Technical Memorandum

LSNA Hydrologic Analysis

DATE: May 20, 2013

TO: Mr. Peter Guillozet, Project Manager
Luckiamute Watershed Council

FROM: Peter Gruendike
River Design Group, Inc.

SUBJECT: Hydrologic Analysis and Recommendations for the Luckiamute State Natural Area

1 INTRODUCTION

The Luckiamute Watershed Council (LWC) contracted with River Design Group, Inc. (RDG) to provide technical assistance for hydrologic analysis and project planning for floodplain enhancement projects at the Luckiamute State Natural Area (LSNA). Major floodplain revegetation efforts are currently underway at the LSNA so this document focuses primarily on potential efforts to improve the hydrologic connectivity of the river-floodplain interface at the site. The hydrologic analysis conducted through remote sensing was used to highlight and identify potential locations that could be investigated more rigorously for possible floodplain restoration or enhancement projects. Potential projects identified through remote sensing were field verified and assessed to determine the feasibility, potential impacts, and overall benefits of the recommended projects.

Owned and managed by the Oregon Parks and Recreation Department (OPRD), the LSNA is divided into two tracts, the North Tract and South Tract, totaling approximately 926 acres. The LSNA contains important floodplain habitats at the confluence of the Luckiamute and Willamette rivers and is considered part of the Luckiamute-Santiam anchor habitat on the Willamette River. Anchor habitats are cold water reaches of the Willamette River that are known to sustain cold water fishes and are considered of high ecological value. The LSNA is home to a variety of at-risk native species that include western pond turtles and red-legged frogs, as well as ESA threatened spring Chinook salmon and steelhead. Figure 1 shows the location of the LSNA project area within the Willamette Basin and its proximity to local municipalities and geographic features.

This Technical Memorandum provides a summary of the hydrologic analysis and recommendations for potential ecological enhancement projects at the LSNA.

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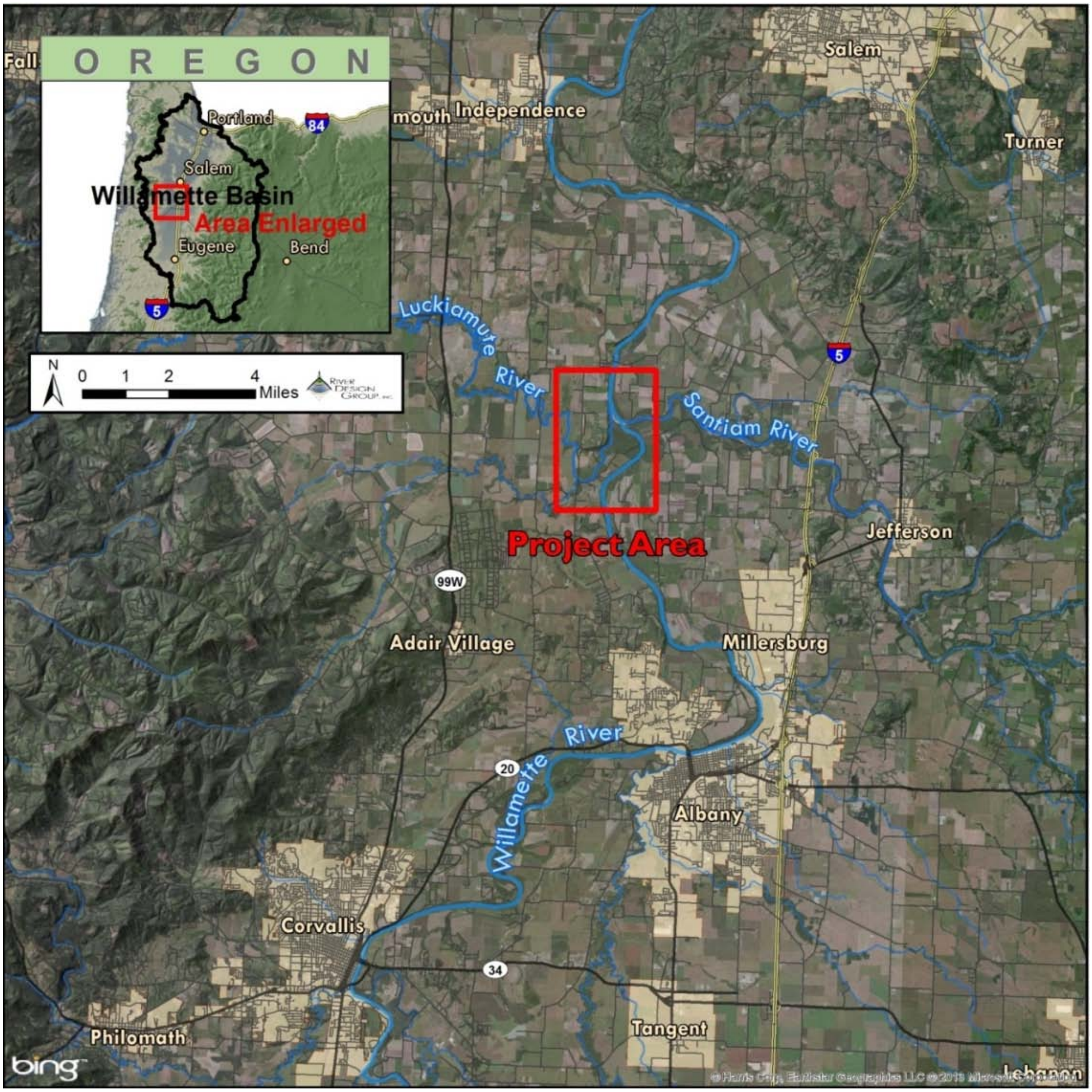


Figure 1-1. Location map of the LSNA project area.

2 HYDROLOGIC ANALYSIS

The LSNA contains a large dynamic floodplain near the confluence of the Luckiamute, Santiam, and Willamette rivers. Despite significant reductions to the frequency and magnitude of large flood events on the Willamette and Santiam rivers due to flood control operations, the LSNA still experiences annual flooding throughout much of the property. 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 floodplain inundation mapping analysis and the subsequent site investigation recommendations. The Albany gage was used to characterize river flows and stage for the LSNA project areas because of its long period of record, its consistent stage-discharge relationship, and its close proximity to the project site. The hydrology of the Luckiamute River watershed may play an important role in hydrologic function at the site, but this analysis was not evaluated as part of this effort. We recommend future hydrologic investigations include a review of the Suver gage on the Luckiamute River. Our expectation is that water surface elevations and floodplain inundation at the LSNA is controlled more so by the Willamette River than the Luckiamute River. However, during more localized precipitation events, LSNA inundation would be primarily affected by Luckiamute River flows.

2.1 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 2-1. 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

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 LSNA project area. 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. 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. Metering peak flows has reduced flood impacts to human infrastructure and enabled occupation and development of the Willamette River floodplain.

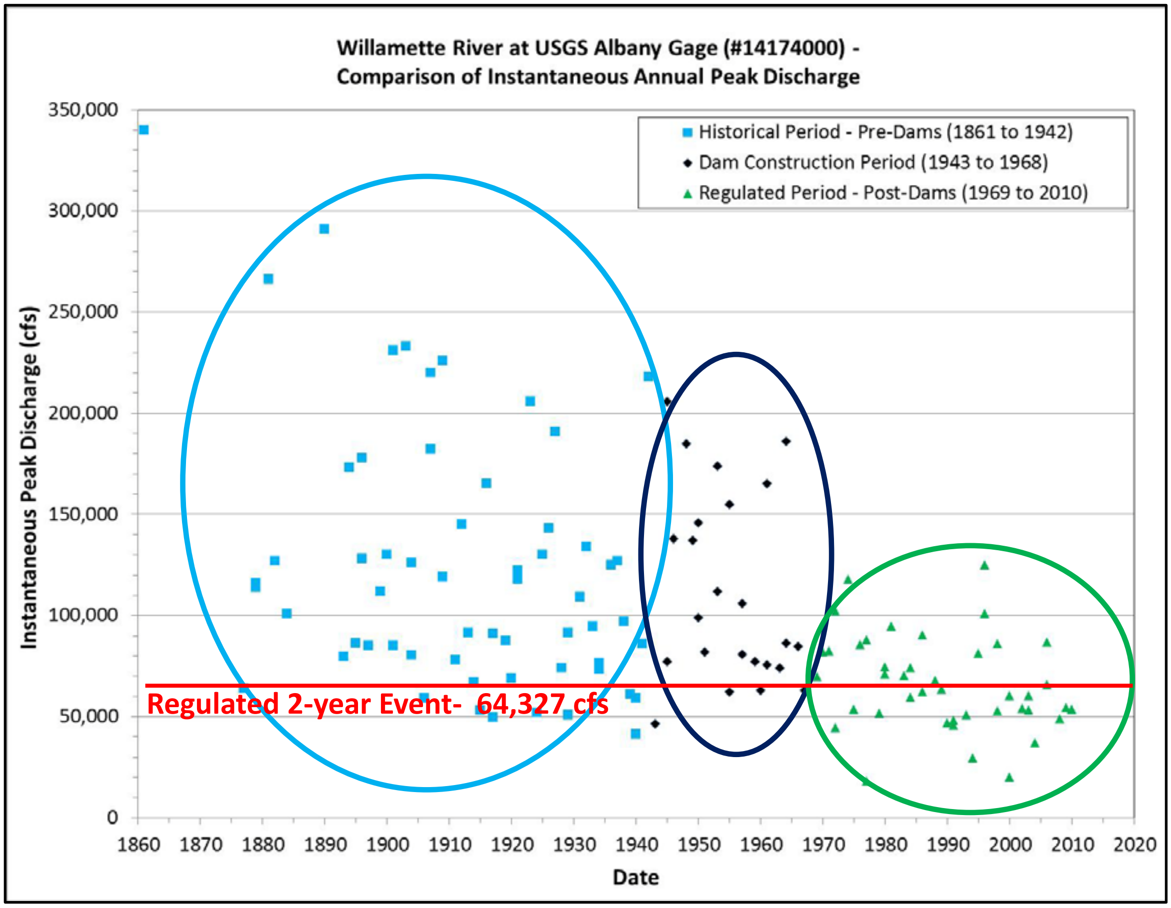


Figure 2-1. A comparison of annual peak flows at the Albany gage on the Willamette River from 1892 to 2010. The three primary river management periods are highlighted. The actual regulated 2-year discharge at the Albany gage is included for illustration. The USACE target 2-year discharge at the Albany gage is 69,500 cfs.

Table 2-2. 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 2010)	66,243
Historical Period 2-year Discharge	106,409
Regulated Period 2-year Discharge	64,327

A 17B flood frequency analysis was completed for the Regulated period (1969 to 2010). Flood frequency results for the Albany gage are included in Table 2-3.

Table 2-3. The flood frequency analysis for the USGS Albany gage (#14174000). The analysis is based on the Regulated period from 1969 to 2010.

Return Period (years)	Percent Change Exceedance (%)	Expected Probability (cfs)	Confidence Limit 0.05 (cfs)	Confidence Limit 0.95 (cfs)
100	1.0	138,016	160,481	115,855
50	2.0	125,982	145,483	107,821
20	5.0	110,073	125,489	96,579
10	10.0	97,738	110,021	87,331
5	20.0	84,703	93,901	76,947
2	50.0	64,327	70,031	59,110
1.25	80.0	48,466	53,364	43,756
1.01	99.0	28,121	33,926	24,118

Figure 2-2 includes a comparison of average mean annual hydrographs from the three river management periods at the Albany gage. The hydrographs show the lower average mean daily discharge in the February to June period, and higher base flows from July through October associated with the regulated period. This pattern illustrates the dampened peak flows and higher base flows derived through flood control operations. Figure 2-3 compares the mean daily flow on September 1 across the three river management periods to show how a representative daily average flow during the base flow portion of the hydrograph has changed over time. Mean daily flows are averaged in Table 2-4 for comparison.

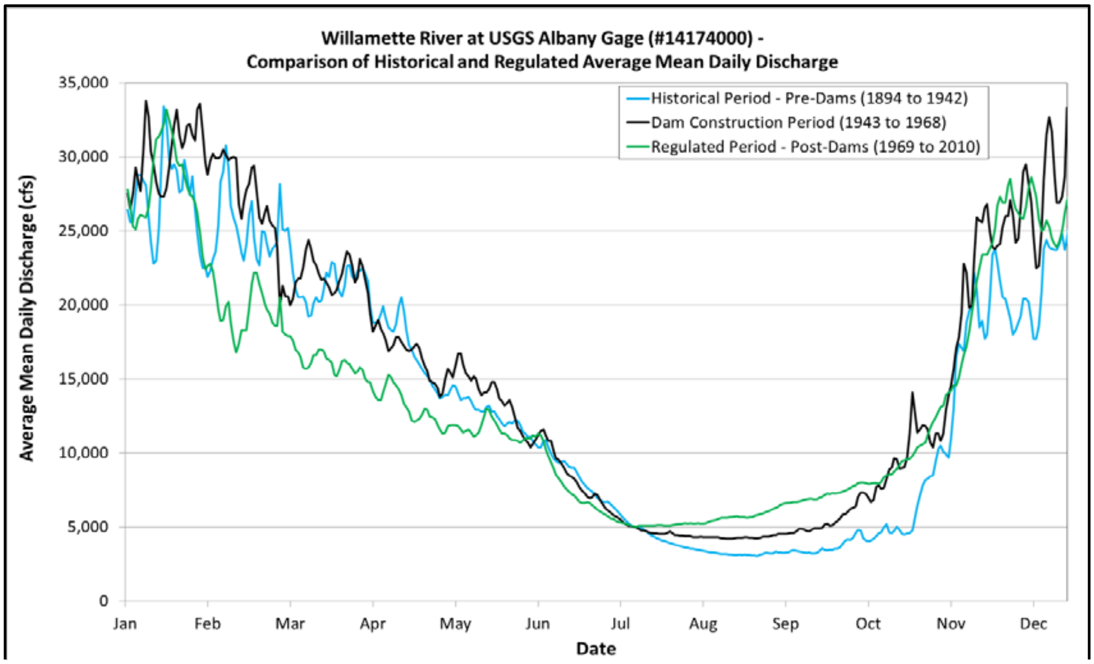


Figure 2-2. A comparison of average mean annual hydrographs for the Willamette River from 1894 to 2010. The three primary river management periods are highlighted. The graph illustrates lower peak flows and higher base flows characteristic of the Regulated period relative to the Historical and Dam Construction periods.

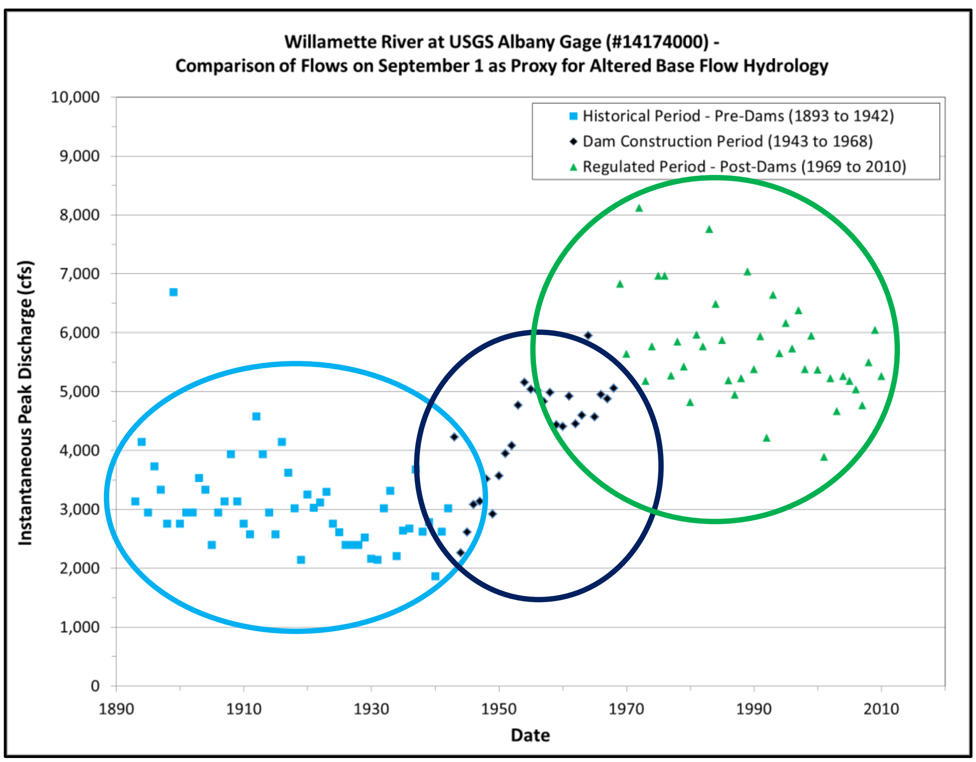


Figure 2-3. A comparison of the mean daily flow on September 1 for each year in the three river management periods as a proxy for summer base flow changes over time in respect to flood control operations in the Willamette River basin.

Table 2-4. A comparison of the mean daily discharge on September 1 for the Willamette River at the Albany gage for the three river management periods.

River Management Period	Mean Daily Discharge On September 1 (cfs)
Historical Period - Pre-Dams (1861 to 1942)	3,054
Dam Construction Period (1943 to 1968)	4,283
Regulated Period - Post-Dams (1969 to 2010)	5,815

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 discharge, and have influenced geomorphic and ecological function in the Willamette River corridor. Compared to historical flows, regulated flows are less likely to interact with the Willamette River floodplain due to the lower discharge magnitude.

2.2 Staff Plate Analysis

RDG established a staff plate network around the LSNA project area to characterize water surface elevations in the LSNA project area and to better understand how water surface elevations in the LSNA relate to Willamette River discharge. Establishing rating curves for the project area is an incremental step in determining existing and potential floodplain inundation frequency and duration. The four staff plate network was set up to monitor floodplain inundation both laterally from the Willamette River to the LSNA interior, and longitudinally paralleling the river from the upstream floodplain to the mouth of the Luckiamute River. Figure 2-4 shows the locations of the staff plate network at the LSNA.

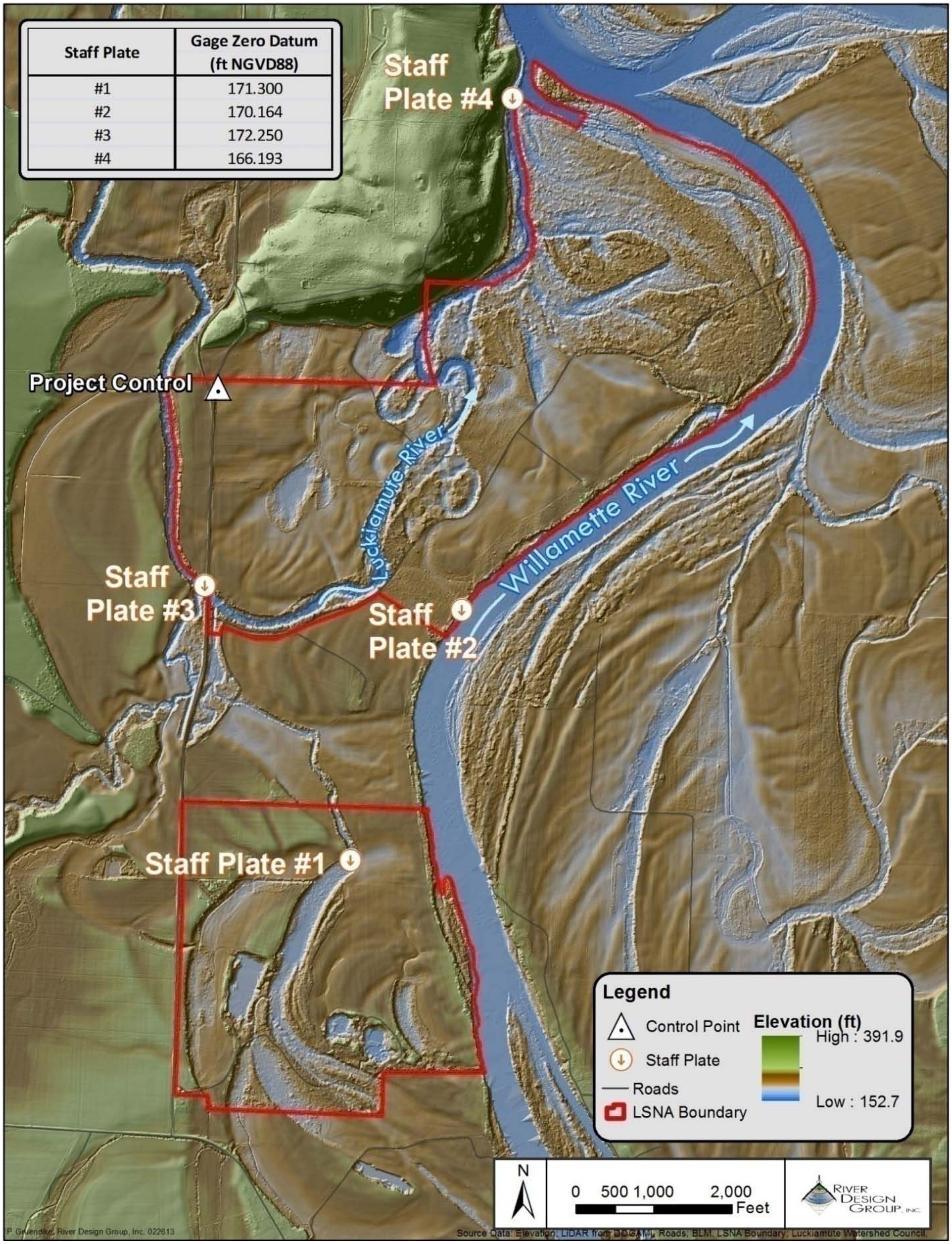


Figure 2-4. Staff plate locations were intended to monitor lateral and longitudinal floodplain inundation at the LSNA properties.

Each staff plate was installed following a multi-step process.

- Selected staff plate location.
- Dug a 1 ft deep by 1 ft wide hole with a post hole digger.
- Drove the 2 inch by 10 ft metal conduit pole into the hole approximately 2 ft using a post driver.
- Poured concrete into the 1 ft hole to anchor conduit pole.
- Fixed three sections of 3 ft tall staff plates to conduit with sheet metal screws.
- Used GNSS GPS unit to survey a minimum of two measurement increments on the bottom staff plate to establish real-world elevation at each staff plate.

Figure 2-5 includes a photo of a completed staff plate.

Figure 2-5. Staff Plate #3 near the confluence of Soap Creek and the Luckiamute River.

The local landowners involved with the project and LWC staff, recorded water surface elevations at the staff plate locations. Landowners and LWC staff provided RDG with the date, time, and observed stage for each staff plate observation. Landowners and LWC staff also pin flagged high water marks when they were unable to access that staff plate networks. RDG used GNSS enabled RTK GPS to later survey the pin flagged observed high water elevations.

For each staff plate observation, RDG calculated the time of travel from the staff plate network to the nearest gage using methods from Harris (1968). The time of travel correction was necessary to best estimate the river discharge at the time of the staff plate observation. This method then enabled a more precise comparison of observed river stage to river discharge.

Figure 2-6 includes a representative rating curve from Staff Plate #4.

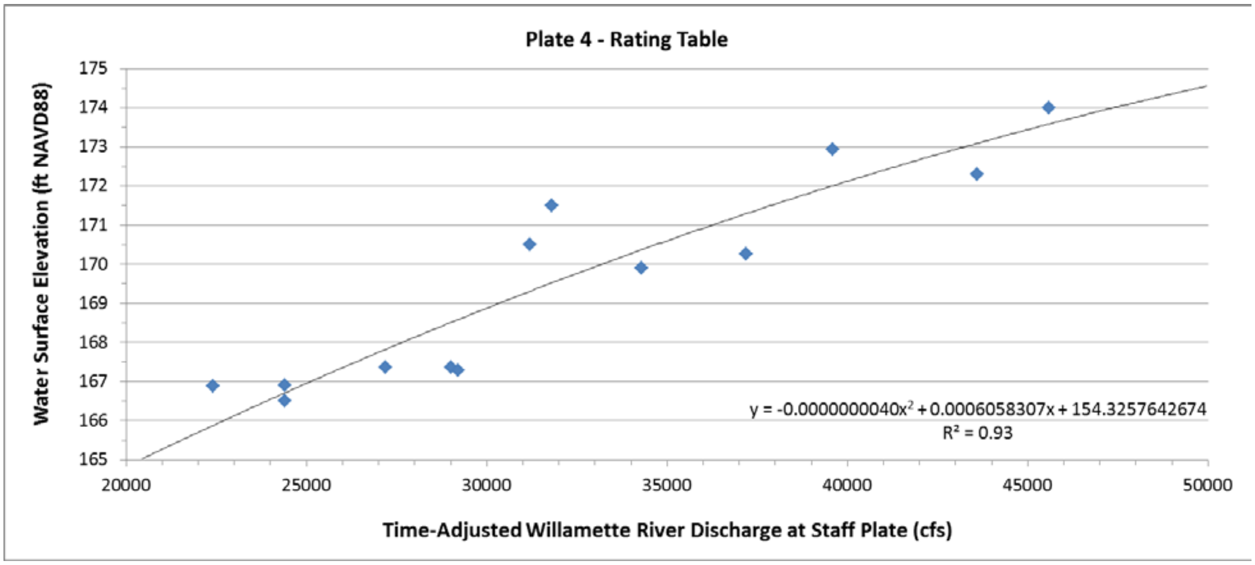


Figure 2-6. Rating curves for Staff Plate #4 at the LSNA. The curve was formulated by relating observed water surface elevations at the staff plate to the time-corrected Willamette River discharge at the USGS Albany gage.

2.3 Flow Duration Analysis

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 2-5 includes the flow duration data. Figure 2-7 includes the flow duration curve for the USGS Albany gage

Table 2-5. Flow duration data for the USGS Harrisburg gage and USGS Albany gage over the regulated period of record (1969 – 2010).

Percent of Time Exceeded	Equivalent Number of Days	Albany Gage Discharge (cfs)	Albany Gage Height (ft)*
99	361	3,960	2.32
95	347	4,501	2.65
90	329	4,940	2.90
80	292	5,600	3.27
50	183	9,060	4.98
25	91	15,500	7.61
15	55	22,900	10.17
10	37	30,900	12.63
5	18	43,200	16.00
2	7	54,300	18.72
1	4	61,159	20.27
0.1	0.4	85,998	25.38

*Gage heights based on USGS rating tables accessed on 02/15/2013.

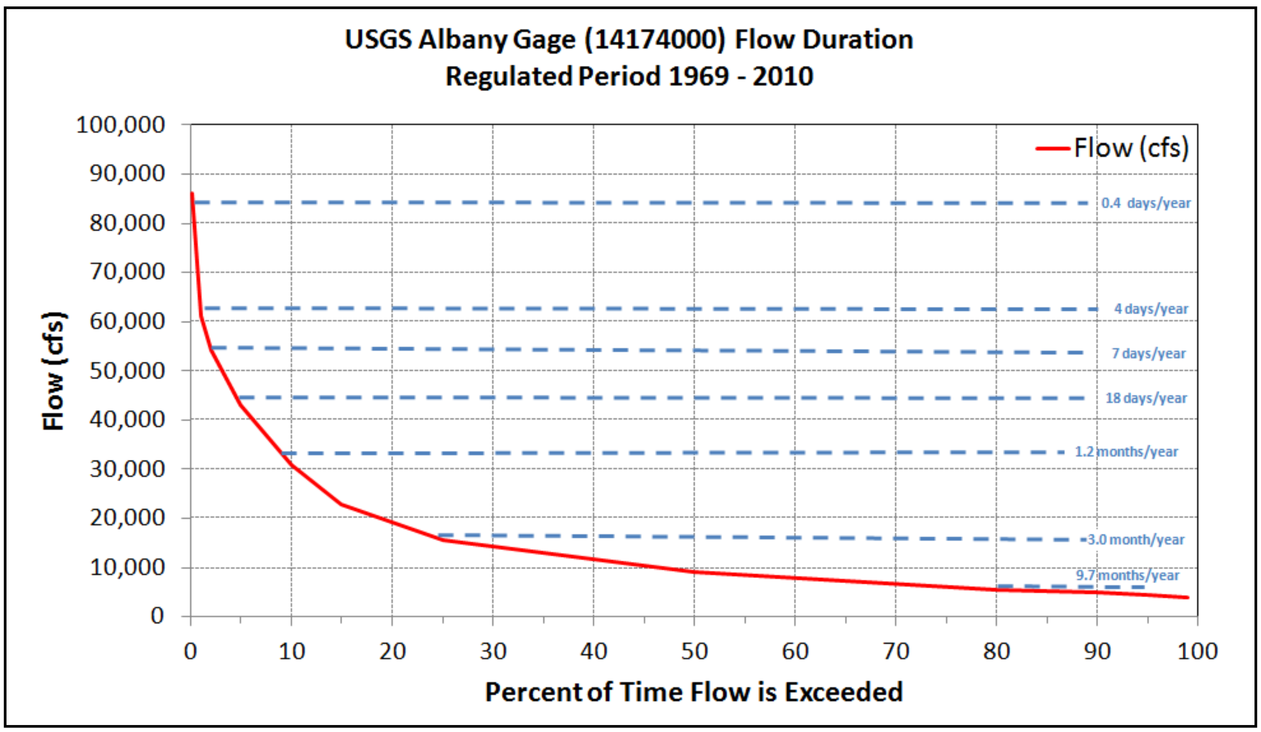


Figure 2-7. The USGS Albany gage flow duration curve based on the regulated period (1969 - 2010).

The flow duration data and the rating table information were used to assess existing and potential floodplain inundation frequency and duration for the LSNA. For example, using the rating curve for Staff Plate #4, a water surface elevation of 173.1 ft equates to a Willamette River discharge of approximately 43,500 cfs. The Albany gage's flow duration curve suggests 43,500 cfs is exceeded less than5% of the year, or approximately 2 weeks per year on average.

From an ecological perspective, increasing the frequency and duration of connection between off-channel floodplain habitats with the Luckiamute and Willamette rivers is expected to benefit juvenile fish that occupy these habitats during winter high flows. Due to river regulation, the Willamette River connects with off-channel habitats much less frequently and for shorter durations relative to historical conditions. Average mean daily flows now exceed 25,000 cfs from mid to late November, and then during the January to February period (see Figure 2-2). For the LSNA, we used 24,000 cfs as a target flow for increasing off-channel connectivity with the Luckiamute and Willamette rivers. This flow occurs for approximately 4-6 weeks in an average year. The water surface elevation associated with the 24,000 cfs event would inundate the LSNA area and allow for fish movement between the river and floodplain.

2.4 Inundation Mapping

ArcGIS tools were used to simulate floodplain inundation to assess potential areas of floodplain inundation. The LiDAR dataset was used to create the underlying topographic surfaces for the project sites and water surface elevations were modeled to inundate various floodplain acreages. Inundation maps for the LSNA (Figure 2-8) were created for the following discharges at the USGS Albany gage; 18,500 cfs, 24,000 cfs, 36,000 cfs, 43,500 cfs, 55,000 cfs, and 69,500 cfs.

Full page maps are also included in Appendix A. The maps show potential floodplain inundation extents with increasing Willamette River discharge. This information is informative for predicting floodplain inundation associated with restoration actions that increase connectivity between the Willamette River and the adjacent floodplain in the LSNA area.

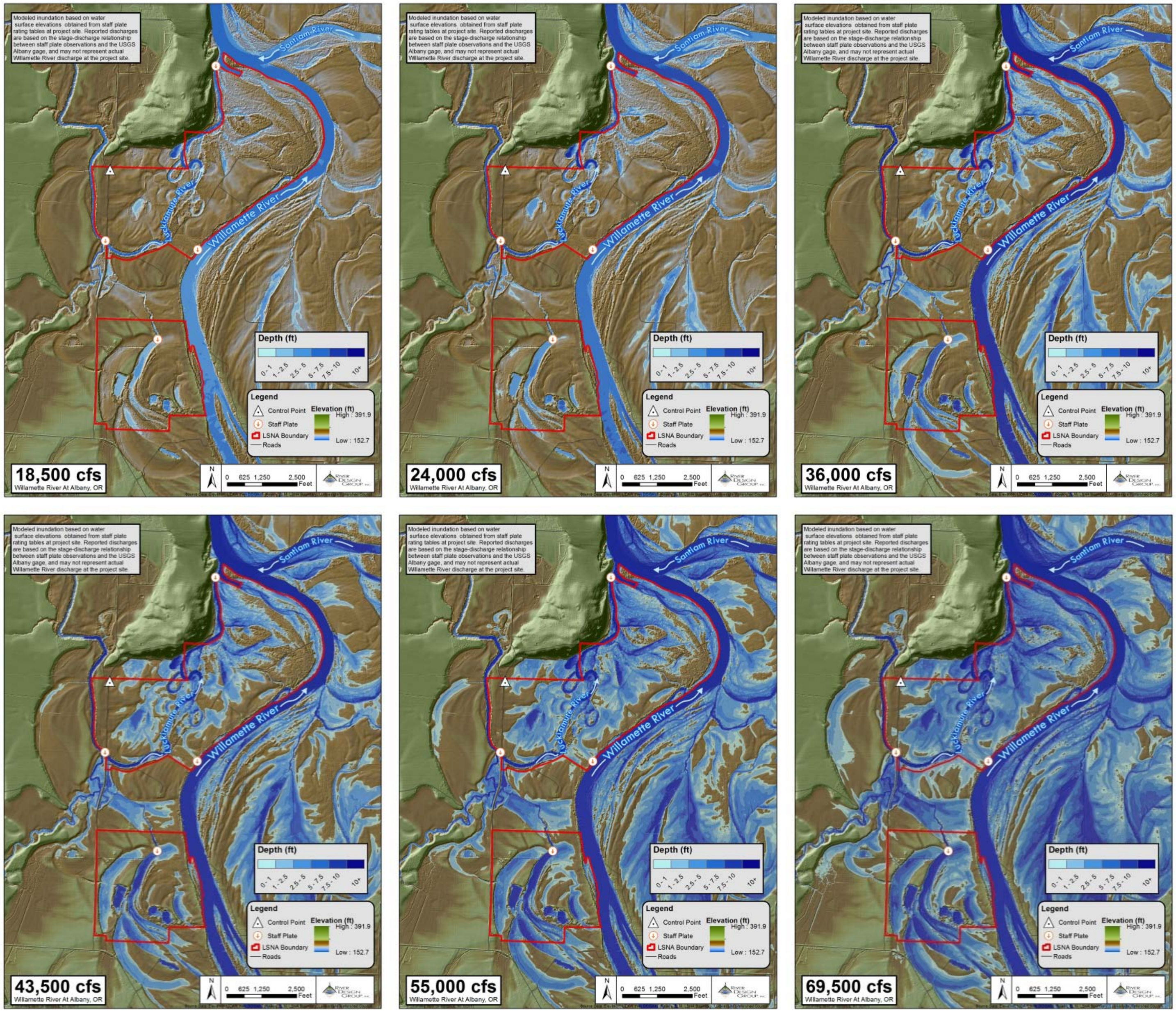


Figure 2-8. Inundation maps prepared for the LSNA for flows from 18,500 cfs to 69,500 cfs. Full page maps are included in Appendix A.

The resulting inundation maps differ from a hydraulic model as they do not consider obstructions to flow, only areas that are lower in elevation than the modeled discharge water surface elevations. In this regard, inundation mapping provides a useful depiction of areas that could be inundated through restoration actions such as berm/levee removal, or floodplain grading. Aerial photography taken by Eagle Digital Imaging, Inc. on April 2, 2012 during flood conditions(Figure 2-9) and ground photographs taken under various conditions were used to validate inundation patterns. Comparing the inundation maps to the 2012 flood air photo also enable the reviewer to identify potential locations where inundation is currently constrained by floodplain infrastructure or topographic features. Areas that do not appear to be flooded in the air photo but are inundated in the inundation maps should be investigated to assess potential limitations to floodplain inundation.

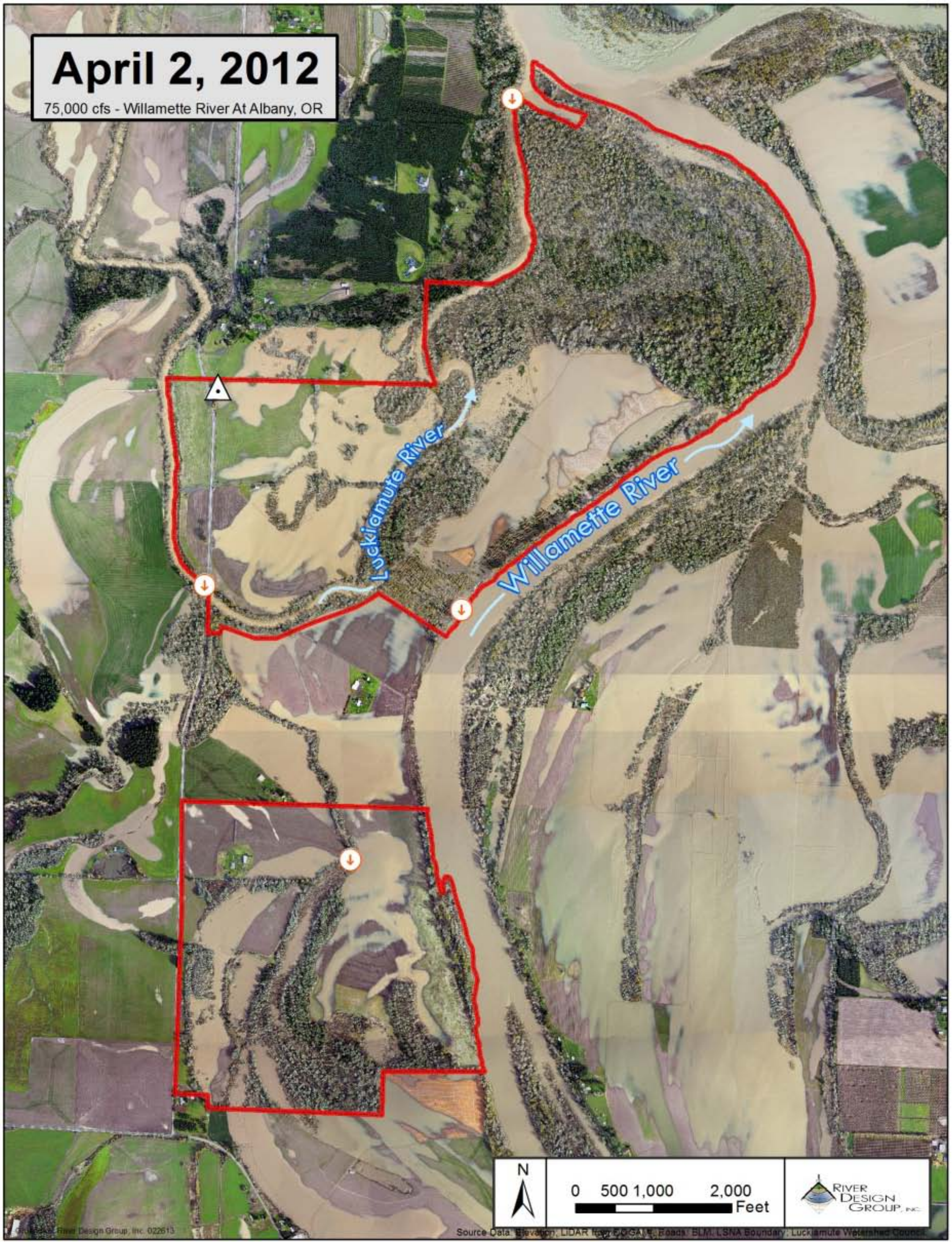


Figure 2-9. Aerial photograph of the LSNA taken on April 2, 2012. The USGS Albany gage registered approximately 75,000 cfs during air photo acquisition. The event was greater than a 2-year flood but less than a 5-year flood at the Albany gage.

3 Remote Sensing Project Scoping

RDG completed remote sensing using the LiDAR surface model and floodplain inundation layers to prepare an initial project scoping. Through the remote sensing effort, potential projects were described for 8 sites in the North Tract and 3 sites in the South Tract (Figure 3-1). The field investigation summarized in *4 Site Reconnaissance* included ground truthing each of the 11 potential project sites.

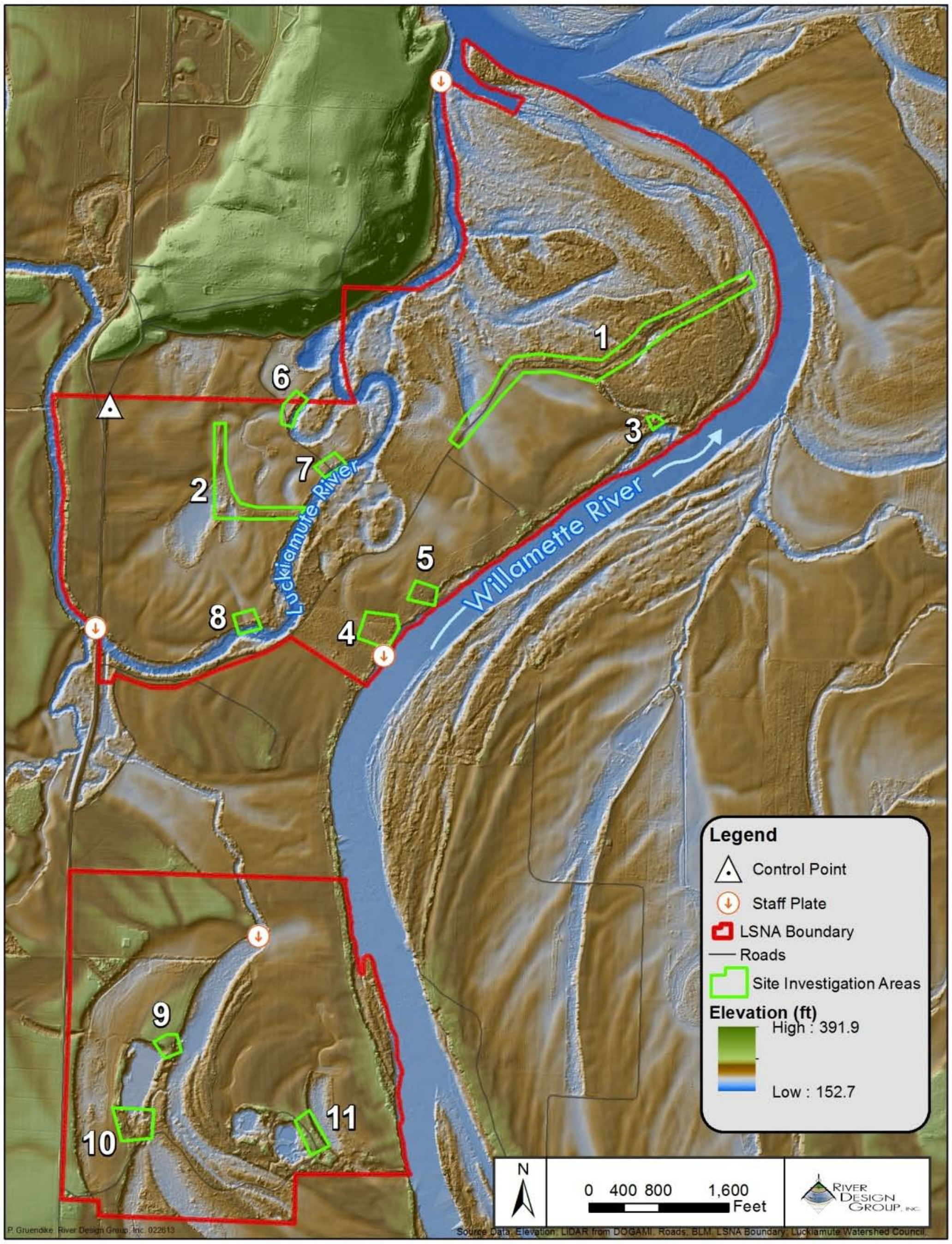


Figure 3-1. Potential project locations identified during remote sensing.

Potential project sites focused on existing roads and floodplain topography that are believed to obstruct flows across the floodplain (Table 3-1). Additional sites for field investigation included land surfaces between the Luckiamute River and floodplain swales and floodplain surfaces that isolate gravel pit ponds from historical meander scrolls.

Table 3-1. Site investigation areas (SIAs) for the LSNA. Information includes a brief summary of existing site conditions and recommendations for future investigations.

Site	Existing Site Characteristics	Recommendation
SIA1	Existing road berm is approximately 2 ft above the adjacent floodplain. Road berm restricts flood water access to floodplain swales.	Investigate road berm to determined degree of current flow through the road prism and the potential for either removing or modifying the road berm to improve floodplain continuity.
SIA2	Existing north-south and east-west floodplain berms channel floodplain swale connectivity adjacent to the Luckiamute River	Explore the potential for removing or modifying berm to improve connectivity among floodplain swales, the Luckiamute River, and a gravel pond. Investigate potential for improving gravel pond habitat.
SIA3	Flood channel linking Willamette River and interior LSNA floodplain may be blocked at Willamette River bank.	Investigate the potential for increase flow into flood channel by removing possible blockage in flood channel.
SIA4	Existing flood channel conveys overbank flows from the Willamette River into interior LSNA floodplain. Mature floodplain forest with multi-level canopy.	Investigate potential to lower the flood channel bed elevation to convey flow at a lower stage on the Willamette River.
SIA5	Existing road berm is approximately 2 ft above the adjacent floodplain. Road berm restricts flood water access to floodplain swales.	Investigate road berm to determined degree of current flow through the road prism and the potential for either removing or modifying the road berm to improve floodplain continuity.
SIA6	A potential floodplain fill may be limiting floodwater access to overflow channels.	Investigate site to determine if actual blockage is present. Blockage removal would increase inundation extent at northern LSNA boundary.
SIA7	A high outside bank on the Luckiamute River may be limiting connectivity between the river and the adjacent floodplain.	Investigate the site to determine if river bank modification has occurred that limits overbank flows. Evaluate the potential to lower the outside bank to improve river-floodplain connectivity.
SIA8	A high outside bank on the Luckiamute River may be limiting connectivity between the river and the adjacent floodplain.	Investigate the site to determine if river bank modification has occurred that limits overbank flows. Evaluate the potential to lower the outside bank to improve river-floodplain connectivity.
SIA9	Gravel pit ponds are isolated during low flows but connect at flood flows. Ponds	Evaluate the potential to modify connections between the gravel pit ponds and the

Table 3-1. Site investigation areas (SIAs) for the LSNA. Information includes a brief summary of existing site conditions and recommendations for future investigations.

Site	Existing Site Characteristics	Recommendation
	may be fish sinks that could be better connected to improve egress from ponds to historical meander scrolls that connect with Soap Creek and the Luckiamute River.	meander scrolls. Determine if gravel pit pond habitat could be improved by reducing shoreline gradients and planting native species.
SIA10	Gravel pit ponds are isolated during low flows but connect at flood flows. Ponds may be fish sinks that could be better connected to improve egress from ponds to historical meander scrolls that connect with Soap Creek and the Luckiamute River.	Evaluate the potential to modify connections between the gravel pit ponds and the meander scrolls. Determine if gravel pit pond habitat could be improved by reducing shoreline gradients and planting native species.
SIA11	Gravel pit ponds are isolated during low flows but connect at flood flows. Ponds may be fish sinks that could be better connected to improve egress from ponds to historical meander scrolls that connect with Soap Creek and the Luckiamute River.	Evaluate the potential to modify connections between the gravel pit ponds and the meander scrolls. Determine if gravel pit pond habitat could be improved by reducing shoreline gradients and planting native species.

4 Site Reconnaissance

On April 19, 2013, RDG conducted a field visit of the SIAs identified through remote sensing and listed previously in section *3 Remote Sensing Project Scoping*. RDG staff used GNSS enabled RTK GPS to evaluate elevations at the eleven SIAs listed in Table 3-1. In general, RDG determined that hydrologic connection at the LSNA is predominantly dictated by existing floodplain topography and not by the presence or absence of man-made obstructions. Relatively intact, the LSNA acts as a functional floodplain and floodwaters are primarily limited by USACE dam operations in the Willamette basin, and not by modifications to the existing topography at the site.

Major modifications to the natural floodplain topography present at the site were mostly attributed to gravel extraction activities in the South Tract. In most cases, the topography identified in the SIA that limits floodplain inundation is adjacent to topography with similar or higher elevations which in turn means that major excavation activities would be necessary to significantly increase floodplain inundation area or inundation frequency. A few recommended actions could be taken to increase floodplain inundation and/or habitat quality with varying degrees of risk and associated impacts.

Historical gravel extraction in the South Tract has produced a series of deep ponds that affect ecological resources in a variety of ways. First, gravel ponds can act as stranding zones for native fish when they use the floodplain during periods of high flow. As floodwaters recede, fish such as juvenile spring Chinook salmon move towards deeper waters. Wetted areas that become disconnected from the mainstem river tend to trap fish where they are subjected to predation and degraded water quality. Secondly, overburden from mining activities act as levees and limit floodwaters from reaching other portions of the floodplain.

As an example, at the LSNA South Tract, the west pond embankments act as a barrier until approximately 43,500 cfs (~2 weeks/year), limiting flood flows from connecting the swales to the east and west of the pond. Figure 4-1 shows the west pond and the surrounding embankments. As high flows connect this area of the floodplain to the Willamette River, fish access floodplain areas for food resources and to escape high velocities and turbulence present in the main channel. As flows begin to recede, fish returning to the main channel from floodplain margins could be drawn to the deep water in the west pond and become trapped as the pond disconnects from the rest of the floodplain and river. Fish trapped in the pond would be subjected to poor water quality and predation.

Figure 4-1. The west pond at the South Tract is a sink for fish moving from the Willamette River into the interior floodplain during high flows. The berm surrounding the pond also limits connection between the river and floodplain. The photo is a view south from SIA #9.

By excavating the areas at SIAs #9 and #10 to the existing floodplain elevation, the floodplain areas of the west pond and west swale would become connected on a more frequent basis, at approximately 36,000 cfs (3-4 weeks/year). Because the bottom of pond elevation is lower than the surrounding floodplain, fish stranding in the west pond could still be an issue. Additional floodplain grading could be completed to the north of the pond with the excavated material used to fill the pond to a more natural floodplain elevation. This would not only increase the acreage of inundated floodplain, but would reduce stranding issues for native fish. However, the amount of fill necessary to grade the pond to create a natural floodplain feature may be cost prohibitive. Also, competing interests with this type of project are present at the west pond site and may affect the feasibility of this type of project. Currently a variety of wildlife use the west pond, including western pond turtles which are on the Oregon Department of Fish and Wildlife's (ODFW) Sensitive Species list. Recreational uses such as bird watching and fishing are also common activities at the west pond.

At the LSNA North Tract, most access roads are located at the existing floodplain elevation and do not adversely impact site inundation potential. Two sites located at SIAs #7 and #8 could have minor bank modifications that would allow swales to connect with the Willamette River at slightly lower flows than under current conditions. Bank modifications would require a small amount of excavation to lower the existing top of bank elevation, and the installation of large wood structures could be used to increase the modified bank stability. Additional habitat structures could be constructed within swales to provide higher quality habitats.

Figure 4-2. At SIA #8, the existing access road is set at the same elevation as the invert of the swale. The bank elevation could be lowered slightly to allow floodwater to access the swale and the pond located to the north.

Table 4-1 includes recommended actions based on the site conditions observed during field reconnaissance, a basic cost estimate is also provided.

Table 4-1. Site investigation areas (SIAs) for the LSNA. Information includes a brief summary of existing site conditions and recommended actions.

Site	Site Characteristics from Site Visit	Recommended Action	Anticipated Cost[1]
SIA1	Road elevation is only slightly higher than the existing floodplain in places, and floodwaters are able to access the floodplain to the south east.	No Action	NA
SIA2	Topography behind berm consistent with top of berm elevation. Inundation limited by existing topography.	No Action	NA
SIA3	Existing flood channel conveys overbank flows from the Willamette River into interior LSNA floodplain. Mature floodplain forest with multi-level canopy to the north.	No Action	NA
SIA4	Existing flood channel conveys overbank flows from the Willamette River into interior LSNA floodplain. Mature floodplain forest with multi-level canopy.	No Action	NA
SIA5	Existing flood channel conveys overbank flows from the Willamette River into interior LSNA floodplain at high flows.	Lower the outside bank and excavate channel approximately 5 ft to an elevation of 175.0 ft to improve river-floodplain connectivity. Large wood structures could be constructed on the Willamette River bank to hold the existing bank line and minimize risk of channel capture. Continue riparian reforestation to stabilize eroding banks.	Medium
SIA6	A natural high bank limits extent of flooding. The adjacent banks match the floodplain elevation and allow water to access the LSNA floodplain.	No Action	NA
SIA7	A high outside bank on the Luckiamute River may be limiting connectivity between the river and the adjacent floodplain.	Lower the outside bank and excavate channel approximately 3 ft to an elevation of 170.0 ft to improve river-floodplain connectivity. Large wood structures could be	Medium

Table 4-1. Site investigation areas (SIAs) for the LSNA. Information includes a brief summary of existing site conditions and recommended actions.

Site	Site Characteristics from Site Visit	Recommended Action	Anticipated Cost[1]
		constructed on the Luckiamute River bank to hold the existing bank line and minimize risk of channel capture. Continue riparian reforestation to stabilize eroding banks.	
SIA8	A high outside bank on the Luckiamute River may be limiting connectivity between the river and the adjacent floodplain.	Lower the outside bank and excavate channel approximately 2 ft to elevation of 172.0 ft to improve river-floodplain connectivity. Additional channel grading could be completed to better connect the swale to the pond area 1000' NW. Large wood structures could be constructed on the Luckiamute River bank to hold the existing bank line and minimize risk of channel capture. Continue riparian reforestation to stabilize eroding banks.	Medium
SIA9	Gravel pond features act as floodplain berms and limit the extent of floodplain connectivity with existing sloughs and the rivers. Gravel ponds act as fish stranding zones and result in loss of native fish due to predation and poor water quality.	Lower berm elevations around gravel pit ponds by 12 ft to approximately 174.0 to match surrounding wetland/slough elevations. Excavated material could be used to fill gravel ponds to similar elevation to alleviate stranding issues. Additional material to fill ponds could be acquired by grading field to the north of the west pond.	Medium for berm excavation, high for pond fill/floodplain grading.
SIA10	Gravel pond features act as floodplain berms and limit the extent of floodplain connectivity with existing sloughs and the rivers. Gravel ponds act as fish stranding zones and result in loss of native	Lower berm elevations around gravel pit ponds by 8 ft to approximately 174.0 to match surrounding wetland/slough elevations. Excavated material could be used to fill gravel	Low for berm excavation, high for pond fill/floodplain grading.

Table 4-1. Site investigation areas (SIAs) for the LSNA. Information includes a brief summary of existing site conditions and recommended actions.

Site	Site Characteristics from Site Visit	Recommended Action	Anticipated Cost[1]
	fish due to predation and poor water quality.	ponds to similar elevation to alleviate stranding issues. Additional material to fill ponds could be acquired by grading field located to the north of the west pond.	
SIA11	Floodplain connectivity limited by existing high topography. Gravel ponds act as fish stranding zones and result in loss of native fish due to predation and poor water quality.	Lower berm elevations between gravel ponds and slough by 15 ft to approximately 170.0 to match existing slough elevations. Excavated material could be used to fill gravel ponds to similar elevation to alleviate stranding issues. Additional material to fill ponds could be acquired by grading field located to the north of the ponds.	Low for berm excavation, high for pond fill/floodplain grading.

[1]: Anticipated cost scale; Low = less than $25, 000, Medium = $25,000 - $100,000, High = greater than $100,000.

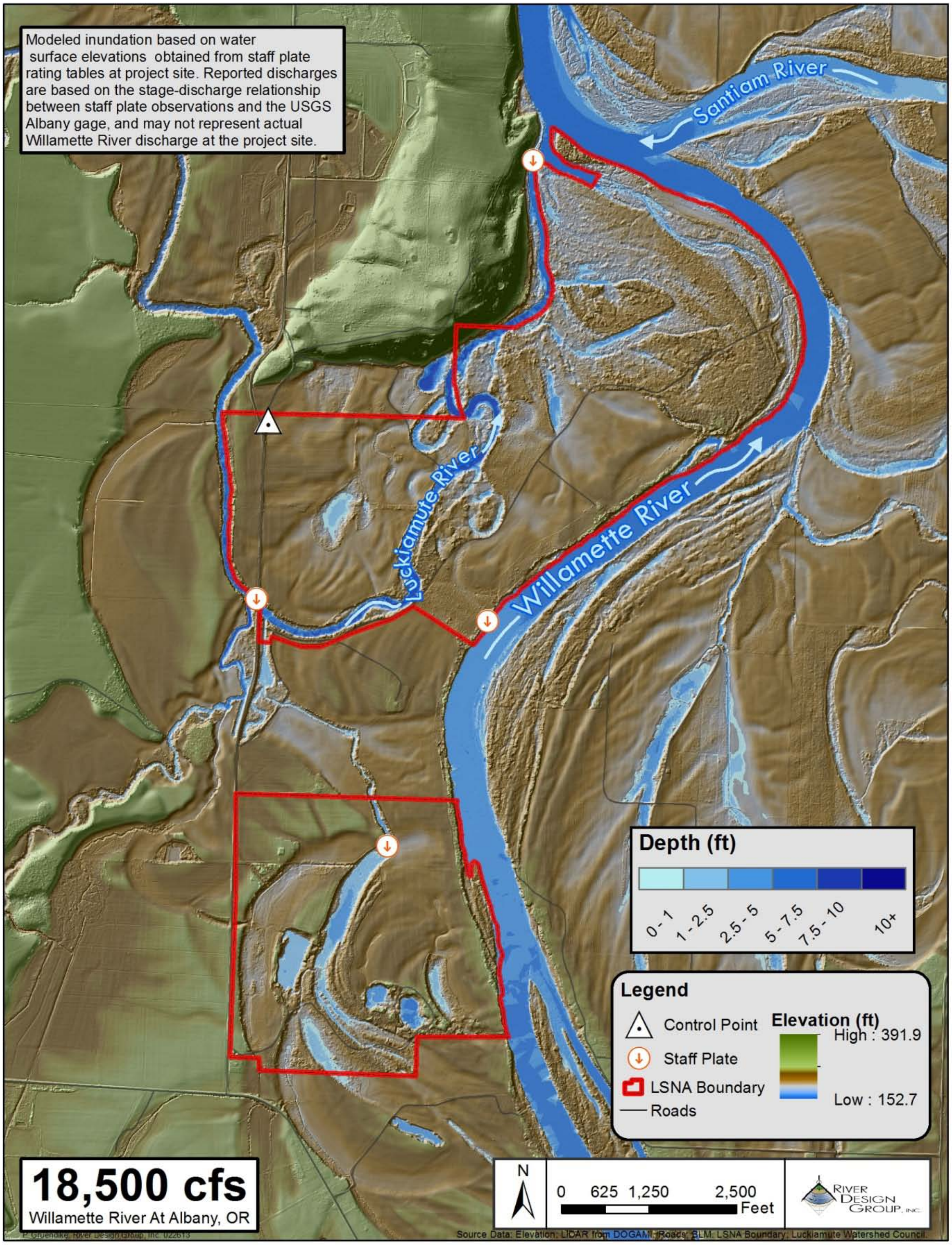
5 Summary

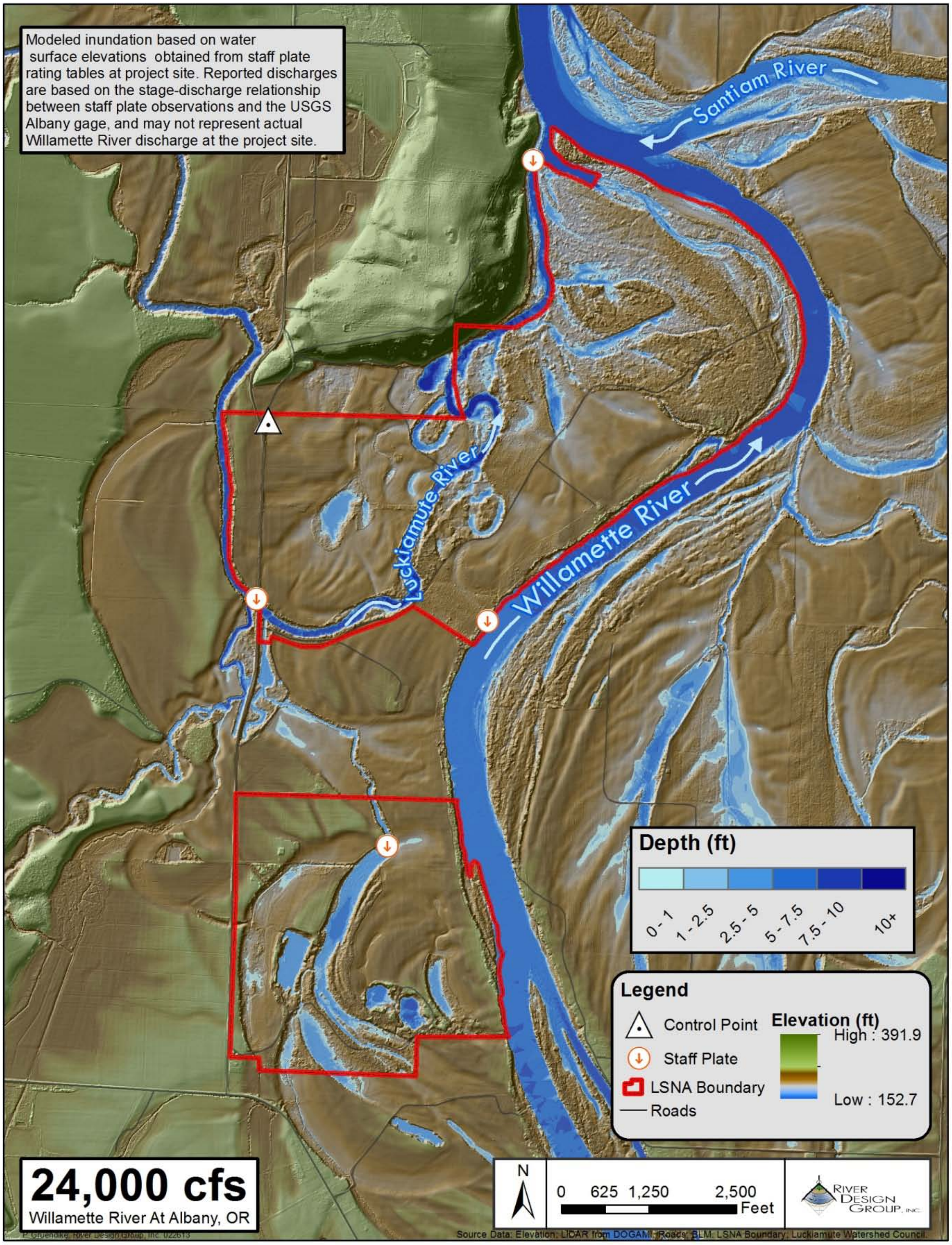
The LSNA provides a variety of habitats for native fish and wildlife found in the Willamette River basin. Major revegetation efforts are currently underway at the site to shift site conditions from historical agricultural and gravel extraction land uses to a naturally functioning floodplain. Combined remote sensing and field reconnaissance efforts were used to identify target areas for improvement of hydrologic function and habitat quality. A field review of potential habitat enhancement areas identified during the intial remote sensing analysis determined that most of the LSNA is characterized by the historical topography with minimial human modifications. There are select opportunities to improve floodplain inundation extent and frequency at LSNA.

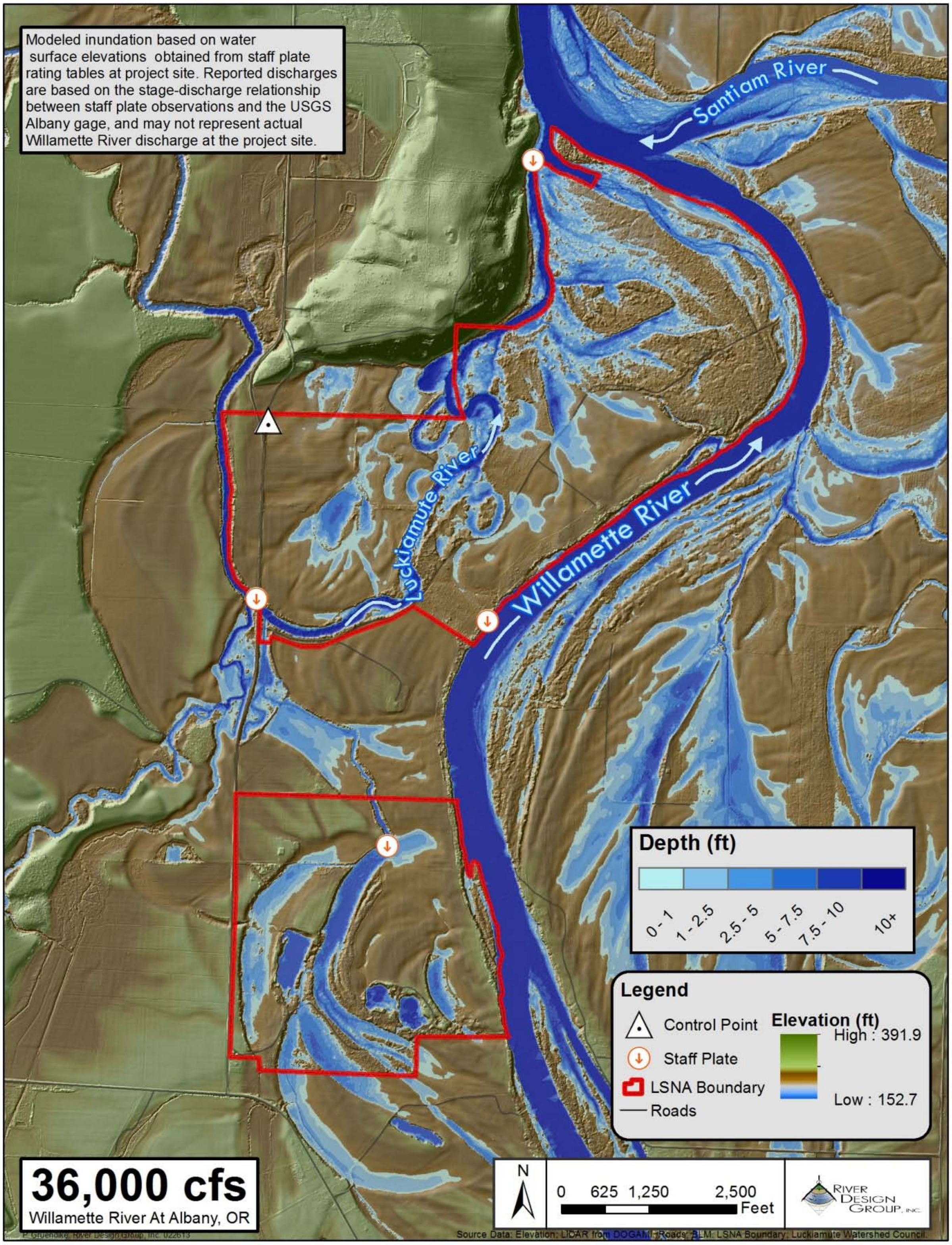
6 References

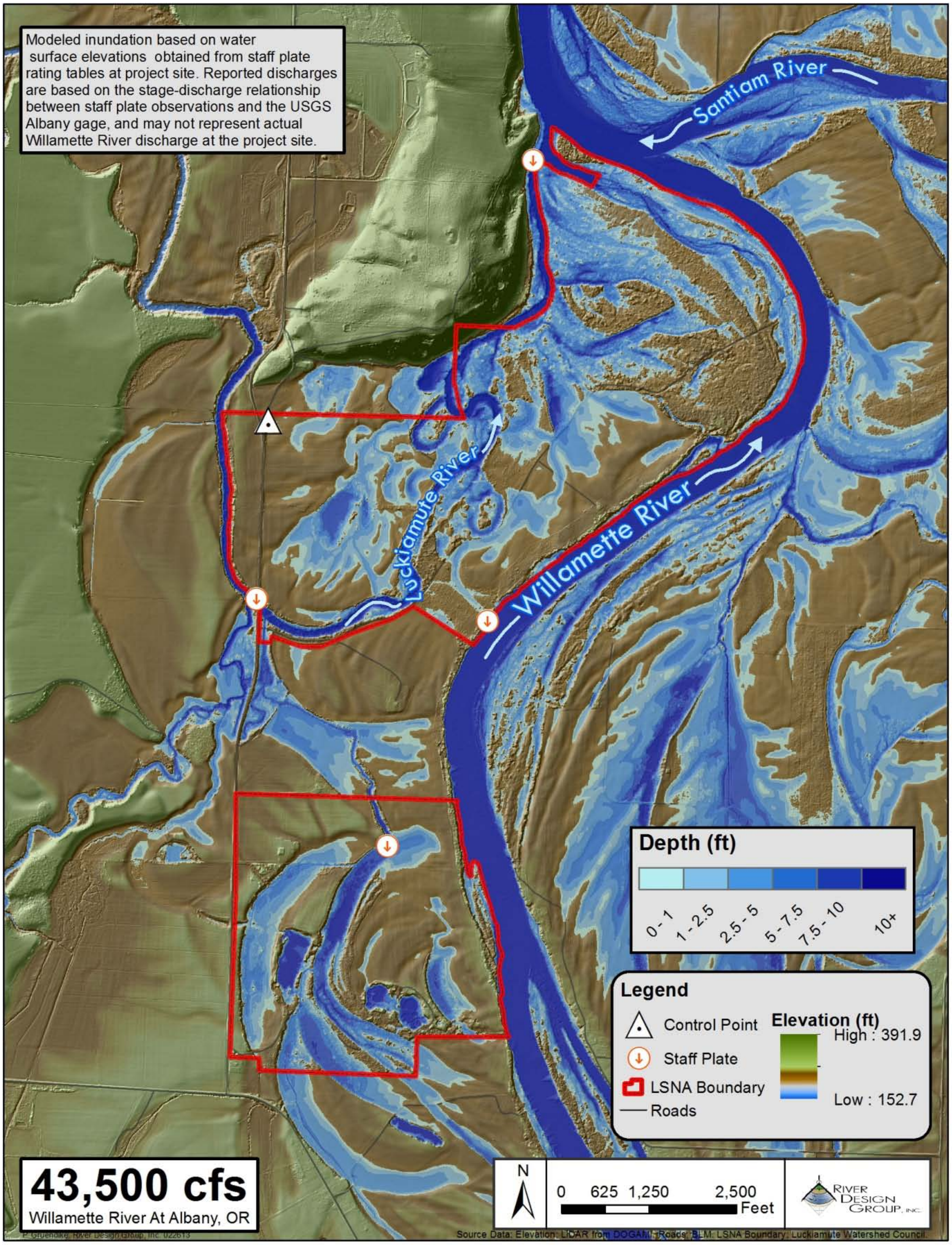
Oregon Parks and Recreation Department (OPRD) 2009. Luckiamute State Natural Area Master Plan.

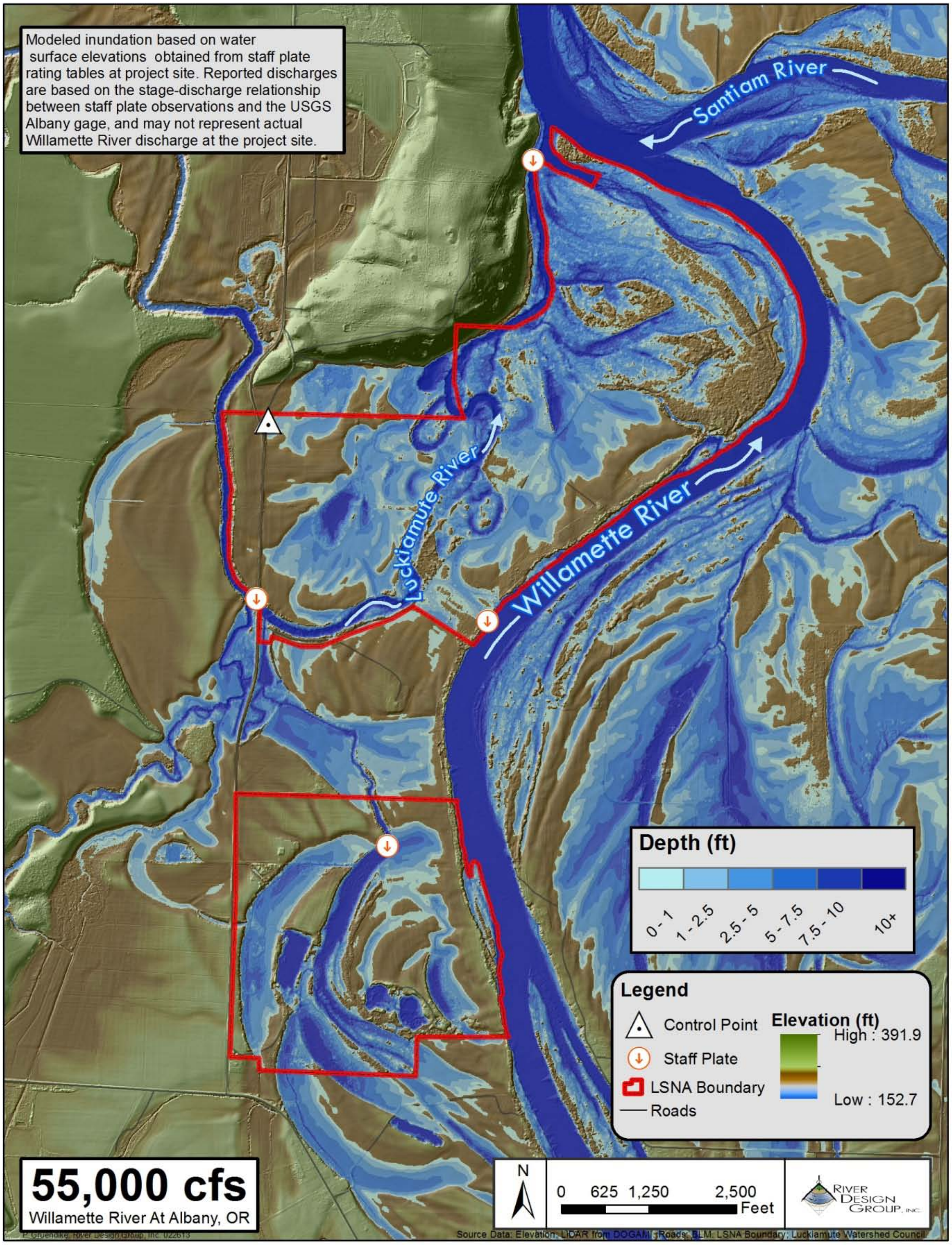
APPENDIX A
LSNA INUNDATION MAPS

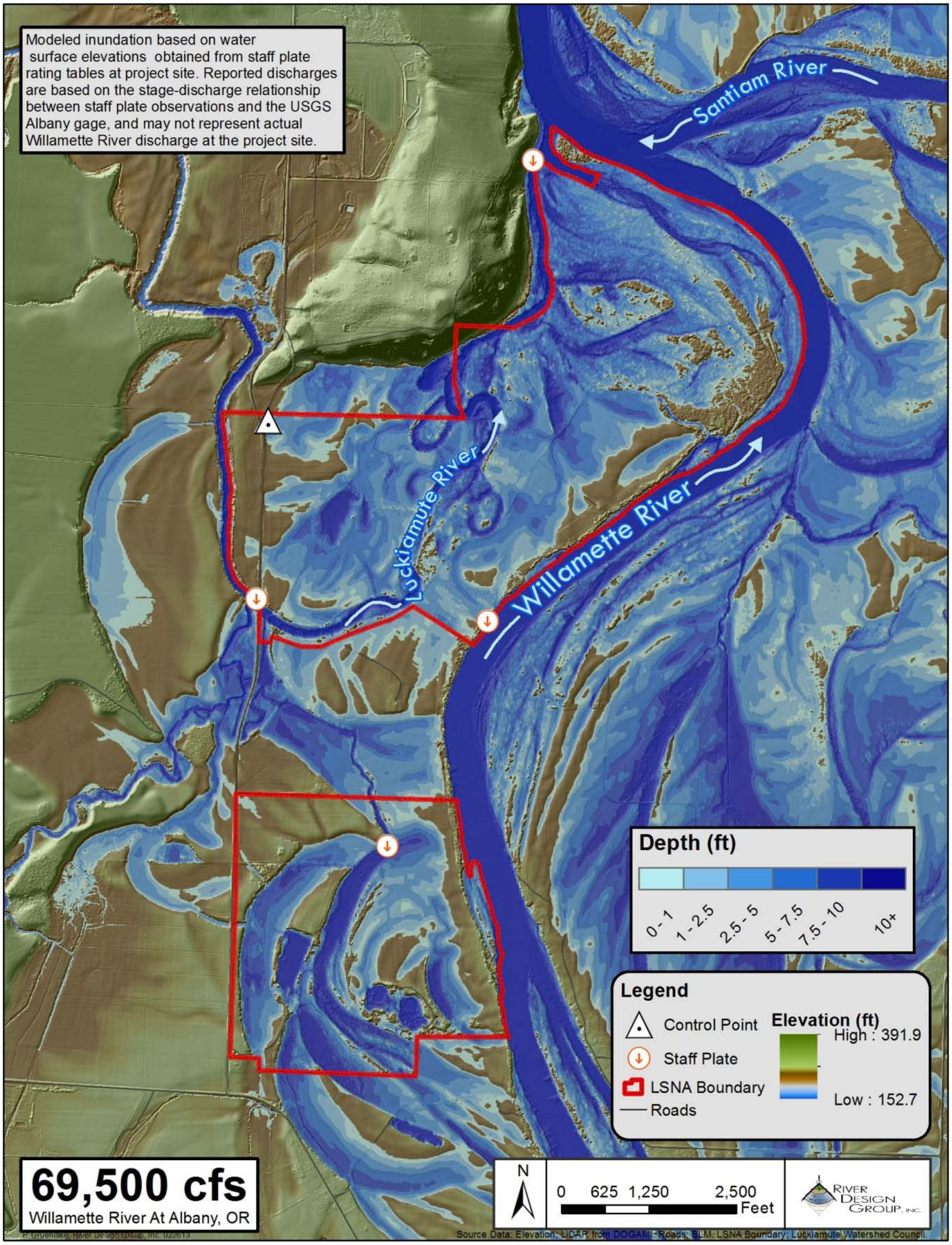

Modeled inundation based on water surface elevations obtained from staff plate rating tables at project site. Reported discharges are based on the stage-discharge relationship between staff plate observations and the USGS Albany gage, and may not represent actual Willamette River discharge at the project site.
Santiam River
Luckiamute River
Willamette River
Depth (ft)
0 - 1
1 - 2.5
2.5 - 5
5 - 7.5
7.5 - 10
10+
Legend
Control Point
Staff Plate
LSNA Boundary
Roads
Elevation (ft)
High : 391.9
Low : 152.7
18,500 cfs
Willamette River At Albany, OR
N
0 625 1,250 2,500
Feet
River Design Group, Inc.
Source Data: Elevation: LiDAR from DOGAMI; Roads: BLM; LSNA Boundary: Luckiamute Watershed Council.


Modeled inundation based on water surface elevations obtained from staff plate rating tables at project site. Reported discharges are based on the stage-discharge relationship between staff plate observations and the USGS Albany gage, and may not represent actual Willamette River discharge at the project site.
Santiam River
Luckiamute River
Willamette River
Depth (ft)
0 - 1
1 - 2.5
2.5 - 5
5 - 7.5
7.5 - 10
10+
Legend
Control Point
Staff Plate
LSNA Boundary
Roads
Elevation (ft)
High : 391.9
Low : 152.7
24,000 cfs
Willamette River At Albany, OR
N
0 625 1,250 2,500
Feet
River Design Group, Inc.
Source Data: Elevation: LiDAR from DOGAMI; Roads: BLM; LSNA Boundary: Luckiamute Watershed Council.


Modeled inundation based on water surface elevations obtained from staff plate rating tables at project site. Reported discharges are based on the stage-discharge relationship between staff plate observations and the USGS Albany gage, and may not represent actual Willamette River discharge at the project site.
Santiam River
Luckiamute River
Willamette River
Depth (ft)
0 - 1
1 - 2.5
2.5 - 5
5 - 7.5
7.5 - 10
10+
Legend
Control Point
Staff Plate
LSNA Boundary
Roads
Elevation (ft)
High : 391.9
Low : 152.7
36,000 cfs
Willamette River At Albany, OR
N
0 625 1,250 2,500
Feet
River Design Group, Inc.
Source Data: Elevation: LiDAR from DOGAMI; Roads: BLM; LSNA Boundary: Luckiamute Watershed Council.


Modeled inundation based on water surface elevations obtained from staff plate rating tables at project site. Reported discharges are based on the stage-discharge relationship between staff plate observations and the USGS Albany gage, and may not represent actual Willamette River discharge at the project site.
Santiam River
Luckiamute River
Willamette River
Depth (ft)
0 - 1
1 - 2.5
2.5 - 5
5 - 7.5
7.5 - 10
10+
Legend
Control Point
Staff Plate
LSNA Boundary
Roads
Elevation (ft)
High : 391.9
Low : 152.7
43,500 cfs
Willamette River At Albany, OR
N
0 625 1,250 2,500
Feet
River Design Group, Inc.
Source Data: Elevation: LiDAR from DOGAMI; Roads: BLM; LSNA Boundary: Luckiamute Watershed Council.


Modeled inundation based on water surface elevations obtained from staff plate rating tables at project site. Reported discharges are based on the stage-discharge relationship between staff plate observations and the USGS Albany gage, and may not represent actual Willamette River discharge at the project site.
Santiam River
Luckiamute River
Willamette River
Depth (ft)
0 - 1
1 - 2.5
2.5 - 5
5 - 7.5
7.5 - 10
10+
Legend
Control Point
Staff Plate
LSNA Boundary
Roads
Elevation (ft)
High : 391.9
Low : 152.7
55,000 cfs
Willamette River At Albany, OR
N
0 625 1,250 2,500
Feet
River Design Group, Inc.
Source Data: Elevation: LiDAR from DOGAMI; Roads: BLM; LSNA Boundary: Luckiamute Watershed Council



Modeled inundation based on water surface elevations obtained from staff plate rating tables at project site. Reported discharges are based on the stage-discharge relationship between staff plate observations and the USGS Albany gage, and may not represent actual Willamette River discharge at the project site.
Santiam River
Luckiamute River
Willamette River
Depth (ft)
0 - 1
1 - 2.5
2.5 - 5
5 - 7.5
7.5 - 10
10+
Legend
Control Point
Staff Plate
LSNA Boundary
Roads
Elevation (ft)
High : 391.9
Low : 152.7
69,500 cfs
Willamette River At Albany, OR
N
0 625 1,250 2,500
Feet
River Design Group, Inc.