

TCG Project No. 16066
Project Description: **Capitol Lake Dam Project**

Sample Description: Six (6) 1-3/4" diameter cores & twelve (12) concrete powders were received for testing. The cores were cut at the depth increments listed below. All samples were dried and crushed to ensure all material passed a #20 Sieve.
The Chloride data is reported by mass of sample.

TCG Technician: MW

	Depth Increments in Inches											
	0 to 1		1 to 2		2 to 3		3 to 4		4 to 5		5 to 6	
Sample ID	Chloride Content ppm	Chloride content (% by mass of sample)	Chloride Content ppm	Chloride content (% by mass of sample)	Chloride Content ppm	Chloride content (% by mass of sample)	Chloride Content ppm	Chloride content (% by mass of sample)	Chloride Content ppm	Chloride content (% by mass of sample)	Chloride Content ppm	Chloride content (% by mass of sample)
Core 1 PM	5258	0.526%	3800	0.380%	2607	0.261%	802	0.080%	221	0.022%	95	0.010%
Core 2 PL	3945	0.395%	2044	0.204%	916	0.092%	246	0.025%	163	0.016%	145	0.015%
Core 3 AL	4617	0.462%	2421	0.242%	1540	0.154%	924	0.092%	418	0.042%	166	0.017%
Core 4 AM	4815	0.482%	2813	0.281%	1947	0.195%	1753	0.175%	704	0.070%	422	0.042%
Core 5 AU	597	0.060%	103	0.010%	55	0.006%	54	0.005%	59	0.006%	59	0.006%
Core 6 PU	476	0.048%	75	0.008%	69	0.007%	71	0.007%	87	0.009%	76	0.008%
Beam Soffit 7,8,9	186	0.019%	49	0.005%	47	0.005%						
Deck Soffit 10,11,12	70	0.007%	34	0.003%	46	0.005%						
East Wing wall 13,14,15	146	0.015%	106	0.011%	111	0.011%						
West Wing wall 16,17,18	861	0.086%	320	0.032%	167	0.017%						

Reviewed By;
Larry Wachowski
Laboratory Manager

2. Concrete Core Photographs

Figure 25: Sample 1 – Pier Wall High Tide

Figure 26: Sample 2 – Pier Wall Low Tide

Figure 27: Sample 3 – Abutment Wall Low Tide

Figure 28: Sample 4 – Pier Wall High Tide

Figure 29: Sample 5 – Abutment Wall Above Tide

Figure 30: Sample 6 – Pier Wall Above Tide

APPENDIX C – Fifth Avenue Dam Capitol Lake Tide Gates Machinery and Controls Assessment

CAPITOL LAKE DAM MACHINERY AND CONTROLS ASSESSMENT

PROJECT NAME: CAPITOL LAKE DAM PRESERVATION

PROJECT NO.: 2016-931

Released: January 30, 2017

Revision: 0

CHRISTOPHER A. HUCK
STATE OF WASHINGTON
37507
REGISTERED PROFESSIONAL ENGINEER
EXPIRES 5 - 29 - 18

Prepared by: Christopher Huck, P.E.
David Wilson, P.E.
Fives Lund LLC
For Moffatt & Nichol

TABLE OF CONTENTS

1 Introduction and Background

The Capitol Lake Tide Gates serve as a level control means for Capitol Lake and helps to prevent flooding of downtown Olympia. The two radial gates operate within an earthen dam separating Budd Inlet and the north Basin of Capitol Lake. The dam also prevents the incursion of Puget Sound salt water into the fresh water lake.

The 24 foot wide east and 36 foot wide west gates are mechanically operated using independent wire rope hoisting systems. The hoists are driven using electric motors through a combination of gear reducer, roller chain, and open gears. Two wire ropes are played out from two rope drums connected through a common drive shaft. The west radial gate has a hydraulically operated back-up system. The tide gate mechanical and control systems are contained within the machinery house located over the top of the two gates on the dam. Stop logs can be inserted upstream of the dam to dewater the gates. All electrical and mechanical tide gate components are inspected and maintained by the State.

Original construction of the dam was completed in 1952. Rehabilitation projects have taken place over time. Table 1-1 summarizes projects and the approximate year of occurrence that are known to the author. This list is not necessarily comprehensive and is based on a review of plan and specification packages provided by the Department of Enterprise Services (DES).

Table 1-1 List of Completed Projects Over Time (Not Exhaustive)

Year	Work Completed
c. 1952	Spillway original construction.
1980	New gate seals installed.
	Generator installed.
	Existing hydraulic backup system pump replaced with motorized pump with valve.
1986	Crater siphon system installed.
	Hoist enclosed gears inspected and serviced.
	Gate seals replaced.
1994	Gates removed and cleaned/repaired.
	Gate seals replaced.
	Catwalks added.
2015	Fish ladder weirs replaced/repaired.
2016	Plastic coated gate hoist wire ropes replaced with stainless steel wire rope.

The spillway has been in operation for over 60 years. In general, the spillway machinery continues to function in the marine environment. No critical areas of concern were noted but the system is, however, showing its age. There are areas of advancing corrosion and wear.

On Tuesday September 6th David Wilson and Christopher Huck of Fives Lund LLC (Lund) arrived at the dam and met with Bing Bristol and TJ Snodderly, of the Washington State Dept. of Enterprises Services, to inspect the dam and discuss tide gate operations. Mr. Bristol has been responsible for operating and maintaining the dam for approximately eight years. The details of the operator interviews and inspection are recorded on the attached site inspection report. This assessment provides a summary of pertinent observations and comments from the operators for each system.

2 INSPECTION OF MACHINERY AND CONTROLS

2.1 Tide Gates Mechanical Machinery

2.1.1 General

Typical operational parameters for the tide gate machinery are as follows: 2 to 3 opening/closing cycles per day in the summer and 8 to 9 opening/closing cycles per day in the winter. The gates are controlled by the METASYS control system which will lift the east gate to fully open for a period of time before fully closing the gate. The lifting of the gate and the time open are based on a Proportional/Integral/differential (PID) algorithm in the METASYS programming that attempts to maintain a particular lake setpoint elevation. This algorithm has input from level sensing equipment on both the lake side and the Budd Inlet side of the gate to prevent the gate from opening when tide levels might allow ingress of saltwater into the lake.

In the winter, when there are increased flooding concerns, the operators sometimes decrease the setpoint elevation. This is a new practice since the last assessment in 2008 when the procedure was to manually override the programming. Operators report that this works well with less adverse effect on the program when it is brought on line after a manual override.

The west gate is also controlled by the METASYS system and works to supplement the smaller east gate during heavy flows. As such, the west gate experiences much fewer cycles than the east gate.

The hoists have a typical cycle time of 15 to 20 minutes per cycle, nearly steady load (no shock loads) with adequate time for the machinery to cool off between cycles. During our inspection all gates were exercised to witness machinery and controls functionality. All observations were made from the machinery house or the gate catwalk.

Figure 2-1 Wire Rope and Drum – East Gate

2.1.2 Ropes, Connections and Drums

Each radial gates is lifted by four wire ropes, one pair at each end of the gate. The ropes are connected to the gates using an "equalizer" plate and pin. The equalizer ensures that the two ropes share the load equally. The previously used plastic coated ropes were replaced in March 2016 with stainless steel rope and appear to be in very good condition. The ropes are stored on two grooved steel drums connected through a common shaft, Figure 2-1. The ropes are wound on the drums in a neat, orderly fashion. No evidence of damage to the wire ropes was observed. Since the rope is stainless steel in contact with a painted steel drum that has breaks in the paint due to age, galvanic corrosion could occur. The attacked substrate would be the drum. It is recommended that the drum surface be monitored for degradation.

The drums have general corrosion (rust) where paint has worn away or degraded.

One of the west gate drums has a broken flange, although this does not appear to be detrimental to gate operation, Figure 2-3.

The drum shafts and couplings have various areas of excessive paint degradation, as shown in Figure 2-2

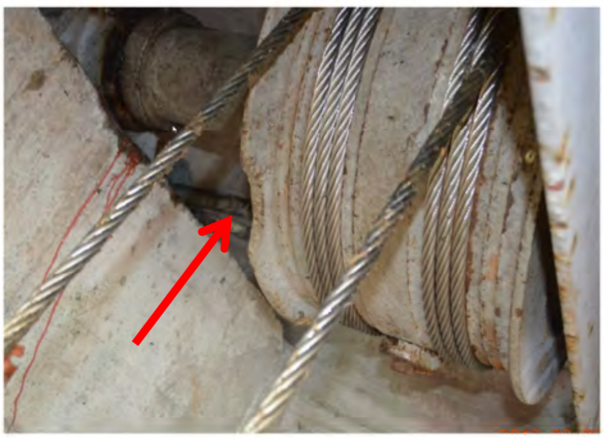

Figure 2-3 Drum Flange – West Gate

Figure 2-2 Shaft and Coupling Paint Degradation – East Gate

Pillow block bearing assemblies support the shaft. All the shaft bearings are fitted with grease couplings for re-lubrication. The pillow blocks are plain bearings. The bearings were not disassembled for this inspection. Lubrication appears adequate.

Figure 2-4 Bearing – Split Line Gap

One of the bearings appears to have a growing gap between the upper and lower housing, as evidenced by lubrication visible coming through the gap, as shown Figure 2-4. Note that several of the pillow blocks are mounted in what is considered the week direction of the block, that is, suspended from the bolts.

Each spillway gate is now provided with a backup limit switch. The 2007 inspection indicated that only one gate had this feature. The operators report that the automated controls have allowed the system to miss the limit from the rotary switch unit in the machine room with the consequence being that the gate was lifted to a hard stop position and the cable broken and the gate dropped. These limits were tested while running each gate and found operate as expected. Figure 2-5.

Figure 2-5 Back-up Limit Switches – Tide Gates

2.1.3 Hoist Equipment

The wire rope drums are connected to an open spur gear set which is driven by a chain and sprocket arrangement. Based upon our limited inspection the gears for both gates appear to be in fair condition with some general wear and excessive wear or damage in limited locations.

Figure 2-6 Broken Tooth – Pinion Gear – East Tide Gate

The pinion gear shown in Figure 2-6 shows a loss of approximately one quarter of the tooth. Much grassy/woody debris is evident trapped within the grease on the flanks as well. The cause of the tooth damage is unknown. A possible cause is during one of the incidents which broke ropes.

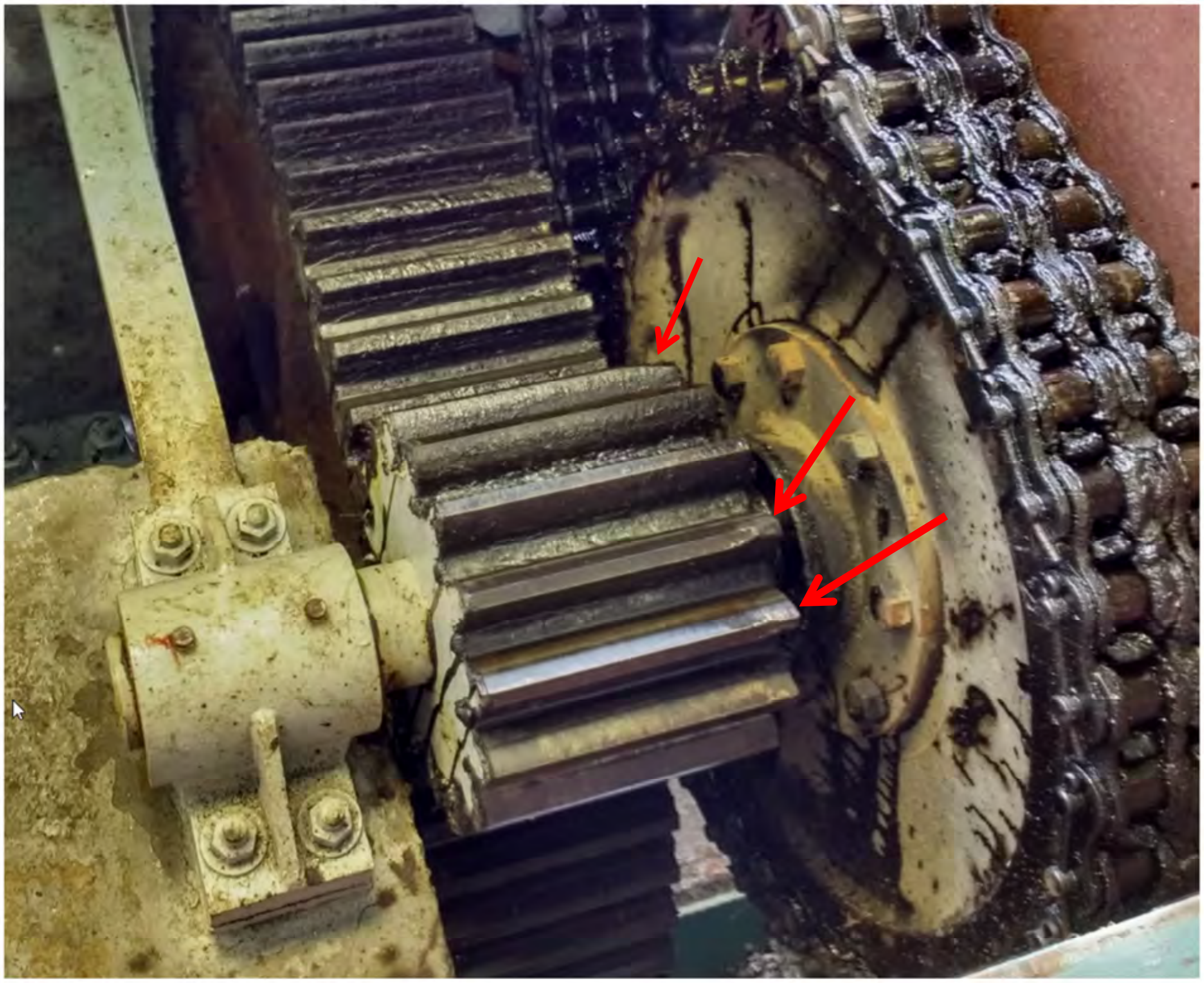

Figure 2-7 Pinion Gear – Worn Corners – West Tide Gate

The west gate pinion, Figure 2-7, also shows some wear but has less woody debris. Some corners have excessively worn corners on one side. These areas do not occur on every tooth but skip certain teeth. Misalignment would normally be expected, however, since it occurs on only a few teeth, an overload condition is expected.

The drive sprockets are connected to a cone type gear reducer with a 625 to 1 gear ratio, see Figure 2-9 and Figure 2-8. The gear reducers do not exhibit any alarming noises or show any signs of leaking oil from the shaft seals. The east and west gate drive mechanisms still have their original gear reducers.

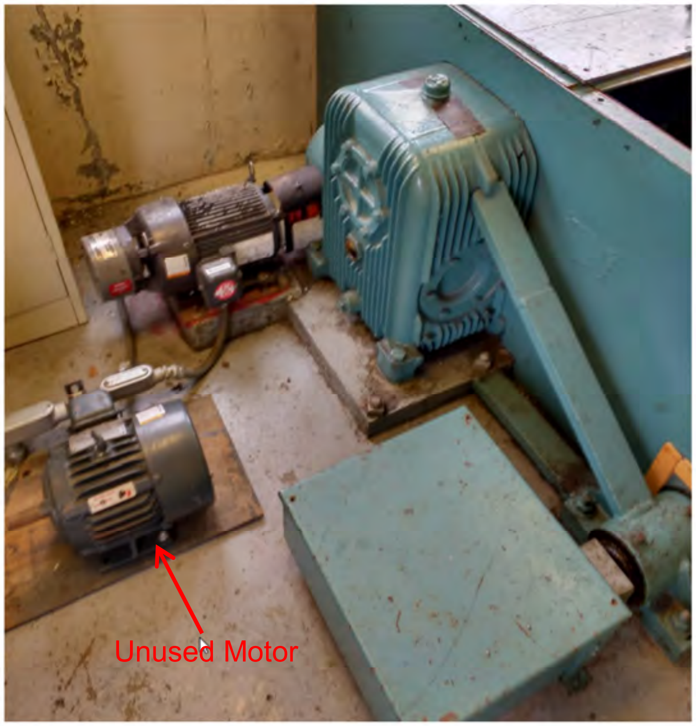

Figure 2-8 East Gate Drive Components

Figure 2-9 West Gate Drive Components

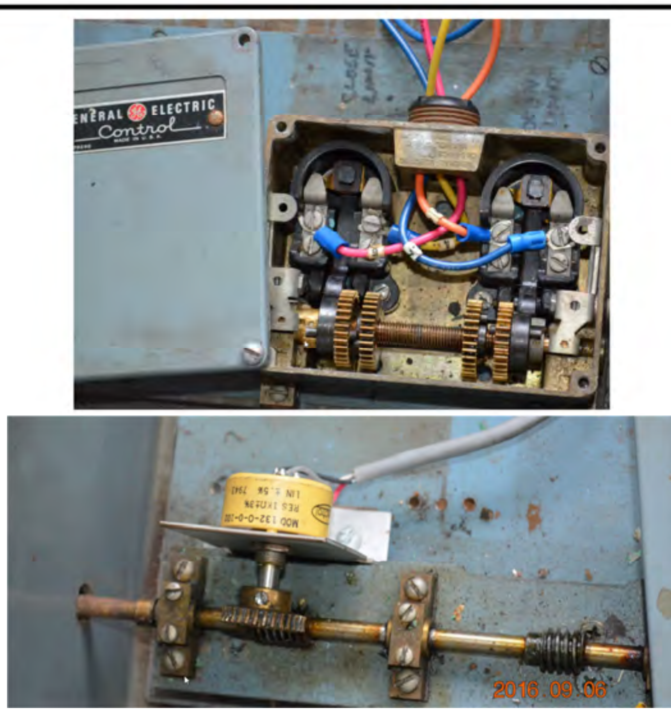

Figure 2-10 Rotary Limit Switch and Position Potentiometer

Each gate has a 3 horsepower electric motor as the prime mover. The motors are connected to the gear reducers through flexible shaft couplings. The motor for the west gate appears to be the original.

Spring set motor brakes hold the gate load when the gates are in their open position. The enclosed brake pads are protected by the brake cover and as such the wear was not observed. No unusual noises were observed when the brakes operated.

Figure 2-11 Coupler Proximity to Gearbox –West Gate

There are rotary limit switches connected to the large sprocket/pinion gear shaft. The aging rotary switch mechanism has a fair amount of dust which appears to have accumulated over time but it appears functional.

The west gate motor coupling was observed to be in very close proximity to the gear box, raising concern of potential future contact and rubbing. See Figure 2-11 Coupler Proximity to Gearbox –West Gate.

Both gearboxes were observed for oil content from the top mounted breather exhaust plug, Figure 2-12. The plugs generally look dirty and ready for replacement.

Figure 2-15 Oil Color – West Gate

Figure 2-14 Oil Color – East Gate

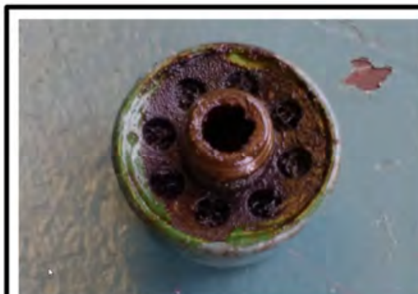

Figure 2-12 Gearbox Breather Plug-Typical Condition

On both gearboxes, the gears on the first stage (motor input stage) appear wet but the oil level cannot be seen. The second stages have the oil level apparent from the open hole. The east gate gearbox oil appears to be clear while the west gate gearbox oil is darker, possibly in need of replacement. See Figure 2-15, Figure 2-14.

Both gates were raised and lowered through a full cycle. No unexpected or loud noises were evident. The system was relatively quiet and appeared to run smoothly. All limits functioned as expected (normal stop and backup stop).

2.1.4 Gate Trunnions

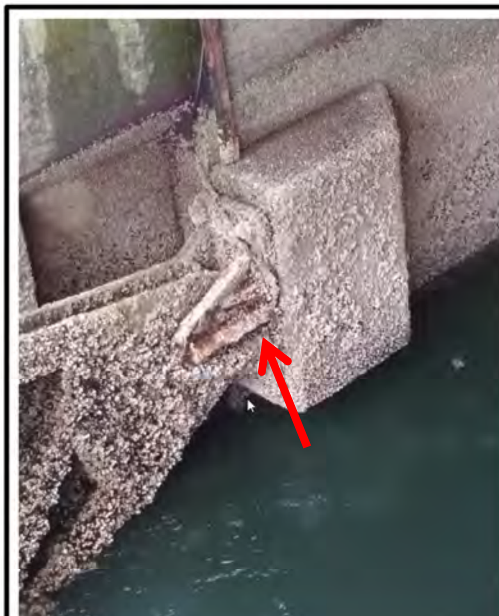

Figure 2-13 Gate Trunnion Connection – Typical Condition

The gate trunnions were observed from the catwalk, Figure 2-13. They are situated at the waterline on the Budd Inlet side of the dam, a very corrosive marine environment. Heavy barnacle encrusting is evident all around the trunnion area. Grease lines extend from the trunnion to a location under a grate just south of the machinery building. Operators report that some of the grease ports are bent and all are difficult to access. Additionally, the operators report that it is difficult if not possible at all to get grease to flow to the trunnion bearing.

2.2 Tide Gate Controls

The dam tide gates are continuously monitored and controlled by a Johnson Controls METASYS control system. The METASYS controller measures the fresh Capitol Lake and the Budd Inlet water levels using four submersible analog sensors located in stilling wells adjacent the west side of the dam, Figure 2-16. These signals are identified as Eastlake, Easttide, Westlake, and Westtide and are displayed on the LCD on the front of the METASYS controller. If the lake level is too high and is above that of Puget Sound, the system opens the east tide gate until the lake level falls into the acceptable range. If the rate at which the lake level is dropping is considered to be too slow, the METASYS controls will open the west gate to increase the discharge rate. When the water level in Puget Sound nears or exceeds that of Capitol Lake, the METASYS closes the east and west tide gates. At the Stillwell, it is noted that several of the cables do not pass through a sealed conduit gland. Rather, the conduit covers are left open and the cables attached with twist-on connectors.

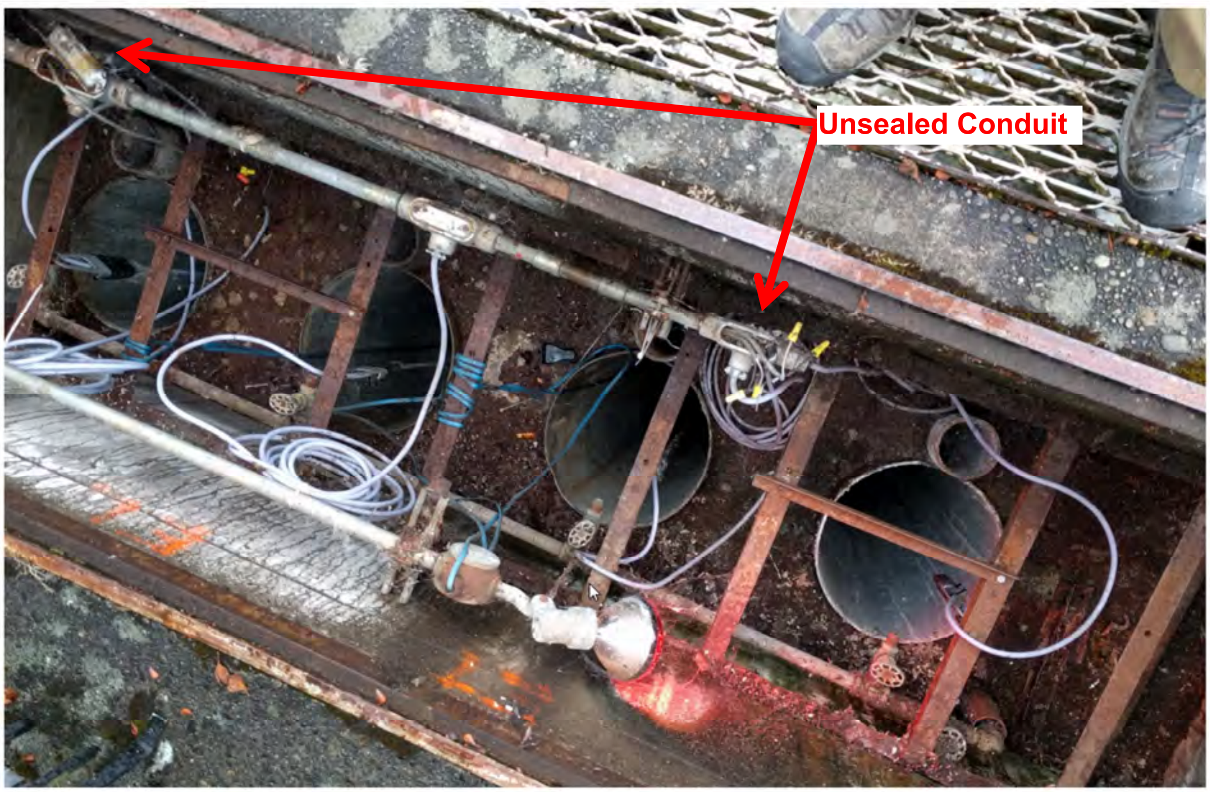

Figure 2-16 Level Sensor Stillwell

Figure 2-17 ATS & Distribution Panel

Additionally, the METASYS can be remotely commanded via the local area network (LAN) from the capitol campus power house, to raise or lower the lake level by opening or closing either or both gates. These types of operations usually occur when a drawdown of the lake is required due to a predicted future event. The LAN also allows users to view, through the METASYS controller, the operational status of the gates and the various water levels. This information is also available locally at the control house through the METASYS operator station.

The METASYS controls the operation of the tide gates by energizing the appropriate motor controller located in the Motor Control Center (MCC) to operate an electric motor to open and close the chosen gate. The METASYS monitors the position of each gate through a signal from a potentiometer that is mechanically connected to the gate by a rotating shaft. A rotary limit switch is also coupled to the shaft and is designed to act as an End Of Travel (EOT) limit, thereby preventing the gates and gearing from being overdriven into the mechanical stop and causing a wire rope failure.

2.3 Electrical Panel and Motor Control Center (MCC)

The distribution panel and motor control center occupy a free-standing multi-compartment two section enclosure. The right hand section houses the panel board (a.k.a., breaker panel) and the automatic transfer switch (ATS). The ATS is used to switch to generator power when the utility power is interrupted. The left hand section is the Motor Control Center (MCC) and houses the motor controllers required for gate operation (see Figure 2-17). Overall the enclosure appears to be in acceptable condition. Surface corrosion is persisting and approaching moderate levels.

Distribution Panel (Right Section): The service entrance, main circuit breaker, panel board, and Automatic Transfer Switch appear to be in good operating order. If this equipment is continued to operate preventive maintenance should be performed in order assure operation.

Motor Control Center (Left Section): The multi-compartmented motor control center houses all the circuit breakers and motor controllers for the three gate motors and the emergency hydraulic power unit pump motor. The controllers and circuit breakers are very old but appear to be in good operating condition. No buzzing of the contactor armatures was detected during the times they were energized, such as would occur if the armatures had been hammered excessively or if dirt and/or iron filings had accumulated. DES staff reported that they measure voltage drop across the motor contactors occasionally and replace the contacts when necessary. Continued active preventive maintenance should keep this equipment reliable for the next ten years or more.

West Gate Motor: The West Tide Gate motor and brake combination appears to be part of the original installation and therefore are about 70 years old. Operation appears to be satisfactory although testing the windings might prove otherwise. This motor is past its useful and reliable life of about 50 years and is overdue for replacement.

East Gate Motor: The original East Tide Gate motor has been replaced with the one currently in use. This motor and brake combination is a modern design (relative to the original) and is about 20 years old. It appears to be operating satisfactorily and should continue for the next thirty years or so.

ATS: The ATS is manufactured by the ASCO with a controller by Automatic Switch Company, model 4200. It appears to be from the original MCC installation. The controls on the front panel of the ATS for testing generator operation are not functioning. However, Mr. Bristol reported that this equipment is maintained by a generator servicer and is functional. All components appear to be in good physical condition.

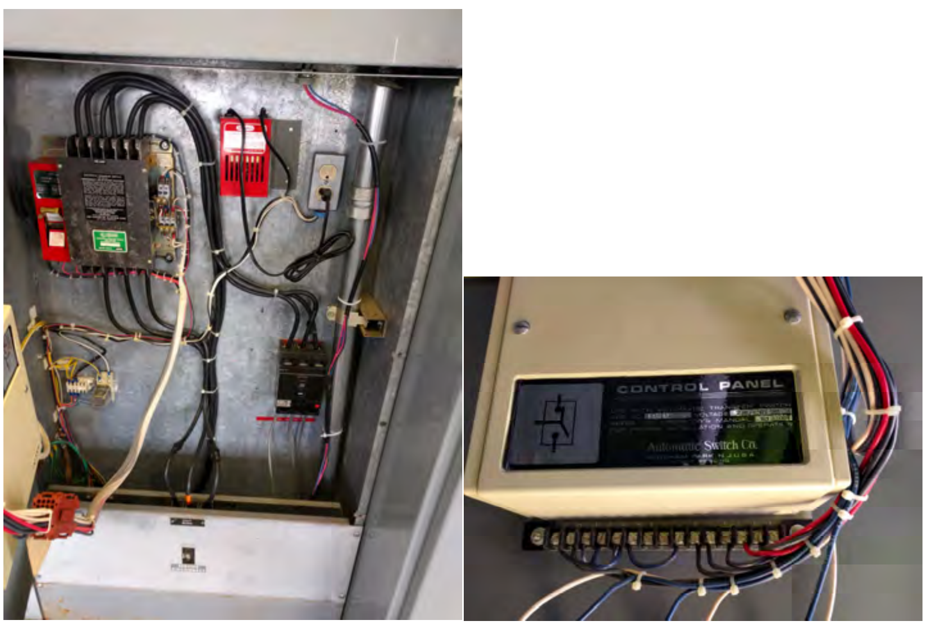

Figure 2-18 ATS (left) and controller (right, located on back of front panel)

2.4 Standby Hydraulic System

The west gate features a hydraulically operated gate back-up system in the event of a failure to the primary wire rope hoist system. The standby system consists of two large hydraulic cylinders with wire rope sheaves attached to the cylinder rods. Normally the system is not attached to the radial gates. This system currently requires divers to attach the ropes to the gates at connections below water. It was reported that it is desired to have chains installed that would allow connection of the standby system ropes to the gate.

Figure 2-19 Hydraulic Cylinders and Reeving System – West Gate

The two hydraulic cylinders lift the west gate, Figure 2-19. The west most cylinder shows sign of advancing corrosion due to peeling paint at the blind end cap, at the tie rods at that end and in along the length, Figure 2-20. The operators further report that when the system was used during the March 2016 rope replacement to support the gate, the east cylinder leaked oil from the blind end cap when under load. No oil was observed when the system was operated during this inspection when the cylinders were moved in and out with no load.

The wire rope and sheaves show signs of general corrosion but appear to be serviceable, Figure 2-21

Figure 2-20 Standby Hydraulic Cylinder – West End – Surface Corrosion

The hydraulic cylinders are controlled via a solenoid operated directional valve located within the machinery room. The solenoid valve is controlled by a hardwired hand controller. The controller is attached to a cable that can be strung out of the machinery building window to be used by someone on the catwalk.

A direct coupled pump is mounted to a 7 ½ horsepower electric motor. A flow splitter appears to be used in this system as well.

The hydraulic system reportedly utilizes a biodegradable fluid. The exact oil product and grade is not known. The date of the last oil change is unknown. The hydraulic reservoir, Figure 2-22, looks to be quite new and replaces the reservoir observed during the 2007 inspection.

There is a filter in the system. The condition of the filter is unknown and the time of last replacement is unknown. The filter does not incorporate a delta pressure or dual pressure gauge arrangement to check pressure drop across the filter.

Figure 2-21 Rope and Reeving – Standby Hydraulic System

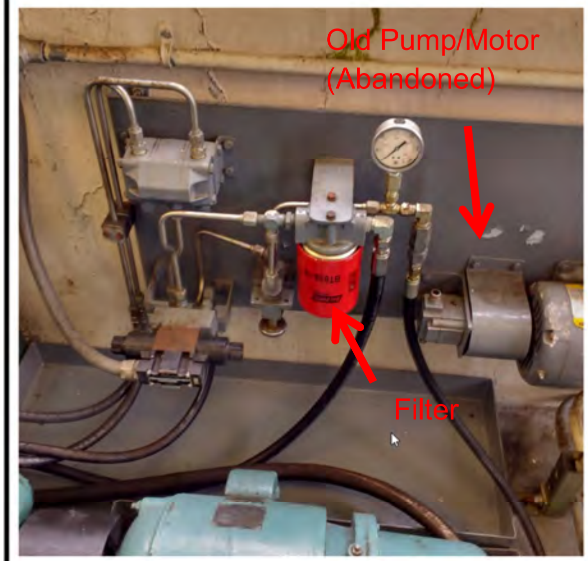

Figure 2-23 Backup Hydraulic System

Figure 2-22 Reservoir

The power unit components, including the reservoir, pump, filter, and valves of the standby hydraulic system appear to be in good condition, Figure 2-23. The pump and motor were obviously replaced at some time as the old pump and motor reside next to the other components. No obvious signs of damage to hoses or connections were observed.

The hydraulic cylinders are judged to be in poor condition and should be overhauled or replaced soon.

2.5 Fish Gate

The fish gate is located at the east end of the tide gates, Figure 2-25. The fish gate is a manually controlled and operated vertical weir gate. For most of the year this gate remains open and water is allowed to flow freely between the water bodies.

Figure 2-25 Fish Gate

Figure 2-26 Gearbox Enclosure and Switch

Figure 2-24 Gearmotor

The gearmotor resides in an enclosed but not weather tight box mounted approximately four feet from the concrete deck, Figure 2-26 and Figure 2-24 . It has an output shaft to another gearbox just to the opposite side of the guardrail. Below the gearbox is a coupling and shaft that extend to the exposed worm gear drive that engages the drum shaft. The coupling beneath the final gearbox, Figure 2-27, is exposed with features that could snag clothing, etc. The flexible elastomeric element of this coupling appears quite degraded and in need of replacement.

Figure 2-27 Exposed Coupling with Degraded Elastomer

The switch that operates the gate is mounted directly beneath the gearbox housing and is accessible to the public.

Figure 2-28 Worm Gear Drive

Figure 2-29 Hoist Drum and Rope

Current procedure appears to preclude unauthorized usage of the gate equipment by opening the disconnect in the locked machinery building.

Gears and bearings appear to be well lubricated. There is general rusting and old paint evident but the gearing appears to be functional and not adversely affected by corrosion. See Figure 2-28.

The wire rope is of a plastic coated type. The plastic appears compromised at the waterline of ropes on each side of the gate and in need of replacement. The drums have old, peeling paint and general rust corrosion but appear functional. See Figure 2-29.

2.6 Siphon System

The siphon system was added to the dam in 1987 to remove accumulated salt water from lake bottom. The vacuum pump serves to prime the siphoning effect of the pipe and the tide. Operators stated that the siphon system has been problematic and in fact has been unused for the last couple of years.

Figure 2-31 Siphon System

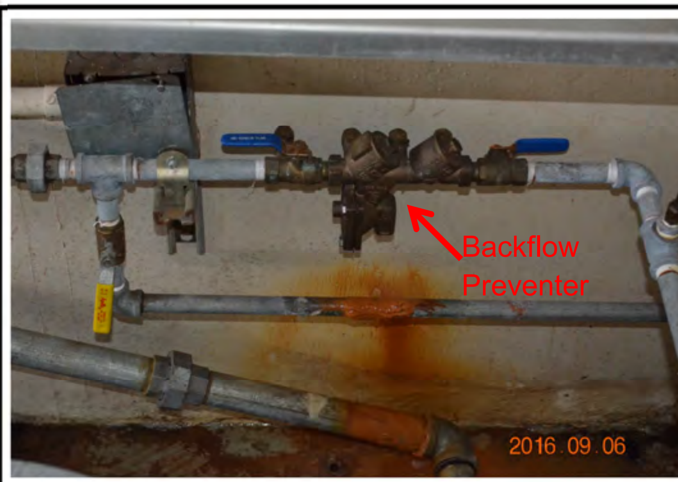

Figure 2-30 Siphon System – Leaking Backflow Preventer

The control system uses a conventional vacuum switch to stop and start the vacuum pump controller. Mr. Bristol reported that the flow indicator light never goes off and he suspects the system to be malfunctioning. During the visit, the siphon system was energized and the vacuum pressure indicator display was witnessed to reach a level of about 5 psi and then lower to approximately 1.5 psi after approximately 60 seconds. There is no way to physically verify whether the water was siphoning as the piping is submerged. Mr. Bristol mentioned that modifications were made to the system that are not reflected in the vacuum diagram posted.

The exhaust muffler and separator on the vacuum pump outflow has significant surface corrosion, Figure 2-31.

The reverse flow preventer that serves the pump is leaking water onto the floor and appears to have been doing so for some time as witnessed by the rust stains, Figure 2-30. This is creating excessive humidity inside of the structure and accelerating corrosion in the environment. This will have an adverse effect on electrical contacts and equipment and should be remedied.

It was further reported that recent investigations have found that the intake of the 12" siphon pipe was buried in mud, preventing function of this system.

2.7 Generator Set

There is a diesel generator set and automatic transfer switch located in the dam machinery room. The generator provides back-up electrical power in case of an outage.

The Onan 15kW back-up generator set is connected to the gate motor power system through the ATS located in the Distribution Panel section. The generator is clean and free of fuel or lubrication leaks. It was reported the generator receives periodic maintenance and is tested under load weekly although this has not been confirmed. It is quite old but appears to be in very good condition. An attempt to start the system using the test switches located on the automatic transfer switch was unsuccessful.

2.8 Capitol Lake Level Controls (METASYS)

The Johnson Controls METASYS computer based control system is performing well and in favorable opinion of the operators. Personnel has learned not to manually adjust gate position, using the push buttons on the MCC front, but rather change the setpoint for the lake and let the controller manipulate the gate position (manually changing gate position introduced error into controller feedback).

Manual operation of the gates is achieved by use of the gate control operator devices (push buttons, selector switches, etc.) located on the MCC front panels. Automatic gate control is also available thru the SCADA system via the Powerhouse and Automation Department terminals.

The METASYS control system hardware and supervisory (SCADA) system software appear to be quite capable of controlling the lake level, however, they are non-industry standard controls for this application and designed for building automation and HVAC applications. Mr.Bristol reports that the METASYS brand was adopted for area campus and therefore resides at the dam. The firmware residing on the controller is not within the scope of this assessment but appears to be controlling the lake level well.

The control panel enclosure has had multiple devices removed from its door over time. This has left open holes in the door. This allows for the ingress of humidity and moisture from the machine room.

2.9 Raceways

Many instances of raceways (conduits) open to atmosphere were identified during the inspection. This includes missing or loose hanging covers on outlet boxes and open ended conduits. This exposes the interior components, particularly the terminals, to humidity, increases resistance, as well as creating other problems.

Figure 2-32 Water ingress via conduits

Figure 2-33 Electrical Shock Hazard, Energized Parts Exposed to Public

3 RECOMMENDATIONS

The tide gate machinery is generally in fair to poor condition due to the advanced age of the components and potential overloads that have occurred over the years. The following tables provide recommendations for actions for rehabilitating and/or extending the life of the machinery.

The table includes a rough order of magnitude cost opinion and a recommended priority. Priority is given as the recommended time in which the item should occur.

Rough order of magnitude (ROM) cost opinion shown is an estimate of the engineering effort, hardware cost, and direct fabrication and/or installation labor cost. The ROM Cost does not include general contractor's overhead and profit, mobilization/demobilization costs, or street closure costs and are based on cost associated with that particular task only. Savings may be realized through performing multiple tasks during a single period of time.

Tide Gates Mechanical Machinery				
No.	**Item**	**Recommended Action**	**Priority**	**ROM Cost Opinion**
1	Gate Trunnion – Lubrication	Replace all of the existing trunnion lubrication ports and tubing. Relocate lubrication access to a protected and accessible location. The existing location under deck grating is difficult to access and lubrication fittings have broken and are no longer usable. Type and grade of lubricant should be assessed for environmental compatibility and robustness in the harsh marine environment.	1 year	$37,500
2	Gate Trunnion – Cleaning and Inspection	The gate trunnions should be dismantled, cleaned of marine life and debris and assessed for wear and damage. The gates and trunnions are at the waterline in saltwater and are encrusted with barnacles.	2 year	$64,600
3	Gate Trunnions – Friction	Take amp meter readings of gate motors from start up through 30 to 60 seconds of movement. Compare to motor rating. The purpose is to assess if gate friction is unduly loading the motor and drive system.	1 mo.	$1,700
4	Gate Bearing Blocks / Shafts / Couplings	Remove bearings and examine shafts and bearings for wear. Replace damaged seals. Replace bearings as needed. Replace any damaged or corroded bolts and tighten to manufacturer's specifications (if available). Replace or refurbish worn shafts. Clean and repaint shaft. Remove and inspect couplings.	3 years	$67,100

Tide Gates Mechanical Machinery				
No.	**Item**	**Recommended Action**	**Priority**	**ROM Cost Opinion**
5	Gate Drums and Rope	Inspect drum surfaces and rope for increased corrosion, particular where the rope contacts the drum. Inspect connections.	6 mo. interval	$500 per interval
6	Exposed Spur Gears	Replace damaged pinions and realign. Remove, clean and inspect all gearing. Re-lubricate before placing back in service.	2 years	$144, 200 (Note: Photos appear to show smaller gears than original specification. Material cost could be lower than budgetary quote)
7	Gear Drive Chain	Replace. No current issues noted but recommend replacement with rehabilitation of gears.	2 years.	Included with Item 6
8	Gear Reducers – Oil Sample and Flush	Obtain oil sample from each gear reducer and obtain lab analysis. Drain each gear reducer to remove any built-up contamination and replace with clean oil.	6 mo.	$300
9	Gear Reducers – Breather Cap	Replace old breather caps with new.	6 mo.	$200
10	Gear Reducers – Replace	Take existing gear reducers from service and send to gear rehabilitator for inspection of gear unit internals. Refurbish as necessary. Alternatively replace the unit with new. Replacement with new would reduce the time a gate would be out of service.	3 yr.	$32,300 (Cost for new gearboxes provided. Lower vendor budgetary estimate than refurbish)
11	West Gate Motor/Brake	Replace motor/brake unit. Existing motor/brake continues to function but appears to be quite old.	1 yr.	$15,000
12	General-Maintenance and Incident Log	Create and maintain a log of all maintenance and incidents that occur. Log should include a schedule for all maintenance and register the date, technician, what was done, and part number/description of any consumables or lubrication used. Log should also include entries for any unscheduled maintenance and/or repair work done to the system.	NA	NA
13	West Gate Motor Coupling	Monitor coupling proximity to gearbox. Adjust position if possible	1 mo.	NA

Tide Gates Mechanical Machinery				
No.	**Item**	**Recommended Action**	**Priority**	**ROM Cost Opinion**
14	Coupling Guards	The shaft couplings connecting the gate electric motors to the gear reducers should have guards installed to be in compliance with OSHA 1917.151 for rotating machinery. The guards can be designed to be easily removed for maintenance or inspection.	1 yr.	$6,500

Tide Gate Controls				
No.	**Item**	**Recommended Action**	**Priority**	**ROM Cost Opinion**
1	Gate Position Sensors	Replace potentiometer and limit switches with updated technology	2 yr.	$9,800

Electrical Panel and Motor Control Center (MCC)				
No.	**Item**	**Recommended Action**	**Priority**	**ROM Cost Opinion**
1	Distribution System	Inspect the distribution and control component contacts, dielectric test, re-torque terminals, bus connections, and circuit breakers	1 yr.	$2,600
2	Conduits	Seal around exterior penetrations, replace all outlet box and conduit body covers	ASAP	$1,300
3	Shock Hazard	Upgrade to weatherproof cover or eliminate receptacle (Figure 2-33)	ASAP	$1,300

Standby Hydraulic System				
No.	**Item**	**Recommended Action**	**Priority**	**ROM Cost Opinion**
1	Gate Attachment	Install chain that allows attachment of the standby ropes to the gate without necessity of diving. Chain should be installed as to not interfere with normal operation of the gate.	6 mo.	$37,500
2	Cylinders	Remove and refurbish or replace the existing hydraulic cylinders. All seals and tie rods should be replaced. Test cylinders at 125% maximum operating pressure prior to return to service.	1 yr.	$32,000

Standby Hydraulic System				
No.	**Item**	**Recommended Action**	**Priority**	**ROM Cost Opinion**
3	Filter	Install pressure gauges before and after the filter to allow pressure drop indication of filter	2 yr.	$12,000
4	Hydraulic Oil	Take sample for laboratory analysis. Biodegradable oils have a useful life of approximately 2 to 3 years. Replace oil as necessary.	1 yr. interval	$100 per test
5	Operate	Operate the back up system to verify system operability. Preference that operation occurs while attached to gate to load the system in as used configuration.	6 mo. to 1 yr.	$1000 per test
6	Rigging	Replace corroded wire ropes as necessary	3 yr.	$10,500
7	Hoses	Inspect all hoses for rubbing and deterioration	6 mo. interval	$1000 per interval
8	Plumbing	Inspect hard plumbing for corrosion and damage.	1 yr. interval	$1000 per interval

Fish Gate				
No.	**Item**	**Recommended Action**	**Priority**	**ROM Cost Opinion**
1	Exposed Coupling	Remove and inspect. At a minimum replace the elastomeric element.	6 mo.	$2000
2	Exposed Coupling-Cover	Install OSHA compliant machine guard around the couplings near the deck. The couplings have features which can snag loose clothing, etc. and are accessible by the public through the guardrail.	6 mo.	$12,600
3	Drive Components	The operator switch for the device can be accessed easily by the public, exposing the device to vandalism or uncontrolled operation of the gate. Place padlocked protective cover to prevent access.	6 mo.	$12,600
4	Wire Rope	Replace the wire ropes. The existing ropes show extensive corrosion near the waterline.	6 mo.	$19,200

Siphon System				
No.	**Item**	**Recommended Action**	**Priority**	**ROM Cost Opinion**
1	Siphon Pipe Intake and Piping.	Recondition the intake which is currently reported to be submerged in mud. Ensure all plumbing throughout the system is cleaned of mud, including the vacuum piping to the vacuum pump.	No Recommendation	NA
2	Exhaust Muffler and Separation Tee	Replace corroded exhaust muffler and tee. (Pending outcome and disposition of Item 1).	No Recommendation	$7,800
3	Backflow Preventer	Repair leak or replace unit. Clean and inspect corroded piping beneath leak. Replace as necessary. Short term, turn off water feed upstream of backflow preventer since siphon system is currently unused. In addition to the pipe corrosion, the water leak maintains a constant puddle on the floor, increasing corrosive humidity in the room and causing potential slip and electrocution hazards.	ASAP	$1000
4	Operations and Maintenance.	The siphon system control function does not appear to be well understood by the operators. Create a detailed O&M to provide guidance for correct vacuum levels, etc.	No Recommendation	$11,800

Generator Set				
No.	**Item**	**Recommended Action**	**Priority**	**ROM Cost Opinion**
1	Generator Maintenance	Ensure that the generator is receiving maintenance and operated on a regular schedule as for other generators on the government campus.	ASAP	NA
2	ATS Maintenance	Ensure proper switching to and from utility power upon loss and resumption of power.	ASAP	NA

Capitol Lake Level Controls (METASYS)				
No.	**Item**	**Recommended Action**	**Priority**	**ROM Cost Opinion**
1	Control Programming	Review and document the program function.	1 yr.	$12,000
2	Control Hardware	Review and assess the hardware for factory obsolescence.	2 yr Interval	$1500 per interval

Capitol Lake Level Controls (METASYS)				
No.	**Item**	**Recommended Action**	**Priority**	**ROM Cost Opinion**
3	Enclosure	Cover holes in door left by prior components to prevent ingress of moisture into panel.	2 mo.	$4,300
4	Level Sensors	Terminate connections at stilling wells within raceway system	3 mo.	$2,200

Electrical Discussion

Generally, the electrical distribution equipment has exceeded its normal life expectancy. It could continue to operate in this state for an undetermined amount of time with continual maintenance. Given the maturity of equipment, some replacement components are no longer manufactured but are available from third party sources (e.g., Ebay). While no singular piece of gate operation equipment appears ready to fail the cumulative effect of the degradation of all equipment is elevating the probability of a malfunction.

If the electrical system is continued to be exposed to the humidity created from the leaking siphon control system it will accelerate the deterioration of the electrical system.

It should be cautioned that a redesign of the facility using the existing structure will subject the facility to updated regulatory design codes (specifically the National Fire Protection Agency) and may compromise the existing floor plan.

4 Recommended Spare Parts and Consumables

Mechanical spares and consumables are items which will be used on a regular basis or have some expectation of wearing out in relatively short intervals. Also included are items with potentially long lead times to acquire.

Table 4-1 Mechanical Spares and Consumables

System	Description	Model/Part/DES No.	Quantity
Tide Gate Machinery, Gear Reducer	Oil, Gear, SAE 85W-140	Chevron RPM SAE 85W-140	5 gallons
Tide Gate Bearings, Plain	Grease, Lithium	Chevron Ultra Duty 2	5 gallons
Hydraulic System	Filter, Spin On, 10 Micron	Baldwin BT839-10	1 each
Gears – External	Lubricant, Solid Film, Exposed Gear, Moly	Chemsearch- GEX	1 can
Tide Gate and Fish Gate Bearing	Pillow Block Bearing	1 each distinct type	1 each distinct type
Coupling, Tide Gate Motor	Insert Elastomer	Lovejoy – PN TBD	1
Coupling, Fish Gate Motor	Insert Elastomer	Unknown	1
Drive Chain – Tide Gate	Drive Chain, Length for one gate	2.5” Pitch, Double	1 length
Tide Gate Gearing	Spur Gear	60” Pitch Dia., 75 tooth, 10” face	1
Tide Gate Gearing	Spur Gear	12” Pitch Dia., 15 tooth, 10” face	1
Tide Gate Gearing	Sprocket	40 tooth, 31.864 Pitch Dia. for Specified Chain	1
Tide Gate Gearing	Sprocket	12 tooth, 9.659 Pitch Dia, for Specified Chain	1
Tide Gate Rigging	Equalizer Plate	Stainless Steel	2 each
Tide Gate Rigging	Cotter Pins	Stainless Steel	5 each size

Table 4-2 Electrical Spares and Consumables

System	Description	Model/Part/DES No.	Quantity
MCC-Contactor	Contacts	Eaton/CH 6-23-2	2
MCC-Contactor	Coil	Eaton/CH 1887-1	2
MCC	Motor controller button set	Eaton/CH E-30XX	2
MCC	Contactor	Eaton/CH A50CNVO	1
Tide Gate	Position Potentiometer	Vishay Spectrol MOD-132-0-0-102	1

APPENDIX A INSPECTION REPORT

CAPITOL LAKE TIDE GATES

OLYMPIA, WA

Site Visit Date: September 06, 2016

Site Inspection – 9/06/2016 Capitol Lake Dam Mechanical/Electrical Inspection

Report Date:	September 16, 2016
Project:	Capitol Lake Dam Preservation Assessment
LEI Project No:	735A
Client:	Moffatt & Nichol / WA State Dept. of Enterprise
Client Ref:	M&N No. 9469 / WA No. 2016-931 B(2)
Inspection Date:	September 06, 2016
Attendees:	
Fives Lund:	David Wilson, P.E. (Electrical), Christopher Huck, PE (Mechanical)
M&N:	Byron Haley, P.E.
WA DES:	Bing Bristol, T.J. Snoderey

1.0 Introduction

David Wilson and Chris Huck of Fives Lund LLC traveled to Olympia, WA for an inspection of the mechanical and electrical systems and components of the hoist components at the Capitol Lake Dam spillway. Fives Lund LLC (dba Lund Engineering, Inc.) performed a similar inspection at this site in 2007.

The inspection occurred on September 06, 2016 and ran from approximately 8:30 a.m. until 1:00 p.m.

This document is based upon a pre-prepared questions and checklist document and is a compilation of notes taken by both David Wilson and Christopher Huck

2.0 Operator/Maintainer Interview

Responses provided by:	Bing Bristol via on-site discussion

No.	Question	Response
Spillway Gate Equipment		
1	Describe basic spillway operation.	DW: Overall system is controlled by establishing a setpoint for Capitol Lake level (typically set at -3.5 feet). Setpoint is manipulated from the Powerhouse, Automation & Controls Division, or at the dam itself. Metasys controller is given Lake setpoint and opens East gate accordingly to maintain level. West gate lags East

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No.	Question	Response
		gate by 6" less. CH: Primary control is via PLC with both lake and tide level sensor input. A PID based algorithm takes the lake and tide level input to generate a percentage value. When this value reaches 80%, the controls fully raise East Gate for some time determined (presumably) by the algorithm. A printed, detailed description of the PLC algorithm and programming was not available.
2	Does a procedure exist for recovery from power outage or seismic event?	DW: Generator automatically provides standby power during outages. No known seismic disaster plan.
3	How often is the spillway operated per day?	DW: Approximately two times per day during summer months and eight to nine times per day during winter months.
4	How does operation vary throughout the year?	DW: Per above.
5	What is the approximate operational range of the gate?	DW: From full open to closed. CH: Gate does not control to intermediate positions. Gate is always opened fully for some period of time and then lowered to fully closed.
6	System is largely operated automatically. How often is the gate operation over ridden and operated manually? Under what circumstances?	DW: System is rarely manually. When severe precipitation is forecast lake levels will be decreased to accommodate needed capacity. CH: Lifting for flood prevention in the past has been a manual operation where personnel depress the contactor button to operate while MetaSys is running. Current procedure is to simply lower the elevation setting during the preparations for the event.
7	2007 report indicates concern about METASYS control response time being slow to respond. Has the system been adjusted? Any improvement?	DW: Bing B. reports that the system seems to underperform some during severe weather conditions of both summer and winter but was stated be a good medium between the two seasons. CH: No current concerns with the system.
8	Are Operation and Maintenance Manuals for the system available? If so, please provide a copy. Are the O&M's current?	DW: None available. Some documentation is available from the original facility design, however, the design has been modified and no updated documentation exists on site short of a document showing how to navigate the Metasys LCD menu. CH: On –site O&M covers only the original electrical system. No mechanical information found or available. No maintenance log on site.
9	2007 report indicates that the rotary back up switch was backed up with a limit switch on the west gate. Has the rotary switch failed since 2007? Has the	DW: No reported rotary switch (i.e., potentiometer) failures. These devices were reported to be a reliable component. No records or reports of back up limit switches being triggered. Back up switch is on both

No.	Question	Response
	back up switch been triggered and/or been effective? Has a back up switch been added to the east gate?	gates. CH: When the incident occurred it appeared that the system lost the gate position potentiometer input. Consequently the gate began to cycle up and down continuously until it happened to go through the stop switch input.
10	We have a Rognlin's report for cable replacement in March 2016. What precipitated the need to replace?	CH: This was a scheduled replacement. The rope is replaced on a 2 year schedule. With old PVF coated rope, typical failure point occurs near the eye fitting connection to the gate.
11	2/2016 report appears to show both stainless steel and PVF coated ropes. Are two different rope styles in use?	CH: The March 2016 replacement was the first use of the stainless steel rope. Previously used PVF coated rope.
12	How have the new ropes performed? When are they scheduled to be inspected?	CH: SS ropes have only been in operation since March. Look good so far. Scheduled replacement is every 2 years.
13	Have all underwater connections been inspected and what is the observed condition?	CH: Yes. See Item 10.
14	What weekly maintenance is performed?	CH: None
15	Monthly?	CH: Pillow block/Babbitt bearings are regreased every 6 months with "Chevron Ultra Duty 2" grease. Exposed gear and chain is sprayed with "Chemsearch GEX Open-Gear Moly Lubricant, H2" every 6 months.
16	Annual?	CH: Gearbox oil changed occasionally. No schedule, 'not often.'
17	Other?	NA
18	Date of last gear box oil sample? Results?	CH: None known.
19	Oil type? Age?	CH: Gearbox oil used: 85W-140. Age unknown.
20	Date of wire rope replacements?	CH: 3/2016
21	External gear lubricant type? Age and/or frequency of replacement?	CH: Exposed gear and chain is sprayed with "Chemsearch".
22	Bearing lubricant? Age and/or frequency of replacement?	CH: Pillow block/Babbitt bearings are regreased every 6 months with "Chevron Ultra Duty 2" grease.
23	Are there any other operational concerns or procedures that should be mentioned?	CH: No.
24	Are there any other maintenance concerns or procedures that should be mentioned?	CH: The remote lubrication ports for the tainter gate bearings are an issue. Some ports are missing, they are generally difficult to access (underneath grate in concrete

No.	Question	Response
		deck). Can't pump the grease through the lines. (Engineer's note: The bearings are at the waterline, Budd Inlet saltwater side and are at times exposed to air and other times submerged. The gate structure in and around the bearings is barnacle encrusted.
25	What is the most representative drawing set?	DW: E & I, Technical Systems Inc. As-Built dated 1980
Fish Gate		
26	Describe basic operation.	CH: Gate is operated manually. Disconnect switch in machine building is closed then a covered switch under the motor/gear assembly is closed. Accessible from the raised deck and by the public. Up/down operation of the switch raises/lowers the gate. No limit controls are used although operator is within close proximity to the gate itself.
27	How often is the gate operated per day?	CH: Not often
28	How does operation vary throughout the year?	CH: Response not recorded.
29	What is the approximate operational range of the gate?	CH: Unknown.
30	What weekly maintenance is performed?	CH: None reported.
31	Monthly?	CH: 6 months bearings.
32	Annual?	CH: None reported.
33	Other?	CH: None reported.
34	Are there any other operational concerns or procedures that should be mentioned?	DW: None reported.
35	Are there any other maintenance concerns or procedures that should be mentioned?	DW: Gate main bearing lubrication.
36	What is the most representative drawing set?	CH: None reported.
37	What access is available to the Fish Gate equipment? Can the Fish Gate be operated during the site visit?	DW: Motor and controls located at main building structure level.. CH: Gate was operated during visit. No concerns presented.
38	Are inspection records available for the gearing and wire rope? If so, please provide.	CH: None reported. Wire rope (plastic coated) had obvious corrosion near the connection to the gate.
Hydraulic Back-up System		
39	Describe basic operation.	CH: Close contact for pump motor. Corded Up/Down

No.	Question	Response
		Button moves the cylinders to lift/lower the gate.
40	How often is the device operated per day/year?	CH: Very infrequent.
41	How does operation vary throughout the year?	NA
42	Hydraulic oil type?	CH: Bio degradable. Specific grade/brand unknown.
43	When was the hydraulic oil last sampled? Results?	CH: Unknown.
44	When was the oil last replaced?	CH: Unknown.
45	Has the reservoir ever been cleaned/inspected? Condition?	CH: Reservoir is relatively new. Replaced within last 5 years or so. (Looks clean. Is new since 2007 inspection.
46	What weekly maintenance is performed?	CH: None.
47	Monthly?	CH: None
48	Annual?	CH: Unknown.
49	Other?	NA
50	The 3/2016 wire rope report indicates leakage from one of the cylinders. Has the cylinder been inspected? Does it still leak? Has it been operated since March?	CH: Cylinder did not leak until it started lifting the gate whereupon it leaked 'a lot'. Cylinder has not been inspected or repaired since this incident.
51	A pressure gauge is not evident on the 1980 schematic. Is there a pressure gauge in the system or a point where a pressure measurement can be taken?	CH: There is a gauge on the pump output. No gauge on the filter for delta pressure to detect filter clogging.
52	Are there any other operational concerns or procedures that should be mentioned?	NA
53	Are there any other maintenance concerns or procedures that should be mentioned?	NA
54	What is the most representative drawing set?	Unknown.
Vacuum Siphon		
55	Describe basic operation.	CH: Electro-mechanical control is based on vacuum pressure switch. System has difficulty maintaining pressure. Hasn't been used in the last couple of years.
56	How often is the device operated per day/year?	CH: Not used.

No.	Question	Response
57	What weekly maintenance is performed?	CH: None reported.
58	Monthly?	CH: None reported.
59	Annual?	CH: None reported.
60	Other?	CH: None reported.
61	Are there any other operational concerns or procedures that should be mentioned?	CH: System has difficulty in maintaining vacuum pressure. Unclear as to source of problem.
62	Are there any other maintenance concerns or procedures that should be mentioned?	CH: Its possible that the siphon intake on the lake side may be buried in the mud. (Conflicting reports on this).
63	Are Operation and Maintenance Manuals for the system available? If so, please provide a copy. Are the O&M's current?	CH: None reported.
Generator		
64	Describe basic operation.	CH: Operates via a automatic transfer switch.
65	How often is the device operated per day/year?	CH: Unknown. There is a person dedicated to on-going checking and maintenance of the generators in and around the capitol campus. Not maintained by DES operators.
66	What weekly maintenance is performed?	CH: None reported. See Item 65
67	Monthly?	CH: None reported. See Item 65
68	Annual?	CH: None reported. See Item 65
69	Other?	CH: None reported. See Item 65
70	Are there any other operational concerns or procedures that should be mentioned?	CH: None reported. See Item 65
71	Are there any other maintenance concerns or procedures that should be mentioned?	CH: None reported. See Item 65 Note: An attempt was made to operate the generator via the ATS switch. The generator did not start.

3.0 Inspection

3.1.1 East Tide Gate Machinery Inspection

No.	Task	Results/Notes
1	General overall appearance: Cleanliness Obvious wear, deterioration	DW (Elect.): 6.5/10, Signs of all of the work that has been performed over the years is accumulating and evident. For example covers and screws missing on various equipment. CH (Mech): 4/10. The equipment has obviously been in service for some time. The equipment in the mechanical building, such as motors and gearboxes looks to be in fair to good shape while external elements such as the exposed gearing and shafts are showing some deterioration. Exposed gears have obvious nicks and scrapes.
2	Operate Gate Up (Full Stroke if Possible): Listen for ambient noise Look for excessive vibration Listen at gearbox and motor with tool. Observe rope/gears. Observe bearing function. Look for grease/fluid leaks Travel Time Holds load when stopped.	CH (Mech): Some motor cover noise due to a loose cover was detected. Not a concern. Otherwise the machinery sounds relatively quiet; no metal-on-metal squeals or other unexpected sounds. The bearing seals on the pinion bearing look like they may be coming out. Recently replaced stainless steel rope looks good.
3	Check function of limit switches. Stop 1 Stop 2	DW: Limit switches for up and down positions properly halted motor operation when driven to extremity of position.
4	Operate Gate Down. Listen for ambient noise Look for excessive vibration Listen at gearbox and motor with tool. Observe rope/gears. Observe bearing function. Look for grease/fluid leaks	CH: Same as for Item 2.
5	Check function of limit switches. Stop 1 Stop 2	Per 3 above.
6	Open power disconnect. Ensure safe access.	DW: Overcurrent protective device within sight and functioning as disconnect. Functions properly as disconnect.
7	Motor: Nameplate Data Appearance (corrosion, damage,etc.) Wiring/Connection condition Leaks Shaft	U.S. Motors Model No.: AD81 3 hp, 208-230/480 VAC, 3 phase, 60/50 Hz 8.5-8/4 FLA Design B Code K 1765 RPM, SF 1.25 Conductors and terminations acceptable.
8	Coupling Nameplate Data	CH: Coupling is a Lovejoy spider type. Rubber insert looks intact. Looks clean, in good condition. Rubber insert looks

No.	Task	Results/Notes
	Appearance (corrosion, wear damage,etc.)	intact.
9	Gearbox Nameplate Data Appearance (corrosion, damage,etc.) Wiring/Connection condition Leaks Shaft Remove access cover. Observe gear condition. Take small oil sample. Look for water, cloudiness, debris.	CH: Western Gear Cone Drive 625:1 ratio, 3.96 HP rating, 1750 rpm input CL4, 765 Ft-Lbs Output. 2 stages observed. Viewed oil from top fill ports on stage 1 and stage 2. Stage 1 gears look 'wet' but it was difficult to see the level. Stage 2 oil level was observable, appears adequate. Sight glass was full. Dipped clean gloved hand into oil and observed that the oil was clear, light brown. Breather cap openings looked worn and dirty.
10	Brake Nameplate Data Appearance (corrosion, damage,etc.) Wiring/Connection condition Leaks Shaft Drum/pad wear	DW/CH: Not inspected as it is a self-contained unit. No slippage witnessed, gate holding properly.
11	Pillow Blocks Nameplate Data Appearance (corrosion, damage,etc.) Leaks	CH: Observable bearings in the hoist system appear to be a babbit plain bearing type. (Specs show them as "self lubricating") The pinion bearing shaft pillow block appeared that the seal was peeling out of the housing. Did not hear any objectionable noise at any of the bearings, either at the enclosed hoist machinery or at the exposed bearings supporting the final hoist drum shaft. Grease is apparent in and around the bearing ends on all bearings. General, light rusting and chipping paint is observable on most bearings. Some bearings are mounted such that the primary hanging force goes through the bolts.
12	Exposed Gear Appearance (corrosion, damage,etc.) Shaft Observe gear condition. Look for wear, nicks, damage. Grease. Look for debris, cleanliness	CH: Observed some light rust marks generally. Also, knicks and scratches and rough appearance were observed on most teeth. Compacted, hardened grease was observed in the roots of the pinions gears. Grassy debris was evident in light quantities throughout. One tooth of the bull gear had a large portion of the tooth missing. Generally, the gears and chain operated with little noise. No clacking or whining was evident.
13	Drum Appearance (corrosion, damage,etc.) Observe condition. Look for wear, nicks, damage.	CH: Some light rusting at various points. Paint coating appears somewhat deteriorated. No obvious signs of excessive wear or damage observed. Increased rust apparent in the rope grooves. Shafting has compromised paint in several locations.

No.	Task	Results/Notes
		Underlying surface appears rusty.
14	Rope and connections Appearance (corrosion, damage,etc.) Observe condition. Look for wear, nicks, damage.	CH: Observable portions of the rope look bright and clean. Noted that the ropes are new as of March 2016 and are stainless steel construction.
15	Over Travel Limit Switch Appearance (corrosion, damage,etc.) Remove cover and observe mechanical condition. Look for wear, nicks, damage. Wiring/Connection condition	DW: Functioning properly, acceptable condition.
16	Gate Position Transmitter Appearance (corrosion, damage,etc.) Wiring/Connection condition	DW: Appearance, conductors, and terminations in acceptable condition.
17	Tide and Lake Level Sensor Appearance (corrosion, damage,etc.) Wiring/Connection condition	DW: Wiring connections exposed to atmosphere (flying splice). Take corrective action to protect connections by placing within outlet box or conduit body.
18	Motor Starter Appearance (corrosion, damage,etc.) Wiring/Connection condition	DW: Per Controller below.
19	Controller Appearance (corrosion, damage,etc.) Wiring/Connection condition	DW: Reversing Contactor- Appearance, conductors, and terminations in acceptable condition.
20		

3.1.2 West Tide Gate Machinery Inspection

No.	Task	Results/Notes
1	General overall appearance: Cleanliness Obvious wear, deterioration	DW (Elect.): 6.5/10, Signs of all of the work that has been performed over the years is accumulating and evident. For example covers and screws missing on various equipment. CH (Mech): 6/10. The equipment has obviously been in service for some time. The equipment in the mechanical building, such as motors and gearboxes looks to be in fair to good shape while external elements such as the exposed gearing and shafts are showing some deterioration. Exposed gears have obvious nicks and scrapes. Noted some strange wear or damage to some pinion gear teeth.
2	Operate Gate Up (Full Stroke if Possible): Listen for ambient noise Look for excessive vibration Listen at gearbox and motor with tool. Observe rope/gears. Observe bearing function. Look for grease/fluid leaks Holds load when stopped.	CH (Mech): Machinery sounds relatively quiet; no metal-on-metal squeals or other unexpected sounds. Recently replaced stainless steel rope looks good.
3	Check function of limit switches. Stop 1 Stop 2	DW: Limit switches for up and down positions properly halted motor operation when driven to extremity of position.
4	Operate Gate Down. Listen for ambient noise Look for excessive vibration Listen at gearbox and motor with tool. Observe rope/gears. Observe bearing function. Look for grease/fluid leaks	CH: Same as for Item 2.
5	Check function of limit switches. Stop 1 Stop 2 (Option: confirm switch operation by manually actuating the switch to verify functioning if gate cannot be driven to switch safely. Develop and document procedure to safely execute prior to attempt.)	Per 3 above.
6	Open power disconnect. Ensure safe access.	DW: Overcurrent protective device within sight and functioning as disconnect. Functions properly as disconnect.
7	Motor: Nameplate Data Appearance (corrosion, damage,etc.) Wiring/Connection condition Leaks	Lima Electric Motor Co. 3 hp, 240V, 3 phase, 60Hz 1800 RPM, FLA 8.5/8/4 Conductors and terminations acceptable.

No.	Task	Results/Notes
	Shaft	
8	Coupling Nameplate Data Appearance (corrosion, wear damage,etc.)	CH: Coupling appears to be a gear type. Did not disassemble to check internal parts. Has very little clearance (millimeters) to the gearbox.
9	Gearbox Nameplate Data Appearance (corrosion, damage,etc.) Wiring/Connection condition Leaks Shaft Remove access cover. Observe gear condition. Take small oil sample. Look for water, cloudiness, debris.	CH: Western Gear Cone Drive 625:1 ratio, 3.96 HP rating, 1750 rpm input CL4, 765 Ft-Lbs Output. 2 stages observed. Viewed oil from top fill ports on stage 1 and stage 2. Stage 1 gears look 'wet' but it was difficult to see the level. Stage 2 oil level was observable, appears adequate. Sight glass was full. Dipped clean gloved hand into oil and observed that the oil was opaque, dark brown. Breather cap openings looked worn and dirty.
10	Brake Nameplate Data Appearance (corrosion, damage,etc.) Wiring/Connection condition Leaks Shaft Drum/pad wear	DW/CH: Not inspected as it is a self-contained unit. No slippage witnessed, gate holding properly.
11	Pillow Blocks Nameplate Data Appearance (corrosion, damage,etc.) Leaks (Noisy bearing noted in 2007 inspection)	CH: Observable bearings in the hoist system appear to be a babbit plain bearing type. Did not hear any objectionable noise at any of the bearings, either at the enclosed hoist machinery or at the exposed bearings supporting the final hoist drum shaft. Grease is apparent in and around the bearing ends on all bearings.
12	Exposed Gear Appearance (corrosion, damage,etc.) Shaft Observe gear condition. Look for wear, nicks, damage. Grease. Look for debris, cleanliness	CH: Observed some light rust marks generally. Also, knicks and scratches and rough appearance were observed on most teeth, although less than for the East Gate. Compacted, hardened grease was observed in the roots of the pinions gears. Several teeth of the pinion gear had observable wear or damage on one side, the side closest to the Bull gear. This issue was observed on several teeth, but not necessarily consecutive teeth. Observed 2 teeth with this issue, then one or two without, then another tooth. Generally, the gears and chain operated with little noise. No clacking or whining was evident.
13	Drum Appearance (corrosion, damage,etc.) Observe condition. Look for wear, nicks, damage.	CH: Some light rusting at various points. Paint coating appears somewhat deteriorated. No obvious signs of excessive wear or damage observed except on one. A portion of one of the drum flanges was broken off. Increased rust apparent in the rope grooves.

No.	Task	Results/Notes
		Shafting has compromised paint in several locations. Underlying surface appears rusty.
14	Rope and connections Appearance (corrosion, damage,etc.) Observe condition. Look for wear, nicks, damage.	CH: Observable portions of the rope look bright and clean. Noted that the ropes are new as of March 2016 and are stainless steel construction.
15	Limit Switch Appearance (corrosion, damage,etc.) Remove cover and observe mechanical condition. Look for wear, nicks, damage. Wiring/Connection condition	DW: Functioning properly, acceptable condition.
16	Gate Position Transmitter Appearance (corrosion, damage,etc.) Wiring/Connection condition	DW: Appearance, conductors, and terminations in acceptable condition.
17	Tide and Lake Level Sensor Appearance (corrosion, damage,etc.) Wiring/Connection condition	DW: Wiring connections exposed to atmosphere (flying splice). Wiring connections exposed to atmosphere (flying splice). Take corrective action to protect connections by placing within outlet box or conduit body.
18	Motor Starter Appearance (corrosion, damage,etc.) Wiring/Connection condition	DW: Per Controller below.
19	Controller Appearance (corrosion, damage,etc.) Wiring/Connection condition	DW: Reversing Contactor- Appearance, conductors, and terminations in acceptable condition.

3.1.3 Telemetry Control System (Metasys)

No.	Task	Results/Notes
1	General overall appearance: Cleanliness Obvious wear, deterioration Wiring/Connection condition	DW: Generally Acceptable. Control Panel Enclosure- 1. Multiple components removed from enclosure door leave interior equipment exposed to humidity. 2. UPS terminations in outlet box at bottom of cabinet are unworkmanlike and conductors are not protected from chafing.
2	Other?	DW: Metasys Controller displays 0.3 foot discrepancy between East and West Lake tide levels.

3.1.4 Fish Gate Machinery Inspection

No.	Task	Results/Notes
1	General overall appearance: Cleanliness Obvious wear, deterioration	DW: Acceptable. CH: Generally clean, although gear lube evident at exposed gears. No obvious signs of corrosion or rust on the gearing. The equipment is mounted to the top edge of the public accessible concrete deck. The moving gear coupling can be easily reached through the guardrail. Actuation switch is easily accessible by public although requires closed disconnect in the gate house. The ropes are obviously rusted near the point of connection to the gate.
2	Operate Gate Up (Full Stroke if Possible): Listen for ambient noise Look for excessive vibration Listen at gearbox and motor with tool. Observe rope/gears. Observe bearing function. Look for grease/fluid leaks Travel Time Holds load when stopped.	CH: Smooth. No apparent squeals or other noise.
3	Check function of limit switches. Stop 1 Stop 2	CH: This system has no limit switches. Relies on observant operator.
4	Operate Gate Down. Listen for ambient noise Look for excessive vibration Listen at gearbox and motor with tool. Observe rope/gears. Observe bearing function. Look for grease/fluid leaks	CH: Smooth. No apparent squeals or other noise.
5	Check function of limit switches. Stop 1 Stop 2	N.A.
6	Open power disconnect. Ensure safe access.	DW: Functions properly.
7	Motor: Nameplate Data Appearance (corrosion, damage,etc.) Wiring/Connection condition Leaks Shaft	CH: The gear motor was difficult to access under its cover. The name plate was very dirty and/or corroded, making reading of the information very difficult. Rubbing with cloth did not clean adequately to read. 1/2 HP, 220V/440V, 3PH
8	Coupling Nameplate Data Appearance (corrosion, wear damage,etc.)	CH: The flexible insert appeared worn and possibly damaged.

No.	Task	Results/Notes
9	Gearbox Nameplate Data Appearance (corrosion, damage,etc.) Wiring/Connection condition Leaks Shaft Remove access cover. Observe gear condition. Take small oil sample. Look for water, cloudiness, debris.	CH: Gear part of gearbox assembly. Looked relatively clean. No obvious signs of damage or wear.
10	Brake (if any) Nameplate Data Appearance (corrosion, damage,etc.) Wiring/Connection condition Leaks Shaft Drum/pad wear	No Brake.
11	Pillow Blocks Nameplate Data Appearance (corrosion, damage,etc.) Leaks (Noisy bearing noted in 2007 inspection)	CH: The lower exposed worm gear bearing appears old with possible seal damage. Drum shaft bearings look adequate.
12	Exposed Gear Appearance (corrosion, damage,etc.) Shaft Observe gear condition. Look for wear, nicks, damage. Grease. Look for debris, cleanliness	CH: No obvious signs of damage. Old paint and grease in evidence. Some rust is visible.
13	Drum Appearance (corrosion, damage,etc.) Observe condition. Look for wear, nicks, damage.	CH: No obvious damage or wear. Look in relatively fair condition. Light rust.
14	Rope and connections Appearance (corrosion, damage,etc.) Observe condition. Look for wear, nicks, damage.	CH: The ropes have obvious signs of corrosion near the water line.
15	Limit Switch Appearance (corrosion, damage,etc.)	N.A.

No.	Task	Results/Notes
	Remove cover and observe mechanical condition. Look for wear, nicks, damage. Wiring/Connection condition	
16	Motor Starter Appearance (corrosion, damage,etc.) Wiring/Connection condition	Reversing Contactor- Conductors, and terminations in acceptable condition.

3.1.5 Hydraulic Backup System Inspection

No.	Task	Results/Notes
1	General overall appearance: Cleanliness Obvious wear, deterioration	CH: Pumps, valves, filters, etc. in machinery room appear clean, adequate. External cylinders have compromised paint, rust. External ropes and sheaves have general rust corrosion. It was noted that the chains intended for connecting the back-up ropes are missing. This requires divers to connect the back up system to the gate.
2	Operate Gate Up: Listen for ambient noise Look for excessive vibration Observe rope. Observe bearing function. Look for grease/fluid leaks Travel Time Holds load when stopped.	CH: Unable to connect the ropes to the gate. Operated cylinders in and out a few inches without load. No obvious leaks were observed. It was relayed by operators that the east cylinder leaks through the east static blind end seal when the gate weight is supported.
3	Operate Gate Down. Listen for ambient noise Look for excessive vibration Observe rope. Observe bearing function. Look for grease/fluid leaks Travel Time	CH: See Item 2.
4	Open power disconnect. Ensure safe access.	
5	Motor: Nameplate Data Appearance (corrosion, damage,etc.) Wiring/Connection condition Leaks Shaft	CH: Siemens 7.5 HP 213TC 230YY/460Y SF 1.15 CH: Appears clean, adequate.
6	Coupling Nameplate Data Appearance (corrosion, wear damage,etc.)	CH: Obscured by cover.
7	Pump Nameplate Data Appearance (corrosion, damage,etc.) Leaks Shaft	CH: V10-IP(?)-IC-20 Gear pump No apparent damage or issues.
8	4 way Valves Nameplate Data Appearance (corrosion, damage,etc.) Leaks	CH: Nachi Model SS-Go1-C7Y-R-C115-E30 3 way, 3 position, P-to-T center No obvious issues.

No.	Task	Results/Notes
9	Filter Nameplate Data Appearance (corrosion, damage,etc.) Leaks Remove filter cartridge – look for tears, dirt, damage. (Last changed?) (Clogging indication?)	Baldwin BT839-10 CH: No apparent issues. Time to last replacement unknown. No leaks observed. (Engineer's note: photo appears to show possible initial cracking of seal.) There is only one pressure gauge in the system. No obvious means of checking for a clogged filter is apparent.
10	Reservoir Appearance (corrosion, damage,etc.) Leaks Oil Sample- Look for dirt, fibers, cloudiness	CH: Reservoir is new since 2007 inspection. Appears clean and full of oil. No oil sample taken. Sight glass oil appears clear. Reportedly uses biodegradable oil. No information of last replacement given.
11	Piping Appearance (corrosion, damage,etc.) Leaks	CH: No immediate signs of wear or hose chafing. No obvious signs of corrosion apparent. (Engineer's note: photos show pump input hose apparently crossing edge of the drip pan below. Possible chafing area here.) External piping and hoses were not closely examined. Appears to be hose zip tied to structural element.
12	Motor Starter Appearance (corrosion, damage,etc.) Wiring/Connection condition	DW: Reversing Contactor- Conductors, and terminations in acceptable condition.
13	Cylinder 1(east) Appearance (corrosion, damage,etc.) Leaks	CH: Minor rust and paint degradation. Reported leak at east end static seal when under load but not observed here. No obvious damage.
14	Cylinder 2 (west) Appearance (corrosion, damage,etc.) Leaks	CH: Much rust on tie rods near middle of cylinder and at west end of barrel and tie rods.
15	Rope and Rigging Appearance (corrosion, damage,etc.)	CH: Some general corrosion is evident.
16		

3.1.6 Generator Inspection

No.	Task	Results/Notes
1	General overall appearance: Cleanliness Obvious wear, deterioration	DW: System appears dated and well maintained and is reported to be exercised weekly by DES personnel. (Operators were unsure and could not confirm if this particular generator was on the regular maintenance schedule).
2	Operate and transfer power: Listen for ambient noise Look for excessive vibration Look for grease/fluid leaks Check Voltage	DW: Documentation of recent test may be used in lieu of actual test, if available. CH: The generator did not start via the ATS when attempted.
3	Turn off. Open power disconnect. Ensure safe access.	DW: DES uncomfortable with this procedure. Test switch on front of transfer switch panel failed to exercise generator.
4	Generator: Nameplate Data Appearance (corrosion, damage,etc.) Wiring/Connection condition Leaks Shaft	DW: Onan 18.75 KVA/15 KW, 120/240V, 3P, 60 Hz 1800 RPM,
5	Transfer Switch and Hardware Nameplate Data Appearance (corrosion, wear damage,etc.) Wiring/Connection condition	DW: Automatic Switch Co. 100A, 120/240V, 3P, 60 Hz Acceptable appearance and condition. Condition and Terminations acceptable.

3.1.7 Vacuum Siphon Inspection

No.	Task	Results/Notes
6	General overall appearance: Cleanliness Obvious wear, deterioration	DW: Not in operation. Leaking, Function unverifiable. Flow indicator light on control panel constantly on. CH: Dripping leak near backflow preventer has formed puddle on the floor. External pipe below is very rusty/orange. Operator reports that system has not been in use for a year or two. Not able to maintain vacuum reading on system and it's not possible to verify if water is flowing through the siphon or in which direction it is flowing. It was also reported that recent inspection may indicate that the lake intake for the siphon may be submerged in mud but there was some doubt as to whether this was actually the case.
7	Operate System: Listen for ambient noise Look for excessive vibration Observe outflow (if possible). Check gauge pressure	DW: Gauges operational but it is unknown what the process is and what values indicate proper operation. Outflow not observable. CH: System was started and run for several minutes. The pressure reading on the LED display nearby read 2.5 psi. This device is not apparent on the 1986 era drawing schematic. No O&M is available to indicate what the proper pressure should be. The vacuum pump control panel has lights for flow/no flow and indicated flow was occurring. It was not possible to verify flow during this inspection.
8	Pump/Motor: Nameplate Data Appearance (corrosion, damage,etc.) Wiring/Connection condition Leaks Shaft	DW: Garner Denver L 200 2BV7061-1AH00-4S-Z No. BN 10013214 004 /0207 EN 60034 1.6 kW 240V, 3P, 60 Hz 3480 RPM, S.F. 1.38
9	Back Flow Preventer. Nameplate Data Appearance (corrosion, wear damage,etc.)	CH: No nameplate data collected. Unit has a leak which forms a puddle on the floor and has corroded the exterior of the pipe below it.
10	Flow Control Valve Nameplate Data Appearance (corrosion, damage,etc.) Leaks	CH: No nameplate data collected. No issues apparent.
11	Solenoid Valve Nameplate Data Appearance (corrosion, damage,etc.) Leaks Wiring/Connection condition	CH: No nameplate data collected. No issues apparent. DW: ASCO Conductors and terminations acceptable
12	Strainer	CH: Strainer is not installed.

No.	Task	Results/Notes
	Nameplate Data Appearance (corrosion, damage,etc.) Open and look for debris, dirt, clogging	
13	Vacuum Switch Nameplate Data Appearance (corrosion, damage,etc.) Leaks Wiring/Connection condition	DW: Johnson Controls Conductors and terminations acceptable CH: No mechanical issues apparent. Function not confirmed.
14	Relief Valve Nameplate Data Appearance (corrosion, damage,etc.) Leaks	Not observed.
15	Check Valve Nameplate Data Appearance (corrosion, damage,etc.) Leaks	Not observed.
16	Priming Valve Nameplate Data Appearance (corrosion, damage,etc.) Leaks	Not observed.
17	Water Quality Instrument Nameplate Data Appearance (corrosion, damage,etc.) Leaks Wiring/Connection condition	Not observed.
18	Plumbing Appearance (corrosion, damage,etc.) Leaks	Some external corrosion due to leak.
19	Conduit and Wiring Appearance (corrosion, damage,etc.) Wiring/Connection condition	Conductors and terminations acceptable

APPENDIX B COST OPINION DETAIL

FIVES LUND LLC
CAPITOL LAKE TIDE GATE - HARDWARE COST OPINION WORKSHEET

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DATE: October 7, 2016
BY: C. Huck
PROJ: 735B
CLIENT: Moffatt & Nichol / Washington State Department of Enterprise Services
NOTE: Washington State Project No. XXX
See Capitol Lake Tide Gate mach. & Controls Assessment Document, Section 3 Tables for Task Descriptions

DESCRIPTION	NOTES	Material / Part Number	UOM	QTY	UNIT COST	EXTENDED COST	MAN HOURS	EXT'D HOURS	LABOR RATE	LABOR COST	SUB-TOTAL
1 - Tide Gates-Gate Trunnion Lubrication Ports											
Tubing, 1/2" x 0.35 Wall (assume 120 feet per Trunnion)	stainlesssteelfittings.com	316ss	Feet	480	$ 2.55	$ 1,224.00	0.10	48	$ 70.00	$ 3,360.00	$ 4,584.00
Fiitings, 1/2" (Assume 1 per 10 feet. 1/2" single ferrule Tee as average)	stainlesssteelfittings.com	316ss	EA	48	$ 40.00	$ 1,920.00	0.20	10	$ 70.00	$ 672.00	$ 2,592.00
Concrete Anchors (Assume 2 per 5 feet)	McMaster	94475A279	EA	192	$ 3.60	$ 691.20	0.25	48	$ 70.00	$ 3,360.00	$ 4,051.20
Strut, 1 5/8"	McMaster	316SS	Feet	50	$ 14.00	$ 700.00	0.05	3	$ 70.00	$ 175.00	$ 875.00
Clamp (assume 1 per 5 feet of tube)	McMaster	3115T94	EA	96	$ 3.70	$ 355.20	0.10	10	$ 70.00	$ 672.00	$ 1,027.20
Fasteners	McMaster	316SS	EA	96	$ 2.50	$ 240.00	0.05	5	$ 70.00	$ 336.00	$ 576.00
Fitting Box	McMaster	75505K22	EA	1	$ 1,000.00	$ 1,000.00	4.00	4	$ 70.00	$ 280.00	$ 1,280.00
Field Tools/Truck Per Day	Engineer's Estimate	NA	EA	8	$ 100.00	$ 800.00	0.00	0	$ 70.00	$ -	$ 800.00
Subconsultant Admin	Engineer's Estimate	NA	Lump	1	$ -	$ -	60.00	60	$ 100.00	$ 6,000.00	$ 6,000.00
Engineer's Fee (Not included in Hardware Total)	See Engineering Cost Estimate	NA	Lump	1	$ -	$ -	NA	NA	NA	$15,655	$ 15,654.60
					Totals - No Engineer's Fee:	**$ 6,930.40**		187		**$ 14,855.00**	**$ 21,785.40**
					Totals - With Engineer's Fee						**$ 37,440.00**
2 - Tide Gates-Gate Trunnion Cleaning and Inspection											
Crane Rental plus Operator	Star Rental Website	NA	Day	10	$ 500.00	$ 5,000.00	8.00	80	$ 90.00	$ 7,200.00	$ 12,200.00
Crew (4 ironworkers per day)	Engineer's Estimate	NA	Day	10	$ -	$ -	32.00	320	$ 70.00	$ 22,400.00	$ 22,400.00
Micellaneous Material	Engineer's Estimate	NA	Lump	1	$ 8,000.00	$ 8,000.00	0.00	0	$ 70.00	$ -	$ 8,000.00
Subconsultant Admin	Engineer's Estimate	NA	Lump	1	$ -	$ -	120.00	120	$ 100.00	$ 12,000.00	$ 12,000.00
Engineer's Fee (Not included in Hardware Total)	See Engineering Cost Estimate	NA	Lump	1	$ -	$ -	NA	NA	NA	$1,687	$10,071
					Totals - No Engineer's Fee:	**$ 13,000.00**		520		**$ 41,600.00**	**$ 54,600.00**
					Totals - With Engineer's Fee						**$ 64,671.00**
3 - Tide Gates-Friction Assessment											
Subconsultant Admin	Engineer's Estimate	NA	Lump	1	$ -	$ -	0.00	0	$ 100.00	$ -	$ -
Engineer's Fee (Not included in Hardware Total)	See Engineering Cost Estimate	NA	Lump	1	$ -	$ -	NA	NA	NA	$6,441	$1,687
					Totals - No Engineer's Fee:	**$ -**		0		**$ -**	**$ -**
					Totals - With Engineer's Fee						**$ 1,687.44**
4- Tide Gates-Bearing Blocks / Shafts / Coupling Inspection											
Crane Rental plus Operator	Star Rental Website	NA	Day	10	$ 500.00	$ 5,000.00	8.00	80	$ 90.00	$ 7,200.00	$ 12,200.00
Crew (4 ironworkers per day)	Engineer's Estimate	NA	Day	10	$ -	$ -	32.00	320	$ 70.00	$ 22,400.00	$ 22,400.00
Micellaneous Material	Engineer's Estimate	NA	Lump	1	$ 15,000.00	$ 15,000.00	0.00	0	$ 70.00	$ -	$ 15,000.00
Subconsultant Admin	Engineer's Estimate	NA	Lump	1	$ -	$ -	80.00	80	$ 100.00	$ 8,000.00	$ 8,000.00
Engineer's Fee (Not included in Hardware Total)	See Engineering Cost Estimate	NA	Lump	1	$ -	$ -	NA	NA	NA	$19,356	$9,471
					Totals - No Engineer's Fee:	**$ 20,000.00**		480		**$ 37,600.00**	**$ 57,600.00**
					Totals - With Engineer's Fee						**$ 67,071.00**

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BY: C. Huck
PROJ: 735B
CLIENT: Moffatt & Nichol / Washington State Department of Enterprise Services
NOTE: Washington State Project No. XXX
See Capitol Lake Tide Gate mach. & Controls Assessment Document, Section 3 Tables for Task Descriptions

DESCRIPTION	NOTES	Material / Part Number	UOM	QTY	UNIT COST	EXTENDED COST	MAN HOURS	EXT'D HOURS	LABOR RATE	LABOR COST	SUB-TOTAL
6&7- Tide Gates-Exposed Gear Rehab											
Crane Rental plus Operator	Star Rental Website	NA	Day	5	$ 500.00	$ 2,500.00	8.00	40	$ 90.00	$ 3,600.00	$ 6,100.00
Crew (3 ironworkers per day)	Engineer's Estimate	NA	Day	5	$ -	$ -	24.00	120	$ 70.00	$ 8,400.00	$ 8,400.00
12 T Sprocket	Gear Works Quote	No. 001	EA	2	$ 2,668.00	$ 5,336.00	2.00	4	$ 70.00	$ 280.00	$ 5,616.00
40T Sprocket	Gear Works Quote	No. 002	EA	2	$ 6,740.00	$ 13,480.00	0.00	0	$ 70.00	$ -	$ 13,480.00
15T Spur Gear	Gear Works Quote	No. 003	EA	2	$ 3,858.00	$ 7,716.00	0.00	0	$ 70.00	$ -	$ 7,716.00
75T Spur Gear	Gear Works Quote	No. 004	EA	2	$ 29,992.00	$ 59,984.00	0.00	0	$ 70.00	$ -	$ 59,984.00
Roller Chain - 2.5 Pitch Double	Engineer's Estimate	Steel	Feet	50	$ 150.00	$ 7,500.00	0.00	0	$ 70.00	$ -	$ 7,500.00
Micellaneous Material	Engineer's Estimate	NA	Lump	1	$ 8,000.00	$ 8,000.00	0.00	0	$ 70.00	$ -	$ 8,000.00
Subconsultant Admin	Engineer's Estimate	NA	Lump	1	$ -	$ -	80.00	80	$ 100.00	$ 8,000.00	$ 8,000.00
Engineer's Fee (Not included in Hardware Total)	See Engineering Cost Estimate	NA	Lump	1	$ -	$ -	NA	NA	NA	$0	$19,356
				Totals - No Engineer's Fee:		$ 104,516.00		244		$ 20,280.00	$124,796.00
				Totals - With Engineer's Fee							$144,152.00
10- Tide Gates-Gearbox Replace/Rehab											
Crane Rental plus Operator	Star Rental Website	NA	Day	1	$ 500.00	$ 500.00	8.00	8	$ 90.00	$ 720.00	$ 1,220.00
Crew (3 ironworkers per day)	Engineer's Estimate	NA	Day	1	$ -	$ -	24.00	24	$ 70.00	$ 1,680.00	$ 1,680.00
New Gearbox (Quotes indicate cheaper new than refurbish)	ConeDrive Quote	UU30-70-A1	EA	2	$ 7,001.00	$ 14,002.00	0.00	0	$ 70.00	$ -	$ 14,002.00
Micellaneous Material	Engineer's Estimate	NA	Lump	1	$ 2,000.00	$ 2,000.00	0.00	0	$ 70.00	$ -	$ 2,000.00
Subconsultant Admin	Engineer's Estimate	NA	Lump	1	$ -	$ -	60.00	60	$ 100.00	$ 6,000.00	$ 6,000.00
Engineer's Fee (Not included in Hardware Total)	See Engineering Cost Estimate	NA	Lump	1	$ -	$ -	NA	NA	NA	$0	$7,395
				Totals - No Engineer's Fee:		$ 16,502.00		92		$ 8,400.00	$ 24,902.00
				Totals - With Engineer's Fee							$ 32,297.00
11- Tide Gates-West Motor/Brake Replacement											
Crane Rental plus Operator	Star Rental Website	NA	Day	1	$ 500.00	$ 500.00	8.00	8	$ 90.00	$ 720.00	$ 1,220.00
Crew (2 ironworkers per day)	Engineer's Estimate	NA	Day	1	$ -	$ -	16.00	16	$ 70.00	$ 1,120.00	$ 1,120.00
New Motor/Brake	Grainger	16G418	EA	1	$ 2,000.00	$ 2,000.00	2.00	0	$ 70.00	$ -	$ 2,000.00
Micellaneous Material	Engineer's Estimate	NA	Lump	1	$ 1,000.00	$ 1,000.00	0.00	0	$ 70.00	$ -	$ 1,000.00
Subconsultant Admin	Engineer's Estimate	NA	Lump	1	$ -	$ -	40.00	40	$ 100.00	$ 4,000.00	$ 4,000.00
Engineer's Fee (Not included in Hardware Total)	See Engineering Cost Estimate	NA	Lump	1	$ -	$ -	NA	NA	NA	$0	$5,660
				Totals - No Engineer's Fee:		$ 3,500.00		64		$ 5,840.00	$ 9,340.00
				Totals - With Engineer's Fee							$ 15,000.24
14-Tide Gates - Coupling Guards											
Crew (2 ironworkers per day)	Engineer's Estimate	NA	Day	1	$ -	$ -	16.00	16	$ 70.00	$ 1,120.00	$ 1,120.00
New Guards	Engineer's Estimate	NA	EA	1	$ 1,000.00	$ 1,000.00	2.00	0	$ 70.00	$ -	$ 1,000.00
Micellaneous Material	Engineer's Estimate	NA	Lump	1	$ 200.00	$ 200.00	0.00	0	$ 70.00	$ -	$ 200.00
Subconsultant Admin	Engineer's Estimate	NA	Lump	1	$ -	$ -	10.00	10	$ 100.00	$ 1,000.00	$ 1,000.00
Engineer's Fee (Not included in Hardware Total)	See Engineering Cost Estimate	NA	Lump	1	$ -	$ -	NA	NA	NA	NA	$3,117
				Totals - No Engineer's Fee:		$ 1,200.00		26		$ 2,120.00	$ 3,320.00
				Totals - With Engineer's Fee							$ 6,436.74

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DESCRIPTION	NOTES	Material / Part Number	UOM	QTY	UNIT COST	EXTENDED COST	MAN HOURS	EXT'D HOURS	LABOR RATE	LABOR COST	SUB-TOTAL
1-Tide Gate Controls											
Crew (2 electricians per day)	Engineer's Estimate	NA	Day	1	$ -	$ -	16.00	16	$ 70.00	$ 1,120.00	$ 1,120.00
New Parts	Engineer's Estimate	NA	EA	1	$ 4,000.00	$ 4,000.00	2.00	0	$ 70.00	$ -	$ 4,000.00
Subconsultant Admin	Engineer's Estimate	NA	Lump	1	$ -	$ -	10.00	10	$ 100.00	$ 1,000.00	$ 1,000.00
Engineer's Fee (Not included in Hardware Total)	See Engineering Cost Estimate	NA	Lump	1	$ -	$ -	NA	NA	NA	NA	$3,635
					Totals - No Engineer's Fee:	$ 4,000.00		26		$ 2,120.00	**$ 6,120.00**
					Totals - With Engineer's Fee						**$ 9,755.36**
1-Electrical Panel and Motor Control Center (MCC) -Inspect contacts, dielectric test, etc.)											
Crew (2 electricians per day)	Engineer's Estimate	NA	Day	1	$ -	$ -	16.00	16	$ 70.00	$ 1,120.00	$ 1,120.00
New Parts	Engineer's Estimate	NA	EA	1	$ 500.00	$ 500.00	2.00	0	$ 70.00	$ -	$ 500.00
Subconsultant Admin	Engineer's Estimate	NA	Lump	1	$ -	$ -	10.00	10	$ 100.00	$ 1,000.00	$ 1,000.00
Engineer's Fee (Not included in Hardware Total)	See Engineering Cost Estimate	NA	Lump	1	$ -	$ -	NA	NA	NA	NA	$0
					Totals - No Engineer's Fee:	$ 500.00		26		$ 2,120.00	**$ 2,620.00**
					Totals - With Engineer's Fee						**$ 2,620.00**
2 & 3-Electrical Panel and Motor Control Center (MCC) - Seal Conduits/Upgrade Receptacle											
Crew (2 electricians per day)	Engineer's Estimate	NA	Day	1	$ -	$ -	16.00	16	$ 70.00	$ 1,120.00	$ 1,120.00
New Parts	Engineer's Estimate	NA	EA	1	$ 500.00	$ 500.00	2.00	0	$ 70.00	$ -	$ 500.00
Subconsultant Admin	Engineer's Estimate	NA	Lump	1	$ -	$ -	10.00	10	$ 100.00	$ 1,000.00	$ 1,000.00
Engineer's Fee (Not included in Hardware Total)	See Engineering Cost Estimate	NA	Lump	1	$ -	$ -	NA	NA	NA	NA	$0
					Totals - No Engineer's Fee:	$ 500.00		26		$ 2,120.00	**$ 2,620.00**
					Totals - With Engineer's Fee						**$ 2,620.00**
1 - Standby Hydraulic System - Gate Attachment											
Crane Rental plus Operator	Star Rental Website	NA	Day	2	$ 500.00	$ 1,000.00	8.00	16	$ 90.00	$ 1,440.00	$ 2,440.00
Crew (3 ironworkers per day)	Engineer's Estimate	NA	Day	2	$ -	$ -	24.00	48	$ 70.00	$ 3,360.00	$ 3,360.00
Chain	Engineer's Estimate	Stainless Steel	Feet	60	$ 120.00	$ 7,200.00	0.00	0	$ 70.00	$ -	$ 7,200.00
Fittings	Engineer's Estimate	Stainless Steel	Feet	4	$ 400.00	$ 1,600.00	0.00	0	$ 70.00	$ -	$ 1,600.00
Parts for Stowing Chain	Engineer's Estimate	NA	EA	2	$ 1,500.00	$ 3,000.00	0.00	0	$ 70.00	$ -	$ 3,000.00
Micellaneous Material	Engineer's Estimate	NA	Lump	1	$ 4,000.00	$ 4,000.00	0.00	0	$ 70.00	$ -	$ 4,000.00
Subconsultant Admin	Engineer's Estimate	NA	Lump	1	$ -	$ -	80.00	80	$ 100.00	$ 8,000.00	$ 8,000.00
Engineer's Fee (Not included in Hardware Total)	See Engineering Cost Estimate	NA	Lump	1	$ -	$ -	NA	NA	NA	$695	$7,902
					Totals - No Engineer's Fee:	$ 16,800.00		144		$ 12,800.00	**$ 29,600.00**
					Totals - With Engineer's Fee						**$ 37,502.12**
2 - Standby Hydraulic System -Cylinders Refurbishment											
Crane Rental plus Operator	Star Rental Website	NA	Day	2	$ 500.00	$ 1,000.00	8.00	16	$ 90.00	$ 1,440.00	$ 2,440.00
Crew (4 ironworkers per day)	Engineer's Estimate	NA	Day	2	$ -	$ -	32.00	64	$ 70.00	$ 4,480.00	$ 4,480.00
Seals, Rods, Tear Down	Engineer's Estimate	NA	Lump	1	$ 5,000.00	$ 5,000.00	0.00	40	$ 100.00	$ 4,000.00	$ 9,000.00
Micellaneous Material	Engineer's Estimate	NA	Lump	1	$ 4,000.00	$ 4,000.00	0.00	0	$ 70.00	$ -	$ 4,000.00
Subconsultant Admin	Engineer's Estimate	NA	Lump	1	$ -	$ -	60.00	60	$ 100.00	$ 6,000.00	$ 6,000.00
Engineer's Fee (Not included in Hardware Total)	See Engineering Cost Estimate	NA	Lump	1	$ -	$ -	NA	NA	NA	$1,800	$6,021
					Totals - No Engineer's Fee:	$ 10,000.00		180		$ 15,920.00	**$ 25,920.00**
					Totals - With Engineer's Fee						**$ 31,941.00**

FIVES LUND LLC
CAPITOL LAKE TIDE GATE - HARDWARE COST OPINION WORKSHEET

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DATE: October 7, 2016
BY: C. Huck
PROJ: 735B
CLIENT: Moffatt & Nichol / Washington State Department of Enterprise Services
NOTE: Washington State Project No. XXX
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DESCRIPTION	NOTES	Material / Part Number	UOM	QTY	UNIT COST	EXTENDED COST	MAN HOURS	EXT'D HOURS	LABOR RATE	LABOR COST	SUB-TOTAL
3 - Standby Hydraulic System -Filter Replacement/Gauges											
Crew (2 pipefitters per day)	Engineer's Estimate	NA	Day	2	$ -	$ -	16.00	32	$ 70.00	$ 2,240.00	$ 2,240.00
Filter and Gauges	Engineer's Estimate	NA	Lump	1	$ 300.00	$ 300.00	0.00	0	$ 100.00	$ -	$ 300.00
Micellaneous Material	Engineer's Estimate	NA	Lump	1	$ 1,000.00	$ 1,000.00	0.00	0	$ 70.00	$ -	$ 1,000.00
Subconsultant Admin	Engineer's Estimate	NA	Lump	1	$ -	$ -	30.00	30	$ 100.00	$ 3,000.00	$ 3,000.00
Engineer's Fee (Not included in Hardware Total)	See Engineering Cost Estimate	NA	Lump	1	$ -	$ -	NA	NA	NA	$11,780	$5,312
					Totals - No Engineer's Fee:	**$ 1,300.00**		62		**$ 5,240.00**	**$ 6,540.00**
					Totals - With Engineer's Fee						**$ 11,851.56**
6 - Standby Hydraulic System - Replace Rigging											
Crew (3 Ironworkers per day)	Engineer's Estimate	NA	Day	2	$ 40.00	$ 80.00	24.00	48	$ 70.00	$ 3,360.00	$ 3,440.00
Wire Rope	Engineer's Estimate	NA	Lump	1	$ 4,000.00	$ 4,000.00	0.00	0	$ 100.00	$ -	$ 4,000.00
Subconsultant Admin	Engineer's Estimate	NA	Lump	1	$ -	$ -	30.00	30	$ 100.00	$ 3,000.00	$ 3,000.00
Engineer's Fee (Not included in Hardware Total)	See Engineering Cost Estimate	NA	Lump	1	$ -	$ -	NA	NA	NA	$798	$0
					Totals - No Engineer's Fee:	**$ 4,080.00**		78		**$ 6,360.00**	**$ 10,440.00**
					Totals - With Engineer's Fee						**$ 10,440.00**
2 - Fish Gate - Coupling Guard											
Crew (2 Ironworkers per day)	Engineer's Estimate	NA	Day	1	$ -	$ -	16.00	16	$ 70.00	$ 1,120.00	$ 1,120.00
Custom Cover	Engineer's Estimate	NA	Lump	1	$ 1,000.00	$ 1,000.00	0.00	0	$ 100.00	$ -	$ 1,000.00
Micellaneous Material	Engineer's Estimate	NA	Lump	1	$ 1,000.00	$ 1,000.00	0.00	0	$ 70.00	$ -	$ 1,000.00
Subconsultant Admin	Engineer's Estimate	NA	Lump	1	$ -	$ -	40.00	40	$ 100.00	$ 4,000.00	$ 4,000.00
Engineer's Fee (Not included in Hardware Total)	See Engineering Cost Estimate	NA	Lump	1	$ -	$ -	NA	NA	NA	#REF!	$5,469
					Totals - No Engineer's Fee:	**$ 2,000.00**		56		**$ 5,120.00**	**$ 7,120.00**
					Totals - With Engineer's Fee						**$ 12,589.00**
3 - Fish Gate -Exposed Switch Cover											
Crew (2 Ironworkers per day)	Engineer's Estimate	NA	Day	1	$ -	$ -	16.00	16	$ 70.00	$ 1,120.00	$ 1,120.00
Custom Cover	Engineer's Estimate	NA	Lump	1	$ 1,000.00	$ 1,000.00	0.00	0	$ 100.00	$ -	$ 1,000.00
Micellaneous Material	Engineer's Estimate	NA	Lump	1	$ 1,000.00	$ 1,000.00	0.00	0	$ 70.00	$ -	$ 1,000.00
Subconsultant Admin	Engineer's Estimate	NA	Lump	1	$ -	$ -	40.00	40	$ 100.00	$ 4,000.00	$ 4,000.00
Engineer's Fee (Not included in Hardware Total)	See Engineering Cost Estimate	NA	Lump	1	$ -	$ -	NA	NA	NA	$0	$5,469
					Totals - No Engineer's Fee:	**$ 2,000.00**		56		**$ 5,120.00**	**$ 7,120.00**
					Totals - With Engineer's Fee						**$ 12,589.00**
4 - Fish Gate - Wire Rope Replacement											
Crane Rental plus Operator	Star Rental Website	NA	Day	2	$ 500.00	$ 1,000.00	8.00	16	$ 90.00	$ 1,440.00	$ 2,440.00
Crew (3 ironworkers per day)	Engineer's Estimate	NA	Day	2	$ -	$ -	24.00	48	$ 70.00	$ 3,360.00	$ 3,360.00
Rope, 6 x 19 IWRC 1/2" (Approximate req'd size - not final)	McMaster	316SS	Feet	100	$ 12.00	$ 1,200.00	0.00	0	$ 100.00	$ -	$ 1,200.00
Fittings	Engineer's Estimate	316SS	EA	2	$ 300.00	$ 600.00		0		$ -	$ 600.00
Micellaneous Material	Engineer's Estimate	NA	Lump	1	$ 2,000.00	$ 2,000.00	0.00	0	$ 70.00	$ -	$ 2,000.00
Subconsultant Admin	Engineer's Estimate	NA	Lump	1	$ -	$ -	40.00	40	$ 100.00	$ 4,000.00	$ 4,000.00
Engineer's Fee (Not included in Hardware Total)	See Engineering Cost Estimate	NA	Lump	1	$ -	$ -	NA	NA	NA	$0	$5,516
					Totals - No Engineer's Fee:	**$ 4,800.00**		104		**$ 4,000.00**	**$ 13,600.00**
					Totals - With Engineer's Fee						**$ 19,116.28**

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DATE: October 7, 2016
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NOTE: Washington State Project No. XXX
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DESCRIPTION	NOTES	Material / Part Number	UOM	QTY	UNIT COST	EXTENDED COST	MAN HOURS	EXT'D HOURS	LABOR RATE	LABOR COST	SUB-TOTAL
2 - Siphon System - Exhaust Muffler and Separation Tee											
Crew (2 pipefitters per day)	Engineer's Estimate	NA	Day	2	$ 40.00	$ 80.00	8.00	16	$ 70.00	$ 1,120.00	$ 1,200.00
Muffler	McMaster	5889K65	EA	1	$ 120.00	$ 120.00	0.00	0	$ 70.00	$ -	$ 120.00
Separation Tee	Engineer's Estimate	316SS	EA	1	$ 200.00	$ 200.00		0	$ 70.00	$ -	$ 200.00
Micellaneous Material	Engineer's Estimate	NA	Lump	1	$ 2,000.00	$ 100.00	0.00	0	$ 70.00	$ -	$ 100.00
Subconsultant Admin	Engineer's Estimate	NA	Lump	1	$ -	$ -	8.00	8	$ 100.00	$ 800.00	$ 800.00
Engineer's Fee (Not included in Hardware Total)	See Engineering Cost Estimate	NA	Lump	1	$ -	$ -	NA	NA	NA	$0	$5,366
					Totals - No Engineer's Fee:	$ 500.00		24		$ 800.00	**$ 2,420.00**
					Totals - With Engineer's Fee						**$ 7,786.28**
4 - Siphon System - Operation and Maintenance											
Engineer's Fee (Not included in Hardware Total)	See Engineering Cost Estimate	NA	Lump	1	$ -	$ -	NA	NA	NA	$0	$11,780
					Totals - No Engineer's Fee:	$ -		0		$ -	**$ -**
					Totals - With Engineer's Fee						**$ 11,779.80**
1 - Capitol lake level Controls (METASYS) - Document Control Function											
Engineer's Fee (Not included in Hardware Total)	See Engineering Cost Estimate	NA	Lump	1	$ -	$ -	NA	NA	NA	$0	$12,037
					Totals - No Engineer's Fee:	$ -		0		$ -	**$ -**
					Totals - With Engineer's Fee						**$ 12,036.72**
3 - Capitol Lake Level Controls - Enclosure Holes											
Crew (2 crew per day)	Engineer's Estimate	NA	Day	1	$ 40.00	$ 40.00	16.00	16	$ 100.00	$ 1,600.00	$ 1,640.00
Parts	Engineer's Estimate	NA	Lump	1	$ 500.00	$ 500.00	0.00	0	$ 70.00	$ -	$ 500.00
Engineer's Fee (Not included in Hardware Total)	See Engineering Cost Estimate	NA	Lump	1	$ -	$ -	NA	NA	NA	$0	$2,114
					Totals - No Engineer's Fee:	$ 540.00		16		$ -	**$ 2,140.00**
					Totals - With Engineer's Fee						**$ 4,253.56**
4 - Capitol Lake Level Controls - Level Sensors - Terminate Connections											
Crew (2 crew per day)	Engineer's Estimate	NA	Day	1	$ 40.00	$ 40.00	16.00	16	$ 100.00	$ 1,600.00	$ 1,640.00
Parts	Engineer's Estimate	NA	Lump	1	$ 500.00	$ 500.00	0.00	0	$ 70.00	$ -	$ 500.00
Engineer's Fee (Not included in Hardware Total)	See Engineering Cost Estimate	NA	Lump	1	$ -	$ -	NA	NA	NA	$0	$0
					Totals - No Engineer's Fee:	$ 540.00		16		$ -	**$ 2,140.00**
					Totals - With Engineer's Fee						**$ 2,140.00**

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*Billing rate/hr	PM Eng II $150	Elect Engr IV $144	Mech Engr. II $99	Mech Engr. I $81	Admin $75	Hours	Cost Labor	DIRECT COSTS: Car Rent Per Day $50	Per Diem Per Day $69	Parking Per Day $15	Cost Direct	Cost ($): Dollars
1 - Tide Gates-Gate Trunnion Lubrication Ports												
Design	10		30			40	$4,465				$0	$4,465
Specification	16					16	$2,400				$0	$2,400
Drawings				40		40	$3,240				$0	$3,240
QC	8					8	$1,200				$0	$1,200
Submittal and RFI Review, Site Visits	20					20	$3,000				$0	$3,000
Admin	8				2	10	$1,350				$0	$1,350
Totals:						**134**	**$15,655**				**$0**	**$15,655**
2 - Tide Gates-Gate Trunnion Cleaning and Inspection												
Design	10					10	$1,500				$0	$1,500
Specification	16					16	$2,400				$0	$2,400
Drawings				16		16	$1,296				$0	$1,296
QC	8					8	$1,200				$0	$1,200
Submittal and RFI Review, Site Visits	20					20	$3,000				$0	$3,000
Admin	4				1	5	$675				$0	$675
Totals:						**75**	**$10,071**				**$0**	**$10,071**
3 - Tide Gates-Friction Assessment												
On-Site	4	4				8	$1,175				$0	$1,175
Write Up	1	2				3	$437				$0	$437
Admin	0				1	1	$75				$0	$75
Totals:						**12**	**$1,687**				**$0**	**$1,687**
4- Tide Gates-Bearing Blocks / Shafts / Coupling Inspection												
Design	10					10	$1,500				$0	$1,500
Specification	12					12	$1,800				$0	$1,800
Drawings				16		16	$1,296				$0	$1,296
QC	8					8	$1,200				$0	$1,200
Submittal and RFI Review, Site Visits	20					20	$3,000				$0	$3,000
Admin	4				1	5	$675				$0	$675
Totals:						**71**	**$9,471**				**$0**	**$9,471**
6&7- Tide Gates-Exposed Gear Rehab												
Reverse Engineer Gears	10		50			60	$6,441				$0	$6,441
Specification	16					16	$2,400				$0	$2,400
Drawings				40		40	$3,240				$0	$3,240
QC	12					12	$1,800				$0	$1,800
Submittal and RFI Review, Site Visits	32					32	$4,800				$0	$4,800
Admin	4				1	5	$675				$0	$675
Totals:						**165**	**$19,356**				**$0**	**$19,356**
10- Tide Gates-Gearbox Replace/Rehab												
Specification	16					16	$2,400				$0	$2,400
Drawings				20		20	$1,620				$0	$1,620
QC	12					12	$1,800				$0	$1,800
Submittal and RFI Review, Site Visits	8					8	$1,200				$0	$1,200
Admin	2				1	3	$375				$0	$375
Totals:						**59**	**$7,395**				**$0**	**$7,395**

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11- Tide Gates-West Motor/Brake Replacement												
Specification	2	12				14	$2,025				$0	$2,025
Drawings		6		8		14	$1,510				$0	$1,510
QC	4					4	$600				$0	$600
Submittal and RFI Review, Site Visits		8				8	$1,150				$0	$1,150
Admin	2				1	3	$375				$0	$375
					Totals:	**43**	**$5,660**				**$0**	**$5,660**
14-Tide Gates - Coupling Guards												
Specification	8					8	$1,200				$0	$1,200
Drawings		1		8		9	$792				$0	$792
QC	2					2	$300				$0	$300
Submittal and RFI Review, Site Visits	4					4	$600				$0	$600
Admin	1				1	2	$225				$0	$225
					Totals:	**25**	**$3,117**				**$0**	**$3,117**
1-Tide Gate Controls												
Specification	2	12				14	$2,025				$0	$2,025
Drawings		2		8		10	$935				$0	$935
QC	1					1	$150				$0	$150
Submittal and RFI Review, Site Visits	2					2	$300				$0	$300
Admin	1				1	2	$225				$0	$225
					Totals:	**29**	**$3,635**				**$0**	**$3,635**
1 - Standby Hydraulic System - Gate Attachment												
Design	4		16			20	$2,181				$0	$2,181
Specification	8					8	$1,200				$0	$1,200
Drawings				16		16	$1,296				$0	$1,296
QC	4					4	$600				$0	$600
Submittal and RFI Review, Site Visits	16					16	$2,400				$0	$2,400
Admin	1				1	2	$225				$0	$225
					Totals:	**66**	**$7,902**				**$0**	**$7,902**
2 - Standby Hydraulic System -Cylinders Refurbishment												
Specification	12					12	$1,800				$0	$1,800
Drawings				16		16	$1,296				$0	$1,296
QC	2					2	$300				$0	$300
Submittal and RFI Review, Site Visits	16					16	$2,400				$0	$2,400
Admin	1				1	2	$225				$0	$225
					Totals:	**48**	**$6,021**				**$0**	**$6,021**
3 - Standby Hydraulic System -Filter Replacement/Gauges												
Specification	4		8			12	$1,391				$0	$1,391
Drawings				16		16	$1,296				$0	$1,296
QC	4					4	$600				$0	$600
Submittal and RFI Review, Site Visits	12					12	$1,800				$0	$1,800
Admin	1				1	2	$225				$0	$225
					Totals:	**46**	**$5,312**				**$0**	**$5,312**

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								DIRECT COSTS				Cost ($)
*Billing rate/hr	PM Eng II $150	Elect Engr IV $144	Mech Engr. II $99	Mech Engr. I $81	Admin $75	Hours	Cost Labor	Car Rent Per Day $50	Per Diem Per Day $69	Parking Per Day $15	Cost Direct	Dollars
2 - Fish Gate - Coupling Guard												
Design				8		8	$648				$0	$648
Specification	8					8	$1,200				$0	$1,200
Drawings				16		16	$1,296				$0	$1,296
QC	2					2	$300				$0	$300
Submittal and RFI Review, Site Visits	12					12	$1,800				$0	$1,800
Admin	1				1	2	$225				$0	$225
					Totals:	**48**	**$5,469**				**$0**	**$5,469**
3 - Fish Gate -Exposed Switch Cover												
Design				8		8	$648				$0	$648
Specification	8					8	$1,200				$0	$1,200
Drawings				16		16	$1,296				$0	$1,296
QC	2					2	$300				$0	$300
Submittal and RFI Review, Site Visits	12					12	$1,800				$0	$1,800
Admin	1				1	2	$225				$0	$225
					Totals:	**48**	**$5,469**				**$0**	**$5,469**
4 - Fish Gate - Wire Rope Replacement												
Review Requirements	2		4			6	$695				$0	$695
Specification	8					8	$1,200				$0	$1,200
Drawings				16		16	$1,296				$0	$1,296
QC	2					2	$300				$0	$300
Submittal and RFI Review, Site Visits	12					12	$1,800				$0	$1,800
Admin	1				1	2	$225				$0	$225
					Totals:	**46**	**$5,516**				**$0**	**$5,516**
2 - Siphon System - Exhaust Muffler and Separation Tee												
Design	1		4			5	$545				$0	$545
Specification	8					8	$1,200				$0	$1,200
Drawings				16		16	$1,296				$0	$1,296
QC	2					2	$300				$0	$300
Submittal and RFI Review, Site Visits	12					12	$1,800				$0	$1,800
Admin	1				1	2	$225				$0	$225
					Totals:	**45**	**$5,366**				**$0**	**$5,366**
4 - Siphon System - Operation and Maintenance												
O&M-Review equipment and Specifications	8	4	16			28	$3,356				$0	$3,356
O&M Document	8	8	40			56	$6,303				$0	$6,303
Drawings				16		16	$1,296				$0	$1,296
QC	4					4	$600				$0	$600
Admin	1				1	2	$225				$0	$225
					Totals:	**106**	**$11,780**				**$0**	**$11,780**

FIVES LUND LLC
CAPITOL LAKE TIDE GATE ENGINEERING COST OPINION
DATE: October 7, 2016
BY: C. Huck
PROJ: 735B
CLIENT: Moffatt & Nichol / Washington State Department of Enterprise Services
NOTE: Washington State Project No. XXX
See Capitol Lake Tide Gate mach. & Controls Assessment Document, Section 3 Tables for Task Descriptions

Fives Lund LLC
13536 Beacon Coal Mine Rd S
Seattle, WA 98178 USA
Tel: (206)753-1900 - Fax: (206)753-1999
www.fivesgroup.com

								DIRECT COSTS				Cost ($)
*Billing rate/hr	PM Eng II $150	Elect Engr IV $144	Mech Engr. II $99	Mech Engr. I $81	Admin $75	Hours	Cost Labor	Car Rent Per Day $50	Per Diem Per Day $69	Parking Per Day $15	Cost Direct	Dollars
1 - Capitol lake level Controls (METASYS) - Document Control Function												
Review Program	2	40				42	$6,050				$0	$6,050
Document Program	2	30				32	$4,612				$0	$4,612
QC		8				8	$1,150				$0	$1,150
Admin	1				1	2	$225				$0	$225
					Totals:	**84**	**$12,037**				**$0**	**$12,037**
3 - Capitol Lake Level Controls - Enclosure Holes												
Design Covers As Needed	1		8			9	$941				$0	$941
Drawings	1			8		9	$798				$0	$798
QC	1					1	$150				$0	$150
Admin	1				1	2	$225				$0	$225
					Totals:	**21**	**$2,114**				**$0**	**$2,114**
4 - Capitol Lake Level Controls - Level Sensors - Terminate Connections												
No Engineering	0				0	0	$0				$0	$0
					Totals:	**0**	**$0**				**$0**	**$0**

APPENDIX D – Geotechnical Engineering Report; Capitol Lake Dam Preservation Assessment

Geotechnical Engineering Report

Capitol Lake Dam Preservation
Olympia, Washington

December 7, 2016
Terracon Project No. 81165060
Washington State Department of Enterprise Services Project No. 2016-931

Prepared for:
Moffatt & Nichol, Inc.
Seattle, Washington

Prepared by:
Terracon Consultants, Inc.
Mountlake Terrace, Washington

December 7, 2016

Moffatt & Nichol, Inc.
600 University Street, Suite 610
Seattle, WA 98101

Attn: Mr. Byron Haley
P: [206] 622-0222
E: BHaley@moffattnichol.com

Re: Geotechnical Engineering Report
Capitol Lake Dam Preservation
Olympia, Washington
Terracon Project Number: 81165060
Washington State Department of Enterprise Services Project No. 2016-931

Dear Mr. Haley:

Terracon Consultants, Inc. (Terracon) has completed the geotechnical engineering services for the above referenced project. This study was performed in general accordance with our proposal number P81165060 dated May 11, 2016 and a Subconsultant agreement between Moffatt & Nichol and Terracon dated July 18, 2016. This report presents the findings of our review of available information, subsurface explorations, and stability analyses.

We appreciate the opportunity to be of service to you on this project. If you have any questions concerning this report, or if we may be of further service, please contact us.

Sincerely,
Terracon Consultants, Inc.

Tori Hesedahl, E.I.T.
Geotechnical Engineer

Dennis R. Stettler, P.E.
Senior Consultant

David A. Baska, Ph.D., P.E.
Department Manager

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EXECUTIVE SUMMARY

Terracon has performed geotechnical engineering services to support a condition assessment of Capitol Lake Dam (also known as Deschutes Dam) in Olympia, Washington. As part of these services we conducted geotechnical explorations which consisted of two borings to a maximum depth below existing grade of about 41½ feet. We also searched for existing subsurface information in publicly available resources, and in our own records.

Based on the information obtained from our subsurface exploration and research of existing information, the following geotechnical considerations were identified:

- Construction records for the dam were not available, therefore we were not able to evaluate the control structure foundations nor were we able to evaluate fill materials, placement or compaction. A 1980 report by Kramer, Chin, & Mayo stated that the spillway structure is supported by timber piles of unknown length.

- Our borings indicate that the embankment consists of loose to medium dense sandy gravel with silt.

- Preliminary embankment stability analyses based on the available information indicates a calculated factor of safety of about 1.3 in the static case with average water levels in Budd Inlet and Capitol Lake. The calculated factor of safety in the static case at extreme low tide is about 1.1 according to our model.

- Terracon's opinion based on our analysis is that the embankment fill and the soil underlying the dam may liquefy in a seismic event with a 224 year return period. Modeling the liquefied foundation soil with reduced strength results in a factor of safety less than 1.0.

- Mitigating the soil liquefaction hazard will likely require ground improvement of the embankment and foundation soils.

This summary should be used in conjunction with the entire report for evaluation purposes. It should be recognized that details were not included or fully developed in this section, and the report must be read in its entirety for a comprehensive understanding of the items contained herein. The section titled **GENERAL COMMENTS** should be read for an understanding of the report limitations.

GEOTECHNICAL ENGINEERING REPORT
Capitol Lake Dam Preservation
Olympia, Washington
Terracon Project No. 81165060
December 7, 2016

1.0 INTRODUCTION

Terracon Consultants, Inc. (Terracon) is pleased to present the results of our geotechnical engineering evaluation of Capitol Lake Dam in Olympia, Washington. Logs of the site explorations by Terracon, along with a site location map and exploration plan, are included in Appendix A of this report. Geotechnical laboratory results are presented in Appendix B and information on the soil classification system is presented in Appendix C. Exploration logs by others are included in Appendix D.

The purpose of these services is to provide information and geotechnical engineering evaluations relative to:

- subsurface soil conditions
- apparent dam condition
- groundwater conditions
- static and seismic stability of the dam

2.0 PROJECT INFORMATION

Capitol Lake Dam is located at the mouth of the Deschutes River where the river empties into Budd Inlet in Olympia, Washington.

According to the Department of Ecology - Water Resources Program Dam Safety Office (DSO) *Inventory of Dams in the State of Washington*, Deschutes Dam impounds Capitol Lake and is an earth fill dam with a crest length of 1,290 feet, and a height of 45 feet. The DSO assigned downstream hazard class 3 to the dam, because of the dam's low downstream hazard potential with zero population at risk. Construction of the dam was completed in 1951 for the purpose of providing recreation. (DSO 2015)

Kramer, Chin, & Mayo (KCM) describe Capitol Lake Dam as being an approximately 800 foot long earth fill dam in their Structural Evaluation Report dated December 1980. Scaling from the plan sheet included as Figure 2 (KCM 1980) indicates that the planned limits of fill along the dam's axis was about 1290 feet, matching DSO's length using their definition of length. Scaling from the plans along the dam's axis from the railroad embankment on the west to Brenner Street on the east gives a length of about 750 feet. By comparison of the plan sheet with 2016 aerial imagery available from Google Earth, it is apparent that fill has been placed on both sides of the dam (to the north and the south of the dam) east of the control structure. Apparent length of the dam from aerial imagery is about 500 feet.

The earth embankment is described on Figure 4 as being constructed with an "impervious earth core" material (KCM 1980). Based on this description we would expect to find relatively well-compacted, fine-grained soil with low plasticity. Flanking the impervious core the original plans show a "semi-pervious transition soil". Soils used in this zone would be expected to be relatively well-compacted, silty sand or gravel. Rip rap armoring was reportedly placed on both the upstream and downstream shells of the dam.

Existing information references elevations in different datums. KCM states in their report that elevations in the original plans (included as figures in their report) reference the City of Olympia Datum, which is 17.97 feet higher than Mean Lower Low Water (MLLW). Moffatt & Nichol provided topographic and bathymetric contours in a CADD drawing for our use. Datum for the contours was not stated but is assumed to reference NGVD29 based on comparison with topographic contours of the area available on Thurston County's web geographic information system portal (GIS). Terracon used NOAA's vdatumweb web application to find the adjustment from NGVD29 to MLLW. NOAA adjusts tidal datums, including MLLW, periodically; Terracon has neglected changes by epoch in comparing elevations from different time periods. To adjust elevations from City of Olympia Datum to NGVD29 we added 10.6 feet.

KCM gives the dam height to be 26.5 feet in their report introduction, then states that top of spillway bottom slab elevation is -32.00 feet and the top of earth dam is at +6.50 feet which gives a height of 39.5 feet. Scaling the embankment cross section shown on Figure 4 (KCM 1980) gives an embankment height of about 40 feet. The Raymond Concrete Pile Co. GOW Division Test Boring Report states mudline elevations at the boring locations referenced to City of Olympia Datum that range from elevation -12.9 feet to -25.7 feet which would give a dam height of 19.4 to 32.3 feet assuming finish grade at elevation +6.5 feet. Topographic and bathymetric contours provided by Moffatt & Nichol indicate that apparent dam height is about 32 feet.

Lake level is maintained by means of a rectangular concrete spillway which is 82 feet wide and 92 feet long with a 167 foot long outfall apron (KCM). The spillway structure is supported by timber piles of unknown length. Pile driving records were not available to Terracon for evaluation of the control structure foundation. The spillway structure supports the road deck for 5th Avenue SW and the crossings for communication, water, sewer, and natural gas utilities. Design water level for the lake was elevation -4 feet with minimum level set by the weir crest at elevation -17 feet City of Olympia Datum (KCM).

Tidal variation of the water level in Budd Inlet is about 22½ feet (KCM).

The following background regarding seismic stability was provided in the Request for Qualifications for this current project:

> "Lake managers have monitored the seismic stability of the dam for many years. Significant quakes occurred in 1949 (magnitude 7.1), in 1965 (magnitude 6.7) and in 2001 (magnitude 6.8). According to the Pacific Northwest Seismograph Network the northern industrial areas of downtown Olympia settled 5 inches as a result of the 1949 quake, as the dam was being built. Through these major shakes and numerous smaller quakes the dam has not been found to have suffered structural damage."

3.0 SURFACE CONDITIONS

Terracon conducted a visual reconnaissance of the areas of the dam accessible to the general public on August 1, 2016. We timed our visit to coincide with a -2.14 foot MLLW tide predicted by the National Oceanic and Atmospheric Administration for shortly before noon that day. The purpose of our reconnaissance was to look for surficial evidence of distress to the embankment. We used the Inspection Guidelines of the Dam Safety Guidelines Part III (DSO 1992) as a guide. Gross signs of instability were not apparent anywhere along the dam. Gross signs would include: sinkholes, large cracks, slumps, scarps, or slides.

Surface cracking, ruts, and holes were not apparent along the crest of the dam. Most of the dam width is paved for 5th Avenue SW, Deschutes Parkway SW, and sidewalks. Vegetation along the top of the dam consisted primarily of lawn. Two apparent small animal burrows were observed in the lawn on the south side of Deshcutes Parkway SW just before the intersection with 5th Avenue SW.

Some minor erosion was observed on the upstream slope near the dam crest, particularly where paths down to the lake were apparent on the west side of the control structure.

Heavy vegetation including trees and blackberries obscured most of the upstream slope, and the downstream slope above the high tide line. In general, heavy vegetation on embankment dam slopes is undesirable since roots can loosen soils and obscure indications of dam distress. Below the high tide line, the rip rap appeared to be in good condition. We were unable to observe the rip rap condition below the water surface at the time of our reconnaissance. We observed no signs of distress from seepage or erosion at the downstream area below the dam.

4.0 SUBSURFACE CONDITIONS

4.1 Geology

The Geologic map of the Tumwater 7.5-minute quadrangle, Thurston County, Washington (Walsh et al 2003) shows the surficial geology for the site is mapped Qf – Fill. Fill consists of clay, silt, sand, gravel, shells, rip-rap, and debris that were placed to raise grade. Based on the time period when major regrading of the area occurred, most of this fill is assumed to be undocumented. The dam itself is an earth fill dam. By comparing the construction drawings to aerial photographs, we infer that fill was placed east of the control structure, on either side (north and south) of the dam.

Underlying the fill around Capitol Lake the geologic cross-section (Walsh et al 2003) shows Qgos – Vashon recessional sand and minor silt. This unit consists mostly of fine- to medium-grained sand with minor silt and is sometimes interbedded with clayey and/or fine sandy silt. Thickness of this unit varies greatly across the published cross-section and on a contour map shown on the geologic map.

4.2 Typical Profile

Based on existing subsurface information and the results of the borings, subsurface conditions on the project site can be generalized as follows:

Stratum	Approximate Depth to Bottom of Stratum (feet)	Material Description	Consistency/ Density
1[1,2]	27 to 35	Embankment Fill sandy GRAVEL with silt	Medium dense becoming loose below about 10 feet below ground surface)(bgs)
2[3]	55	Estuarine Deposits SILT, SAND, and SHELLS – embankment fill gravels may have mixed with silt at contact	Soft to Medium Stiff / Loose
3[4]	20 to 400	Vashon recessional sand and minor silt	Stiff to Hard

1. Construction records were not available. Based on construction methods typical to the time of construction, we assume that fill was placed without moisture and density control. This material is typically variable in composition, consistency, density, moisture, and depth. It was difficult to discern the depth of the contact between native soil and embankment fill due to poor recovery in the samplers.
2. Boring B-1 was terminated in this unit due to borehole caving.
3. Boring B-2 was terminated at this depth in heaving sands.
4. Depth to bottom of stratum is inferred from the geologic map.

Embankment fill material encountered in the borings (generally sandy gravel with silt) is not consistent with the impervious fill material described on the section view in the original plans. It should be noted that field visual classification of the embankment fill in the borings completed by Terracon is not consistent with the laboratory testing completed by Terracon. The SPT split-spoon diameter excludes gravels larger than about 1.75 inches in diameter. Consequently, laboratory testing of grain size distribution did not include the presence of larger gravel. Abundant gravel was observed in the auger cuttings from boring B-2. Abundant rock chips were observed in the wash from boring B-1. Drilling action observed during both borings was indicative of gravelly soil. Therefore, the soil description on the boring logs and on the subsurface profile and cross section are interpreted as being predominately gravel with variable sand and silt content.

Underlying soils encountered in the GOW borings are generally consistent with the mapped geology.

4.3 Groundwater

Groundwater was observed in boring B-2 at about 12.5 feet below ground surface. Groundwater levels can be expected to vary seasonally and from year to year depending on precipitation, site utilization, and other on- and off-site factors. Groundwater levels will also fluctuate with tide and lake water levels.

5.0 ANALYSIS AND CONCLUSIONS

Terracon used the available information to make inferences and develop slope stability models to evaluate the stability of the dam for both static and seismic loading. Borings B-1 and B-2 were advanced by Terracon in 2016 for this evaluation. Raymond Concrete Pile Company's GOW Division drilled borings in 1948 to explore the subsurface prior to dam construction. These boring logs along with topographic and bathymetric contours were used to create the subsurface profile along the dam axis and a cross section is included in Appendix A. Previous borings along the 4th Avenue SW bridge alignment located to the north of the dam and borings advance for commercial projects east of the dam were also reviewed to provide additional information regarding soil conditions in the area.

5.1 Static Slope Stability

From the boring logs and subsurface profile and cross section we created a model in the slope stability modeling program SLIDE 6.012. The model is intended to represent a cross section of the dam with generalized soil conditions. A static surcharge of 250 pounds per square foot is modeled on the dam crest to account for traffic loading in the static case. Runs were made with water levels at the Budd Inlet side of the model simulating mean sea level and extreme low tide. We understand that lake level is managed to vary no more that about 2 to 3 feet, so lake level variation was not modeled.

Our preliminary modeling results indicate that the dam is stable in the static case, with a calculated factor of safety of about 1.3 assuming Budd Inlet at MSL as shown on Exhibit F-1. This modeling is consistent with the dam history and visual observations of the dam condition during our reconnaissance, which did not disclose areas of noticeable dam embankment distress.

The most critical static case appears to occur at an extreme low tide at the downstream toe of the dam. We estimate a calculated factor of safety of about 1.1 using our lower bound estimate of soil strength (ϕ = 28°) at the contact between the dam fill and former estuary bottom (Exhibit F-2). Our lower bound estimate is based on interpreting "muck" logged near mudline in most of the GOW borings to be loose to very loose, saturated, silt with variable sand content. It should be noted that if the loose surficial soil at the previous mudline were removed or displaced during original construction of the dam, better soil than assumed in our analyses could be present near the contact of the dam embankment and the mudline. However, the lack of construction records related to the dam construction does not allow alternate interpretations of the ground conditions present at the contact between the dam embankment and the previous mudline.

5.2 Seismic Slope Stability

5.2.1 Recent Historical Earthquakes

The 1949 Olympia earthquake occurred during the early stages of dam construction. The magnitude of the earthquake was 7.1 (**M**7.1) and the epicenter was located about 17 km northeast of the site. A seismograph station located about 1 km southeast of the dam recorded a maximum peak ground acceleration (PGA) value of 0.28g. Although no ground failures were reported at the location of the dam, bank failures were observed around the perimeter of Capitol Lake.

The level of ground shaking at the dam site during the 1965 Seattle-Tacoma earthquake (**M**6.5) was noticeably less than that felt during the 1949 earthquake. In addition to the lower magnitude, the lower level of shaking at the site during the 1965 event may be attributed to the greater epicentral distance (60 km). The maximum value of PGA for the 1965 earthquake, recorded at the same station as the 1949 event, was 0.20g. Despite the lower ground motion value, earthquake-induced soil liquefaction (described below) and resulting lateral spreads were observed at various bank locations around Capitol Lake. Exhibit G-1 includes a photograph of liquefaction-related damage from the 1965 Seattle-Tacoma earthquake along Deschutes Parkway SW.

Liquefaction features, including lateral spreads, were observed at several of the same locations following the 2001 Nisqually earthquake (**M**6.8) as those observed following the 1965 event. The Nisqually earthquake had an epicentral distance from the dam of 18 km. The Washington State Department of Transportation seismograph station located less than 1 km northeast of the dam recorded a maximum PGA value of 0.26g. Observations of liquefaction and lateral spreading along Deschutes Parkway SW, and other locations in the vicinity of Capitol Lake, were documented in Bray et al. (2001). Exhibit G-2 includes two photographs of liquefaction-related damage from the 2001 earthquake. One photograph was taken at the same location as the photograph from 1965 indicating that earthquake-induced liquefaction tends to occur at the same location during subsequent earthquakes.

Exhibit G-3 includes additional ground motion data for the 2001 Nisqually earthquake. The data was obtained from the Center for Engineering Strong Motion Data and includes recorded accelerograms and computed response spectra from the WSDOT seismograph station. Subsurface conditions at the station are similar to those at Capitol Lake Dam. A notable difference between the two sites is that the dam's embankment fill is gravelly and slightly stiffer than the sandy fill at the lab location. In addition, the embankment geometry would alter ground motions with respect to those at the relatively level lab site. None-the-less, ground motions at the surface of the two sites would likely have been similar.

5.2.2 Earthquake Sources

The 1949, 1965, and 2001 earthquakes described above originated from within the Juan de Fuca plate as it was being assimilated into Earth's mantle at depths of 50 to 60 km. Consequently, these events are termed Intraplate earthquakes. In addition to their relatively great depth, Intraplate earthquakes are characterized by maximum magnitudes of 7.0 to 7.5.

Two other earthquake sources have been identified in the Pacific Northwest. One of these sources is the Cascadia Subduction Zone (CSZ) located off the west coast of North America from Cape Mendocino, California to Vancouver Island, British Columbia, Canada. Because of the potentially long (1,200 km) rupture length of the CSZ, **M**9.0+ earthquakes are possible from this source. The earthquakes occur at the interface between the subducting Juan de Fuca plate and the North American plate. CSZ earthquakes are generally thought to occur on average every 500 years. The last of these great earthquakes struck Washington State approximately 300 years ago.

Crustal earthquake sources in the Puget Sound basin have been difficult to locate because of the thick deposits of glacial sediments and the dense vegetation. Geophysical methods, such as gravimetric surveys, have allowed us to map a series of east-west trending basins in the region. In theory, the northern and southern boundaries of these basins are delineated by high angle faults. One of these inferred fault traces (termed the Olympia structure) passes within 1 km of the dam site (Clement et al., 2010). Surface expression of this potential fault has not been identified. However, other crustal earthquake sources have been mapped throughout the Puget Sound basin. The U.S. Geological Survey (USGS) estimates that these crustal sources are capable of **M**7.5 earthquakes.

It is important to note that future ground shaking from any of these three earthquake sources could exceed the levels of ground shaking experienced by the dam in the 1949, 1965, and 2001 earthquakes.

5.2.3 Earthquake Ground Shaking and Other Hazards

The most common parameter to quantify earthquake ground shaking is peak ground acceleration (PGA). PGA is the maximum horizontal value of ground acceleration recorded at a site during the seismic event. As seen in Section 5.2.1, PGA correlates well to earthquake magnitude and source-to-site distance. However, local soil conditions, the mechanism of fault rupture (e.g., strike-slip or reverse), site topography, and other factors affect the recorded value of PGA.

To evaluate the effects of strong ground shaking at the Capitol Lake Dam site, we first computed the values of PGA for different earthquake return periods. Exhibit G-4 shows the relationship between PGA and return period using a USGS-developed web-based tool (http://geohazards.usgs.gov/deaggint/2008/). The tool computes ground motion values probabilistically from all known earthquake sources using a scientifically-based range of magnitude and distance values for each source, and a database of past seismic activity on those sources. From Exhibit G-4, it can be seen that the corresponding earthquake return period for the amplitude of ground shaking experienced at the site during the 2001 Nisqually earthquake (PGA = 0.26g) is about 200 years.

A secondary effect of strong ground shaking, with significant implications for Capitol Lake Dam, is soil liquefaction. Liquefaction occurs in soils located below the water table. Loose sands are most susceptible to liquefaction, but non-plastic and low plasticity fine-grained (silt and clay) soils are also susceptible. During strong ground shaking, the soil particles want to densify, but the loading is too rapid for the water to dissipate and the soil particles lose their grain-to-grain contact. Consequently, the once stable soil deposit becomes a viscous fluid mass with reduced strength.

The bank failures observed during past earthquakes around Capitol Lake are the result of loose, saturated soils liquefying and losing strength. Failure surfaces developed in the low strength materials and the overlying soils displaced in the direction of least resistance (i.e., toward the lake). If ground shaking is strong enough, liquefaction may occur to considerable depth in susceptible soils.

5.2.4 Embankment Stability under Earthquake Loading

We evaluated the potential for soil liquefaction of the embankment foundation soils using the Simplified Procedure originally developed by Seed and Idriss (1971). The procedure quantifies earthquake loading with values for **M** and PGA. Resistance to liquefaction is quantified by Standard Penetration Test (SPT) N-values obtained from drilling and sampling during subsurface exploration. We relied upon subsurface information obtained during our recent exploration program, as well as the past exploration programs described above, for our evaluation. We concluded from our evaluation that the embankment foundation soils could liquefy with PGA values as low 0.30g. More specifically, the loose to medium dense sand layer we modeled between the elevations of -25 and -35 feet (NGVD 29) could liquefy and lose strength. Although our evaluation of seismic stability focused on the foundation soils, loose to medium dense portions of the embankment fill located below the water table may also liquefy during strong ground shaking events. Exhibit G-4 indicates that a PGA value of 0.30g equates to an earthquake return period of approximately 225 years.

In order to quantify the post-liquefaction strength of the sand layer underlying the embankment, we employed methods developed by Seed and Harder (1990) and Idriss and Boulanger (2008). Both methods equate post-liquefaction strength to SPT N-values, however, the latter method also considers effective vertical stress at the SPT sample locations. We concluded from these analyses that the post-liquefaction strength could range from 200 to 500 psf.

Exhibit G-5 shows our slope stability results after assigning a post-liquefaction strength of 500 psf to the foundation sand layer. The factor of safety is less than 1.0 indicating that significant embankment displacements (i.e., greater than 1 m) would occur. The displacements could damage outlet works, reduce freeboard, and even result in overtopping of the dam.

5.2.5 Uncertainty in Analyses and Results

The following is a partial list of sources of uncertainty in our analyses and results:

- Our exploration program was limited to two borings, and only one of those borings penetrated below the bottom of the embankment and into the foundation soils.
- Data from previous exploration programs lacked detailed information regarding drilling and sampling procedures to verify that SPT N-values were obtained following ASTM standards.
- An understanding of lateral continuity of liquefiable layers is critical to evaluation of slope stability during earthquake loading. We assumed a continuous layer of liquefiable soil under the embankment, but assigned a post-liquefaction strength that was at the upper end of the computed range of values, in part, to account for zones of non-liquefiable material in the layer.

5.2.6 Established Dam Safety Criteria

Seismic design criteria for dams and embankments varies between agencies. The Washington State Department of Ecology Dam Safety Office did not include specific seismic design criteria in their 1992 guidelines. The following criteria is included in the Natural Resources Conservation Service (NRCS), Seismic Analysis Manual (2014 Draft) prepared in part by Terracon:

> "The rarity of the earthquake considered in embankment dam analysis varies with the hazard rating of a dam and are based on exceedance probability which translates to a return period. In NRCS 60 the considered loadings vary from 1000 to 10,000 years (Table 2.1). The operating basis earthquake loading is based on more common and less severe earthquakes varying from 250 to 500 year return intervals (Table 2.2). Within NRCS guidelines, a dam must be built to survive the

maximum design earthquake without catastrophic failure causing a rapid release of water. The dam must also handle the operating basis earthquake and remain functional such that the dam and appurtenances can pass the principal spillway flood and that subsequent failure due to other factors is unlikely until repairs can be made."

Table 2.1: Maximum Earthquake Loading for Dams

Clear Day Hazard* Classification	Annual Exceedance Probability	Return Period (Years)	Approximate probability of exceedance in 50 years
Low	1 x 10^{-3}	1,000	5%
Significant	4 x 10^{-4}	2,500	2%
High	1 x 10^{-4}	10,000	0.5%

*Clear Day Hazard: Hazards represented by earthquake-induced clear day dam failure with the reservoir at the normal pool (from draft TR60; NRCS, 2014).

Table 2.2: Operating Basis Earthquake Loading for Dams

Hazard* Classification	Annual Exceedance Probability	Return Period (Years)	Approximate probability of exceedance in 50 years
Low	----------	-------	-----
Significant	4 x 10^{-3}	250	20%
High	2 x 10^{-3}	500	10%

*Hazard Classification: Hazards represented by dam failure with reservoir retention at or above the upper limit of the flood-retarding pool.

5.2.7 Mitigation

When rehabilitating an existing embankment dam, the properties of the dam and/or foundation soil may be improved, the geometry of the existing dam may be modified, or a combination of these methods may be utilized. The following is a brief listing of potential mitigation methods:

- A berm may be constructed to buttress the dam and improve the embankment's stability.
- Drains may be added to improve stability by lowering the phreatic surface and provide relief for earthquake-induced pore pressures.
- Stone columns could be installed to increase the density of loose soils and act as drains to reduce liquefaction potential.
- Deep soil mixing or jet grouting could be used to improve shear strength of the materials and provide containment of liquefiable soils.

- Compaction grouting may be used to densify loose granular soils and reinforce fine-grained soils.

Given our current understanding of the embankment fill and foundation materials, we anticipate that deep soil mixing or jet grouting in combination with a berm to buttress the downstream toe of the dam would be the most economically feasible mitigation method. It is likely that some form of drainage (e.g., a blanket drain) would be installed with the new buttress. In our opinion, this combination of mitigation methods could be used to improve stability of the dam for earthquake return periods of 1,000 years or greater, while toe berm(s) and drainage may be sufficient for lesser return periods.

Assuming a zone of mitigation that extends 800 feet along the length of the dam, we developed the rough order of magnitude costs listed below:

Mitigation Method	Average Width of Mitigation Zone (feet)	Average Thickness of Mitigation Zone (feet)	Cost per cubic foot ($)	Approximate Estimated Cost ($M)
Deep Soil Mixing or Jet Grouting	80 to 100	35	5 to 7	15
Buttressing Berm (downstream)	50 to 70	25	1.0 to 1.5	1.5
Drainage	80 to 100	1.5	3 to 5	0.5

6.0 CONCLUSIONS AND RECOMMENDATIONS

Our understanding of the embankment construction, foundation soils, and potential earthquake loading leads us to the conclusion that Capitol Lake Dam is susceptible to significant displacements during ground shaking at ground motion levels that are slightly in excess of what the embankment has experienced in the past.

The subsurface exploration and laboratory testing programs completed for this study were not comprehensive. In order to properly evaluate stability, estimate displacements, and to develop mitigation measures, a thorough subsurface exploration program would be required. We recommend additional SPT borings and advancement of CPT soundings to characterize the embankment and foundation materials. Measurement of shear wave velocity values would also aid the assessment of seismic site response.

7.0 GENERAL COMMENTS

The analysis and recommendations presented in this report are based upon the data obtained from the borings performed at the indicated locations and from other information discussed in this report. This report does not reflect variations that may occur between borings, across the site, or due to the modifying effects of construction or weather. The nature and extent of such variations may not become evident until additional explorations are conducted or during or after any additional construction at the dam. If variations appear, we should be immediately notified so that further evaluation and supplemental recommendations can be provided.

The scope of services for this project does not include either specifically or by implication any environmental or biological (e.g., mold, fungi, bacteria) assessment of the site or identification or prevention of pollutants, hazardous materials or conditions. If the owner is concerned about the potential for such contamination or pollution, other studies should be undertaken.

This report has been prepared for the exclusive use of Moffatt & Nichol and the Washington State Department of Enterprise Services for specific application to the project discussed and has been prepared in accordance with generally accepted geotechnical engineering practices. No warranties, either express or implied, are intended or made. In the event that changes in the nature, design, or location of the project as outlined in this report are planned, the conclusions and recommendations contained in this report shall not be considered valid unless Terracon reviews the changes and either verifies or modifies the conclusions of this report in writing.

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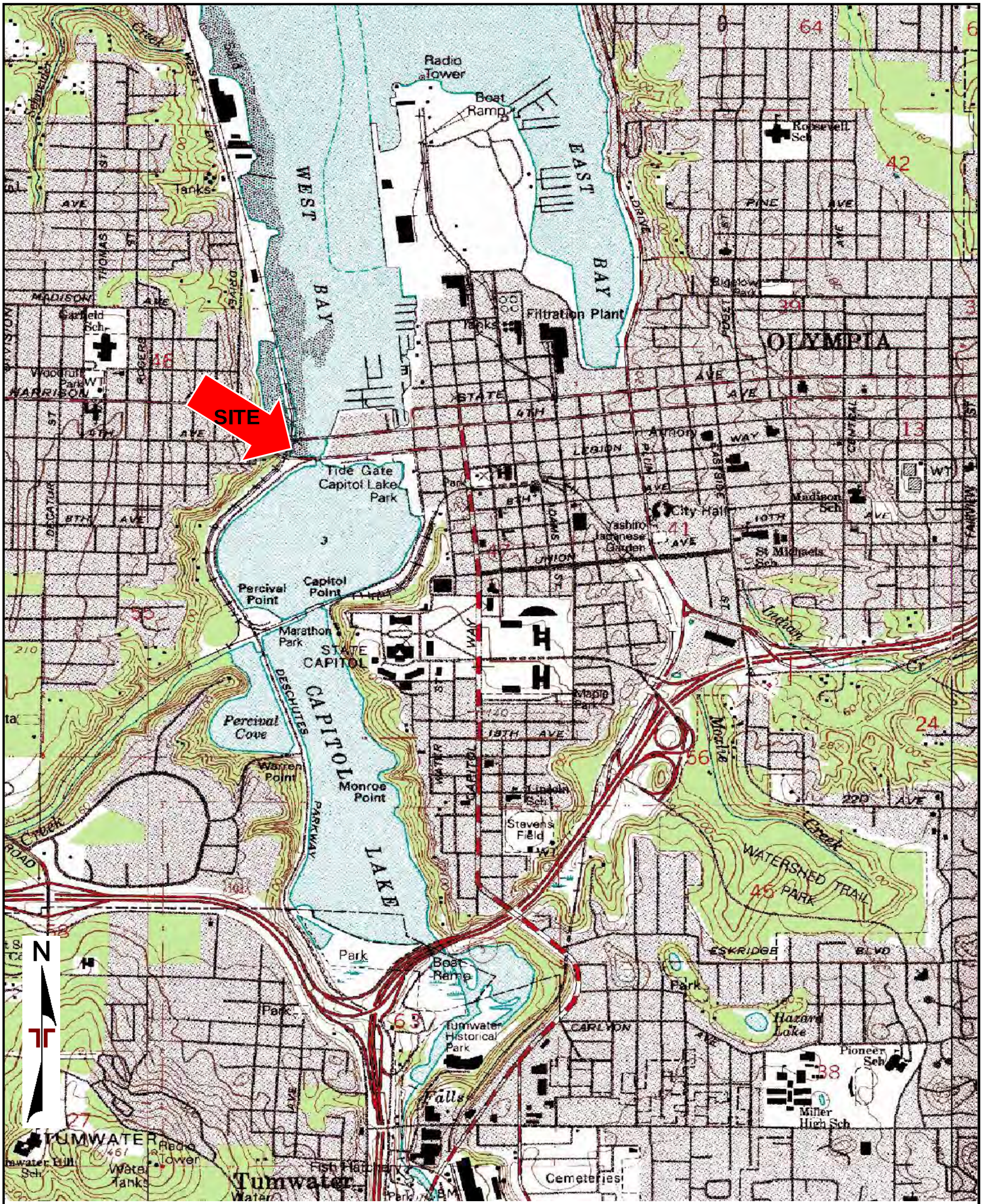
APPENDIX A
FIELD EXPLORATION



TOPOGRAPHIC MAP IMAGE COURTESY OF THE U.S. GEOLOGICAL SURVEY
QUADRANGLES INCLUDE: TUMWATER, WA (1/1/1997) and LACEY, WA (1/1/1997).

Project Manager: D. Stettler	Project No. 81165060	Terracon	SITE LOCATION	Exhibit
Drawn by: T. Hesedahl	Scale: 1"=2,000'	21905 64th Ave W Ste 100	Capitol Lake Dam	A-1
Checked by: D. Stettler	File Name: ExhA1.docx	Mountlake Terrace, WA 98043-2251	5th Ave SW	
Approved by: D. Stettler	Date: 9/14/2016		Olympia, WA	

Aerial Imagery ©2016 Google

SEE LEGEND, EXHIBIT A-5

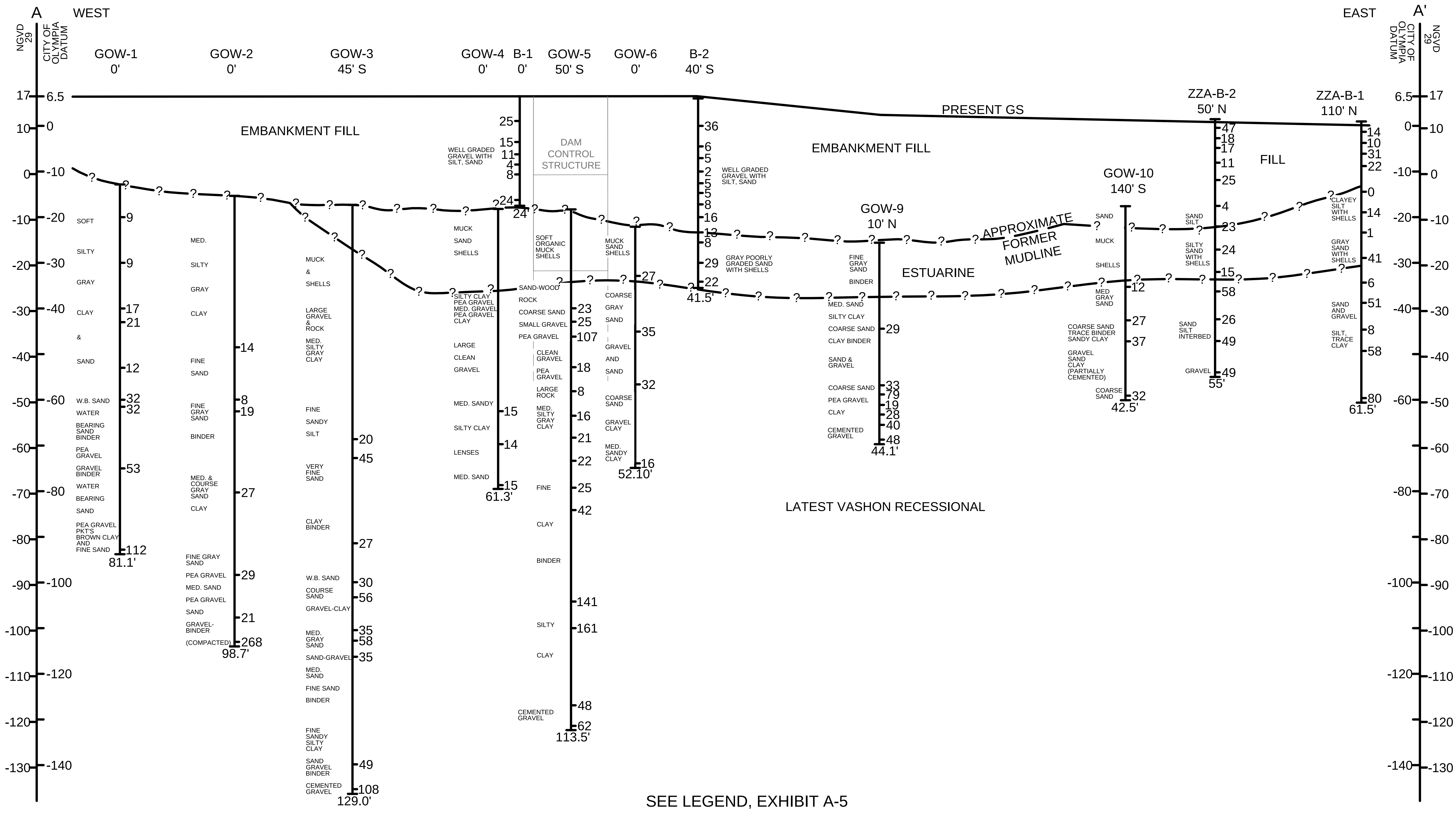
120 0 30 60 120
SCALE IN FEET

Project Mngr: DRS	Project No. 81165060		
Drawn By: AMP	Scale: AS SHOWN		
Checked By: TLH	File No. Exhibit A-2		
Approved By: DRS	Date: September 2016		

Terracon
Consulting Engineers and Scientists
21905 64th Avenue W, Ste 100 Mountlake Terrace, WA 98043
PH. (425) 771-3304 FAX. (425) 771-3549

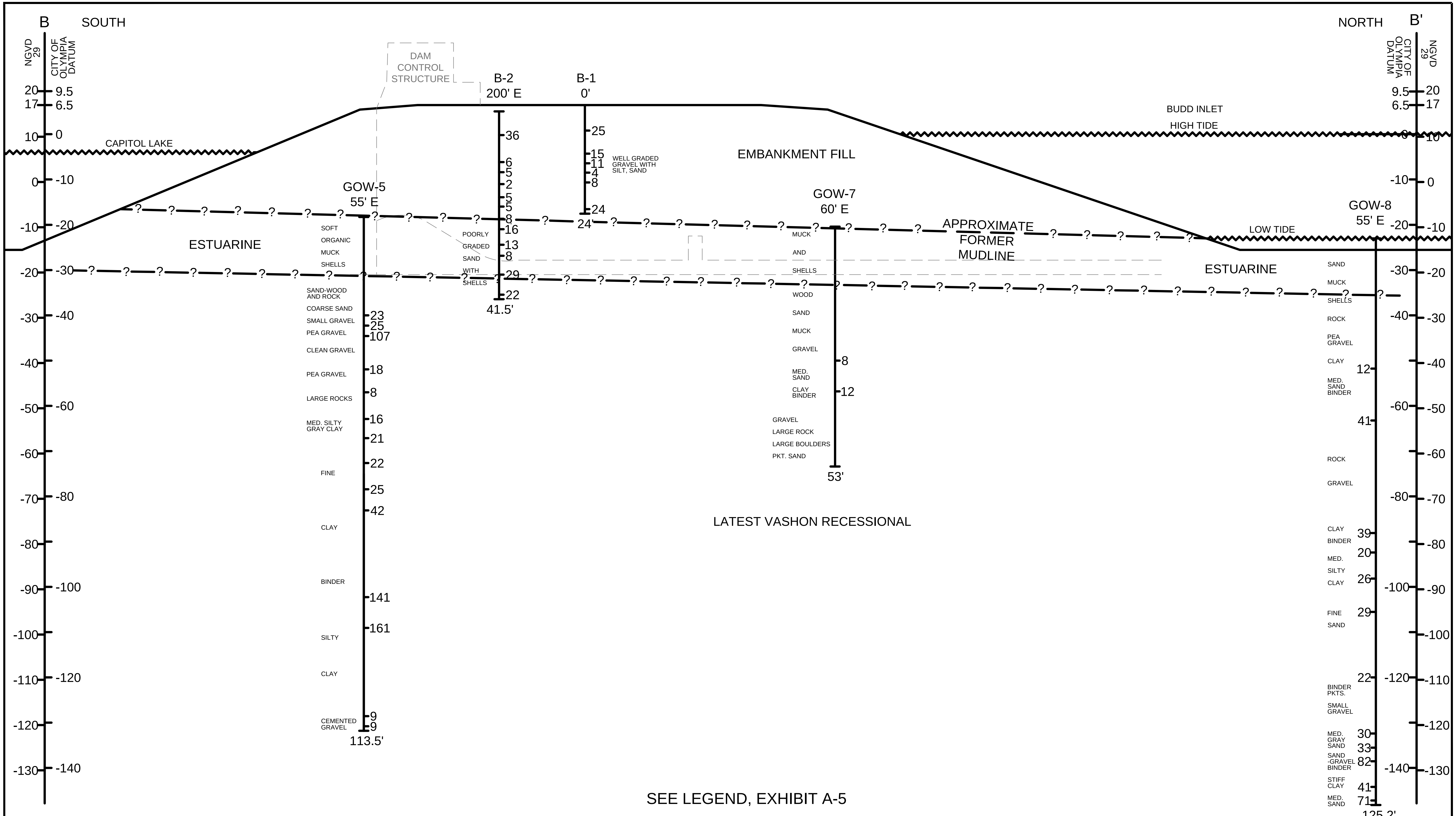
SITE AND EXPLORATION PLAN
CAPITOL LAKE DAM
Olympia, Thurston County, Washington

EXHIBIT
A-2



HORIZONTAL & VERTICAL SCALE: 20 0 5 10 20 SCALE IN FEET

Project Mngr: DRS	Project No. 81165060	Terracon Consulting Engineers and Scientists	**SUBSURFACE PROFILE**
Drawn By: AMP	Scale: AS SHOWN	21905 64th Avenue W, Ste 100 Mountlake Terrace, WA 98043	CAPITOL LAKE DAM
Checked By: TLH	File No. Exhibit A-3	PH. (425) 771-3304 FAX. (425) 771-3549	Olympia, Thurston County, Washington
Approved By: DRS	Date: September 2016		EXHIBIT A-3



SEE LEGEND, EXHIBIT A-5

HORIZONTAL & VERTICAL SCALE: 20 0 5 10 20

SCALE IN FEET

Project Mngr: DRS	Project No. 81165060		
Drawn By: AMP	Scale: AS SHOWN		
Checked By: TLH	File No. Exhibit A-4		
Approved By: DRS	Date: Septemeber 2016		

Terracon
Consulting Engineers and Scientists

21905 64th Avenue W, Ste 100 Mountlake Terrace, WA 98043
PH. (425) 771-3304 FAX. (425) 771-3549

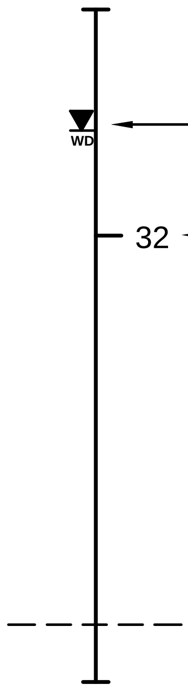
SUBSURFACE CROSS SECTION

CAPITOL LAKE DAM
Olympia, Thurston County, Washington

EXHIBIT

A-4

SUBSURFACE PROFILE AND CROSS SECTION LEGEND



ZZA-B-1
30' N — EXPLORATION NUMBER AND OFFSET IN FEET AND DIRECTION FROM SECTION LINE

GROUNDWATER LEVEL AT TIME OF DRILLING

32 — STANDARD PENETRATION TEST (SPT) BLOWCOUNT

APPROXIMATE SOIL UNIT BOUNDARY (INTERPOLATED BETWEEN EXPLORATIONS)

TD=32.5 — TOTAL DEPTH OF EXPLORATION IN FEET

SUBSURFACE PLAN LEGEND

B-1	TERRACON BORING (2016)
ZZA-B-1	ZIPPER ZEMAN ASSOCIATES BORING (2007)
GOW-1	RAYMOND CONCRETE PILE CO. GOW DIVISION BORING (1948)
GE-B-5	GEOENGINEERS BORING (1999)

PLAN AND GENERALIZED SUBSURFACE PROFILE NOTES:

1. THE SUBSURFACE CONDITIONS SHOWN ON THE GENERALIZED SUBSURFACE PROFILES ARE BASED UPON INTERPOLATION BETWEEN WIDELY SPACED EXPLORATIONS AND MAY NOT REPRESENT ACTUAL SUBSURFACE CONDITIONS. SIMPLIFIED NAMES ARE SHOWN FOR SOIL DEPOSITS, BASED ON GENERALIZATIONS OF SOIL DESCRIPTIONS. SEE EXPLORATION LOGS AND REPORT TEXT FOR MORE DETAILED SOIL AND GROUNDWATER DESCRIPTIONS.

2. NGVD 29 IS 10.6 FEET HIGHER THAN CITY OF OLYMPIA DATUM.

Project Mngr: DRS	Project No. 81165060	
Drawn By: AMP	Scale: NOT TO SCALE	
Checked By: TLH	File No. Exhibit A-5	
Approved By: DRS	Date: September 2016	

Terracon
Consulting Engineers and Scientists
21905 64th Avenue W, Ste 100 Mountlake Terrace, WA 98043
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LEGEND
CAPITOL LAKE DAM
Olympia, Thurston County, Washington

EXHIBIT
A-5

Field Exploration Description

The proposed boring locations were laid out in the field by a Terracon representative using a Google Earth. Ground surface elevations indicated on the boring logs were interpolated from topographic contours available from Thurston County's web geographic information system portal <http://www.geodata.org/website/cadastral/viewer.htm>. These elevation contours are referenced to NGVD 29. The locations and elevations of the borings should be considered accurate only to the degree implied by the means and methods used to define them.

The borings were drilled with a truck-mounted rotary drill rig using mud rotary and hollow-stem augers to advance boreholes B-1 and B-2, respectively. Samples of the soil encountered in the borings were obtained using the split-barrel sampling procedures.

In the split-barrel sampling procedure, the number of blows required to advance a standard 2-inch O.D. split-barrel sampler the last 12 inches of the typical total 18-inch penetration by means of a 140-pound hammer with a free fall of 30 inches, is the standard penetration resistance value (SPT-N). This value is used to estimate the in situ relative density of cohesionless soils and consistency of cohesive soils.

An automatic SPT hammer was used to advance the split-barrel sampler in the borings performed on this site. A significantly greater efficiency is achieved with the automatic hammer compared to the conventional safety hammer operated with a cathead and rope. This higher efficiency has an appreciable effect on the SPT-N value. The effect of the automatic hammer's efficiency has been considered in the interpretation and analysis of the subsurface information for this report.

The samples were tagged for identification, sealed to reduce moisture loss, and taken to our laboratory for further examination, testing, and classification. Information provided on the boring logs attached to this report includes soil descriptions, consistency evaluations, boring depths, sampling intervals, and groundwater conditions. The borings were backfilled with bentonite chips prior to the drill crew leaving the site.

A field log of each boring was prepared by a Terracon geotechnical engineer. These logs included visual descriptions of the materials encountered during drilling as well as the engineer's interpretation of the subsurface conditions between samples. Final boring logs included with this report represent the engineer's interpretation of the field logs and include modifications based on laboratory observation and tests of the samples.

BORING LOG NO. B-1

PROJECT: Capitol Lake Dam

CLIENT: Moffatt & Nichol
Seattle, Washington

SITE:
Olympia, Washington

LOCATION See Exhibit A-2

Latitude: 47.04351° Longitude: -122.90937°

Approximate Surface Elev: 14 (Ft.) +/-

DEPTH	Description	ELEVATION (Ft.)
0.5	**FILL - ASPHALT CONCRETE**, 6" thickness	13.5+/-
1.1	**FILL - PORTLAND CEMENT CONCRETE**, 7" thickness	13+/-
17.0	**FILL - WELL GRADED SANDY GRAVEL WITH SILT (GW-GM)**, brown, medium dense, moist, driller notes gravelly drilling, rock chips and wood fibers in the wash **(DAM EMBANKMENT FILL)** No recovery No recovery, rock chips and wood fibers in the wash loose, No recovery	-3+/-
24.0	Driller notes smoother drilling **SILTY, SANDY GRAVEL (GM)**, loose, advanced 5-inch diameter casing to 20 feet medium dense, No recovery	-10+/-
	Boring Terminated at 24 Feet	

DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	SAMPLE ID	WATER CONTENT (%)	PERCENT FINES
5		X	9	8-12-13 N=25	S-1	9	8
10		X	0	2-8-7 N=15	S-2		
		X	0	2-6-5 N=11	S-3		
15		X	0	3-2-2 N=4	S-4		
	▽	X	1	3-4-4 N=8	S-5		
20							
		X	0	6-11-13 N=24	S-6		

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic SPT Hammer

Advancement Method:
Mud rotary - 6-inch tricone to 17.5'
5-inch diameter casing to 25 feet and 5" tricone to 22.5 feet

Abandonment Method:
Borings backfilled with bentonite chips upon completion

See Exhibit A-6 for description of field procedures
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.
Elevations were interpolated from a topographic site plan.

Notes:

WATER LEVEL OBSERVATIONS

▽ *17.5' While drilling*

Terracon
21905 64th Ave W Ste 100
Mountlake Terrace, WA

Boring Started: 8/16/2016	Boring Completed: 8/16/2016
Drill Rig: B-61	Driller: Holocene
Project No.: 81165060	Exhibit: A-7

BORING LOG NO. B-2

PROJECT: Capitol Lake Dam

CLIENT: Moffatt & Nichol
Seattle, Washington

SITE:
Olympia, Washington

LOCATION See Exhibit A-2

Latitude: 47.04344° Longitude: -122.90856°

Approximate Surface Elev: 16 (Ft.) +/-

DEPTH	LOCATION / DESCRIPTION	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	SAMPLE ID	WATER CONTENT (%)	PERCENT FINES
0.5	**FILL - SOD**	15.5+/-								
	FILL - WELL GRADED SANDY GRAVEL WITH SILT (GW-GM), olive gray, dense, moist, cuttings prediominately gravel **(DAM EMBANKMENT FILL)**									
			5		X	11	15-15-21 N=36	S-1	9	9
	loose, No recovery		10		X	0	2-3-3 N=6	S-2		
	wet, gravel lodged in shoe			▽ (14')	X	6	4-2-3 N=5	S-3		
	very loose, No recovery		15		X	0	1-1-1 N=2	S-4		
	loose				X	0	2-2-3 N=5	S-5		
			20		X	0	3-2-3 N=5	S-6		
					X	0	3-4-4 N=8	S-7		
			25							

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic SPT Hammer

Advancement Method:
Hollow Stem Auger - 4 1/4-inch ID

Abandonment Method:
Borings backfilled with bentonite chips upon completion

See Exhibit A-6 for description of field procedures

See Appendix B for description of laboratory procedures and additional data (if any).

See Appendix C for explanation of symbols and abbreviations.

Elevations were interpolated from a topographic site plan.

Notes:

WATER LEVEL OBSERVATIONS

▽ *14' While drilling*

Terracon
21905 64th Ave W Ste 100
Mountlake Terrace, WA

Boring Started: 8/16/2016	Boring Completed: 8/16/2016
Drill Rig: B-61	Driller: Holocene
Project No.: 81165060	Exhibit: A-8

BORING LOG NO. B-2

PROJECT: Capitol Lake Dam

CLIENT: Moffatt & Nichol
Seattle, Washington

SITE:
Olympia, Washington

LOCATION See Exhibit A-2
Latitude: 47.04344° Longitude: -122.90856°
Approximate Surface Elev: 16 (Ft.) +/-

DEPTH	Description	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	SAMPLE ID	WATER CONTENT (%)	PERCENT FINES
	FILL - WELL GRADED SANDY GRAVEL WITH SILT (GW-GM), olive gray, dense, moist, cuttings prediominately gravel **(DAM EMBANKMENT FILL) *(continued)***				X	0	4-8-8 N=16	S-8		
27.0	medium dense	-11+/-								
	POORLY GRADED SAND (SP), trace silt, fine to coarse, gray, medium dense, wet, with shell fragments **(ESTUARINE DEPOSITS)**				X	7	4-8-5 N=13	S-9		
	loose, No recovery		30		X	0	4-5-3 N=8	S-10		
	medium dense		35		X	18	5-12-17 N=29	S-11	19	3
41.5		-25.5+/-	40		X	18	2-11-11 N=22	S-12		
	Boring Terminated at 41.5 Feet									

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic SPT Hammer

Advancement Method:
Hollow Stem Auger - 4 1/4-inch ID

Abandonment Method:
Borings backfilled with bentonite chips upon completion

See Exhibit A-6 for description of field procedures
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.
Elevations were interpolated from a topographic site plan.

Notes:

WATER LEVEL OBSERVATIONS
▽ *14' While drilling*

Terracon
21905 64th Ave W Ste 100
Mountlake Terrace, WA

Boring Started: 8/16/2016
Boring Completed: 8/16/2016
Drill Rig: B-61
Driller: Holocene
Project No.: 81165060
Exhibit: A-8

APPENDIX B
LABORATORY TESTING

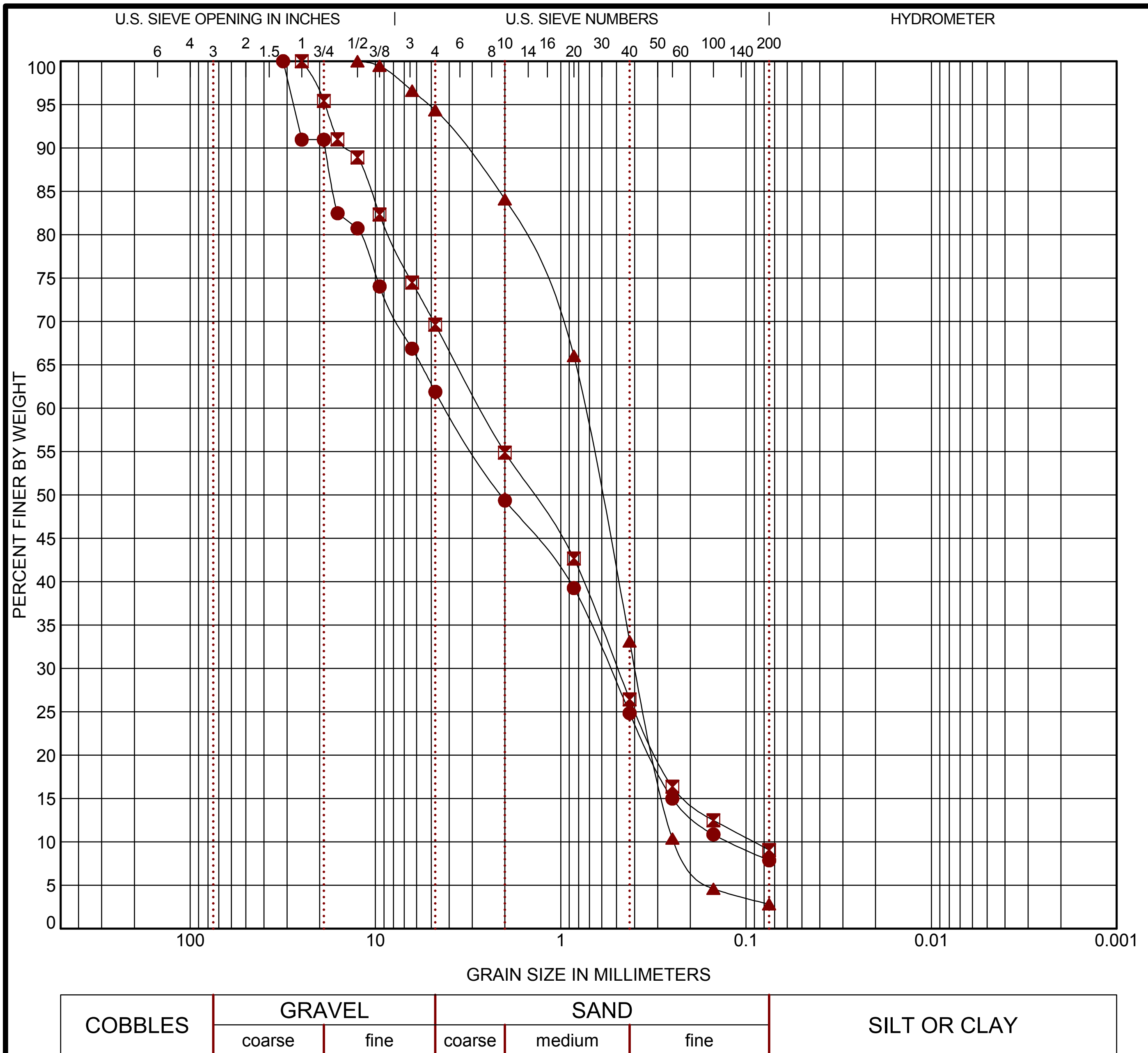
Laboratory Testing Description

Soil samples were tested in the laboratory to measure their natural water content. The test results are provided on the boring logs included in Appendix A.

Descriptive classifications of the soils indicated on the boring logs are in accordance with the enclosed General Notes and the Unified Soil Classification System. Also shown are estimated Unified Soil Classification Symbols. A brief description of this classification system is attached to this report in Appendix C. All classification was by visual manual procedures. Selected samples were further classified using the results of grain size distribution testing. Grain size distribution plots are included in this appendix. Fines content results are also provided on the boring logs.

GRAIN SIZE DISTRIBUTION

ASTM D422 / ASTM C136



Boring ID	Depth	USCS Classification	LL	PL	PI	Cc	Cu
● B-1	5 - 6.5	POORLY GRADED SAND WITH SILT AND GRAVEL (SP-SM)				0.58	33.89
⊠ B-2	5 - 6.5	WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)				1.00	29.81
▲ B-2	35 - 36.5	POORLY GRADED SAND (SP)				0.86	3.10

Boring ID	Depth	D_{100}	D_{60}	D_{30}	D_{10}	%Gravel	%Sand	%Fines
● B-1	5 - 6.5	31.5	4.169	0.545	0.123	38.1	54.0	7.9
⊠ B-2	5 - 6.5	25	2.7	0.495	0.091	30.4	60.6	9.1
▲ B-2	35 - 36.5	12.5	0.749	0.395	0.242	5.6	91.5	2.8

PROJECT: Capitol Lake Dam

SITE: Olympia, Washington

Terracon
21905 64th Ave W Ste 100
Mountlake Terrace, WA

PROJECT NUMBER: 81165060

CLIENT: Moffatt & Nichol
Seattle, Washington

EXHIBIT: B-2

APPENDIX C
SUPPORTING DOCUMENTS

GENERAL NOTES

DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

SAMPLING		WATER LEVEL		FIELD TESTS	
	Standard Penetration Test		▽ Water Initially Encountered ▽ Water Level After a Specified Period of Time ▼ Water Level After a Specified Period of Time Water levels indicated on the soil boring logs are the levels measured in the borehole at the times indicated. Groundwater level variations will occur over time. In low permeability soils, accurate determination of groundwater levels is not possible with short term water level observations.		**N** Standard Penetration Test Resistance (Blows/Ft.) **(HP)** Hand Penetrometer **(T)** Torvane **(DCP)** Dynamic Cone Penetrometer **(PID)** Photo-Ionization Detector **(OVA)** Organic Vapor Analyzer

DESCRIPTIVE SOIL CLASSIFICATION

Soil classification is based on the Unified Soil Classification System. Coarse Grained Soils have more than 50% of their dry weight retained on a #200 sieve; their principal descriptors are: boulders, cobbles, gravel or sand. Fine Grained Soils have less than 50% of their dry weight retained on a #200 sieve; they are principally described as clays if they are plastic, and silts if they are slightly plastic or non-plastic. Major constituents may be added as modifiers and minor constituents may be added according to the relative proportions based on grain size. In addition to gradation, coarse-grained soils are defined on the basis of their in-place relative density and fine-grained soils on the basis of their consistency.

LOCATION AND ELEVATION NOTES

Unless otherwise noted, Latitude and Longitude are approximately determined using a hand-held GPS device. The accuracy of such devices is variable. Surface elevation data annotated with +/- indicates that no actual topographical survey was conducted to confirm the surface elevation. Instead, the surface elevation was approximately determined from topographic maps of the area.

STRENGTH TERMS

RELATIVE DENSITY OF COARSE-GRAINED SOILS (More than 50% retained on No. 200 sieve.) Density determined by Standard Penetration Resistance		CONSISTENCY OF FINE-GRAINED SOILS (50% or more passing the No. 200 sieve.) Consistency determined by laboratory shear strength testing, field visual-manual procedures or standard penetration resistance		
Descriptive Term (Density)	**Standard Penetration or N-Value Blows/Ft.**	**Descriptive Term (Consistency)**	**Unconfined Compressive Strength Qu, (psf)**	**Standard Penetration or N-Value Blows/Ft.**
Very Loose	0 - 3	Very Soft	less than 500	0 - 1
Loose	4 - 9	Soft	500 to 1,000	2 - 4
Medium Dense	10 - 29	Medium Stiff	1,000 to 2,000	4 - 8
Dense	30 - 50	Stiff	2,000 to 4,000	8 - 15
Very Dense	> 50	Very Stiff	4,000 to 8,000	15 - 30
		Hard	> 8,000	> 30

RELATIVE PROPORTIONS OF SAND AND GRAVEL

Descriptive Term(s) of other constituents	Percent of Dry Weight
Trace	< 15
With	15 - 29
Modifier	> 30

GRAIN SIZE TERMINOLOGY

Major Component of Sample	Particle Size
Boulders	Over 12 in. (300 mm)
Cobbles	12 in. to 3 in. (300mm to 75mm)
Gravel	3 in. to #4 sieve (75mm to 4.75 mm)
Sand	#4 to #200 sieve (4.75mm to 0.075mm
Silt or Clay	Passing #200 sieve (0.075mm)

RELATIVE PROPORTIONS OF FINES

Descriptive Term(s) of other constituents	Percent of Dry Weight
Trace	< 5
With	5 - 12
Modifier	> 12

PLASTICITY DESCRIPTION

Term	Plasticity Index
Non-plastic	0
Low	1 - 10
Medium	11 - 30
High	> 30

Terracon

UNIFIED SOIL CLASSIFICATION SYSTEM

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests [A]					Soil Classification: Group Symbol	Soil Classification: Group Name [B]
Coarse Grained Soils: More than 50% retained on No. 200 sieve	**Gravels:** More than 50% of coarse fraction retained on No. 4 sieve	**Clean Gravels:** Less than 5% fines [C]	Cu ≥ 4 and 1 ≤ Cc ≤ 3 [E]		GW	Well-graded gravel [F]
			Cu < 4 and/or 1 > Cc > 3 [E]		GP	Poorly graded gravel [F]
		Gravels with Fines: More than 12% fines [C]	Fines classify as ML or MH		GM	Silty gravel [F,G,H]
			Fines classify as CL or CH		GC	Clayey gravel [F,G,H]
	Sands: 50% or more of coarse fraction passes No. 4 sieve	**Clean Sands:** Less than 5% fines [D]	Cu ≥ 6 and 1 ≤ Cc ≤ 3 [E]		SW	Well-graded sand [I]
			Cu < 6 and/or 1 > Cc > 3 [E]		SP	Poorly graded sand [I]
		Sands with Fines: More than 12% fines [D]	Fines classify as ML or MH		SM	Silty sand [G,H,I]
			Fines classify as CL or CH		SC	Clayey sand [G,H,I]
Fine-Grained Soils: 50% or more passes the No. 200 sieve	**Silts and Clays:** Liquid limit less than 50	**Inorganic:**	PI > 7 and plots on or above "A" line [J]		CL	Lean clay [K,L,M]
			PI < 4 or plots below "A" line [J]		ML	Silt [K,L,M]
		Organic:	Liquid limit - oven dried	< 0.75	OL	Organic clay [K,L,M,N]
			Liquid limit - not dried			Organic silt [K,L,M,O]
	Silts and Clays: Liquid limit 50 or more	**Inorganic:**	PI plots on or above "A" line		CH	Fat clay [K,L,M]
			PI plots below "A" line		MH	Elastic Silt [K,L,M]
		Organic:	Liquid limit - oven dried	< 0.75	OH	Organic clay [K,L,M,P]
			Liquid limit - not dried			Organic silt [K,L,M,Q]
Highly organic soils:	Primarily organic matter, dark in color, and organic odor				PT	Peat

[A] Based on the material passing the 3-inch (75-mm) sieve

[B] If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

[C] Gravels with 5 to 12% fines require dual symbols: GW-GM well-graded gravel with silt, GW-GC well-graded gravel with clay, GP-GM poorly graded gravel with silt, GP-GC poorly graded gravel with clay.

[D] Sands with 5 to 12% fines require dual symbols: SW-SM well-graded sand with silt, SW-SC well-graded sand with clay, SP-SM poorly graded sand with silt, SP-SC poorly graded sand with clay

[E] $Cu = D_{60}/D_{10}$ $\quad Cc = \dfrac{(D_{30})^2}{D_{10} \times D_{60}}$

[F] If soil contains ≥ 15% sand, add "with sand" to group name.

[G] If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

[H] If fines are organic, add "with organic fines" to group name.

[I] If soil contains ≥ 15% gravel, add "with gravel" to group name.

[J] If Atterberg limits plot in shaded area, soil is a CL-ML, silty clay.

[K] If soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel," whichever is predominant.

[L] If soil contains ≥ 30% plus No. 200 predominantly sand, add "sandy" to group name.

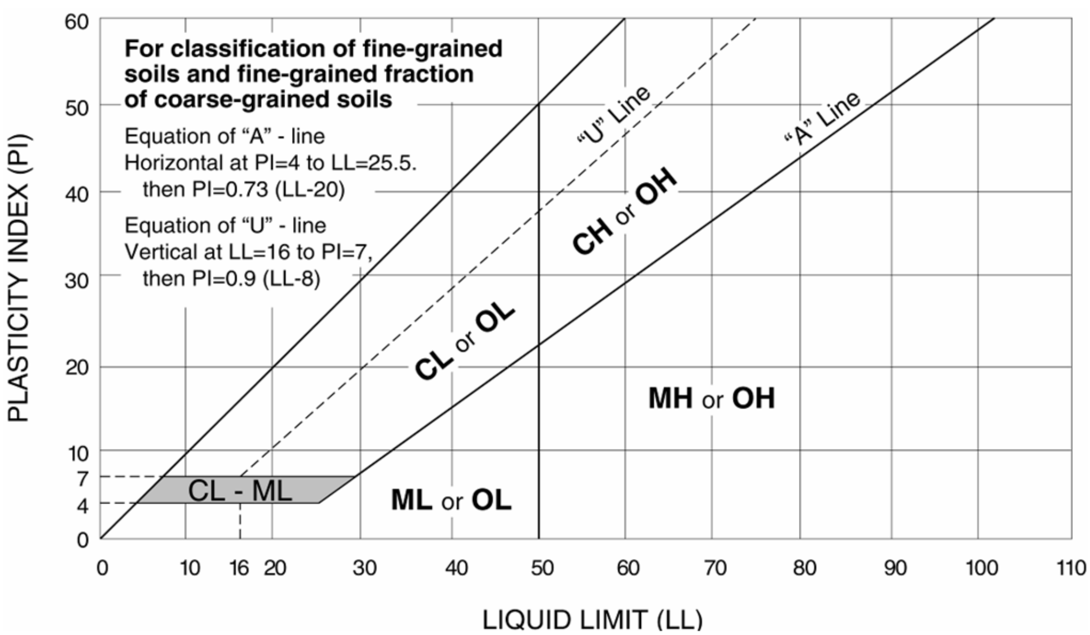
[M] If soil contains ≥ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.

[N] PI ≥ 4 and plots on or above "A" line.

[O] PI < 4 or plots below "A" line.

[P] PI plots on or above "A" line.

[Q] PI plots below "A" line.



APPENDIX D
BORINGS BY OTHERS

Form 209B—160 Pads—1-45

TEST BORING REPORT

Raymond Concrete Pile Co.

NEW YORK **GOW DIVISION** BOSTON

To JAMES W. CAREY & ASSOCIATES, SEATTLE, WASHINGTON Date APRIL30 1948

Address

We have completed the following borings for you at DESCHUTES BASIN PROJECT OLYMPIA, WASHINGTON

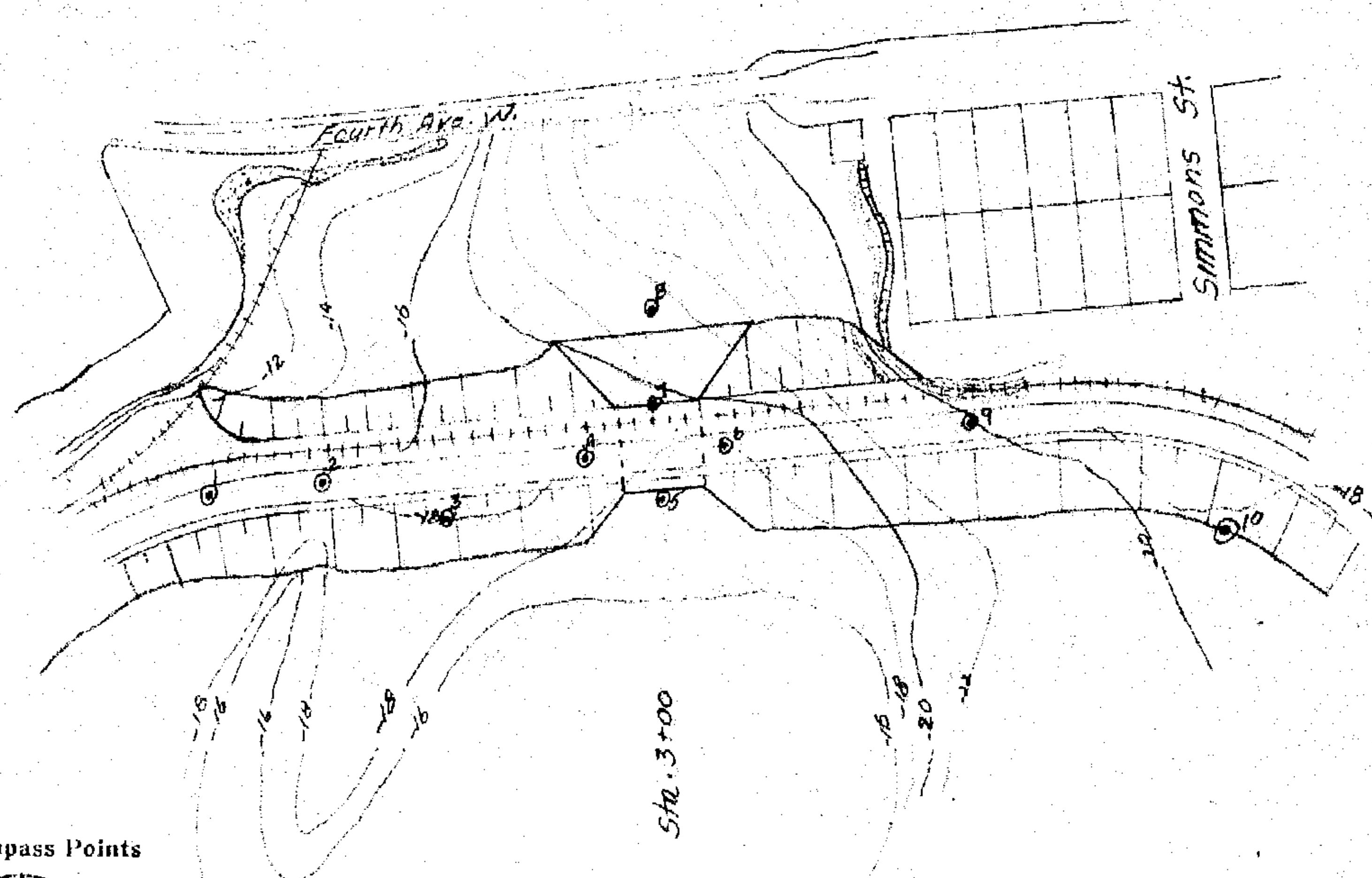
with results as shown below and, in accordance with your instructions, we have sent labelled samples of the strata encountered

To YOURSELVES Address SEATTLE, WASHINGTON

Via under date of The Gow Company, Inc.

LOCATION PLAN

Scale 1" = 200'



Compass Points

Job No. B. -4616

Sheet 1 of 4

By E. LITTLEFIELD

Exhibit: D-1

Form 2090—50 Pads—3-42

TEST BORING REPORT

Raymond Concrete Pile Co.

NEW YORK **GOW DIVISION** BOSTON

To JAMES W. CAREY & ASSOCIATES, SEATTLE, WASHINGTON **Date** APRIL 30 **194** 8 **Job No.** B-4416

Location of Borings DESCHUTES BASIN PROJECT, OLYMPIA, WASHINGTON

All borings are plotted to a scale of 1" = 8 ft. using OLYMPIA DATUM **as a fixed datum.**

No. 1

Depth	Material	Blows / Sample
0	El. -12.0	
	Soft	9
	Silty	9
	Gray	17
		21
	Clay	
	&	12
	Sand	
48.3		32
48.8	W.B. sand	32
	Water Bearing Sand Binder	
58.7	Pea Gravel	
60.0	Gravel Binder	53
	Water Bearing Sand	
69.3	Pea Gravel	
	PKts Brown clay & Fine Sand	
81.1		42

No. 2

Depth	Material	Blows / Sample
0	El. -15.4	
	Med	Shelby
	Silty	Porter
	Gray	Porter
	clay	Porter
30.4		
	Fine	14
	Sand	Porter
43.6		8
	Fine Gray Sand Binder	19
53.3		
	Med & Coarse Gray Sand	21
	Clay	
77.0		
	Fine	
	Gray Sand	29
	Pea Gravel	
87.0		
	Med sand	21
92.10	Pea Gravel	
	Sand	
	Gravel-Bi...	
98.7	(Compacted)	269

No. 3

Depth	Material	Blows / Sample
0	El. -17.4	
	Muck & Shells	Shelby
9.6		
	Large Gravel & Rock	
16.6		
	Med Silty Gray clay	16
		16
29.0		
		11
	Fine	16
	Sandy	17
		17
	Silt	20
54.3		
	Very	45
	Fine sand	
	clay	27
	Binder	
81.0		
82.0	W.B. sand	30
	Coarse sand	56
85.0	Gravel clay	
	Med Gray	
91.6	Sand	
	Sand-Gravel	35
	Med	58

No. 4

Depth	Material	Blows / Sample
0	El. -18.2	
	Muck	Shelby
	Sand	Shelby
	Shells	Shelby
20.7	Silty clay	Porter
23.0	Pea Gravel	
	Med Gravel	
	Peg Gravel	
26.3	Clay	
	Large Clean Gravel	Porter
37.1		
	Med	
	Sandy	15
		Porter
	Silty	
	Clay	14
		Porter
	Lenses	
	Med	
	Sand	
61.4		15

Exhibit: D-1

Depth	Material	Blows
48-3	W.B. sand	32
48-8	Water Bearing Sand Binder	32
58-7	Pea Gravel	
60-0	Gravel Binder	53
	Water Bearing Sand	
69-3	Pea Gravel	
	PkTs Brown clay & Fine sand	112
81-1		

Depth	Material	Blows
	Fine Gray sand Binder	19
53-3		
	Med & Coarse Gray Sand	27
	Clay	
77-0		
	Fine Gray sand	29
	Pea Gravel	
87-0		
	Med sand	21
92-10	Pea Gravel	
	Sand Gravel-Binder (Compacted)	268
98-7		

Depth	Material	Blows
		17
	Silt	20
54-3		
	Very Fine sand clay Binder	45
		27
81-0	W.B. sand	30
82-0	Coarse sand	56
85-0	Gravel clay	
	Med Gray Sand	
91-6		35
	Sand-Gravel	
93-6		58
	Med Sand	35
	Fine sand	
	Binder	
112-6		
	Fine Sandy Silty Clay	
121-0	Sand Gravel	49
122-0	Cemented Gravel	
129-0		108

Depth	Material	Blows
	Sandy	15 Porter
	Silty	
	Clay	14 Porter
	Lenses	
	Med Sand	15
61-4		

All elevations are at mud line

Exhibit: D-1

Figures in right hand column indicate number of blows required to drive sampling pipe one foot, using 140-lb. weight falling 30 inches.

Total Footage 370' 0"
Foreman LLOYD DIETZ
Classification by LLOYD DIETZ
Sheet 2 **of** 4

Form 209C—50 Pads—3-42

TEST BORING REPORT

Raymond Concrete Pile Co.

NEW YORK **GOW DIVISION** BOSTON

To JAMES W. CAREY & ASSOCIATES, SEATTLE, WASHINGTON **Date** APRIL 30 **194** 8 **Job No.** B-4616

Location of Borings DESCHUTES BASIN PROJECT, OLYMPIA, WASHINGTON

All borings are plotted to a scale of 1" = 8 ft. using OLYMPIA DATUM **as a fixed datum.**

No. 5

Depth	Material	Sample / Blows
0	El.-18.4	
	Soft	
	Organic	
	Muck	Shelby
	Shells	
16-6	Sand-Wood	
18-2	rock	Shelby
	Coarse	
	Sand	23
25-0	Small Gravel	
27-0	Pea Gravel	25
		107
	Clean	
	Gravel	
	Pea Gravel	18
37-3	Large Rock	
	Med	8
	Silty	
	Gray	16
	Clay	
		21
52-6		
		22
	Fine	
		25
		42
	Clay	
	Binder	
89-0		
		141
	Silty	

No. 6

Depth	Material	Sample / Blows
0	El.-22.1	
	Muck	
	Sand	Shelby
	Shells	Shelby
11-2		Porter
		Porter 27
	Coarse	
	Gray	
	Sand	35
25-0		
	Gravel	
	&	
		32
	Sand	
37-8		
	Coarse	
	Sand	
	Gravel	
46-0	Clay	
	Med	
	Sandy	
	Clay	
52-10		16

No. 7

Depth	Material	Sample / Blows
0	El.-20.5	
	Muck	
	&	Shelby
	Shells	Shelby
14-0		
	Wood	Shelby
	Sand	
	Muck	Shelby
	Gravel	
27-0		
	Med	8
	Sand	
		12
	Clay	
	Binder	
42-0		
	Gravel	
	Large Rock	
	Large Boulder	
53-0	Pkt. Sand	

No. 8

Depth	Material	Sample / Blows
0	El.-23.3	
	Sand	
		Shelby
	Muck	
	Shells	Shelby
16-0		
	Rock	Shelby
	Pea Gravel	
	Clay	
28-6		
	Med Sand	12
33-0	Binder	
	Rock	
		41
	&	
	Gravel	
59-0		
	Clay Binder	39
66-2		
	Med	20
	Silty	
		26
	Clay	Porter
79-2		
	Fine	29
	Sand	

Elevation	Material	Blows
	Silty	
	Gray	76
	Clay	
		21
52-6		
		22
	Fine	
		25
		42
	clay	
	Binder	
89-0		
		141
	Silty	
		162
	Clay	
111-0	Cemented	48
13-6	Gravel	62

Elevation	Material	Blows
[illegible]		
	Coarse	
	Sand	
	Gravel	
46-0	clay	
	Med	
	Sandy	
	Clay	
52-10		16

Elevation	Material	Blows
	Binder	
42-0		
	Gravel	
	Large Rock	
	Large Boulders	
53-0	Pkt. Sand	

Elevation	Material	Blows
	Rock	
		41
	Gravel	
[illegible]		
	Clay Binder	39
66-2		
	Med	20
	silty	
		26
	Clay	Porter
79-2		
	Fine	29
	sand	
		Porter
	Binder	
		22
	Pkts.	
	small	
	Gravel	
106-1		
	Med	
		30
	Gray	
		35
	sand	
117-0	Sand-Gravel	82
	Binder	
119-10	Stiff clay	41
	Med sand	
125-2		71

All elevations are at mud line

Exhibit: D-1

Figures in right hand column indicate number of blows required to drive sampling pipe one foot, using 140-lb. weight falling 30 inches.

Total Footage 344' 6"
Foreman KENNETH DIETZ
Classification by KENNETH DIETZ
Sheet 3 **of** 4

Form 209C—50 Pads—3-42

474

TEST BORING REPORT

Raymond Concrete Pile Co.

NEW YORK **GOW DIVISION** BOSTON

To JAMES W. CAREY & ASSOCIATES, SEATTLE, WASHINGTON **Date** APRIL 30 **194**8 **Job No.** B-4616

Location of Borings DESCHUTES BASIN PROJECT, OLYMPIA, WASHINGTON

All borings are plotted to a scale of 1" = 8 ft. using OLYMPIA DATUM **as a fixed datum.**

No. 9

Depth	Material	Samples
0	El. -25.7	
	Fine Gray Sand	Shelby
11-6	Binder	
	Med Sand	Shelby
17-0	Silty clay	
20-6	Coarse Sand, Clay Binder	29
29-0	Sand & Gravel	
	Coarse Sand	33, 79
	Pea Gravel	19
38-0	Clay	
	Cemented	28
44-1	Gravel	40, 48

No. 10

Depth	Material	Samples
0	El. -17.7	
	Sand	
	Muck	Shelby
15-6	Shells	Shelby
21-2	Med Gray Sand	12
25-6	Coarse Sand, Trace Binder	27
28-0	Sandy Clay	
38-4	Gravel Sand Clay (Partially Cemented)	37
42-6	Coarse Sand	32

All elevations are at mud line

Elev.	Material	Blows
		79
38.0	Clay	
	Cemented	28
	Gravel	40
44.1		48

42.0 Sand 32

All elevations are at mud line.

Exhibit: D-1

Figures in right hand column indicate number of blows required to drive sampling pipe one foot, using 140-lb. weight falling 30 inches.

Total Footage 86' 7"
Foreman KENNETH DIETZ
Classification by KENNETH DIETZ
Sheet 4 **of** 4

SOIL CLASSIFICATION SYSTEM

MAJOR DIVISIONS			GROUP SYMBOL	GROUP NAME
COARSE GRAINED SOILS More Than 50% Retained on No. 200 Sieve	GRAVEL More Than 50% of Coarse Fraction Retained on No. 4 Sieve	CLEAN GRAVEL	GW	WELL-GRADED GRAVEL, FINE TO COARSE GRAVEL
			GP	POORLY-GRADED GRAVEL
		GRAVEL WITH FINES	GM	SILTY GRAVEL
			GC	CLAYEY GRAVEL
	SAND More Than 50% of Coarse Fraction Passes No. 4 Sieve	CLEAN SAND	SW	WELL-GRADED SAND, FINE TO COARSE SAND
			SP	POORLY-GRADED SAND
		SAND WITH FINES	SM	SILTY SAND
			SC	CLAYEY SAND
FINE GRAINED SOILS More Than 50% Passes No. 200 Sieve	SILT AND CLAY Liquid Limit Less Than 50	INORGANIC	ML	SILT
			CL	CLAY
		ORGANIC	OL	ORGANIC SILT, ORGANIC CLAY
	SILT AND CLAY Liquid Limit 50 or More	INORGANIC	MH	SILT OF HIGH PLASTICITY, ELASTIC SILT
			CH	CLAY OF HIGH PLASTICITY, FAT CLAY
		ORGANIC	OH	ORGANIC CLAY, ORGANIC SILT
HIGHLY ORGANIC SOILS			PT	PEAT
SOIL PREDOMINANTLY COMPOSED OF COAL FRAGMENTS (SEE NOTE BELOW)			CF	COAL FRAGMENTS

NOTES:

1. Field classification is based on visual examination of soil in general accordance with ASTM D2488-90.
2. Soil classification using laboratory tests is in general accordance with ASTM D2487-90.
3. Descriptions of soil density or consistency are based on interpretation of blow count data, visual appearance of soils, and/or test data.
4. Fill beneath much of the site consists of coal fragments. The coal originated from mining operations conducted on nearby properties. The texture of this material varies, but consists predominantly of silt- and sand-size coal fragments with occasional gravel-size fragments.

SOIL MOSTURE MODIFIERS:

Dry - Absence of moisture, dusty, dry to the touch

Moist - Damp, but no visible water

Wet - Visible free water or saturated, usually soil is obtained from below water table

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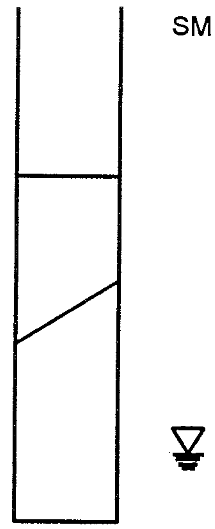
SOIL CLASSIFICATION SYSTEM

FIGURE A-1

LABORATORY TESTS

AL	Atterberg Limits
CP	Compaction
CS	Consolidation
DS	Direct shear
GS	Grain size
%F	Percent fines
HA	Hydrometer Analysis
SK	Permeability
SM	Moisture Content
MD	Moisture and density
SP	Swelling pressure
TX	Triaxial compression
UC	Unconfined compression
CA	Chemical analysis

SOIL GRAPH:



SM Soil Group Symbol (See Note 2)

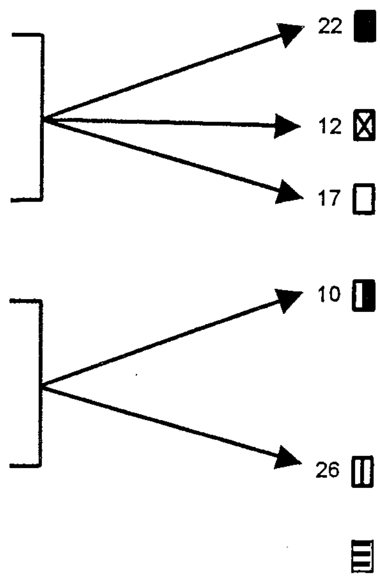
Distinct Contact Between Soil Strata

Gradual or Approximate Location of Change Between Soil Strata

Water Level

Bottom of Boring

BLOW COUNT/SAMPLE DATA:



Blows required to drive a 2.4-inch I.D. split-barrel sampler 12 inches or other indicated distances using a 300-pound hammer falling 30 inches.

22 Location of relatively undisturbed sample

12 Location of disturbed sample

17 Location of sampling attempt with no recovery

Blows required to drive a 1.5-inch I.D. (SPT) split-barrel sampler 12 inches or other indicated distances using a 140-pound hammer falling 30 inches.

10 Location of sample obtained in general accordance with Standard Penetration Test (ASTM D-1586) procedures

26 Location of SPT sampling attempt with no recovery

Location of grab sample

"P" indicates sampler pushed with weight of hammer or against weight of drill rig.

NOTES:

1. The reader must refer to the discussion in the report text, the Key to Boring Log Symbols and the exploration logs for a proper understanding of subsurface conditions.
2. Soil classification system is summarized in Figure A-1.

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KEY TO BORING LOG SYMBOLS

FIGURE A-2

Exhibit: D-2

0000-000-00-0000 XXX:XXX:xxx 00/00/00 (a-2ns.ppt)

BORING B-3

TEST DATA

DESCRIPTION

Surface Elevation (ft.): 66.4

Depth (ft)	Lab Tests	Moisture Content (%)	Dry Density (pcf)	Blow Count	Group Symbol	Description
0					CONCRETE	Portland cement concrete sidewalk, 11 inches thick
1					ML	Mottled orange and brown silt with sand, occasional gravel and trace organic material (medium stiff, moist) (fill)
3	SM	21		5		
8	MD	24	92	2		Grades to soft
12.5					ML	Brown silt with trace fine sand and trace organic matter (soft to medium stiff, moist)
13	SM	39		4		
18	MD,GS DS,CS	40	81	2		Becomes gray and brown with some orange mottling
23	SM	30		15		Becomes stiff with fine sand
28	MD,UC	41	80	2		Grades to soft with trace sand
33	SM	27		38	ML	Bluish gray silt with trace fine sand (hard, moist)
38				61		

DEPTH IN FEET

Note: See Figure A-2 for explanation of symbols

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LOG OF BORING

FIGURE A-5

Exhibit: D-2

JEB:GWH:vc 6/16/99

BORING B-3
(Continued)

TEST DATA

Depth (feet)	Lab Tests	Moisture Content (%)	Dry Density (pcf)	Blow Count	Group Symbol	Description
40					SP/SP-SM	Brown fine to coarse sand with trace silt interbedded with fine to medium sand with silt and occasional gravel (very dense, wet)
43	SM	19		50/5"		
46–47					SP-SM	Brown fine to coarse sand with silt, gravel and occasional cobbles (very dense, wet)
48	MD	18	116	50/4"		
53–54					SP	Grayish brown fine to medium sand with occasional gravel (very dense, wet)
54	SM	21		81		
57					SP-SM	Brown fine to coarse sand with silt and occasional gravel (dense, wet)
58	MD	20	109	57		

Boring completed at a depth of 59.0 feet on 02/24/99.
Ground water encountered at an approximate depth of 42.0 feet during drilling.
Ground water rose to an approximate depth of 27.0 feet at completion of boring.

DEPTH IN FEET: 40, 45, 50, 55, 60, 65, 70, 75, 80

Note: See Figure A-2 for explanation of symbols

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LOG OF BORING

FIGURE A-5

Exhibit: D-2

BORING B-5

TEST DATA

DESCRIPTION

Surface Elevation (ft.): 57.5

Depth (ft)	Lab Tests	Moisture Content (%)	Dry Density (pcf)	Blow Count
~3	SM	36		9
~8	GS,MD	29	93	1
~13	SM	18		14
~18	MD	11	129	10
~23	SM	30		24
~28	SM	32		30

Group Symbol	Description
TOPSOIL	Topsoil zone, 6 inches thick
SM	Brown silty fine sand (loose, wet) (fill)
ML	Brown sandy silt (soft to medium stiff, wet)
ML	Brown silt with trace fine sand (stiff, moist to wet)
SM	Mottled grayish brown and orange silty fine to coarse sand with gravel (loose to medium dense, moist)
ML	Brown silt with trace fine sand (very stiff, moist to wet)

DEPTH IN FEET: 0, 5, 10, 15, 20, 25, 30, 35, 40

Boring completed at a depth of 29.0 feet on 02/24/99.
Ground water encountered at an approximate depth of 2.0 feet during drilling.

Note: See Figure A-2 for explanation of symbols

JEB:GWH:vc 6/15/99

0415-018-01

GeoEngineers

LOG OF BORING

FIGURE A-7

Exhibit: D-2

BORING B-6

TEST DATA

DESCRIPTION

Surface Elevation (ft.): 50.2

Depth (ft)	Lab Tests	Moisture Content (%)	Dry Density (pcf)	Blow Count	Group Symbol	Description
0					TOPSOIL	Grass and topsoil zone, 6 inches thick
0.5					SM	Brown silty fine to coarse sand with occasional gravel (loose, moist to wet) (fill)
3				10		
8	SM	7		27	GW-GM	Brown fine to coarse gravel with silt, sand, and occasional cobbles (medium dense, wet)
13	GS,MD	8	135	15		
17					ML	Brown silt with trace fine sand (medium stiff, moist)
18	SM	47		7		
23	AL,MD, DS	39	82	4		
28	SM	37		16		
33	MD	32	87	6		
38	SM	39		13		

DEPTH IN FEET (0–40)

Note: See Figure A-2 for explanation of symbols

0415-018-01 JEB:GWH:vc 6/15/99

GeoEngineers

LOG OF BORING

FIGURE A-8

Exhibit: D-2

TEST DATA

BORING B-6
(Continued)

DEPTH IN FEET

Depth (ft)	Lab Tests	Moisture Content (%)	Dry Density (pcf)	Blow Count	Samples	Group Symbol	DESCRIPTION
43	MD	28	96	41	■	SP-SM	Brown fine to coarse sand with silt, gravel and cobbles (dense, wet)
47						ML	Brown silt with fine sand (hard, moist to wet)
48	SM	36		39	◨		

Boring completed at a depth of 49.0 feet on 02/26/99.
Ground water encountered at an approximate depth of 12.0 feet during drilling.

Depth scale: 40, 45, 50, 55, 60, 65, 70, 75, 80

Note: See Figure A-2 for explanation of symbols

JEB:GWH:vc 6/16/99

0415-018-01

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LOG OF BORING

FIGURE A-8

Exhibit: D-2

BORING B-7

TEST DATA

DESCRIPTION

Surface Elevation (ft.): 12.1

Depth in Feet	Lab Tests	Moisture Content (%)	Dry Density (pcf)	Blow Count	Samples	Group Symbol	Description
0						SM	Brown silty fine to coarse sand with occasional gravel and trace organic matter, glass and brick fragments (medium dense, moist) (fill)
3	SM	10		22			
8	SM	11		30			
13				6			Becomes loose
18	MD	24	102	8		ML	Brownish gray silt with trace fine sand (medium stiff, moist to wet)
22						SM	Grayish brown silty fine to coarse sand with gravel (medium dense, wet)
23				23			
28	SM	5		20			
33	SM	18		40		SM	Brownish gray silty fine to medium sand with occasional gravel and shell fragments (dense, wet)
38	GS,MD	21	106	5		SP-SM	Grayish black fine to coarse sand with silt, occasional gravel and shell fragments (loose to medium dense, wet)

Note: See Figure A-2 for explanation of symbols

0415-018-01 JEB:GWH:vc 6/16/99

GeoEngineers

LOG OF BORING

FIGURE A-9

Exhibit: D-2

TEST DATA

BORING B-7
(Continued)

DESCRIPTION

DEPTH IN FEET (40–80)

Lab Tests	Moisture Content (%)	Dry Density (pcf)	Blow Count	Samples	Group Symbol	Description
SM	23		16			
MD	128	36	7		PT/OL	Brown peat and organic silt (medium stiff, moist)
					SP-SM	Gray fine sand with silt (dense, wet)
SM	28		35			
MD	25	101	6		SP	Grayish black fine to coarse sand with occasional gravel, trace silt and organic matter (loose, wet)
SM	19		50/5"			Grades to very dense
MD	26	92	5		ML	Gray silt with trace fine sand (soft to medium stiff, moist)
SM	37		26			Grades to very stiff
SM	31		42			Boring completed at a depth of 79.0 feet on 02/25/99. Ground water encountered at an approximate depth of 9.0 feet during drilling.

Note: See Figure A-2 for explanation of symbols

JEB:GWH:vc 6/16/99

0415-018-01

Geo Engineers

LOG OF BORING

FIGURE A-9

Exhibit: D-2

TEST DATA

BORING B-9

DESCRIPTION

Surface Elevation (ft.): 33.6

Depth (ft)	Lab Tests	Moisture Content (%)	Dry Density (pcf)	Blow Count	Group Symbol	Description
0					SM	Brown silty fine to coarse sand with occasional gravel and trace organic matter (medium dense, moist) (fill)
~5.5	SM	90		14		
~10.5	SM	37		6	ML	Brown and orange silt with occasional gravel, trace sand and organic matter (medium stiff, moist)
~15.5	AL,MD, UC	36	86	4		
~20.5	SM	31		26		
~25.5	MD	32	89	7		
~30.5	SM	39		11		Grades to grayish brown
~35.5				6		

DEPTH IN FEET (0–40)

Note: See Figure A-2 for explanation of symbols

JEB:GWH:vc 6/15/99

0-1...18-01

GeoEngineers

LOG OF BORING

FIGURE A-11

Exhibit: D-2

BORING B-9
(Continued)

TEST DATA

DESCRIPTION

Depth in Feet	Lab Tests	Moisture Content (%)	Dry Density (pcf)	Blow Count	Samples	Group Symbol	Description
40	SM	32		16	◨		Grades to brown with sand lenses
45	MD	33	89	10	■		
~48						SP	Brown fine to medium sand with trace silt (medium dense, wet)
50	SM	25		18	◨	ML/SP-SM	Interbedded layers of brown sandy silt and fine to medium sand with silt (very stiff/medium dense, moist to wet)
55	SM	25		39	◨		
60	SM	20		39	◨		
~62						ML	Brown silt with trace fine sand (very stiff, moist to wet)
65	SM	30		34	◨		
70	MD	37	84	13	■		Grades to stiff

Boring completed at a depth of 71.5 feet on 03/03/99.
Ground water encountered at an approximate depth of 40.0 feet during drilling.

DEPTH IN FEET (40–80)

Note: See Figure A-2 for explanation of symbols

0...18-01 JEB:GWH:vc 6/15/99

GeoEngineers

LOG OF BORING

FIGURE A-11

Exhibit: D-2

TEST DATA

BORING B-10

DESCRIPTION

Surface Elevation (ft.): 12.2

Depth in Feet	Lab Tests	Moisture Content (%)	Dry Density (pcf)	Blow Count	Samples	Group Symbol	Description
0						SM	Brown silty fine to coarse sand with occasional gravel and trace organic matter (loose, moist to wet) (fill)
5	SM	30		11			
						SP	Grayish black fine to coarse sand with shell fragments, occasional gravel, trace silt and organic matter (loose, wet)
10	SM	25		8			
15				7			
20	SM	72		14			
						ML	Gray silt with trace fine sand (medium stiff, wet)
25				8			
30	SM	35		24			
35	MD	34	87	3			Grades to soft
40							

Note: See Figure A-2 for explanation of symbols

JEB:GWH:vc 6/16/99

0415-018-01

GeoEngineers

LOG OF BORING

FIGURE A-12

Exhibit: D-2

TEST DATA

BORING B-10
(Continued)

Depth (ft)	Lab Tests	Moisture Content (%)	Dry Density (pcf)	Blow Count	Samples	Group Symbol	DESCRIPTION
40	SM	38		15		ML	Gray silt with trace fine sand (stiff to hard, wet)
45				17			
50	SM	34		38			
55	MD	41	79	41			

Boring completed at a depth of 56.5 feet on 03/02/99.
Ground water encountered at an approximate depth of 11.0 feet during drilling.

DEPTH IN FEET (scale 40–80)

Note: See Figure A-2 for explanation of symbols

JEB:GWH:vc 6/16/99

0415-018-01

GeoEngineers

LOG OF BORING

FIGURE A-12

Exhibit: D-2

TEST DATA

BORING B-11

Depth (ft)	Lab Tests	Moisture Content (%)	Dry Density (pcf)	Blow Count	Group Symbol	DESCRIPTION (Surface Elevation (ft.): 16.3)
0					GP-GM	Brown fine to coarse gravel with sand, silt, cobbles and trace organic matter (medium dense, moist to wet) (fill)
5	SM	13		13		
~6.5					ML	Gray silt with trace sand and organic matter (very soft, moist to wet)
10	SM	42		P		
15	MD,CS	35	87	7		Grades to brownish gray and medium stiff
~20					ML	Gray sandy silt (stiff, wet)
20	SM	39		17		
25	MD	29	94	15		
30	SM	36		28		
35	MD	36	85	11		

DEPTH IN FEET (0–40)

Note: See Figure A-2 for explanation of symbols

JEB:GWH:vc 6/16/99

0415-018-01

GeoEngineers

LOG OF BORING

FIGURE A-13

Exhibit: D-2

TEST DATA

BORING B-11
(Continued)

DESCRIPTION

Depth in Feet	Lab Tests	Moisture Content (%)	Dry Density (pcf)	Blow Count	Samples	Group Symbol	Description
40	SM	41		25			Grades to very stiff
45	MD	30	92	27			
50	SM	38		30			
55	MD	30	93	25			
60	SM	35		44			

Boring completed at a depth of 61.5 feet on 03/04/99.
No ground water encountered during drilling.

DEPTH IN FEET: 40, 45, 50, 55, 60, 65, 70, 75, 80

Note: See Figure A-2 for explanation of symbols

JEB:GWH:vc 6/16/99

0415-018-01

GeoEngineers

LOG OF BORING

FIGURE A-13

Exhibit: D-2

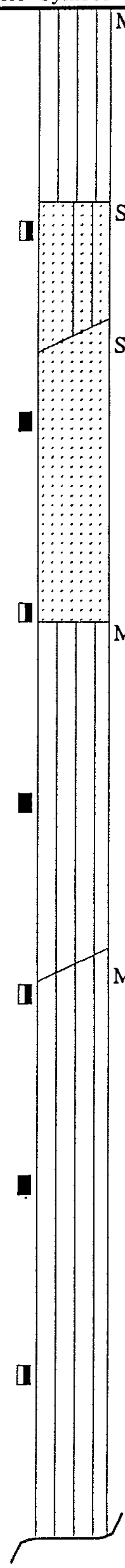
BORING B-12

TEST DATA

DESCRIPTION

Surface Elevation (ft.): 5.7

Depth in Feet	Lab Tests	Moisture Content (%)	Dry Density (pcf)	Blow Count	Samples	Group Symbol	Description
0						ML	Brown silt with sand and organic matter (soft, moist to wet)
5	SM	30		14		SP-SM	Gray fine to coarse sand with silt and shell fragments (medium dense, wet)
						SP	Dark gray to brown fine to coarse sand with shell fragments and occasional gravel and trace silt (loose, wet)
10	GS,MD	18	105	3			
15	SM	38		3		ML	Gray sandy silt with shell fragments (soft, wet)
20	MD	25	94	3			
25	SM	37		15		ML	Gray silt with trace fine sand (stiff to very stiff, moist to wet)
30	MD	39	82	9			
35	SM	34		45			
40							



Note: See Figure A-2 for explanation of symbols

0415-018-01 JEB:GWH:vc 6/15/99

GeoEngineers

LOG OF BORING

FIGURE A-14

Exhibit: D-2

TEST DATA

BORING B-12
(Continued)

DESCRIPTION

Depth (ft)	Lab Tests	Moisture Content (%)	Dry Density (pcf)	Blow Count	Samples	Group Symbol
40	MD	34	88	13		
45	SM	36		14		
50	SM	33		32		
55	SM	38		41		

Boring completed at a depth of 56.5 feet on 03/02/99.
Ground water encountered at an approximate depth of 5.0 feet during drilling.

DEPTH IN FEET: 40, 45, 50, 55, 60, 65, 70, 75, 80

Note: See Figure A-2 for explanation of symbols

0415-018-01 JEB:GWH:vc 6/15/99

GeoEngineers

LOG OF BORING

FIGURE A-14

Exhibit: D-2

TEST DATA

BORING B-13

DESCRIPTION

Surface Elevation (ft.): -10.6

Lab Tests	Moisture Content (%)	Dry Density (pcf)	Blow Count
			3
SM	25.0		20
SM	64.0		3
MD	32.0	90	8
SM	19.0		30
GS,MD	13.0	121	15
SM	12.0		34
MD	33.0	88	9

Group Symbol	Description
SP-SM	Gray fine to coarse sand with silt, gravel and shell fragments (loose, wet)
ML	Gray silt with trace sand, shell fragments and organic matter (medium stiff, moist to wet)
	Grades to medium stiff
SP	Grayish black fine to medium sand with trace silt and occasional gravel (medium dense, wet)
SW	Grayish black to brown fine to coarse sand with gravel and trace silt (medium dense, wet)
ML	Gray silt with trace sand (stiff to very stiff, wet)

DEPTH IN FEET: 0, 5, 10, 15, 20, 25, 30, 35, 40

Note: See Figure A-2 for explanation of symbols

JEB:GWH:vc 6/16/99

0415-018-01

GeoEngineers

LOG OF BORING

FIGURE A-15

Exhibit: D-2

TEST DATA

BORING B-13
(Continued)

DESCRIPTION

Depth in Feet (approx.)	Lab Tests	Moisture Content (%)	Dry Density (pcf)	Blow Count	Samples	Group Symbol	Description
43	SM	35		17	◨		
48	MD	32	91	20	■		
52	SM	40		24	◨		
57	MD	40	83	12	■		
62	SM	29		24	◨		
72				26	■		
78						ML	Gray sandy silt (very stiff, moist)

DEPTH IN FEET (scale 40 to 80)

Note: See Figure A-2 for explanation of symbols

JEB:GWH:vc 6/16/99

0415-018-01

GeoEngineers

LOG OF BORING

FIGURE A-15

Exhibit: D-2

TEST DATA

BORING B-13
(Continued)

DESCRIPTION

Lab Tests	Moisture Content (%)	Dry Density (pcf)	Blow Count	Samples	Group Symbol	Description
SM	25		32	◨		
					ML	Gray silt with trace sand (very stiff, moist)
MD	27	100	27	■		
SM	22		64	◨		Becomes interbedded with fine to coarse sand
					SP-SM	Gray fine to medium sand with silt (medium dense, wet)
SM	26		23	◨		

Boring completed at a depth of 113.0 feet below mudline on 03/12/99.

DEPTH IN FEET: 80, 85, 90, 95, 100, 105, 110, 115, 120

Note: See Figure A-2 for explanation of symbols

JEB:GWH:vc 6/16/99

0415-018-01

GeoEngineers

LOG OF BORING

FIGURE A-15

Exhibit: D-2

BORING B-14

TEST DATA

DESCRIPTION

Surface Elevation (ft.): -8.9

Depth in Feet	Lab Tests	Moisture Content (%)	Dry Density (pcf)	Blow Count	Group Symbol	Description
0					SP	Black fine to medium sand with shells and trace silt (loose, wet)
	SM	30		5		
				2		
11					ML	Gray sandy silt (soft, wet)
	SM	35		2		
16					SP-SM	Gray fine to coarse sand with silt and gravel (dense, wet)
				37		
	SM	16		46		
				26		
	SM	11		50/4"		
36.5					ML	Gray silt with trace fine sand (stiff, wet)
	MD	30	93	19		
40						

Note: See Figure A-2 for explanation of symbols

JEB:GWH:vc 6/16/99

0415-018-01

GeoEngineers

LOG OF BORING

FIGURE A-16

Exhibit: D-2

TEST DATA

BORING B-14
(Continued)

Depth (ft)	Lab Tests	Moisture Content (%)	Dry Density (pcf)	Blow Count	Samples	Group Symbol	DESCRIPTION
42	SM	35		10			
49	MD	32	88	10			
54	SM	29		10			
59	MD	33	89	11			
64	SM	34		23			
70	MD	24	97	11		ML	Gray sandy silt (stiff, moist to wet)
75	SM	38		19		ML	Gray silt with trace sand and organic matter (very stiff, moist)

DEPTH IN FEET: 40, 45, 50, 55, 60, 65, 70, 75, 80

Note: See Figure A-2 for explanation of symbols

0415-018-01 JEB:GWH:vc 6/16/99

GeoEngineers

LOG OF BORING

FIGURE A-16

Exhibit: D-2

TEST DATA

BORING B-14
(Continued)

Depth (ft)	Lab Tests	Moisture Content (%)	Dry Density (pcf)	Blow Count	Samples	Group Symbol	DESCRIPTION
80	MD	32	88	39			Becomes hard
	SM	32		42			
	MD	29	96	37			
	SM	31		50/3"			
							Boring completed at a depth of 99.0 feet below mudline on 03/11/99.

DEPTH IN FEET: 80, 85, 90, 95, 100, 105, 110, 115, 120

Note: See Figure A-2 for explanation of symbols

GeoEngineers

LOG OF BORING

FIGURE A-16

Exhibit: D-2

GEB:GWH:vc 6/16/99

PROJECT: Capital Center Building	**JOB NO.:** 81065153	**BORING:** B-1	**PAGE 1 OF 3**
Location: Olympia, WA	**Approximate Surface Elevation:** 11.5 feet		

Depth (ft)	Soil Description	Sample Type	Sample Number	Ground Water	Penetration Resistance (Blows per foot; ▲ Standard, △ Other; ● Moisture)	N-values	Testing
0	3 ½" Asphalt						
	Medium dense, moist to wet, brown, fine to medium SAND with trace silt (Fill)	2-inch O.D. split spoon	S-1			14	
5	Loose, wet to saturated, dark gray, silty SAND with trace shells and gravel and some wood (Fill)	2-inch O.D. split spoon	S-2	▼ ATD		10	
	Grades to dense, wet, no wood	2-inch O.D. split spoon	S-3			31	
10	Grades to medium dense	2-inch O.D. split spoon	S-4			22	
	Very soft, wet, dark gray SILT with some sand and trace shells (Fill)	2-inch O.D. split spoon	S-5			0	
15							
	Medium dense, wet, gray SAND with some silt and shells (Fill)	2-inch O.D. split spoon	S-6			14	200W
20							
	Very soft, wet to saturated, dark gray, clayey SILT with trace sand and trace shells (Fill)	2-inch O.D. split spoon	S-7			1	Att
25							

Explanation

Symbol	Meaning
I	2-inch O.D. split spoon sample
II	3-inch I.D Shelby tube sample
⊗	No Recovery
▼ ATD	Groundwater level at time of drilling or date of measurement

Monitoring Well Key

- Clean Sand
- Bentonite
- Grout/Concrete
- Screened Casing
- Blank Casing

Moisture Content

Plastic Limit — Natural — Liquid Limit

Testing Key

GSA = Grain Size Analysis
200W = 200 Wash Analysis
Att. = Atterberg Limits
Consol. = Consolidation Test

PROJECT: Capital Center Building **JOB NO.:** 81065153 **BORING:** B-1

Location: Olympia, WA **Approximate Surface Elevation:** 11.5 feet

Depth (ft)	Soil Description	Sample Type	Sample Number	Ground Water	Penetration Resistance (Blows per foot)	N-values	Testing
25	Very soft, wet to saturated, clayey SILT with trace sand and trace shells (Fill)						
30	Dense, wet, dark gray SAND with some silt and shells (Fill)	2-inch O.D. split spoon	S-8			41	200W
35	Grades to loose, fine to medium, silty	2-inch O.D. split spoon	S-9			6	200W
40	Very dense, wet, dark gray, SAND with trace gravel (Native)	2-inch O.D. split spoon	S-10			51	
45	Medium stiff, wet, dark gray, sandy SILT with trace to some clay (Native)	2-inch O.D. split spoon	S-11			8	
50	Very dense, wet, gray, gravelly SAND with some silt (Native)	2-inch O.D. split spoon	S-12			58	GSA

Penetration Resistance: ▲ Standard; △ Other; Blows per foot: 0, 10, 20, 30, 40, 50

Explanation

- 2-inch O.D. split spoon sample
- 3-inch I.D Shelby tube sample
- No Recovery
- Groundwater level at time of drilling or date of measurement (ATD)

Monitoring Well Key

- Clean Sand
- Bentonite
- Grout/Concrete
- Screened Casing
- Blank Casing

Moisture Content

Plastic Limit — Natural — Liquid Limit

Testing Key

GSA = Grain Size Analysis
200W = 200 Wash Analysis
Att. = Atterberg Limits
Consol. = Consolidation Test

Zipper Zeman Associates, Inc.
Geotechnical and Environmental Consulting

BORING LOG	Exhibit: D-3
Date Drilled: 9/21/2006	Logged By: BAG

Location: Olympia, WA | **Approximate Elevation:** 11.5 feet

Depth (ft)	Soil Description	Sample Type	Sample Number	Ground Water	Penetration Resistance (Blows per foot; ▲ Standard, △ Other; 0–50)	N-values	Testing
50	Very dense, wet, gray, gravelly SAND with some silt (Native)						
55		2-inch O.D. split spoon	S-13		▲	61	
	No recovery - probable sandy GRAVEL	2-inch O.D. split spoon	S-14		▲	80	
60	Boring completed at approximately 60 feet on 9/21/06. Groundwater observed at 7 feet at time of drilling.						
65							
70							
75							

Explanation

- 2-inch O.D. split spoon sample
- 3-inch I.D Shelby tube sample
- No Recovery
- Groundwater level at time of drilling or date of measurement (ATD)

Monitoring Well Key

- Clean Sand
- Bentonite
- Grout/Concrete
- Screened Casing
- Blank Casing

Moisture Content

Plastic Limit — Natural — Liquid Limit

Testing Key

GSA = Grain Size Analysis
200W = 200 Wash Analysis
Att. = Atterberg Limits
Consol. = Consolidation Test

PROJECT: Capital Center Building	**JOB NO.:** 81065153	**BORING:** B-2	**PAGE 1 OF 3**
Location: Olympia, WA	**Approximate Surface Elevation:** 12.0 feet		

Depth (ft)	Soil Description	Sample Type	Sample Number	Ground Water	N-values	Testing
0	4" Asphalt					
	No recovery, probable dense, GRAVEL (Fill)	2-inch O.D. split spoon	S-1		47	
5		2-inch O.D. split spoon	S-2	▼ ATD	18	
	Medium dense, wet to saturated, gray, silty SAND with trace to some gravel (Fill)					
	No recovery - probable silty SAND	2-inch O.D. split spoon	S-3		17	
10	Grades to dark gray with some silt, trace shells, trace organics and trace gravel	2-inch O.D. split spoon	S-4		11	200W
15	Grades to fine to medium, silty, no gravel	2-inch O.D. split spoon	S-5		20	
20	Soft, wet to saturated, dark gray, sandy SILT with trace clay interbedded with silty sand with trace shells (Fill)	2-inch O.D. split spoon	S-6		4	200W
25	Medium dense, wet, dark gray SAND with some shells and some silt (Fill)	2-inch O.D. split spoon	S-7		27	200W

Penetration Resistance: ▲ Standard, △ Other; Blows per foot: 0, 10, 20, 30, 40, 50

Explanation

- 2-inch O.D. split spoon sample
- 3-inch I.D Shelby tube sample
- ⊗ No Recovery
- ▼ ATD Groundwater level at time of drilling or date of measurement

Monitoring Well Key
- Clean Sand
- Bentonite
- Grout/Concrete
- Screened Casing
- Blank Casing

Moisture Content

Plastic Limit — Natural — Liquid Limit

Testing Key
- GSA = Grain Size Analysis
- 200W = 200 Wash Analysis
- Att. = Atterberg Limits
- Consol. = Consolidation Test

ZZA **Zipper Zeman Associates, Inc.** Geotechnical and Environmental Consulting	**BORING LOG**	Exhibit: D-3
	Date Drilled: 9/22/2006	**Logged By: BAG**

Location: Olympia, WA **Approximate Surface Elevation:** 12.0 feet

Depth (ft)	Soil Description	Sample Type	Sample Number	Ground Water	Penetration Resistance (Blows per foot; ▲ Standard, △ Other; 0–50)	N-values	Testing
25	Medium dense, wet, dark gray SAND with some shells and some silt (Fill)						
30		2-inch O.D. split spoon	S-8		▲	24	
35	Grades to trace gravel	2-inch O.D. split spoon	S-9		▲	15	
	Grades to silty						
	Very dense, wet, dark gray, SAND with some silt and trace shells (Native)	2-inch O.D. split spoon	S-10		● ▲	58	GSA
40							
	Medium dense, wet, dark gray SAND with trace silt and sandy SILT Interbed (Native)	2-inch O.D. split spoon	S-11		▲	26	
45							
	Dense, wet, gray, sandy GRAVEL with trace silt (Native)	2-inch O.D. split spoon	S-12		▲	49	
50							

Explanation

- 2-inch O.D. split spoon sample
- 3-inch I.D Shelby tube sample
- ⊗ No Recovery
- ▼ ATD Groundwater level at time of drilling or date of measurement

Monitoring Well Key

- Clean Sand
- Bentonite
- Grout/Concrete
- Screened Casing
- Blank Casing

Moisture Content

Plastic Limit — Natural — Liquid Limit

Testing Key

GSA = Grain Size Analysis
200W = 200 Wash Analysis
Att. = Atterberg Limits
Consol. = Consolidation Test

PROJECT: Capital Center Building	**JOB NO.:** 81065153	**BORING:** B-2	**PAGE 3 OF 3**
Location: Olympia, WA	**Approximate Elevation:** 12.0 feet		

Depth (ft)	Soil Description	Sample Type	Sample Number	Ground Water	Penetration Resistance (▲ Standard, △ Other; Blows per foot 0–50)	N-values	Testing
50	Dense, wet, gray, sandy GRAVEL with trace silt (Native)						
	Grades to 2" sandy SILT interbed and with trace sand	I	S-13		▲ 49	49	
55	Boring completed at approximately 55 feet on 9/22/06. Groundwater observed at 5 feet at time of drilling.						
60							
65							
70							
75							

Explanation

- I — 2-inch O.D. split spoon sample
- II — 3-inch I.D Shelby tube sample
- ⊗ — No Recovery
- ▼ ATD — Groundwater level at time of drilling or date of measurement

Monitoring Well Key

- Clean Sand
- Bentonite
- Grout/Concrete
- Screened Casing
- Blank Casing

Moisture Content

Plastic Limit — Natural — Liquid Limit

Testing Key

- GSA = Grain Size Analysis
- 200W = 200 Wash Analysis
- Att. = Atterberg Limits
- Consol. = Consolidation Test

Zipper Zeman Associates, Inc. Geotechnical and Environmental Consulting	**BORING LOG**	Exhibit: D-3
	Date Drilled: 9/22/2006	**Logged By: BAG**

APPENDIX E
PREVIOUS DAM EVALUATIONS

Kramer, Chin & Mayo, Inc. Consulting Engineers, Architects, Applied Scientists

December 29, 1980

Mr. Richard Ewan
Division of Engineering and Architecture
206 General Administration Building
Olympia, WA 98504

Reference: Structural Evaluation Report
for Capitol Lake Dam

Dear Mr. Ewan:

We are pleased to submit to you three (3) copies of the attached report and appendices which entail the structural evaluation for the Capitol Lake Dam.

In submitting this report, we are fulfilling the preliminary phase of our investigation requirements of our agreement No. 80-118A. A further field inspection will be made to check the toe condition of the upperstream face of the embankment when the reservoir is drained to its lowest water level. At that time, an addendum to these findings will be issued to form the final report.

If you have any questions concerning this submittal, please contact this office at your convenience.

Sincerely yours,

KRAMER, CHIN & MAYO, INC.

William A. Cranston, P.E.
Manager
Structural/Mechanical Group

TCW/WAC:bd

Enclosures

1917 First Avenue
Seattle, Washington 98101

TABLE OF CONTENTS

LIST OF FIGURES

1. INTRODUCTION

Capitol Lake Dam (see Figure 1) is located at Budd Inlet at the so-called Deschutes Basin, Olympia, Washington. This dam was designed and built during the late 1940's and early 1950's under the authorization of the Act of the Legislation of the State of Washington Chapter 186, Session Law of 1947. The main structures of the subject project, as shown in Figure 2, consist of the following:

a. An earth-fill dam, approximately 800 feet long, 80 feet wide across the top, and approximately 26.5 feet high.

b. A reinforced concrete spillway structure approximately 82 feet wide with both slab and downstream apron approximately 167 feet long. The major structural elements of the spillway structure include:

- Flood discharge channels complete with radial control gates, control and operating equipment
- Fishway
- Operating control house
- Wing walls
- Cutoff and under drain
- Bridge across the spillway
- Protective log boom

In September 1980, the Department of General Administration, Division of Engineering and Architecture, hired the firm of Kramer, Chin & Mayo, Inc., Consulting Engineers, Architects and Applied Scientists, to evaluate the structural safety of the Capitol Lake Dam. The scope of service was outlined in our proposal dated July 3, 1980 (see Appendix A).

This report presents the results of the engineering review and visual inspection of the current structural condition and integrity of the embankment (earth-fill dam) and spillway. It is considered a preliminary report. A further field investigation will be made to check the toe condition of the upper stream face of the earth dam when the lake is drained to its lowest water level. At that time, an addendum to these findings will be issued to form the final report.

2. BASIS FOR THE ORIGINAL DESIGN

The original design of the Capitol Lake Dam and Spillway structures was based on the data and assumptions listed below:

- Elevations used in original design referred to City of Olympia datum 0.00 = elevation + 17.97 above mean lower low water (MLLW) of U.S.G.S. datum.
- Highest observed tide at elevation -0.20.
- Lowest observed tide at elevation -22.67
- Design for maximum tidal range of 22.47 feet.
- Design normal water surface of Deschutes Lake at elevation -4.0.
- Top of spillway bottom slab at elevation -32.00.
- Crest of Ogee weir at elevation -17.0.
- Bottom of highway girder at elevation +3.00.
- Top of earth-fill dam (roadway) at elevation +6.50.
- The spillway structure was designed for a maximum flow of 10,000 cubic feet per second at high tide stage plus allowance for free board.

Since the construction of Capitol Lake Dam, the extreme recorded discharge of the Deschutes river near Olympia has been 6,080 cubic feet per second, occurring on December 13, 1955. The original hydraulic and hydrologic design assumption appears to have been reasonable and adequate; however, an update using the 30 years additional data now available would be desirable to reevaluate the adequacy of the spillway outlet and flood routing procedures. The lake water level is basically controlled by the fishway and radial gates. A modification of the automatic control system which operates the radial gates makes it possible to maintain the lake water level within a range of a couple of inches. This modification was placed in operation in November, 1980.

On the basis of original design, it is our opinion, that the assumptions set for Capitol Lake Dam design are adequate and reasonable.

3. SPILLWAY STRUCTURES

A reinforced concrete spillway structure supported on timber piling is located in the dam at Budd Inlet. This spillway structure is a rectangular box section approximately 92 feet in length (perpendicular to the main axis of the dam), by 82.5 feet in width (parallel to the main axis of dam), with parallel wing walls 72 feet in length at upstream end, and parallel wing walls and concrete apron 75 feet in length at the downstream end. Across the top of the main spillway structure are a concrete slab and girder roadway deck and the gate control house deck. The main spillway is a rigid concrete frame construction, divided into three channels, two of which are flood discharge channels and one of which is a fishway channel.

3.1 Flood Discharge Channels

The flood discharge channels shown in Figure 3 have minimum clear width of 36 feet and 24 feet, respectively. The upstream ends of the discharge channels contain a gravity overflow ogee weir with crest elevation at -17.0, surmounted by radial gates and operation equipment installed in the control house above.

The automatic control system for the radial gate was recently modified as discussed in Section 2. It is suggested that a review of the emergency procedures for the facility should be made by the organization responsible for its operation.

3.2 Fishway Channel

The fishway channel located at the easterly side of the spillway structure has a 9-foot 6-inch clear width. The fishway is operated by a hydraulically operated and controlled tidal gate at its downstream end and a manually controlled weir at its upstream end. Timber baffles form a fish ladder for the anadromous fish run.

The current condition of the tidal gate is unknown. The tidal gate does not function as it was originally designed since the salt water flows back through the fish way at high tide level; however, the improper operation of the tidal gate does not affect the safety and integrity of the dam and spillway structure.

3.3 Control House

The control house is constructed on top of the spillway at the upstream end. It is a reinforced concrete building approximately 26 feet long by 15 feet wide, housing reduction gears, electric motors, control panel and miscellaneous appurtenances. Based on visual observation, the control house is structurally sound.

3.4 Wing Walls

The wing walls located at upstream and downstream ends are reinforced concrete cantilever retaining structures on pile foundations. From the appearance of the walls above the water line: there is no evidence of cracking or movement. Based upon visual observation, the wing walls are structurally sound.

3.5 Cut-off Wall and Underdrain

In accordance with the original design of Capitol Lake Dam, cut-off walls were provided for the spillway structure to protect against any tendency for seepage along the planes of contact between the concrete structure and soil material.

The upstream cut-off wall consisted of a single row of interlocking steel sheet piling 12 feet in length driven to a penetration of 12.5 feet below the bottom of the main spillway floor slab, terminating in a concrete seal-wall lying transversely beneath the main slab at the extreme upstream end of the main spillway structure and extending up the outside of each outer spillway wall to an elevation of 0.00.

The central cut-off wall consisted of a concrete seal-wall lying beneath the main slab and extending up the outside face of each side wall to an elevation of 0.00.

The downstream cut-off wall consisted of a single row of steel sheet piling 10 feet in length driven along a line extending transversely under the spillway downstream apron and wing-wall footings.

In addition to the cut-off, an underdrain was provided to intercept any seepage which might occur. The underdrain system of this structure consisted of a core of clean graded sand and gravel approximately 2 feet deep by 6 feet wide extending transversely beneath the main spillway slab approximately 15 feet downstream from the central cut-off wall, with bleeder pipes extending from the gravel core upward through the spillway slab.

Both cut-off and subdrain systems are inaccessible. Visual observations indicated no flow through the subdrains. There are at least two reasons which lead us to believe that the existing systems are functioning as originally designed.

a. The cut-off wall was driven below the tidal fluctuation zone. Corrosion of steel sheets under this condition should be minor. We anticipate the life of this kind of structure to be fifty years or more.

b. There is no visual evidence of uplift movement or settlement distress in the spillway structure or the adjacent embankment.

3.6 Log Boom

A fixed floating log boom approximately 240 feet long was originally installed upstream of the spillway. For some reason, the log boom is no longer in service. It is our opinion that the log boom was provided to prevent floating debris from reaching the radial gate and fishway, and to assist in preventing erosion of the embankment by wave action. This is especially important for the bank protection at the east side of the upstream face where part of the riprap has been removed to develop the park parking lot.

3.7 Spillway Structure

Considering the spillway structure as a whole, it is our opinion that the structure is in very good condition and we believe that the spillway structure is operationally and structurally sound.

4. EMBANKMENT - EARTH-FILL DAM

4.1 General

The embankment - earth-fill dam was constructed from the materials selected from Percival Creek borrow pit, as shown in Figure 4. The soils used for embankment construction were as follows:

Group 1

The soil in this group consists generally of loam and sandy loam containing varying amounts of gravel and cobbles. The soil as indicated in this group was classified as "impervious fill" and was used to construct the center core of the dam.

Group 2

The soils in this group consist of sand, gravel, and cobbles mixed in varying proportions and were classified "semipervious fill."

Since no soil borings have been conducted in this investigation (subsoil exploration is not included in the scope of consulting engineering service), we assumed that the material used met all original design and construction requirements. The safety investigation of the earth-fill dam is based on appearance observation only. Particular attention has been given to detecting the following major concerns:

a. Any evidence of cracking, tilting, deterioration, leakage, seepage, instability, or loss of integrity of the earth-fill dam.

b. Any evidence of landsliding, displacement, settlement, or cavitation.

c. Slope instability, erosion, and loss of riprap protection.

d. Improper functioning of drains.

e. Any potential problems under seismic actions.

Besides, KCM, Inc. also retained Converse Ward Davis Dixon, a geotechnical consulting engineering firm, to assist the preliminary soil analysis. A written report of their findings, conclusions and recommendations is presented in Appendix B.

The summary of the embankment examination concerning the Capitol Lake earth-fill dam safety is as follows:

4.2 Earthfill Dam

As shown in Figure 4, the dike embankment is approximately 80 feet wide across the top and an average 200 feet toe to toe across the bottom. Average height of the embankment is about 26.5 feet (38 feet high from bottom of foundation to top of crest). It was designed to resist 18.5 feet average differential water pressure. The slope of the embankment is protected by riprap placed at a 3:1 slope at both sides of embankment.

Based on our findings it appears that the dike is in good service condition. There is no evidence of cracking, differential settlement, cavitation, or landsliding. The upstream embankment face above the normal water level had a substantial amount of shrub-type vegetation. The larger vegetation should be removed and the root systems should be grubbed and replaced with compacted fill.

4.3 Bank Slope Stability and Riprap Protection

There are several minor bank erosions found at the east side upstream, which is probably due to wave action at higher water surface.

We also found some minor damage to the riprap at the east side downstream; however, those minor defects do not affect the integrity, stability, or safety of the earth-fill dam.

In general, based on the visual inspeciton, it is our opinion that the slope of the earth-fill dam seems stable and riprap protection is in good service condition.

4.4 Seismic Stability

In accordance with the seismic zone map and the historic seismic activities, Capitol Lake Dam is located within Seismic Zone III. An equivalent static load factor of 0.1 g associated with other assumptions is used to evaluate the stability of the earth dam due to inertia force and hydrodynamic actions under earthquake excitation. The result of equivalent static forces analysis indicates that the embankment section as shown in Figure 4 is stable, provided the interface of embankment and existing subgrade and the embankment foundation conditions are stable during any major events.

The design and construction of this earthfill dam was done in accordance with the normal standards of the industry of 30 years ago. This did not include extensive subgrade exploration and testing or the sophisticated soil analysis that are commonly done these days. As can be seen in the Appendix B reported by our soils consultant for this investigation, there is not sufficient data to fully evaluate this facility by current standards. The major deficiencies of information are subgrade conditions interface of embankment and existing subgrade and potential for massive earth slides around the perimeter of the reservoir. It is our opinion that potential problems in any of these areas is low but a quantitative evaluation would require additional soil exploration.

b. The riprap protection on both sides of embankment where minor damage occurs need remedial work. It is suggested that a test drill of emergency procedures and a minor engineering inspection of the embankment concerning slope protection and stability be conducted prior to the beginning of the rainy season each year.

c. The damaged log boom on the upstream side should be repaired.

d. Larger vegetation should be removed from the upstream face and crest of the embankment. The root systems should be grubbed and replaced with compacted fill.

e. Consideration should be given to a geologic evaluation of the reservoir perimeter to identify any potential landslides or other geologic hazards which might cause large movements of soil into the reservoir, with a resulting displacement of large amounts of reservoir water.

f. Consideration should also be given to a program of soil borings, sampling and laboratory test and analysis to identify the actual foundation and embankment conditions and evaluate the seismic stability of the embankment.

5. CONCLUSION AND RECOMMENDATION

On the basis of our findings, the following conclusion and recommendations are drawn concerning the structural safety of Capitol Lake Dam at Deschutes Basin, Olympia, Washington.

5.1 Conclusions

a. The Capitol Lake Dam and its related structures are classified in the category of small dam. Its hazard potential concerning loss of life and economic loss is low.

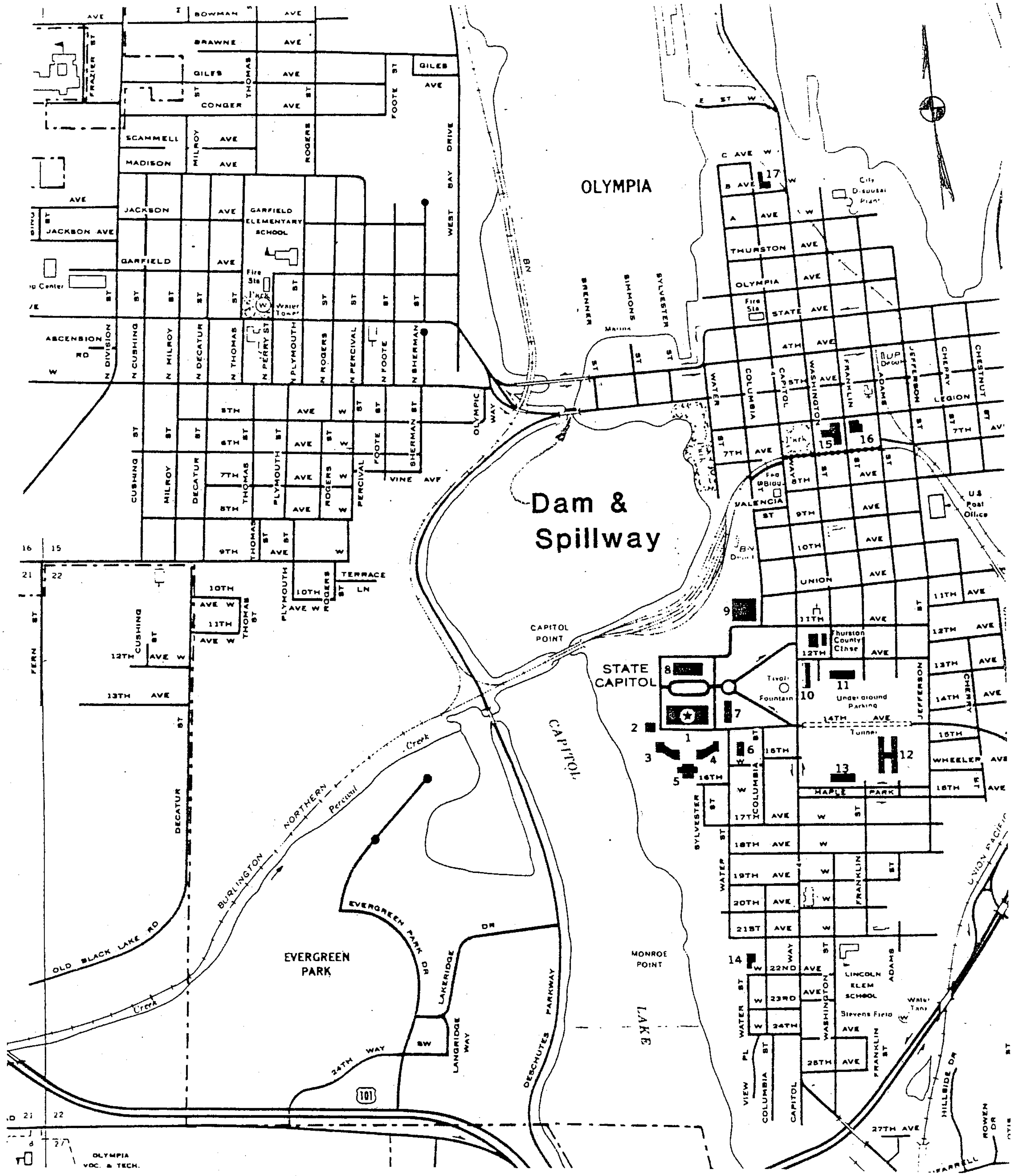
b. The design of the embankment and spillway structure appears to be reasonable and adequate.

c. The spillway construction appears to be structurally sound; all elements are continuing to function as designed, with proper operation and adequate maintenance.

d. The performance of the embankment over the past 30 years has been satisfactory and its current condition appears to be stable and safe to maintain the lake at its designed water level under normal condition. However, as pointed out by the geotechnical consulting engineer, in the absence of test data the actual condition and margin of safety against failure of the foundation and the lower (end dump) portion of embankment fill under severe earthquake excitation are unpredictable.

5.2 Recommendations

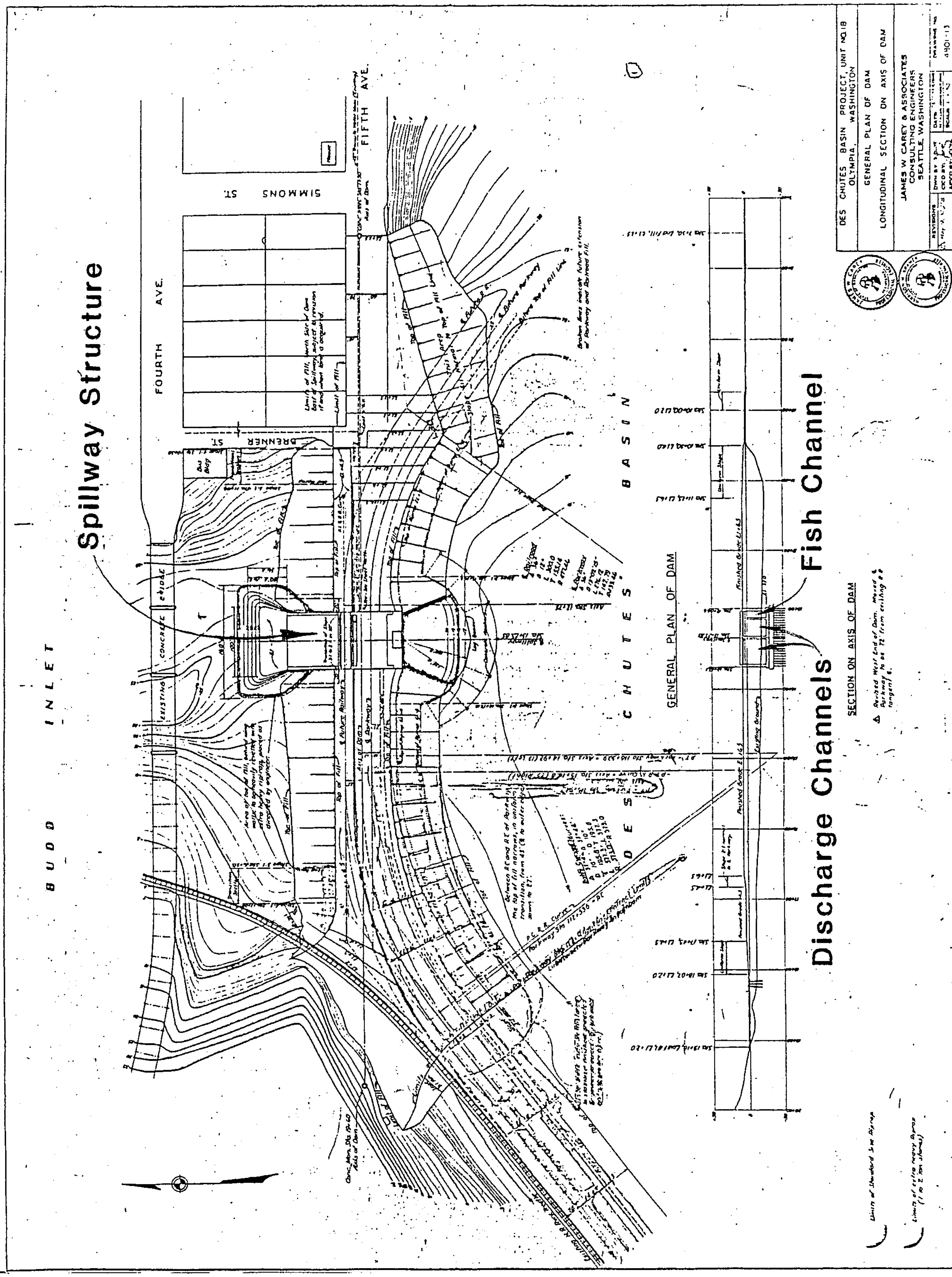
a. A further field inspection to check upstream embankment face and toe condition is required at the lowest lake water level when the lake water is drained.



CAPITOL LAKE DAM LOCATION MAP

Kramer, Chin & Mayo, Inc.
Consulting Engineers. Architects. Applied Scientists
1917 First Avenue. Seattle. Washington 98101
Phone (206) 447-5300

FIG. 1



CAPITOL LAKE DAM AND SPILLWAY SITE PLAN

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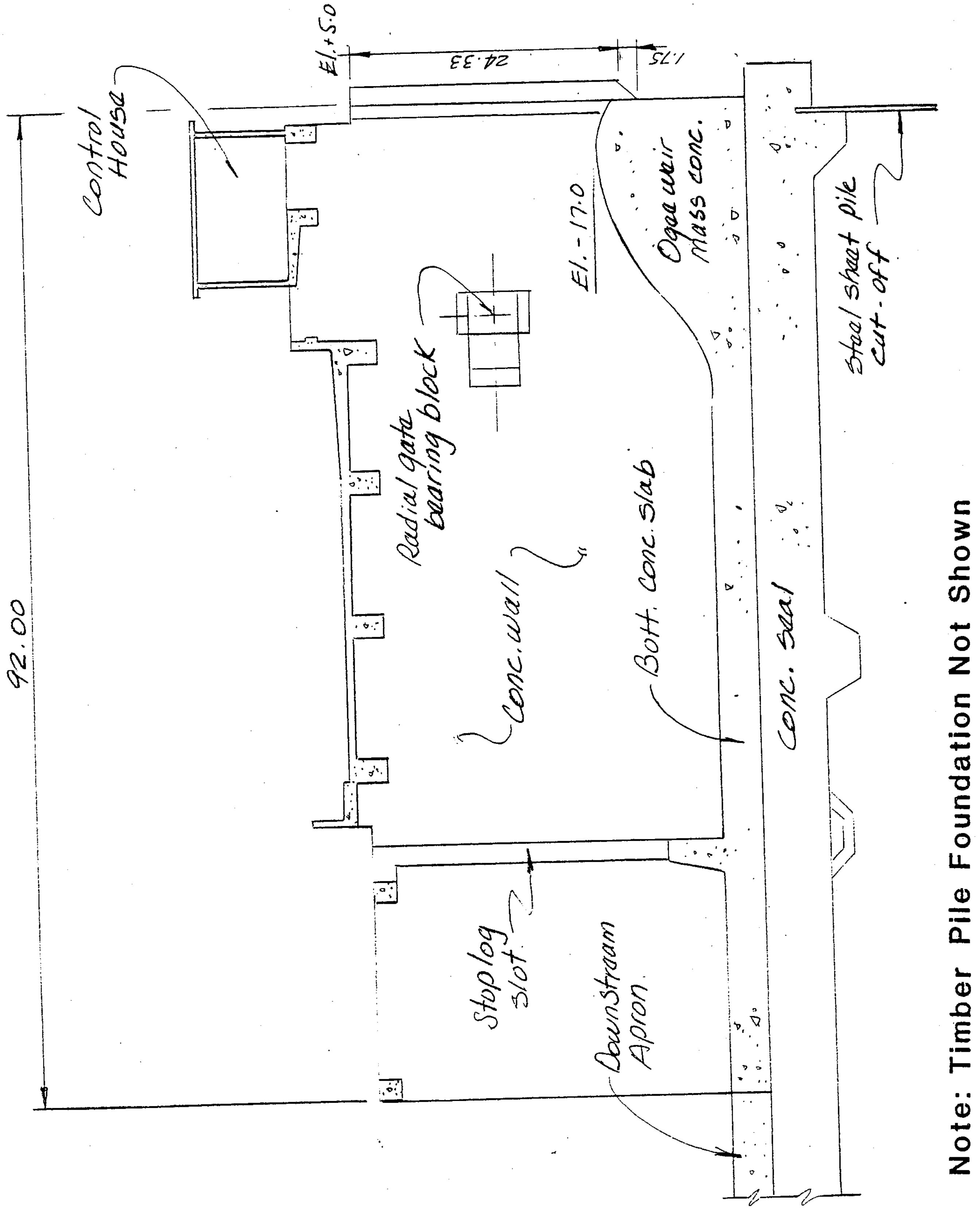
Phone (206) 447-5300

FIG. 2



TYP. SECTION THRU SPILLWAY DISCHARGE CHANNEL

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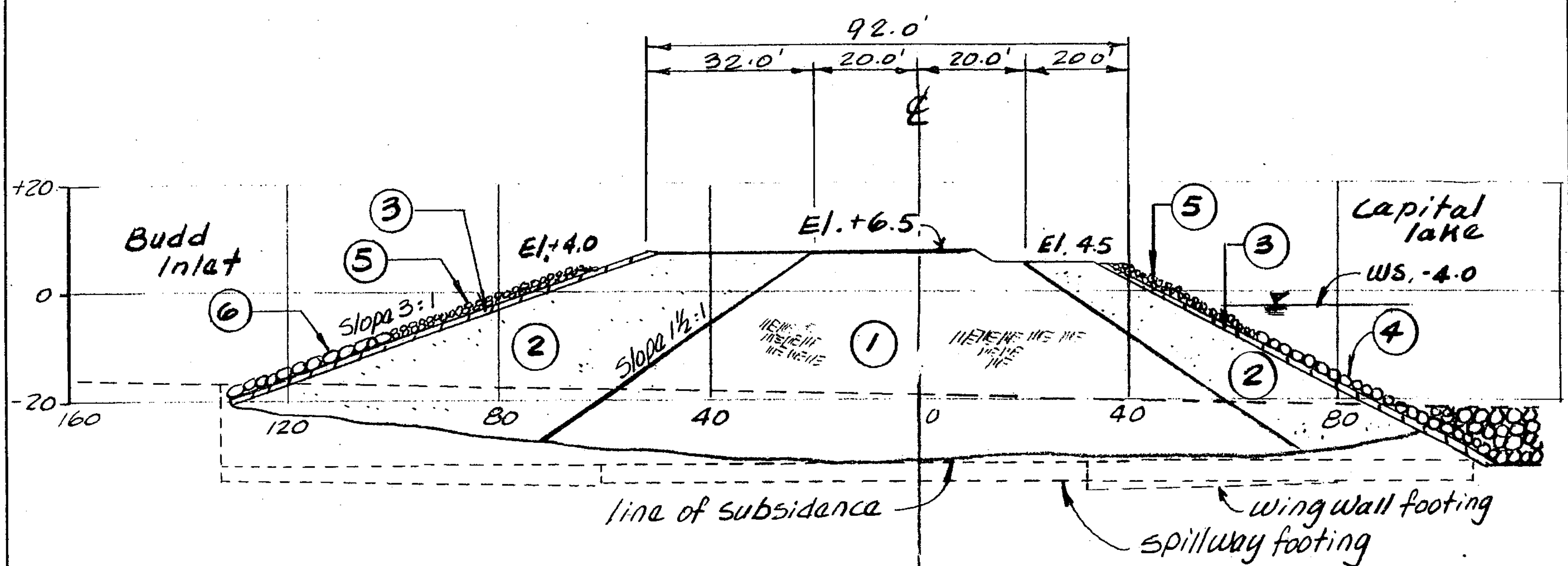
Phone (206) 447-5300

FIG. 3

1. Group 1 Soils, Impervious Earth Core
2. Group 2 Soils, Semipervious Transition Zone
3. 1′ Selected Sand & Gravel Filter Blanket
4. Rip-Rip (1 Ton) Slope 2:1 @ Spillway Flatten To 3:1
5. 2′-0″ Thick Rip-Rap Protection
6. Rip-Rap (1 Ton) Below Elev. -8.0



Elev. Shown Based on City of Olympia Datum

TYPICAL EARTH FILL DAM SECTION

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FIG. 4

APPENDIX A

PROPOSAL FOR SAFETY
EVALUATION OF CAPITOL
LAKE DAM

Kramer, Chin & Mayo, Inc. Consulting Engineers, Architects, Applied Scientists

KCM #974-01

July 3, 1980

Mr. Richard Ewan
Division of Engineering and Architecture
206 General Adminsitration Bldg.
Olympia, WA 98504

Subject: Proposal for Safety Evaluation of Capital Lake Dam

Dear Mr. Ewan:

We are pleased to resubmit our proposal for the safety evaluation of Capital Lake Dam in Olympia, In the formulation of this proposal, we have relied upon the U.S. Army Corps of Engineers "Recommended Guidelines for Safety Inspection of Dams" to establish the proposed scope of work.

As we discussed on July 2, 1980, the investigation now concentrates on the structural condition and integrity of the spillway structure and embankment. In reformulating the project, I have assumed that a diver is no longer necessary since the upstream portion of the structure can be investigated when the lake is drained in September, and the downstream portion during very low tides which regularly occur. The result of this investigation will be a report of the general structural condition of the dam.

As you requested, we have deleted the hydraulic and hydrologic work that was included in our previous submittal. I should point out that, although we have designed the modifications to the gate control system, these changes were only undertaken to improve the system reliability, and did not include any evaluation of the dam's capability of handling a design flood.

The attached sheets detail the tasks and staff hours necessary to accomplish the investigation. Included in these hours are the time required to coordinate the work of a geotechnical consultant. The geotechnical consultant would be required to review the existing data on embankment fill and foundation conditions and evaluate, if possible, the potential for damage under normal or seismic loading. He would also determine the necessity for follow-on work such as a soil boring program and the mathematical modeling of the stability of the embankment under seismic loading.

Also attached is the estimate of the cost of the project. Total estimated cost, including subconsultants, amounts to $8,533. We propose to complete the project three months after receipt of Notice to Proceed from the State, assuming that the lake is drained in September.

1917 First Avenue
Seattle, Washington 98101
Phone (206) 447-5300

In the execution of this project we, of course, would require access to any State records on modifications to the dam and procedures for operation and maintenance.

With our past involvement in the Capitol Lake project, we are very interested in performing these evaluation services. If, after your review of this proposal, you wish to discuss it further, we would be happy to meet with you at your convenience. Please do not hesitate to call me if you have any questions.

Sincerely,

KRAMER, CHIN & MAYO, INC.

William A. Cranston, P.E.
Manager, Structural/Mechanical Group

WAC:pa
Enclosure

Estimate of Professional Services (STAFF HOURS)

KCM No.: 974-01
Sheet: 1 of 2
Date: July 3, 1980

CLIENT/PROJECT
Division of Engineering & Architecture
Safety Evaluation of Capitol Lake Dam

Task	Staff Requirement (staff hours)						
	Project Management	Project Leader	Professional Staff	Technical Staff	Clerical Staff	Other	TOTALS
1. Assembly and Review of Project Documents	1	4	8	8	-		21
2. Site Visits and Structural Inspections	-	6	20	8	-	Travel	34
3. Preliminary Geotechnical Analysis	-	2	-	-	1	Geo. Eng. @ $2,000	3
4. Survey of Embankment and Spillway	1	4	16	-	1	Travel	22
5. Review of Structural Design	2	4	16	-	1		23
6. Quality Control and Review	4	4	-	-	2		10
7. Report	2	12	12	18	12	Printing	56
TOTALS	10	36	72	34	17		169

APPENDIX B

PRELIMINARY GEOTECHNICAL EVALUATION

ConverseWardDavisDixon

Geotechnical Consultants

PRELIMINARY GEOTECHNICAL EVALUATION

Condition of Capitol Reservoir Embankment Dam

Olympia, Washington

Conducted for:

Kramer, Chin and Mayo, Inc.

CWDD Project No. 80-5246-01

December 23, 1980

Converse Ward Davis Dixon, Inc.

300 Elliott Avenue West
Suite 150
Seattle, Washington 98119
Telephone 206 285-5200

ConverseWardDavisDixon

Geotechnical Consultants

December 23, 1980 80-5246-01

Kramer, Chin and Mayo, Inc.
1917 First Avenue
Seattle, Washington 98101

Attention: Messrs. T.C. Wang and Bill Cranston

Gentlemen:

Attached is our report of a preliminary geotechnical evaluation of the condition of the Capitol Reservoir embankment dam. This work was performed pursuant to your Work Order No. 1851, dated November 12, 1980.

We have presented our preliminary findings with regard to the condition of the embankment and other appurtenant features. Lack of good engineering data on the foundation and embankment soils preclude making more definitive conclusions than those presented.

We have discussed the content of this report with Messrs. T.C. Wang and John McGlenn of Kramer, Chin and Mayo, Inc. If you have any questions or comments, we will be pleased to respond.

Very truly yours,

CONVERSE WARD DAVIS DIXON, INC.

John S. Lloyd
John S. Lloyd
Senior Engineer

JSL/kpp

Converse Ward Davis Dixon, Inc.
300 Elliott Avenue West
Suite 150
Seattle, Washington 98119
Telephone 206 285-5200

1. INTRODUCTION

This report presents the results of a preliminary geotechnical evaluation of the condition of the Capitol Reservoir embankment dam, located in Olympia, Washington. The purpose of the evaluation was to provide a preliminary assessment of the safety of the embankment and to develop recommendations for further study, if warranted.

Our scope of work consisted of (1) review of readily available data concerning the facility, (2) a visual observation of the dam by a senior civil engineer from our staff, (3) slope stability calculations using a range of assumed soils properties, and (4) the preparation of this report.

This report is preliminary in nature, and is not intended to be sufficiently thorough and complete to be a definitive assessment of the safety of the embankment. This report contains recommendations concerning a scope of work necessary to establish the condition of the embankment with a higher level of certainty.

2. PROJECT DESCRIPTION AND HISTORY

The Capitol Reservoir (also called Capitol Lake) embankment dam is located at the mouth of the Deschutes River in Olympia, Washington. The reservoir outlet empties into Budd Inlet, an arm of southern Puget Sound. We understand that the dam was constructed during 1949 and 1950 under contracts administered by the State of Washington. The design of the dam and spillway outlet works was by the engineering firm James W. Carey and Associates. The project was known as the Deschutes Basin Project at that time.

The facility consists of an embankment dam with a maximum structural height (bottom of foundation to top of crest) of about 38 feet, a crest length of about 800 feet, and crest width of about 80 feet. Near the center of the embankment, there is a concrete lined overflow spillway 82 feet wide, with two 24-foot by 36-foot radial gates, each with its own discharge channel, and a nine-foot six-inch wide fishway channel, also fitted with a radial gate at the upstream end. The outlet channels of the spillway are supported by a grid of driven timber piling. The spillway has a reported design capacity of 10,000 cfs. The dam crest has a design elevation of 6.5 (City of Olympia datum) and serves as the roadway for Fifth Avenue, a major Olympia arterial.

The embankment was reportedly constructed with two materials zones. Group 1 soils, comprising the core, were described in the specifications as "loam and sandy loam containing varying amounts of gravel and cobbles." Group 2 materials, comprising the upstream and downstream shells, was likewise described as "sand, gravel, and cobbles, mixed in varying proportions." Group 3 soils were "fine sand with some strata containing silt" and were also utilized as shell materials. A select layer of sand and gravel, chosen from the Group 2 soils, was specified as a drainage blanket for both slopes, covered by a two-foot thick layer of riprap, also on both embankment slopes. The upstream and downstream slopes were both designed at 3H:1V (horizontal to vertical), except for a section at 2H:1V on the downstream slope adjacent to the spillway. With the exception of the riprap, all embankment materials came from a borrow area in the reservoir, known as the Percival Creek borrow area.

According to the specifications, the lower portions of the embankment were constructed by first partially excavating "muck and other soft material" and then by end-dumping the Group 1 soils, and "squeezing" the remaining "soft material" to the inboard and outboard sides of the embankment. Above elevation 0, the embankment was constructed as a rolled earthfill.

The impounded reserovir is about 10,000 feet long and about 2,500 feet wide, at its widest point. The normal water surface elevation is about elevation -3.5 (City of Olympia datum), and the highest tide prior to 1949 was elevation -0.17. (City of Olympia datum elevation -9.79 = elevation 0 USC&GS MSL 1929 datum). The spillway gates are automatically operated to maintain the reservoir level and to close at high tide, as during high tide, the elevation of Budd Inlet is at times above the reservoir elevation.

Operation of the facility is reportedly by the State of Washington, with the fish channel and gate independently operated by the State Fisheries Commission.

Kramer, Chin and Mayo personnel have reported that the facility has operated essentially normally since its completion, with no history of major operational problems or deficiencies. Modifications to the automatic operating system for the radial gates were recently completed.

3. SITE GEOLOGY

The site is within the Puget Trough section of the Pacific Border physiographic province. The Puget Trough is a long northward trending lowland between the Cascade Mountains on the east and the Coast Range on the west, extending from west central Oregon into Canada. Except for isolated "islands" of older consolidated rocks, the entire basin has been partly filled with unconsolidated fluvial and glacial materials of Pleistocene age.(1)

While no specific site geologic mapping was included as part of this preliminary scope of work, published data indicates that the principal surficial deposits in the vicinity of the site are Recessional sands, gravels, till, and outwash deposits of the Vashon Drift. (The most recent of as many as four periods of continental glaciation thought to have occurred.) Noble(2) has modeled a geologic section passing through Budd Inlet about six miles north of the site which shows that older, Kitsap formation, Salmon Springs Drift, and undifferentiated pre-Salmon Springs deposits lie in order below the Vashon deposits. This section shows Budd Inlet as having its floor in the pre-Salmon Springs deposits, with the present sea level elevation falling within the Salmon Springs outwash or Kitsap formation. Another modeled section passing through the Deschutes River about two miles south of the site shows recent alluvium successively over Vashon recessional and till deposits, Salmon Springs outwash, pre-Salmon Springs deposits, and, to the west, older Tertiary volcanic rocks.

Artim(3) has mapped the entire perimeter of the reservoir as a Class 3, inferred "unstable" area, where old or recently active landslides commonly occur, due to steep topography or underlying geologic materials.

---

(1) Wallace and Molenaar, "Geology and Groundwater Resources of Thurston County, Washington, Vol. 1, 1961.

(2) Noble, John B., "Geologic Sections, Thurston County, Washington," 1962.

(3) Artim, Ernest R., "Slope Stability Map of Thurston County, Washington," 1976, Map No. GM-15, State of Washington Department of Natural Resources, Division of Geology and Earth Resources.

4. ON-SITE OBSERVATIONS

An inspection of the dam was made on November 19, 1980 by the writer, Mr. John S. Lloyd, of this firm, in company with Mr. T.C. Wang, of Kramer, Chin and Mayo. A brief summary of the writer's observations were as follows:

(1) The reservoir water level prevented observation of most of the upstream face of the embankment. Upon arrival at the site, the tide was relatively low, permitting inspection of most of the downstream face. The observed portions of the embankment appeared to be in generally good condition, with no observed cracking, slumps, misalignment or excessive settlement.

(2) Riprap at some locations appeared to be marginally deficient, with gaps exposing fine-grained soils.

(3) The spillway and discharge channel concrete appeared to be in good condition, with no excessive cracking, spalling or other visually apparent deficiencies.

(4) Both 24-foot by 36-foot radial gates were operated through a partial cycle without difficulty. The backsides of the gates and operating arms were covered with barnacles.

(5) The upstream embankment face above the normal reservoir level had a substantial amount of shrub-type vegetation.

(6) As the tide came in, water flowed from Budd Inlet through the fishery channel into the reservoir.

(7) The gate house and operating controls appeared to be in a generally well-maintained condition.

(8) The wire ropes for the gate hoists appeared to be relatively new.

(9) The float well chamber was not fitted with a lock, and is accessible to the general public.

(10) The spillway log boom was not in place. The logs comprising the boom were observed near the shore, west of the spillway.

5. ENGINEERING ANALYSES

Preliminary calculations of slope stability were made for the outboard (Budd Inlet) side of the embankment. In the absence of test data, a range of estimated soil strengths and locations of the phreatic surface, based on our experience and judgement from other similar projects, were utilized. Computer searches for potential failure surfaces were conducted using a range of soil friction angles for each of two assumed soil phreatic surfaces. The range of assumed soil friction angles and the two phreatic surfaces were chosen to represent our estimate of the limits within which the actual conditions will be found. Because of this lack of actual data, no numerical results of the analysis are presented. A qualitative assessment is that if the soil strengths of the foundation or embankment soils should be proven to fall into the lower end of the estimated range of soil strengths used in the analysis, the calculated factors of safety of the embankment could be shown to be less than those normally accepted by current design practice, for both static and estimated seismic loadings. Again, with better data on soil strengths and location of the phreatic surface, a more definitive assessment could be made.

6. CONCLUSIONS AND RECOMMENDATIONS

1. The design of the embankment appears to have been within normally accepted standards of practice for its time, and the dam appears to be in good condition. The performance of the embankment over its 30 year life has been satisfactory, and the apparent absence of unusual movements or evidence of distress tends to lead to the conclusion that the embankment will probably continue to perform well in the immediate future, if conditions remained unchanged.

   Some question does exist, however, as to the actual condition and margin of safety against failure of the foundation and lower (end-dumped) portions of the embankment fill. The effectiveness and thoroughness of the construction procedure in removing unsuitable soft foundation soils is not known, and the lower, dumped portion of the embankment is almost certainly of lower strength than the upper rolled portion. Historically, earth dams constructed of dumped or sluiced materials are more likely to fail than rolled, compacted embankments. Also, deficiencies in the foundation, such as unremoved zones of soft soil, are a leading cause of failure of earth dams. A program of test borings, sampling, and testing would be required to establish the foundation and embankment conditions, to within a more acceptable level of certainty, and to quantitatively evaluate the stability of the embankment and its foundation.

2. The site is relatively close, about ten miles, from the epicenter of the April 13, 1949, magnitude 7.1 Olympia earthquake. The embankment construction had reportedly just begun when this earthquake occurred. The site should be considered susceptible to another similar earthquake; the performance of the embankment in the event of another such earthquake cannot be predicted with the available data on the embankment and foundation soils. The need for a seismic stability evaluation of the dam should be based in part on the consequences of failure of the embankment. Such a study would include a geologic and historic evaluation of the site seismicity, development of one or more design earthquakes, test

borings and laboratory testing, and a slope stability evaluation of the embankment and foundation, including seismic loadings based on the design earthquake(s). In this writer's opinion, the presence of a busy traffic arterial on the crest of the dam indicates a potential, although probably small, for loss of life in the event of total failure. Any consequences of the sudden release of reservoir water into Budd Inlet would also have to be evaluated.

3. The spillway log boom should be replaced in its proper position. If this is neglected, a large flood could bring sufficient debris to jam the spillway gates, with failure by overtopping as a possible consequence.

4. A re-evaluation of the flood hydrology of the lower Deschutes River Basin may be warranted. The original design hydrologic studies appear to have been reasonable and adequate; however, an update using the 30 years of additional data now available would be desirable to further substantiate the adequacy of the spillway outlet works and flood routing procedures.

5. A review of the emergency procedures for the facility should be made by the organization responsible for its operation. If an emergency preparedness plan does not now exist, one should be developed, implemented, and subjected to periodic test drills.

6. The cover for the float well chamber should be fitted with a lock.

7. The condition of the lower reaches of the inboard embankment should be visually inspected by a qualified observer at the next time the reservoir level is substantially lowered. This reportedly will be done sometime in early 1981.

8. The riprap should be repaired to fill in areas which have inadequate coverage.

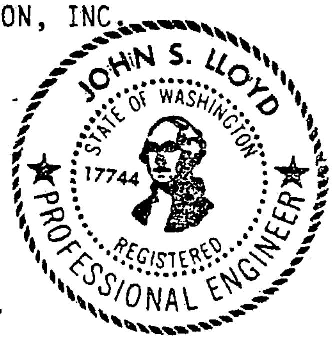
9. Larger vegetation should be removed from the upstream face and crest of the embankment. The root systems should be grubbed and replaced with compacted fill.

10. Consideration should be given to a geologic evaluation of the reservoir perimeter to identify any potential landslides or other geologic hazards which might cause large movements of soil into the reservoir, with a resulting displacement of large amounts of reservoir water.

CLOSURE

This report has been prepared in accordance with generally accepted principles of geotechical engineering practice. We make no other warranty, either express or implied.

CONVERSE WARD DAVIS DIXON, INC.

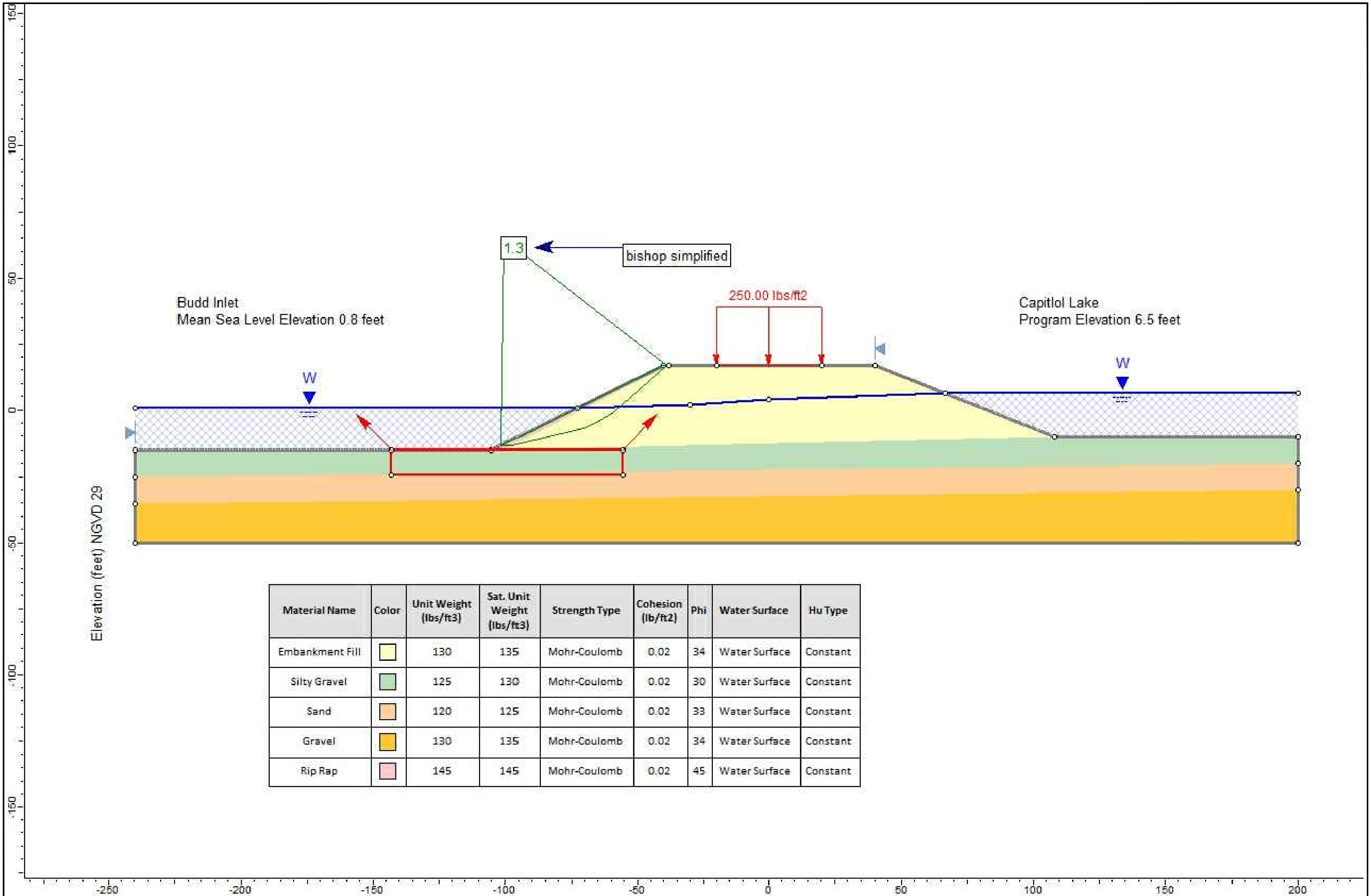


John S. Lloyd
Senior Engineer

Eugene R. McMaster
Vice President

JSL/ERM/kpp

APPENDIX F
STATIC SLOPE STABILITY



Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (lb/ft2)	Phi	Water Surface	Hu Type
Embankment Fill		130	135	Mohr-Coulomb	0.02	34	Water Surface	Constant
Silty Gravel		125	130	Mohr-Coulomb	0.02	30	Water Surface	Constant
Sand		120	125	Mohr-Coulomb	0.02	33	Water Surface	Constant
Gravel		130	135	Mohr-Coulomb	0.02	34	Water Surface	Constant
Rip Rap		145	145	Mohr-Coulomb	0.02	45	Water Surface	Constant

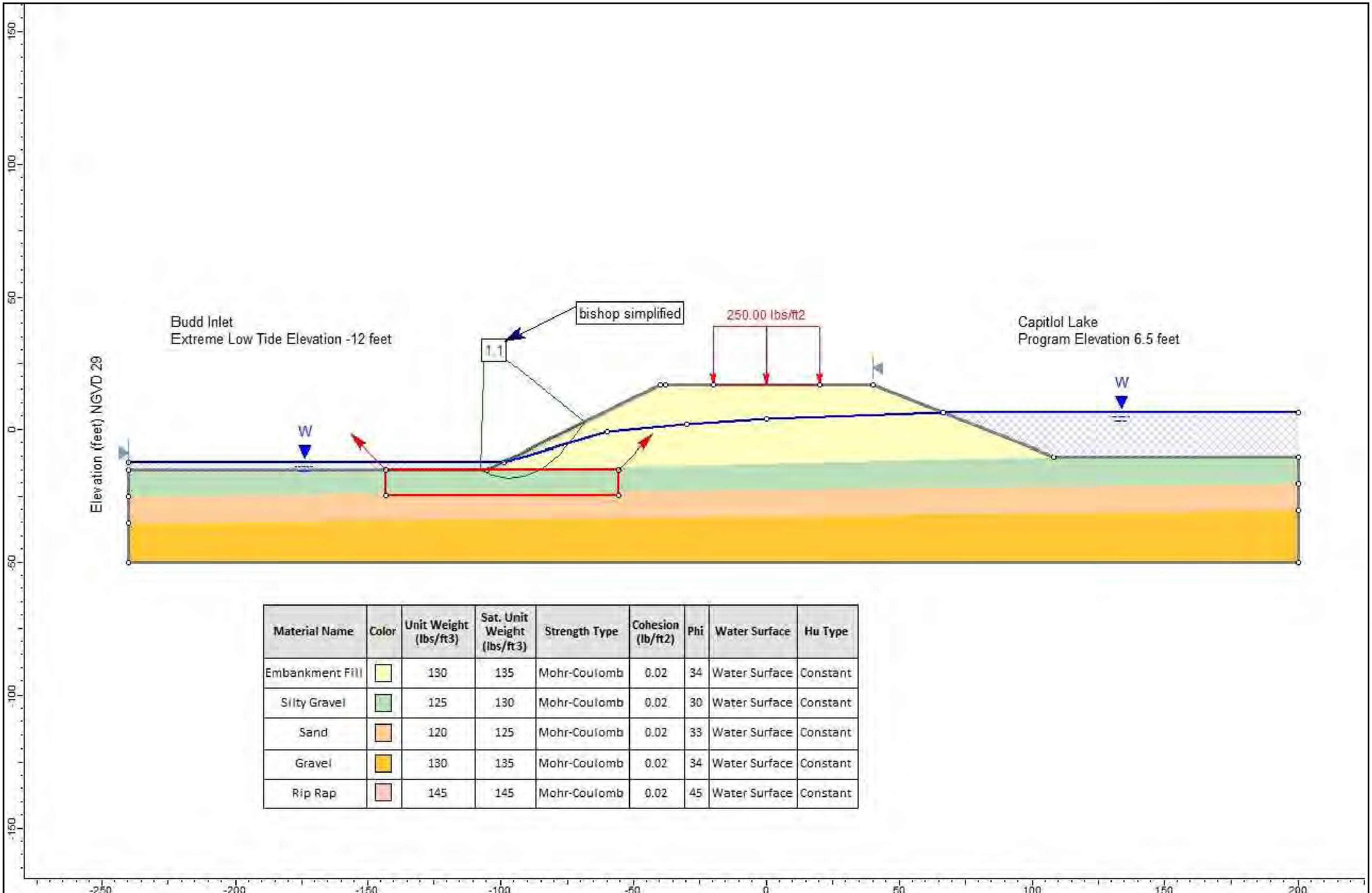
Project Mngr: DAB	Project No. 81165060		
Drawn By: AMP	Scale: AS SHOWN		
Checked By: DAB	File No. Exhibit F-1		
Approved By: DAB	Date: October 2016		

Terracon
Consulting Engineers and Scientists
21905 64th Avenue W., Ste 100 Mountlake Terrace, WA 98043
PH. (425) 771-3304 FAX. (425) 771-3549

STATIC SLOPE STABILITY (AT MEAN SEA LEVEL)

CAPITOL LAKE DAM
Olympia, Thurston County, Washington

EXHIBIT
F-1



Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (lb/ft2)	Phi	Water Surface	Hu Type
Embankment Fill		130	135	Mohr-Coulomb	0.02	34	Water Surface	Constant
Silty Gravel		125	130	Mohr-Coulomb	0.02	30	Water Surface	Constant
Sand		120	125	Mohr-Coulomb	0.02	33	Water Surface	Constant
Gravel		130	135	Mohr-Coulomb	0.02	34	Water Surface	Constant
Rip Rap		145	145	Mohr-Coulomb	0.02	45	Water Surface	Constant

Project Mngr: DAB	Project No. 81165060
Drawn By: AMP	Scale: AS SHOWN
Checked By: DAB	File No. Exhibit F-2
Approved By: DAB	Date: October 2016

Terracon
Consulting Engineers and Scientists
21905 64th Avenue W., Ste 100 Mountlake Terrace, WA 98043
PH. (425) 771-3304 FAX. (425) 771-3549

STATIC SLOPE STABILITY (AT EXTREME LOW TIDE)

CAPITOL LAKE DAM
Olympia, Thurston County, Washington

EXHIBIT
F-2

APPENDIX G
SEISMIC SLOPE STABILITY

(a)

(b)

LIQUEFACTION-RELATED DAMAGE FROM (a) THE 1965 SEATTLE-TACOMA EARTHQUAKE (b) THE 2001 NISQUALLY EARTHQUAKE (KRAMER 2008). NOTE THAT BOTH PHOTOGRAPHS WERE TAKEN AT ABOUT THE SAME LOCATION ALONG DESCHUTES PARKWAY SW.

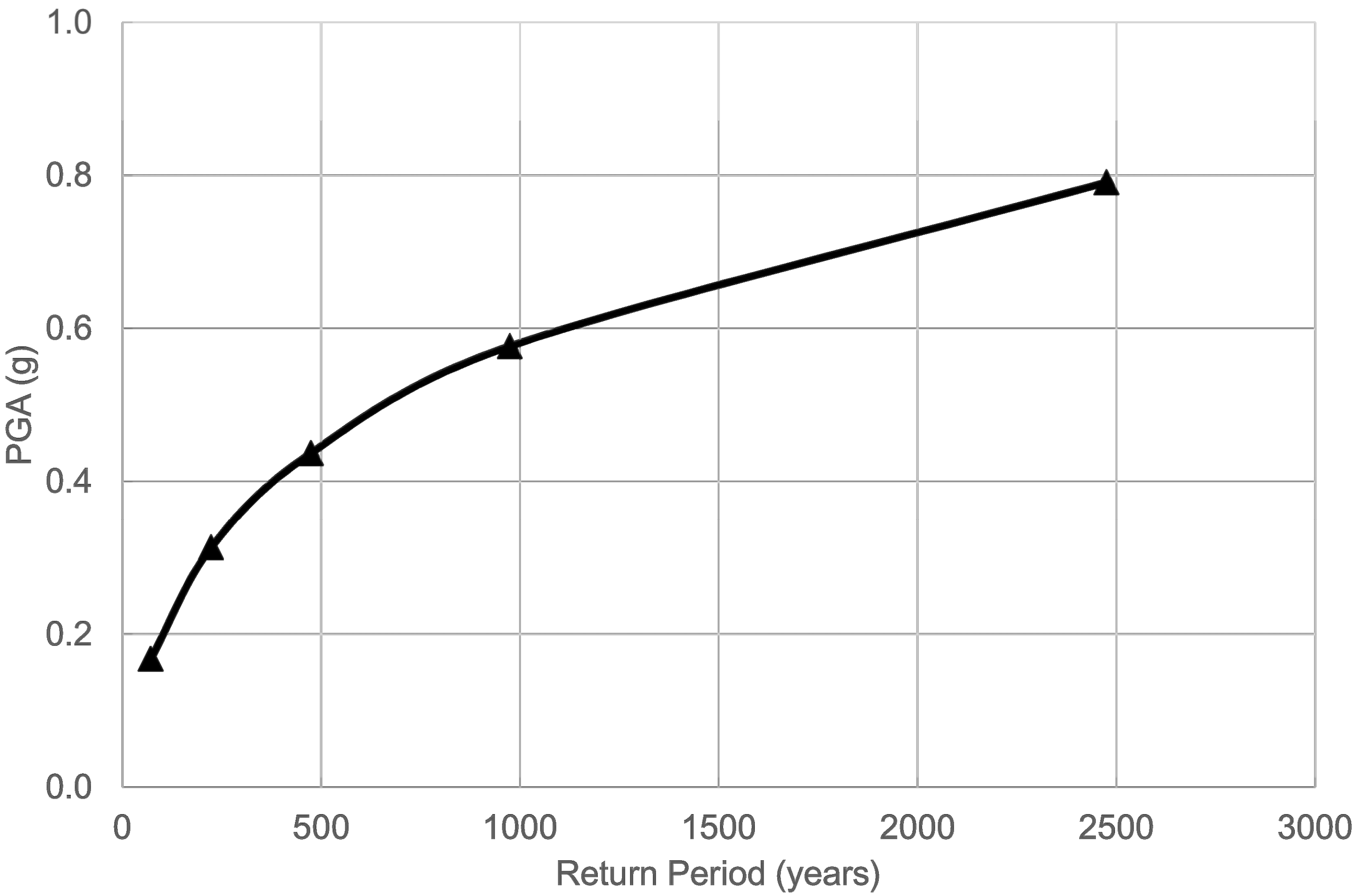
Project Mngr: DAB	Project No. 81165060	**Terracon** Consulting Engineers and Scientists	CAPITOL LAKE DAM Olympia, Thurston County, Washington	EXHIBIT
Drawn By: AMP	Scale: AS SHOWN			G-1
Checked By: DAB	File No. Exhibit G-1	21905 64th Avenue W., Ste 100 Mountlake Terrace, WA 98043		
Approved By: DAB	Date: October 2016	PH. (425) 771-3304 FAX. (425) 771-3549		

LIQUEFACTION-RELATED DAMAGE FROM THE 2001 NISQUALLY EARTHQUAKE
AT THE END OF DESCHUTES PARKWAY SW (BRAY ET AL., 2001)

Project Mngr: DAB	Project No. 81165060	Terracon Consulting Engineers and Scientists
Drawn By: AMP	Scale: AS SHOWN	21905 64th Avenue W., Ste 100 Mountlake Terrace, WA 98043
Checked By: DAB	File No. Exhibit G-2	PH. (425) 771-3304 FAX. (425) 771-3549
Approved By: DAB	Date: October 2016	

CAPITOL LAKE DAM
Olympia, Thurston County, Washington

EXHIBIT
G-2



PLOT OF PEAK GROUND ACCELERATION (PGA) VS. EARTHQUAKE
RETURN PERIOD FOR SOILS WITH Vs =590 ft/sec.

Project Mngr: DAB	Project No. 81165060	Terracon Consulting Engineers and Scientists	CAPITOL LAKE DAM	EXHIBIT	
Drawn By: AMP	Scale: AS SHOWN		Olympia, Thurston County, Washington	G-3	
Checked By: DAB	File No. Exhibit G-3	21905 64th Avenue W., Ste 100 Mountlake Terrace, WA 98043			
Approved By: DAB	Date: October 2016	PH. (425) 771-3304 FAX. (425) 771-3549			

Acceleration

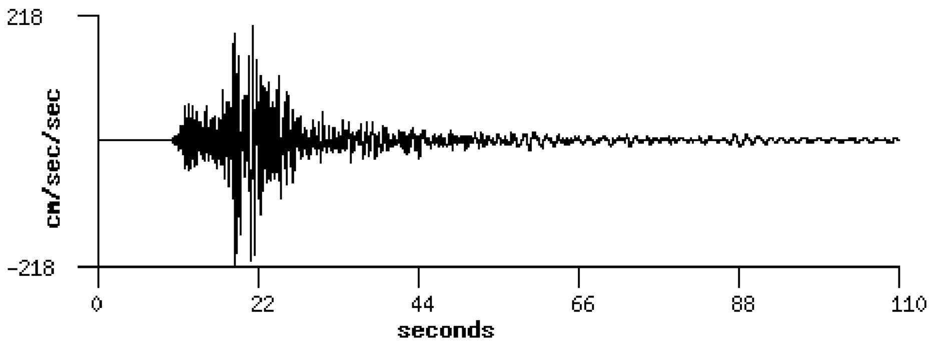
Station: Olympia, WA - Washington Dept of Transportation Highway Test Lab - GS State & N Washington
Station Owner: United States Geological Survey
Station Latitude & Longitude: 47.0470, -122.8990

Earthquake: Nisqually 2001-02-28 18:54:31 UTC

Hypocentral Distance: 55.5 km

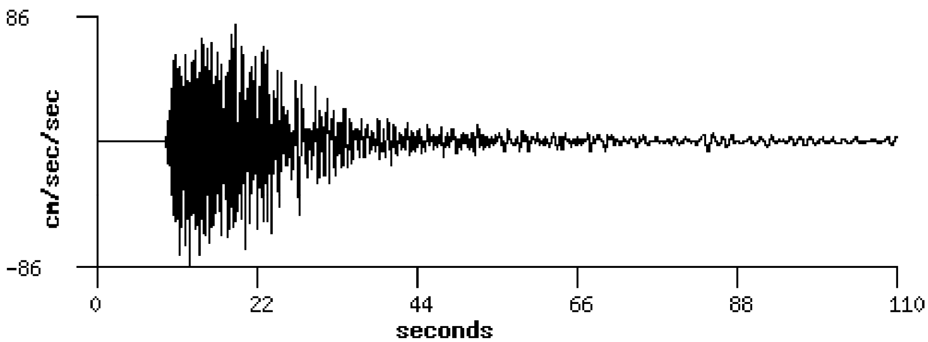
(Use the back button on your browser to return to the previous page)

Component: 180 Ground Level

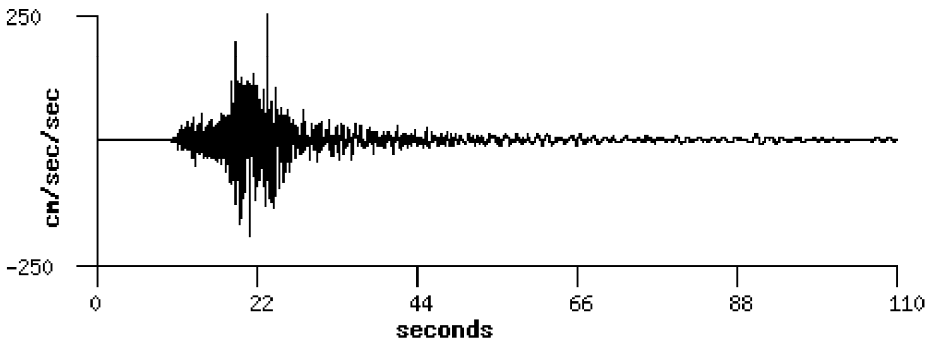


Component: Up Ground Level

Project Mngr: DAB	Project No. 81165060	Terracon Consulting Engineers and Scientists	**NISQUALLY EARTHQUAKE DATA**	EXHIBIT
Drawn By: AMP	Scale: AS SHOWN		CAPITOL LAKE DAM Olympia, Thurston County, Washington	G-4A
Checked By: DAB	File No. Exhibit G-4A	21905 64th Avenue W., Ste 100 Mountlake Terrace, WA 98043		
Approved By: DAB	Date: October 2016	PH. (425) 771-3304 FAX. (425) 771-3549		



Component: 270 Ground Level



Project Mngr: DAB	Project No. 81165060	Terracon Consulting Engineers and Scientists	**NISQUALLY EARTHQUAKE DATA**	EXHIBIT
Drawn By: AMP	Scale: AS SHOWN		CAPITOL LAKE DAM	
Checked By: DAB	File No. Exhibit G-4B	21905 64th Avenue W., Ste 100 Mountlake Terrace, WA 98043	Olympia, Thurston County, Washington	G-4B
Approved By: DAB	Date: October 2016	PH. (425) 771-3304 FAX. (425) 771-3549		

STRONG-MOTION VIRTUAL DATA CENTER (VDC)

Global Component of the Center for Engineering Strong Motion Data

Response Spectra

Station: Olympia, WA - Washington Dept of Transportation Highway Test Lab - GS State & N Washington
Station Owner: United States Geological Survey
Station Latitude & Longitude: 47.0470, -122.8990

Earthquake: Nisqually
Hypocentral Distance: 55.5 km

Processing Info: USGS

(Use the back button on your browser to return to the previous page)

Reconfigure Plots:

% Damping 5

Accleration Units g

Max Period 10 (sec)

Scale Factor for Data 1

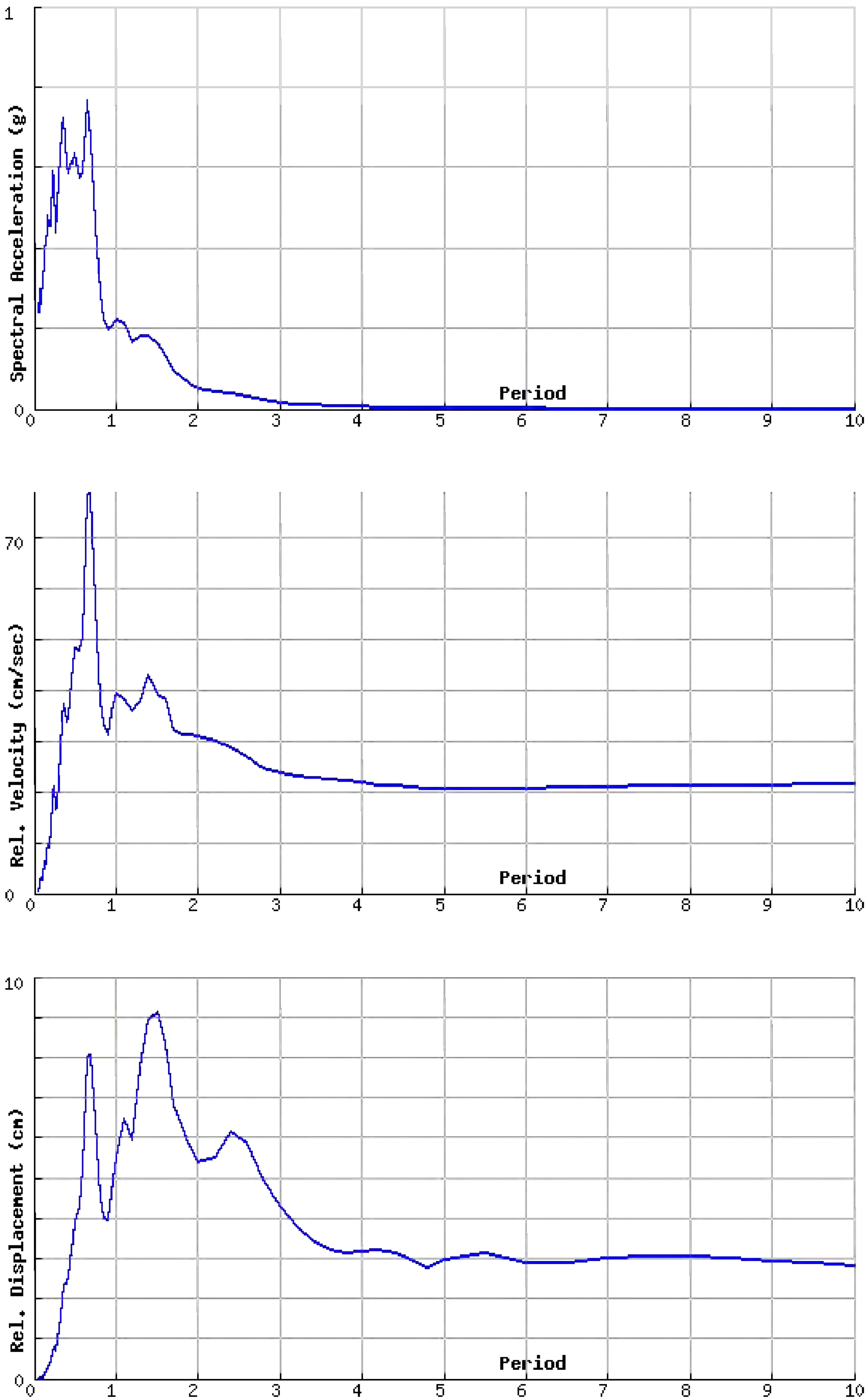
Overlay response spectrum:

- (●) None
- ( ) UBC 1997 Help
  - C_a
  - C_v
- ( ) IBC 2000 or ( ) Ground-motion Help
  - S_{DS}
  - S_{D1}
- ( ) Generic design spectrum Help
  - Max
  - C_a
  - T_1
  - T_2
  - T_3

Redraw

Component: 180 Ground Level **PGA:** -217.70 cm/s/s

Project Mngr: DAB	Project No. 81165060	Terracon Consulting Engineers and Scientists	NISQUALLY EARTHQUAKE DATA
Drawn By: AMP	Scale: AS SHOWN	21905 64th Avenue W., Ste 100 Mountlake Terrace, WA 98043	CAPITOL LAKE DAM
Checked By: DAB	File No. Exhibit G-4C	PH. (425) 771-3304 FAX. (425) 771-3549	Olympia, Thurston County, Washington
Approved By: DAB	Date: October 2016		EXHIBIT G-4C



Project Mngr: DAB	Project No. 81165060
Drawn By: AMP	Scale: AS SHOWN
Checked By: DAB	File No. Exhibit G-4D
Approved By: DAB	Date: October 2016

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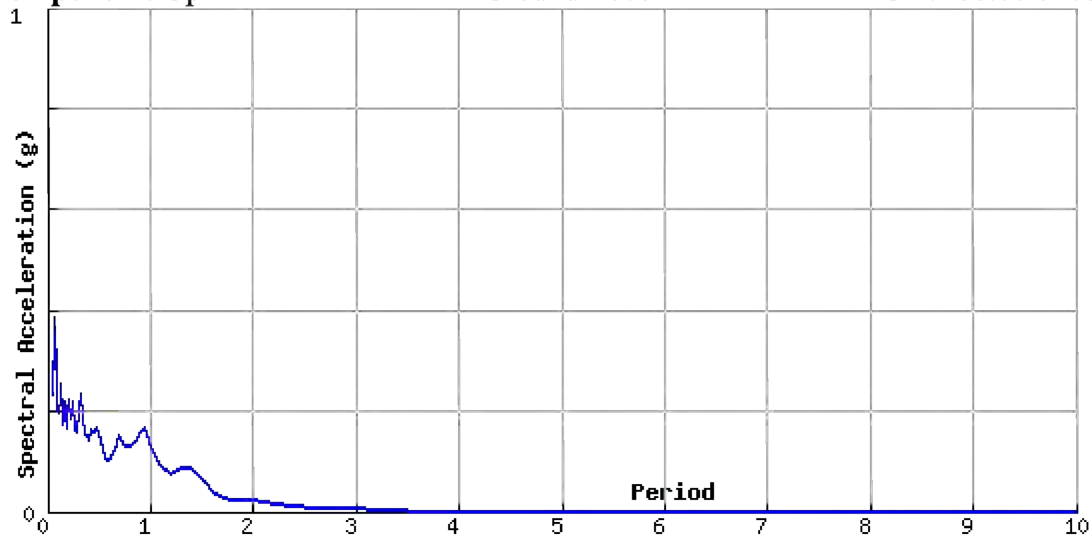
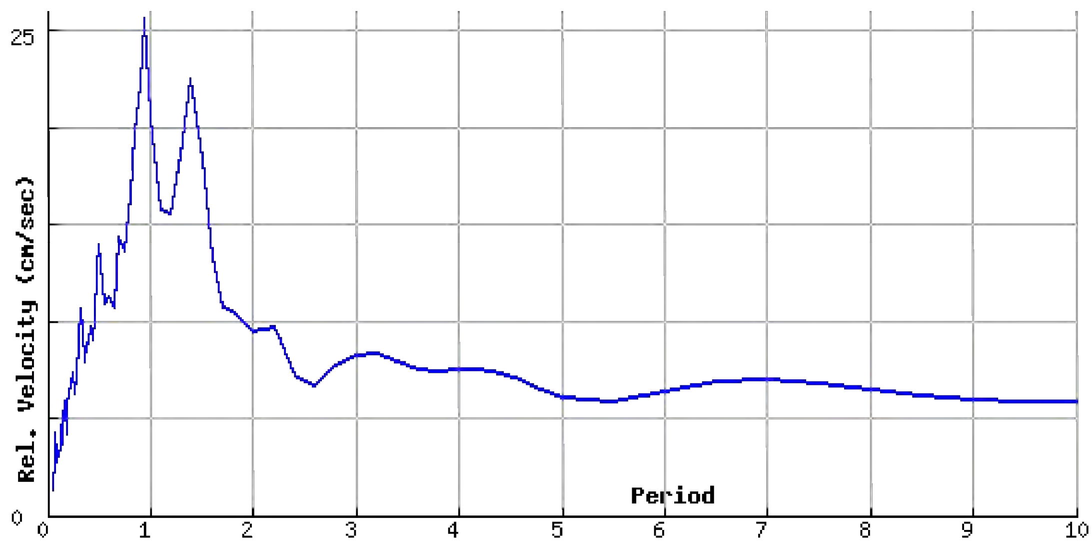
NISQUALLY EARTHQUAKE DATA

CAPITOL LAKE DAM
Olympia, Thurston County, Washington

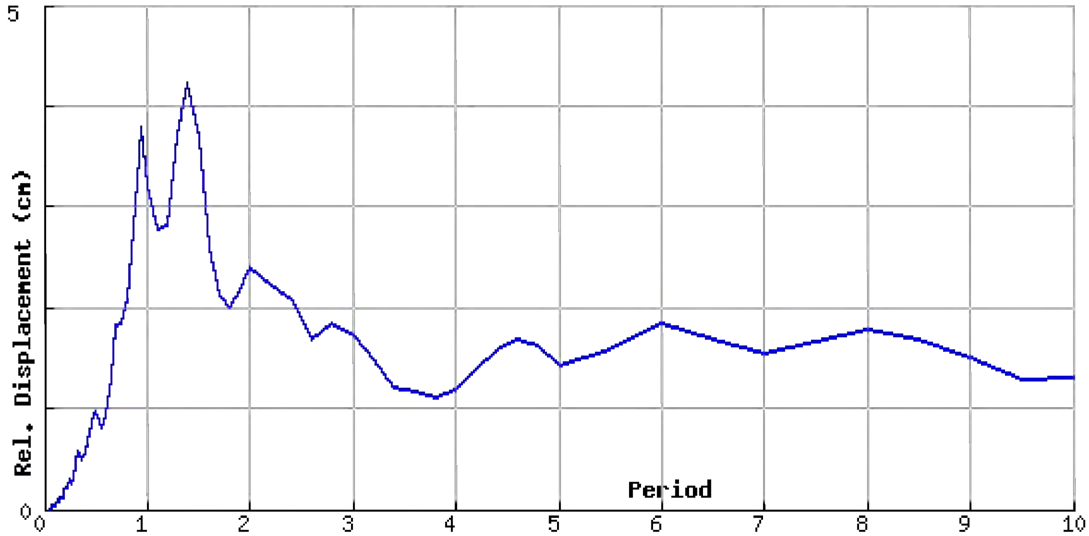
EXHIBIT
G-4D

Component: Up Ground Level **PGA:** -86.00 cm/s/s



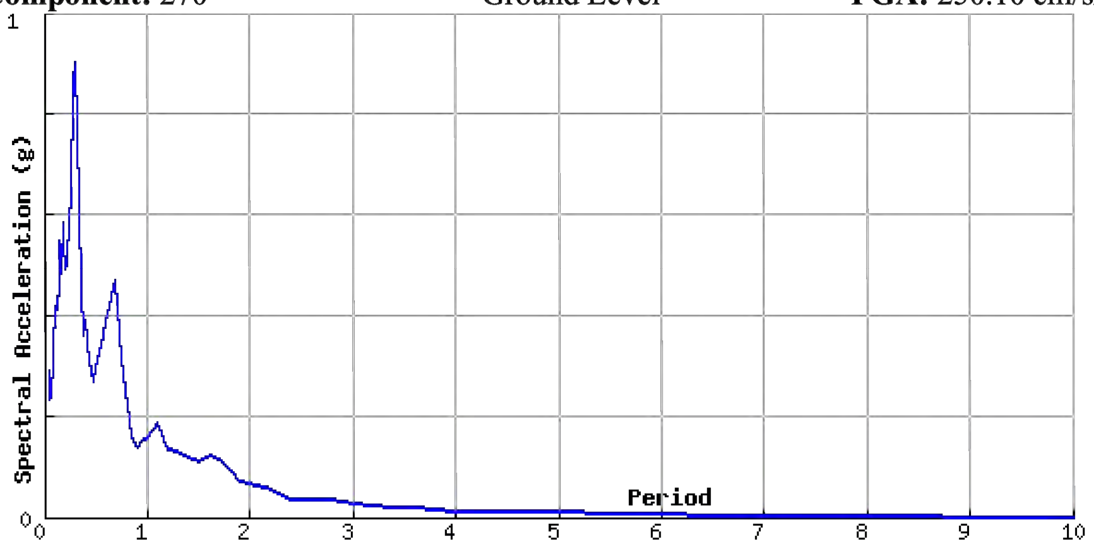


Project Mngr: DAB	Project No. 81165060	Terracon Consulting Engineers and Scientists	**NISQUALLY EARTHQUAKE DATA**	EXHIBIT
Drawn By: AMP	Scale: AS SHOWN		CAPITOL LAKE DAM	
Checked By: DAB	File No. Exhibit G-4E	21905 64th Avenue W., Ste 100 Mountlake Terrace, WA 98043	Olympia, Thurston County, Washington	G-4E
Approved By: DAB	Date: October 2016	PH. (425) 771-3304 FAX. (425) 771-3549		

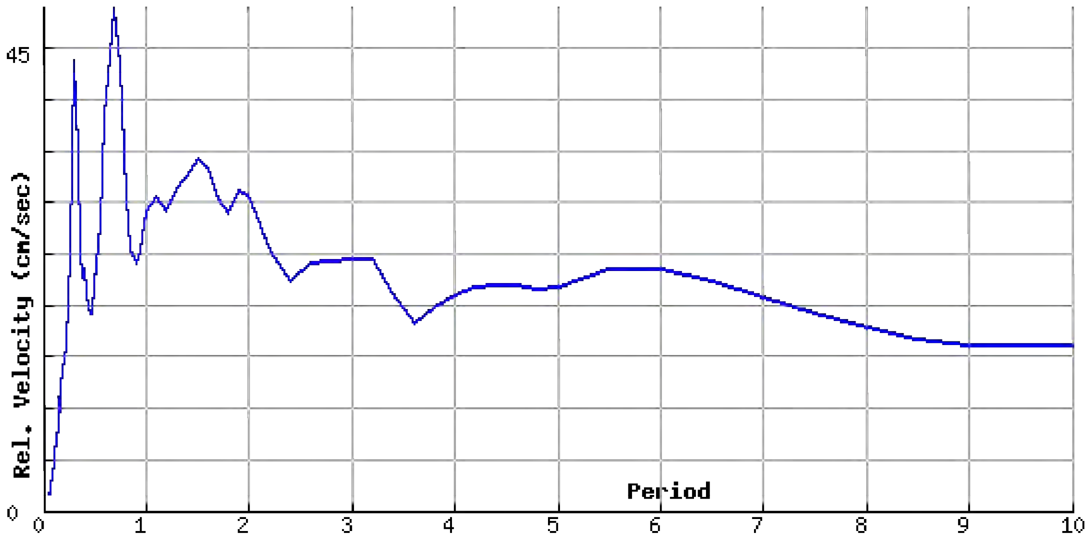


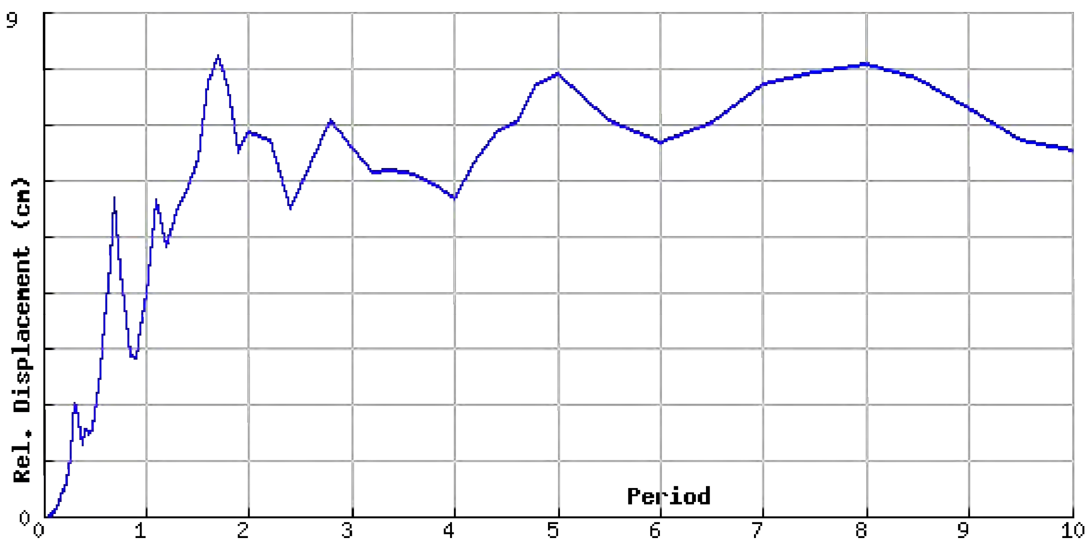
low-cut causal butterworth filter with flc = 0.040 and order = 4

Component: 270 Ground Level **PGA:** 250.10 cm/s/s



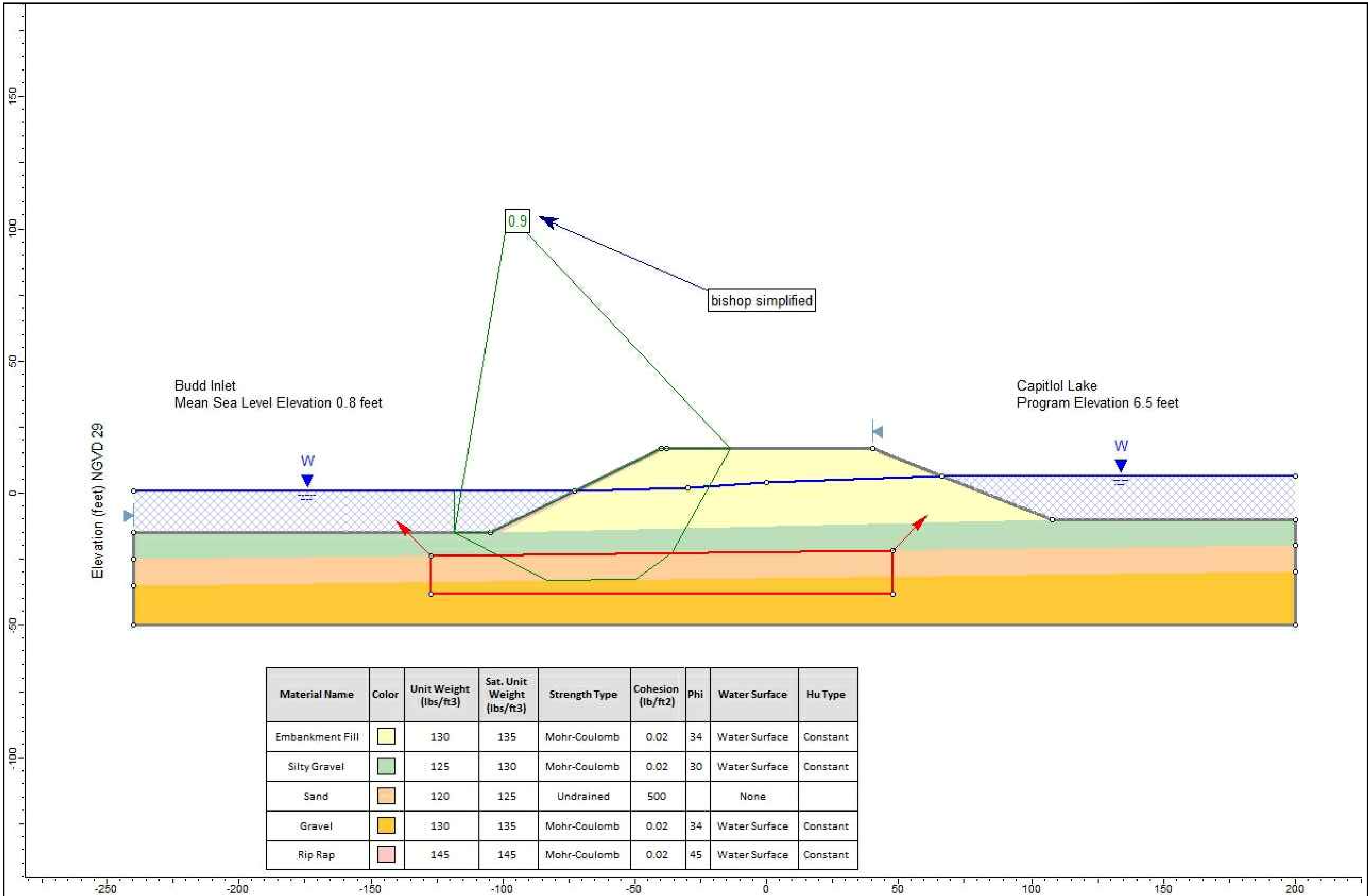
Project Mngr: DAB	Project No. 81165060	Terracon Consulting Engineers and Scientists	NISQUALLY EARTHQUAKE DATA	EXHIBIT
Drawn By: AMP	Scale: AS SHOWN	21905 64th Avenue W., Ste 100 Mountlake Terrace, WA 98043	CAPITOL LAKE DAM	G-4F
Checked By: DAB	File No. Exhibit G-4F	PH. (425) 771-3304 FAX. (425) 771-3549	Olympia, Thurston County, Washington	
Approved By: DAB	Date: October 2016			





low-cut causal butterworth filter with flc = 0.040 and order = 4

Project Mngr: DAB	Project No. 81165060	Terracon Consulting Engineers and Scientists	NISQUALLY EARTHQUAKE DATA	EXHIBIT
Drawn By: AMP	Scale: AS SHOWN		CAPITOL LAKE DAM Olympia, Thurston County, Washington	G-4G
Checked By: DAB	File No. Exhibit G-4G	21905 64th Avenue W., Ste 100 Mountlake Terrace, WA 98043		
Approved By: DAB	Date: October 2016	PH. (425) 771-3304 FAX. (425) 771-3549		



Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (lb/ft2)	Phi	Water Surface	Hu Type
Embankment Fill		130	135	Mohr-Coulomb	0.02	34	Water Surface	Constant
Silty Gravel		125	130	Mohr-Coulomb	0.02	30	Water Surface	Constant
Sand		120	125	Undrained	500		None	
Gravel		130	135	Mohr-Coulomb	0.02	34	Water Surface	Constant
Rip Rap		145	145	Mohr-Coulomb	0.02	45	Water Surface	Constant

Project Mngr: DAB	Project No. 81165060		
Drawn By: AMP	Scale: AS SHOWN		
Checked By: DAB	File No. Exhibit G-5		
Approved By: DAB	Date: October 2016		

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Consulting Engineers and Scientists

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POST-LIQUEFACTION SLOPE STABILITY

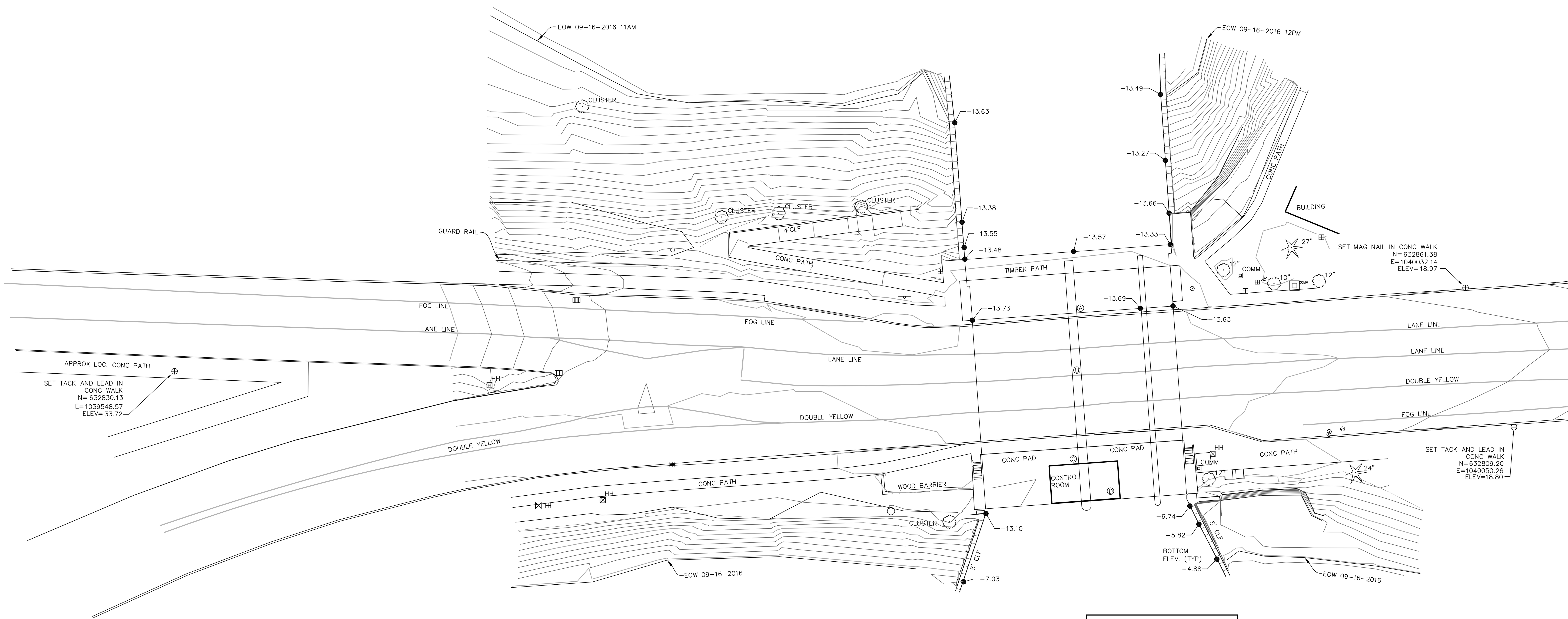
CAPITOL LAKE DAM
Olympia, Thurston County, Washington

EXHIBIT
G-5

APPENDIX E – TOPOGRAPHIC SURVEY CAPITOL LAKE DAM

TOPOGRAPHIC SURVEY CAPITOL LAKE DAM

THURSTON COUNTY, WASHINGTON



DATUM CONVERSION CHART PER ABAM DRAWING TITLED "CAPITOL LAKE TIDE GATE REPAIRS PROJECT NO. 92-263H" AND NOAA STATION AT BUD INLET		
CITY OF OLYMPIA	NAVD 88	MLLW
-17.97'	-4.03'	0.00'

ABAM ELEVATION COMPARISON					
POINT	DESCRIPTION	ABAM ELEV (CITY OF OLYMPIA)	PGS INC. ELEV (NAVD88)	DIFFERENCE	Δ*
Ⓐ	TOP OF CONCRETE SPILLWAY	-27.0'	-13.5'	13.5'	0.4'
Ⓑ	CENTERLINE OF 5TH AVE	+6.6'+/-	+20.4'	13.8'	0.1'
Ⓒ	TOP OF CONCRETE PAD	+11.0'	+24.2'	13.2'	0.7'
Ⓓ	TOP OF CONTROL HOUSE	+21.0'	+34.4'	13.3'	0.6'

*WHERE Δ IS THE DISCREPANCY BETWEEN CALCULATED CONVERSION FACTOR AND MEASURED DIFFERENCE BETWEEN CITY OF OLYMPIA AND NAVD 88 DATUMS.

HORIZONTAL DATUM:

THE HORIZONTAL DATUM FOR THIS SURVEY IS NAD 83(11) WASHINGTON STATE PLANE, SOUTH ZONE, BASED ON GPS TIES TO WSDOT MONUMENT GP34005-38 (MONUMENT ID 1037) AND THE WASHINGTON STATE VIRTUAL REFERENCE STATION NETWORK.

VERTICAL DATUM:

THE VERTICAL DATUM FOR THIS SURVEY IS NAVD 88, BASED ON GPS TIES TO A PUBLISHED ELEVATION FOR WSDOT MONUMENT GP 34005-38 (MONUMENT ID 1037)
ELEVATION: 111.069 FEET

SURVEY NOTES:

COMPARING PGS INC. 2016 SURVEY WHICH INCLUDED CONVENTIONAL TOTAL STATION DATA COMBINED WITH HIGH DEFINITION 3-D LASER SCANNING TO THE DRAWINGS CREATED BY ABAM DATED 05-05-1995 YIELDED AN AVERAGE VERTICAL DIFFERENCE BETWEEN THE TWO OF 13.4' WITH EXTREME LOW AND HIGH COMPARISONS AT 13.2' AND 13.8' RESPECTIVELY (SEE TABLE ABOVE). ALL ELEVATION COMPARISONS IN THIS DRAWING DO NOT TAKE INTO ACCOUNT THE POSSIBLE SETTLEMENT OR OTHER MOVEMENTS OF THE DAM.

LEGEND:

- ⊕ MONITORING CONTROL POINT
- ○ SANITARY SEWER MANHOLE
- HH ELECTRIC HAND HOLE
- WATER METER
- WATER VALVE
- CATCH BASIN
- COMM COMMUNICATIONS RISER
- POWER POLE
- GAS VALVE
- TREE (DECIDUOUS)
- TREE (CONIFER)
- CLF CHAINLINK FENCE
- Ⓒ ELEVATION COMPARISON POINT (TYP)

N

GRAPHIC SCALE

0 10 20 40

(IN FEET)
1 inch = 20 ft.
CONTOUR INTERVAL = 1 FEET

REVISIONS

REV.	DESCRIPTION	BY	DATE
1	ADDED ELEVATION COMPARISON TABLE	CMH	10-2-16
2	ADDED DATUM COMPARISON TABLE	CMH	10-27-16

RONNIE G. HILLIARD
STATE OF WASHINGTON
35971
REGISTERED PROFESSIONAL LAND SURVEYOR
2-1-17

PACIFIC GEOMATIC SERVICES, INC.
LAND SURVEYING & MAPPING SERVICES
QUALITY SERVICE - CREATIVE SOLUTIONS
6608 216TH STREET SW, STE. 304
MOUNTLAKE TERRACE, WA 98043
PHONE:(425) 778-5620 FAX:(425) 775-2849
WEB: www.PacGeoInc.com
PGS INC

SHEET TITLE: TOPOGRAPHIC SURVEY CAPITOL LAKE DAM

CLIENT: MOFFET & NICHOL SEATTLE, WASHINGTON

DRAWN BY: CMH
SCALE: 1" = 20'
DATE: 09/28/2016
JOB NUMBER: 16-036-01

CHECKED BY: RGH
DRAWING NAME: 1603601_C3D.DWG
SHEET: 1 OF 1