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TNC - Salmon River Estuary Project

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CIVIL ENGINEERING PROGRAM

CE 483 Senior Design Project I
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Written Report

Project: Salmon River Estuary Project, Portland, OR

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1. INTRODUCTION

The Nature Conservancy (TNC) in Oregon is interested in cooperating with coastal partners to increase awareness of the impact roads have on estuaries and to develop co-benefit projects that improve Oregon's roads, estuaries, and coastal communities. In partnership with TNC, University of Portland Civil Engineering students, Shea Chun, Alyssa Lau, Mustaf Mohammad, Bailey Smithline, and Sean Urabe (Group 5) collaborated with Oregon Department of Transportation (ODOT) and United States Forest Services (USFS) to develop alternatives to improve the aquatic ecosystem of the Salmon River Estuary in Oregon.

1.1 Project Description

The Salmon River Estuary is located near Otis, Oregon, approximately 92 miles southwest of Portland, Oregon. It covers approximately 500 acres of land and is located within the Cascade Head Scenic-Research Area. Group 5's Salmon River Estuary Project focuses on restoring the aquatic ecosystem interconnectivity associated with the portion of US Highway 101 that runs through the southeast part of the estuary. Figures 1 and 2, show the location of the estuary and the project site.

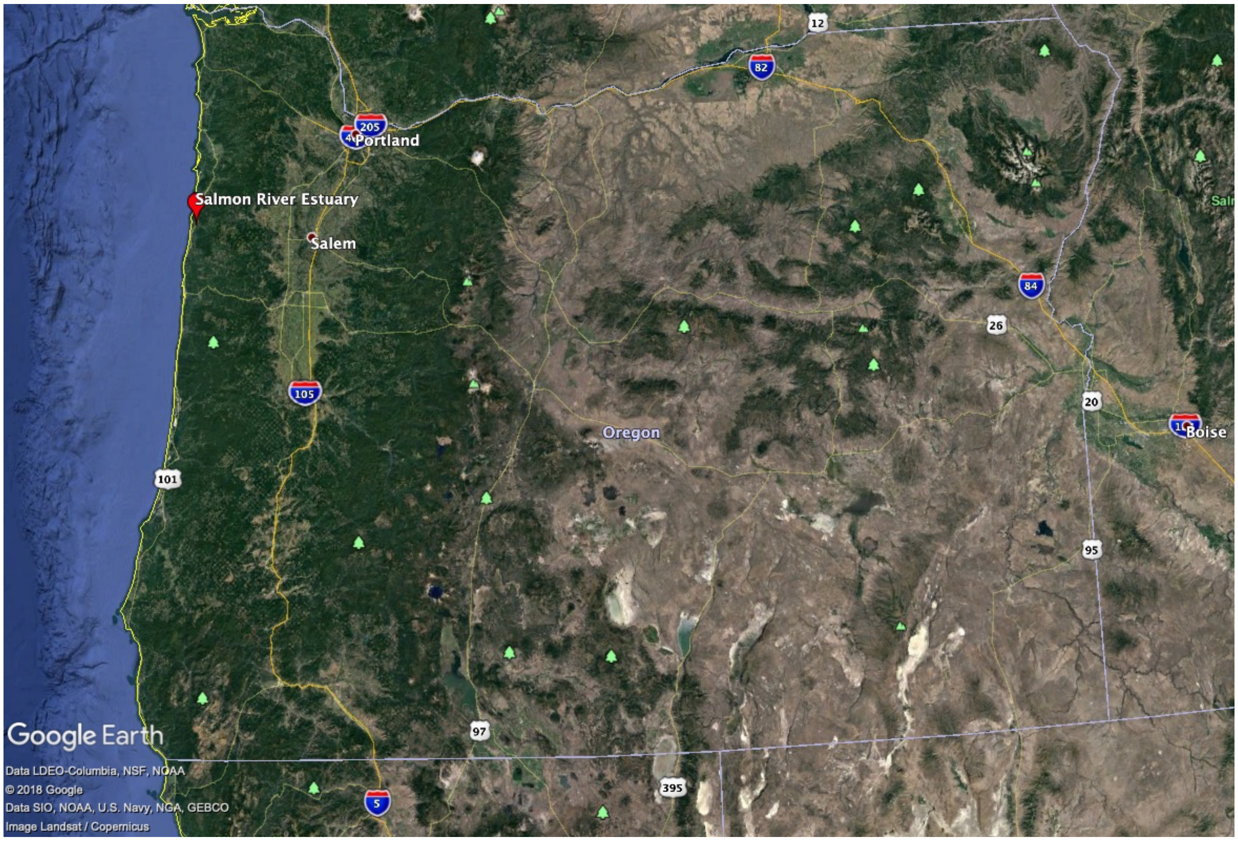


Figure 1. *Location Map-1.* (Google Inc, 2018)

Figure 2. *Location Map-2.* (ArcGIS, 2018)

1.2 Problem Definition

Oregon's estuaries host a wide variety of species of birds, fish, amphibians and mammals. The health of these estuaries is dependent on water connectivity, which distributes nutrients, sediments, and allows for the mixing of freshwater and saltwater. Healthy estuaries have productive ecosystems and protect coastal communities from storm surges, sea level rise, as well as other natural disasters. The health of Oregon's estuaries is being impacted by existing roads or highways that run through or near them. According to a study done by TNC, over 372 miles of roadway run near or cross through an estuary. Of this amount, approximately 18 miles of state managed highways and 165 miles of county/local roads cross through estuaries. These roadways are built on fill or gravel and act as dikes, impacting water connectivity, restricting fish passage, and limiting the amount of habitat available. Additionally, since these roadways are built on fill or gravel, they are vulnerable to earthquakes. Though the roadways are impacting estuaries, they are integral for connecting people and are important in emergency situations. The challenge is to provide safe roadways and minimize their impact on estuaries, while also planning for seismic activity and changes in sea level (Pickering et al., 2018).

1.3 Project Overview and Scope

Our group's Civil Engineering Senior Design Project for the Salmon River Estuary is to formulate, evaluate, and screen potential solutions in order to recommend and design a project to restore the aquatic interconnectivity of the estuary that is impacted by U.S. Highway 101. The highway runs through the southeast portion of the Salmon River Estuary. Our group is also responsible for designing a safe means of transportation by considering future changes in sea level and seismic activity.

The scope of work for this project includes details on project management, survey data analysis, alternative design analysis, cost analysis, engineering report, and final design approach. Project management details the specific project coordination, schedule, memorandums and meetings. Survey data analysis comprises the topographic files of the site provided to our group by the ODOT and USFS. Our alternative design analysis will focus on the following: floating bridge, elevated roadway, multiple culverts, and removing a section of the highway that runs through the estuary. Each alternative will be evaluated by its environmental impacts, constructability, economic aspects and feasibility. Furthermore, we will discuss the impacts of leaving the site in its existing condition.

1.4 Project Report

The intent of this report is to document Group 5's Civil Engineering Senior Design Project for aquatic ecosystem restoration of the Salmon River Estuary in Oregon. This report will explain the background of the project, our design alternative analysis, our design recommendation, and will provide supporting material such as calculations and drawings.

2. BACKGROUND

2.1 History of the Problem and Current Conditions

The Salmon River Estuary has a long history of human use and has been an integral resource for communities. Archaeological evidence shows that Native American villages depended on the estuary as their primary source of food as early as 1020 AD. In 1855, President Franklin Pierce created the Siletz Oregon Coast Reservation that protected areas around Cascade Head, including the Salmon River estuary. However, since 1865, portions of the Siletz Reservation were opened to white settlements. In 1895, the remaining land was opened to settlement. Afterwards, farmers constructed dikes, tidal gates and ditches to create and protect pastures as well as farmland. In 1961, a portion of U.S. Highway 101 was built across the estuary to decrease travel time. Consequently, the highway acted as a dike. It was built with one bridge crossing over the Salmon River and contained no culverts, cutting off the flow of the Salmon and Fraser Creek. The highway and dikes built in the estuary limited the marshes inflow of nutrient rich sediment and ocean water. The diked marshes experienced a 1.13 ft. decrease in surface elevations. The tidal gates cut off accessibility to tidal channels for migrating fish. As a result, by the 1960's, 75% of the lower Salmon River marsh was diked and converted to pastures. In 1965, a recreational park called Pioneer Town was built in the estuary, at the junction of Highway 18 and U.S Highway 101. Later the park became an amusement park called Pixieland, shown in Figure 3, and eventually went bankrupt in 1974 (Anderson et al., 2006 ; Ellingson and Ellis-Sugai, 2014).

Figure 3. *Pixieland*. (Ellingson and Ellis-Sugai, 2014)

The restoration of the Salmon River estuary started with the removal of dikes in 1978. Since then, dikes and tide gates continued to be removed in order to restore the wetlands within the estuary. One notable restoration project was the restoration of Pixieland. Formally known as Pioneer Town, Pixieland occupied 57 acres and was surrounded by a dike, which allowed the site to be developed. A tide gate was also installed at the mouth for Fraser Creek and an RV park was built east of Pixieland. USFS bought both properties in 1982. Restoration of Pixieland and the RV park started in 2007 and the earthwork was completed in 2011. The first part of the restoration in 2007 focused on removing invasive plants and all infrastructure. The second phase in 2011 focused on the hydrologic restoration of the estuary by removing the dikes and creating new stream channels. Currently, the restored land is healthy with tree growth and grass. Figure 4 shows the current conditions of the resorted site (Ellingson and Ellis-Sugai, 2014).

Figure 4. *Restored Pixieland* (Google Inc., 2018)

Currently, most of the dikes and tidal gates built in the 1960's were removed, as a part of the restoration efforts by USFS. U.S. Highway 101 still runs through the estuary for approximately one mile. With only one bridge over the Salmon river, the highway acts a large dike, blocking the distribution of water, nutrients, and sediments. A culverts was added under the highway, southwest of the existing bridge in September 2015, to increase tidal flow and to allow for fish passage in Fraser Creek (Oregon Department of Transportation, 2014). Figure 5 shows the Fraser Creek flowing through the existing culverts.

Figure 5. *Fraser Creek Culvert* (Ellingson, 2018)

There are many disadvantages to using single culverts, including negative impacts to the environment and connectivity for aquatic life. According to the Washington Department of Fish and Wildlife (WDFW) Water Crossing Design Guidelines, culverts that are small with respect to the tidal range affect fish passage, tidal inundation, tidal channel developments and salinity mixing. The portion of Highway 101 passing through the Salmon River Estuary does not currently have enough properly sized culverts to provide sufficient water flows and connectivity.

2.2 Jurisdictional and Regulatory

Due to the environmental sensitivity and location of our project, coordination with the following organizations may be required: USFS, The Nature Conservancy (TNC), U.S. Fish and Wildlife Service, Oregon Department of Fish and Wildlife, National Marine Fishery Service, Oregon Department of State Lands (ODSL), Oregon Department of Transportation (ODOT), Federal Highway Administration (FHWA), Environmental Protection Agency (EPA), and U.S. Army Corps of Engineers (USACE). and the Cascade Head Scenic Research Area.

Coordination with USFS is required since the Salmon River Estuary is located in the Cascade Head Scenic Research Area. USFS is in charge of the Cascade Head Scenic Research Area. The Cascade Head Scenic Research Area is the only Scenic Research site in the United States and was created by congress to protect scenic and environmental qualities of the headland. In the Estuarine and Associated Wetlands Zone, the area is protected for sport fishing, waterfowl hunting, and salt marsh restoration. In addition, USFS owns most of the project area and has past experience with restoration work within the Salmon River Estuary; therefore, coordinating with them will be beneficial. TNC has experience with Oregon's estuaries and is a possible partner for this project. There are some endangered species within the Salmon River estuary that may require coordination with the U.S Fish and Wildlife Service, Oregon Department of Fish and Wildlife, as well as the National Marine Fisheries Service, as these agencies manage, enhance, and protect endangered species. Coordination with ODSL is required, as they issue Right-of-Entry Permits to gain access to tidally influenced lands (Ellingson and Ellis-Sugai, 2014). ODOT owns and maintains U.S. Highway 101 and therefore, any changes made to the roadway will require their approval and designs must meet their specifications. FHWA also has regulations on safety and highway design that should be met. EPA coordination is required since our project area is greater than an acre and will require a National Pollutant Discharge Elimination System (NPDES) permit, which is issued by the EPA (EPA, 2018). The NPDES permit also covers discharge of storm water runoff from construction sites. USACE issues permits for fill removal in a wetland.

Regulatory requirements that apply to this project include the following: Section 401 of the Clean Water Act of 1972, Section 404(b)(1) of the Clean Water Act of 1972. Our project is required to be in accordance with Section 401 of the Clean Water Act of 1972, which requires a water quality certification from the State agency, with any project that involves moving or placing fill in a wetland. Section 404(b)(1) is administered by the USACE which regulates the discharge of dredged and fill material into waters of the U.S., including wetlands. The guidelines for Section 404(b)(1) require that the project is the least environmentally damaging practicable alternative. The least environmentally damaging alternative will not cause or contribute to the violation of applicable state or Federal laws, such as water quality standards or the Endangered Species Act and will not result in significant degradation of waters of the United States. The least environmentally damaging alternative also requires that appropriate and practicable steps are taken to minimize the adverse impacts of the project on wetlands and other waters (U.S. Army Corps of Engineers, n.d.).

Figure 6 is from the "Lower Salmon River Project," a report completed in 2006 by graduate students on the restoration of the Salmon River Estuary. The figure gives an example and visual representation of a few of the relevant jurisdictions and regulations that may apply to the estuary.

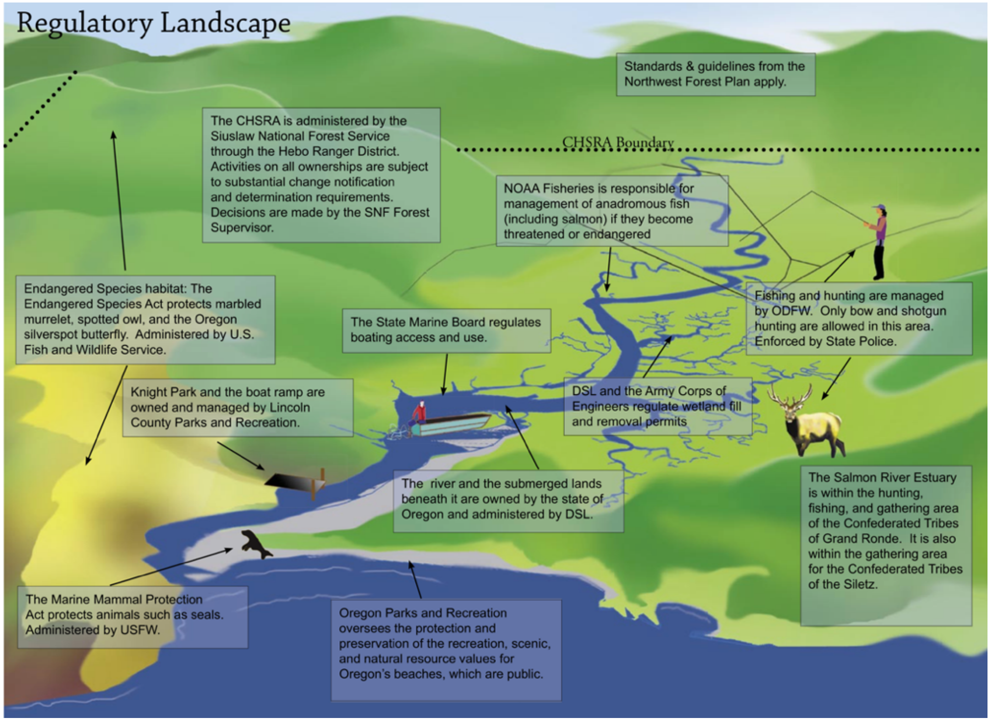


Figure 6. *Regulatory Landscape* (Anderson et al., 2006)

2.3 Environmental Aspects

Estuaries are complicated ecosystems that are home to a wide variety of species. The health of an estuary is dependent of the water connectivity and the mixture of fresh and saltwater. To help restore connectivity, new channels may need to be constructed. Disturbing a large area of the Salmon River Estuary could also affect its health and animals who depend on it. Therefore, project area and grading for our project should be minimized. To not disrupt the migration of fish and animals, time and duration of construction are important factors to consider. For example, the Salmon River Estuary hosts young Coho and Chinook Salmon, which move down to the lower estuary during the summer, where they spend most of their juvenile life (Ellingson and Ellis-Sugai, 2014). Therefore, constructing in the summer is not ideal and should be avoided, due to the high number of fish. ODFW has additional rules about allowable time to do work in streams and estuaries. For the Salmon River Estuary the ideal construction time is between November 1st to February 15th (ODFW, 2008).

By addressing the challenges associated with U.S. Highway 101, our project will improve the overall health of the Salmon River Estuary by increasing water connectivity and flow to help facilitate mixing, as well as restoring tidal influence. Restoring tidal influence is important for improving the salinity gradient, which young salmon rely on, to help transition from salt to freshwater. This will help support and increase the population of the juvenile salmon and other aquatic species. Increasing water connectivity will also increase fish passage and the distribution of nutrients and sediment. These nutrients are important for the development of juvenile salmon and other marine life (Anderson et al., 2006). In addition, increasing sediment distribution will help the estuary to adapt to sea level rise, since sediments coming from upstream will help increase the elevation of the estuary.

2.4 Stakeholders

The stakeholders for this project are TNC, ODOT, USFS, the surrounding community, and recreational users of the Salmon River Estuary. TNC and USFS would like this project to improve the overall health of the estuary by restoring water connectivity. In addition, TNC would like our project to applicable to be other similar impacted estuaries in Oregon. ODOT would like a safe and functional road that meets their design and safety specifications. Furthermore, ODOT and TNC would like the roadway to be accessible during emergency situations, such as earthquakes. Recreational users and the community utilize the Salmon River Estuary for activities such as kayaking and fishing. They would like to still have access to the Salmon River Estuary and to the coast. Parties interested in the project could include the United States Fish and Wildlife Service, Oregon Department of Fish and Wildlife, Federal Highway Administration, and private landowners.

2.5 Political and Societal Aspects

Our design recommendation is based on the desires of the different stakeholders, as noted previously. The Salmon River Estuary is a highly used and visible area, the public has concerns about the protection of the area and recreational use. In the community, there are some people who would like additional recreational development in the estuary and there are others who would like to enhance the protection of it (Ellingson and Ellis-Sugai, 2014). Early education and communication with all stakeholders and the community is important.

The traffic volume along the existing highway is low; therefore, closing the highway for construction should not be an issue. Additionally, during the construction of the project, a detour route will be provided for motorists.

Since our project is a restoration effort, similar to past restorations by USFS, potential funding sources for this project may include the following: Oregon Watershed Enhancement Board, USFWS Coastal Wetland Grant Program, Oregon Department State Lands, ODOT, and Siuslaw National Forest (Ellingson and Ellis-Sugai, 2014).

2.6 Global Factors

With climate change, the amount of greenhouse gases entering the atmosphere will increase temperatures. Average annual temperatures for the Pacific Northwest are expected to increase by 3.2 °F by the 2040's and 5.3 by the 2080's. This increase in temperature will cause sea levels to rise. With the current greenhouse gas emissions rate, global sea levels are expected to rise by at least 3ft by the end of the century. Although local sea level rises are variable, it will greatly affect Oregon's estuaries. Figure 7 shows inundation levels with a one-foot rise in sea level and Figure 8 shows the inundation levels with a three-foot rise within the Salmon River Estuary.

These figures from U.S Climate Resilience Toolkit, Climate Explorer, show the significant increase in the amount of water within the estuary as sea levels increase. Therefore, in order to be prepared for the increases in sea levels, our design will be considering at least a five-foot rise in sea level. In addition to sea level rises, climate change is anticipated to increase the intensity of rain storm events. Current trends suggest that in the future, frequency of precipitation will decrease, and rainfall intensity will increase. To account for the increased intensity of precipitation, our design will account for a 100-year storm event. The number of coastal storms is also predicted to increase due to climate change. Large coastal storms bring powerful storm surges and heavy precipitation which will raise water levels in the estuary. Ultimately, coastal storms reshape estuaries and therefore, we are designing for the worst-case scenario (Oregon Department of Fish and Wildlife, 2013). Figure 9 from the Sea Level Rise Exposure Inventory shows the predicted 2050 inundation levels for the Salmon River Estuary and anticipates both coastal flooding and sea level rise.

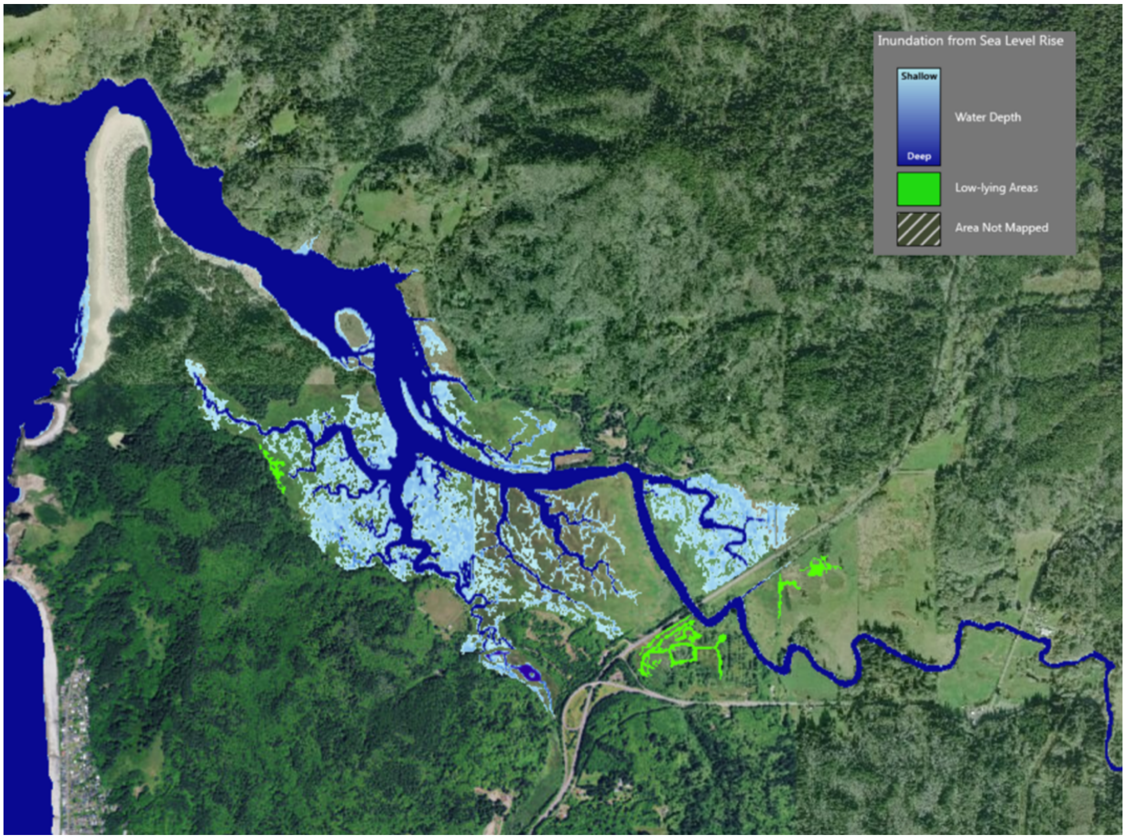


Figure 7. *One-Foot Rise in Sea Level*. (U.S. Federal Government, 2018)

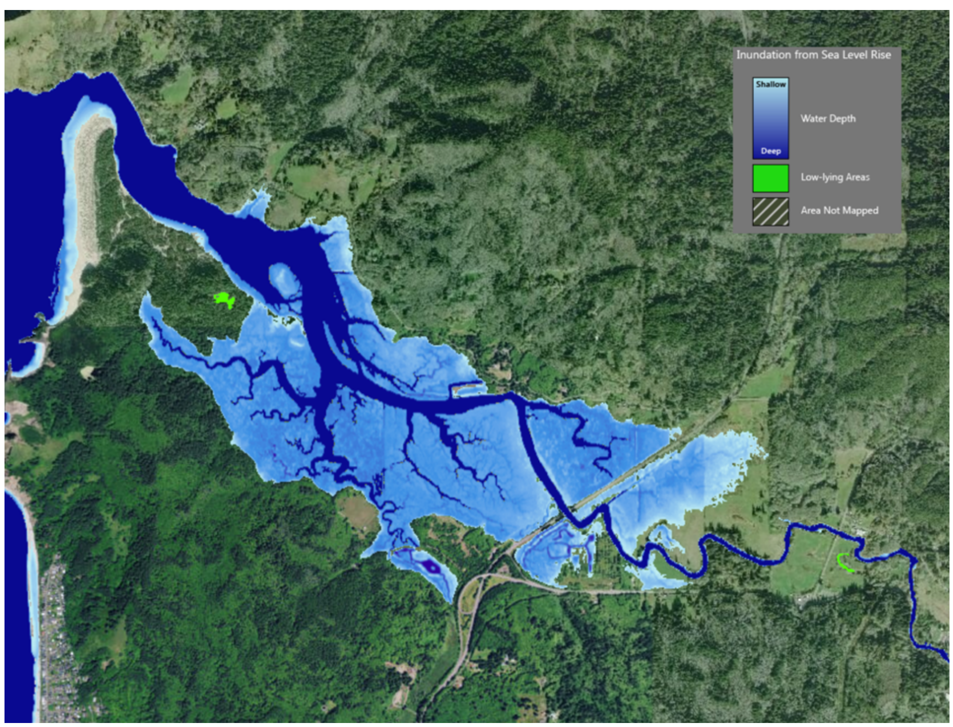


Figure 8. *Three-Foot Rise in Sea Level*. (U.S. Federal Government, 2018)

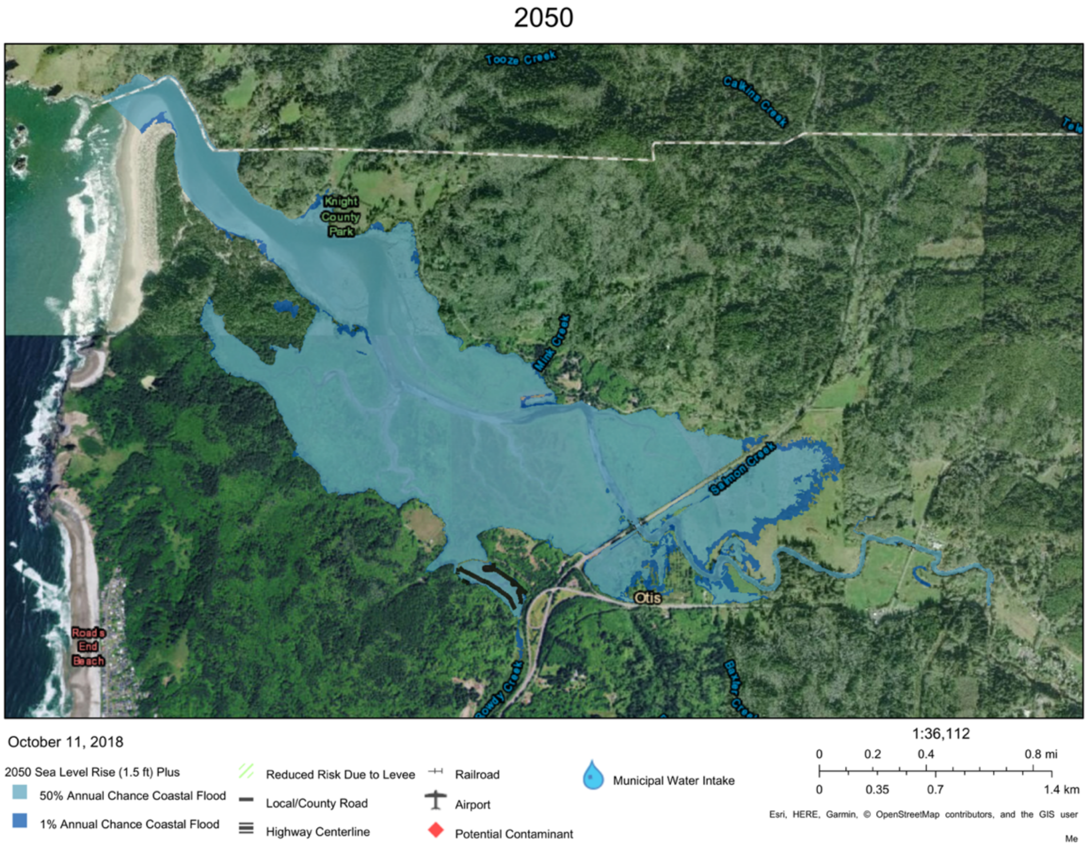


Figure 9. *Year 2050 Sea Level Rise (1.5ft) and Annual Costal Flooding.*
(NOAA, 2018)

Future seismic activity must also be considered in our design. In the future, Oregon could experience a 9.0 magnitude earthquake caused by seismic activity in the Cascadia Subduction Zone, a 600-mile fault stretching from northern California to British Columbia. Scientists are currently predicting roughly a 40% chance that a magnitude 9.0 or higher, earthquake will occur within the next 50 years. Currently, the portion of U.S highway 101 running through the estuary is vulnerable to earthquakes and liquefaction, since it is built on fill made of native soil and gravel. Our design will ensure that proper material is used to avoid liquefaction and the recommended design will be structurally sound in the event of an earthquake (Office of Emergency Management, n.d.).

2.7 Constructability and Economic Aspects

A formal budget was not given to us by TNC. We understand that the more benefits our project has, the more funding our project will receive. We acknowledged that regardless of the alternative, the project will be expensive due to the magnitude of the project and the environmental sensitivity of the Salmon River Estuary. Due to the environmental sensitivity of the estuary, construction may pose a challenge because special techniques may be required to minimize environmental impact. In addition, choosing equipment that will have the smallest impact on the land is an important part of this project. According to the report by USFS, working in marshes requires low ground pressure machines to minimize soil compaction and displacement. In addition, wheeled machines cause rutting and are not ideal for work in marshes (Ellingson and Ellis-Sugai, 2014). In order to reduce rutting from equipment, debris mats should be used. Construction practices should follow Chapter 4: Construction Practices for Environmental Stewardship of AASHTO's, Compendium of Environmental Stewardship Practices in Construction and Maintenance (Center for Environmental Excellence, 2004).

2.8 Data Collected

TNC has provided our group with three different reports. The first report, *Where Road Projects Could Improve Oregon's Estuaries and Benefit Local Communities*, is a study done by TNC and discusses the locations in Oregon where road projects could benefit estuaries as well as communities. According to the study done by TNC, the Salmon River Estuary is the third most vulnerable estuary. This vulnerability is associated with tsunamis, seismic life-line route vulnerability and sea-level rise inundation risk. The second report, *Lower Salmon River Project*, discusses a study conducted by graduate students and their recommendations for the Salmon River Estuary's restoration. The last report provided to us by TNC was, *Restoring the Salmon*

River Estuary Journey and Lessons Learned Along the Way, which discusses the lessons learned from recent and past Salmon River Estuary restoration efforts. ODOT has provided us with plans of the existing Fraser Creek culvert, a geotechnical report of the borings done for the existing culvert and AutoCAD files of the existing roadway. The geotechnical report discusses the composition and strength of the soil. Traffic information for the mile of Highway 101 running through the estuary was found through ODOT's ArcGIS. Lidar of the Salmon River Estuary has been downloaded from State of Oregon Department of Geology and Mineral Industries website. USFS has provided our group with a hydraulic report for the Salmon River Estuary and HEC-RAS files.

3. Scope of Work

TASK 1. PROJECT MANAGEMENT

The team provided information about the direction and coordination of the project to TNC throughout the course of the project.

Subtask 1.1 Project Coordination

The team communicated with TNC via, telephone, email and facetime meetings throughout the duration of the project. Meeting record documentations have been kept and are in Appendix B.

Subtask 1.2 Project Schedule

The team developed a project schedule and continually updated the schedule throughout the course of the project. Schedules were provided to TNC regularly and upon important updates.

Subtask 1.3 Progress Memorandums

The team provided biweekly progress memorandums to Dr. Inan and Dr. Cara Poor. See Appendix G.

Subtask 1.4 Meetings

The team has scheduled, and conducted meetings as follows throughout the duration of the project:

- Biweekly meetings with faculty advisor Dr. Poor
- Biweekly Meetings with industry advisor Ms. Pickering from TNC

TASK 2: SURVEY

Preexisting topographic files was provided by Oregon Department of Transportation and Forest Service. Topographic files will include:

- Elevations of existing roadway
- Information on existing bridge

- Contours
- Flow Data

Additional necessary information was collected through site visits.

TASK 3: ALTERNATIVE ANALYSIS

A total of four alternatives was analyzed. The alternatives are a floating bridge, an elevated roadway, having multiple culverts, and removing the section of highway running through the estuary. The analysis of each design included the discussion of environmental impacts, feasibility, constructability, and economic aspects. A cost estimate was done for the recommended alternative. A discussion of leaving site as is has been included.

TASK 4: DESIGN APPROACH

Based on alternative design analysis, the final recommended design for the Oregon Salmon River Estuary Connectivity Project is having multiple culverts in series. This alternative will entail designing culverts, culvert foundation, culvert placement and alignment as well as providing a hydraulic restoration plan, rerouting traffic,. The design includes:

- Discussion of the scope of work, processes, or systems used for the design.
- Design standards that were used.
    - ODOT Hydraulic Manual
    - Washington Department of Fish and Wildlife (WDFW) Water Crossing Guidelines
- Summary of the completed design.
- Design figures and hydraulic calculations
    - Manning's Equation to calculate max flow and velocity
- Description of modern engineering tools used.

- Recommended hydraulic restoration plan
- Recommended traffic control plan

Subtask 4.1 Design Drawings

- Plan and Profile view of project
- Section view of roadway
- Section view of Culvert
- Traffic control placement
- Comprehensive view of design

Subtask 4.2 Final Design

AutoCAD drawings of the final design was submitted to The Nature Conservancy by (April 28, 2018). Calculations used are included.

Subtask 4.2 Deliverables:

- Electronic copy of AutoCAD plans (PDF)
- Hydraulic restoration recommendations
- Traffic control recommendations
- Recommended design specifications (PDF)
- Cost estimate (PDF)

TASK 5: DESIGN SCHEDULE

See Figures 28 and 29 in Appendix A.4 for a tentative project schedule. The team has worked on an alternative analysis between August and December of 2018 and submitted chosen alternative at the end of December. The design phase was between January and April of 2019. Final design recommendations were delivered at the end of April.

TASK 6: COST ANALYSIS

A detailed cost estimate of recommended final design is provided. It entails cost of materials, labor, mobilization, design, construction and will include a 20% contingency. The Nature Conservancy did not provide a project cost estimate. A proposed budget was determined by the team.

TASK 7: ENGINEERING REPORT

We have provided a detailed report on our design recommendations for the Salmon River Estuary to The Nature Conservancy. This report includes:

- Introduction to the Project
- Project Background
- Design approach and Design Alternatives Evaluation
- Design of Recommended Alternative
- Discussion and Project Conclusion
- Meeting Minutes and Meeting Agendas
- Drawings
- Progress Memorandums
- Project Team Contract
- Miscellaneous

RELATED ITEMS THAT WILL NOT BE PERFORMED OR DELIVERED

The following items are outside the scope of work:

- Ecological restoration recommendations
- Erosion Control Plans

4. DESIGN APPROACH

To restore connectivity to the Salmon River Estuary the following designs were considered and researched:

- Elevated Roadway
- Floating Bridge
- Multiple Culverts
- Highway Removal and Rerouting

4.1 Alternative Design Analysis

Each of our design alternatives requires the removal of the existing mile-long segment of U.S. Highway 101 through the Salmon River Estuary. Therefore, the feasibility of each design alternative will be evaluated based on the design and construction of the structure on its own.

4.1.1 Keeping Existing Conditions

Keeping the existing project conditions, the health of the Salmon River Estuary may continue to degrade. The mile of U.S Highway 101 will continue to impact water connectivity and the distribution of nutrients that aquatic life in the estuary depend on. Currently, the highway is not designed to adapt to sea level rise or increases in coastal flooding. In addition, the current composition of the highway is vulnerable to liquefaction in the event of an earthquake. We will not be considering this as an alternative.

4.1.2 Elevated Roadway

Aside from completely removing the section of highway that runs through the Salmon River Estuary, the elevated roadway option produces minimal damaging impacts on the health of the estuary. This design alternative has already been implemented in estuaries across the world such as the Broadmeadow Estuary in North Fingal, Ireland shown in Figure 10. The Nature Conservancy emphasized the importance of water connectivity within the Salmon River Estuary. Since the roadway will be elevated and not built on fill, but on concrete piles or beams, the possibility of water flow from the north side of the highway to the south side of the highway will be increased substantially. Vegetation and plant species within the estuary are important to its rich ecosystem. While an elevated roadway can restrict sunlight exposure to vegetated areas directly below the structure, an arc shape design would minimize the affected area (Wilcox, 2016). One additional harmful impact to consider from this design alternative is the possibility of metal contaminants from brake pads of vehicles passing over the estuary. These contaminants could migrate from the elevated roadway into the estuary. Sock filters or cartridge filters are a viable option for treating runoff from the elevated roadway. These filters would be beneficial in reducing contamination in the estuary. An elevated roadway will provide a greater distance from the ground of the estuary to the traveling vehicles over the estuary, which could help reduce potential pollution. Considering the benefits and disadvantages of the elevated roadway design alternative, one can see that it is an ideal option because it continues to allow vehicle travel through the estuary while minimizing the environmental impacts.

Figure 10. *Broadmeadow Estuary, North Fingal* (Caffery et. al. 2003)

The current geotechnical conditions of the Salmon River Estuary create challenges to establishing structures in the estuary. Based on the conditions of the soil at specific locations, certain piles or weight bearing portions of the roadway will have differing depths. The variability of soil conditions might also cause conflicts in construction timeline and a schedule should be made to accommodate for these difficult conditions. Additionally, we acknowledge that the salt water from the estuary could be corrosive to certain materials of an elevated structure; therefore, there must be certain limitations on the materials used. We recommend a design that does not incorporate steel because of the possible corrosion and maintenance problems. Preserving the conditions of the estuary poses another challenge to the constructability of an elevated roadway. To minimize the impacts on the estuary, the construction zone cannot span too far into the estuary. Smaller equipment is necessary to accommodate for a small construction zone (Wilcox, 2016).

As an alternative design, an elevated roadway is expected to be the most expensive alternative. Elevated roadways require more structural components and geotechnical considerations than floating bridges, culverts and removal of the highway. Additionally, we expect an elevated roadway to require more structural concrete which costs about $725/yd^3 (WSDOT, 2016). By using precast structural components, we could expect to reduce the amount of construction time, therefore minimizing the cost of manual onsite labor. Similarly, manufacturing and installation of precast concrete components will be less dependent on weather and site conditions which can be beneficial to an efficient construction schedule (Metromont, n.d.).

A budget has not been set for the project. However, the cost of this design alternative will be appropriately weighted in our decision matrix. Based on other similar designed roadways, we estimate that this alternative will cost at least $150 million. By acquiring a great amount of funding from public sources and stakeholders to increase the possible project budget, an elevated roadway can be feasible.

4.1.3 Floating Bridge

Another alternative for improving the connectivity of the Salmon River Estuary is a floating bridge. The purpose of a floating bridge is to provide a route of transportation across an obstacle, such as a body of water. Floating bridges or pontoon bridges have been historically used for military purposes but have recently become a modern and widely-used transportation system. Floating bridges are mostly applicable across large bodies of water that span approximately 2-5km with a depth of 30-60m and have a soft bottom bed extending approximately 30-60ft. An example of a floating bridge is the Evergreen Point Floating Bridge in Seattle, Washington, shown in Figure 11 below (Encyclopedia Britannica, 2018).

Figure 11. *Evergreen Point Floating Bridge* (WSDOT, 2018)

Floating bridges are reliant on the buoyancy of the water to support its weight. The weight of the water displaced by the pontoons equates to the weight of the structure itself (WSDOT, 2018). These bridges are constructed on pontoons, or large, watertight structures filled with air, which are placed side by side to form a continuous structure or placed across a larger structure or superstructure. The floating bridge also consists of a structural and anchoring system which provides proper positioning for the pontoons. Instead of large structural supports, a floating bridge implements a cable and anchor system. The cables, which are buried into the bottom bed of the body of water, are attached to the pontoons in order to keep the pontoons in place. The pontoons and structural components of the bridge may be made of concrete, wood, or steel. Concrete is most commonly used for its durable properties, including corrosion resistance, fire resistance, and dampening characteristics. Floating bridges may also have moveable components for the passage of ships or boats. As with any other transportation system, a floating bridge requires maintenance to prolong the life of the project. However, a floating bridge doesn't require any further maintenance as compared to a standard bridge or roadway (Chen and Duan, 2000).

Regarding improving the connectivity of the Salmon River Estuary, a floating bridge is an appropriate alternative. Because a floating bridge rests on the surface of the body of water it spans across, a floating bridge minimizes its environmental impact. Water and aquatic life are able to move freely beneath the pontoons and between the cables, which would increase the connectivity of the estuary. In addition, floating bridges are able to adapt to tidal changes and flooding. This characteristic allows the portion of Highway 101 that spans across the estuary to be useable year-around, including during emergencies. Moreover, floating bridges are less prone to damages from earthquakes, particularly because of the unique structure of the bridge. Lastly, a floating bridge is an opportune long-term investment. Floating bridges are often less costly than other bridges, particularly because of their lack of large structural components. Additionally, flooding expenses that often occur with cut and fill roads will be avoided with the implementation of a floating bridge (Climate-ADAPT, 2015).

The implementation of a floating bridge is not without its concerns. During the summer months, the estuary is mostly dry, in which the bottom bed of the estuary is exposed. In this case, the floating bridge would rest upon the bed or bottom of the estuary. As mentioned in an earlier paragraph, there is currently one bridge and one culvert located along the portion of Highway 101 crossing the estuary. These current conditions provide more connectivity of the estuary than a floating bridge would in the event that the floating bridge did rest on the bed of the estuary, which is a probable occurrence in the summer months. The floating bridge will also be an obstacle to boaters and recreational users who fish or explore the estuary. Without a moveable component to allow the passage of small boats, users will not be able to freely move about the estuary. In addition, windstorms and waves pose a large threat to floating bridges. Although the weather near the site location is particularly calm, in regard to winds and waves, throughout the estuary, it is important to consider the possibility of waves and winds. Pontoons can be severely damaged in wind and wave storms, which may lead to the infiltration of water into the pontoons, resulting in the sinking of the floating bridge. Furthermore, tsunamis and smaller waves such as seiches can create underwater landslides, affecting the anchoring system positioning the bridge's pontoons in place (Climate-ADAPT, 2015).

Additionally, a budget has not been decided for the project. By acquiring a great amount of funding from public sources and stakeholders to increase the project budget, a floating bridge becomes even more feasible. Based on other similar designs, a floating bridge of this magnitude would cost approximately $100 million.

4.1.4 Multiple Culverts

Constructing multiple concrete box culverts in series along the highway will encourage mixing and resolve the issue of connectivity (WDFW, 2013). Figure 12 shows an example of multiple box culverts in series on a smaller scale.

Figure 12. *Multiple Box Culverts.* (Hudson Civil Products, n.d.)

The benefits of having multiple box culverts are similar to having a bridge or an elevated roadway. The use of multiple culverts increases and maximizes the amount of space underneath the roadway, allowing for the restoration of historic estuarian channels and will facilitate the creation of new channels. This will allow for sediment and nutrient distribution that is crucial for the functioning of a healthy estuary (WDFW, 2013). In addition, the culverts will increase the amount of fish passages by providing a fish-friendly route of transportation, while maintaining natural creek substrate and streambed conditions (University of Wisconsin-Extension, 2018).

Installation of multiple concrete culverts, compared to a floating bridge or an elevated roadway, is a more feasible option as each culvert can be pre-casted off site, transported to the site, and installed immediately with ease. This eliminates the time needed for onsite forming, placement, and curing of concrete. In addition, pre-cast culverts can be prefabricated to custom dimensions and is a great option as it will increase constructability. This will decrease the overall time of construction and minimize the effects of construction on the estuary.

While multiple culverts have not been done on such a large scale, we estimate that it will cost less than elevated roadways and floating bridges. The Oregon Department of Transportation cost for the existing culverts was priced at $1.1 million (ODOT, 2014). Based on this price, we estimate the multiple culvert alternative will cost approximately $55 million. The funding for the existing culverts came from ODOT's fish passage improvement initiatives and its modernization program (ODOT, 2018). This initiative demonstrates ODOT's motivation to complete similar projects and suggests that there is potential funding for the Salmon River Estuary.

Multiple culverts are a feasible solution to increase connectivity while keeping construction costs relatively low. The improvements will lead to a more natural condition, resulting in the following:

- Greater fish passage and transportation of sediments and nutrients throughout the estuary.
- Increased flow capacity lowering the risk of flooding.
- Reduction of peak flow velocity during storms.
- Reestablishment of beneficial flow paths within the estuary.

4.1.5 Highway Removal and Rerouting

In this alternative, we are proposing that the mile of U.S. Highway 101 running through the estuary to be removed. This portion is shown in red in Figure 13. As shown in Figure 13, drivers who are traveling north or south who need to use U.S. Highway 101, during and after construction, will need to make a detour onto NE Three Rocks Rd. and connect to the old U.S. Highway 101. Drivers can then use Highway 18 to reconnect to U.S. Highway 101 if they are coming from the north. If drivers are coming from the south, they would follow Highway 18, then old U.S. Scenic Highway 101, then NE three Rocks Rd, and finally back so U.S. Highway 101. This route, shown in yellow in Figure 13, will become permeant once the mile of U.S Highway 101 running through the estuary is removed.

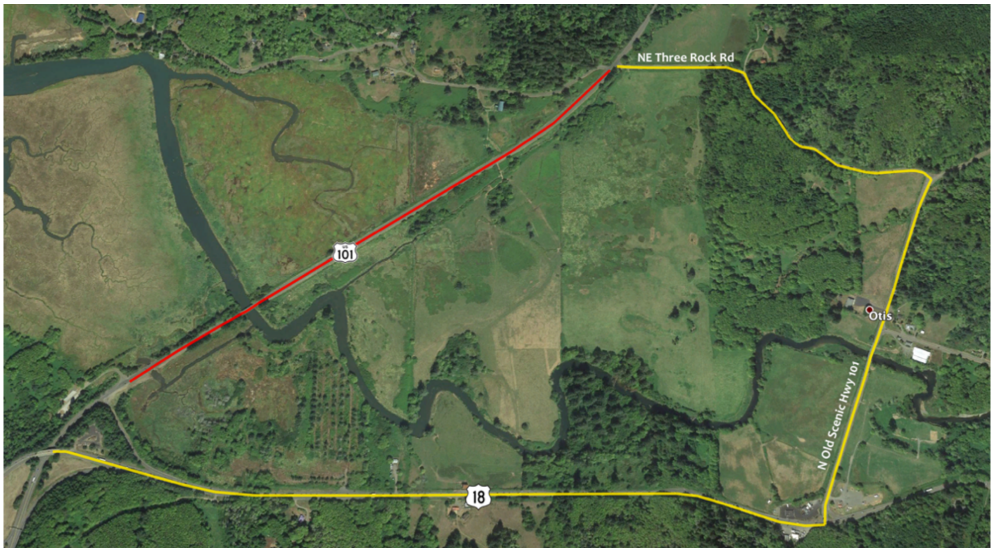


Figure 13. *Detour and Rerouting for U.S. Highway 101*

The average annual daily traffic on this road is between 2,500-5,000 vehicles per hour. Approximately 14% of the average annual daily traffic consists of heavy vehicles. Even if the maximum daily traffic was added the traffic stream of old scenic U.S. Highway 101 and Highway 18, the additional number of vehicles would not warrant any additional lanes. The section of road that NE Three Rocks Rd. will be sharing with U.S Highway 101 will need to be updated to highway standards. According to ODOT, a rural two-lane highway that has an ADT over 2000, and design speed of 55 mph, shall have width of traveled way of 24 ft. The shoulder width shall be eight feet. The highway shall have a maximum grade of 4%, and a degree of curvature of 6°30'. The stopping sigh distance shall be 495 ft. The pavement should have a slope of 2%. The width of the lanes shall be 12 ft in each direction (ODOT, 2012). Additionally, if the additional vehicles from U.S. Highway 101 begins to cause delays and increase the density of traffic on NE Three Rocks Rd, extra lanes would need to be added to accommodate the increase in flow.

The implementation of these alternatives will involve two main stages. The first stage would be updating NE Three Rocks Rd to highway standards. During the first stage, drivers will still be able to use U.S. Highway 101 to access the coast. After, NE Three Rocks Rd is updated, the second stage is to remove the portion of U.S. Highway 101 running through the estuary. During the removal of the highway, the updated NE Three Rocks Rd will be opened for use.

While this option will disturb the estuary in the short term due to construction, in the long term it will allow the estuary to return to its natural state. This option will be the least expensive option as it does not require any structural components and only entails removing the highway as well as updating NE Three Rocks Rd to highway standards. According to the Cost Estimating Guide for Road Construction by United States Department of Agriculture (USDA) Forest Service excavation cost is about $\$2.85/yd^3$ and hauling cost can be around $2.43 per ton (USDA, 2017). These costs may be higher when hauling and disposing asphalt. Additionally, because these amounts are estimates from Montana and Idaho, cost might be higher on the Oregon Coast. This is the most sustainable option because once the removal of the road is finished and the restoration is complete, the site will require minimal maintenance.

The widening of NE Three Rocks Rd is estimated to cost $1.56 million and the removal of Highway 101 is estimated to cost $1.5 million. An interchange at N Old Scenic Highway 101 and Highway 18 may be required for safety and to accommodate for the increase amount of traffic The implementation of this interchange constructed between N Old Scenic Highway 101 and US Highway 18, is estimated to cost $5.85 million. Without the consideration of hauling and material transportation this alternative is estimated to cost about $8.91 million.

For this alternative to be feasible a grade separation; such as an interchange, would need to be implemented at the junction between old U.S. Scenic Highway 101 and US highway 18. This will help motorist move more efficiently in the traffic stream. However, warrants are necessary for an interchange. These warrants are; Design Designation – Fully Access Controlled Facilities, Reduction of Bottlenecks or Congestion, Reduction of Crash Frequency and Severity, Site Topography, Traffic Volume, Road User Benefits – Cost of Delays and Congestion (ODOT, 2012). Currently, we do not meet all of the stated warrants therefore, it does not make sense to use an interchange at this location. There are also space limitations required between interchanges. In rural roadways there must be at a minimum three miles between two interchanges. Due to the existence of a nearby interchange, an additional interchange would violate the space limitations. The final reason why an interchange would currently not work is because of access limitations on the site. For all rural interchanges, accesses shall be controlled at a minimum distance of 1320 feet from the centerline of the ramp. Additionally, no private access should be allowed across from the interchange ramp terminal. Since in this location there is a gas station and a popular local café, we cannot implement an interchange because it would eliminate access. New roads would need to be constructed to allow vehicles to enter and exit the traffic stream on Highway 18 and N Old Scenic Highway 101. The construction of an interchange would also mean that we would have to purchase surrounding properties from the gas station and café. Given these reasons an interchange would not be feasible in this location.

The road is currently used as part of an evacuation route for natural disasters such as tsunamis. Therefore, removing the road, though there are many environmental benefits, the surrounding community will be inconvenienced by an increase in commute time. For these reasons, the removal and rerouting of the highway is not the best option for this project.

4.2 Decision Matrix

A decision matrix was used to evaluate each design alternative based on the following factors; sustainability, cost, maintenance, constructability, environmental impact, stakeholder benefits, safety and global factors. Each category was respectively weighted to have a maximum score of 100. Sustainability was given a max score of 5. Our team believed that sustainability was important to consider, however was not important as environmental impacts. Cost was given a max score of 15, since there is no budget for the project, we acknowledge the importance of seeking out sources of funding. Maintenance was given a max score of 5. This score was allocated because the team believes that post construction maintenance is not of primary concern to the project. Next, constructability was given a max score of 10. This score represents the challenges posed by constructing within an environmentally sensitive area. The largest factor in our decision matrix is environmental impact. The maximum score give to this category is 25. The score was given because the main goal of the project is to improve the health of the Salmon River Estuary. Stakeholder benefit was given a max score of 15 because it is important that the team considers the effects that the project will have on all stakeholders. We acknowledge that we cannot satisfy all of our stakeholders with this project. Safety was given a maximum score of 10. It is important that our design is safe for both the environment and the public. Our last category in the design matrix is global factors. This category received a maximum score of 15 and it entails the alternatives ability to adjust to global factor such as climate change. Our goal for this design is to recognize the challenges presented climate change and natural disasters. As shown in our decision matrix in Table 1, the design alternative with the highest score was the multiple culverts alternative.

Table 1. *Decision Matrix*

Factors	Maximum Score	Elevated Roadway	Floating Bridge	Multiple Culverts	Highway Removal
Sustainability	5	2	3	4	4
Cost	15	5	6	9	10
Maintenance	5	3	3	4	5
Constructability	10	4	3	10	9
Environmental Impact	25	22	15	23	25
Stakeholder Benefit	15	14	10	13	2
Safety	10	9	7	9	9
Global Factors	15	10	12	12	14
TOTAL	**100**	**69**	**59**	**84**	**78**

4.3 Recommended Design

Our recommended design for the Salmon River Estuary is having multiple culverts in series. The work involved with choosing this alternative includes conducting a traffic analysis, providing traffic control recommendations and hydraulic restorations recommendations. Figure 14 gives an idea of how the estuary will look, once this project is implemented. Figure 15 shows the estuary prior to the construction of U.S Highway 101 and it is an example of how the natural channel patterns will be restored after the instillation of the culverts.

Figure 14. *Multiple culverts along Hwy. 101*

Figure 15. *Historic channel patterns.* (Ellingson and Ellis-Sugai, 2014)

5. DESIGN OF RECOMMENDATION

5.1 Design

5.1.1 Culvert Design

For our recommended culverts in series design, we recognized that the time frame for construction is short, as the in-water work period for the Salmon River Estuary is between November 1st to February 28th. Therefore, we have recommended the use of precast culverts, to increase constructability and decrease the duration of construction. For precast culverts, we decided upon Columbia Precast Products (CPP) as they are local to Oregon and Washington. While CPP does custom pre-cast box culverts, it can only be fabricated to have a maximum width of 12 feet. We determined 12 feet was not wide enough to pass potential large debris. Therefore, we decided to choose CPP's pre-cast three-sided bridge with inverted installation. The three-sided bridges can be prefabricated to have a maximum width of 34 feet and with an inverted installation it will mimic a box culvert (CPP, n.d). Therefore, we will continue to refer to the inverted three-sided bridges as box culverts. Figure 16 and Figure 17, shows details of a three-sided bridge with inverted installation.

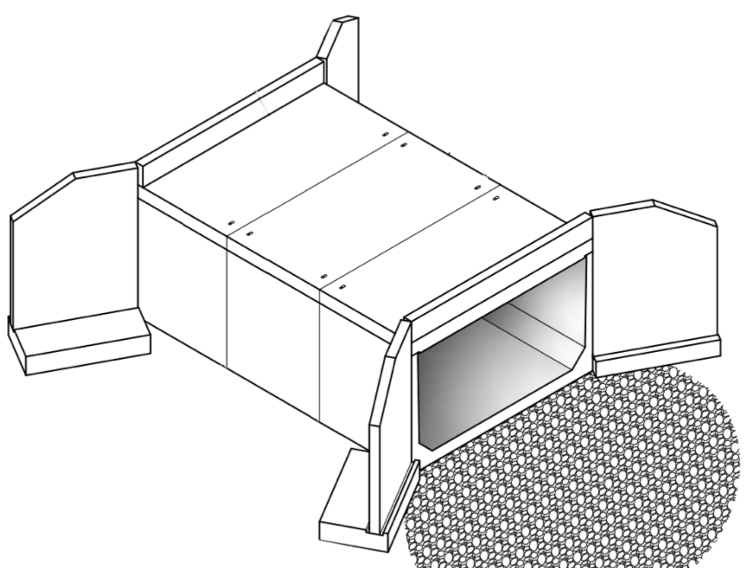


Figure 16. *Three-Sided Bridge- Inverted Installation.* (CPP, n.d.)

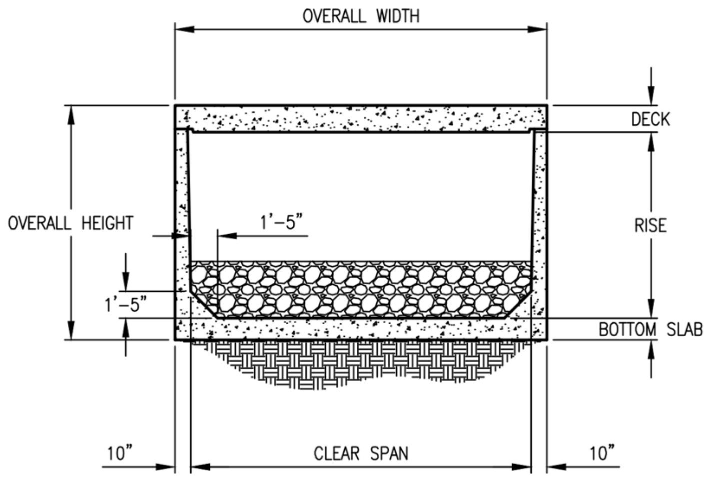


Figure 17. *Three-Sided Bridge- Inverted Installation- Section View.* (CPP, n.d.)

The goal of our recommended culvert design is to maximize the openings underneath the highway in order to restore water connectivity within the estuary. To do this we decided to use with the maximum dimensions that CPP offers for three-sided bridges, which has a 34 feet wide clear span, with a 10-foot rise and a 10 feet long section length. For the bed of the culvert we decided to have 1-foot of Class 50 riprap to address erosion and 2 feet of excavated soil from the estuary, to mimic a natural stream bed. This leaves a 7-foot clearance, between the top of the soil and the top of the culvert, allowing for sufficient maximum flow and adequate space for wildlife to travel under the roadway. Also included in the design is a small channel for low flow in the summer months. The low flow channel was based on the Fraser Creek culvert project. A section view of our designed culvert can be found on sheet C-4 in Appendix C.

The foundation design for the culverts were based on design recommendations made in the ODOT geotechnical report from the Fraser Creek culvert project (ODOT, 2014). Therefore, due to the weak and soft organic tidal deposits, we recommend excavation and replacement of at least 4 feet of material directly below the bottoms of the culverts. The replacement material should consist of compacted structural backfill. Structural backfill consist of earthen material used to create a strong and stable base (American Foundry Society, n.d.). The foundation should also include two layers of geogrid with 24-inch spacing, which will act to reinforce the foundation. There should also be a layer of drainage geotextile to allow for subsurface drainage. The replacement fill, geogrid and geotextile, will help maintain the integrity of the culverts in the event of an earthquake (ODOT, 2014). The location of the geogrid layers and geotextile layer can be seen on sheet C-4 in Appendix C.

The alignment of the culverts will be placed in series with five 10-foot long sections to span the width of the roadway. The placement of the culverts will start at the existing culvert, as indicated by the red line (STA. 0+00) in Figure 18. Then it will end 50 ft. away from the start of the bridge, as indicated by the orange line (STA. 8+56). Culvert placement will start again at 50 feet away from the end of the bridge, indicated by the blue line (STA. 12+56), with the purple line (STA 33+96) showing where the culvert placement will end. The 50-foot spacing between the bridge ends, acts as a buffer zone, to ensure the culverts will not disturb the foundation of the bridge. Profile view of the alignment is on sheets C-5 to C-10 in Appendix C.

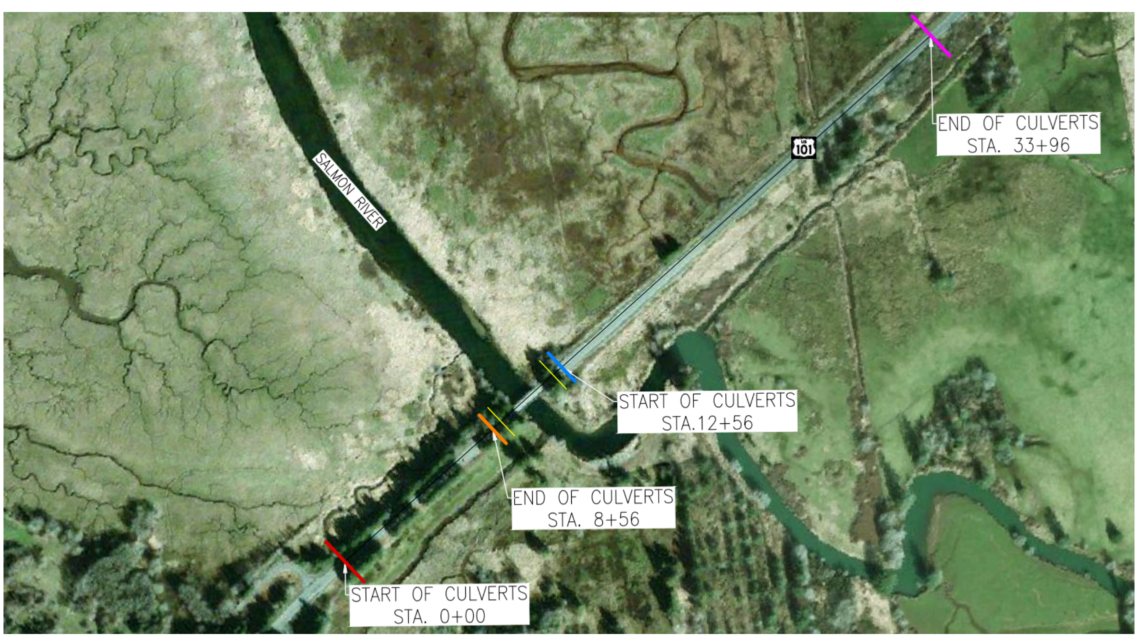


Figure 18. *Location of Culverts*

In the design of the culverts, we factored in aspects such as economic, environmental, social, political, ethical, safety, constructability, and sustainability. To support Oregon's local economy, we decided to choose a local company for the pre-cast culverts. In addition, by choosing a local company the project becomes more cost effective, by reducing transportation costs. To address the need and desires of all stakeholders, we ensured that the culverts would help restore the estuary and would not impede public access. Ethically, by choosing our culvert design alternative we are fulfilling our duty to the public by providing safe transportation, emergency access, access to the estuary, as well as restoring the estuary. To improve the safety of the roadway, our design removes the weak soil that is prone liquefaction and replaces it with structural backfill and geogrid and geotextile reinforcements.

Constructability was also considered in our design as the in-water work period for the Salmon River Estuary only spans four months. Constructability was our main reason for choosing precast culverts, as it can be delivered to the site and installed efficiently. The environmental aspects were our most important factor. In our design, we made sure there was enough clearance for wildlife, such as elk, to pass under the roadway, thereby decreasing the amount of vehicle collisions with animals. In addition, in the design of the culverts, we made sure to maximize the openings to allow for the restoration of water connectivity within the estuary. We have also calculated the maximum velocity for each culvert using Manning's equation, to ensure that the velocity was low enough to support the passage of juvenile fish (WDFW, 2013).

To factor in sustainability in our design, we ensured that each culvert could handle a high amount of flow in a case of an intense storm. To accomplish this, we used Manning's equation to calculate the maximum flow within the culverts (See Appendix D). Climate change was also factored into our design, specifically increases in sea level and inundation levels. Using the Army Corps of Engineers Sea Level Rise Calculator and the nearest gauge, located at Yaquina River, OR, we found that by the year 2100, the Salmon River Estuary would nearly experience a projected maximum of 5.3 ft rise in sea level, as shown Figure 19. As seen in sheets C-5 to C-10 in Appendix C, the elevations of our culvert design would be able to account for the maximum projected sea level rise.

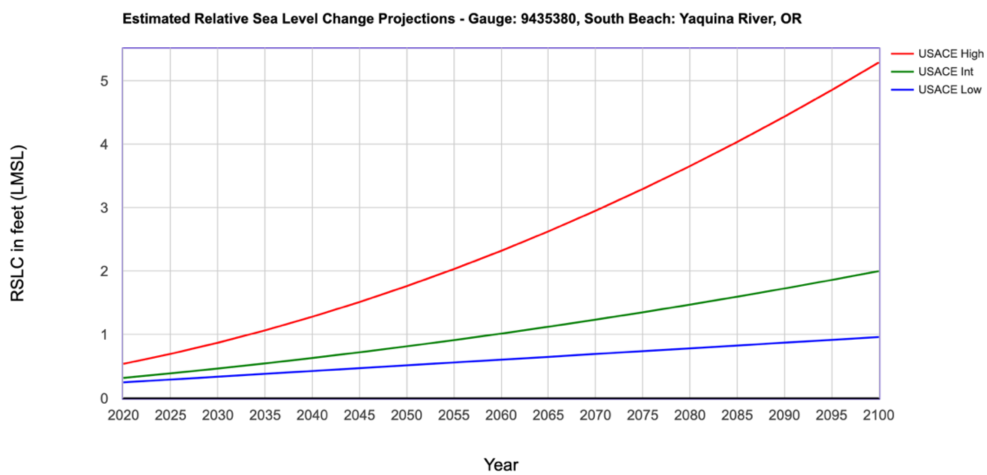


Figure 19. *Estimated Relative Sea Level Change Predication-Gauge 9435380.* (USACE, 2019)

5.1.2 Roadway Design

Since our structure is made of concrete and functions similarly to a small bridge, the pavement can be designed as a bridge deck overlay. ODOT does not have specific specifications and design methods for bridge deck designs; therefore, based upon WSDOT Bridge Deck Paving design recommendations and professional consultations; the roadway will consist of 2 inches of hot mix asphalt (HMA) and 8 inches of aggregate base material (WSDOT, n.d.).

5.1.3 Signage for Traffic Control Plans

In accordance with the Manual on Uniform Traffic Control Devices (MUTCD), three road closed ahead sign will be placed at increments of 500 ft from road closure. Three “Fines are higher” signs shall be placed at increments of 500 ft apart from the road closure to inform drivers that they are entering a work zone. A stop shall be placed where US Highway 101 meets Three Rocks Road. A "Stop sign ahead" sign shall be placed 500ft from the initial stop sign. Detour signs are used at every turning place to direct drivers back on to US Highway 101 using the detour route. Sign heights should be at a minimum of seven feet to ensure visibility. Barricades should be placed at each end of the project site. A reduced speed limit sign will be used on Three Rocks to ensure safe truck travel. Table 2 shows the signage used in traffic control plans. Traffic control plan can be found on sheets C-11 to C-14 in Appendix C.

Table 2. *MUTCD Signs for Traffic Control*

SIGNS	CODE
Stop Sign	R1-1
Stop Sign Ahead Sign	W3-1
Barricade	
Road Closed Sign	R11-2
Speed Limit Sign	R2-1
Detour Sign	M4-9
Road Closed Ahead	W20-3
Detour Ahead Sign	W20-2
Road Work Ahead	W20-1

5.2 Hydraulic Restoration Recommendations

To increase the speed of recovery of the Salmon River Estuary we recommend the construction of channels after the installation of the culverts. This would encourage channel formation and would help restore water connectivity. Channel construction as recommended by the ODOT geotechnical report from the Fraser Creek culvert project should occur in the summer months. This will minimize disturbance of the existing soft tidal deposits that are susceptible to weakening by construction operations (ODOT, 2014).

The channels should be designed in accordance with Stream Restoration Design from the National Engineering Handbook issued by the United States Department of Agriculture (USDA).

Based on the handbook, we recommend the design and construction of an alluvial-intermittent channel. An alluvial channel will allow sediment to flow downstream without significant degradation of the channel. An intermittent channel will allow flow to occur during certain times of the year (USDA, 2007). In the Salmon River Estuary, these channels will have little to no flow in the summer months when there is little precipitation and high rates of evaporation. Placement and arrangement of the channels are to be determined through additional hydrologic studies.

5.3 Maintenance Recommendations

After implementation, it is important to maintain the culverts to allow for effective fish passage and flow. According to the ODOT Hydraulics Manual, box culverts with buried inverts require clearance of obstructions and the replacement of the natural bed material when necessary. To accommodate for obstructions, our design incorporated a wider opening than the Fraser Creek culvert. This larger opening should reduce the amount of debris caught in the culverts and facilitate fish passage as well as navigation of wildlife. Additionally, our design provides proper clearance for any small equipment necessary to maintain the culverts. We recommend periodic culvert inspections conducted on a semiannual basis and after large storm events (ODOT, 2014).

5.4 Envision

To understand the benefits and effects of our design recommendation for the Salmon River Estuary, the Envision checklist was used and can be found in Appendix F. The Envision checklist is an assessment system used to help engineers successfully implement sustainable infrastructure projects. The checklist measures the sustainability of a project beginning with the design followed by construction and maintenance (ASCE, 2019). To do this, the checklist is separated into 5 topics: quality of life, leadership, resource allocation, natural world, and climate and risk. Our overall envision score is displayed in Figure 20.

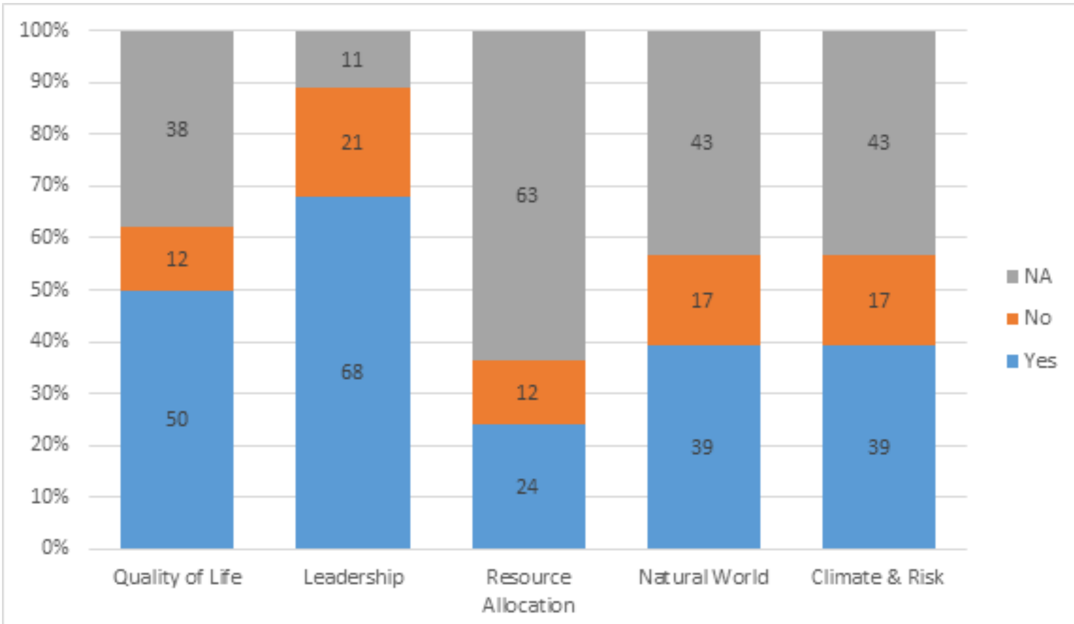


Figure 20. *Envision Tabulation*

The Quality of Life portion of our project was assessed through the purpose of the project, the wellbeing of the public, and protection of the community. The project is intended to improve the quality of life of the community by addressing the needs of the community and reducing negative impacts on the community. This is achieved because the implementation of our design will restore the health of the estuary and the recreational users will benefit from this. The project also enhances the wellbeing of the public by improving mobility by assessing existing and forecasted traffic patterns. Additionally, we intend to improve and maintain safety by implementing appropriate signage and accessibility. Lastly, the project is intended to preserve and restore public land. This is achieved because our multiple culvert design will allow for the natural flow of water from the north side of the highway to the south side.

Collaboration, management, and planning are the basis in which we scored our project on the Envision checklist. We have collaborated with our stakeholders and emphasized the importance of sustainability as a core value to our project. We intend to maximize our sustainable measures when possible in order to achieve the most beneficial design for the community in which we are serving. In terms of management, this project will be an integrated feature within the community, optimizing performance. We recognize the importance of maintenance in order to ensure our design endures throughout the course of its life. Maintenance recommendations have been made and can be found in Section 5.3. Additionally, our project will adhere to applicable regulations and policies found in Appendix A.5. This will facilitate in ensuring the useful life of the project.

Through the Envision checklist, resource allocation was evaluated based on materials, energy, and water. In terms of materials, this project intends to use manufacturers that value sustainable practices and policies. Additionally, we propose that materials such as structural backfill and geogrid are supplied by local sources to support local companies and reduce the cost and impact of material transportation. We do not plan to conduct an assessment of the embodied energy of key materials over the project life. Additionally, our team has decided that monitoring the performance of energy systems on our project is not applicable to the scope of work we intend to fulfill. Our project is designed to protect aquatic species over the course of construction as well as restore the quality of water supply to an undeveloped ecosystem. The project does not involve potable water systems; therefore, these sections were not applicable to our envision score.

Unfortunately, in the Natural World category of envision we find that our project cannot avoid developing in an ecologically valuable area because the focus of our project is to improve a prime habitat. The project will identify and document these areas and increase the area of said habitat through habitat restoration, increasing water connectivity within the estuary. Safeguarding aquifers and preserving groundwater resources is not within the scope of our project. When evaluating the preservation of floodplains, this project will modify and improve the existing infrastructure that is subject to damage by flood. Landscaping is also not within our scope of work, so the impacts of pesticides and fertilizers is not applicable to our envision score. When evaluating biodiversity, we intend to protect and preserve the biodiversity through our restoration efforts. However, we do not intend to restore 100% of the soils disturbed during construction because of the need for structural backfill, which provides stability to our design. The intention of the project is to maintain or enhance; hydrologic connection, water quality, habitat, sediment transport, and the aquatic ecosystem.

The Climate and Risk score is tabulated by looking at the emission and resilience of the project. Evaluation of the carbon cycle and pollutants are not applicable to our project and not within the scope of work. The project team will develop a climate impact assessment and review and identify potential risks and vulnerabilities made worse by the project. The project will be designed to recover from specific hazards but, a hazards analysis of man-made hazards will not be conducted. Additionally, the project will not reduce the heat island effects by reducing the percentage of low solar reflective index (SRI) surfaces.

Overall, based on the Envision Checklist, we believe that in many categories our project ranks as superior on the envision spectrum. The team notes that in each category when evaluating the items that were applicable to our project, we had more answers that were sustainably beneficial than non-beneficial.

5.5 Cost Analysis

A preliminary cost analysis was performed for the recommended final design using a cost-based estimate approach. This cost analysis included the estimated quantities and prices of materials and labor required to complete the multiple culvert design alternative. The quantities of each item were calculated from the final design drawings. Most costs were estimated using RSMeans data, an online construction cost database software. RSMeans provided up-to-date cost estimates of materials and labor based on construction data collected from the local region. Using design manuals and construction websites, the group was able to verify each item's cost to ensure the accuracy of the RSMeans estimations. Basic cost analysis is shown in Table 3 and Complete cost analysis calculations can be found in Appendix E.

Table 3. *Basic Costs Analysis (In millions of dollars)*

CONSTRUCTION COST		
Culvert	$	19.50
Riprap	$	1.30
Guardrails	$	0.17
Geotextile	$	0.12
Structural Backfill	$	13.60
Aggregate Base	$	0.96
Tree/Bush Removal	$	0.84
Excavation	$	2.60
MHMAC Wearing Course	$	0.92
TOTAL Construction Cost	**$**	**40.10**
PRE-DESIGN		
5% of construction cost	**$**	**2.00**
DESIGN		
10% of construction cost	**$**	**4.00**
CONSTRUCTION MANAGEMENT		
10% of construction cost	**$**	**4.00**
CONSTRUCTION		
Mobilization and Demobilization	$	4.00
Bonds and Materials	$	0.81
	$	**4.81**
TOTAL COST	**$**	**54.9**
TOTAL COST + 20% CONTINGENCY	**$**	**65.9**

The pre-fabricated culverts are the largest percentage of the design's construction cost. The final design will require 420 pre-fabricated box culverts, each costing $46,500, totaling $19.5 million. This nearly $20 million figure does not include the transportation of the culverts, or the labor costs associated with their installation. The structural backfill is the next largest percentage of the design's construction cost. The structural backfill material and labor is estimated to cost a total of $13.6 million. Subsurface excavation will cost approximately $2.6 million. The material and labor cost of other items, such as the aggregate base, and wearing course of the road, rip-rap and rock lining, geotextile fabrics, and guardrails will be approximately $3.5 million. Clearing and grubbing ten acres of brush as well as excavation of soils will cost approximately $3.4 million. The total estimated construction cost, including materials and labor for the aforementioned items, is $40.1 million.

A cost-based estimate includes several other categories in which costs are incurred. These categories include pre-design services, design services, construction management services, transportation services, and bonds and insurance costs. Each category's cost is based upon a percentage of the labor and materials cost, which is mentioned in the previous paragraph. We have estimated that the total cost for pre-design services and design services will be approximately $6.0 million where pre-design services and design services amount to 5% and 10% of the total construction cost respectively. Construction management services cost approximately 10% of the total construction cost, amounting to $4.0 million. Transportation services, which includes the mobilization and de-mobilization of equipment, cost approximately 10% of the total cost of construction, also amounting to $4.0 million. Bonds and insurance, cost approximately 2% of the total construction cost, amounting to $0.81 million. In total, the project will cost approximately $54.9 million.

Due to the fact that this project is a preliminary design, we recommend a contingency fund of 20% of the total estimated cost. This contingency is larger than the industry standard to account for any permitting, unforeseen issues, traffic control plans, specialized equipment, as well as any additional materials or labor required during construction. Factoring in the 20% contingency, the total estimated cost of the project is approximately $65.9 million.

As noted previously in the report, the project is not constrained to a budget. However, such an estimate, as given above, will allow stakeholders to determine the feasibility of the project in the future, depending on the number of interested parties willing to fund the project.

5.6 Other Impacted Estuaries

The recommended alterative, of having multiple culverts in series, can be applied to similarly impacted estuaries around Oregon. According to a study done by TNC, the top three estuaries that are currently highly impacted by highways and roads are, Coos Bay, Tillamook Bay, and Umpqua Estuary (Pickering et al., 2018). Similar to the Salmon River Estuary, these three estuaries are disturbed by roadways built on fill, affecting water connectivity. In addition, the roadways affecting these three locations are also vulnerable to seismic activity and are ODOT priorities. The red lines in Figure 21, Figure 22, and Figure 23, represent roadways or highways crossing through these estuaries.

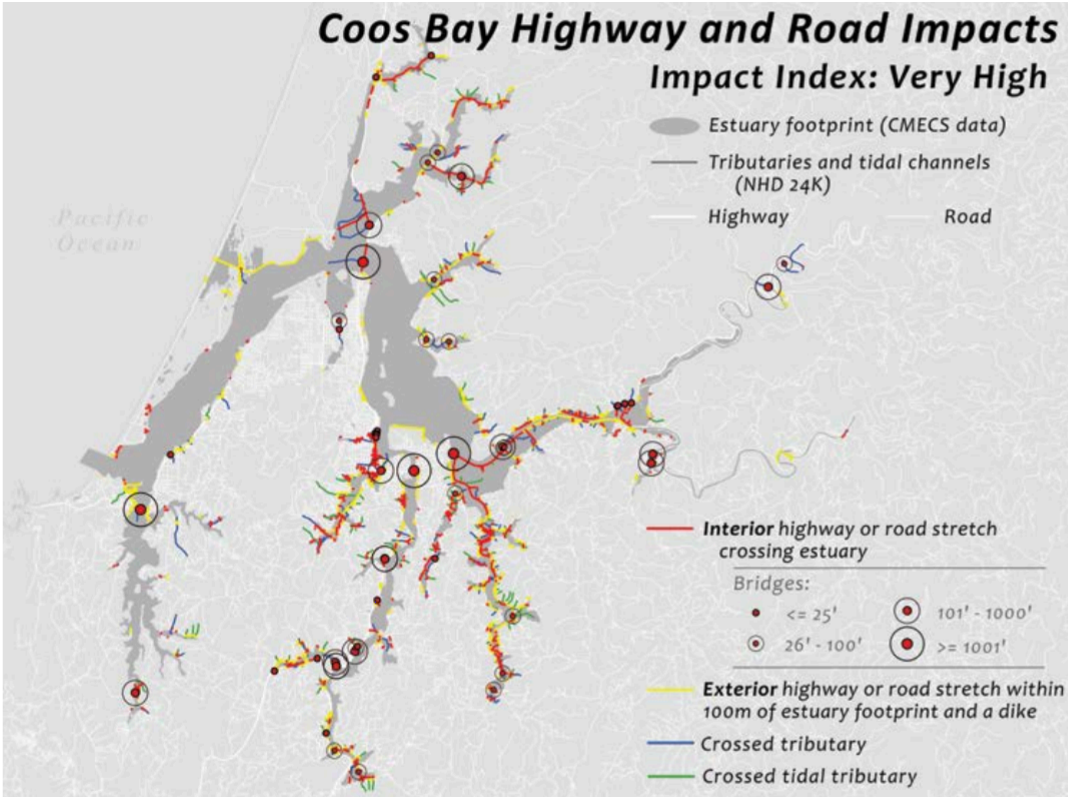


Figure 21. *Coos Bay Highway and Road Impacts*

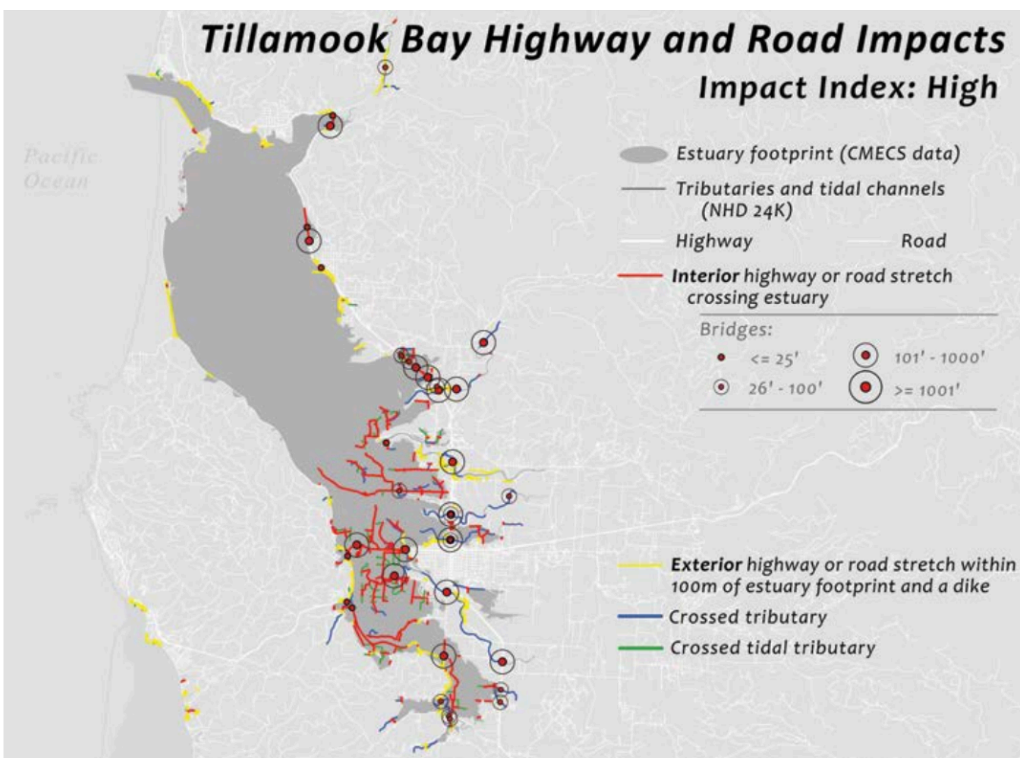


Figure 22. *Tillamook Bay Highway and Road Impacts*

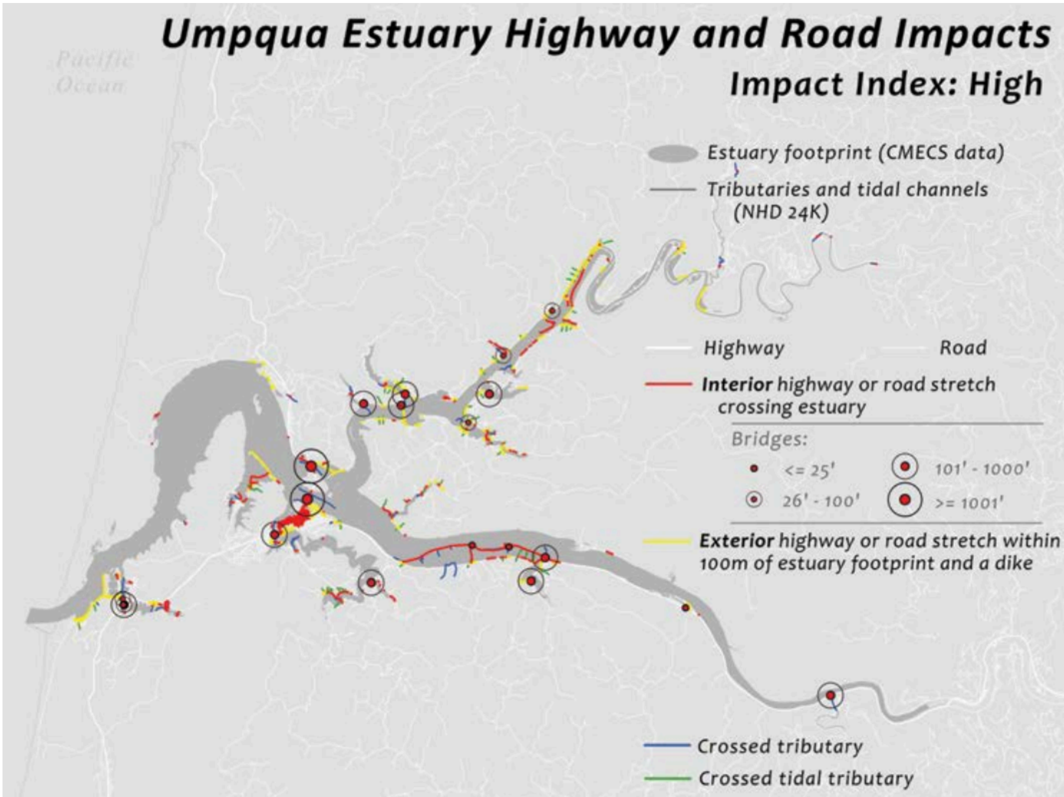


Figure 23. *Umpqua Estuary Highway and Road Impacts*

As represented by Figure 21, Figure 22, and Figure 23, the significant amount of red lines shows the need for a solution to restore these impacted areas. Our recommendation can be applied to various locations around the Coos, Tillamook, and Umpqua Estuaries. The dimensions of the recommended precast three-sided bridge, with inverted installation, can be adjusted to optimize water connectivity at each location. Figure 24 and Figure 25 show locations in Coos Bay where multiple box culverts would increase and restore water connectivity. In both these locations there is only one opening where water can flow through. Similarly, Figure 26 and Figure 27 show locations in Tillamook and Umpqua, respectively, where multiple culverts would be an effective solution. Existing openings in these figures are circled in red.

Figure 24. *Where multiple culverts in series could be applied -Coos Bay-Location #1*

Figure 25. *Where multiple culverts in series could be applied -Coos Bay-Location #2*

Figure 26. *Where multiple culverts in series could be applied -Umpqua Estuary*

Figure 27. *Where multiple culverts in series could be applied -Tillamook Estuary*

By implementing our recommend design at other locations in Oregon, the health of the estuaries could be restored and would benefit coastal communities as well as the greater state of Oregon. As mentioned earlier in the report, some of the many benefits to restoring estuaries include, locally reducing the risk of flooding, increasing amount of fish-passage, increasing survival rate of juvenile fish as well as, encouraging the mixing of salt and fresh water. These benefits would overall strengthen Oregon's fishing industry and would result in a boost in Oregon's economy.

REFERENCES

Arkansas Highway and Transportation Department. (July 2016). “Estimated costs per mile” <https://www.arkansashighways.com/roadway_design_division/Cost%20per%20Mile%20(JULY%202016).pdf> (December 5, 2018).

ASCE. (n.d.). “Envision Checklist” < https://www.asce.org/envision/>. (April, 2019).

Caffrey J., Burton T. And Higgins J. (2003). “Broadmeadow Estuary Bridge: Integration Of Design and Construction.” *Institution Of Engineers Of Ireland*, <https://www.engineersireland.ie/EngineersIreland/media/SiteMedia/groups/Divisions/civil/Broadmeadow-Estuary-Bridge-Integration-of-Design-and-Construction.pdf?ext=.pdf> (November, 2018).

Center of Environmental Excellence. (2004). “Construction in and around Drainage Areas and Streams, Wetlands, and Other Environmentally Sensitive Areas.” *AASHTO Construction Practices for Environmental Stewardship, Chapter 4,* <https://environment.transportation.org /environmental_issues/construct_maint_prac/compendium/manual/4_4.aspx> (November, 2018).

Chen, W. & Duan, L. (2000). *Bridge Engineering Handbook*. Boca Raton, Florida: CRC Press LLC

Columbia Precast Products. (n.d). "3-Sided Bridges”

European Climate Adaptation Platform. (2015). “Floating or Elevated Roads.” *Climate-ADPAT*, <https://climate-adapt.eea.europa.eu/metadata/adaptation-options/floating-or-elevated-roads> (November, 2018).

Ellingson, S., & Ellis-Sugai, J. (2014). “Restoring the Salmon River Estuary Journey and

Lessons Learned Along the Way.” *USFS*, <https://www.fs.usda.gov/Internet /FSE_DOCUMENTS/fseprd563410.pdf>

Encyclopedia Britannica. (August 14, 2018). “Pontoon Bridge.” <https://www.britannica.com/technology/pontoon-bridge> (November, 2018).

EPA. (n.d.). “Federal Environmental Requirements for Construction.” *EPA Construction Sector (NAICS 23)*, < https://www.epa.gov/regulatory-information-sector/construction -sector-naics-23> (November, 2018)

EPA. (2010). “National Pollutant Discharge Elimination System (NPDES) Permit Writers' Manual.” < https://www.epa.gov/sites/production/files/2015-09/documents/pwm_2010.pdf> (November, 2018).

Greene, C., Hall, J., Smith, P. And Small, D. (2017). “Effects of intertidal water crossing structures on estuarine fish and their habitat: a literature review and synthesis.” *NOAA Fisheries & Washington Department of Fish and Wildlife*, <http://www.skagitclimatescience.org/wp-content/uploads/2018/07/Greene-et-al.-2017-review-on-intertidal-water-crossing-structures-and-fish-1.pdf> (March 2019).

Greer, A, M. Bushman, C.C. Chase, G. Morehead and S. Schrock. (2006). *Lower Salmon River Project, Continuing a Vision for a Treasured Landscape*, Lincoln County, Oregon.

Keating, K., Kitchen, A., & Pettit, A. (2014). “Cost Estimation for Culverts Summary of Evidence.” *Environmental Agency,* <http://evidence.environmentagency.gov.uk/ FCERM/Libraries/FCERM_Project_Documents/SC080039_cost_culverts.sflb.ash> (November 2018)

Lariner, M. (2002). “Fish Passage Through Culverts, Rock Weirs and Estuarine Obstructions.”

KMAE, <https://www.kmae-jojournal.org/articles/kmae/pdf/2002/04/kmae2002364s119.pdf> (February 2019).

Metromont. (February 22, 2017). “7 Advantages of Precast Concrete.” *Metromont*, <http://www.metromont.com/7-advantages-of-precast-concrete> (November 2018).

NOAA. (2018). “Sea Level Rise Exposure Inventory.” <https://www.coastalatlas.net/sealevelriseviewer/> (November 2018).

Office of Emergency Management. (n.d.). “Cascadia Subduction Zone.” *Hazards and Preparedness,* < https://www.oregon.gov/OEM/hazardsprep/Pages /Cascadia-Subduction- Zone.aspx> (November 2018).

Oregon Department of Transportation. (April 2014). “Culverts.” *ODOT Hydraulics Manual*.

Oregon Department of Transportation. (August 2014). *Geotechnical Report for Fraser Creek Culvert Project*, Lincon County, Oregon.

Oregon Department of Transportation. (2018). “Region 2: Willamette Valley and Northwest Oregon (Manzanita, Tillamook)”. *U.S. 101 Manzanita Avenue to Neahkahnie Creek Culvert Replacement and Highway Realignment,* <https://www.oregon.gov/odot/projects/pages/project-details.aspx?project=11258> (November 2018).

Oregon Department of Transportation. (2018). “Region 2: Willamette Valley and Northwest Oregon (Yamhill)”. *OR 22 Sourgrass Creek Culvert Replacement,* <https://www.oregon.gov/odot/projects/pages/project-details.aspx?project=K19935> (November 2018).

Oregon Department of Transportation. (2012). Rural highway design (non-freeway). *ODOT Highway Design Manual*.

Oregon Department of Transportation. (September 2016). "Temporary Traffic Control Handbook for Operations of Three Days or Less." <https://www.oregon.gov/ODOT/Engineering/Docs_TrafficEng/OTTCH-v2011.pdf> (November 2018).

Oregon Department of Transportation. (2018). "Traffic Manual." <https://www.oregon.gov/ODOT/Engineering/Docs_TrafficEng/Traffic-Manual.pdf> (November 2018).

Pickering, Jones, Aldos, & Schindel. (September 2018). Where Road Projects Could Improve Oregon's Estuaries and Benefit Local Communities. *TNC*.

Soetens, F. & de Kluyver, D. (2003). "Staying Afloat – A Road to the Future." *TNO Traffic and Transport*, <http://www.iiinstitute.nl/sites/default/files/FloatingRoad_343.pdf> (November 2018).

University of Wisconsin-Extension (UWEX). "Fish Friendly Culverts." < http://clean-water.uwex.edu/pubs/pdf/fishfriendlyculverts.pdf> (March 2019).

USDA Forest Service Northern Region Engineering. (2017). "Cost Estimate Guide for Road Construction." *Regions 1 Division of Engineering U.S. Department of Agriculture, Forest Service,* <https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5279284.pdf> (November 2018).

U.S. Army Corps of Engineers. (n.d.). "U.S. Army Corps of Engineers Permitting Process Information." *U.S Army Corps of Engineers Permitting,* <https://www.lrl.usace.army.mil/Portals/64/docs/regulatory/Permitting/PermittingProcessInformation.pdf> (November 2018).

U.S. Department of Agriculture. (n.d.). Salmon River Estuary. *Forest Service,*

<https://www.fs.usda.gov/detail/siuslaw/landmanagement/resourcemanagement/?cid=fsbdev7_007294> (November 2018).

U.S. Department of Agriculture. (August 2007). “Basic Principles of Channel Design.” *Stream Restoration Design National Engineering Handbook* <https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17783.wba>

U.S. Federal Government. (2018) “U.S. Climate Resilience Toolkit Climate Explorer.” <https://climate-explorer2.nemac.org> (November 2018).

U.S. Fish & Wildlife Service. (June, 2008). “Oregon Guidelines for Timing Of In-Water Work To Protect Fish and Wildlife Resources.” <https://www.dfw.state.or.us/ lands/ inwater/Oregon Guidelines_for_Timing_of_%20InWater_Work2008.pdf> (November 2018).

U.S. Fish & Wildlife Service. (n.d.). “OFWO About Us.” *Oregon Fish and Wildlife Office,* <https://www.fws.gov/oregonfwo/articles.cfm?id=149489554> (November 2018).

U.S. Fish & Wildlife Service. (January 2013). “Climate Change and Oregon’s Estuaries.” *Oregon Fish and Wildlife* Office, <https://www.dfw.state.or.us/conservationstrategy/docs/climate_change/ ClimateChangeEstuaries_Fact_Sheet.pdf> (November 2018).

Wargo, R. (2003). “A Comparison of Single Cell vs. Multi-Cell Culverts.” *Lehigh University*, <https://preserve.lehigh.edu/cgi/viewcontent.cgi?article=1831&context=etd> (November 2018).

Washington Dept. of Fish and Wildlife. (2013). “Water Crossing Design Guidelines.” <https://wdfw.wa.gov/publications/01501/wdfw01501.pdf> (November 2018).

Washington State Department of Transportation. (2018). “SR 520 Bridge Replacement and HOV Program – Floating Bridge Facts.” <https://www.wsdot.wa.gov/Projects/SR520Bridge /About/BridgeFacts.htm> (November 2018).

Washington State Department of Transportation. (2018). “SR 520 – Floating Bridge and Landings Project – Complete August 2017.” Retrieved from <http://www.wsdot.wa.gov/ Projects/SR520/BridgeAndLandings/default.htm> (November 2018).

Wilcox, K. (May, 2016). “Elevated Roadway Opens Over Mitigation Break”. *ASCE Magazine*. <https://www.asce.org/magazine/20160524-elevated-roadway-opens-over-mitigation-bank/> (November 2018).

WSDOT. (June, 2016). “WSDOT Highway Construction Costs.” <https://www.wsdot.wa.gov/NR/rdonlyres/A8EE6CB0-46F6-4EE8-95A3-62E9B793F31C/0/CostIndexData.pdf> (November 2018).

WSDOT. (n.d.). “WSDOT Bridge Deck Paving”.

APPENDIX A: TEAMWORK AND PROFESSIONALISM

A.1 Interaction and Organization

During the semester the group consistently communicated via text and during regularly scheduled meetings. In order to maintain sufficient communication, the group met with faculty and industry advisors on a biweekly basis. Meetings with TNC were conducted via phone conference while meetings with Dr. Poor were conducted face to face. Internal group meeting were conducted weekly. These weekly meetings took place after meetings with TNC and Dr. Poor. To simplify communication with our industry advisor we delegated Alyssa Lau as our communications liaison. Alyssa completed any necessary email communication with industry advisors in order to streamline information back and forth. Alyssa also served as group leader by providing the group with general goals to be completed. Each individual within the group displayed leadership by maintaining communication, completing assigned tasks, delegating general tasks and creating a personal agenda. Interactions between the group were kept casual in order to allow for comfortability when sharing conflicting ideas. Interactions with TNC were kept professional to display absolute focus on the project. To track progress throughout the course of CE 483, the group members took turns recording notes and uploading them to a shared file where we could track information gathered. Additionally, a time sheet was created and shared to tabulate the weekly hours spent on the project by each group member. Group decisions were mostly made under absolute consensus. In the event of conflicting decisions, the group would discuss until consensus was reached. The decision of our chosen design alternative was made using a decision matrix. The decision matrix is comprised of scores given to each alternative by the group members. The alternative with the highest score is the one the group plans to consider during CE 484.

A.2 Independent Research

Aspects that were not covered in our engineering courses but were important to the projects are understanding the fundamental ecosystem of an estuary and the wildlife that depend on it. Our industry advisor, Debbie Pickering, was instrumental in providing material that allowed us to understand the important functions of an estuary. The team has also learned how to evaluate the level of service of a two-lane highway. While we cover the concept of level of service in transportation engineering and traffic engineering, we do not learn about how to evaluate it for a two-lane highway. As our project concerns a two-lane highway, it is important for us to evaluate the highway based on its level of service in order to determine whether improvements are needed.

A.3 Engineering Tools

The engineering tools used for this project were, ArcGIS, Excel, Word, AutoCAD and Microsoft Project. ArcGIS was used to create location map for our report. Excel was used to make our cost analysis and keep track of each team member's hours and tasks assigned. Word was used to write meeting minutes and this report. HEC-RAS was used to view files sent over from USFS. AutoCAD was used to draw our designs. Lastly, Microsoft Project was used to come up with a project schedule as well as to keep track of completed tasks.

Table 4. *Engineering Tools Used*

Engineering Tools Used
ArcGIS
Excel
Word
Microsoft Project
AutoCAD

A.4 Separation of Work and Project Schedule

Because of the immensity of this project, the corresponding work for this project will be split between two semesters of the school year. During the fall semester, the group mainly focused on background research and investigated different design alternatives for the project. During the second semester, the group mainly focused on designing and implementing the chosen design alternative, as determined by a decision matrix analysis in the first semester. The following paragraphs will further explain the work completed in the first semester, as well as tasks that have been completed in the second semester.

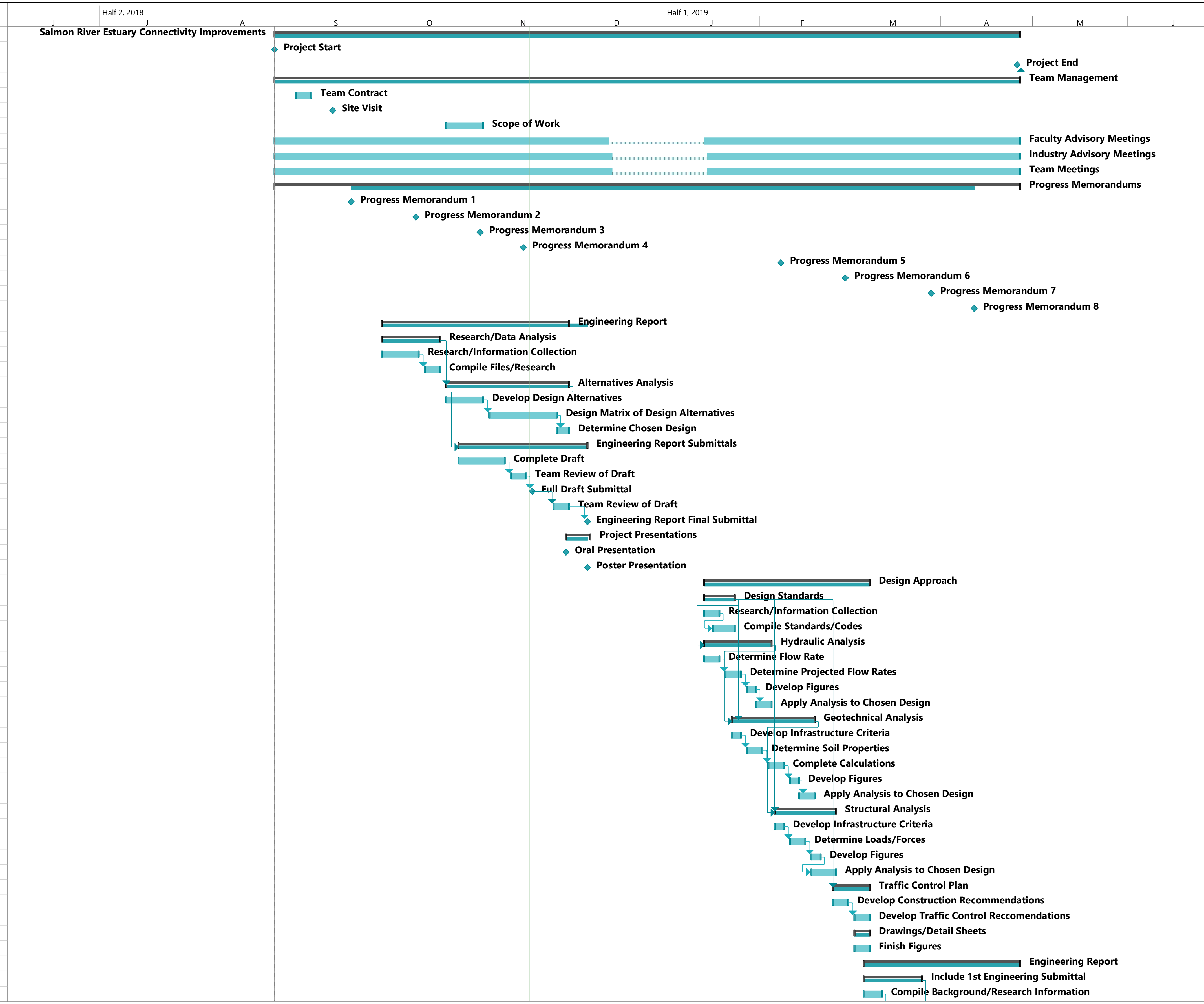
In the beginning of the fall semester, the group concentrated on project fundamentals, including a team charter and a team contract. The group also arranged times and locations of weekly team and advisory meetings. Additionally, the team stressed the importance of clear communication and other important groupwork skills to ensure that the team would be successful in the end. Several weeks into the first semester, a schedule, using Microsoft Project, was developed for both the first and second semesters. Background research was conducted mainly on Oregon estuaries and the project's site location. The information collected through this research focused on the history of the Salmon River Estuary, the Salmon River Estuary's current conditions, and other factors concerning the health and well-being of the estuary. Design alternatives were also developed and researched. The final design was chosen through the use of a decision matrix analysis which allowed the team to score each alternative out of a pre-determined weighted number. The group finished the semester by completing the final written report and preparing two presentations: an oral presentation and a poster presentation.

As stated in an earlier paragraph, the second semester was dedicated to designing the chosen alternative as determined by the group's decision matrix analysis. The proposed design approach for our chosen alternative included more research and information collection, as well as a compilation of standards and codes. These standards and codes formed the basis of the team's design, specifically standards and codes from the WDFS Culvert Design Manual as well as the ODOT Culvert Design Manual. The team performed calculations to determine the details of the chosen design as well as researched pre-fabricated materials to ease the construction process. The team has developed appropriate figures, graphs, and charts when necessary, and provide drawings of our final design. In addition, the team has recommended possible implementation techniques, which may require traffic control plans and construction schedules. Similarly, to the first semester, a final written report was written, and team has prepared an oral presentation.

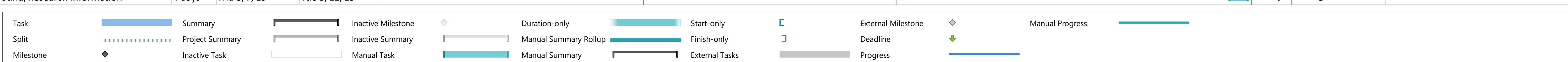
The Microsoft Project schedule provided the team with concrete deadlines and an overview of what was needed to be accomplished during the capstone project. Throughout the entire year, the team strived to conform to the proposed schedule; however, towards the end of our design phase in the second semester, the team encountered unforeseen challenges and the project schedule needed to be altered. The group failed to include a sufficient amount of flexibility between each scheduled task and thus, work was delayed. In the end, the team was able to reorganize and finish the tasks that needed to be completed. The team's Microsoft Project Schedule is shown in Figure 28 and Figure 29.

Figure 28. *Microsoft Project Schedule-1*

ID	Task Name	Duration	Start	Finish
1	**Salmon River Estuary Connectivity Improvements**	**175 days**	**Mon 8/27/18**	**Fri 4/26/19**
2	Project Start	0 days	Mon 8/27/18	Mon 8/27/18
3	Project End	0 days	Fri 4/26/19	Fri 4/26/19
4	**Team Management**	**175 days**	**Mon 8/27/18**	**Fri 4/26/19**
5	Team Contract	5 days	Mon 9/3/18	Fri 9/7/18
6	Site Visit	0 days	Sat 9/15/18	Sat 9/15/18
7	Scope of Work	10 days	Mon 10/22/18	Fri 11/2/18
8	Faculty Advisory Meetings	154 days	Mon 8/27/18	Fri 4/26/19
9	Industry Advisory Meetings	154 days	Mon 8/27/18	Fri 4/26/19
10	Team Meetings	154 days	Mon 8/27/18	Fri 4/26/19
11	**Progress Memorandums**	**175 days**	**Mon 8/27/18**	**Fri 4/26/19**
12	Progress Memorandum 1	0 days	Fri 9/21/18	Fri 9/21/18
13	Progress Memorandum 2	0 days	Fri 10/12/18	Fri 10/12/18
14	Progress Memorandum 3	0 days	Fri 11/2/18	Fri 11/2/18
15	Progress Memorandum 4	0 days	Fri 11/16/18	Fri 11/16/18
16	Progress Memorandum 5	0 days	Fri 2/8/19	Fri 2/8/19
17	Progress Memorandum 6	0 days	Fri 3/1/19	Fri 3/1/19
18	Progress Memorandum 7	0 days	Fri 3/29/19	Fri 3/29/19
19	Progress Memorandum 8	0 days	Fri 4/12/19	Fri 4/12/19
20	**Engineering Report**	**45 days**	**Mon 10/1/18**	**Fri 11/30/18**
21	**Research/Data Analysis**	**15 days**	**Mon 10/1/18**	**Fri 10/19/18**
22	Research/Information Collection	10 days	Mon 10/1/18	Fri 10/12/18
23	Compile Files/Research	5 days	Mon 10/15/18	Fri 10/19/18
24	**Alternatives Analysis**	**30 days**	**Mon 10/22/18**	**Fri 11/30/18**
25	Develop Design Alternatives	10 days	Mon 10/22/18	Fri 11/2/18
26	Design Matrix of Design Alternatives	16 days	Mon 11/5/18	Mon 11/26/18
27	Determine Chosen Design	4 days	Tue 11/27/18	Fri 11/30/18
28	**Engineering Report Submittals**	**30 days**	**Fri 10/26/18**	**Fri 12/7/18**
29	Complete Draft	11 days	Fri 10/26/18	Fri 11/9/18
30	Team Review of Draft	5 days	Mon 11/12/18	Fri 11/16/18
31	Full Draft Submittal	0 days	Mon 11/19/18	Mon 11/19/18
32	Team Review of Draft	5 days	Mon 11/26/18	Fri 11/30/18
33	Engineering Report Final Submittal	0 days	Fri 12/7/18	Fri 12/7/18
34	**Project Presentations**	**6 days**	**Fri 11/30/18**	**Fri 12/7/18**
35	Oral Presentation	0 days	Fri 11/30/18	Fri 11/30/18
36	Poster Presentation	0 days	Fri 12/7/18	Fri 12/7/18
37	**Design Approach**	**40 days**	**Mon 1/14/19**	**Fri 3/8/19**
38	**Design Standards**	**8 days**	**Mon 1/14/19**	**Wed 1/23/19**
39	Research/Information Collection	5 days	Mon 1/14/19	Fri 1/18/19
40	Compile Standards/Codes	5 days	Wed 1/16/19	Wed 1/23/19
41	**Hydraulic Analysis**	**16 days**	**Mon 1/14/19**	**Mon 2/4/19**
42	Determine Flow Rate	5 days	Mon 1/14/19	Fri 1/18/19
43	Determine Projected Flow Rates	5 days	Mon 1/21/19	Fri 1/25/19
44	Develop Figures	3 days	Mon 1/28/19	Wed 1/30/19
45	Apply Analysis to Chosen Design	3 days	Thu 1/31/19	Mon 2/4/19
46	**Geotechnical Analysis**	**19 days**	**Wed 1/23/19**	**Mon 2/18/19**
47	Develop Infrastructure Criteria	3 days	Wed 1/23/19	Fri 1/25/19
48	Determine Soil Properties	5 days	Mon 1/28/19	Fri 2/1/19
49	Complete Calculations	5 days	Mon 2/4/19	Fri 2/8/19
50	Develop Figures	3 days	Mon 2/11/19	Wed 2/13/19
51	Apply Analysis to Chosen Design	3 days	Thu 2/14/19	Mon 2/18/19
52	**Structural Analysis**	**14 days**	**Wed 2/6/19**	**Mon 2/25/19**
53	Develop Infrastructure Criteria	3 days	Wed 2/6/19	Fri 2/8/19
54	Determine Loads/Forces	5 days	Mon 2/11/19	Fri 2/15/19
55	Develop Figures	3 days	Mon 2/18/19	Wed 2/20/19
56	Apply Analysis to Chosen Design	6 days	Mon 2/18/19	Mon 2/25/19
57	**Traffic Control Plan**	**10 days**	**Mon 2/25/19**	**Fri 3/8/19**
58	Develop Construction Recommendations	5 days	Mon 2/25/19	Fri 3/1/19
59	Develop Traffic Control Reccomendations	5 days	Mon 3/4/19	Fri 3/8/19
60	**Drawings/Detail Sheets**	**5 days**	**Mon 3/4/19**	**Fri 3/8/19**
61	Finish Figures	5 days	Mon 3/4/19	Fri 3/8/19
62	**Engineering Report**	**37 days**	**Thu 3/7/19**	**Fri 4/26/19**
63	**Include 1st Engineering Submittal**	**13 days**	**Thu 3/7/19**	**Mon 3/25/19**
64	Compile Background/Research Information	4 days	Thu 3/7/19	Tue 3/12/19



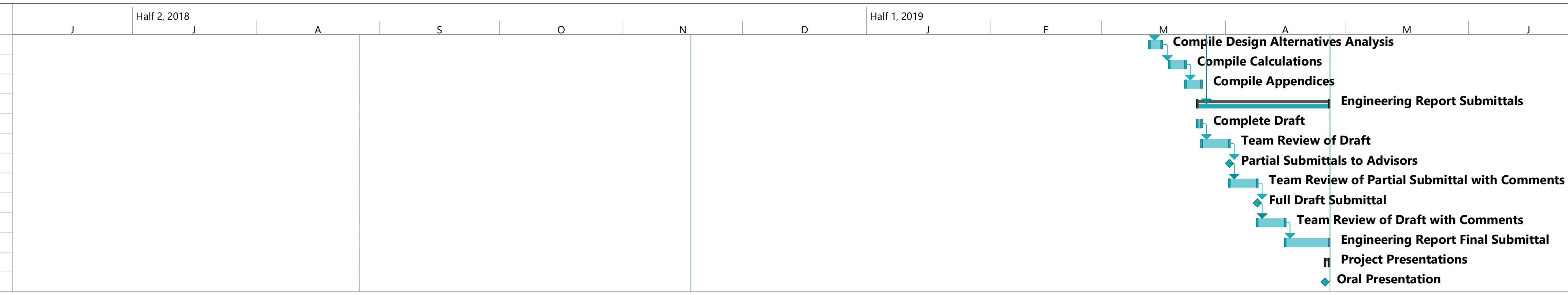
Project: Capstone Schedule - M
Date: Sun 11/18/18



Page 1

Figure 29. *Microsoft Project Schedule-2*

ID	Task Name	Duration	Start	Finish
65	Compile Design Alternatives Analysis	3 days	Wed 3/13/19	Fri 3/15/19
66	Compile Calculations	4 days	Mon 3/18/19	Thu 3/21/19
67	Compile Appendices	2 days	Fri 3/22/19	Mon 3/25/19
68	**Engineering Report Submittals**	**25 days**	**Mon 3/25/19**	**Fri 4/26/19**
69	Complete Draft	1 day	Mon 3/25/19	Mon 3/25/19
70	Team Review of Draft	5 days	Tue 3/26/19	Mon 4/1/19
71	Partial Submittals to Advisors	0 days	Tue 4/2/19	Tue 4/2/19
72	Team Review of Partial Submittal with Comments	5 days	Tue 4/2/19	Mon 4/8/19
73	Full Draft Submittal	0 days	Tue 4/9/19	Tue 4/9/19
74	Team Review of Draft with Comments	5 days	Tue 4/9/19	Mon 4/15/19
75	Engineering Report Final Submittal	9 days	Tue 4/16/19	Fri 4/26/19
76	**Project Presentations**	**1 day**	**Fri 4/26/19**	**Fri 4/26/19**
77	Oral Presentation	0 days	Fri 4/26/19	Fri 4/26/19



Project: Capstone Schedule - M
Date: Sun 11/18/18

Task	Summary	Inactive Milestone	Duration-only	Start-only	External Milestone	Manual Progress
Split	Project Summary	Inactive Summary	Manual Summary Rollup	Finish-only	Deadline	
Milestone	Inactive Task	Manual Task	Manual Summary	External Tasks	Progress	

Page 2

A.5 Codes

The team expects the codes in Table 5 to be applicable to our project. For our design, standards in Table 6 were used.

Table 5. *List of Applicable Codes*. (ODOT, 2018)

Authority	Document	Code	Title
ODOT	Traffic Manual (2018)	2.1	Traffic-Roadway Section
ODOT	Traffic Manual (2018)	2.2	Region Traffic Unit
ODOT	Traffic Manual (2018)	2.3	Other Traffic Related Units within ODOT
ODOT	Traffic Manual (2018)	5.1	Delegated Authorities of the State Traffic-Roadway Engineer
ODOT	Traffic Manual (2018)	6.1	Access Management
ODOT	Traffic Manual (2018)	6.2	Active Warning Signs at Bridges and Tunnels
ODOT	Traffic Manual (2018)	6.4	Capacity Analysis
ODOT	Traffic Manual (2018)	6.5	Crash Analysis
ODOT	Traffic Manual (2018)	6.6	Crosswalks
ODOT	Traffic Manual (2018)	6.7	Flashing Beacons
ODOT	Traffic Manual (2018)	6.10	Highway Safety Engineering
ODOT	Traffic Manual (2018)	6.12	Interchanges
ODOT	Traffic Manual (2018)	6.13	Illumination
ODOT	Traffic Manual (2018)	6.14	Intersections
ODOT	Traffic Manual (2018)	6.15	Land Use and Transportation
ODOT	Traffic Manual (2018)	6.16	Lanes
ODOT	Traffic Manual (2018)	6.19	Manual on Uniform Traffic Control Devices

Authority	Document	Code	Title
ODOT	Traffic Manual (2018)	6.24	Pavement Markings
ODOT	Traffic Manual (2018)	6.26	Road Closures
ODOT	Traffic Manual (2018)	6.28	Rumble Strips
ODOT	Traffic Manual (2018)	6.29	Safe Speed on Curves
ODOT	Traffic Manual (2018)	6.30	Safety Corridors
ODOT	Traffic Manual (2018)	6.31	Sight Distance
ODOT	Traffic Manual (2018)	6.32	Signs
ODOT	Traffic Manual (2018)	6.34	Speed Zones
ODOT	Traffic Manual (2018)	6.35	Traffic Calming
ODOT	Traffic Manual (2018)	6.36	Traffic Signals
ODOT	Traffic Manual (2018)	6.37	Traffic Impact Studies
ODOT	Traffic Manual (2018)	6.38	Truck Routes
ODOT	Traffic Manual (2018)	6.39	Turn Lanes
ODOT	Traffic Manual (2018)	6.40	Turn Prohibitions
ODOT	Traffic Manual (2018)	6.42	Visibility
ODOT	Traffic Manual (2018)	6.43	Work Zones
ODOT	Traffic Manual (2018)	7.2	Forms
ODOT	Traffic Manual (2018)	7.4	Crash Analysis
ODOT	Traffic Manual (2018)	7.6	Legal Authority
ODOT	OTTCH (2016)	1.2	Planned, Emergency, and Special Event Traffic Control
ODOT	OTTCH (2016)	1.3	Land Closures, Diversions, and Detours

Authority	Document	Code	Title
ODOT	OTTCH (2016)	1.4	Worker Safety Apparel
ODOT	OTTCH (2016)	1.5	Surveying and Similar Work
ODOT	OTTCH (2016)	1.6	Bicycle and Pedestrian Considerations
ODOT	OTTCH (2016)	1.7	Night Operations
ODOT	OTTCH (2016)	1.9	Pavement Markings
ODOT	OTTCH (2016)	2.1	Work Zone Components
ODOT	OTTCH (2016)	2.2	Tapers
ODOT	OTTCH (2016)	2.3	Device Spacing
ODOT	OTTCH (2016)	2.4	Device Placement
ODOT	OTTCH (2016)	2.5	Signs
ODOT	OTTCH (2016)	3.1	Flagging and Other Traffic Control Measures
ODOT	OTTCH (2016)	4.1	Signs
ODOT	OTTCH (2016)	4.2	Barricades, Cones, Drums, and Tubular Markers
ODOT	OTTCH (2016)	4.3	Lights and Lighted Signs
ODOT	OTTCH (2016)	4.4	Shadow and Protection Vehicles
ODOT	OTTCH (2016)	5.0	Detail Drawings
ODOT	OTTCH (2016)	5.1	Mobile Operations
ODOT	OTTCH (2016)	5.2	Shoulder Work
ODOT	OTTCH (2016)	5.3	Two-Lane, Two-Way Roads
ODOT	OTTCH (2016)	5.6	Intersection Operations
ODOT	OTTCH (2016)	6.1	Incident Traffic Control

Authority	Document	Code	Title
ODOT	OTTCH (2016)	6.2	Incident Response Needs
ODOT	OTTCH (2016)	6.3	Detours
ODOT	OTTCH (2016)	6.4	Safety Apparel
ODOT	OTTCH (2016)	6.5	Emergency Response Example

Table 6. *Other applicable standards*

Authority	Document	Code	Title
ODFW	Oregon Guidelines For Timing Of In-Water Work To Protect Fish And Wildlife Resources (2008)	N/A	N/A
WDFW	Water Crossing Design Guideline (2013)	N/A	N/A
EPA	Clean Water Act (1972)	Section 401	Certification
EPA	NPDES (2010)	Section 4.3.9	Stormwater Discharges Associated with Construction Activity
AASHTO	Environmental Stewardship Practices, Procedures, and Policies for Highway Construction and Maintenance (2004)	Chapter 4	Construction Practices for Environmental Stewardship
USFW	Endangered Species Act (1973)	N/A	N/A
FHWA	MUTCD	N/A	N/A

A.6 Billable Hours

Table 7 shows the hours spent on the project by each group member on a weekly basis. It also shows the total hours per week, total hours per person, and the total number of hours spent on the project thus far.

Table 7. *Billable Hours*

WEEK	Shea Chun	Alyssa Lau	Mustaf Mohamed	Bailey Smithline	Sean Urabe	COMBINED TOTAL
8/26 - 9/1	1.5	1.5	1.5	1.5	1.5	**7.5**
9/2 - 9/8	1.5	1.5	1.5	1.5	1.5	**7.5**
9/9 - 9/15	8	8	8	8	8	**40**
9/16 - 9/22	1	1	1	1	1	**5**
9/23 - 9/29	2	3	2	2	3	**12**
9/30 - 10/6	3	4	3.5	3	2	**15.5**
10/7 - 10/13	4	3	2.5	3	4.5	**17**
10/14 - 10/20	5	6	5	6	5	**27**
10/21 - 10/27	5	5	4	5	4	**23**
10/28 - 11/3	5	6	4.5	7	4.5	**27**
11/4 - 11/10	8	7	6	7	8	**36**
11/11 - 11/17	13	10	15	10	7	**55**
1/20 -1/26	1	2	1.5	2	1	**7.5**
1/27 - 2/2	1	1.5	1	1.5	1	**6**
2/03 - 2/9	2.5	3	2	3	2	**12.5**
2/10 - 2/16	2	2	1.5	1.5	2	**9**
2/17 - 2/23	5	6	2	6	5	**24**
2/24 - 3/2	6	5	5	7	6	**29**
3/3 - 3/9	0.5	0.5	0.5	1	6	**8.5**
3/10 - 3/16	3	2	4	2	3	**14**
3/17 - 3/23	5	5	4	5	5	**24**
3/24 - 3/30	6	5	5.5	5	5.5	**27**
3/31 - 4/6	5	5	5	5	6	**26**
4/7 - 4/13	9	10	7.5	9	8	**43.5**
TOTAL	**103**	**103**	**94**	**103**	**100.5**	**503.5**

A.7 Individual Contributions

A.7.1 Fall 2018

Alyssa Lau was responsible for the introduction and the background of the paper. This included researching and writing about the history of the Salmon River Estuary, the current conditions or the site, judicial aspects, environmental aspects, stake holder aspects, political aspects, societal aspects, global factors, constructability aspects, economic factors and data collected. She was also responsible for writing about keeping existing conditions of the Salmon River Estuary.

Sean Urabe performed research on and wrote about the feasibility, constructability and effectiveness of installing multiple culverts. He also compiled a table of codes and a table of billable hours spent on the project.

Mustaf Mohamed did research on the developmental codes in Lincoln county, cost estimate on high way removal, and level service evolution for a two-lane highway. He was in charge of writing about the highway removal and rerouting of the alternative analysis section.

Bailey Smithline was responsible for detailing the scope of work within the written report. Additionally, Bailey was responsible for researching and completing the elevated roadway alternative written analysis based on environmental impact, constructability, economic factors and feasibility. Lastly, she wrote a review on the team's ability to display leadership, effectively communicate, keep organized, and make collective decisions.

Shea Chun was responsible for researching and completing the written analysis of the floating bridge alternative in regard to particular aspects such as functionality, environmental impact, cost, and constructability. In addition, she was responsible for analyzing the scheduling and separation of the team's work between first and second semester. Thirdly, she completed a tentative schedule for the first and second semester through the use of Microsoft Project.

A.7.2 Spring 2019

Alyssa Lau was responsible for compiling and formatting the design drawings as well as writing the culvert design portion of the paper. This included explaining the different components of the culvert design such as the foundation and composition of culvert bed. In addition, she wrote about how non-technical aspects such as economic, environmental, social, political, ethical, safety, constructability, and sustainability, affected the design.

Sean Urabe researched culvert design using resources such as the ODOT's design manual. Sean also worked on the cost analysis for the recommended final design which included individual calculations and a written summary. Finally, he produced cross sectional drawings of the roadway design.

Mustaf Mohamed was responsible for investigating roadway design and traffic control plans. He produced a pavement design for the culverts and produced the traffic control drawings. In addition, he was in charge of reading the MUTCD, to ensure the traffic control plans adhered to the standards

Bailey Smithline was responsible for completing and writing the analysis for the Envision checklist. She also researched WDFW standards for culvert design in an environmentally sensitive area. She wrote the report sections on post construction maintenance required for the design and the roadway design. Additionally, Bailey completed the section view drawing of the multiple culvert design. She tabulated the team's hours for Spring 2019. Finally, Bailey compiled the meeting agendas as well as meeting minutes for the five meetings with our industry advisor.

Shea Chun was responsible for researching and implementing Oregon Department of Transportation's (ODOT) culvert design manual. In addition, she was responsible for producing a cost estimate for the project using RSMeans and other data. Thirdly, she reviewed the use of the Microsoft Project schedule (that was previously compiled in the first semester) during the entire year.

APPENDIX B: Meeting Minutes and Meeting Agendas

B.1 Meeting Minutes with Dr. Poor

B.2 Meeting Minutes with Debbie Pickering

<u>**APPENDIX C: Drawings**</u>

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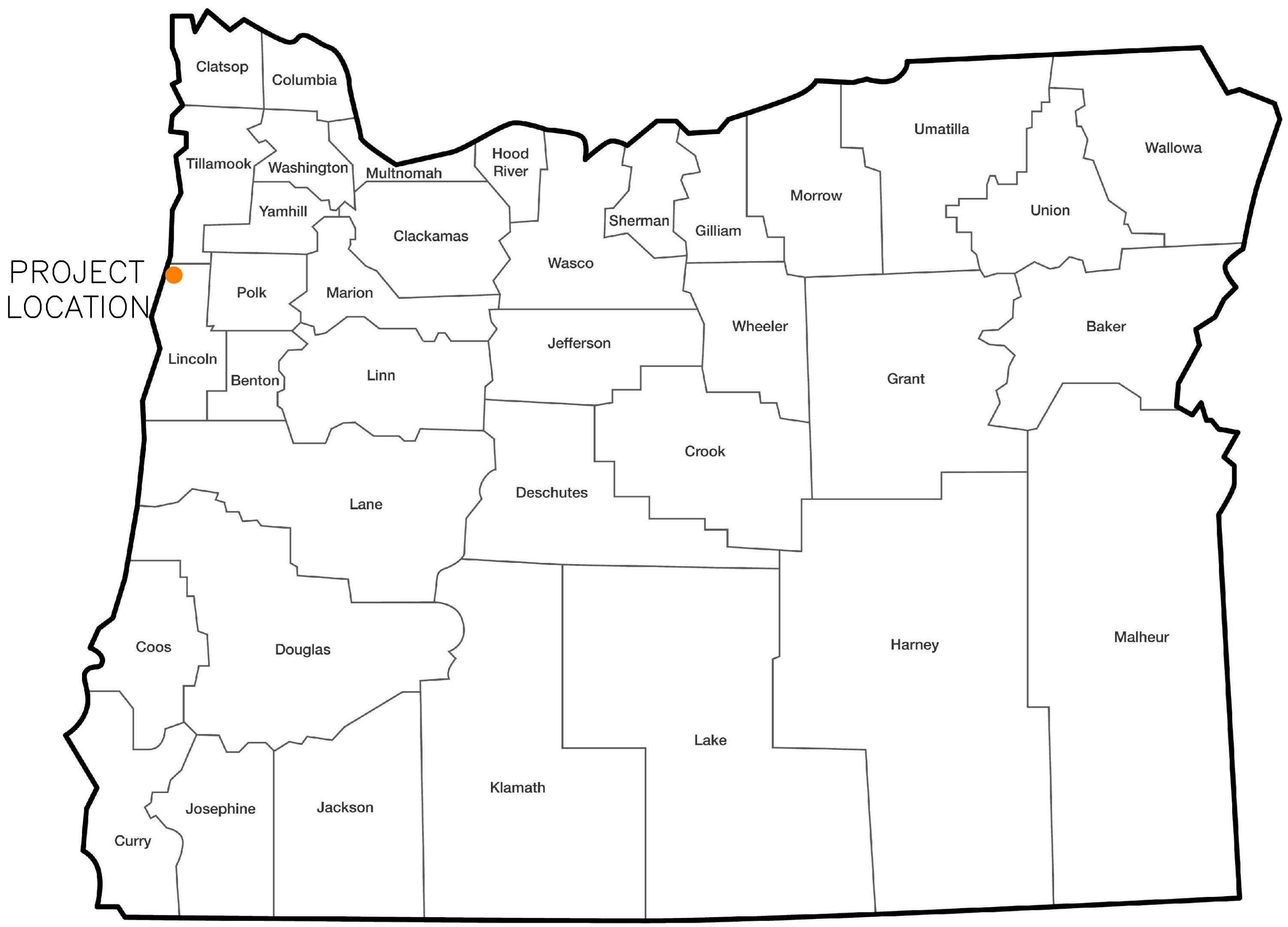
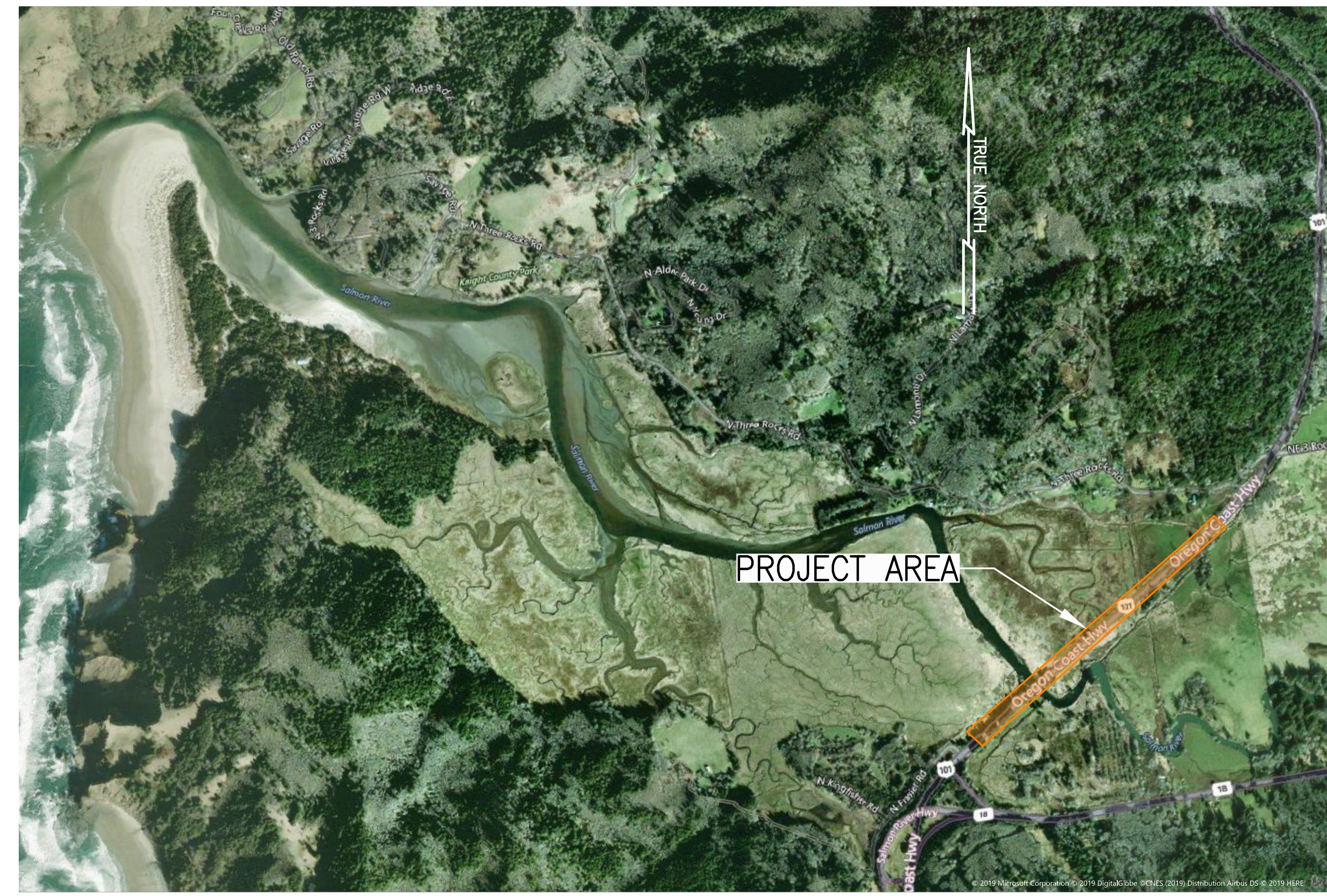




CE 484 - CIVIL ENGINEERING CAPSTONE II

SALMON RIVER ESTUARY PROEJCT

OTIS, OREGON

INDEX OF SHEETS

SHEET NO.	DESCRIPTION	SHEET NO.	DESCRIPTION
T-1	TITLE SHEET	C-8	PROFILE AND PLAN VIEW-4
C-1	PROJECT MAP	C-9	PROFILE AND PLAN VIEW-5
C-2	COMPREHENSIVE DETAIL	C-10	PROFILE AND PLAN VIEW-6
C-3	TYPICAL ROADWAY SECTION	C-11	TRAFFIC CONTROL PLAN -1
C-4	CULVERT SECTION	C-12	TRAFFIC CONTROL PLAN -2
C-5	PROFILE AND PLAN VIEW-1	C-13	TRAFFIC CONTROL PLAN -3
C-6	PROFILE AND PLAN VIEW-2	C-14	TRAFFIC CONTROL PLAN -4
C-7	PROFILE AND PLAN VIEW-3	C-15	GUARD RAIL DETAILS (BR266)

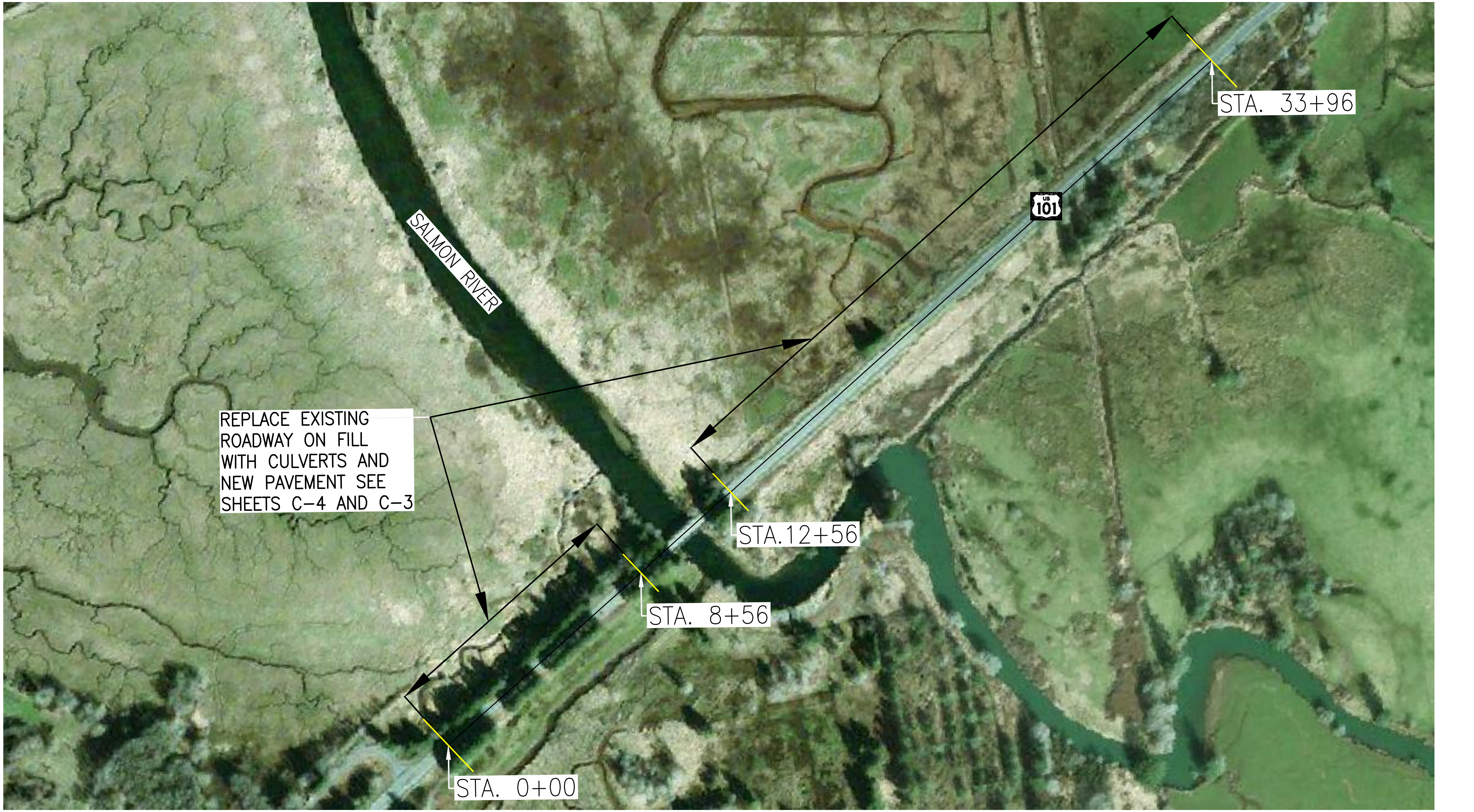
University of Portland

TEAM MEMBERS: A. LAU, B. SMITHLINE, S. CHUN, S. URABE, AND M. MOHAMED

DATE: APRIL 26, 2019

SHEET 1 OF 16 SHEETS

DRAWING NO. T-1



PROJECT MAP–SALMON RIVER ESTUARY
NOT TO SCALE

PROJECT AREA
FROM: STA. 0+00 to STA. 8+56
AND
STA. 12+56 to STA. 33+96

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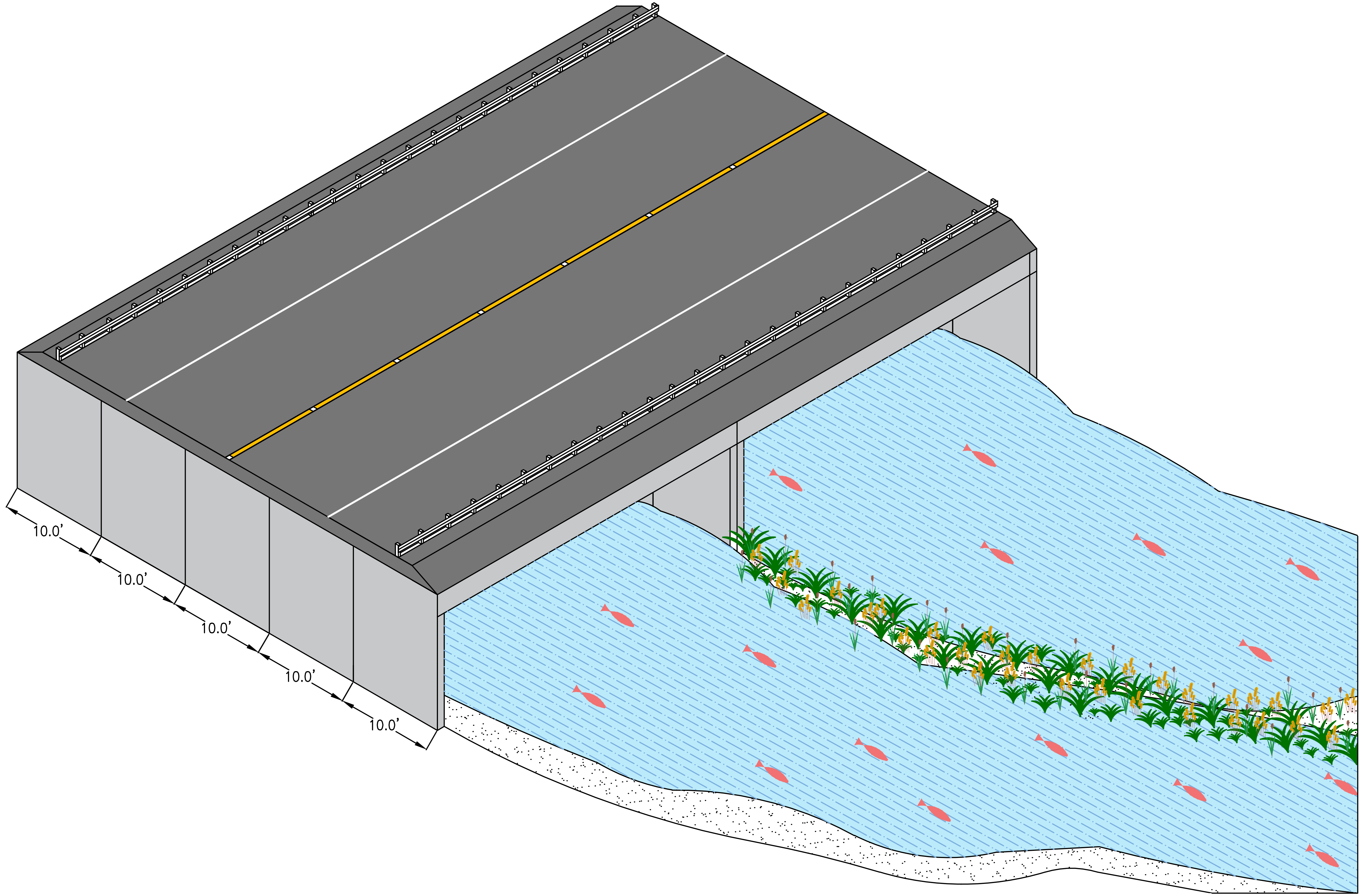
SALMON RIVER ESTUARY PROJECT
OTIS OREGON

PROJECT MAP

TEAM NAMES: A. LAU, B. SMITHLINE, S. CHUN, S. URABE, AND M. MOHAMED		
DRAWING AUTHOR: ALYSSA LAU	SHEET 2	DRAWING NO. C–1
DATE: APRIL 26, 2019	OF 16 SHEETS	



COMPREHENSIVE VIEW

NOT TO SCALE

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SALMON RIVER ESTUARY PROJECT

OTIS OREGON

COMPREHENSIVE DETAIL

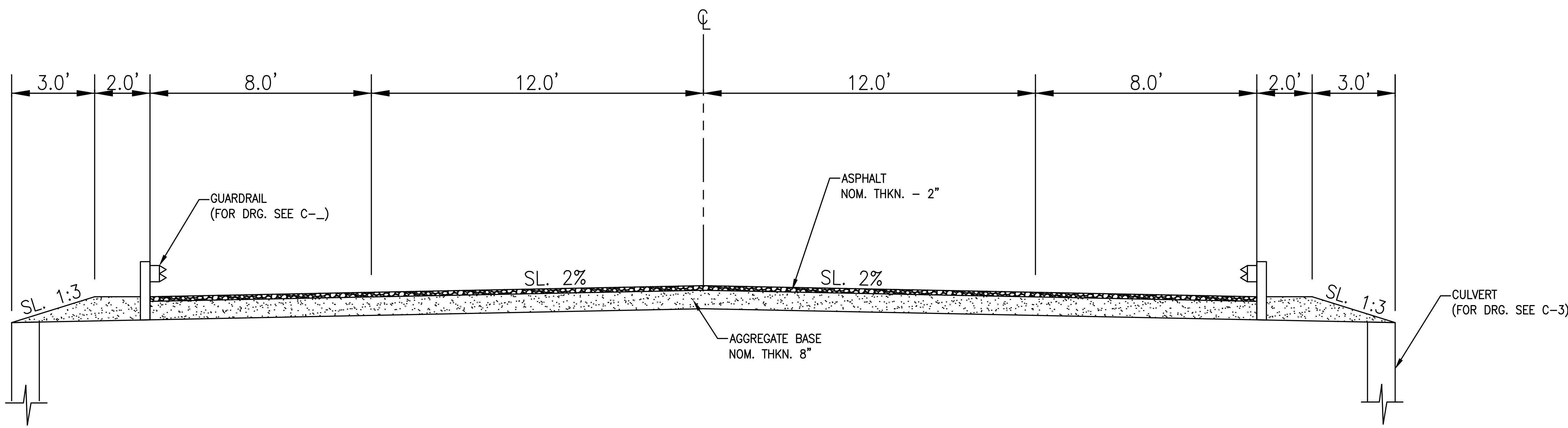
TEAM NAMES: A. LAU, B. SMITHLINE, S. CHUN, S. URABE, AND M. MOHAMED

DRAWING AUTHOR: ALYSSA LAU

DATE: APRIL 26, 2019

SHEET 3 OF 16 SHEETS

DRAWING NO. C–2

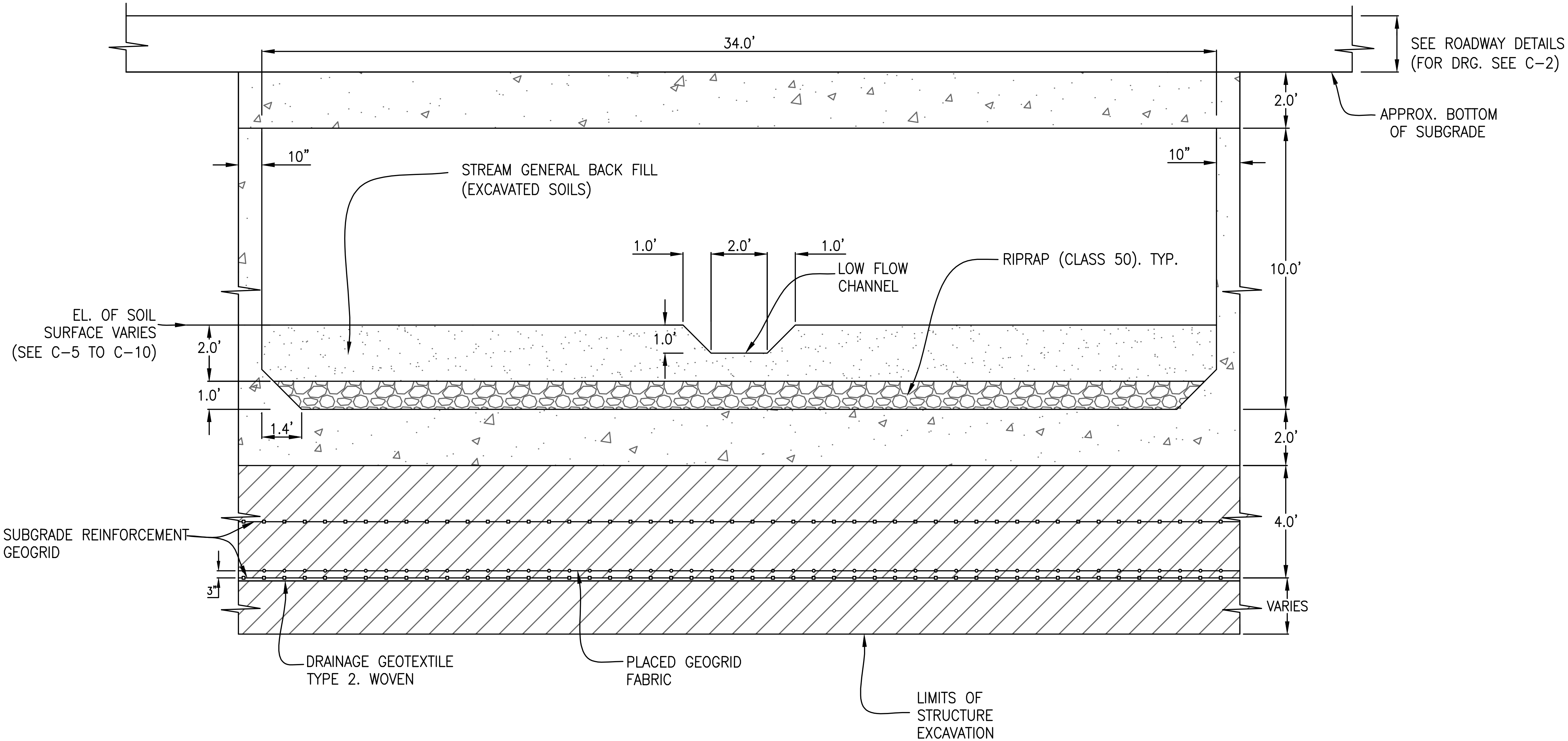


TYPICAL ROADWAY SECTION

SCALE: 1"=2'

FOR: STA. 0+00 TO STA. 8+56 AND STA. 12+56 TO STA. 33+96

University of Portland	
CE 484 - CIVIL ENGINEERING CAPSTONE II **SALMON RIVER ESTUARY PROJECT** OTIS OREGON	
TYPICAL ROADWAY SECTION	
TEAM NAMES: A. LAU, B. SMITHLINE, S. CHUN, S. URABE, AND M. MOHAMED	
DRAWING AUTHOR: SEAN URABE	SHEET 4
DATE: APRIL 26, 2019	OF 16 SHEETS
DRAWING NO.	C-3



TYPICAL SECTION–INVERTED CULVERT

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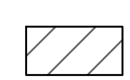

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CULVERT SECTION

TEAM NAMES:	A. LAU, B. SMITHLINE, S. CHUN, S. URABE, AND M. MOHAMED		
DRAWING AUTHOR:	BAILEY SMITHLINE	SHEET 5	DRAWING NO. C-4
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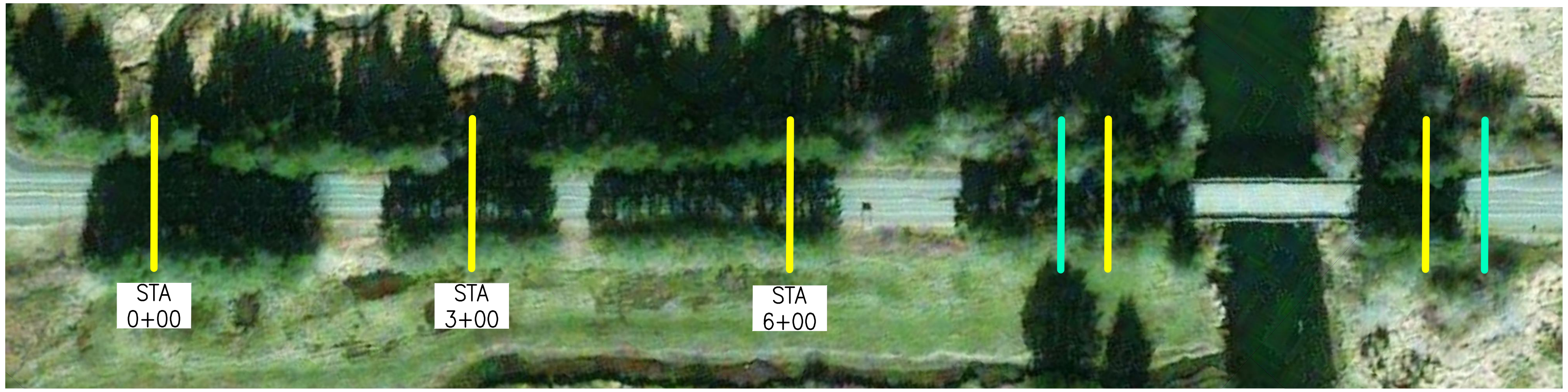

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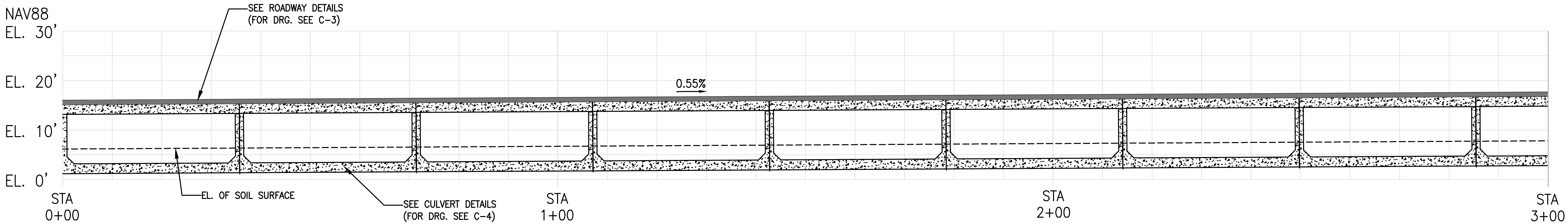
NOT TO SCALE



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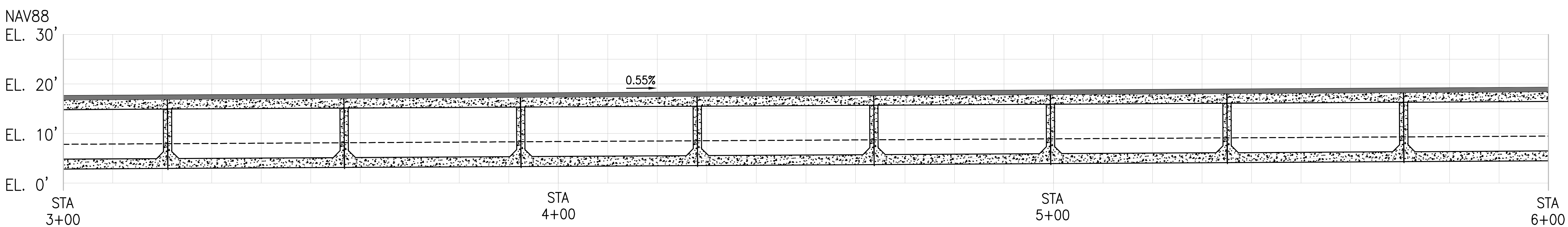

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SCALE: 1"=10'

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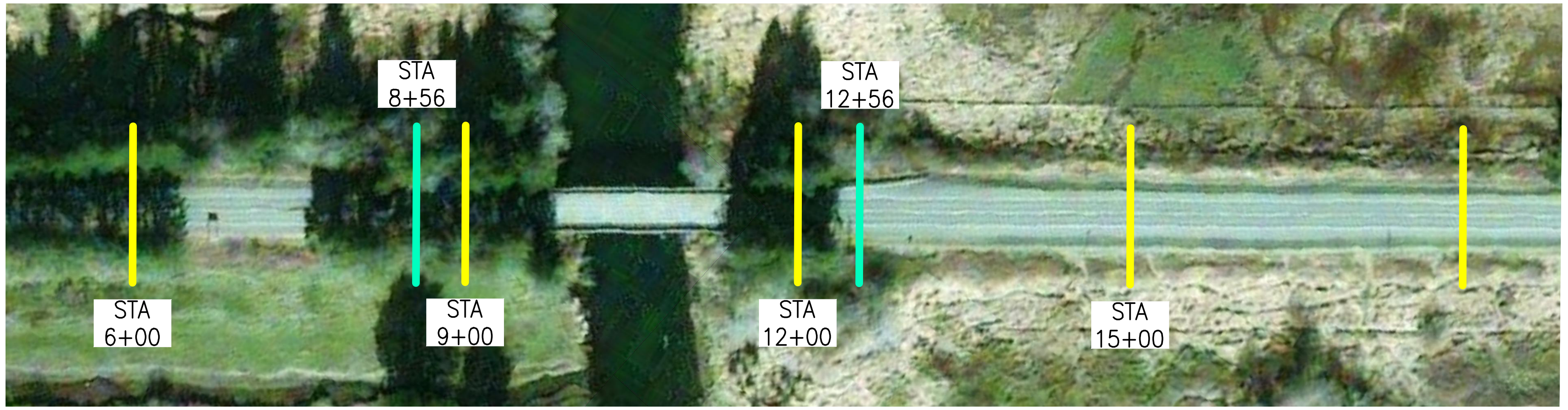
SALMON RIVER ESTUARY PROJECT

OTIS OREGON

PLAN AND PROFILE VIEW – 1

TEAM NAMES:	A. LAU, B. SMITHLINE, S. CHUN, S. URABE, AND M. MOHAMED		
DRAWING AUTHOR:	ALYSSA LAU	SHEET 6	DRAWING NO. C-5
DATE:	APRIL 26, 2019	OF 16 SHEETS	



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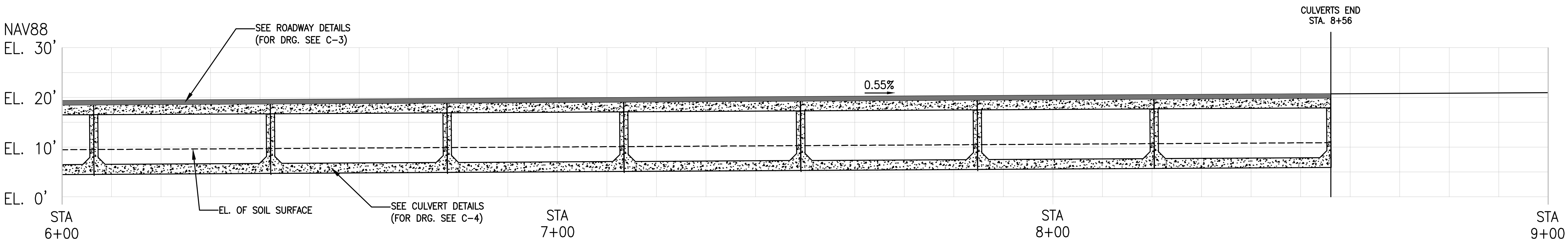
NOT TO SCALE



PROFILE STA. 6+00 TO STA. 9+00

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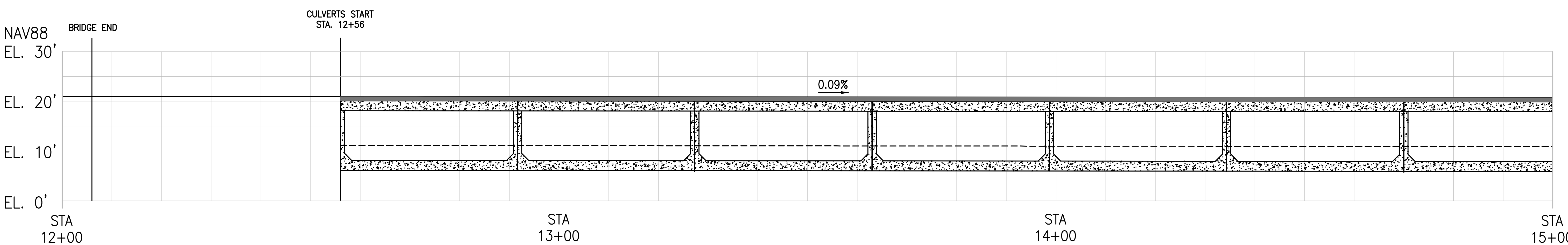

PROFILE STA. 12+00 TO STA. 15+00

SCALE: 1"=10'

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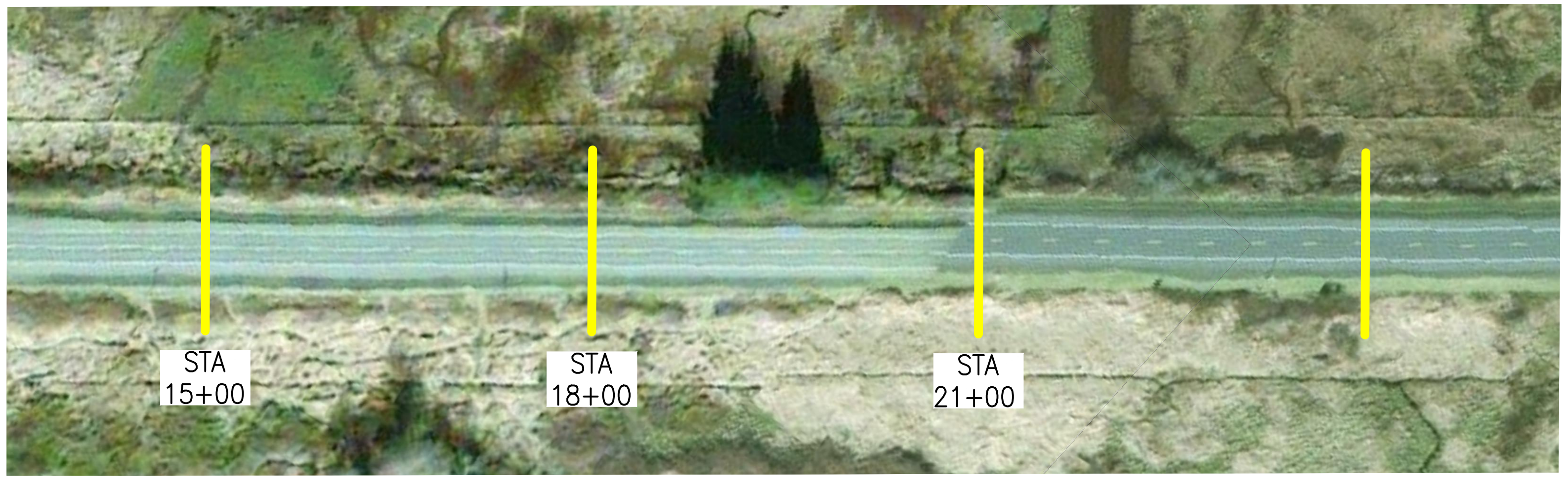
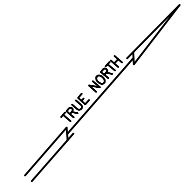
SALMON RIVER ESTUARY PROJECT

OTIS OREGON

PLAN AND PROFILE VIEW – 2

TEAM NAMES:	A. LAU, B. SMITHLINE, S. CHUN, S. URABE, AND M. MOHAMED
DRAWING AUTHOR:	ALYSSA LAU
DATE:	APRIL 26, 2019
SHEET 7 OF 16 SHEETS	DRAWING NO. C–6





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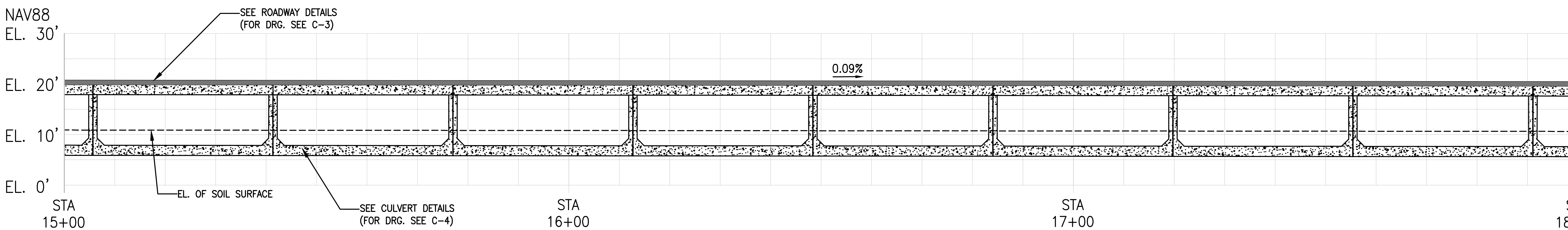

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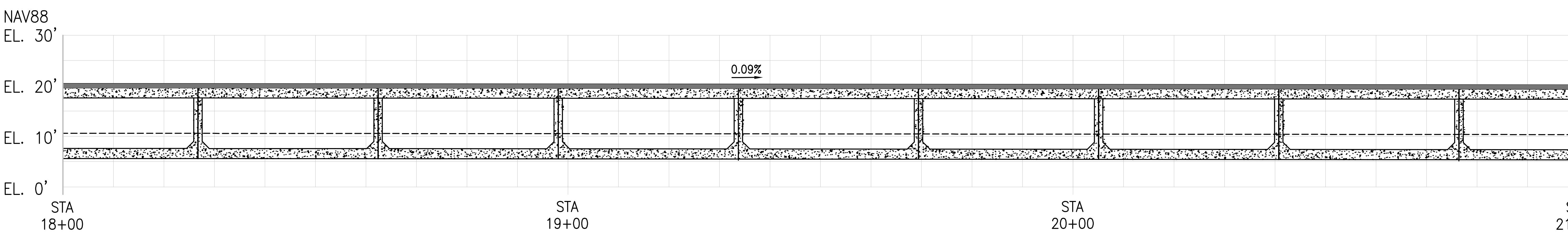

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SCALE: 1"=10'

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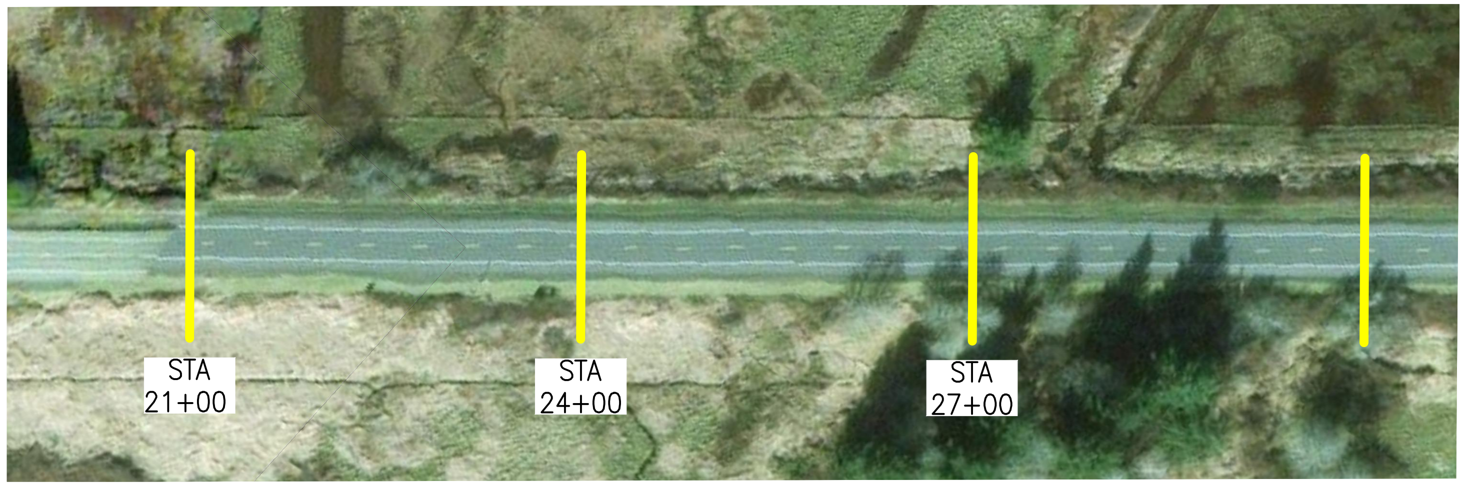
CE 484 - CIVIL ENGINEERING CAPSTONE II

SALMON RIVER ESTUARY PROJECT

OTIS OREGON

PLAN AND PROFILE VIEW – 3

TEAM NAMES:	A. LAU, B. SMITHLINE, S. CHUN, S. URABE, AND M. MOHAMED
DRAWING AUTHOR:	ALYSSA LAU
DATE:	APRIL 26, 2019
SHEET 8 OF 16 SHEETS	DRAWING NO. C–7



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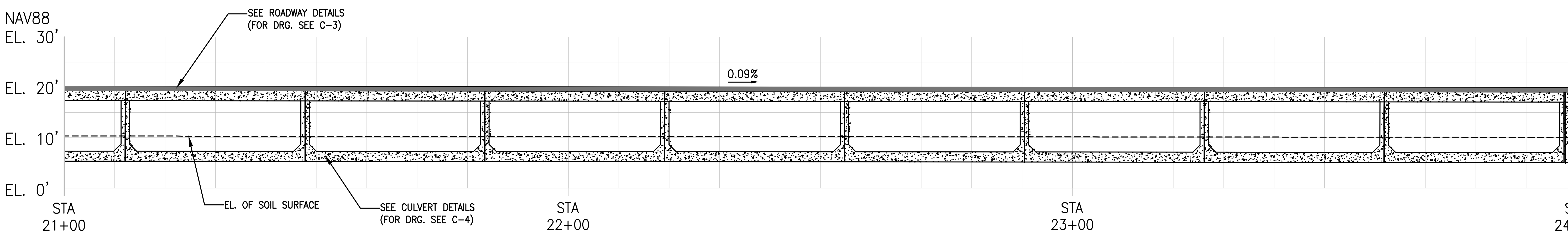

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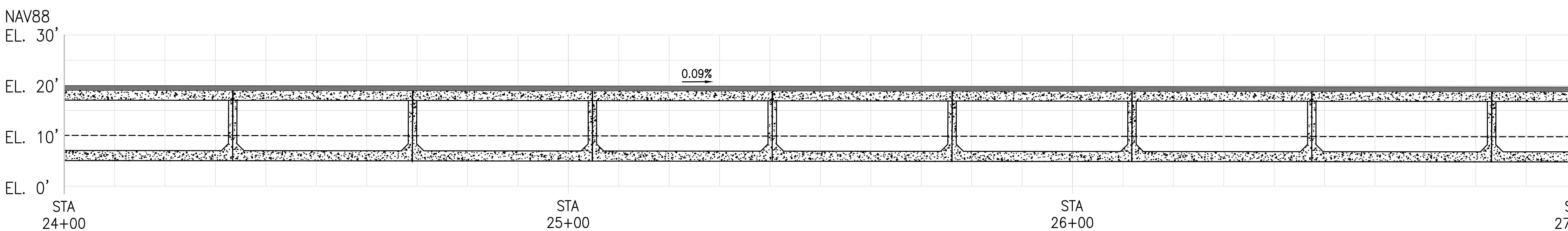

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SCALE: 1"=10'

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SALMON RIVER ESTUARY PROJECT
OTIS OREGON

PLAN AND PROFILE VIEW – 4

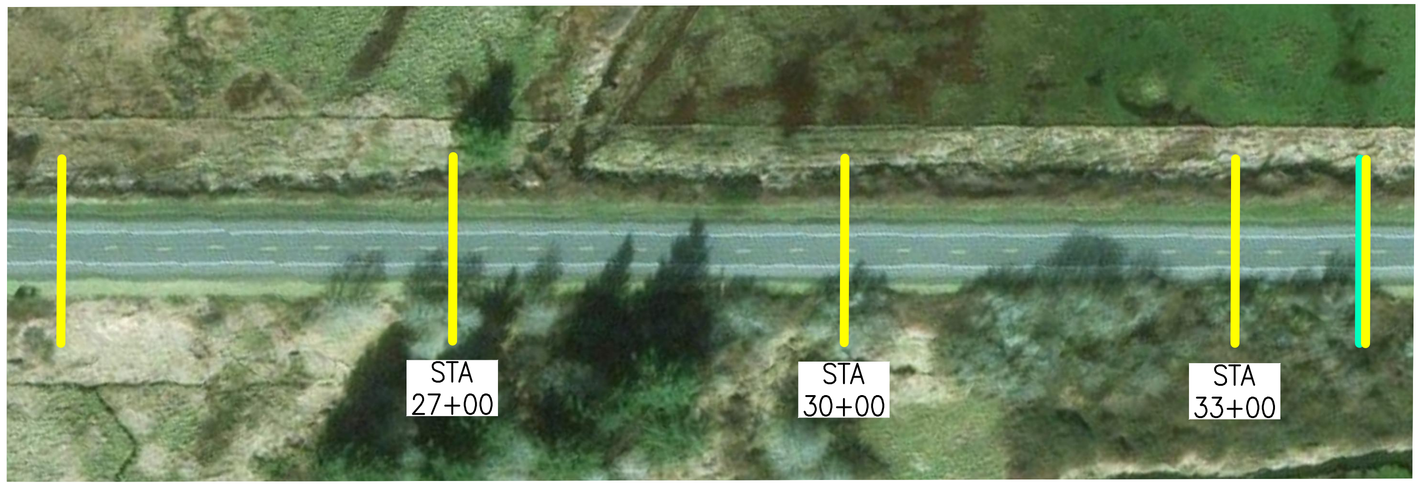
TEAM NAMES: A. LAU, B. SMITHLINE, S. CHUN, S. URABE, AND M. MOHAMED

DRAWING AUTHOR: ALYSSA LAU

DATE: APRIL 26, 2019

SHEET 9 OF 16 SHEETS

DRAWING NO. C–8



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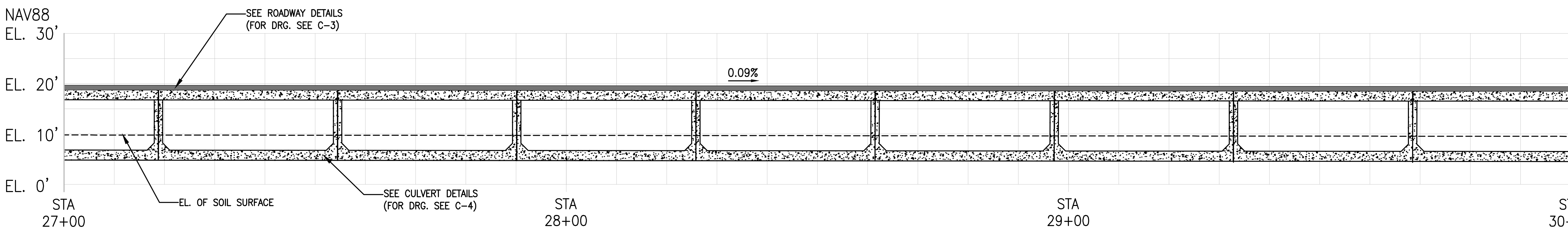

PROFILE STA. 27+00 TO STA. 30+00

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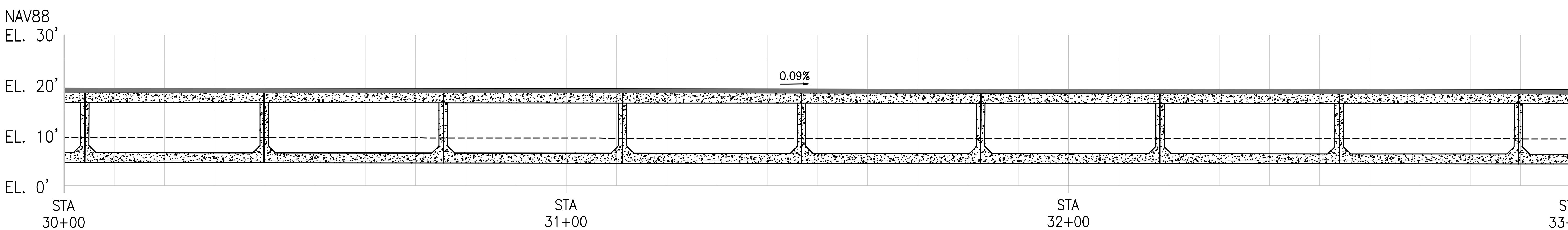

PROFILE STA. 30+00 TO STA. 23+00

SCALE: 1"=10'

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CE 484 - CIVIL ENGINEERING CAPSTONE II

SALMON RIVER ESTUARY PROJECT

OTIS OREGON

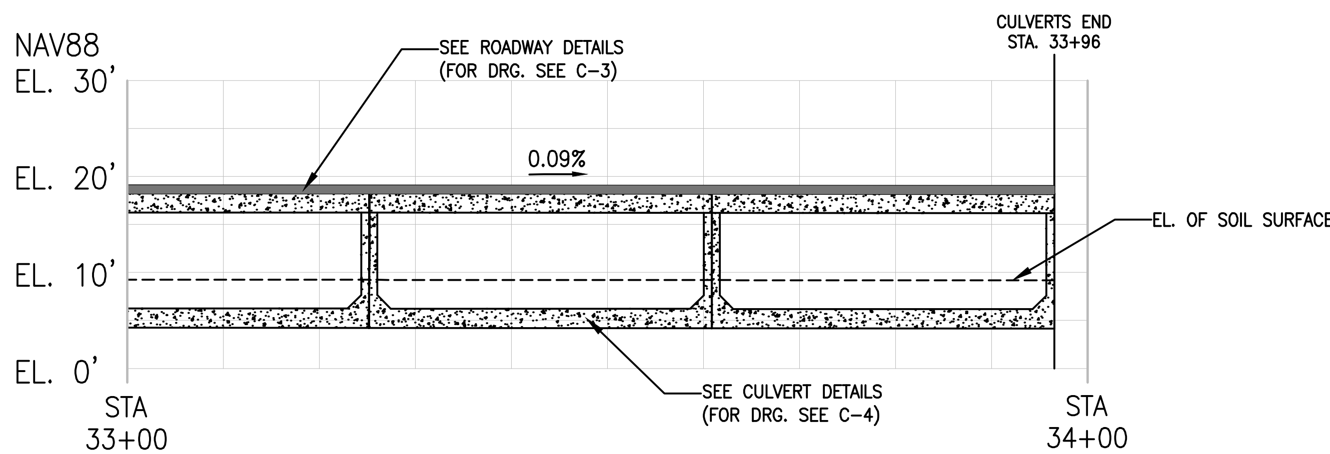
PLAN AND PROFILE VIEW – 5

TEAM NAMES:	A. LAU, B. SMITHLINE, S. CHUN, S. URABE, AND M. MOHAMED		
DRAWING AUTHOR:	ALYSSA LAU	SHEET 10	DRAWING NO. C–9
DATE:	APRIL 26, 2019	OF 16 SHEETS	

TRUE NORTH

PLAN STA. 33+00 TO STA. 34+00

NOT TO SCALE



PROFILE STA. 33+00 TO STA. 34+00

SCALE: 1"=10'

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CE 484 - CIVIL ENGINEERING CAPSTONE II

SALMON RIVER ESTUARY PROJECT

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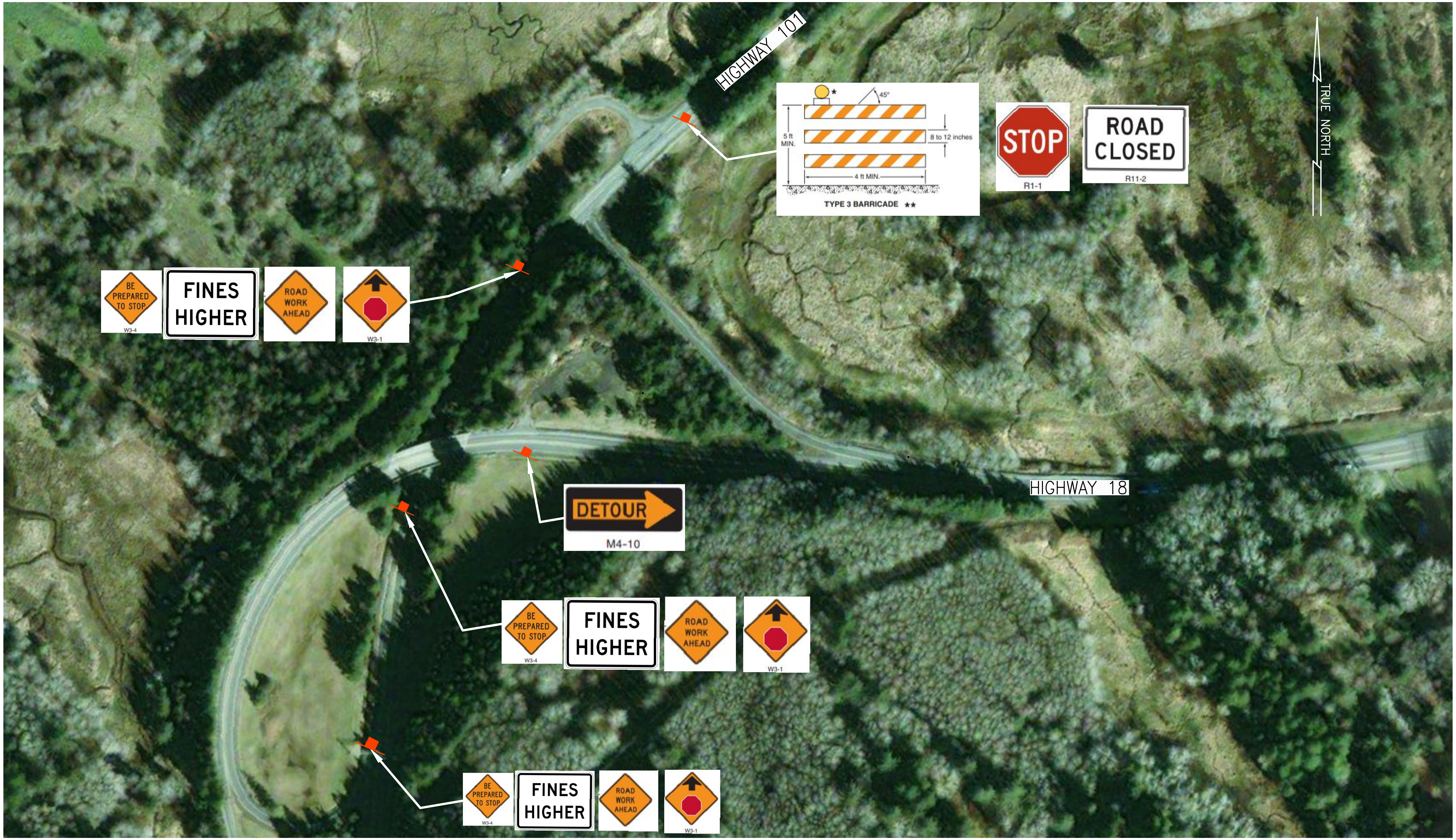
PLAN AND PROFILE VIEW – 6

TEAM NAMES:	A. LAU, B. SMITHLINE, S. CHUN, S. URABE, AND M. MOHAMED		
DRAWING AUTHOR:	ALYSSA LAU	SHEET 11	DRAWING NO. C–10
DATE:	APRIL 26, 2019	OF 16 SHEETS	



HIGHWAY 101/HIGHWAY 18

NOT TO SCALE

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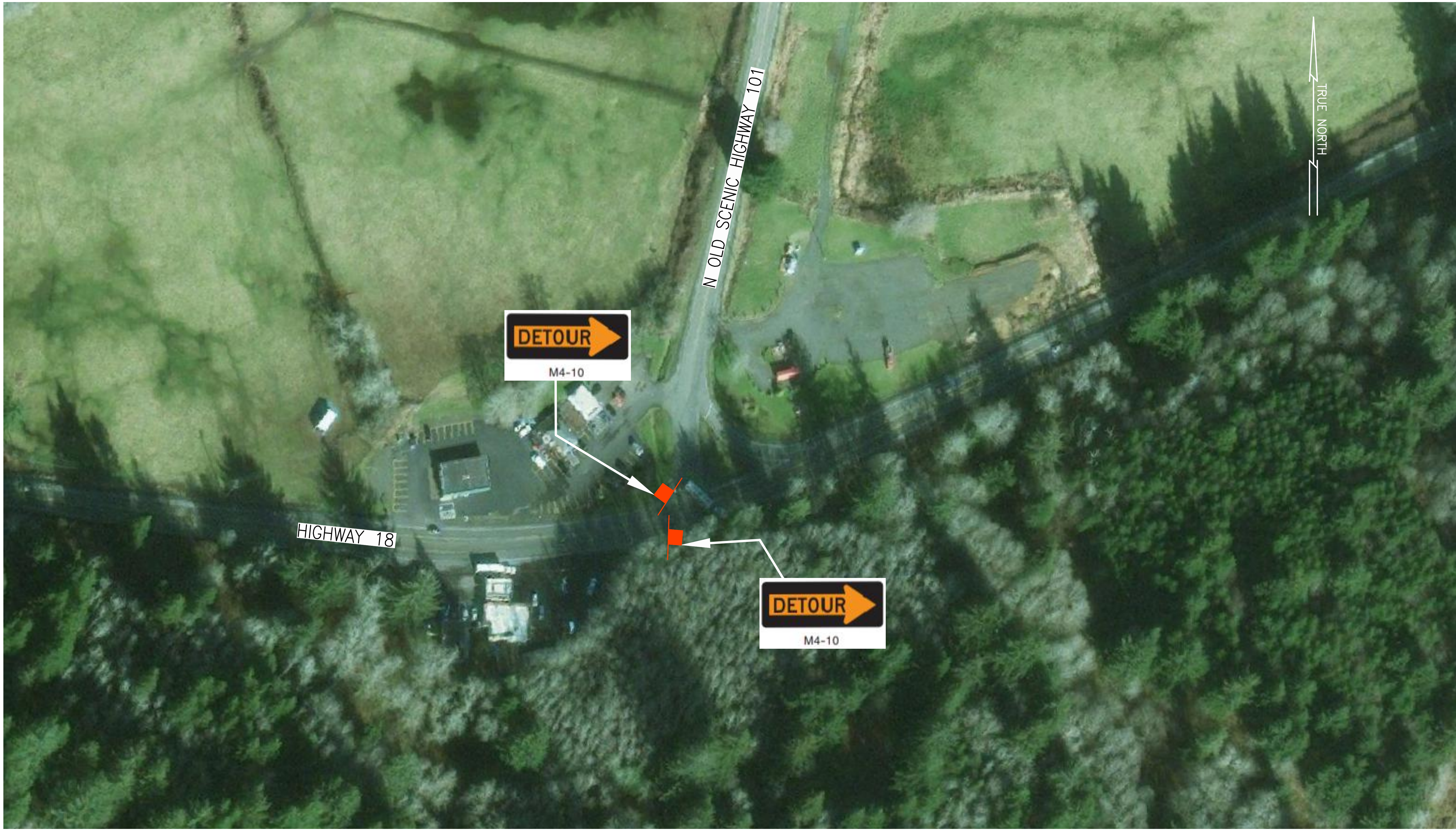
SALMON RIVER ESTUARY PROJECT

OTIS OREGON

TRAFFIC CONTROL PLAN -1

TEAM NAMES:	A. LAU, B. SMITHLINE, S. CHUN, S. URABE, AND M. MOHAMED		
DRAWING AUTHOR:	MUSTAF MOHAMED	SHEET 12	DRAWING NO. C-11
DATE:	APRIL 26, 2019	OF 16 SHEETS	



N OLD SCENIC HIGHWAY 101/HIGHWAY 18

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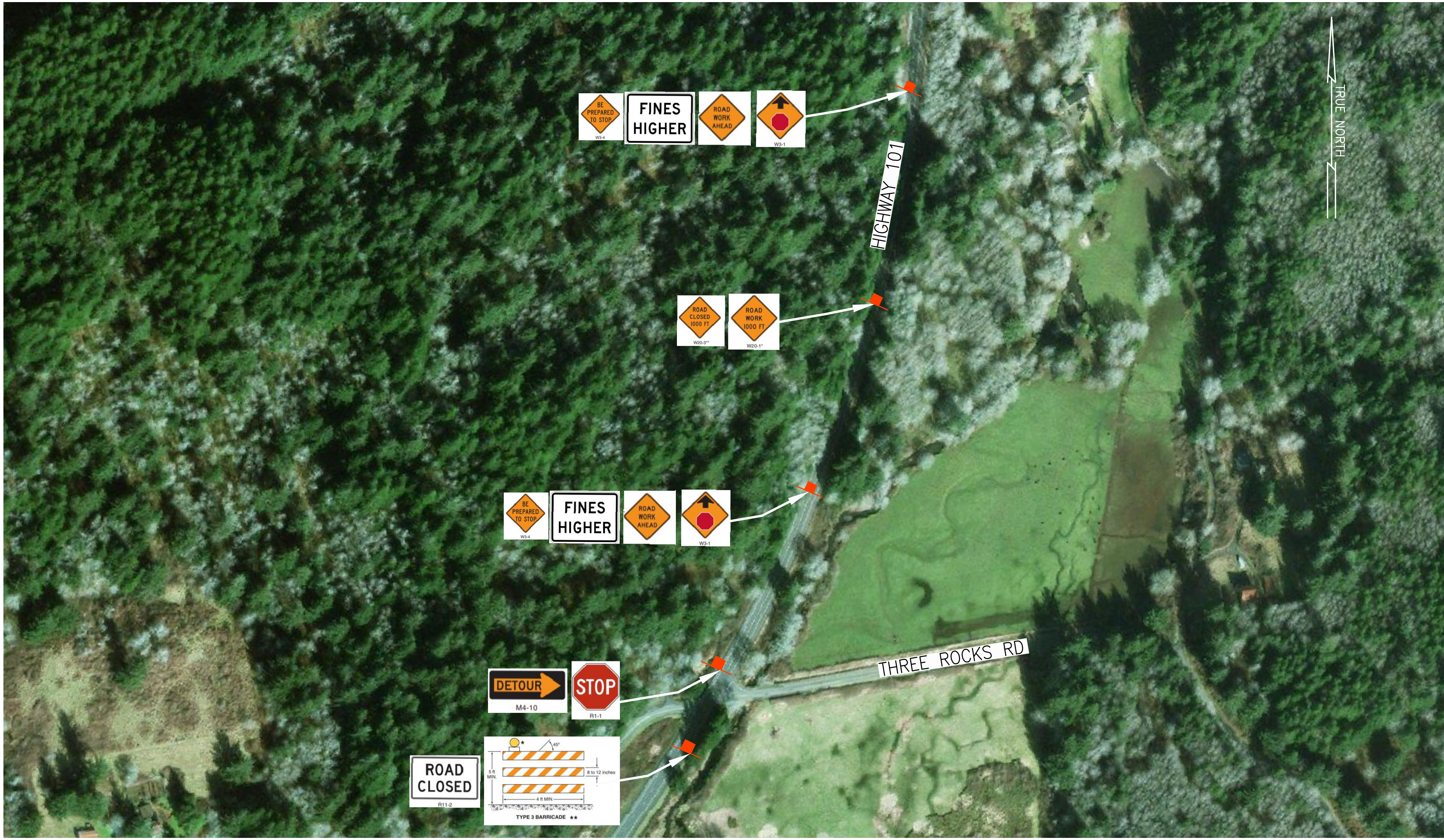
CE 484 - CIVIL ENGINEERING CAPSTONE II

SALMON RIVER ESTUARY PROJECT

OTIS OREGON

TRAFFIC CONTROL PLAN -2

TEAM NAMES:	A. LAU, B. SMITHLINE, S. CHUN, S. URABE, AND M. MOHAMED
DRAWING AUTHOR:	MUSTAF MOHAMED
DATE:	APRIL 26, 2019
SHEET 13 OF 16 SHEETS	DRAWING NO. C-12



HIGHWAY 101/THREE ROCKS RD

NOT TO SCALE

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SALMON RIVER ESTUARY PROJECT

OTIS OREGON

TRAFFIC CONTROL PLAN -3

TEAM NAMES:	A. LAU, B. SMITHLINE, S. CHUN, S. URABE, AND M. MOHAMED
DRAWING AUTHOR:	MUSTAF MOHAMED
DATE:	APRIL 26, 2019
SHEET 14 OF 16 SHEETS	DRAWING NO. C-13

NORTH SCENIC HIGHWAY 101/ THREE ROCKS RD.

NOT TO SCALE

University of Portland

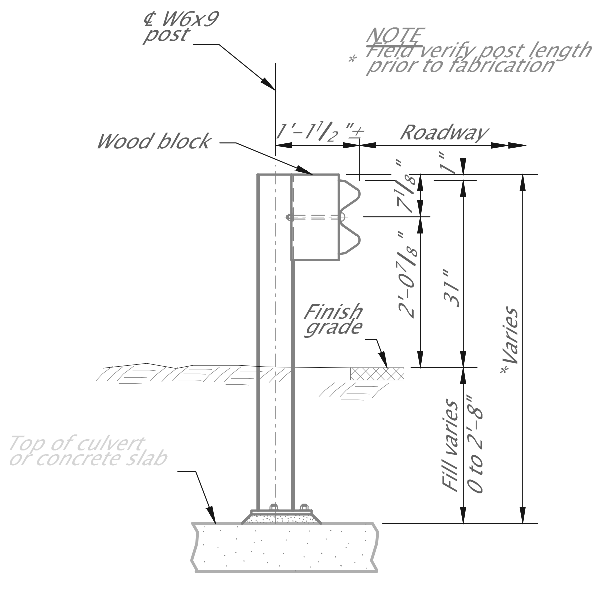
CE 484 - CIVIL ENGINEERING CAPSTONE II

SALMON RIVER ESTUARY PROJECT

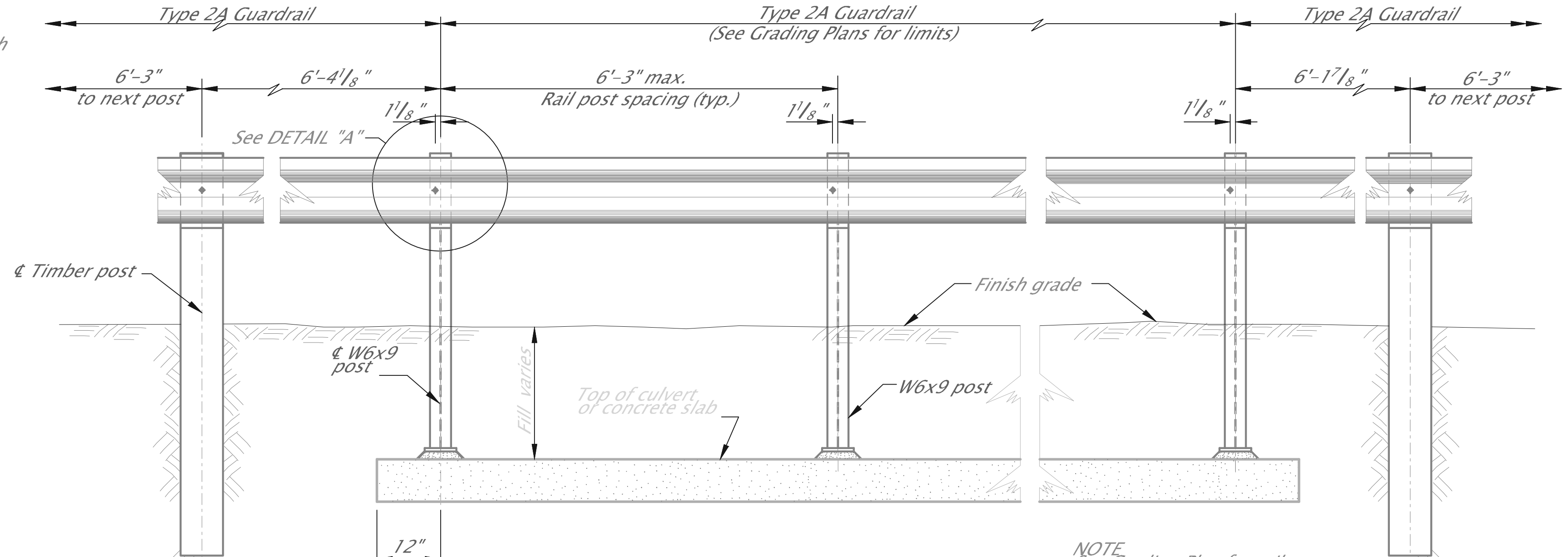
OTIS OREGON

TRAFFIC CONTROL PLAN -4

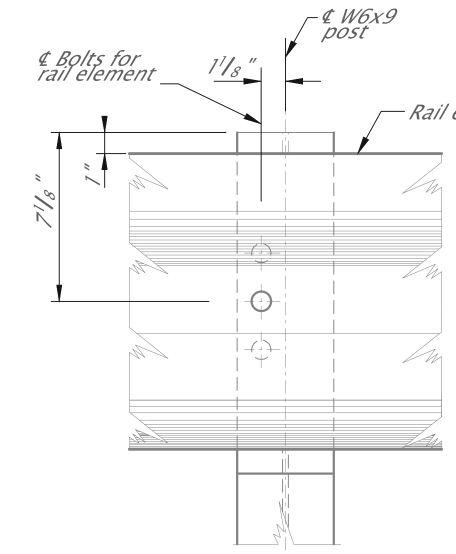
TEAM NAMES:	A. LAU, B. SMITHLINE, S. CHUN, S. URABE, AND M. MOHAMED		
DRAWING AUTHOR:	MUSTAF MOHAMED	SHEET 15	DRAWING NO. C-14
DATE:	APRIL 26, 2019	OF 16 SHEETS	



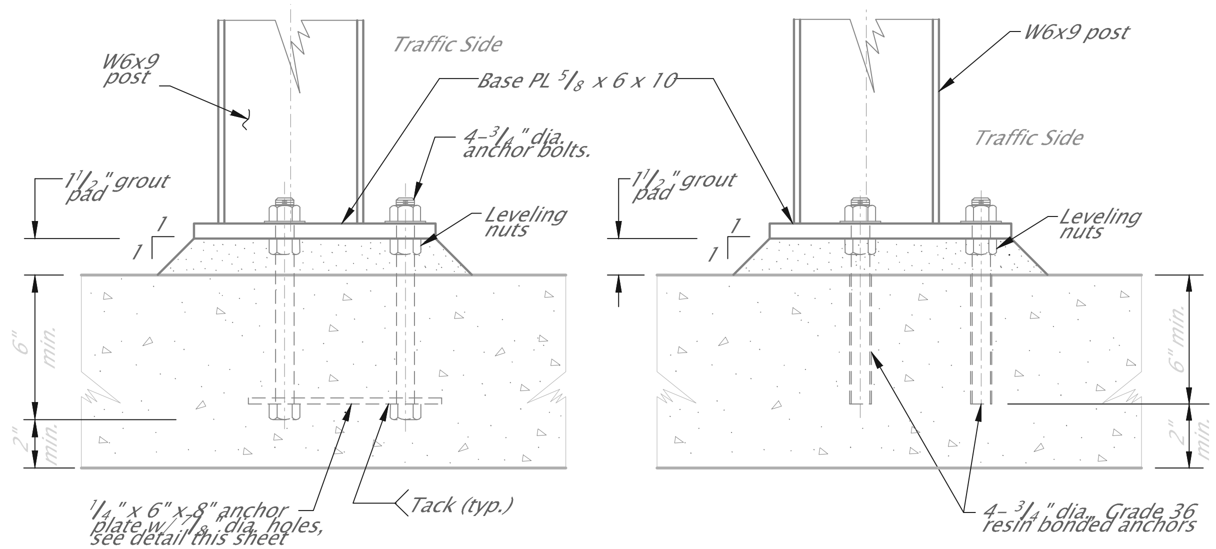
TYPICAL SECTION



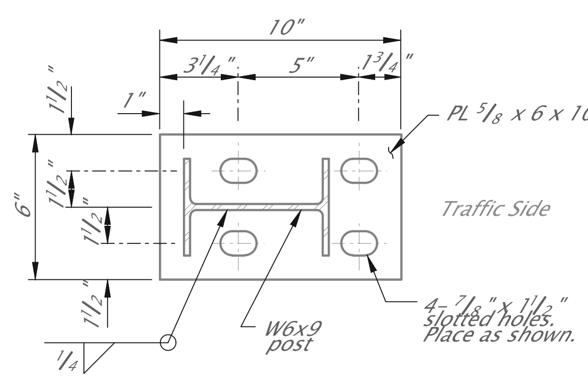
ELEVATION



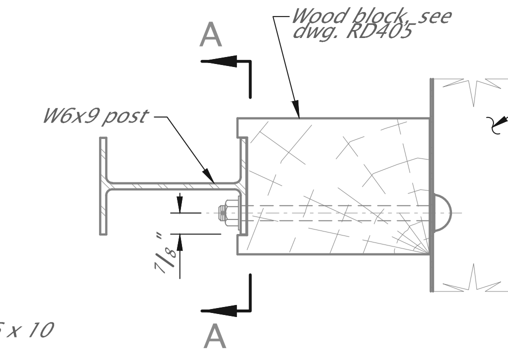
DETAIL "A"



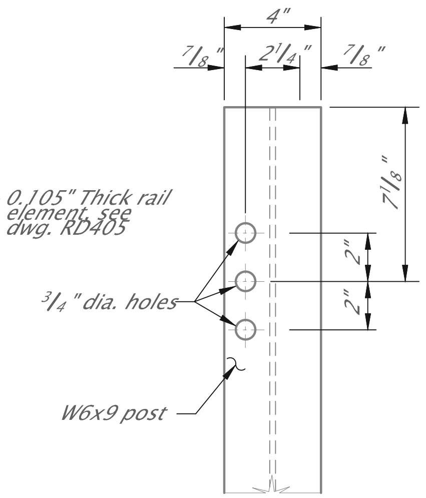
BASE PLATE DETAILS



BASE PLATE DETAILS



TOP VIEW

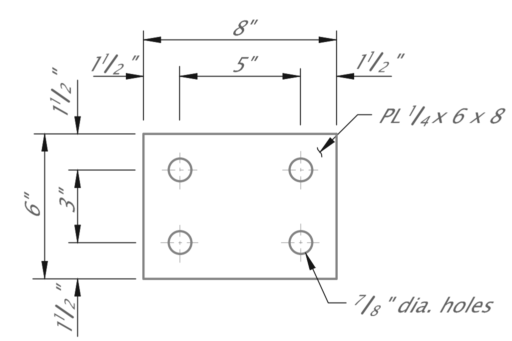


SECTION A-A

Accompanied by dwgs. RD480, RD405

GENERAL NOTES:

Use guardrail hardware as shown on dwg. RD405.
Fabricate railing to the horizontal and vertical alignment of the roadway. Installing posts normal to grade.
Provide all structural steel (except anchor bolts) conforming to AASHTO M183 (ASTM A36).
Provide all bolts meeting ASTM A307, except as noted.
Hot-dip galvanize all structural steel after fabrication.
Provide Grade 36 anchor bolts according to ODOT Specification 02560.30 (a) (Alternate "A").
Provide and install Grade 36 resin bonded anchors according to ODOT Specification 00535.
Coat all buried steel for immersion exposure with an approved product from the qualified products list for structural coatings.
Prepare and coat surfaces according to section 00594 of Oregon Standard Specification.



ALTERNATE "A" ANCHOR PLATE

GUARD RAIL DETAILS (BR266) ARE FROM ODOT'S ARCHIVE OF STANDARD DRAWINGS. PLEASE SEE THE FOLLOWING LINK FOR MORE INFORMATION:
https://www.oregon.gov/ODOTEngineering/Pages/Drawings-Bridge.aspx

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SALMON RIVER ESTUARY PROJECT
OTIS OREGON

GUARD RAIL DETAILS (BR266)

TEAM NAMES:	A. LAU, B. SMITHLINE, S. CHUN, S. URABE, AND M. MOHAMED		
DRAWING AUTHOR:	ODOT	SHEET 16	DRAWING NO. C-15
DATE:	APRIL 26, 2019	OF 16 SHEETS	

br266.dgn 03-2017

APPENDIX D: Calculations

Traffic Calculations:

Level of service calculation for the two-lane highway was evaluated using percent time spend following.

Formulas:

$PTSF_d = BPTSF_d + F_n(vd/(v_d+v_o))$ Percent time spent following

$BPTSF_d = 100[1-exp(a(v_d\ )^b]$

Highway 18 information from ODOT Trans-GIS

AADT range = 10,0001-15000
K= 15.3%
Direction factor (D) = 58
Average AADT = 12,500
Heavy Vehicle factor = 8.25%

Highway 101 information from ODOT Trans-GIS

AADT range = 2,501-5,000
K = 13.6%
Direction factor (D) = 56%
Average AADT = 3750
Heavy Vehicle factor = 13.5%

v_{d1}' = 12500*0.58*0.153 = 1109
v_{o1}' = 12500*0.42*0.153 = 803
PHF = 1, level terrain
F_{hv} = 1/(1+.0.0825(1-1)=1
V_d = 1109/1*1*1=1109
V_o= 803
V_d = 1395

v_{d2}' = 3750.5*0.136*0.56 = 286
v_{o2}' = 3750.5*0.136*0.44 = 224
PHF = 1, level terrain
F_{hv}=1
V_{d2} = 286
V_{d2} = 224
V_o = 1027

$BTSF_d = 100[1-exp(-0.0058(1395)^{0.821})] = 89$
$PTSF_d = 89 + 5.9(1395/2422) = 93\%$
LOS E

Hydraulic Calculations:

Manning's Equation:

$$Q = \frac{1.49}{n} * A * R^{\frac{2}{3}} * S^{\frac{1}{2}}$$

$$V = \frac{1.49}{n} * R^{\frac{2}{3}} * S^{\frac{1}{2}}$$

Where,

Q = Discharge, cfs
V = Velocity, ft/ sec
n = Manning's Roughness coefficient
A = Cross Sectional Area of Flow, sqft
R = Hydraulic Radius, ft
S = Slope of Conduit, ft/ft

Assuming full flow

$$R = \frac{A}{P} = \frac{34' * 7'}{2 * 34' + 2 * 7'} = 2.902\ ft$$

$$Q = \frac{1.49}{0.05} * 238 * 2.902^{\frac{2}{3}} * 0.0005^{\frac{1}{2}}$$

Q = 322 cfs; maximum flow for each culvert

$$V = \frac{1.49}{0.05} * 2.902^{\frac{2}{3}} * 0.0005^{\frac{1}{2}}$$

V= 1.3 fps, velocity at maximum flow for each culvert

According to WDFW Water Crossing Design Guidelines the allowable velocity for fish with culvert lengths between 10-100ft is 4 ft/s.

According to FishXing the swim speed for juvenile salmon (Coho, Chinook,Steelhead, Chum, Pink) can be calculated using the equation:

swim speed (ft/s) = 0.638L(in)-0.0172

Assuming the average length of a juvenile salmon is 3 inches the corresponding swim speed is:

swim speed (ft/s) = 0.638(3 in)-0.0172 = 1.89 fps, maximum velocity does not exceed swim speed.

Therefore, our design supports the passage of juvenile and adult fish.

APPENDIX E: Cost Analysis

RSMeans Data Sheet:

Quantity	Description	Unit	Material	Labor	Equipment	Total	Ext. Mat.	Ext. Labor	Ext. Equip.	Ext. Total
105000	Plant-mix asphalt paving, for highways and large paved areas, wearing course, 2" thick, no hauling included	S.Y.	$ 7.80	$ 0.51	$ 0.45	$ 8.76	$ 819,000	$ 53,550	$ 47,250	$ 919,800
54444	Subsurface investigation, test pits, loader/backhoe, heavy soil	C.Y.	$ -	$ 28.50	$ 19.40	$ 47.90	$ -	$ 1,551,654	$ 1,056,214	$ 2,607,868
14190	Rip-rap and rock lining, random, broken stone, 3/8 to 1/4 C.Y. pieces, machine placed for slope protection, grouted	S.Y.	$ 63.50	$ 19.55	$ 7.25	$ 90.30	$ 901,065	$ 277,415	$ 102,878	$ 1,281,357
105000	Geosynthetic soil stabilization, geotextile fabric, woven, 200 lb. tensile strength	S.Y.	$ 0.94	$ 0.19	$ -	$ 1.13	$ 98,700	$ 19,950	$ -	$ 118,650
3067620	Backfill, structural, common earth, 55 HP wheeled loader, 50' haul, excludes compaction	L.C.Y.	$ -	$ 2.84	$ 1.60	$ 4.44	$ -	$ 8,712,041	$ 4,908,192	$ 13,620,233
10	Selective clearing, brush, medium clearing, with dozer, ball and chain, excludes removal offsite	Acre	$ -	$ 380.00	$ 860.00	$1,240.00	$ -	$ 3,800	$ 8,600	$ 12,400
105000	Base course drainage layers, aggregate base course for roadways and large paved areas, stone base, compacted, 3/4" stone base, to 8" deep	S.Y.	$ 8.00	$ 0.33	$ 0.84	$ 9.17	$ 840,000	$ 34,650	$ 88,200	$ 962,850
Total						**$ 1,402**	**$ 2,658,765**	**$ 10,653,059**	**$ 6,211,333**	**$ 19,523,157**

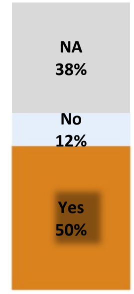
Cost-Based Estimate Analysis

CONSTRUCTION COST				
CULVERT	$46,500 per culv.	420 total culv.		$19,530,000.00
RIPRAP	REFER TO RSMeans DATA SHEET			$ 1,281,357.00
GUARDRAILS	$2 per sqr. Ft	42,000 sqr. Ft of Workspace		$ 168,000.00
GEOTEXTILE	REFER TO RSMeans DATA SHEET			$ 118,650.00
STRUCTURAL BACKFILL	REFER TO RSMeans DATA SHEET			$13,620,233.00
AGGREGATE BASE	REFER TO RSMeans DATA SHEET			$ 962,850.00
TREE/BRUSH REMOVAL	$ 40 per LF	21,000 LF of Roadway		$ 840,000.00
EXCAVATION	REFER TO RSMeans DATA SHEET			$ 2,607,868.00
MHMAC WEARING COURSE	REFER TO RSMeans DATA SHEET			$ 919,800.00
STREAMBED SOILS	USE EXISITING SOIL ON SITE			
			TOTAL	**$40,048,758.00**
PRE-DESIGN				
5% OF CONSTRUCTION COST			**TOTAL**	**$ 2,002,437.90**
DESIGN				
10% OF CONSTRUCTION COST			**TOTAL**	**$ 4,004,875.80**
CONSTRUCTION MANAGEMENT				
10% OF CONSTRUCTION COST			**TOTAL**	**$ 4,004,875.80**
CONSTRUCTION				
MOBILIZATION AND DE-MOBILIZATION (10% OF CONSTRUCTION COST)				$ 4,004,875.80
BONDS AND INSURANCE (2% OF MATERIALS COST)				$ 800,975.16
			TOTAL	**$ 4,805,850.96**
			FINAL TOTAL	**$54,866,798.46**
20% CONTINGENCY			**GRAND TOTAL**	**$65,840,158.15**

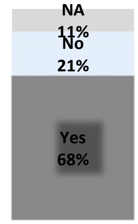
APPENDIX F: Envision Results

Envision Rating System
Self-Assessment Checklist
Salmon River Estuary

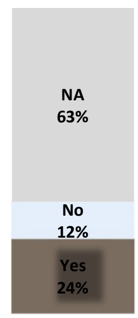
				Y	N	NA	
1	QUALITY OF LIFE	PURPOSE	QL1.1 Improve community quality of life	2	0	1	2 of 2
2			QL1.2 Stimulate sustainable growth and development	1	0	2	1 of 1
3			QL1.3 Develop local skills and capabilities	0	0	3	0 of 0
4		COMMUNITY	QL2.1 Enhance public health and safety	0	1	0	0 of 1
5			QL2.2 Minimize noise and vibration	0	1	0	0 of 1
6			QL2.3 Minimize light pollution	0	0	1	0 of 0
7			QL2.4 Improve community mobility and access	3	0	0	3 of 3
8			QL2.5 Encourage alternative modes of transportation	0	0	2	0 of 0
9			QL2.6 Improve site accessibility, safety and wayfinding	2	1	0	2 of 3
10		WELLBEING	QL3.1 Preserve historic and cultural resources	2	0	0	2 of 2
11			QL3.2 Preserve views and local character	1	0	1	1 of 1
12			QL3.3 Enhance public space	2	0	0	2 of 2
			TOTAL	13	3	10	13 of 16



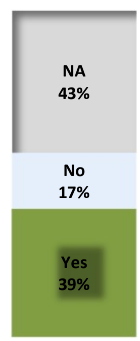
13	LEADERSHIP	COLLABORATION	LD1.1 Provide effective leadership and commitment	2	1	0	2 of 3
14			LD1.2 Establish a sustainability management system	1	0	0	1 of 1
15			LD1.3 Foster collaboration and teamwork	3	0	0	3 of 3
16			LD1.4 Provide for stakeholder involvement	2	0	1	2 of 2
17		MANAGEMENT	LD2.1 Pursue by-product synergy opportunities	0	1	0	0 of 1
18			LD2.2 Improve infrastructure integration	3	0	0	3 of 3
19		PLANNING	LD3.1 Plan for long-term monitoring and maintenance	1	1	0	1 of 2
20			LD3.2 Address conflicting regulations and policies	1	1	0	1 of 2
21			LD3.3 Extend useful life	0	0	1	0 of 0
			TOTAL	13	4	2	13 of 17



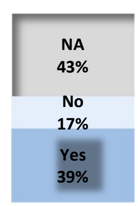
22	RESOURCE ALLOCATION	MATERIALS	RA1.1 Reduce Net Embodied Energy	0	0	2	0 of 0
23			RA1.2 Support Sustainable Procurement Practices	2	1	0	2 of 3
24			RA1.3 Use Recycled Materials	0	0	2	0 of 0
25			RA1.4 Use Regional Materials	2	0	0	2 of 2
26			RA1.5 Divert Waste from Landfills	0	0	3	0 of 0
27			RA1.6 Reduce Excavated Materials Taken off Site	1	2	0	1 of 3
28			RA1.7 Provide for Deconstruction and Recycling	0	0	3	0 of 0
29		ENERGY	RA2.1 Reduce energy consumption	0	2	1	0 of 2
30			RA2.2 Use renewable energy	0	0	2	0 of 0
31			RA2.3 Commission and monitor energy systems	0	0	3	0 of 0
32		WATER	RA3.1 Protect fresh water availability	5	0	2	5 of 5
33			RA3.2 Reduce potable water consumption	0	0	4	0 of 0
34			RA3.3 Monitor water systems	0	0	4	0 of 0
			TOTAL	10	5	26	10 of 15



35	NATURAL WORLD	SITING	NW1.1 Preserve prime habitat	3	2	0	3 of 5
36			NW1.2 Protect wetlands and surface water	0	2	1	0 of 2
37			NW1.3 Preserve prime farmland	1	0	0	1 of 1
38			NW1.4 Avoid adverse geology	0	0	3	0 of 0
39			NW1.5 Preserve floodplain functions	3	1	2	3 of 4
40			NW1.6 Avoid unsuitable development on steep slopes	1	0	1	1 of 1
41			NW1.7 Preserve greenfields	1	1	0	1 of 2
42		LAND & WATER	NW2.1 Manage stormwater	0	0	2	0 of 0
43			NW2.2 Reduce pesticide and fertilizer impacts	0	0	5	0 of 0
44			NW2.3 Prevent surface and groundwater contamination	0	0	3	0 of 0
45		BIODIVERSITY	NW3.1 Preserve species biodiversity	4	0	0	4 of 4
46			NW3.2 Control invasive species	0	0	3	0 of 0
47			NW3.3 Restore disturbed soils	0	2	0	0 of 2
48			NW3.4 Maintain wetland and surface water functions	5	0	0	5 of 5
			TOTAL	18	8	20	18 of 26



49	CLIMATE	EMISSION	CR1.1 Reduce greenhouse gas emissions	0	0	2	0 of 0
50			CR1.2 Reduce air pollutant emissions	0	0	2	0 of 0
51			CR2.1 Assess climate threat	1	0	0	1 of 1
52			CR2.2 Avoid traps and vulnerabilities	2	0	0	2 of 2
53		RESILIENCE	CR2.3 Prepare for long-term adaptability	1	0	0	1 of 1
54			CR2.4 Prepare for short-term hazards	1	1	0	1 of 2
55			CR2.5 Manage heat islands effects	0	1	0	0 of 1
			TOTAL	5	2	4	5 of 7



APPENDIX G: Progress Memorandums

APPENDIX H: Project Team Contract

APPENDIX I: Draft Reports