Truax Island - Dead River Crossing Alternatives Analysis

Prepared for

Calapooia Watershed Council

Oregon Parks and Recreation Department

Prepared by

RDG
RIVER DESIGN GROUP

October 4, 2016

www.riverdesigngroup.com

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1 Introduction

The Calapooia Watershed Council (CWC) and Oregon Parks and Recreation Department (OPRD) retained River Design Group, Inc. (RDG) to prepare an alternatives analysis for a road crossing at Truax Island, a Willamette River Greenway property between Corvallis and Albany (Figure 1-1) that is managed by OPRD. Truax Island is bounded by the Dead River, an active side channel to the Willamette River. The access road to Truax Island, which was historically used by both OPRD and Knife River Corporation, crosses Dead River. Prior to the road failure, OPRD accessed the island to maintain vegetation and the park in a natural condition. Knife River maintains an active mining permit to a floodplain gravel pit that was developed to meet aggregate demands in the early 2000s.

The access road to the site is a low volume, narrow one lane road with an asphalt surface. A 5 ft diameter corrugated metal pipe (CMP) culvert located on the east side of the crossing progressively failed over time due to annual overtopping and scouring of the channel and road subgrade materials on the downstream side of the road. The scoured road surface has impacted the road width to the extent the road is no longer usable for vehicle traffic.

RDG was instructed to prepare a culvert replacement alternatives analysis to address the failed culvert. The goal of the alternatives analysis is to evaluate three cost-effective crossing replacement alternatives that would restore vehicle access to Truax Island, improve hydraulic connectivity and fish passage in Dead River through the crossing site, and minimize long-term crossing maintenance. Conceptual drawings for the three alternatives are included in Attachment A and a cost comparison is included in Attachment B.

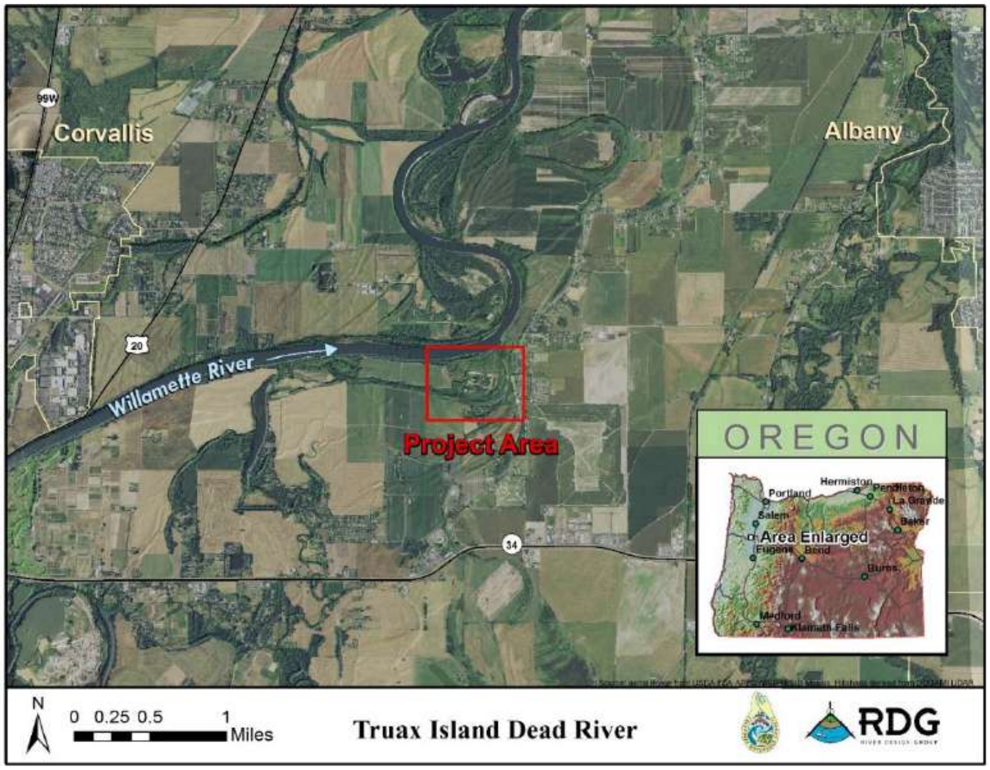


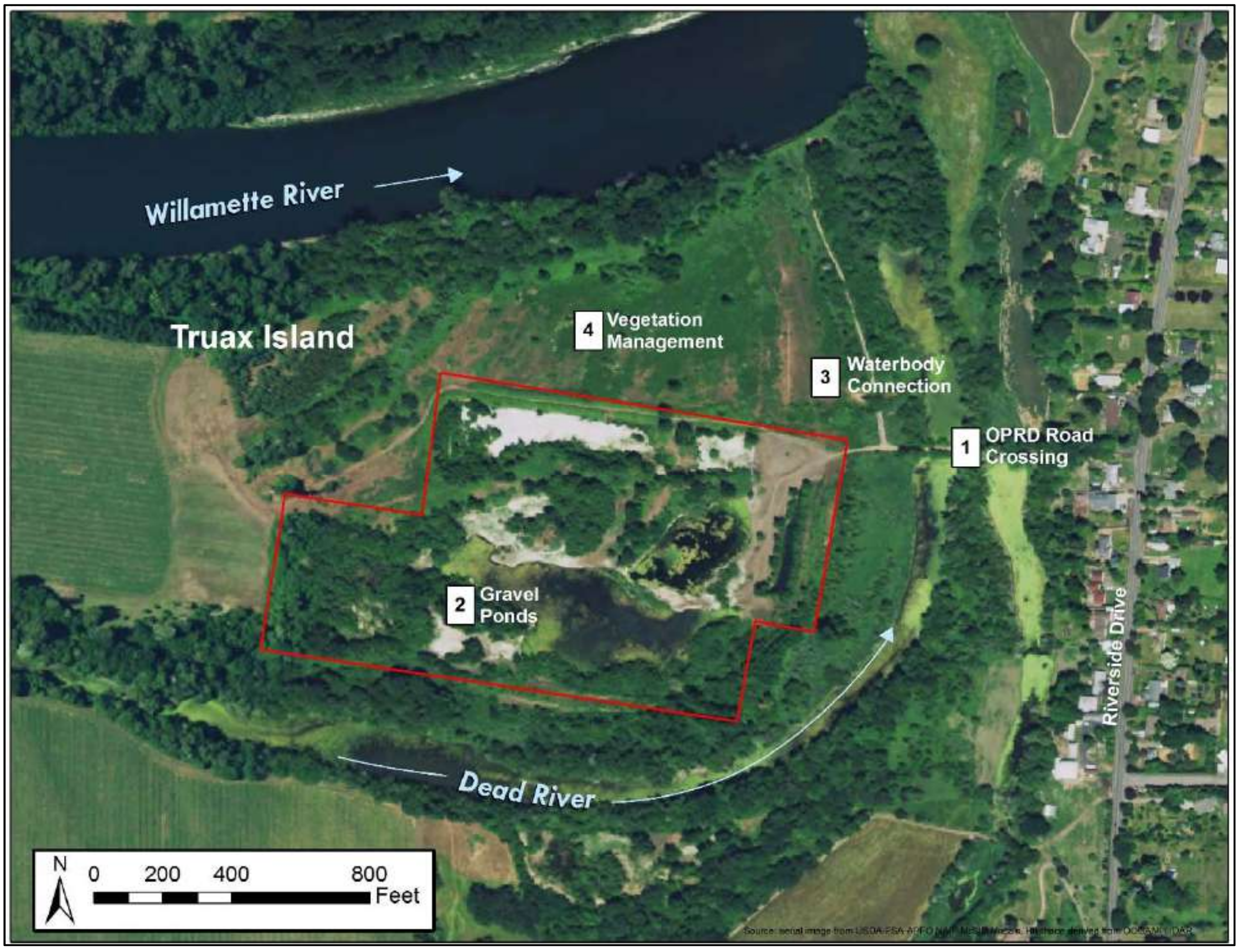
Figure 1-1. Location map of the Truax Island-Dead River project area.

1.1 Standard of Practice

River Design Group, Inc. works exclusively in the river environment on river restoration and fish passage projects throughout the northwest with many years of experience with similar projects. We have a staff with licensed civil engineers in the State of Oregon and which all work was either performed by or supervised.

1.2 Dead River Description

The Dead River is an active side channel to the mainstem Willamette River and defines the southern and eastern boundaries of Truax Island (Figure 1-2). The Dead River maintains connection with the Willamette River year-round. The upstream margin of the island is not sharply defined, and upstream connection of the Willamette River to Dead River is likely through subsurface flow during low flow and by surface flow from smaller side channels and swales during higher flows. During summer low flows, the Dead River stagnates resulting in full surface algae coverage, poor water quality through depressed dissolved oxygen concentrations, and degraded habitat conditions.



Source: aerial image from USDA-FSA-APFO NAIP MrSID Mosaic. Hillshade derived from DOGAMI LiDAR

Figure 1-2. An aerial view of Truax Island and Dead River with highlighted potential treatment areas.

Dead River has an active channel width of 110 to 150 feet with typical channel depths of several feet depending on river stage. Streambed substrates in the vicinity of the crossing are predominately made up of fines with small gravels. Streambanks and the floodplain immediately adjacent to Dead River have dense vegetation with deciduous trees and blackberry on river right and tall reeds and grasses on river left. The crossing overtops at flows between 25,000 and 30,000 cfs on the Willamette River gage at Albany.

1.3 Site Survey

Topographic and bathymetric surveys were completed by RDG in spring 2016 using a survey-grade GPS, total station, and a single beam sonar unit. The bathymetric survey was conducted on March 24, 2016 when flows were approximately 30,000 cfs on the Willamette River gage at Albany. The survey extent was approximately 1,000 ft upstream of the crossing and over 500 ft downstream to the tree line near the mouth of Dead River. A detailed GPS and total station survey of the crossing was completed on June 24, 2016 when flows were approximately 6,000 cfs on the Willamette River gage at Albany. Data from the two surveys were combined using AutoCAD Civil 3D to create a surface model of the site. Attachment A contains a base map drawing of the existing site conditions from the surveys. Ground-based field photos and low-elevation aerial photos were collected during several field visits spanning a range of flow conditions. Combined, these field data were used to characterize the project area on Dead River.

1.4 Culvert and Road Details

The culvert and crossing is located on the OPRD access road to Truax Island off of Riverside Drive, north of State Highway 34. The 10 ft wide crossing road runs east-west for 150 ft across the Dead River (Figure 1-3). The crossing is gravel road fill with an asphalt surface.

A 5 ft diameter corrugated metal pipe (CMP) culvert on the east side of the crossing provides conveyance for Dead River flows prior to the road overtopping. The culvert has been collapsed on its upstream end, trapping debris, limiting its conveyance effectiveness, and increasing the backwater effect of the crossing and degree of overtopping and scour, particularly at higher flows. The downstream end of the culvert has been damaged and removed along with the overlying road fill. This failure makes the crossing impassable for all but pedestrian traffic and poses a safety hazard. The culvert is undersized relative to even moderate flows on Dead River, which increases the frequency with which the crossing is overtopped and increases scour at the outlet.

Figure 1-3. Similar view of the OPRD road during low (top) and high (bottom) flows on Dead River. The bottom photo was taken at approximately 30,000 cfs at the Albany gage on the Willamette River downstream of the Dead River confluence with the Willamette River. The gravel deposit in the lower photo is adjacent to the failure culvert.

2 Fish Presence and Fish Passage Requirements

2.1 Fish Species Present and Periodicity

Among the native species expected to use seasonally flooded habitats in the upper Willamette River, three are listed as threatened or endangered under the U.S. Endangered Species Act. Listed species include the Upper Willamette spring Chinook salmon, Upper Willamette River steelhead (to the Calapooia River mouth, inclusive), and bull trout. Oregon chub were delisted in 2015. Juvenile spring Chinook salmon and steelhead rear in the Upper Willamette River from several months (Chinook) to up to four years (steelhead) before outmigrating to the ocean. Rearing duration is influenced by life history strategy and stream conditions. Other species, such as coastal cutthroat trout, use the mainstem Willamette River and likely inhabit floodplain side channels in the winter and spring, although they may also use cold water seeps into floodplain side channels during summer base flows.

Due to native resident fish presence throughout the year, a fish passage solution that will function throughout the entire year, similar to the adjacent stream channel upstream and downstream of the crossing, is necessary.

3 Hydrologic Analysis

The following sections evaluate the effects of flood control operations on the Willamette River and summarize the U.S. Geological Survey (USGS) stream gage at Albany; the gage used in the Dead River existing condition analysis and site recommendations. The Albany gage was used to characterize river flows and stage for the Dead River because of its long period of record, its consistent stage-discharge relationship, and its close proximity to the project site.

3.1 Willamette Basin Hydrology

The Willamette River is highly regulated by 13 dams including 11 flood control dams and 2 reregulating dams (although Foster Dam serves partially as a re-regulating dam for the larger upstream Green Peter Dam) that affect the natural flow of water in the Willamette River Basin (OWRD 1991; Rounds 2010). In reviewing the history of flood control operations in the Willamette River Basin, three river management periods were delineated:

- Pre-1942: Historical or Pre-regulation period
- 1943 to 1968: Dam Construction period
- 1969 to Present: Regulated period

Table 2-1 includes a list of the dams upstream from the Albany area and their date of completion. Flood control operations have had a profound effect on the Willamette River hydrograph. Runoff retention and later release from flood control reservoirs effectively reduces flood peaks while increasing base flows relative to the historical condition.

Table 3-1. Flood control dams located in the Willamette Basin upstream from the USGS Albany gage.

Dam Name	Location	Year Completed	Height (ft)	Storage (acre-ft)	Upstream Dams
Blue River Dam	Blue River	1969	270	89,500	
Cottage Grove Dam	CF Willamette River	1942	95	32,900	
Cougar Dam	SF McKenzie River	1963	452	219,000	
Dexter Dam	MF Willamette River	1954	93	NA	Lookout Point, Hills Creek
Dorena Dam	Row River	1949	145	77,600	
Fall Creek Dam	Fall Creek	1966	180	125,000	
Fern Ridge Dam	Long Tom River	1941	44	116,800	
Hills Creek Dam	MF Willamette River	1961	304	355,500	
Lookout Point Dam	MF Willamette River	1954	276	455,800	Hills Creek

Table 2-2 includes a breakout of the average annual peak discharge for the Historical, Dam Construction, and Regulated periods. Over time, the magnitude and variability of annual peak flows have been reduced and simplified. At the Albany gage, the average annual peak flow is now about half what it was historically, and the regulated 2-year return interval discharge is approximately 65% of the historical, pre-dam 2-year discharge.

Table 3-2. A comparison of the average annual peak discharge for the Willamette River at the Albany gage for the three river management periods. The 2-year discharge for the Historical and Regulated periods is included for comparison.

River Management Period	Average Annual Peak Discharge (cfs)
Historical Period - Pre-Dams (1861 to 1942)	124,215
Dam Construction Period (1943 to 1968)	109,352
Regulated Period - Post-Dams (1969 to 2013)	66,336
Historical Period 2-year Discharge	106,409
Regulated Period 2-year Discharge	64,591

Figure 2-1 shows annual peak flows for the Willamette River recorded at the Albany gage station (USGS #14174000). The Albany gage was used to calibrate stage discharge relationships for the hydrologic analysis for the Dead River project site. Annual peak flow data have been continuously monitored at the Albany gage since 1877. As flow data preceded the Dam Construction period which began in 1943, peak flow comparisons can be made over the 133 years the gage has been operational. Metering peak flows has reduced flood impacts to human infrastructure and enabled occupation and development of the Willamette River floodplain. However, it has also resulted in a reduction of inundated habitat and channel complexity, negatively affecting habitats that support native species and juvenile fish that rely on low velocity, vegetated habitats for winter-time rearing.

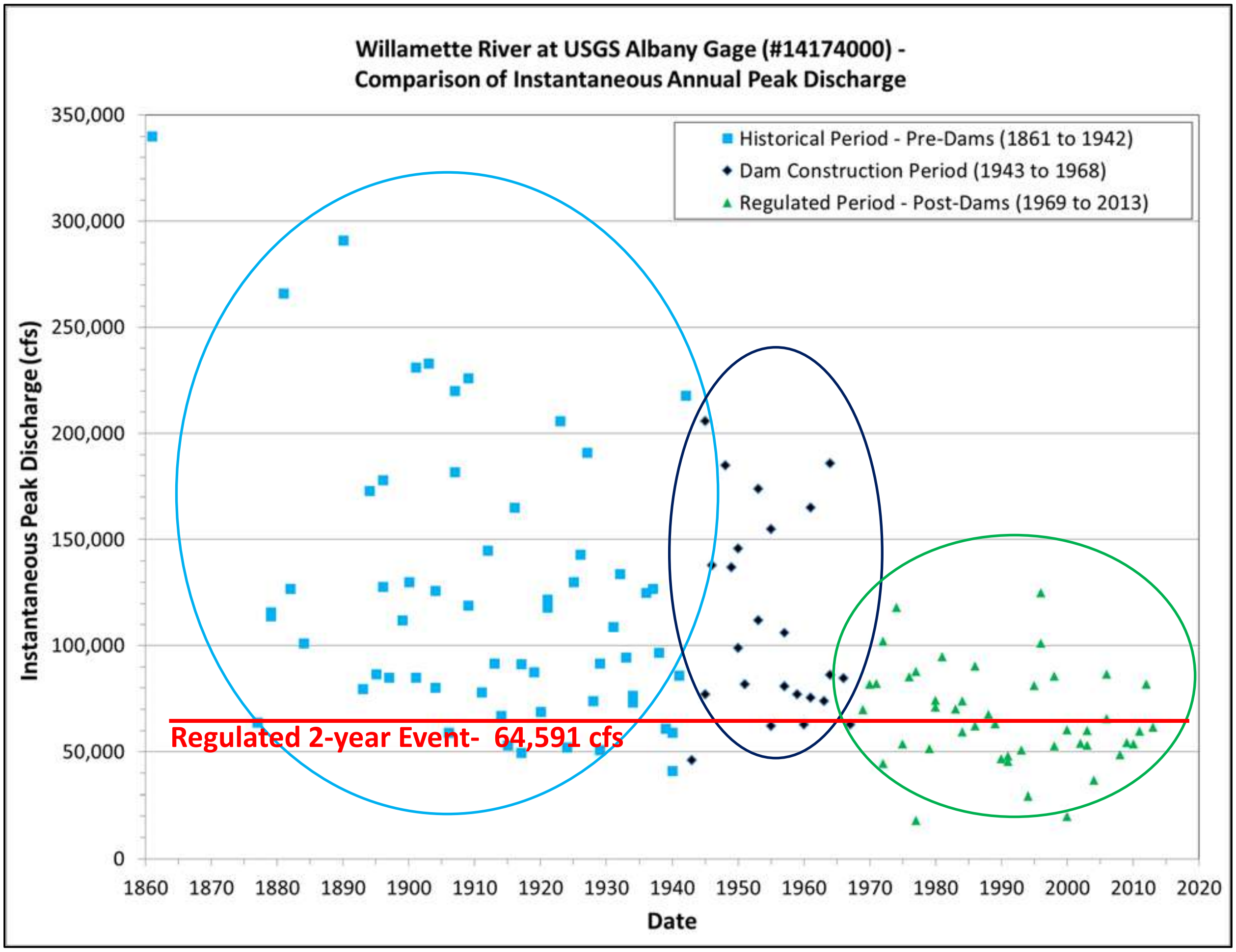


Figure 3-1. A comparison of annual peak flows at the Albany gage on the Willamette River from 1892 to 2013. The three primary river management periods are highlighted. The actual regulated 2-year discharge at the Albany gage is included for illustration. The USACE target 2-year discharge at the Albany gage is 69,500 cfs.

Natural condition and regulated condition flood frequency calculations for the USGS gage were completed by USACE (2014). Results are presented in Table 2-3.

Table 3-3. A comparison of flood frequency analysis for the Natural and Regulated periods (USACE 2014).

Return Period (years)	Natural Conditions (cfs)	Regulated Conditions (cfs)
100	293,620	177,003
50	257,509	151,112
20	212,046	121,819
10	178,797	102,749
5	145,628	85,449
2	98,087	63,700
1.25	65,587	50,714
1.11	53,192	46,031
1.05	44,847	42,921
1.01	32,822	38,576

A flow duration analysis was completed for the USGS Albany gage in order to better understand the frequency and duration of high flow events on the Willamette River during the Regulated period. Mean annual flows for the Regulated period were used to complete the flow duration analysis. Table 2-4 includes the flow duration data. Figure 2-3 includes the flow duration curves for the USGS Albany gage.

Table 3-4. Flow duration data for the USGS Albany gage over the regulated period of record (1969 – 2013).

Percent of Time Exceeded	Equivalent Number of Days	Albany Gage Discharge (cfs)	Albany Gage Height (ft)*
99	361	3,980	2.33
95	347	4,530	2.66
90	329	4,970	2.92
80	292	5,630	3.28
50	183	9,100	4.99
25	91	15,700	7.7.0
15	55	23,100	10.25
10	37	30,870	12.64
5	18	43,200	16.00
2	7	54,300	18.72
1	4	61,300	20.30
0.1	0.4	63,671	20.82

*Gage heights based on USGS rating tables accessed April 2014.

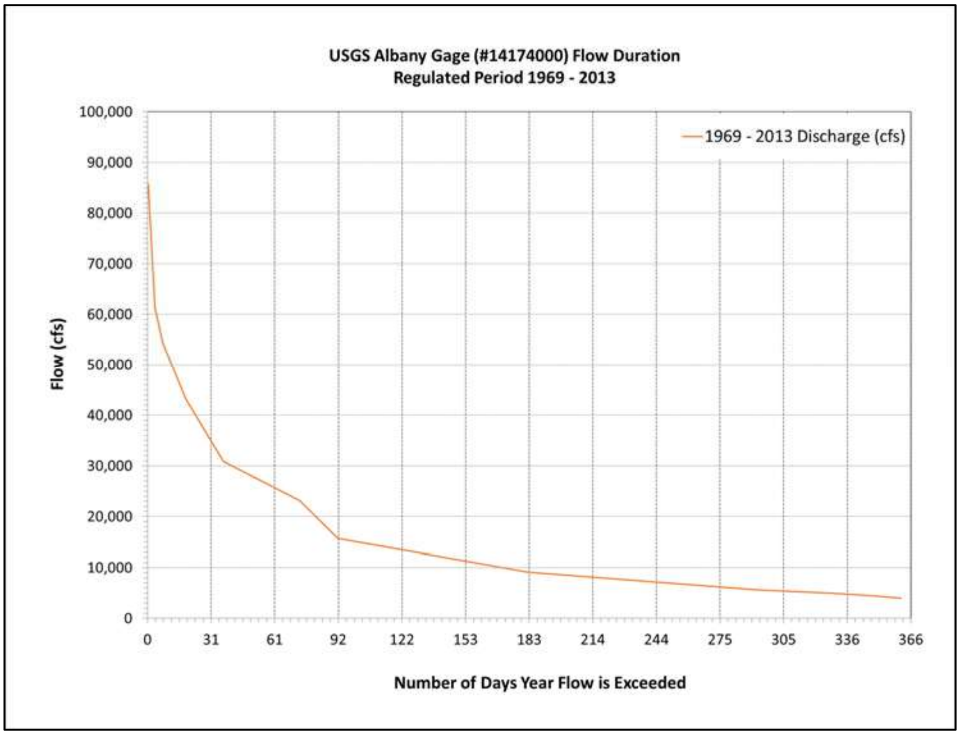
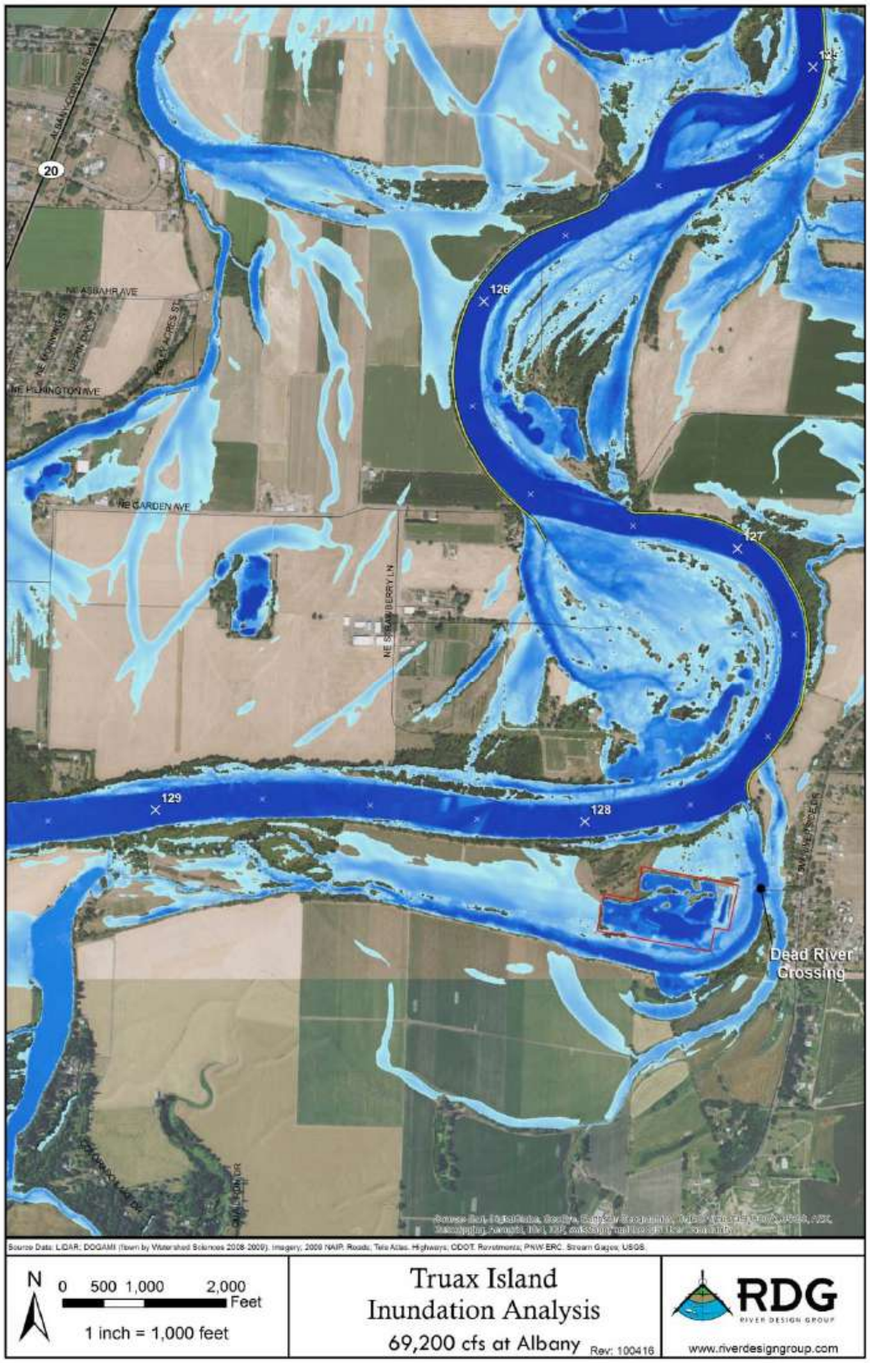


Figure 3-2. The USGS Albany gage flow duration curve based on the regulated period (1969 - 2010).

The flow duration data and the rating table information were used to assess floodplain inundation frequency and duration at Dead River. As an example of how the flow duration curve can be used, the Willamette River extensively inundates the floodplain at Dead River at approximately 55,000 cfs. The Albany gage's flow duration curve suggests 54,300 cfs is exceeded less than 2% of the year, or approximately 7 days per year on average. This information is useful for evaluating floodplain habitat conditions and assessing the potential for modifying existing floodplain elevations for restoration actions.

3.2 Inundation Mapping

ArcGIS tools were used to simulate potential areas of floodplain inundation within Truax Island. A LiDAR dataset was used to create the underlying topographic surfaces for the project areas and water surface elevations were modeled to inundate floodplain surfaces under a regulated 2-year flow (Figure 2-4). The regulated 2-year flow was selected as a frequent flow that has ecological importance for fish inhabiting the upper Willamette River system. The resulting inundation layer provides a useful tool for identifying potential floodplain restoration areas, locating possible obstructions to river-floodplain habitat interaction, and to assist with locating possible floodplain refugia habitats for native fish species including federally-listed spring Chinook salmon. The inundation mapping is not meant for floodplain managers or regulatory agencies for floodplain management.



Source Data: LiDAR; DOGAMI (flown by Watershed Sciences 2008-2009). Imagery; 2009 NAIP. Roads; Tele Atlas. Highways; ODOT. Revetments; PNW-ERC. Stream Gages; USGS.

Figure 3-3. The 2-year flow inundation map prepared for Dead River. The modeled inundation level represents a discharge of 69,500 cfs as measured at the USGS gage at Albany, OR. USACE revetments are noted by the yellow lines. The Truax Island gravel pit boundary is noted by the red outline.

Aerial photography taken by Eagle Digital Imaging, Inc. on January 28, 2012 during flood conditions (Figure 2-5) was used to calibrate the 2-year inundation model. The flood air photo for Truax Island shows similar results as predicted by the inundation mapping. Water depths at the Dead River crossing exceed 5 ft at the 2-year flood.

Figure 3-4. Aerial photograph of the Truax Island area taken on January 28, 2012. The USGS Albany gage registered approximately 69,200 cfs during air photo acquisition. USACE revetments are noted by the yellow lines. The Truax Island gravel pit boundary is noted by the red outline.

3.3 Fish Passage Flows

ODFW publishes design flow requirements for fish passage in Oregon Administrative Rules (OAR) Division 412. ODFW criteria state that high fish passage design flow is the mean daily average stream discharge that is exceeded 5% of the time during the period when ODFW determines that native migratory fish require fish passage. Likewise, low fish passage is the stream discharge that is exceeded 95% of the time during the period of interest for fish passage. Flow in the Dead River is largely dependent upon the stage of the Willamette River. The flow and stage in the Willamette River at the 5% and 95% yearly exceedance values will be used to determine fish passage design flows in the Dead River.

3.4 Hydrologic Summary

In summary, flood control operations have reduced flood magnitudes while also increasing summer time base flows beneficial for irrigation, industrial water availability, dilution of municipal and industrial discharges, and recreation. Hydrographic modifications have influenced the magnitude of return interval events, such as the 2-year flow, and have influenced geomorphic and ecological function in the Willamette River corridor. For areas of the Willamette River floodplain such as Truax Island, regulated flows have resulted in less hydrologic interaction between the river and floodplain surfaces. Historically, the Willamette River regularly inundated the Truax floodplain, creating diverse, dynamic habitats. Truax Island continues to be frequently inundated during high flows on the Willamette River when the Willamette backwaters the Dead River. Improved hydraulic connectivity through the Dead River crossing will improve fish passage and debris transport during elevated flows.

4 Willamette River Fish Community

4.1 Ecological Framework

Inundated river floodplains provide diverse aquatic habitats for fish and other vertebrates. In many rivers, native fish species are adapted to having seasonal access to refuges where they can find shelter spawn, rear, and forage, and foraging habitats (Bayley 1991; Sommer et al. 2004; Colvin et al. 2009). In Pacific Northwest rivers, where most flooding typically coincides with the onset of less favorable conditions characterized by cold water temperatures and decreasing photo period in winter, inundated floodplain habitats provide fish with low velocity habitats that may also be more productive than the mainstem channel. Similarly, groundwater-influenced floodplain habitats provide warmer temperatures that may also support a more substantial forage base relative to the mainstem river (Giannico and Hinch 2007).

Colvin et al. (2009) found native fish species in the Calapooia River drainage (tributary to the Willamette River southeast of the project area) are adapted to a flood-pulse-driven environment and respond to annual changes in discharge by moving into seasonally inundated habitats. Movement of native species from the mainstem channel onto the floodplain may be critical to fish survival, sheltering them from high water velocities during the coldest months (Giannico and Healey 1998a) while increasing the foraging and reproductive opportunities of some species in early spring (Sommer et al. 2004, Colvin et al. 2006).

In addition to anthropogenic river corridor alterations, native fish in the Willamette River Valley also interact with a host of exotic fish and amphibians including the American bullfrog (*Rana catesbeiana*) (Colvin et al. 2009). The introduction of these species began in the late 1800s, and the current list of most common introduced species includes the bullfrog and bluegill (*Lepomis macrochirus*), green sunfish (*L. cyanellus,*), warmouth (*L. gulosus*), pumpkinseed (*L. gibbosus*), largemouth bass (*Micropterus salmoides*), smallmouth bass (*M. dolomieu*), mosquitofish (*Gambusia affinis*), yellow perch (*Perca flavescens*), and brown bullhead (*Ameiurus nebulosus*) and yellow bullhead (*A. natalis*) (Colvin et al. 2009, S. Gregory, Oregon State University, unpublished data). Common carp (*Cyprinus carpio*) inhabit the Truax Island gravel pit pond complex and likely the Dead River year-round. These introduced species modify habitat, compete with, and/or prey upon native species.

Among the native species expected to use seasonally flooded habitats in the upper Willamette River, three are listed as threatened or endangered under the U.S. Endangered Species Act. Listed species include the Upper Willamette spring Chinook salmon, Upper Willamette River steelhead (to the Calapooia River mouth, inclusive), and bull trout. Oregon chub was delisted in 2015. Juveniles spring Chinook salmon and steelhead rear in the Upper Willamette River from several months (Chinook) to up to four years (steelhead) before outmigrating to the ocean. Rearing duration is influenced by life history strategy and stream conditions.

For exotic fish species in the Willamette River valley, winter use of intermittent watercourses is probably limited by physiological constraints resulting from the low water temperatures that prevail in these channels or developmental requirements for spawning in spring and summer (Colvin et al. 2009). Colvin et al. (2009) suggested as the flooding period in the Willamette Valley coincides with low water temperatures and the migratory response of exotic species does not occur until spring, the patterns observed in the current climate of the Willamette River valley tend to support the prediction that winter-time flooding may benefit native species to a greater extent than introduced warm water species.

4.2 Willamette River Fish Community in the Vicinity of Truax Island

Fish sampling records provided by Oregon Department and Fish and Wildlife (ODFW) and Oregon State University (OSU) provide a summary of fish inhabiting the nearby Bowers Rock State Park (BRSP) gravel pit ponds located to the north and downstream from Truax Island (Table 4-1). The floodplain fish community sampled at BRSP and other floodplain habitats at Green Island, Snag Boat Bend, and Sam Daws Landing, are likely similar to the fish community at Truax Island. Table 4-2 includes a summary of fish sampled by OSU in the gravel pit pond and other waterbodies in the vicinity of Bowers Rock State Park (Table 4-2). Graphical comparisons are included in Figure 4-1 and Figure 4-2.

Non-native fish were more abundant than native fish in the BRSP gravel pit pond and the other gravel pit pond on OPRD property that was previously used to wash gravels during the BRSP gravel pit development. The number of native fish and native species were substantially higher in the Willamette River during summer sampling.

Sampling in Coon Creek (a floodplain side channel geomorphically similar to Dead River) provided the only seasonal comparison for a single water body. Numbers of native fish were substantially greater than non-native fish during the spring sampling, but only slightly greater during summer sampling. Six native species and five non-native species were found during both Coon Creek sampling periods. Coon Creek was identified as a cold water refugia that would likely be more hospitable to native fish species during the summer time when mainstem water temperatures increase (S. Gregory, unpublished data, 2010). Cold water refugia were identified as off-channel areas that had water temperatures in September 2010 that were 2°C colder than adjacent mainstem locations. Of the 71 cold water points sampled in the 2010 inventory, five of the points were located in Coon Creek downstream of the BRSP gravel pit pond.

Table 4-1. Fish sampling results from ODFW survey of the BRSP gravel pit pond and gravel washing pond completed on April 6, 2000.

Species	Count	Percent of Sample (%)	Average Size (mm)
Largescale sucker[1]	8	11	432
Largemouth bass	5	7	177
Bluegill	54	77	87
Yellow perch	3	4	127

[1]: Native fish species

Table 4-2. OSU fish sampling results for BRSP gravel pit pond, Coon Creek, the Little Willamette River, and the Willamette River in proximity of BRSP (OSU, unpublished data, 2012).

		Individual Fish				Species			
Site	Period	# Native	# Non-Native	% Native	% Non-Native	# Native	# Non-Native	% Native	% Non-Native
Bowers Rock Gravel Pit Pond	SPR	2	371	0.5	99.5	2	6	25	75
Coon Creek	SPR	120	19	86	14	6	5	55	45
Coon Creek	SUM	58	31	65	35	6	5	55	45
Little Willamette River	SUM	15	21	42	58	4	3	57	43
Willamette River (RM 120.5)	SUM	255	7	97	3	12	4	75	25
Willamette River (RM 121.0)	SUM	270	4	98.5	1.5	13	2	87	13
Willamette River (RM 123.0)	SUM	71	0	100	0	8	0	100	0
Willamette River (RM 123.75)	SUM	20	13	61	39	6	4	60	40

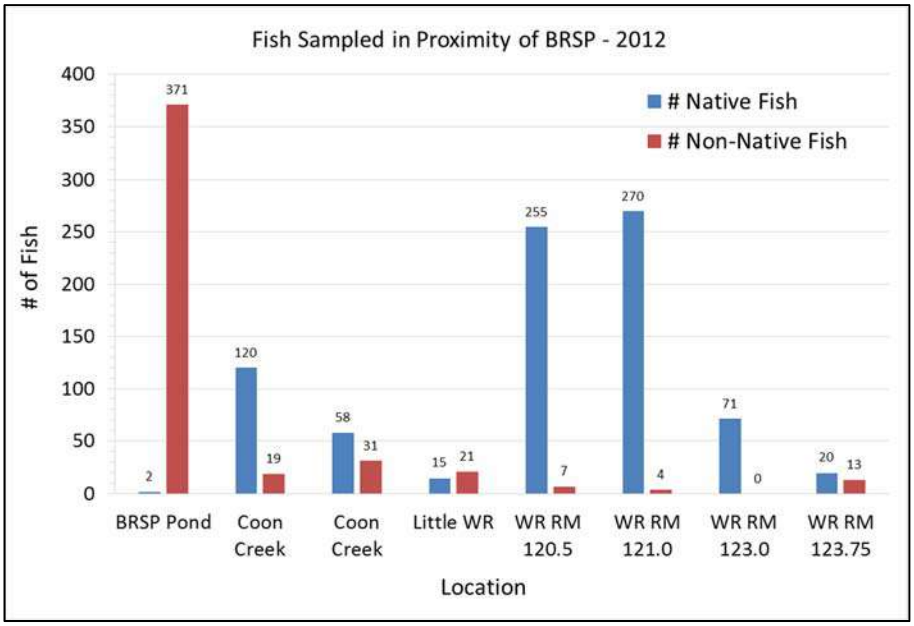


Figure 4-1. A comparison of the number of native and non-native fish sampled in proximity of BRSP in 2012 (OSU, unpublished data, 2012). Tabular data included in Table 4-2.

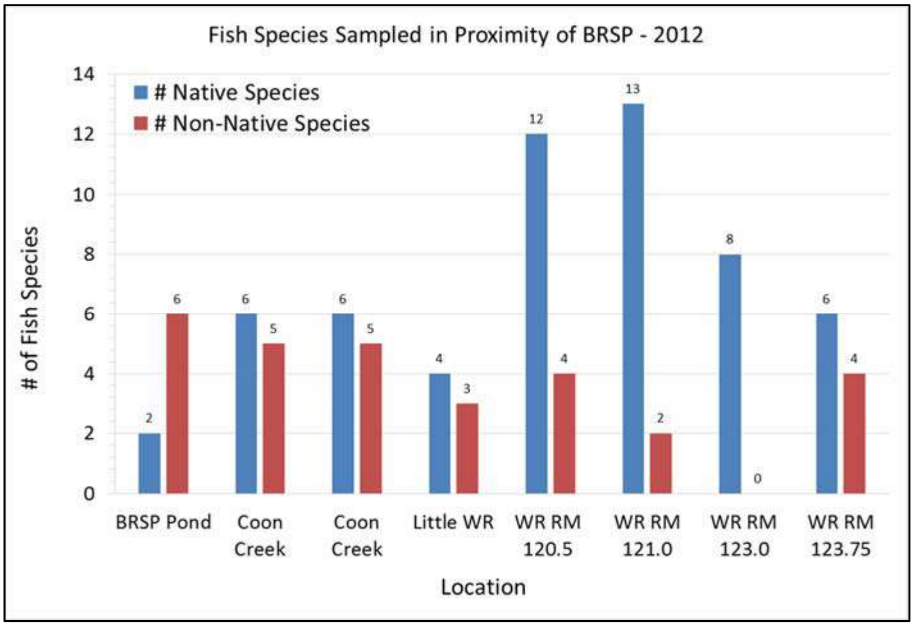


Figure 4-2. A comparison of the number of native and non-native fish species sampled in proximity of BRSP in 2012 (OSU, unpublished data, 2012). Tabular data included in Table 4-2.

4.3 Special Habitat Needs and Species Status

The following section presents the habitat needs for three native species of concern that may use inundated floodplain habitats during high water events. The species include Upper Willamette River (UWR) spring Chinook salmon (*Oncorhynchus tshawytscha*), Oregon chub (*Oregonichthys crameri*), and coastal cutthroat trout (*O. clarki clarki*). Juvenile UWR steelhead may also rear in the Truax Island project area.

Spring Chinook salmon

Rearing: Juvenile UWR spring Chinook salmon in the Willamette River Basin display diverse migratory life histories, with some individuals outmigrating as fry, et al. outmigrating the spring or fall of the following year (Schroeder et al. 2007). Like other salmonids, juvenile Chinook salmon require cold water (less than 64 °F or 17.8 °C), high dissolved oxygen levels, and deep pools for feeding and cover from predators. Juvenile Chinook prefer moderate flow with gravel and cobble substrate. While spring Chinook salmon will rear in the mainstem Willamette River, access to tributary streams and off-channel habitat to find refuge from high flows in spring is also important.

Sub-yearling fry likely originating in the McKenzie River drainage, disperse in the Willamette River and are found downstream to the Santiam River confluence with the Willamette River by late December to early January. Fry tend to be edge-oriented and use low velocity edge habitats that require minimal energy expenditure. Connected off-channel habitats are important for fry development. By mid-June to July, sub-year smolts outmigrate to the Columbia River on their way to the Pacific Ocean.

Yearling fish move out of natal areas to the Willamette River by the fall of their first year. From ODFW sampling, approximately 30% of yearling fish outmigrate in the fall and 70% overwinter in the lower McKenzie River and Willamette River. Overwintering fish typically show up in the Willamette River in the vicinity of the Santiam River confluence between September and October. These fish also move into off-channel habitats during winter high flows to take advantage of lower velocity, productive floodplain habitats. Overwintering yearling smolts outmigrate to the Pacific Ocean during spring runoff (K. Schroeder, ODFW, personal communication).

From January through May, both fish life histories inhabit the mainstem Willamette River and use connected off-channel habitats to minimize energy expenditures to maximize growth (K. Schroeder, ODFW, personal communication).

The upper Willamette River basin's evolutionary significant unit (ESU) of spring Chinook salmon was listed as threatened under the Endangered Species Act (ESA) by NOAA-Fisheries on March 24, 1999. A primary goal in the recovery process for Willamette River spring Chinook salmon is to increase off-channel rearing habitat.

Oregon chub

Oregon chub are endemic to the Willamette River basin and are typically found in off-channel habitats such as beaver ponds, oxbow channels, backwater sloughs, and flooded marshes. These habitats usually have little or no water flow, have silty and organic substrate, and have an abundance of aquatic vegetation and cover for hiding and spawning. In the last 100 years, off-channel habitats have disappeared because of changes in seasonal flows due to flood control dam operations, channelization of the Willamette River and its tributaries, and agricultural practices. This loss of habitat, combined with the introduction of non-native fish species to the

Willamette Valley, has restricted the distribution of Oregon chub and led to a sharp decline in their abundance (Bangs et al. 2011).

Coastal cutthroat trout

Rearing and Adult: Juvenile and adult resident coastal cutthroat reside in both tributary streams and mainstem rivers. Cutthroat trout often inhabit very small streams with gradients up to 12 percent. Resident forms of coastal cutthroat trout typically remain in or relatively close to their natal streams. Cutthroat trout will move up and down the stream, particularly to escape warm water temperatures in the summer and into seasonal streams to escape high flows in the winter. Adult and juvenile cutthroat trout require cool water temperatures (less than 64 °F or 17.8 °C), and high dissolved oxygen levels.

5 Hydraulics Summary

5.1 Flow Conditions

The pattern and conditions of flow through the Dead River project site vary depending upon the stage of the Willamette River. At low discharges on the Willamette River, there is very little flow through Dead River, and most flow originates from groundwater inputs. The regional groundwater table is higher to the south and lower to the north, following the overall gradient of the Willamette River, and flow in the Dead River is from south to north.

At moderate discharges on the Willamette River, the Dead River backwaters from the Willamette River at the downstream connection. Water is essentially ponded in the Dead River under these conditions.

At high discharges on the Willamette River, the Willamette River crests its banks upstream from the project site. Under these conditions, the Dead River conveys water as a portion of the active floodplain of the Willamette River.

Specific stage thresholds on the Willamette River will be evaluated in modeling to link the flow conditions in Dead River with specific stages and discharges on the Willamette. Flow conditions and their significance are summarized below in Table 5-1.

Table 5-1. Dead River flow conditions at various Willamette River stages.

Willamette River Stage	Project Site Flow Conditions / Significance
Low Stage	Dead River flows influenced by groundwater inputs, hydraulic gradient from south to north. Low fish passage flow occurs under these conditions.
Moderate Stage	Dead River is backwatered by confluence with Willamette River and the road may overtop. High fish passage flow occurs under these conditions.
High Stage	Dead River conveys flow from south to north as part of the Willamette River floodplain. High stage flood events exceed fish passage flows, but will be used for structure stability design.

5.2 Modeling Approach

All hydraulic modeling will be developed using HEC-RAS for hydraulic modeling. HEC-RAS v4.1.0 (USACE 2010) is a 1-dimensional, steady-state, hydraulic. The model solves the energy equation using an iterative approach for a given hydraulic condition. This technique results in a solution to all variables in the energy equation (i.e., velocity, hydraulic head, friction losses, etc.) at any given or interpolated cross-section. Inherent assumptions of the model are that the situation is steady-state, gradually varied, channel slopes are less than 1 on 10, and flow is 1-dimensional and uniform within a streamline. The model has the ability to simulate subcritical flow, supercritical flow, and a combination of the two for open channels. The model will produce average channel velocities at each cross-section and has the ability to produce pseudo two-dimensional velocities at a cross-section.

Model architecture will be tailored to the different flow conditions present at Truax Island. Low flows are evaluated using a single reach model of the Dead River. Moderate and high flows are evaluated using a split-flow model to distribute flow between the Willamette River and the Dead River using a lateral weir where the floodplain overtops to flow through Dead River.

Boundary conditions for flow in this reach are taken from a calibrated reach-scale model of the Willamette (Enright 2011). Stage-discharge relationships taken from the calibrated reach-scale model are used as boundary conditions for the smaller, project-specific model for Truax Island.

For the selected design approach, fish passage performance will be assured using a hydraulic design approach. Hydraulics of the streambed and the upstream and downstream reaches will be used to assure bed stability and size streambed material at the crossing inlet and outlet. The proposed crossings are countersunk so that sufficient depth and low enough velocities exist at the fish passage design flows to provide passage. Design values for stability design will be evaluated over a range of flows because limiting forces for stability design may occur at a moderate discharge rather than a peak discharge.

6 Road Crossing Alternatives

Three fish passage alternatives for the Dead River stream crossing were developed for stakeholder review. Several site condition constraints, outlined below, helped guide the initial selection of potential crossing alternatives.

Road elevation - Hydraulic modeling and field observations have documented the access road is submerged 5-6 ft deep during the 2-year flood on the Willamette River. The road frequently overtops in the winter and spring as the Willamette River rises in response to rain events and snowmelt. Crossing alternatives should be minimally affected by annual road overtopping in order to minimize maintenance.

Dead River groundwater connectivity – The Dead River channel is connected with groundwater year-round and is backwatered by the Willamette River during winter and spring. Since the culvert replacement would occur during the summer in-water work window, groundwater will need to be managed during the culvert replacement. Crossing alternatives that minimize the duration of channel dewatering would reduce overall construction cost.

Dead River channel bed – Understanding the channel bed surface materials and underlying sediments is necessary for designing crossing abutment systems. A geotechnical analysis is typically completed to inform the crossing design. Selecting crossing alternatives that can be implemented with only a limited understanding of underlying channel bed materials is another cost saving measure.

Road use – The Truax Island crossing is a low volume road that will likely have limited access in the future. A gate at the eastern entrance to the road is maintained by OPRD and Knife River. Vehicle access to Truax Island is expected to include OPRD maintenance equipment such as mowers and light to moderate load trucks, Knife River gravel haul trucks for potential future gravel extraction, and utility company trucks. Although the crossing driving surface width should exceed the existing adjacent road width in the event larger vehicles need to access the property in the future and to comply with rural fire code, the cost of the crossing alternatives should be in-line with the expected levels of future road use.

Crossing alternatives descriptions are included in the following sections. All crossings were selected to be low-profile, which provide conveyance area low in the channel and do not require the road surface to be raised, which will maintain existing flood conveyance.

6.1 Alternative 1: Concrete Box Culvert – 26 ft Span

Alternative 1 includes a precast concrete box culvert fabricated by Oldcastle Precast. The box culvert has a 26 ft span x 10 ft rise and a 20 ft length. The box culvert is delivered in seven pieces including three floor slabs and four three-sided boxes which are off-loaded by crane at the installation site. The installation site is dewatered prior to installing the floor slabs. Gravel is placed to form a leveling pad where the floor slabs are to be placed. Once the floor slabs are placed and connected to each other, the three sided boxes are then installed. Curbs and/or guardrails may be installed following box culvert installation. Riprap (i.e., angular rock) is added to the upstream and downstream sides of the box culvert for scour protection. Figure 6-1 includes a typical concrete box culvert section view. Construction and post-project photos of the Green Island box culvert are included in Figure 6-2.

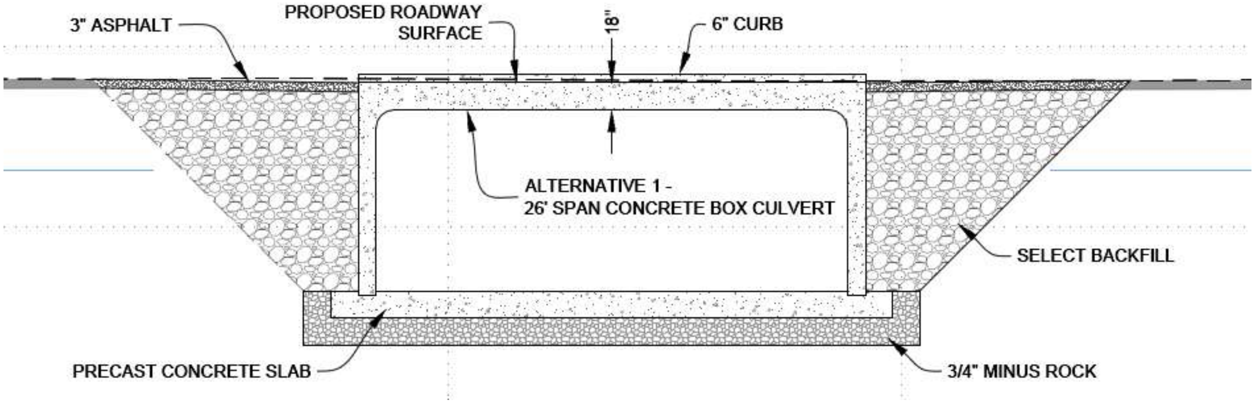


Figure 6-1. A typical concrete box culvert cross-section.

Figure 6-2. Installation of the Green Island box culvert in 2013 (left) and post-high water in 2014 (right).

Since a crane is needed to install the box culvert, a gravel work pad would be constructed adjacent to the roadbed. During construction, the crane would be positioned on the work pad to enable the crane to remove and install the culvert pieces from a flatbed truck which would back down the access road to the installation site. Due to the very confined work site, the box culvert would have to be loaded at Oldcastle Precast in the order the pieces will be placed at the installation site. Following the completion of the culvert installation, the work pad would be removed and the construction materials hauled back to the Knife River gravel pit.

The concrete box culvert would be set to the existing road surface elevation so minimal road modifications would be necessary. Asphalt would be applied to the box culvert surface to match the adjacent road surface elevation.

Alternative 1 will meet the project goals of flow and fish passage connectivity and minimal maintenance. Because of the continuous floor, this alternative is less sensitive to foundation conditions than an open bottomed structure. Based on similar concrete box culverts we have built on other Willamette River side channels, we expect the proposed box culvert to function appropriately over the expected range of flows at the site. Additionally, based on post-project monitoring at other sites, box culvert maintenance should be minimal.

6.2 Alternative 2: Low Profile Arch – 23 ft Span

Alternative 2 is a low profile, open-bottom arch with a 23 ft span x 10 ft 3 inch rise and 26 ft length. A low profile open-bottom arch is a structural steel plate arch constructed from multiple plates of corrugated steel set on concrete strip footings. The arch can be fabricated adjacent to the installation area and then placed on pre-fabricated concrete footings using an excavator. The stream channel inside the open-bottom arch is easily constructed due to the open area during construction and this structure can be considered similar to a bridge opening. To ensure the adequacy of existing site conditions and soils to support concrete bearing foundations for this alternative, a geotechnical study of the site would be performed prior to the design, or the design would include importing sufficient material to ensure bearing capacity requirements of the arch footings are met once the underlying channel bed materials are exposed during construction.

Figure 6-3 includes a cross-section schematic of a low profile open-bottom arch culvert. Figure 6-4 includes a photo of a completed open-bottom arch culvert.

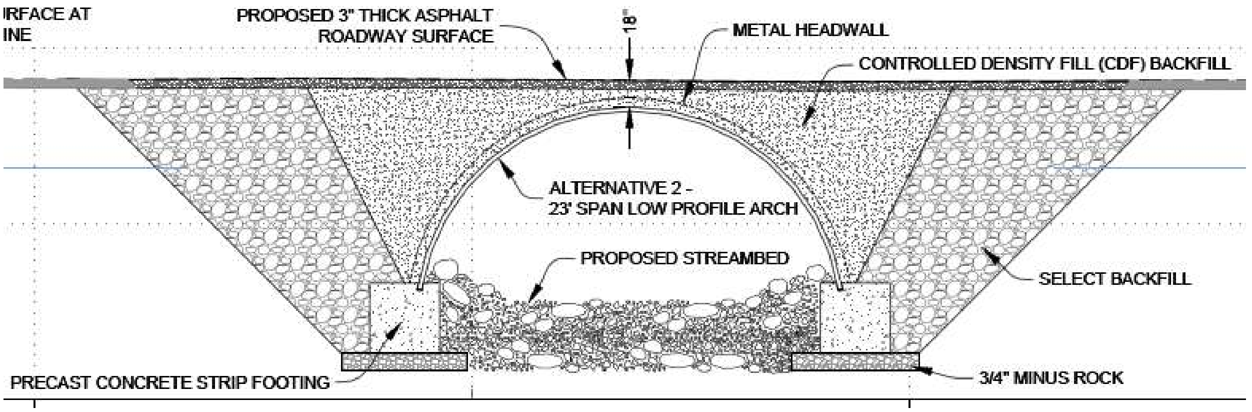


Figure 6-3. A typical open-bottom low profile arch culvert cross-section.

Figure 6-4. View of an open-bottom arch culvert with installed streambed.

Alternative 2 will meet the project goals of flow and fish passage connectivity and minimal maintenance. The open-bottom arch includes engineered streambed material to minimize the potential for channel scour through the arch. Uncertainty of the underlying channel bed material may require additional channel dewatering, excavation, and material import to ensure sufficient bearing capacity for the arch footings.

6.3 Alternative 3: Aluminum Structural Plate Box Culvert – 25 ft Span

Alternative 3 is a closed-bottom aluminum plate box culvert with a 24 ft 8 inch span x 10 ft 3 inch rise and 26 ft length. An aluminum plate box culvert is constructed from multiple plates of structural corrugated aluminum, bolted together on-site to construct the box culvert. The construction process would be very similar to Alternative 2.

The box culvert has a continuous floor, which has advantages in accommodating low bearing capacity soils and variations or unexpected conditions in foundation soils. The continuous bottom is also resistant to scour. The box culvert has a rectangular section and is low-profile, which allows the road surface over the proposed crossing to match the adjacent road surface without raising the road.

Figure 6-5 includes a cross-section schematic of an aluminum structural plate box culvert. Figure 6-6 includes an example photo of an aluminum structural plate box culvert.

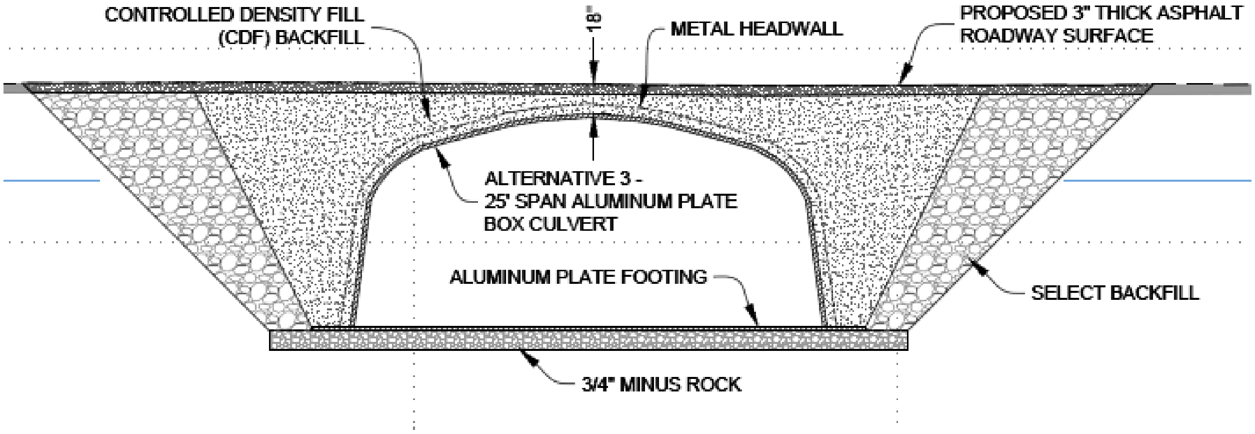


Figure 6-5. A typical structural plate box culvert cross-section.

Figure 6-6. View of an aluminum structural plate box culvert.

Alternative 3 will meet the project goals of flow and fish passage connectivity, and require minimal maintenance. The continuous floor makes the structure able to accommodate a range of foundation conditions and makes it resistant to scour.

6.4 Alternatives Discussion

Each alternative provides adequate fish passage to meet regulatory requirements and provides sufficient peak flow conveyance for the 100-year flood. However, each alternative varies in regards to constructability, cost, maintenance, potential longevity, and risk. Relative characteristics of the alternatives is provided in Table 6-1.

	Alternative 1 Concrete Box Culvert	Alternative 2 Open-Bottom Arch	Alternative 3 Aluminum Plate Box Culvert
Fish Passage Performance	Good	Good	Good
Flood Capacity	> 100-yr	> 100-yr	> 100-yr
Debris Maintenance	Medium	Medium	Medium
Cost	High	Medium	Low
	($226,000)	($191,000)	$175,000)
Constructability	Moderate/Difficult	Moderate	Moderate
Longevity	Greatest	Moderate	Moderate
Risk	Low	Moderate/High	Moderate/Low

Alternative 1 – Concrete Box Culvert has been successfully implemented at other Willamette River floodplain crossings similar to the Dead River crossing. Site constraints at the Dead River site which would require building a construction pad for the crane, increase the implementation cost for this alternative. The concrete box would likely have the greatest longevity but would provide similar levels of fish passage, and flow and debris conveyance relative to the other two alternatives. The mass of concrete makes the structure very resistant to flotation, and the continuous bottom is resistant to scour. Based on the expected construction cost, Alternative 1 was not selected as the preferred alternative.

Alternative 2 – Open-bottom Arch is the second most expensive alternative and would have an intermediate level of constructability. Site excavation depth would be greater than the two solid bottom options in order to meet bearing capacity requirements and minimize scour potential for the arch footings. The footings for the open-bottom arch can be formed on-site or precast off-site and hauled to the project site. Due to the location of the project and the site conditions, it is likely that footings would be precast and transported to the site which also simplifies construction since concrete does not have to be placed at the site. Once the footings are in place, a significant advantage of this alternative is the streambed can be constructed with the convenience of having the entire area open for construction access and rock placement. The engineered streambed requires oversized materials to be resistant to scour. Based on the expected construction cost and uncertainty associated with the underlying channel bed materials and bearing capacity requirements, Alternative 2 was not selected as the preferred alternative.

Alternative 3 – Aluminum Structural Plate Box Culvert is the least expensive alternative and would also have an intermediate level of constructability. Fish passage performance, conveyance of flow and debris, and overall geometry would be very similar to the other alternatives. Versus an open-bottomed structure, the continuous floor of the structural plate box provides scour resistance and accommodates varying foundation conditions. Alternative 3 was selected as the preferred alternative because it achieves project objectives with the least anticipated cost.

Attachment B provides an itemized probable construction cost opinion for each of the alternatives. Most of the site preparation, mobilization, and streambed construction is similar for the three alternatives. The primary difference in the three alternatives is the cost for each structure. Costs for the open-bottom arch and aluminum structural plate box culvert were obtained from Pacific Corrugated Pipe Company in Eugene, Oregon. Costs for the concrete box culvert are based on estimates from Oldcastle Precast and other recently installed structures.

7 References

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ATTACHMENT A

TRUAX ISLAND – DEAD RIVER CULVERT CROSSING REPLACEMENT ALTERNATIVES PLANS

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TRUAX ISLAND

DEAD RIVER CULVERT CROSSING REPLACEMENT ALTERNATVES

ALBANY, OREGON

▚ DRAFT ▚

PROJECT PARTNERS

PROJECT DESCRIPTION

THE CALAPOOIA WATERSHED COUNCIL (CWC) AND OREGON PARKS AND RECREATION DEPARTMENT (OPRD) RETAINED RIVER DESIGN GROUP, INC. (RDG) TO PREPARE AN ALTERNATIVES ANALYSIS FOR A ROAD CROSSING AT TRUAX ISLAND, A WILLAMETTE RIVER GREENWAY PROPERTY BETWEEN CORVALLIS AND ALBANY THAT IS MANAGED BY OPRD. TRUAX ISLAND IS BOUNDED BY THE DEAD RIVER, AN ACTIVE SIDE CHANNEL TO THE WILLAMETTE RIVER. THE ACCESS ROAD WHICH WAS HISTORICALLY USED BY BOTH OPRD AND KNIFE RIVER CORPORATION TO ACCESS TRUAX ISLAND PROGRESSIVELY FAILED OVER TIME DUE TO ANNUAL OVERTOPPING AND SCOURING OF THE CHANNEL AND ROAD SUBGRADE MATERIALS ON THE DOWNSTREAM SIDE OF THE ROAD. RDG WAS INSTRUCTED TO PREPARE A CULVERT REPLACEMENT ALTERNATIVES ANALYSIS TO ADDRESS THE FAILED CULVERT. THE GOAL OF THE ALTERNATIVES ANALYSIS IS TO EVALUATE THREE COST-EFFECTIVE CROSSING REPLACEMENT ALTERNATIVES THAT WOULD RESTORE VEHICLE ACCESS TO TRUAX ISLAND, IMPROVE HYDRAULIC CONNECTIVITY AND FISH PASSAGE IN DEAD RIVER THROUGH THE ROAD SITE, AND MINIMIZE LONG-TERM CROSSING MAINTENANCE.

SPATIAL REFERENCE

SURVEY CONTROL USED FOR THE PROJECT IS PROVIDED ON DRAWING 2.0 AND COORDINATES CORRESPOND TO THE TOP CENTER OF CONTROL MARKERS.

LIDAR, GPS RTK, AND TOTAL STATION:
HORIZONTAL PROJECTION: OREGON STATE PLANE NORTH — SURVEY DATE: 03/23/16
HORIZ DATUM: NAD83 — UNITS: US FEET — LIDAR COLLECTED: 2009
VERT DATUM: NAVD88 — UNITS: US FEET

STANDARD OF PRACTICE

RDG WORKS EXCLUSIVELY IN THE RIVER ENVIRONMENT AND EMPLOYS THE MOST CURRENT AND ACCEPTED PRACTICES AVAILABLE FOR PLANNING AND DESIGN OF RESTORATION AND CHANNEL ENHANCEMENT PROJECTS. ALL WORK WAS PERFORMED OR DIRECTED BY A REGISTERED PROFESSIONAL CIVIL ENGINEER WITH PAST EXPERIENCE IN FISH PASSAGE AND ROAD CROSSING DESIGN.

REUSE OF DRAWINGS

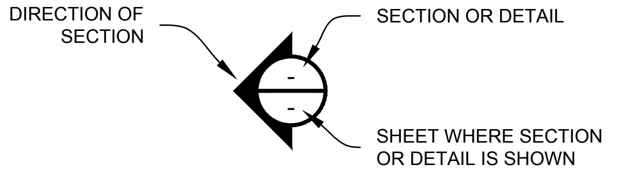
THESE DRAWINGS, THE IDEAS AND DESIGNS INCORPORATED HEREIN, AS AN INSTRUMENT OF PROFESSIONAL SERVICE, ARE THE PROPERTY OF RIVER DESIGN GROUP, INC. (RDG) AND ARE NOT TO BE USED, IN WHOLE OR IN PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF RDG. LIKEWISE, THESE DRAWINGS MAY NOT BE ALTERED OR MODIFIED WITHOUT AUTHORIZATION OF RDG. DRAWING DUPLICATION IS ALLOWED IF THE ORIGINAL CONTENT IS NOT MODIFIED.

DRAWING INDEX

PROJECT VICINITY MAP

Source: aerial image from USDA-FSA-APFO NAIP MrSID Mosaic. Hillshade derived from DOGAMI LIDAR

SW 1/4 OF SECTION 28, T.11S., R.04W., WILLAMETTE MERIDIAN
LINN COUNTY, OREGON
USGS QUADRANGLE: RIVERSIDE, OR



CROSS-SECTION SHEET REFERENCE

RDG
RIVER DESIGN GROUP
236 Wisconsin Avenue
Whitefish, MT 59937
406.862.4927
311 SW Jefferson Avenue
Corvallis, OR 973333
541.738.2920

COVER SHEET
TRUAX ISLAND
ALBANY, OREGON

NO.	DATE	BY	DESCRIPTION	CHK
*	10/04/16	DF	DRAFT	CS

PROJECT NUMBER
RDG-16-019

DRAWING NUMBER
1.0

Drawing 0 of 5

Oct 04, 2016 - 12:46pm M:\Projects\2016\RDG-16-019 Truax Island Dead River\CAD\10(Truax Island) - Crossing Alternatives.dwg

① **EXISTING CONDITIONS PLAN VIEW**

1" = 200'

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PROJECT OVERVIEW

TRUAX ISLAND
ALBANY, OREGON

NO.	DATE	BY	DESCRIPTION	CHK
*	10/04/16	DF	DRAFT	CS

PROJECT NUMBER
RDG-16-019

DRAWING NUMBER
2.0

Drawing 2 of 5

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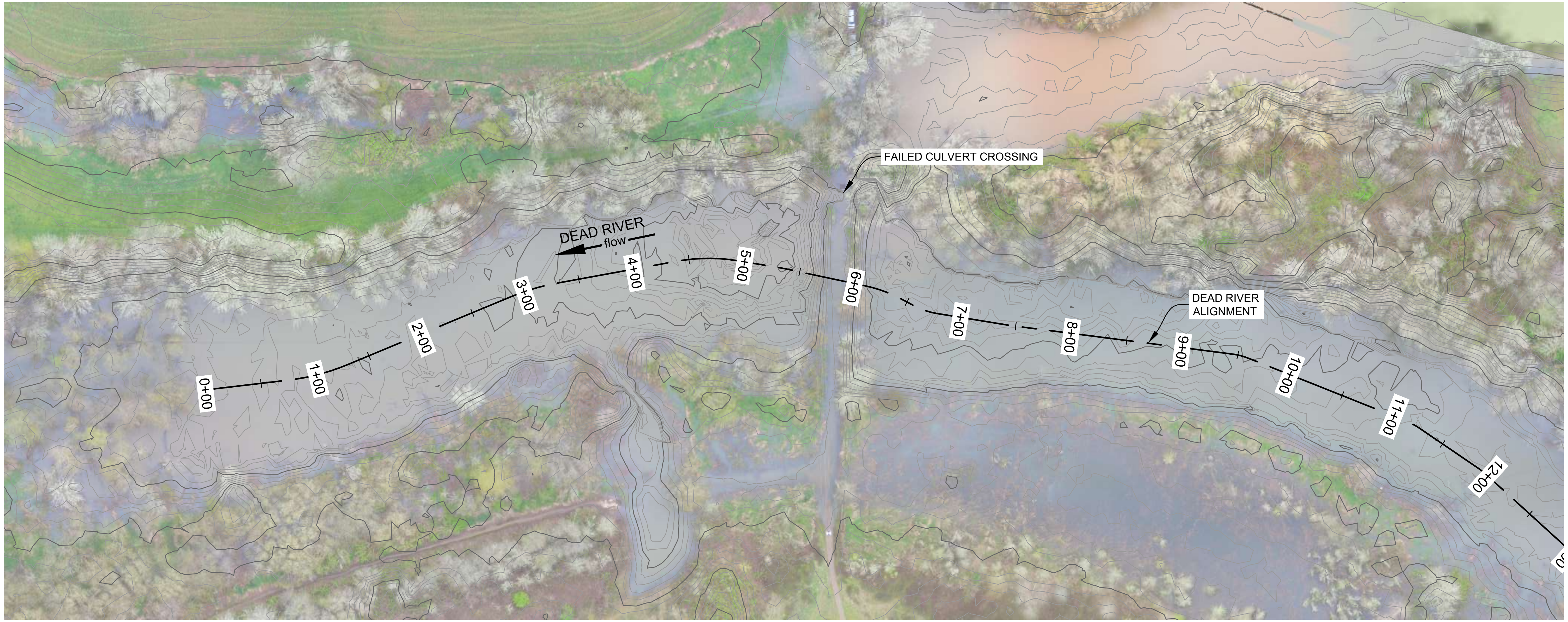
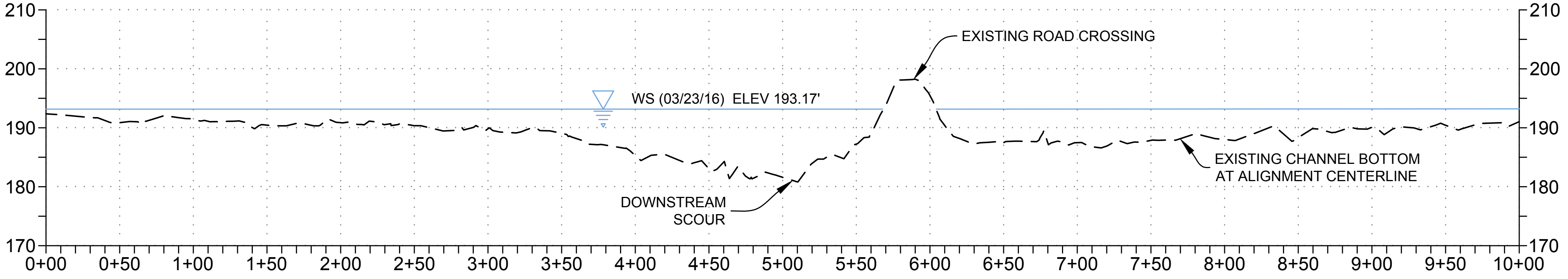


① **EXISTING CONDITIONS PLAN VIEW**

1" = 100'



② **PROPOSED LONG PROFILE**

HORIZ 1" = 100'
VERT 1" = 25'

DRAFT

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EXISTING CONDITIONS

TRUAX ISLAND
ALBANY, OREGON

NO.	DATE	BY	DESCRIPTION	CHK
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PROJECT NUMBER
RDG-16-019

DRAWING NUMBER
2.1

Drawing 3 of 5

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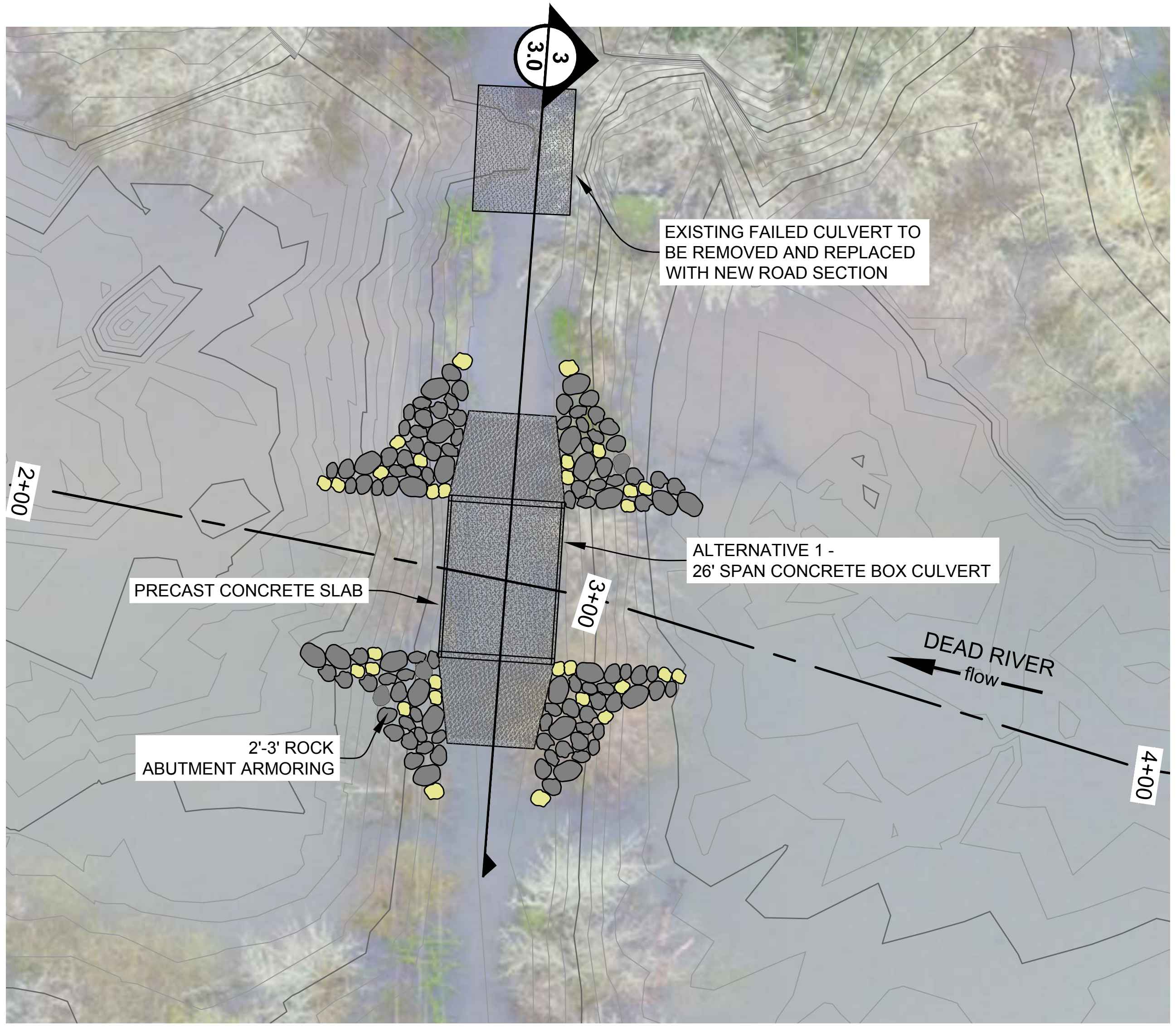

1

ALTERNATIVE 1 - 26' CONCRETE BOX CULVERT PLAN VIEW

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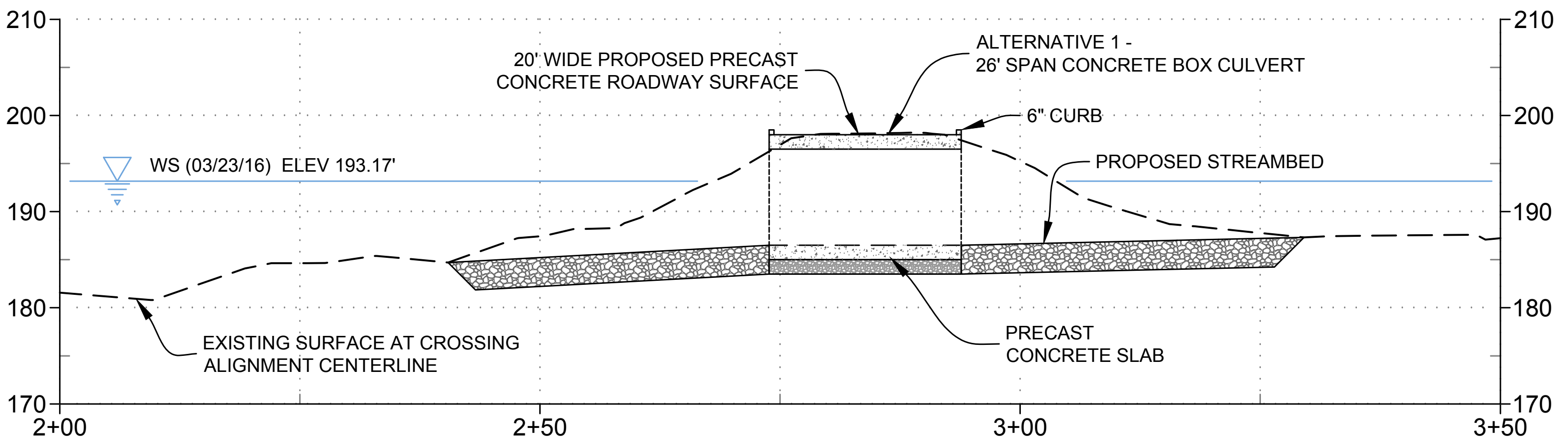

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ALTERNATIVE 1 - 26' CONCRETE BOX CULVERT LONG PROFILE

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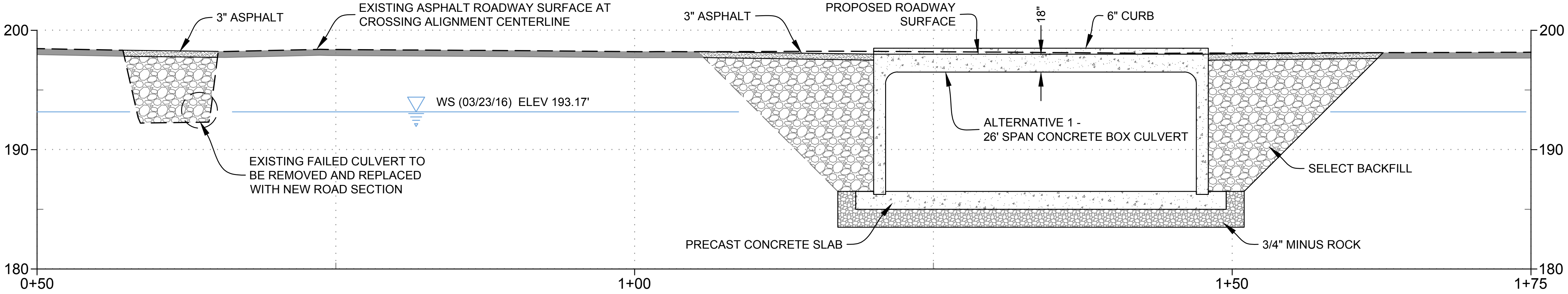

3

ALTERNATIVE 1 - 26' CONCRETE BOX CULVERT CROSS SECTION

HORIZ 1" = 10'
VERT 1" = 10'

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ALTERNATIVE 1
26' CONCRETE BOX CULVERT

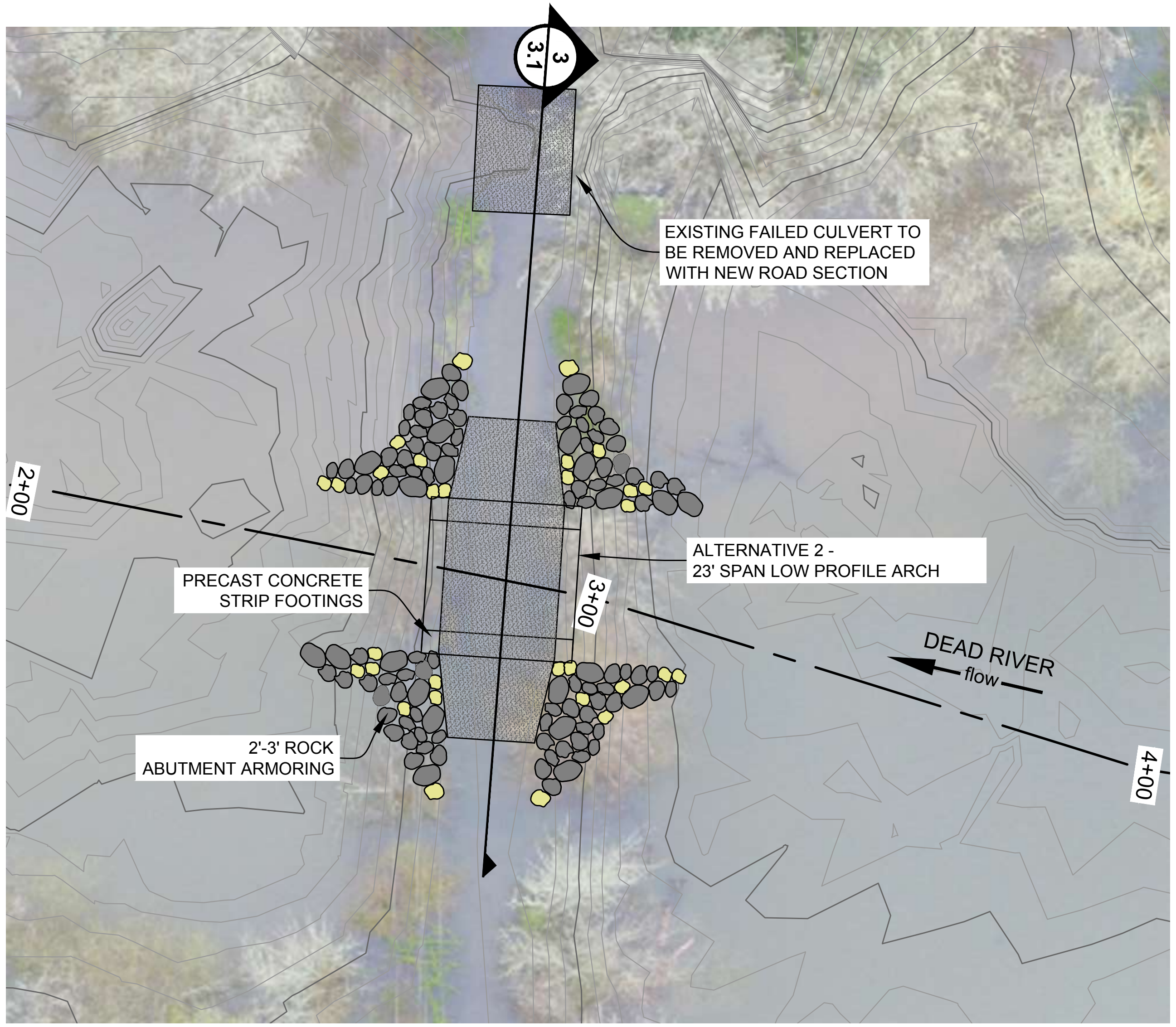
TRUAX ISLAND
ALBANY, OREGON

NO.	DATE	BY	DESCRIPTION	CHK
*	10/04/16	DF	DRAFT	CS

PROJECT NUMBER
RDG-16-019

DRAWING NUMBER
3.0

Drawing 3 of 5



① ALTERNATIVE 2 - 23' LOW PROFILE ARCH PLAN VIEW

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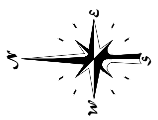

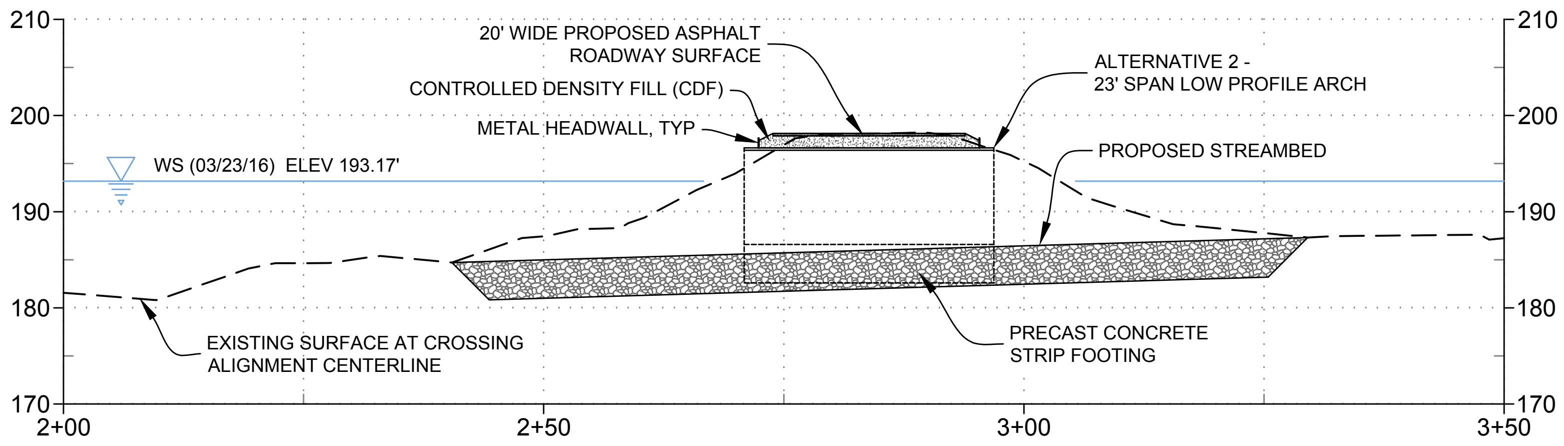

② ALTERNATIVE 2 - 23' LOW PROFILE ARCH PROFILE

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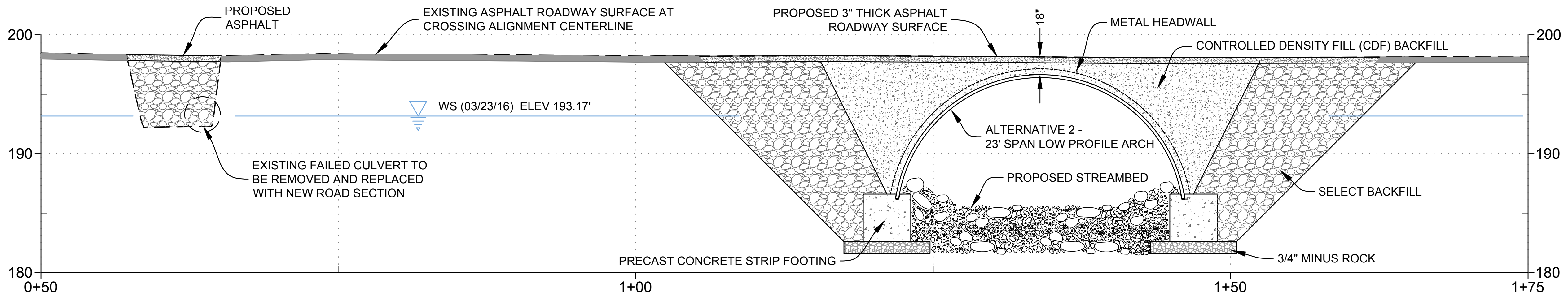

③ ALTERNATIVE 2 - 23' LOW PROFILE ARCH CROSS SECTION

HORIZ 1" = 20'
VERT 1" = 20'

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ALTERNATIVE 2 - 23' LOW PROFILE ARCH

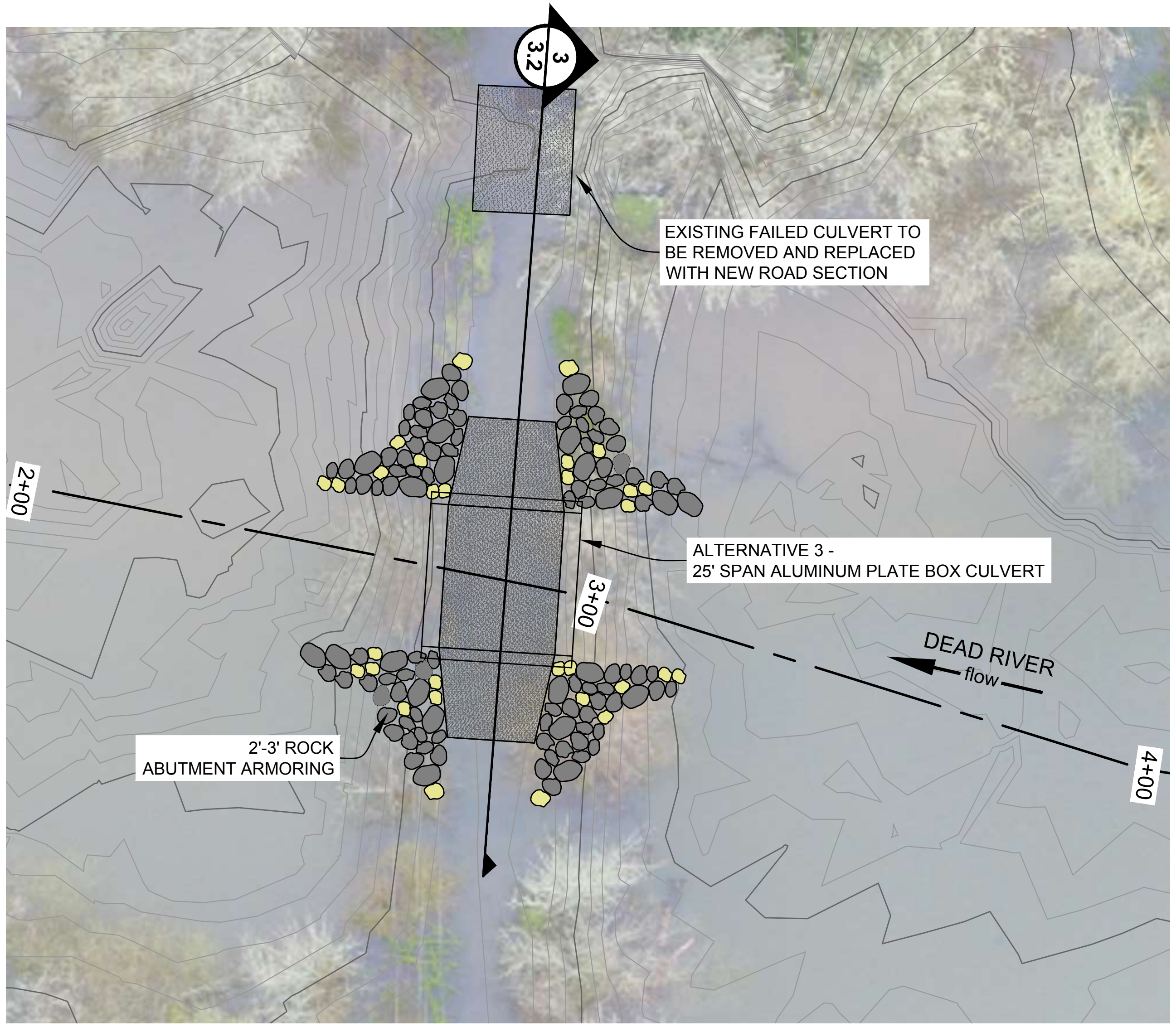
TRUAX ISLAND
ALBANY, OREGON

NO.	DATE	BY	DESCRIPTION	CHK
*	10/04/16	DF	DRAFT	CS

PROJECT NUMBER
RDG-16-019

DRAWING NUMBER
3.1

Drawing 4 of 5



① ALTERNATIVE 3 - 25' ALUMINUM PLATE BOX CULVERT PLAN VIEW

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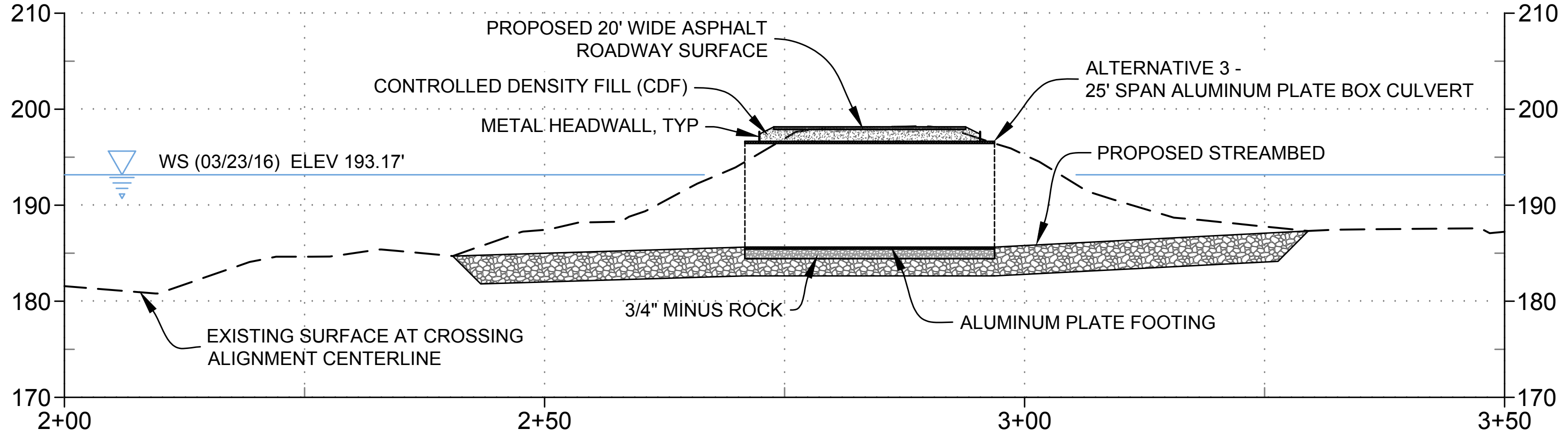

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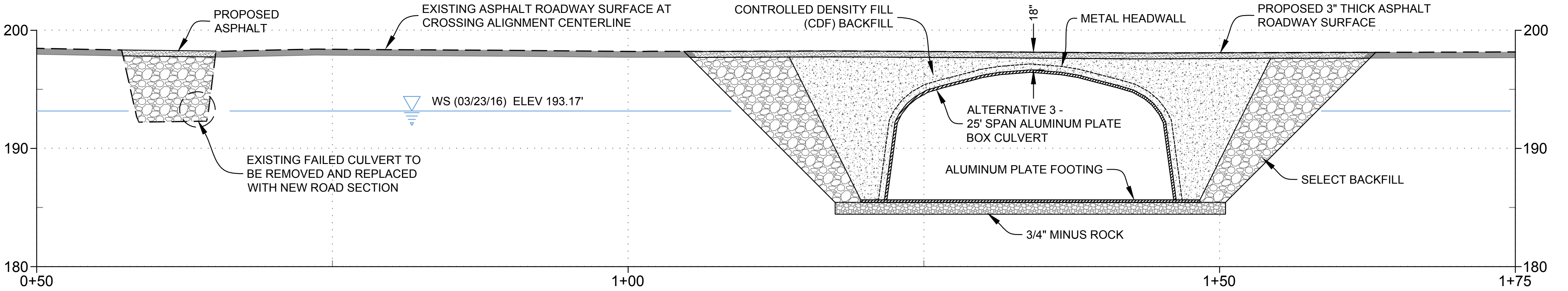

③ ALTERNATIVE 3 - 25' ALUMINUM PLATE CULVERT CROSS SECTION

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ALTERNATIVE 3
25' ALUMINUM PLATE BOX CULVERT

TRUAX ISLAND
ALBANY, OREGON

NO.	DATE	BY	DESCRIPTION	CHK
*	10/04/16	DF	DRAFT	CS

PROJECT NUMBER
RDG-16-019

DRAWING NUMBER
3.2

Drawing 5 of 5

ATTACHMENT B

TRUAX ISLAND – DEAD RIVER CULVERT CROSSING REPLACEMENT COST OPINION

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Project: Truax Island
Title: Alternatives Cost Opinion
Client: Calapooia Watershed Council
Description: Probable Construction Cost for Alternatives Development
Date: September 27, 2016

RIVER DESIGN GROUP

		Alternative 1 - 26' Concrete Box Culvert			Alternative 2 - 23' Low Profile Arch			Alternative 3 - 25' Aluminum Plate Box Culvert		
		Quantity	**Unit Cost**	**Cost**	**Quantity**	**Unit Cost**	**Cost**	**Quantity**	**Unit Cost**	**Cost**
On-site Construction Oversight & Inspection				**$ 7,480**			**$ 7,480**			**$ 7,480**
1.1	Project Engineer	32 hrs	$100	$ 3,200	32 hrs	$100	$ 3,200	32 hrs	$100	$ 3,200
1.2	Fisheries Biologist	32 hrs	$100	$ 3,200	32 hrs	$100	$ 3,200	32 hrs	$100	$ 3,200
1.3	Survey Crew for project layout	6 hrs	$180	$ 1,080	6 hrs	$180	$ 1,080	6 hrs	$180	$ 1,080
Construction Costs				**$ 218,857**			**$ 184,029**			**$ 167,903**
2.1	**Mobilization / Demobilization**			**$ 12,500**			**$ 4,500**			**$ 4,500**
	Each piece of equipment	3 each	$1500 /ea	$ 4,500	3 each	$1500 /ea	$ 4,500	3 each	$1500 /ea	$ 4,500
	Crane	1 each	$8000 /ea	$ 8,000	0 each	$8000 /ea	$ -	0 each	$8000 /ea	$ -
2.2	**Site Prep & Access**			**$ 4,300**			**$ 2,960**			**$ 2,960**
	Develop access and work pad	1 each	$3500 /job	$ 3,500	1 each	$2160 /job	$ 2,160	1 each	$2160 /job	$ 2,160
	Clear vegetation / fencing to access stream	1 each	$800 /job	$ 800	1 each	$800 /job	$ 800	1 each	$800 /job	$ 800
	Powerline Grounding	1 each	$12000 /job	$ 12,000	1 each	$12000 /job	$ 12,000	1 each	$12000 /job	$ 12,000
2.3	**Dewatering / Work Area Isolation / Erosion Control**			**$ 12,800**			**$ 14,800**			**$ 14,800**
	Work site dewatering/pump/piping	1 job	$10000 /job	$ 10,000	1 job	$12000 /job	$ 12,000	1 job	$12000 /job	$ 12,000
	Defish work site	1 job	$2000 /job	$ 2,000	1 job	$2000 /job	$ 2,000	1 job	$2000 /job	$ 2,000
	Temporary Erosion Control	1 job	$800 /job	$ 800	1 job	$800 /job	$ 800	1 job	$800 /job	$ 800
2.4	**Excavation and Disposal / Hauling**			**$ 12,300**			**$ 14,940**			**$ 12,560**
	Bulk Excavation	540 cy	$12 /cy	$ 6,480	660 cy	$12 /cy	$ 7,920	530 cy	$12 /cy	$ 6,360
	Asphalt cutting and removal	30 cy	$30 /cy	$ 900	30 cy	$30 /cy	$ 900	30 cy	$30 /cy	$ 900
	Stockpiling	120 cy	$6 /cy	$ 720	220 cy	$6 /cy	$ 1,320	150 cy	$6 /cy	$ 900
	Disposal / Hauling	420 cy	$10 /cy	$ 4,200	480 cy	$10 /cy	$ 4,800	440 cy	$10 /cy	$ 4,400
2.5	**Install New Stream Crossing**			**$ 117,910**			**$ 86,025**			**$ 83,383**
	26' span x 10' rise x 20' wide, Precast box culvert, full floor	1 each	$90000 /ea	$ 90,000	-	-	$ -	-	-	$ -
	24'-8" span x 10'-6" Rise x 20' wide, Aluminum Plate Box Culvert	-	-	$ -	1 each	$35615 /ea	$ 35,615	-	-	$ -
	23' x 10'-3" Rise x 20' wide, Aluminum Plate Arch	-	-	$ -	-	-	$ -	1 each	$45573 /ea	$ 45,573
	Precast footings for arch	-	-	$ -	31 cy	$450 /cy	$ 13,950	-	-	$ -
	Bedding / Foundation preparation (Leveling Pad)	46 cy	$35 /cy	$ 1,610	30 cy	$35 /cy	$ 1,050	46 cy	$35 /cy	$ 1,610
	Structure Assembly and Installation	1 each	$11300 /ea	$ 11,300	1 job	$12960 /job	$ 12,960	1 job	$16200 /job	$ 16,200
	Select granular backfill / Native backfill	120 cy	$35 /cy	$ 4,200	170 cy	$35 /cy	$ 5,950	100 cy	$35 /cy	$ 3,500
	Controlled Density Fill (reduces height of cover)	0 cy	$114 /cy	$ -	50 cy	$114 /cy	$ 5,700	50 cy	$114 /cy	$ 5,700
	Guardrail	2 each	$4000 /ea	$ 8,000	2 each	$4000 /ea	$ 8,000	2 each	$4000 /ea	$ 8,000
	Abutment Scour Protection	80 cy	$35 /cy	$ 2,800	80 cy	$35 /cy	$ 2,800	80 cy	$35 /cy	$ 2,800
2.6	**Simulated Streambed / Inlet & Outlet Apron**			**$ 20,700**			**$ 27,000**			**$ 18,000**
	Simulated Streambed & Inlet/Outlet apron	230 cy	$90 /cy	$ 20,700	300 cy	$90 /cy	$ 27,000	200 cy	$90 /cy	$ 18,000
2.7	**Road Restoration**			**$ 6,000**			**$ 6,000**			**$ 6,000**
	Road top course - 3" AC pavement	133 sy	$45 /sy	$ 6,000	133 sy	$45 /sy	$ 6,000	133 sy	$45 /sy	$ 6,000
2.8	**Site Cleanup / Erosion Control / Planting**			**$ 3,800**			**$ 3,800**			**$ 3,800**
	Erosion control seeding	0.25 acre	$800 per acre	$ 200	0.25 acre	$800 per acre	$ 200	0.25 acre	$800 per acre	$ 200
	Mulching	0.25 acre	$800 per acre	$ 200	0.25 acre	$800 per acre	$ 200	0.25 acre	$800 per acre	$ 200
	Laborer 1	60 hrs	$40 /hr	$ 2,400	60 hrs	$40 /hr	$ 2,400	60 hrs	$40 /hr	$ 2,400
	Upland trees	0.25	$2000 per acre	$ 500	0.25 acre	$2000 per acre	$ 500	0.25	$2000 per acre	$ 500
	Riparian planting	0.25 acre	$2000 per acre	$ 500	0.25 acre	$2000 per acre	$ 500	0.25 acre	$2000 per acre	$ 500
2.9	**Risk /Uncertainty**									
	Contingency based on variables	15%		**$ 28,547**	15%		**$ 24,004**	15%		**$ 21,900**
				$ 226,337			**$ 191,509**			**$ 175,383**

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