North Fork Walla Walla River Sam's-Rea Design

Conceptual Design Report

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Walla Walla Basin Watershed Council

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Executive Summary

Background

The Walla Walla Basin Watershed Council (WWBWC) North Fork (NF) Walla Walla River Sam's-Rea Design Project (the Project) is located on the NF Walla Walla River, approximately 10 miles upstream from Milton-Freewater, Oregon. The NF Walla Walla River flows for 18.8 miles from its headwaters in the coniferous forested, western slopes of the Blue Mountains through volcanic canyons to a predominately cottonwood river valley before reaching its confluence with the South Fork Walla Walla River. The Project boundaries encompass a 5.2-mile stretch, extending from the end of the paved NF Walla Walla Road and locked gate upstream to Little Meadow Creek (Figure ES-1). The Project reach includes large properties that are primarily owned by the Sam's and Rea's families, as well as a smaller portion that is owned by the Hancock Timber Partnership and John Hancock Life Insurance Company.

The desired outcome of the Project is a restoration condition that consists of a properly functioning, complex, and self-sustaining river system with a reconnected floodplain featuring vibrant, productive riparian features. Overall Project construction is scheduled to occur within the July to September 2023 to 2027 instream work periods. This report, prepared by Jacobs and Cramer Fish Sciences (Cramer) (the design team), summarizes the existing conditions assessment and the conceptual restoration design (15% design level) for the Project reach.

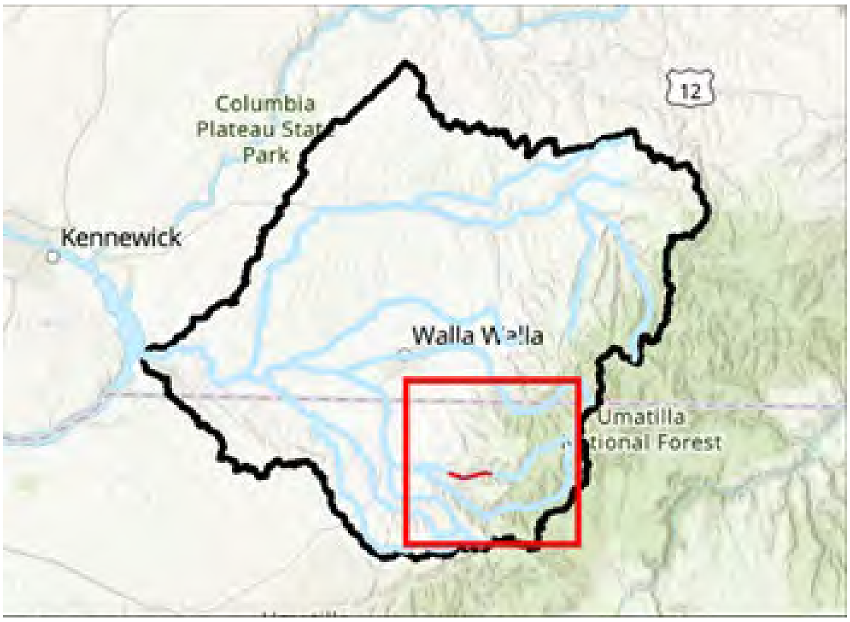

Figure ES-1. Project Location for the North Fork Walla Walla River Sam's-Rea Reach Restoration Project

As 1 of the 62 subbasins based on Columbia River tributaries, a plan was locally developed for the Walla Walla Subbasin through the Northwest Power and Conservation Council regional response to Endangered Species Act-listed Columbia Basin fish and wildlife (Subbasin Plan) (WWWPU and WWBWC 2004). The guiding vision for the Walla Walla Subbasin is a healthy ecosystem with abundant, productive, and diverse populations of aquatic and terrestrial species that supports the social, cultural, and economic well-being of the communities within the subbasin and the Pacific Northwest. The aquatic focal species in the subbasin include steelhead (*Oncorhynchus mykiss),* spring Chinook salmon (*O. tshawytscha*), and bull trout (*Salvelinus confluentus*). Additional aquatic species of interest include Pacific lamprey (*Entosphenus tridentatus*), mountain whitefish (*Prosopium williamsoni*), and freshwater mussels.

The Subbasin Plan (WWWPU and WWBWC 2004) included an aquatic habitat assessment that identified stream reaches with high-potential restoration and protection values. In priority restoration areas, key limiting factors for steelhead and spring Chinook were identified. Priority protection areas protect current habitat conditions with the expectation of achieving no loss of function and allow for natural attenuation of limiting factors over time to benefit aquatic habitat. The NF Walla Walla River, from the mouth to Little Meadow Creek, has been identified as a priority protection area and a priority restoration area. Above Little Meadow Creek, the NF Walla Walla River has been identified as a priority protection area (WWWPU and WWBWC 2004).

Large floods in February and May 2020 created natural disturbances, and human-initiated (anthropogenic) actions were implemented after the floods. Natural disturbances included bank erosion, channel migration and avulsion, and transport and deposition of sediment and large woody debris in the channel and on the floodplain. Anthropogenic actions included construction of pushup levees through the Project reach to channelize the river and direct flow away from the road and irrigation structures.

An unpaved road within the floodplain parallels the north bank of the river through most of the Project reach. Travel through the Project reach and access into the upper watershed are difficult, due to significant erosion of the roadway that has occurred where the road intersects ephemeral drainages, or ravines, that flow into the main stem. The road also disconnects numerous spring seep sources from the main stem, which has caused ponding on the uphill side of the roadway and has reduced groundwater inputs into the main stem. Figure ES-2 shows the location of these springs and ravines in the Project reach.

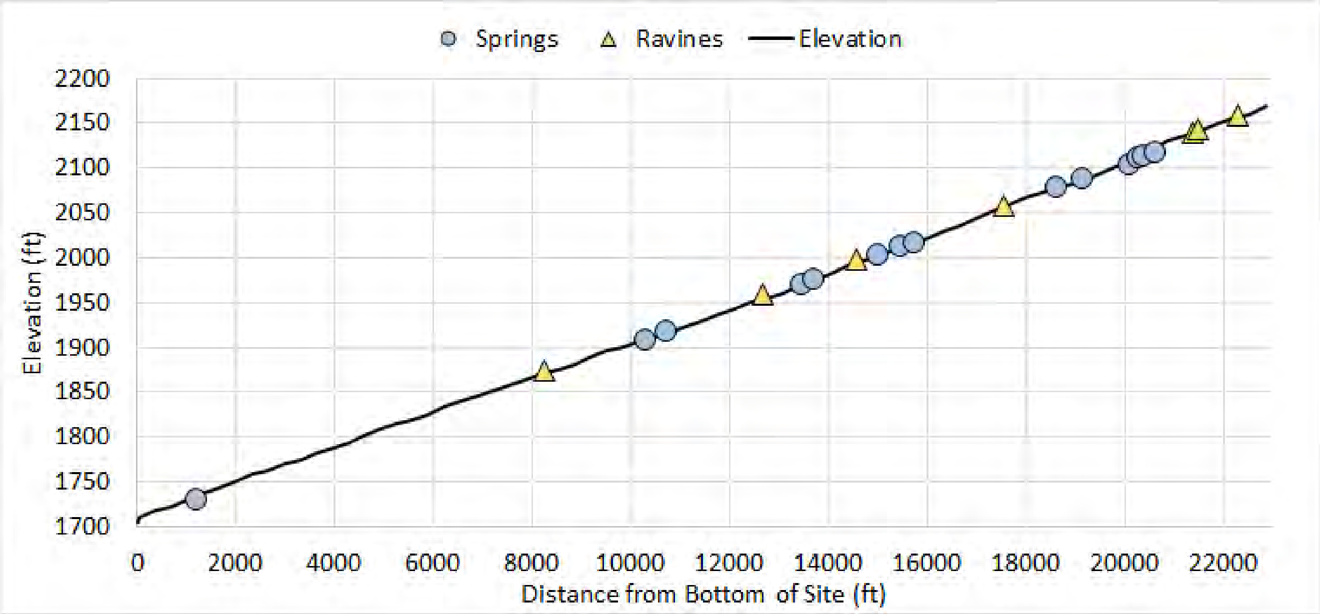

Figure ES-2. Main Stem Channel Bed Longitudinal Profile with Locations of Springs and Ravines that Cross the North Fork Walla Walla River Road through the Project Reach
Note: For all graphics, the left side of the horizontal axis is the downstream end.

Vision and Goals

Within the NF Walla Walla River, summer steelhead, bull trout, and resident trout are present. In addition to the presence of these anadromous and resident fish species, the NF Walla River has consistent flows in the summer and fall, and experiences ongoing natural disturbance processes (such as mass failures, floods, and fires) that create and maintain habitat complexity for aquatic and terrestrial species in the channel, floodplain, and riparian areas. The continued presence of these natural disturbance processes in the NF Walla Walla River provides an opportunity for ecological restoration. Furthermore, large parcels of private property with interested landowners provide additional opportunities specific to the Sam's-Rea Reach.

The stakeholders and landowners envision the Sam's-Rea Reach as a self-sustaining, shaded, perennial channel with variable velocities, depths, and substrates. Off-channel habitats (side channels and backwater connections) would intercept the groundwater, interact frequently with the main stem (an upstream surface water connection at least once every other year on average), experience sediment flushing flows every few years, and maintain a year-round downstream surface water connection with the main stem. The floodplain would have a complex topography with depression areas and upland areas that support a diverse mix of native aquatic, riparian, and upland vegetation.

Building on the Subbasin Plan (WWWPU and WWBWC 2004), landowner perspectives provided by WWBWC, Bonneville Power Administration (BPA) funding priorities, and WWBWC priorities, Project goals include the following:

1) Respect landowners' desires, maintain access to private properties, and collaborate with stakeholders.
2) Work with, not against, physical processes that increase hydraulic, geomorphic, and habitat complexity.
3) Improve connectivity vertically, laterally, and longitudinally for water, sediment, woody material, and aquatic species within the valley.
4) Increase the extent and diversity of riparian vegetation and forage (grasses) on floodplains and terraces.

Field Reconnaissance

On September 10, 2021, a site visit was conducted by staff from WWBWC, BPA, and the design team to:

- Make observations
- Address priority data gaps
- Collect additional data at the spring and ravine locations
- Validate preliminary hydraulic modeling results and proposed reach breaks
- Identify Project opportunities

The group also discussed and agreed upon the design approach, which has been described in the Conceptual Design subsection of this Executive Summary, as well as in Section 3). During the site visit, the streamflow in the NF Walla Walla River was measured as 6 cubic feet per second (cfs) from Oregon Water Resources Department (OWRD) gage 14010800.

Current Conditions

The 2020 floods and subsequent emergency repair work – individually and together – created large and lasting changes to the river and floodplain, including some impacts to the existing road and irrigation diversion. Changes from the floods included channel avulsions, erosion of streambanks, and uprooting and transport of many large trees. Changes from the repair work included construction of new road segments through new channel and floodplain, construction of pushup levees blocking the upstream ends of new channel segments, and replacement of displaced diversion structures.

Levees constrict the channel and initiate an unsustainable negative feedback loop of processes that destabilize the channel. For example, a constricted channel:

- Increases velocities and shear stresses
- Increases channel bed and bank erosion
- Reduces groundwater elevations
- Reduces forage for wildlife and livestock

Even with just 1 year of flows following the channel-constricting road near River Mile 8.1, field observations suggest that the channel is actively incising (downcutting).

Hydrologic Analysis

Hydrology of the NF Walla Walla River was evaluated to characterize the magnitude of large floods and low flow conditions in the Sam's-Rea Reach. A flood frequency analysis was performed for the NF Walla Walla River using the annual peak discharge data collected at OWRD gage station 14010800. Representative flows include the following: 2-year flow (479 cfs), 10-year flow (910 cfs), and 100-year flow (1,567 cfs).

Hydraulic Modeling

A preliminary two-dimensional (2D) unsteady flow hydraulic model was developed for the Project area using the U.S. Army Corps of Engineers Hydrologic Engineering Center's River Analysis System (HEC-RAS) modeling software version 5.07 (HEC-RAS v5.0.7) in conjunction with the 2016 HEC-RAS User's Manual (USACE 2016) to support the development of conceptual alternatives. The model simulates water flow over a digital surface that represents the terrain of the valley bottom and river channels. A 2D model was chosen over a one-dimensional (1D) model for this Project because a 2D model produces greater detail on water level, velocity, shear stress, and other hydraulic parameters. Moreover, a 1D model would not sufficiently characterize the complex topographic and hydraulics within the Project site. The purpose of the model, at this phase, is to produce reasonable estimates of water surface extents and flow patterns at low flow, 2-year flow, and 100-year flow recurrence intervals. Appendix A presents maps with model results.

Reach Characterization

The characterization of source, transport, and response reaches are critical to understanding watershed- and reach-scale hydrologic, hydraulic, and geomorphic processes, and to designing projects that are self-sustaining. The valley bottom width in the NF Walla Walla River fluctuates with fans, terraces, exposed bedrock, and the valley margin that force more confined sections. Reaches within the Project area were determined based on defining characteristics within the valley bottom, alluvial channels, and contributing hillslopes. Eight distinct reaches were identified based on longitudinal differences in hydrogeomorphic characteristics that influence river form and function (Figure ES-3). The downstream half of the Project area is generally wider than the upstream half. Channel slope is approximately 2%, and low flow (6 cfs) channel widths range from 11 to 15 meters.

Note: National Agriculture Imagery Program (NAIP) 2020 imagery.

Figure ES-3. Overview of Reach Break Locations

Conceptual Design

Successful and sustainable restoration of the NF Walla Walla River will require a long-term perspective that works with, not against, natural disturbance processes like the 2020 floods. The overarching design approach is to jump-start physical processes that initiate a self-sustaining positive feedback loop that will gradually improve channel and floodplain function, stability, and habitat. Specifically, the design team recommends implementing restoration design elements that decrease velocity and shear stress in the main channel, secondary channels, and floodplain. Passive and active restoration elements can be implemented to jump-start hydraulic, geomorphic, and vegetative processes. For example, by adding stream roughness in the form of wood habitat structures and by reconnecting the channel to floodplains, the design team can initiate a positive cascade of self-sustaining physical and biological responses.

Subsurface flows in the NF Walla Walla River result from a lack of fines in the channel bed, specifically in the interstitial spaces. The fine sediment supply is available – the challenge is trapping and storing sediment in the channel and on the floodplain. The supply, transport, and deposition of sediment is extremely important from an ecological standpoint. By using hydraulic model results and field data to determine mobile sediment sizes (to be completed during a future design phase), the potential transport of bed material can be assessed to inform design. During the site visit, WWBWC and BPA participants endorsed this process-based design approach, with one additional request from BPA – to the extent possible, look for opportunities to phase the work starting downstream and working upstream.

A guiding principle of process-based river restoration is to work with fluvial processes to create and maintain quality riparian and aquatic habitats. The NF Walla Walla River has abundant alluvial sediment and has the competence to transport sediment effectively. This conceptual design takes advantage of active sediment transport, erosion, and deposition processes in the Project area by adding structural elements (for example, stable wood and rock) at key locations. The concept design incorporates:

- Addition of structural elements
- Increasing floodplain roughness
- Pushup levee modifications
- Maintaining proposed channels
- Spring protection and reconnection

Appendix A provides all the conceptual design elements that have been visualized on maps. The design elements have been assigned a 3-tier priority ranking (1 = highest priority, and 3 = lowest priority) based on the magnitude of geomorphic and biologic uplift, if implemented. Furthermore, the concepts have been presented "a la carte", meaning that if all Tier 1 priorities are implemented, elements from Tier 2 and 3 priorities may be added, where appropriate, without committing to the entire suite of options. The tier prioritization is as follows:

- Tier 1 priorities:
  - Spring reconnection
  - Levee setback
  - Secondary channel junction stabilization
  - Habitat structures within the main stem
- Tier 2 priorities:
  - Levee modification
  - Habitat structures within side channels
  - Increase in floodplain roughness

- Tier 3 priorities:
  - Levee abandonment
  - Habitat structures within flood channels

Recommended Restoration Monitoring

With baseline pre-Project data (field, LiDAR, and drone imagery), well-defined goals and objectives, and a potential restoration of more than 5 miles of river, the Project is ideally suited for efficient implementation and effectiveness monitoring. Like any successful implementation and effectiveness monitoring program, the plan needs to have clear questions based on the goals, the Smart, Measurable, Attainable, Relevant, Timebound (SMART) objectives, and the scale of the Project and monitoring.

Key metrics for most of these questions can be selected from ongoing BPA and Salmon Recovery Funding Board monitoring (Roni et al. 2019, 2020). Quantifiable targets to evaluate physical and biological response and effectiveness of key design elements (for example, large wood structures, side channel connectivity, and levees) will be developed during the preliminary or final design phase. With the exception of temperature, many of these questions and their associated metrics can be assessed with remote sensing, including green LiDAR, aerial imagery, hydraulic modeling, and compared during pre-Project, as-built, and post-Project phases. Simple temperature loggers, ground water wells, and water quality monitoring can be added, depending upon the level of resolution and specific targets set during the final design phase. The final components of the monitoring approach will be analysis and reporting and development of an adaptive management approach that is consistent with WWBWC and landowner goals, should the monitoring indicate deviations from Project SMART objectives and targets.

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Acronyms and Abbreviations

C	degrees Celsius
≥	greater than or equal to
2D	two-dimensional
BPA	Bonneville Power Administration
cfs	cubic feet per second
DTM	digital terrain model
HEC-RAS	Hydrologic Engineering Center's River Analysis System
km^2	square kilometer(s)
LWD	large woody debris
m	meter(s)
m^3	cubic meter(s)
NF	North Fork
OWRD	Oregon Water Resources Department
PALS	post-assisted log structure
the Project	Walla Walla River Sam's-Rea Design Project
RM	River Mile
SF	South Fork
SRFB	Washington Salmon Recovery Funding Board
TMDL	total maximum daily load
USACE	U.S. Army Corps of Engineers
WSE	water surface elevation
WWBWC	Walla Walla Basin Watershed Council
WWWPU	Walla Walla Watershed Planning Unit

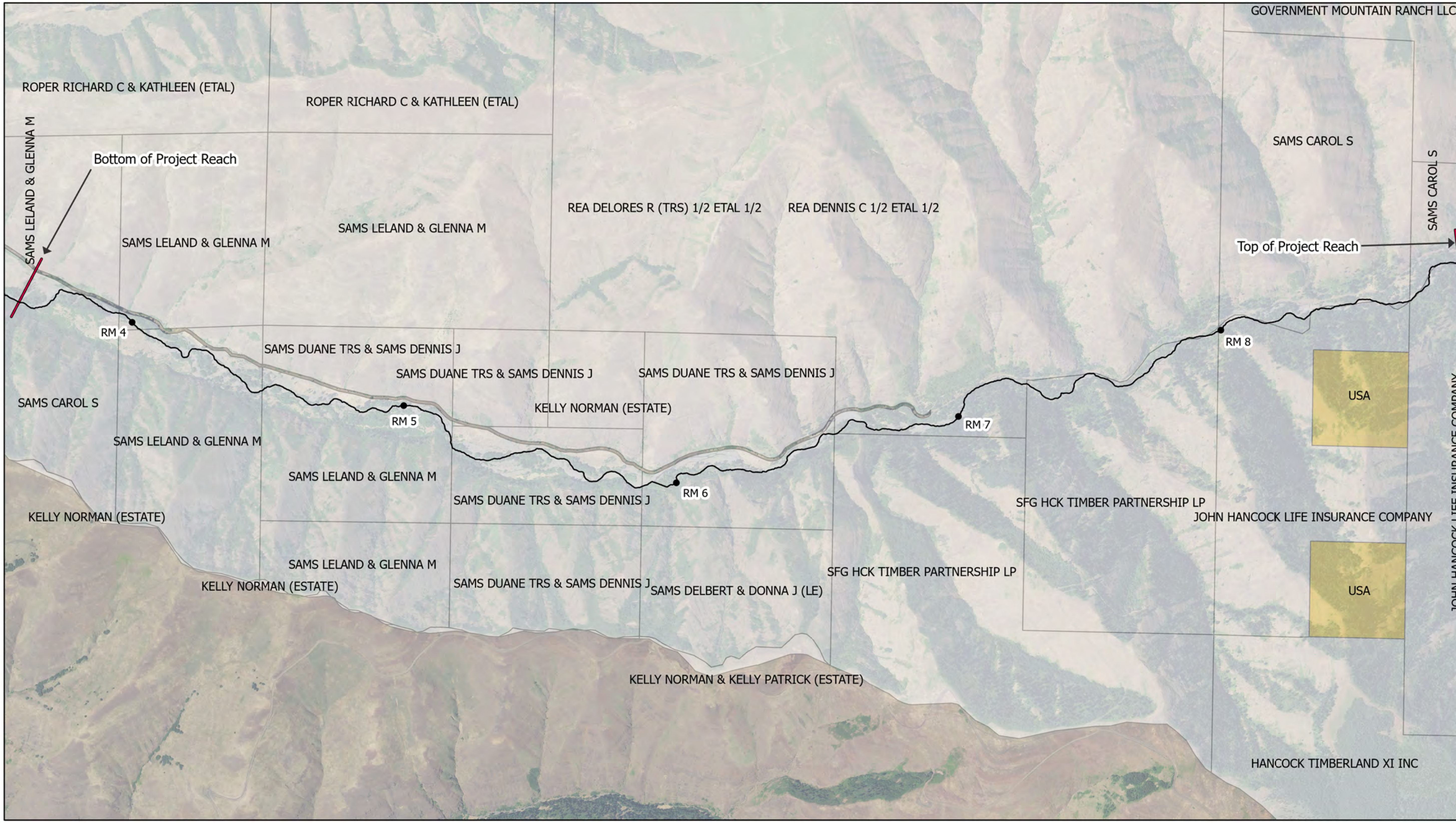
1. Introduction

The Walla Walla Basin Watershed Council (WWBWC) North Fork (NF) Walla Walla River Sam's-Rea Design Project (the Project) is located on the NF Walla Walla River, approximately 10 miles upstream from Milton-Freewater, Oregon. The Project boundaries encompass a 5.2-mile stretch, extending from the end of the paved NF Walla Walla Road and locked gate upstream to Little Meadow Creek. The Project reach includes large properties that are primarily owned by the Sam's and Rea's families, as well as a smaller portion that is owned by the Hancock Timber Partnership and John Hancock Life Insurance Company. Figure 1 shows the Project extents and property ownership boundaries. The desired outcome of the Project is a restoration condition that consists of a properly functioning, complex, and self-sustaining river system with a reconnected floodplain featuring vibrant, productive riparian features. Overall Project construction is scheduled to occur within the July to September 2023 to 2027 instream work periods. This report, prepared by the Jacobs and Cramer Fish Sciences (Cramer) (the design team), summarizes the existing conditions assessment and the conceptual restoration design (15% design level) for the Project reach.

1.1 Background

The NF Walla Walla River originates in the Blue Mountains of northeastern Oregon and flows west to its confluence with the South Fork (SF) Walla Walla River, where the main stem Walla Walla River forms. The main stem flows north through Milton-Freewater, then into Washington, where it goes west through the Walla Walla Valley before joining the Columbia River. The entire Walla Walla Subbasin, shown on Figure 2, encompasses 1,758 square miles, located in Walla Walla and Columbia counties in southeast Washington and Umatilla County in northeast Oregon. Primary water bodies include the Walla Walla River and Touchet River, a tributary to the Walla Walla River. Approximately 90% of the subbasin is privately owned, with 9% managed by federal/state agencies. The Confederated Tribes of the Umatilla Indian Reservation own approximately 8,700 acres within the subbasin. As 1 of the 62 subbasins based on Columbia River tributaries, a plan was locally developed for the Walla Walla Subbasin through the Northwest Power and Conservation Council regional response to Endangered Species Act-listed Columbia Basin fish and wildlife (Subbasin Plan) (WWWPU and WWBWC 2004). The Walla Walla Subbasin planning process included the Walla Walla Watershed Planning Unit, the WWBWC, the Washington Department of Fish and Wildlife, the Oregon Department of Fish and Wildlife, private landowners, and others.

The guiding vision for the Walla Walla Subbasin is a healthy ecosystem with abundant, productive, and diverse populations of aquatic and terrestrial species that supports the social, cultural, and economic well-being of the communities within the subbasin and the Pacific Northwest. The aquatic focal species in the subbasin include steelhead (*Oncorhynchus mykiss),* spring Chinook salmon (*O. tshawytscha*), and bull trout (*Salvelinus confluentus*). Additional aquatic species of interest include Pacific lamprey (*Entosphenus tridentatus*), mountain whitefish (*Prosopium williamsoni*), and freshwater mussels. The Subbasin Plan (WWWPU and WWBWC 2004) included an aquatic habitat assessment that identified stream reaches with high-potential restoration and protection values. In priority restoration areas, key limiting factors for steelhead and spring Chinook were identified. Priority protection areas protect current habitat conditions with the expectation of achieving no loss of function, and allow for natural attenuation of limiting factors over time to benefit aquatic habitat. The NF Walla Walla River, from the mouth to Little Meadow Creek, has been identified as a priority protection area and a priority restoration area. Above Little Meadow Creek, the NF Walla Walla River has been identified as a priority protection area (WWWPU and WWBWC 2004).



LEGEND
- NF Walla Walla River
- Project Reach Boundaries

Property Ownership
- Bureau of Land Management
- Private

N W E S

0 0.1 0.2 0.3 0.4 0.5
Miles

FIGURE 1
Sam's-Rea Project Reach Property Ownership Map
North Fork Wall Walla River Sam's-Rea Design
Conceptual Design Report

Jacobs CRAMER FISH SCIENCES An Employee Owned Consulting Company

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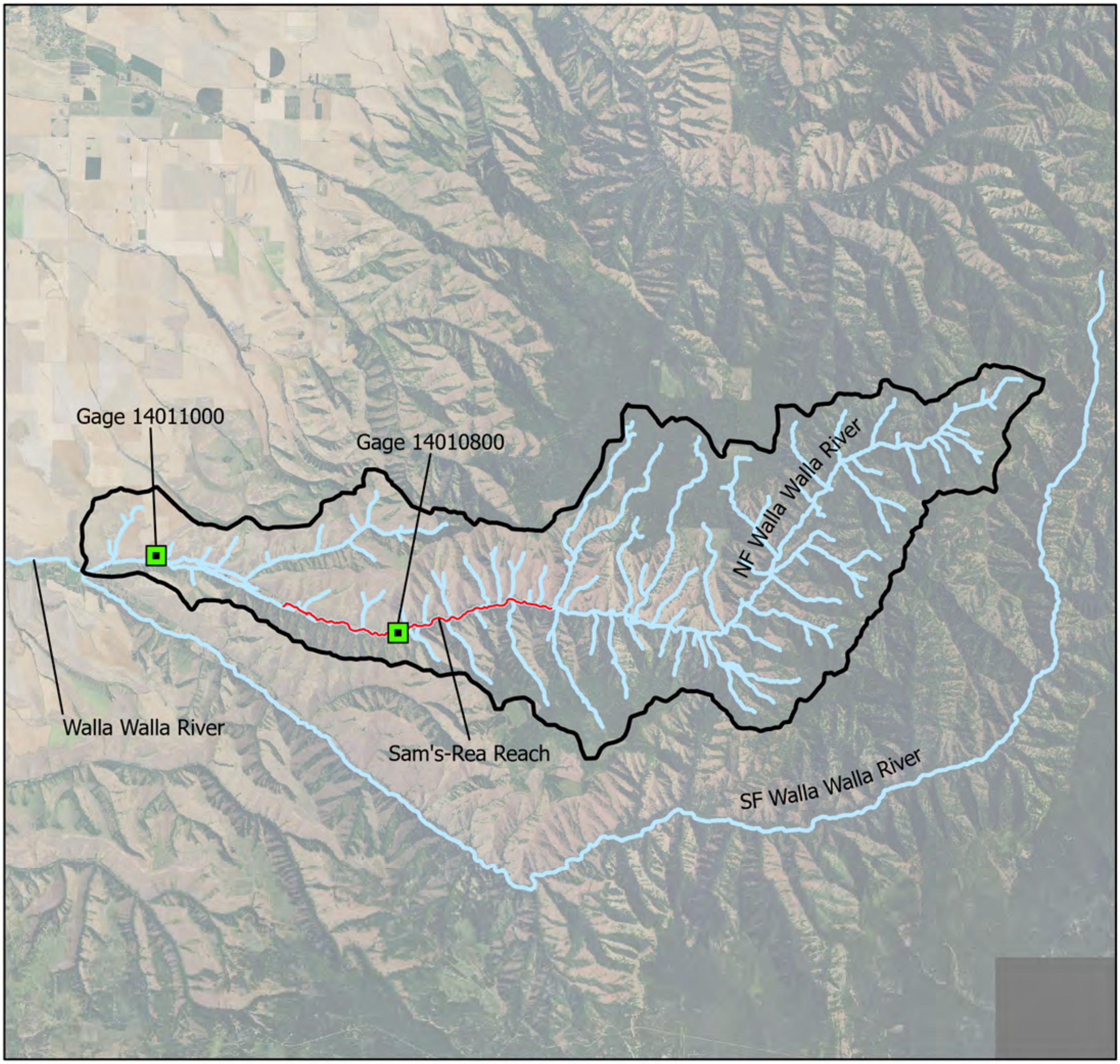
1.2 North Fork Walla Walla River – Sam's-Rea Project Reach Description

The NF Walla Walla River flows for 18.8 miles from its headwaters in the coniferous forested, western slopes of the Blue Mountains through volcanic canyons to a predominately cottonwood river valley before reaching its confluence with the SF Walla Walla River. In the middle portion of the watershed, the valley bottom widens and the stream gradient decreases. This transition corresponds to a shift in land use from forested, less disturbed reaches to cattle grazing. The 5.2-mile Project reach of the NF Walla Walla River, shown on Figure 2, is in this transition zone. Above the Project reach, the landscape is a mix of private timberlands and public forests with high-quality aquatic and terrestrial habitat. Below the Project reach, private residences and agricultural lands predominate. The Project reach has been identified in the Subbasin Plan (WWWPU and WWBWC 2004) as a priority protection area and a priority restoration area.

Findings from the Subbasin Plan (WWWPU and WWBWC 2004) identified the following limiting habitat attributes:

- Sediment
- Large woody debris (LWD)
- Key habitat (pools)
- Riparian function
- Stream confinement
- Summer water temperature
- Bed scour
- Low flow

More recently, this reach has been prioritized by the WWBWC for restoration because of its status as a priority restoration area in the Subbasin Plan (WWWPU and WWBWC 2004), the small number of landowners in the expansive reach, and the significant disturbance to the reach from recent flood events.



LEGEND

- Project Reach
- Watershed Boundary
- Rivers and Streams
- Stream Gages

N

0 1.25 2.5 Miles

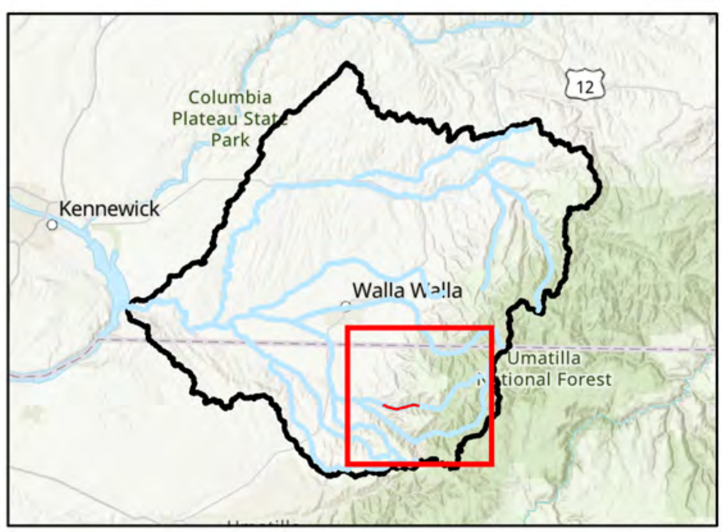


FIGURE 2
Watershed Map
North Fork Walla Walla River Sam's-Rea Design
Conceptual Design Report

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CRAMER FISH SCIENCES
An Employee Owned Consulting Company

Large floods in February and May 2020 created natural disturbances, and anthropogenic actions were implemented after the floods. Natural disturbances included bank erosion, channel migration and avulsion, and transport and deposition of sediment and LWD in the channel and on the floodplain. Anthropogenic actions included construction of pushup levees through the Project reach to channelize the river and direct flow away from the road and irrigation structures. Oregon Water Resources Department (OWRD) stream gage 14010800 was damaged during the 2020 flooding, and the peak flow rate was not recorded. Following the high-water episodes, emergency repair work was conducted to the road throughout the Project reach, and the gage station was repaired by OWRD.

WWBWC staff performed a habitat assessment survey of the NF Walla Walla River in May and June 2020, following spring runoff. Table 1 presents findings from this survey. The survey was conducted using the Oregon Department of Fish and Wildlife Aquatic Inventories Protocol (Moore et al. 2017). As a reference, the Project reach begins at River Mile (RM) 3.6 and ends at RM 8.8.

Table 1. Postflood Habitat Assessment Results from a Survey of the North Fork Walla Walla River

Habitat Criteria	Surveyed Section	
	RM 3.6 – RM 5.8	RM 5.8 – RM 9.3
Dominant morphology	Multithread	Single thread
Land use	Light grazing and rural residential	Light grazing and mature timber
% Riffle	93%	83%
% Pool	5%	2%
Dominant substrate	Cobble (51%)	Gravel (47%)
Secondary substrate	Gravel (42%)	Cobble (43%)
Mean gradient	2.6%	2.8%
Mean channel shade	41%	52%
Large wood/100 m	3.7	3.8
Wood volume/100 m	4.4 m^3	6.3 m^3
Riparian corridor	Bare rock and deciduous trees	Mixed conifers and deciduous trees

Source: WWBWC, 2021.

Notes:

m = meter(s)
m^3 = cubic meter(s)

An unpaved road within the floodplain parallels the north bank of the river through most of the Project reach. Travel through the Project reach and access into the upper watershed are difficult, due to significant erosion of the roadway that has occurred where the road intersects ephemeral drainages, or ravines, that flow into the main stem. The road also disconnects numerous spring seep sources from the main stem, which has caused ponding on the uphill side of the roadway and has reduced groundwater inputs into the main stem. Figure 3 shows the location of these springs and ravines in the Project reach. The proposed improvements to reconnect these springs to the main channel have been addressed in detail in the Springs Reconnection Memo (Appendix B).

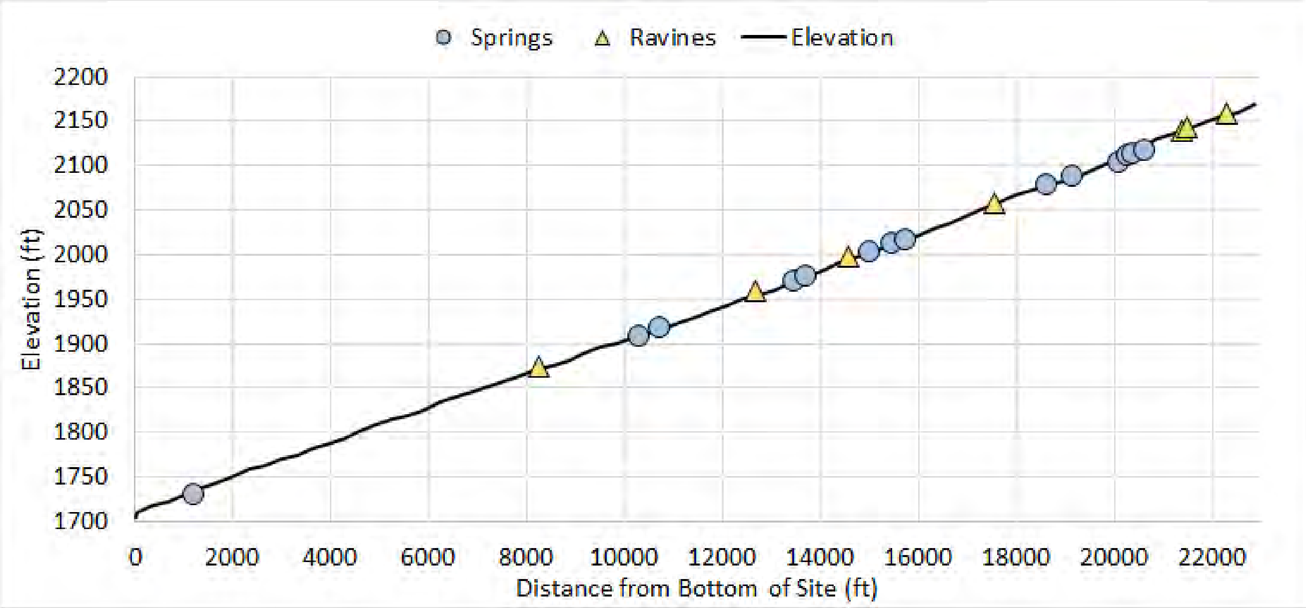


Figure 3. Main Stem Channel Bed Longitudinal Profile with Locations of Springs and Ravines that Cross the North Fork Walla Walla River Road through the Project Reach
Note: For all graphics, the left side of the horizontal axis is the downstream end.

Water temperature is a priority consideration in the NF Walla Walla River due to the threatened status of bull trout and summer steelhead, pursuant to the Endangered Species Act. Currently, the NF Walla Walla River is 303(d)-listed for temperature by the Oregon Department of Environmental Quality, and a total maximum daily load (TMDL) for temperature has been established (DEQ 2005). The goal of the TMDL is a natural stream temperature pattern. Point sources are few in the watershed, and the population density is low. Anthropogenic causes of stream heating are associated with flow reduction, vegetation loss, and channel straightening and widening.

1.3 Visions, Goals, Objectives, and Design Criteria

As previously noted, the overarching vision has been stated in the Subbasin Plan: "The vision for the Walla Walla Subbasin is a healthy ecosystem with abundant, productive, and diverse populations of aquatic and terrestrial species that supports the social, cultural, and economic well-being of the communities within the Subbasin and the Pacific Northwest" (WWWPU and WWBWC 2004).

Within the NF Walla Walla River, summer steelhead, bull trout, and resident trout are present. In addition to the presence of these anadromous and resident fish species, the NF Walla River has consistent flows in the summer and fall, and experiences ongoing natural disturbance processes (such as mass failures, floods, and fires) that create and maintain habitat complexity for aquatic and terrestrial species in the channel, floodplain, and riparian areas. The continued presence of these natural disturbance processes in the NF Walla Walla River provides an opportunity for ecological restoration. Furthermore, large parcels of private property with interested landowners provide additional opportunities specific to the Sam's-Rea Reach.

In recognizing the subbasin vision and opportunities at the NF Walla Walla River watershed scale, WWBWC and the design team developed the following vision, goals, and objectives specific to the Sam's-Rea Reach.

1.3.1 Vision

WWBWC, the Bonneville Power Administration (BPA), and landowners envision the Sam's-Rea Reach as a self-sustaining, shaded, perennial channel with variable velocities, depths, and substrates. Off-channel habitats (side channels and backwater connections) would:

- Intercept the groundwater

- Interact frequently with the main stem (an upstream surface water connection at least once every other year on average)
- Experience sediment flushing flows every few years
- Maintain a year-round downstream surface water connection with the main stem

The floodplain would have complex topography with depression areas and upland areas that support a diverse mix of native aquatic, riparian, and upland vegetation. Wood structures would provide habitat complexity in the main stem, off-channel, and floodplain, and create roughness and micro-sites for establishing vegetation on the floodplain. Recolonization of the site by beavers would contribute to Project success and sustainability. Figure 4 illustrates an existing portion of the Sam's-Rea Reach that contains many of the elements of this vision.

Figure 4. Postrestoration Vision for the North Fork Walla Walla River Sam's-Rea Reach

Taken by: Reid Camp (Cramer) *Date taken: September 10, 2021*

1.3.2 Goals

Building on the Subbasin Plan, landowner perspectives provided by WWBWC, BPA funding priorities, and WWBWC priorities, Project goals include the following:

1) Respect landowners' desires, maintain access to private properties, and collaborate with stakeholders.
2) Work with, not against, physical processes that increase hydraulic, geomorphic, and habitat complexity.
3) Improve connectivity vertically, laterally, and longitudinally for water, sediment, woody material, and aquatic species within the valley.
4) Increase the extent and diversity of riparian vegetation and forage (grasses) on floodplains and terraces.

1.3.3 Objectives

Building upon the vision and goals, the following objectives were developed:

1) Provide forage and water for wildlife and livestock.
2) Protect the existing road at vulnerable locations using levee setbacks.
3) Reduce potential downstream impacts to private property from high flows.
4) Increase the frequency, duration, and volume of flow on the floodplain and through off-channel habitats.
5) Raise groundwater elevations to increase establishment and survival of riparian vegetation and forage grasses on terraces and floodplains.
6) Maintain continuity of sediment inputs from colluvial (ravines) and alluvial (tributary) sources.
7) Increase the quality (complexity, cover, and hydraulic conditions) and quantity of aquatic (juvenile and adult salmonid) and benthic (macroinvertebrate) habitat.
8) Improve water quality (temperature and turbidity).
9) Increase the quality (diversity) and quantity of riparian and wetland habitat.
10) Improve adult salmonid spawning and holding habitat in the main stem.
11) Consider actions to improve resilience to climate change and land management (logging and grazing) in the Project area.

1.3.4 Design Criteria

Working from these objectives, WWBWC and the Jacobs-Cramer design team developed the following qualitative and quantitative design criteria for the Sam's-Rea Reach concept design:

1) Provide surface flow connectivity between the main stem, the floodplain, off-channel habitat (side channels and backwater connections), and tributaries (always greater than or equal to [≥] 2-year flow; ≥ low flow, where possible).
   a) Where off-channel grading has been incorporated, demonstrate hydraulic modeling velocities less than 2.0 feet per second and depths greater than 0.5 feet at the 2-year flow.
2) Protect and enhance existing springs and reconnect the springs with off-channel habitats or the main stem with culverts or permeable fills, as appropriate (always ≥ 2-year flow; ≥ low flow, where possible).
3) Improve floodplain and off-channel connectivity to attenuate peak flows, increase groundwater storage and water table, increase low flow volume and duration, and improve water quality (temperature and turbidity) (≥ 2-year flow).
   a) Temperatures for optimal growth and survival of bull trout are recognized between 10.2 degrees Celsius (C) and 14.2°C (Selong et al. 2001).
4) Decrease channel shear stress to reduce channel bed and bank scour, increase sediment deposition, increase groundwater storage and water table, and increase vegetation establishment and survival (≥ 2-year flow).
5) Incorporate large rock and large wood, increase the riparian and floodplain vegetation extent and diversity to provide channel and floodplain complexity and stability, and improve habitat and water quality (temperature and turbidity).
   a) Increase LWD abundance in the main stem and off-channel habitat to meet target densities (Fox and Bolton 2007), and support recruitment of wood over the long term. Qualifying wood pieces have been defined as those exceeding 10 centimeters in diameter and 2 m in length, and key pieces have been defined as wood pieces with a minimum volume ≥ 9 m^3, preferably with the root wad intact.
   b) Target wood density for total pieces is ≥ 35 pieces per 100 m.

c) Target wood density for key pieces is ≥ two pieces per 100 m.

d) Target wood volume is ≥ 15 m^3 per 100 m.

The following design criteria will be considered during future phases:

1) Develop and implement effectiveness monitoring to document Project responses to restoration actions.

2) Update and maintain irrigation diversions to reduce impacts to salmonids.

2. Existing Conditions Assessment

2.1 Field Reconnaissance

On September 10, 2021, a site visit was conducted by staff from WWBWC, BPA, and the design team (Figure 5) to:

- Make observations
- Address priority data gaps
- Collect additional data at the spring and ravine locations
- Validate preliminary hydraulic modeling results and proposed reach breaks
- Identify Project opportunities

The group also discussed and agreed upon the design approach, which has been described in Section 3. During the site visit, the streamflow in the NF Walla Walla River was measured as 6 cubic feet per second (cfs) from OWRD gage 14010800.

Figure 5. Site Visit Team Near the Upstream End of the Project Reach (September 10, 2021)

Taken by: Eric Hoverson (WWBWC) *Date taken: September 10, 2021*

Evidence of valley-scale, natural geomorphic processes, such as channel migration, channel avulsion, and the transport and deposition of sediment and LWD, were observed in the Sam's-Rea Reach of the NF Walla Walla River. These geomorphic processes may appear to be destructive immediately following a large flood, but they facilitate the development of dynamic, self-formed, and self-sustaining wetland-stream complexes that are high-quality habitats for fish and wildlife. New growth of native riparian and wetland vegetation was observed on exposed gravel bars and in the floodplains, and new habitat features were naturally formed in- and off-channel throughout the Project reach. In some locations, these geomorphic processes resulted in damage to the unpaved roadway, fences and corrals, and irrigation diversions within the floodplain. Where the road crosses the eight ravines shown on Figure 3 and in Appendix A, ephemeral runoff has caused significant erosion of the roadway prism. While not explicitly included in the conceptual river restoration design, grading and drainage improvements to the access road will be necessary to facilitate construction equipment access.

Evidence of anthropogenic actions to the stream channel was also observed during the site visit. In total, 10 pushup levees channelize the river and block flow to side channels and floodplains. Figures 6 and 7 illustrate the size and scale of these levees, and Appendix A includes the location of each levee. Although these levees are intended to reduce flood damages to the road, they drastically reduce natural floodplain function during high flow events and exacerbate downstream flooding. During the low flow conditions present during the site visit, numerous off-channel habitat features, such as side channels and alcoves, were disconnected by these levees, greatly reducing aquatic habitat complexity and connectivity. These disconnections are likely present across a wide range of flows, reducing multiple habitat uses for native salmonids throughout the Project reach.

Figure 6. Pushup Levee Constructed After the 2020 Flood Events (Near River Mile 9.1; Photo is Facing Downstream, and Staff are Standing on Top of the Levee on River Right)

Taken by: Robert Zabrowski (Jacobs) *Date taken: September 10, 2021*

Figure 7. Pushup Levee Drastically Reducing Side Channel and Floodplain Connectivity (Near River Mile 6.2; River and Levee are on the Far Left, Disconnected Floodplain is on the Right, Road is on the Far Right, Photo is Facing Downstream)

Taken by: Robert Zabrowski (Jacobs) *Date taken: September 10, 2021*

2.2 Hydrologic Analysis

Hydrology of the NF Walla Walla River was evaluated to characterize the magnitude of large floods and low flow conditions in the Sam's-Rea Reach. A flood frequency analysis was performed for the NF Walla Walla River using the annual peak discharge data collected at OWRD gage station 14010800 (location shown on Figure 2), and Table 2 includes the resulting peak flow statistics. Additionally, a daily flow duration analysis was performed with the daily discharge data collected at this stream gage to determine the daily mean flow values that have been exceeded for various percentages of the total period of record. Figure 8 shows the daily flow duration curve from this analysis. Appendix B includes a detailed memorandum describing the complete hydrologic analysis of the NF Walla Walla River.

Table 2. Peak Flow Statistics for the North Fork Walla Walla River Sam's-Rea Reach

Return Period (years)	Peak Discharge (cfs) for NF Walla Walla River (OWRD 14010800)	Confidence Limits (cfs)	
		0.05	0.95
2	479	545	422
5	728	856	636
10	910	1,117	782
50	1,358	1,908	1,106
100	1,567	2,352	1,241
200	1,788	2,875	1,375
500	2,102	3,710	1,550

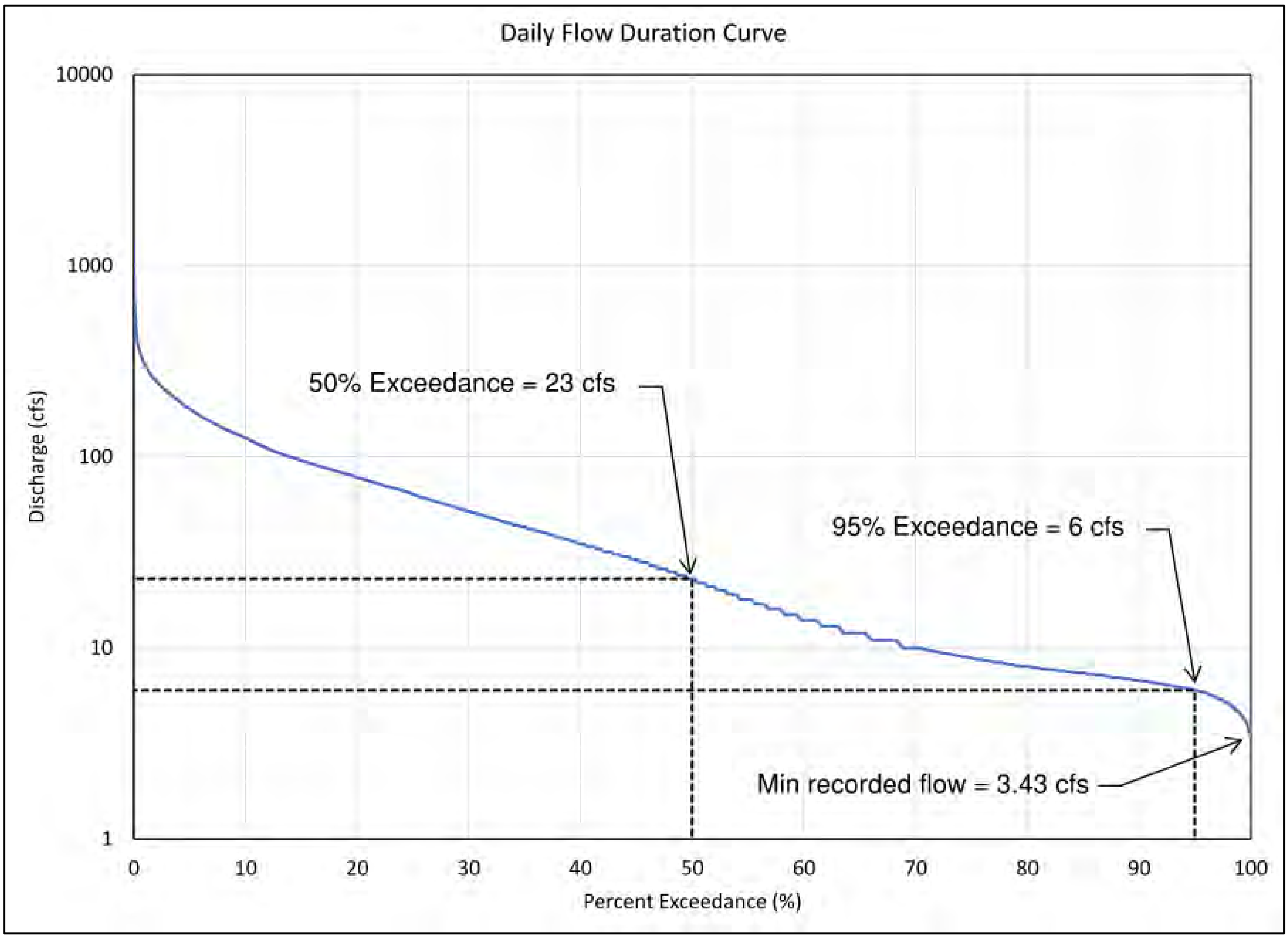


Figure 8. Daily Flow Duration Curve for the North Fork Walla Walla River Sam's-Rea Reach

2.3 Hydraulic Modeling

A preliminary, two-dimensional (2D), unsteady flow hydraulic model was developed for the Project area using the U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center's River Analysis System (HEC-RAS) modeling software version 5.07 (HEC-RAS v5.0.7) in conjunction with the 2016 HEC-RAS User's Manual (USACE 2016) to support the development of conceptual alternatives. The model simulates water flow over a digital surface that represents the terrain of the valley bottom and river channels. A 2D model was chosen over a 1D model for this Project because a 2D model produces greater detail on water level, velocity, shear stress, and other hydraulic parameters. Moreover, a 1D model would not sufficiently characterize the complex topographic and hydraulics within the Project site. The purpose of the model, at this phase, is to produce reasonable estimates of water surface extents, water depth, water velocity, and shear stress at low flow, 2-year flow, and 100-year flow recurrence intervals. These results have been combined with aerial imagery, detrended LiDAR, and field validation to identify restoration opportunities.

2.3.1 Model Development

The RAS Mapper interface was used develop the model geometry and compile the necessary data and spatial layers. The terrain used to create the model was based on green LiDAR flown for the Project area in July 2021. Green LiDAR penetrates water and therefore provides a continuous surface of elevation values for the entire watershed, including the channel bed. The model was constructed using a 1-m resolution digital terrain model (DTM) produced from the green LiDAR. The original DTM of the watershed was clipped to include the Project area +400 m upstream and downstream. A perimeter for the 2D modeled flow area was drawn across the entire valley. Within the perimeter, a 5-foot computational mesh was created and refined using a breakline representing the main stem channel (Note: The dual use of metric and imperial units is common practice with hydraulic modeling. Restoration results have been presented in imperial units.) The default calculation options and tolerances were used for preliminary model development (Table 3). Future model refinements may include updates to the selected parameter inputs.

Table 3. Default and Selected Calculation Options and Tolerances Used in HEC-RAS v5.07 for Preliminary Hydraulic Model Development

Parameter	Default	Selected
Theta (0.6-1.0)	1	1
Theta warmup (0.6 – 1.0)	1	1
WSE tolerance (max 0.2 foot)	0.01	0.01
Volume tolerance (feet)	0.01	0.01
Maximum iterations	20	20
Equation set	Diffusion wave	Diffusion Wave
Initial conditions ramp-up fraction (0-1)	0.1	0.1
Number of time slices (integer value)	1	1

Note:

WSE = water surface elevation

The upstream and downstream boundary conditions were set by enforcing a breakline in the computational mesh and the upstream and downstream extents of the model. Normal depth was used for the downstream boundary condition with an estimated friction slope of 0.015, based on the channel bed slope at the bottom of the site. An artificial hydrograph was created for each flow (low flow, 2-year flow, and 100-year flow), where flows ramped up linearly for 45 time steps before reaching the modeled discharge. The model was then allowed to run an additional 50 time steps at the modeled discharge to ensure convergence.

An iterative approach was used to develop and refine the preliminary model. The model was first run with an assumed Manning's N roughness value of 0.035 that was applied globally throughout the computational mesh to produce a WSE of the low flow channel. The low flow WSE was used to create a roughness layer, retaining a Manning's N value of 0.035 for the main channel. All other areas were assigned a default N value of 0.06 based on Chow (1959).

2.3.2 Model Results

Preliminary model results were visualized and evaluated using geographic information system to produce reach-scale maps showing water surface extents and flow patterns for the low flow, 2-year flow, and 100-year flow simulations. Appendix A provides these maps, and Figure 9 shows a cross-section with the water surface elevation results from the three model simulations.

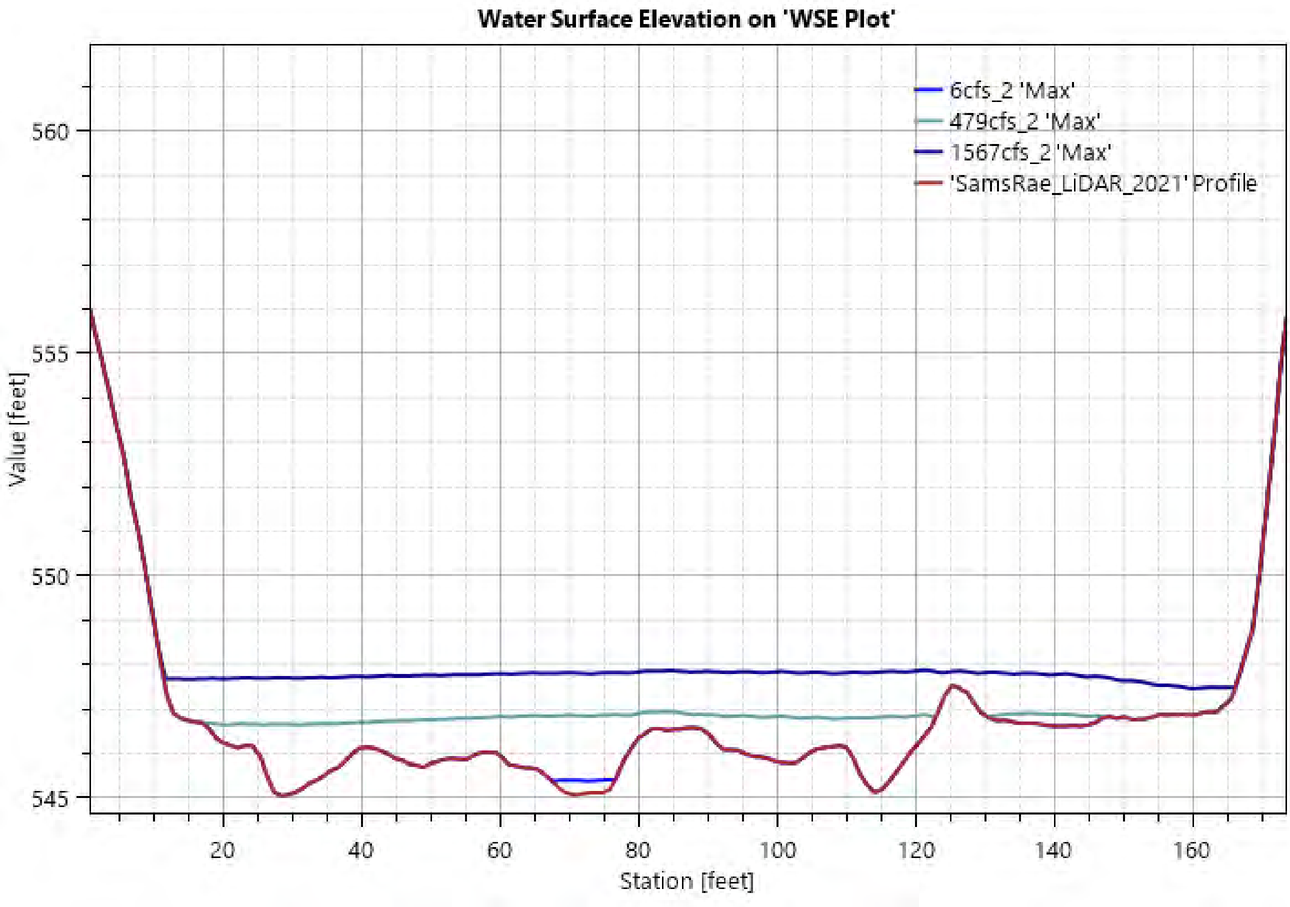


Figure 9. Water Surface Elevations for Flows Modeled at Low Flow (6 cfs), 2-year Flow (479 cfs), and 100-year Flow (1,567 cfs) Showing a Well-connected Floodplain (Note the Presence of Multiple Channels in the LiDAR Terrain Profile)

2.3.3 Future Model Development

The purpose of the model, at this phase, is to efficiently produce reasonable estimates of water surface extents and flow patterns at low flow, 2-year flow, and 100-year flow recurrence intervals, to inform the conceptual design. Future model development will include additional refinement of the terrain, cell spacing, break lines, Manning's N roughness regions and values, and computation parameters. Calibration of the model will be performed using WSE visible in recent aerial imagery and water depth and velocity cross-sections that have been measured in the field. Following these refinements, the hydraulic model will be utilized for detailed analysis of water depth, velocity, and shear stress at specific locations within the Project reach, as well as further refinement of the design elements that have been recommended in this report.

2.4 Reach Characterization

The characterization of source, transport, and response reaches are critical to understanding watershed- and reach-scale hydrologic, hydraulic, and geomorphic processes, and to designing projects that are self-sustaining. The NF Walla Walla River originates in the Blue Mountains and is oriented east to west. The valley position is heavily influenced by Columbia River Basalt flows (primarily the Grande Ronde and Wanapum flows). The adjacent hillslope soils are dominated by gravelly and cobbly silt loam, with contributions of finer sediment (silty loam and decomposed plant material), especially near the upstream extent of the Project area. Ephemeral drainages have the potential to deliver alluvium (sediment delivered by a stream) and colluvium (sediment from hillslope) to the valley bottom during flood events. Moreover, because intense localized rainstorms are relatively common, ephemeral drainages can contribute significant amounts of sediment. These ephemeral drainages also increase in density moving upstream, acting as a localized source of sediment that is transported by the NF Walla Walla River to lower reaches.

The prevalence of steep ephemeral drainages containing loose soils, combined with a flashy hydrograph, creates a fluvial environment that can change drastically in a single flood event. This is further evidenced by the dominance of well-drained alluvial soils (xerofluvents) throughout the valley bottom. In other words, the NF Walla Walla River and its valley bottom were formed over millennia by floods similar to the 2020 event, and similar events will occur in the future. When floods occur, the portions of the valley bottom essentially reset – topsoil is eroded, riparian vegetation is removed, and the channel planform adjusts. During floods, areas that contain dense riparian vegetation, particularly galleries of canopy species, such as cottonwood and alder, tend to remain intact and provide long-term stability.

A river valley bottom represents the maximum extent of potential floodplain and channel migration zone. The valley bottom width in the NF Walla Walla River fluctuates with fans, terraces, exposed bedrock, and the valley margin that forces more confined sections (Figure 10). The downstream half of the Project area is generally wider than the upstream half. This trend is expected when moving upstream in a watershed; however, fans from tributaries impose additional confinement on the valley bottom.

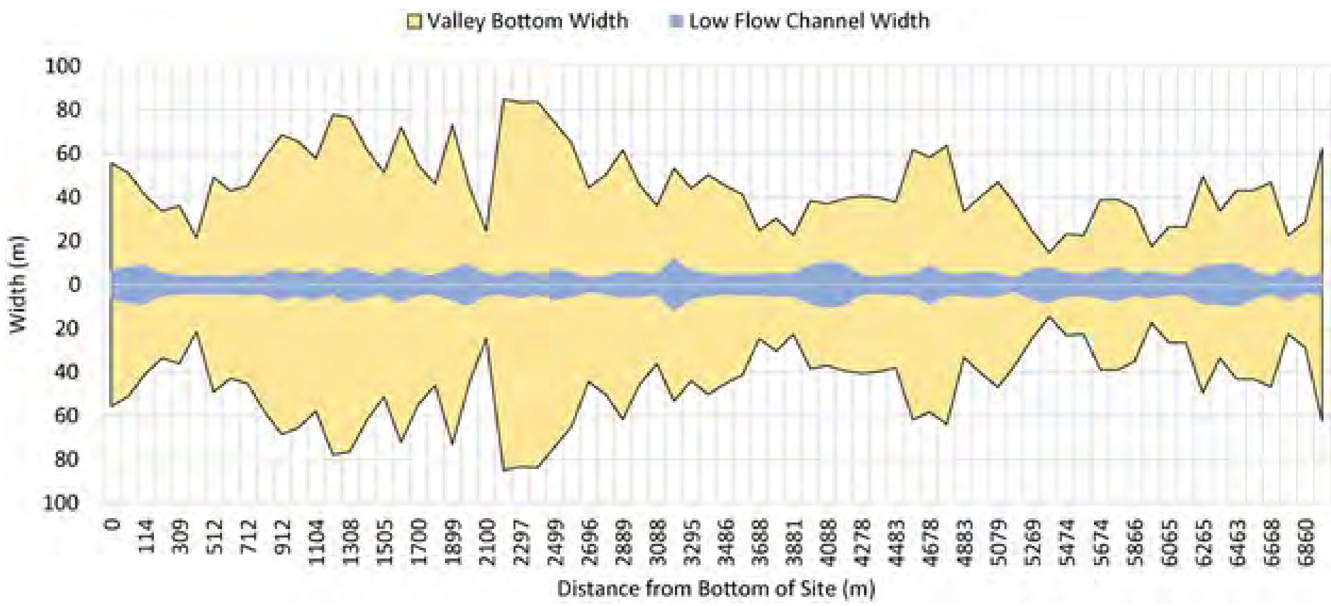


Figure 10. Profile of Valley Bottom Width and Low Flow Wetted Channel Width Through the Project Area

Reaches within the Project area were determined based on defining characteristics within the valley bottom, alluvial channels, and contributing hillslopes. Eight distinct reaches were identified based on longitudinal differences in hydrogeomorphic characteristics that influence river form and function (Figure 11). Each reach was further refined based on a visual assessment of condition using remote sensing analysis and ground validation. Reach lengths range from 563 to 1,410 m, with an average reach length of 924 m (Table 4). Tables 5 and 6 summarize defining characteristics of each reach.

Note: National Agriculture Imagery Program (NAIP) 2020 imagery.

Figure 11. Overview of Reach Break Locations

Table 4. General Reach Location Characteristics

Reach	RM Start	RM End	Length (m)	Minimum Elevation (m)	Maximum Elevation (m)	Upstream Drainage Area (km^2)
1	3.6	4.2	850.7	519.7	536.1	96.4
2	4.2	5.2	1,409.5	537.5	562.6	94.2
3	5.2	5.8	847	564.4	579.1	92.9
4	5.8	6.3	701.3	581.0	592.0	90.7
5	6.3	6.7	562.5	594.3	604.2	89.8
6	6.7	7.4	990.6	606.8	625.5	87.7
7	7.4	8.2	1,100.7	627.5	649.1	83.6
8	8.2	8.8	933.2	651.1	661.0	81.2

Note:
km^2 = square kilometer(s)

Table 5. Dominant Geology, Dominant Soils Found in Adjacent Contributing Hillslopes, Valley Confinement Class, and Sediment Process Zones of Reaches within the Project Area

Reach	Dominant Geology	Contributing Hillslope Soils	Confinement Class	Sediment Process Zone
1	Grande Ronde Basalt and Quaternary Alluvium	Very gravelly and cobbly silt loam	Partly Confined	Transport
2	Grande Ronde Basalt and Quaternary Alluvium	Very gravelly and cobbly silt loam	Laterally Unconfined	Depositional

Table 5. Dominant Geology, Dominant Soils Found in Adjacent Contributing Hillslopes, Valley Confinement Class, and Sediment Process Zones of Reaches within the Project Area

Reach	Dominant Geology	Contributing Hillslope Soils	Confinement Class	Sediment Process Zone
3	Grande Ronde Basalt and Quaternary Alluvium	Silty loam, some gravel and cobble	Laterally Unconfined	Depositional
4	Grande Ronde Basalt and Quaternary Alluvium	Very gravelly and cobbly silt loam	Partly Confined	Transitional
5	Grande Ronde Basalt and Quaternary Alluvium	Very gravelly and cobbly silt loam	Confined	Transport
6	Wanapum Basalt and Quaternary Alluvium	Very gravelly and cobbly silt loam; decomposed plants and loam	Partly Confined	Transitional
7	Grande Ronde Basalt and Quaternary Alluvium	Silty loam, some cobble; decomposed plants and loam	Confined	Transport
8	Grande Ronde Basalt and Quaternary Alluvium	Silty loam, some cobble; decomposed plants and loam	Partly Confined	Transitional

Table 6. Defining Valley Bottom and Channel Characteristics of Reaches Within the Project Area

Reach	Sinuosity	Mean Slope (%)	Maximum Slope (%)	Mean Valley Bottom Width (m)	Mean Channel Width at Low Flow (m)	Side Channel Count	Total Side Channel Length (m)	Flood Channel Count	Total Flood Channel Length (m)	Secondary Channel Ratio
1	1.15	2.09	2.35	83.63	11.22	1	40	8	978	1.14
2	1.19	1.91	2.45	119.04	12.36	11	1,251	14	1,282	0.95
3	1.16	1.85	2.36	131.75	10.59	3	464	6	1,269	1.32
4	1.17	1.87	2.09	84.33	12.28	2	237	4	788	1.09
5	1.17	2.06	2.51	69.53	14.82	2	357	4	351	0.77
6	1.17	2.15	2.69	88.80	10.87	2	278	4	525	0.63
7	1.15	2.16	3.20	59.52	12.99	2	412	1	193	0.40
8	1.16	1.96	2.37	82.36	12.37	2	227	4	382	0.52

2.5 Reach Descriptions

2.5.1 Reach 1

Reach 1 begins at the downstream end of the Project area near RM 3.6 and ends at RM 4.2. The first spring enters the valley bottom near RM 3.95. The channel is one of the least sinuous reaches in the Project area and is partly confined. The channel is laterally confined on the right (facing downstream) bank by the NF Walla Walla River Road and valley margin, and is confined on the left bank by a terrace. The terrace elevation is low enough near RM 4.1 that some flood flows may have limited access; otherwise, other opportunities for lateral connectivity do not exist. The 2020 flood did force some lateral scour against the terrace near RM 3.9 and RM 4.1, which slightly expanded the amount of available floodplain in this reach. The channel makes a hard turn left near RM 3.75 and ends up against the south valley margin below the Project area. A ribbon of deciduous trees remains intact between the active channel and the road, and a gallery of alder and cottonwood is on the left bank between RM 3.7 and RM 3.9.

2.5.2 Reach 2

Reach 2 begins at RM 4.2 and ends at RM 5.2. The channel in this reach is the most sinuous in the Project area and is laterally unconfined. This reach has a relatively wide valley bottom with a well-connected floodplain, several perennial side channels, and several flood channels and flood-outs. The valley bottom extends to the valley margin throughout most of the reach. Some secondary channels run adjacent to the road, but the main stem channel runs through the center of the valley bottom. Large swaths of topsoil have eroded away between RM 4.3 and RM 4.4, and near RM 4.6, leaving exposed cobble. Several galleries of alder and cottonwood remain intact; the topsoil and undergrowth in these areas also remain intact.

2.5.3 Reach 3

Reach 3 begins at RM 5.2 and ends at RM 5.8. The first ravine is located at RM 5.5 and contributes smaller colluvium than adjacent hillslopes (mostly silty loam and some cobble). The channel sinuosity is relatively low for an unconfined reach; however, an appropriate meander pattern is developing as are alternate bars and diagonal bars, resulting in some planform complexity. Likewise, several secondary channels exist in the valley bottom. The valley bottom in this reach is the widest section within the Project area. The main stem channel avulsed during the 2020 flood, creating a new channel near the center of the valley between RM 5.3 and 5.6. The previous main stem channel is now a large alcove at its downstream confluence with the new main stem. A large flood-out near RM 5.45 ramped a significant amount of sediment onto the right bank floodplain. Alder and cottonwood galleries remain intact and provide stability for the main stem and secondary channel banks.

2.5.4 Reach 4

Reach 4 begins at RM 5.8 and ends at RM 6.3, and contains the state flow gage monitoring station near the upstream extent. Two springs enter the valley bottom near RM 5.95 and RM 6.0. The main stem channel is partly confined and adjacent or near the southern valley margin for the full length of this reach. The 2020 flood forced a substantial avulsion away from the southern valley margin and scoured the topsoil on the riverbank between RM 6.0 and RM 6.2. In some areas, the floodplain was overtopped with cobble/gravel sheets, leaving the topsoil intact, but was buried by freshly deposited alluvium. However, the main stem remains in the previous location along the southern valley margin, and the flood flow path contains defined channels that remain puddled during low flow. The flood flow path is at a lower elevation than the main stem channel, but surface flow has been cut off from the main stem by a new levee near the upstream extent of the reach. A high likelihood exists that the next channel-forming floods will result in another avulsion through the levee, as the main stem channel occupies the lower elevation flood channel. The main stem channel between RM 5.8 and RM 5.9 also avulsed, moving the channel from the right to the left valley margin. Canopy species (mostly alder and cottonwood) remain mostly intact; however, much of the understory is covered by alluvium.

2.5.5 Reach 5

Reach 5 is the shortest reach in the Project area, beginning at RM 6.3 and ending at RM 6.7. The second ravine is located near RM 6.45, and two springs enter the valley bottom near RM 6.6 and RM 6.7. Despite being confined, the channel exhibits a meander pattern with sinuosity similar to the rest of the Project area. Confinement in this reach is primarily driven by an intrusion of Wanapum Basalt, beginning near RM 6.4, that crosses the valley bottom at the top of the reach near RM 6.7. A large avulsion occurred near the top of the reach that scoured most of the floodplain on river right between RM 6.55 and RM 6.7. The avulsed channel is at a lower elevation than the current main stem and remains puddled; however, a new levee is preventing flow from entering the preferential channel. Although the natural channel pattern would put most surface flows into the avulsed channel, the levee is pinning the main stem against the southern valley margin. Despite the confined valley bottom, a few flood channels may provide energy dissipation during moderate floods. Downstream of the avulsion, most of the canopy species remain intact; however, most of the understory and floodplain in this reach is covered in fresh alluvium.

2.5.6 Reach 6

Reach 6 begins at RM 6.7 and ends at RM 7.4. This reach is partly confined, beginning adjacent to the left valley margin at the downstream extent of the reach, then crossing the valley bottom to the right valley margin near RM 7.0, and returning to the left valley margin at the upstream extent. This reach begins at an intrusion of Wanapum Basalt and geologic fault, which confines the valley bottom. The third ravine is located near RM 6.85, and three springs enter the valley bottom near RM 6.95, RM 7.05, and RM 7.1. The main stem channel between RM 7.0 and RM 7.3 is over-widened, and although alternate bars are developing, the channel lacks structural elements needed to maintain complex topography. Most of the canopy is dominated by alder and remains mostly intact. The areas with more dense alder galleries retained topsoil and understory vegetation; however, alluvium now covers much of the valley bottom between RM 6.7 and RM 7.0.

2.5.7 Reach 7

Reach 7 begins at RM 7.4 and ends at RM 8.2. This reach is confined and is the steepest section in the Project area. The fourth ravine is located at RM 7.5, and six springs enter the valley bottom at RM 7.7, RM 7.85, RM 8.05, RM 8.1, RM 8.15, and RM 8.2. Confinement is primarily driven by shallow Grande Ronde Basalt, with exposed sections between RM 7.5 and RM 7.8. Several secondary channels provide some energy dissipation during floods. However, a side channel between RM 7.6 and RM 7.8 remains puddled and is disconnected from the main stem by a new levee. This same levee artificially pins the main stem against the left valley margin, greatly restricting lateral connectivity. A flood channel between RM 8.0 and RM 8.1 is disconnected from the main stem by a new road prism. Currently, this flood channel is being fed by springs and provides some habitat as an off-channel pool; however, its utility is limited because it is poorly connected to the main stem. A left flood channel between RM 7.8 and RM 8.0 contains off-channel pools and wetland habitat during low flow. Much of the alder- and cottonwood-dominated canopy remains intact, but most of the valley bottom is covered in freshly deposited alluvium.

2.5.8 Reach 8

Reach 8 begins at RM 8.2 and ends at the top of the Project area near RM 8.8. The remaining four ravines are located at RM 8.35, RM 8.36, RM 8.55, and RM 8.75. This reach is partly confined as the channel navigates between the left and right valley margins, fans, and terraces. A small complex of side channels near the bottom of the reach connects flood channels between this reach and Reach 7. The channel throughout most of this reach is homogeneous with very few structural elements in the low flow channel. The main stem between RM 8.5 and RM 8.7 is naturally confined between a large fan on the right and the valley margin on the right. Although most of the canopy is intact, several floodplain pockets were scoured and are now exposed sheets of alluvium.

3. Conceptual Design Approach

The 2020 floods and subsequent emergency repair work – individually and together – created large and lasting changes to the river and floodplain, including some impacts to the existing road and irrigation diversion. Changes from the floods included channel avulsions, erosion of streambanks, and uprooting and transport of many large trees. Changes from the repair work included construction of new road segments through new channel and floodplain, construction of pushup levees blocking the upstream ends of new channel segments, and replacement of displaced diversion structures.

Levees constrict the channel and initiate an unsustainable negative feedback loop of processes that destabilize the channel. For example, a constricted channel increases velocities and shear stresses, increases channel bed and bank erosion, reduces groundwater elevations, and reduces forage for wildlife and livestock. Even with just 1 year of flows following creation of the channel-constricting road near RM 8.1, field observations suggest that the channel is actively incising (downcutting). Figure 12 shows this location.

Figure 12. River Reach Near River Mile 8.1 that is Experiencing Active Channel Downcutting (Incision) Due to Confinement

Taken by: Steve Clayton (Jacobs) *Date taken: September 10, 2021*

Successful and sustainable restoration of the NF Walla Walla River will require a long-term perspective that works with, not against, natural disturbance processes like the 2020 floods. These disturbance processes are required to create and maintain habitat complexity, including supplying spawning gravels to the tributaries and main stem channels and creating bare, moist alluvial substrate to allow natural recruitment of alder, willow, and cottonwood on point bars, islands, and floodplains. Together, these processes ultimately contribute to channel stability, channel shading, and reduced water temperature, as well as recruitment of large wood to the channel for geomorphic and habitat complexity. These processes also create and maintain deep pools for fish refuge and rearing, as well as trapping and storage of gravels for fish spawning.

As described in the following sections, with time, positive feedback loops establish additional benefits extending beyond the immediate channel and floodplain, such as increases in the groundwater table and volume and duration of low flows, which together help to increase forage and water for wildlife and livestock.

3.1 Design Approach

The overarching design approach is to jump-start physical processes that initiate a self-sustaining positive feedback loop that will gradually improve channel and floodplain function, stability, and habitat. Specifically, the design team recommends implementing restoration design elements that decrease velocity and shear stress in the main channel, secondary channels, and floodplain. Passive and active restoration elements can be implemented to jump-start hydraulic, geomorphic, and vegetative processes. For example, by adding stream roughness in the form of wood habitat structures and by reconnecting the channel to floodplains, the design team can initiate a positive cascade of self-sustaining physical and biological responses. Subsurface flows in the NF Walla Walla River result from a lack of fines in the channel bed, specifically in the interstitial spaces. The fine sediment supply is available – the challenge is trapping and storing sediment in the channel and on the floodplain. The supply, transport, and deposition of sediment is extremely important from an ecological standpoint. By using hydraulic model results and field data to determine mobile sediment sizes (to be completed during a future design phase), the potential transport of bed material can be assessed to inform design.

To work with (rather than against) the existing channel condition (slope, planforms, and geometry) and manage construction costs (reduce earthwork), the design team recommends focusing restoration actions strategically and "letting the river do the work", where possible. For example, rather than excavating new channels and enforcing a potentially unsuitable planform, the conceptual design prioritizes setting back levees, where possible, to give the river the space to form its own flow paths, allowing for more natural channels and habitat features. In locations where road protection is required, structures could be considered.

Designing and constructing a single-threaded meandering channel is a suitable approach in some geomorphic settings, but the planform of the NF Walla Walla River in the Project reach tends more toward a wandering or braided (multithread) channel rather than a nonbraided (meandering, single thread) channel. Factors that contribute toward a braided channel include increases in slope, discharge, and sediment supply. Figure 13 illustrates the relative position of the Project reach on a graphic prepared by USACE (1994), which summarizes threshold lines of five different studies comparing slope-discharge relationships and channel planforms. With a channel-forming (2-year) discharge of 479 cfs and an average slope of approximately 2%, the Project reach plots well into the range of braided channels (see the red dot on Figure 13); therefore, trying to design and construct a single-threaded meandering channel is not recommended as a sustainable and stable approach in this river system.

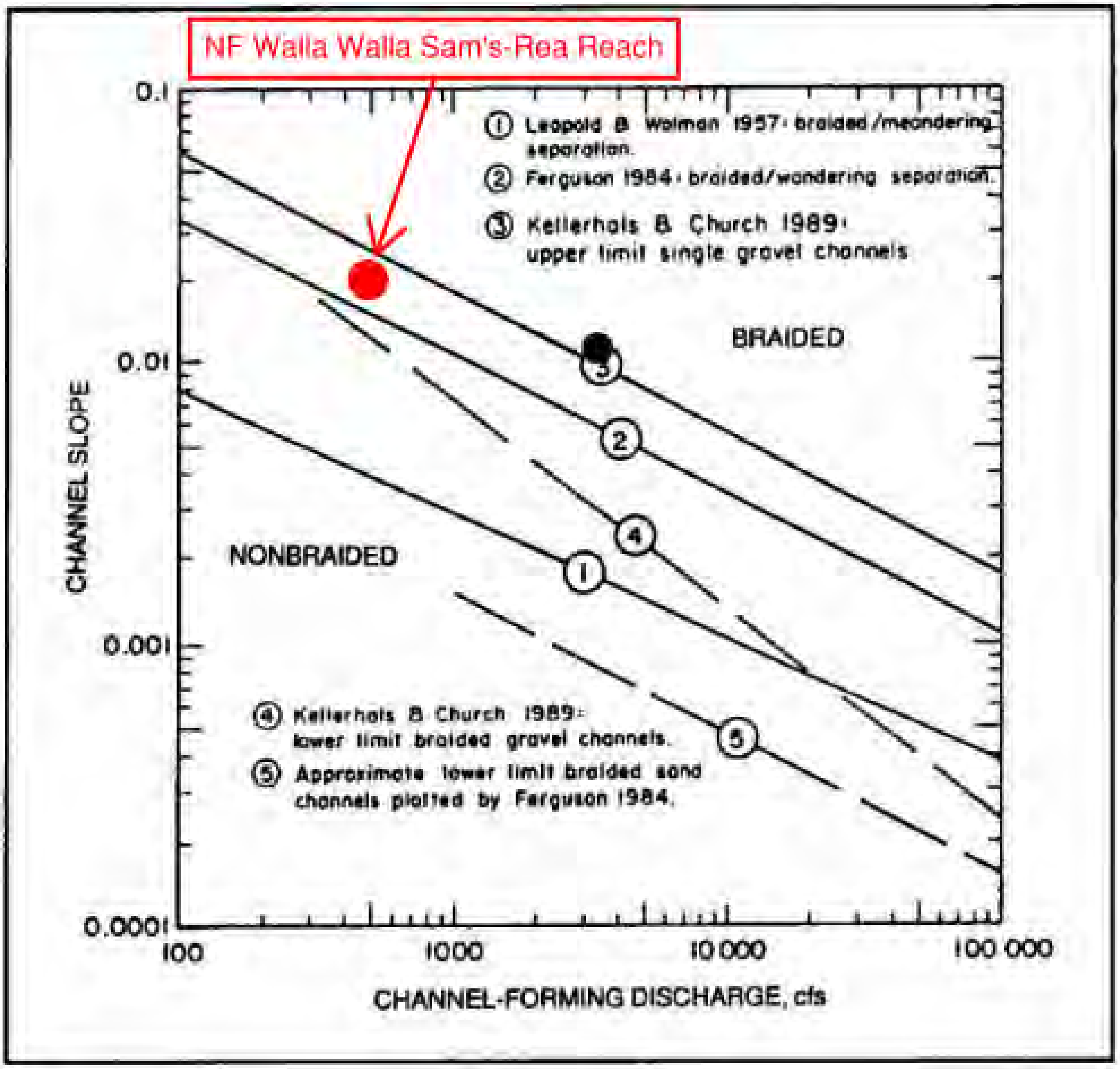


Figure 13. Project Reach (2-year Discharge and Reach Average Slope) Plot Position on Slope-discharge Chart Distinguishing Braided from Nonbraided Channels
Source: USACE, 1994.

During the site visit, WWBWC and BPA participants endorsed this process-based design approach, with one additional request from BPA – to the extent possible, look for opportunities to phase the work starting downstream and working upstream. This sequencing suggestion has been included in the prioritization considerations, but not as the primary factor. Additional design considerations, including wetlands and cultural resources, will be addressed during subsequent phases.

3.2 Restoration Design Elements

A guiding principle of process-based river restoration is to work with fluvial processes to create and maintain quality riparian and aquatic habitats. The NF Walla Walla River has abundant alluvial sediment and has the competence to transport sediment effectively. This conceptual design takes advantage of active sediment transport, erosion, and deposition processes in the Project area by adding structural elements (for example, stable wood and rock) at key locations. The dimensions and orientation of a structural element will affect how it interacts with flood flows to create predictable areas of secondary channel and floodplain connection, erosion (for example, pool creation and lateral movement), and deposition (for example, riffle/bar creation and sort sediment). Moreover, because the floodplain is well-connected during frequent floods (that is, bankfull, 2-year recurrence), increasing floodplain roughness is expected to increase fine sediment retention on the floodplain. Kick-starting the floodplain recovery process is expected to improve the survival of riparian plantings and increase resiliency against erosional effects of the next inevitable large flood. In several cases, pushup levees are inhibiting recovery by limiting lateral connectivity, which also increases the potential for floods to cause major damage; therefore, several levees have been identified to be relocated or removed. There are also several springs entering the north side (right) of the valley bottom. The springs may provide cold water inputs, contribute to wetland habitat, and/or provide off-channel habitat for a variety of species. Finally, the recent flood events caused several main stem channel avulsions, created new secondary channels, and scoured away large swaths of topsoil and riparian vegetation.

The concept design focuses around maintaining these new flow paths and providing some structural stability to increase resiliency. Appendix A provides maps that show all the conceptual design elements that have been summarized by priority and reach in Table 7, discussed herein. Specifically, the concept design incorporates structure elements, floodplain roughness, channel grading, and spring protection.

- Add structural elements:
  - Large jam: A jam composed primarily of LWD, containing at least three key pieces with root wads intact. The jam is partially buried in the streambed, wedged around live trees and/or ballasted with boulders to increase stability. These structures are focused primarily at secondary channel junctions and areas where the goal is to persuade the main stem channel to move in a chosen direction.
  - Small jam: A jam composed primarily of LWD containing at last one key piece with an intact root wad. The jam is partially buried in the streambed, wedged around live trees, and/or ballasted with boulders to increase stability. These structures are to be used to enhance existing quality habitat or create new quality habitat as they interact with flood flows.
  - Boulder rib: A configuration of large boulders arranged as a lateral feature along the streambed or as clusters to disrupt homogenous flow. The boulders will be large enough to persist through large flood events. These structures are to be used to enhance existing quality habitat or create new quality habitat as they interact with flood flows. They will be used as a replacement for wood structures in confined reaches with greater stream power and sediment transport competence.
- Increase floodplain roughness:
  - Riparian plantings: Using a mixture of live cuttings, bare root stock, buried live logs, potted sapling stock, and other best practices, establish riparian vegetation throughout exposed alluvial sheets in the floodplain. Vegetation will naturally establish over time, but additional planting efforts will help kick-start riparian recovery.
  - Floodplain fences: Use small structures composed of LWD that are mostly perpendicular to the dominant flow path across the floodplain. These small structures will increase roughness and promote deposition of fine sediment on the floodplain during floods. They may be built with heavy machinery or by using low-tech methods, such as post-assisted log structures (PALS). These locations will likely become hotspots for natural vegetation recruitment.
- Address pushup levees:
  - There are three primary options for addressing both pushup levees and natural levees:
    1) When a levee is increasing confinement, but it is still needed to protect infrastructure, it may be set back from its current location (levee setback).
    2) In some cases, only a portion of a levee needs to be removed or the levee may be perforated at key locations to allow lateral connection (levee modification).
    3) Some levees are not detrimental to achieving the design objectives and may be left as-is in their current location and condition (levee abandonment).

- Maintain existing channels:
  - Main: The main stem channel contains most of the surface water during base flows and is the focus for most of the proposed habitat improvement work.
  - Side: Side channels are a secondary channel that maintains perennial flow. Related to the conceptual design, these channels are either currently perennial or will be, following construction of the proposed design. Side channels provide vital habitat for salmonids and offer high flow refuge during large floods.
  - Flood: Flood channels are a secondary channel that only contains surface flow during flood events. During base flow, they are either dry or remain puddled. Flood channels provide lateral accommodation space for floods, which can greatly dissipate energy and reduce flood damage. Flood channels also provide refuge to salmonids during flood events. In rivers such as the NF Walla Walla River, flood channels are often avulsion pathways and the main stem channel may swap between them following channel changes that result from high flows.

The design elements have been incorporated into the concept design in several ways and will be refined in future design phases to achieve structure, reach, and Project objectives. The design elements have been assigned a 3-tier priority ranking (1 = highest priority, and 3 = lowest priority) based on the expected magnitude of geomorphic and biologic benefits. As Figure 14 illustrates, the concept maps in Appendix A indicate the priority tier for each design element.

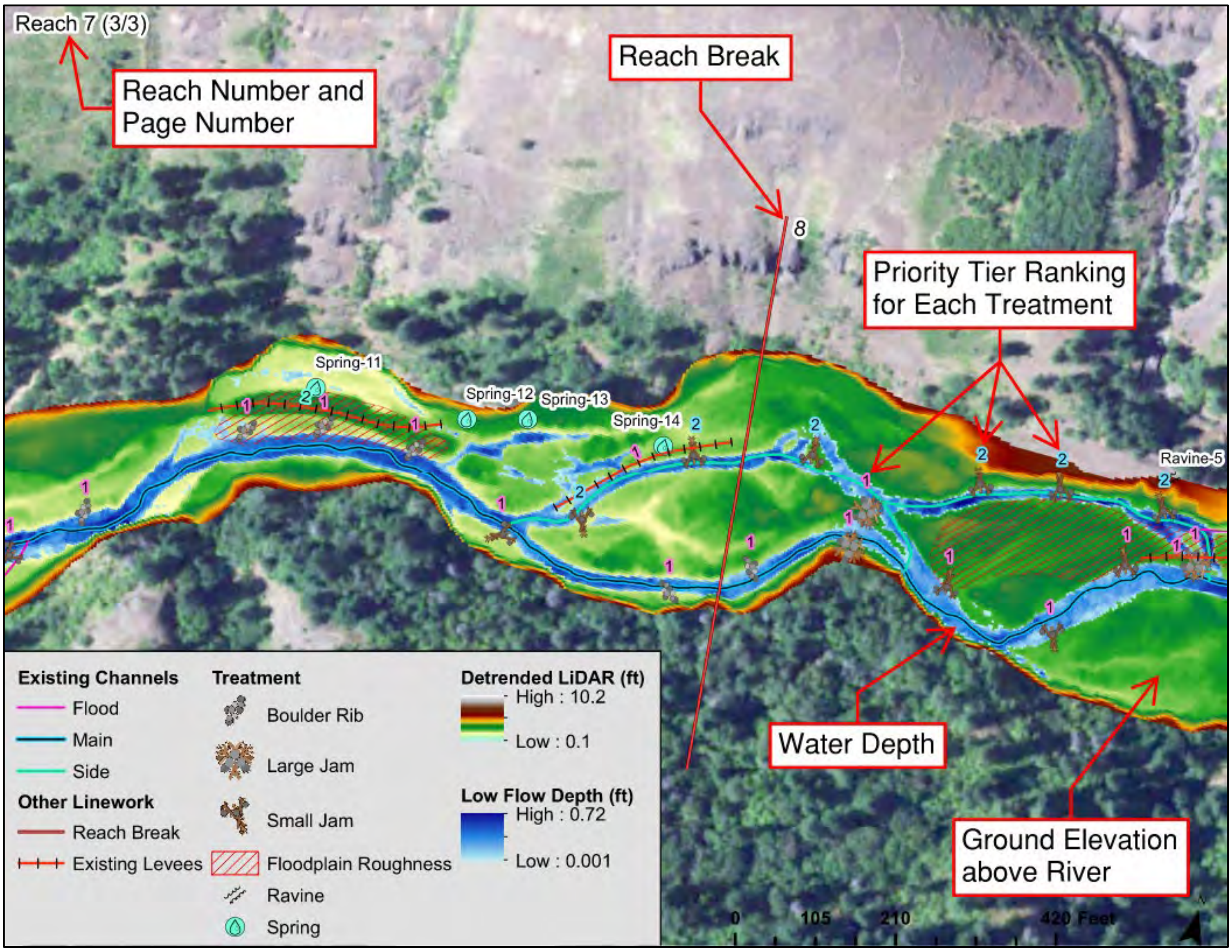


Figure 14. Concept Map Example, including Priority Tier Rankings for each Design Element

Table 7 summarizes the design elements from Appendix A, by reach and priority tier. For the entire 5.3-mile Project reach, a total of 31 boulder ribs, 44 large jams, and 205 small jams have been proposed. The total proposed increase in floodplain roughness is more than 30 acres.

The most restoration would be expected to occur if all the design elements were to be implemented. However, due to potential constraints that are not yet understood (for example, landowner priorities, available construction funding, and permitting considerations), all elements may not be constructable; therefore, the design team recommends first implementing the Tier 1 priorities, then Tier 2, then Tier 3. Additionally, BPA prefers to start large projects at the downstream end and work upstream; therefore, the initial phases of construction may want to focus on Tier 1 priorities near the downstream end. For example, potential projects for the first year of construction might be 3 large jams, 14 small jams, and up to 4 acres of floodplain roughness (top row of Table 7 [Reach 1 Priority Tier 1]). Selection of initial projects will be addressed in future design phases following input from landowners and additional field reconnaissance (for example, wetland and cultural resources investigations).

Table 7. Proposed Design Elements by Reach and Priority Tier for the Project Reach

		Elements (count)				Floodplain Roughness (acres)
Reach	**Priority Tier**	**Boulder Rib**	**Large Jam**	**Small Jam**	**Total Elements**	**Total**
1	1		3	14	17	
1	2			1	1	
1	3		1	11	12	
1	**Total**		**4**	**26**	**30**	**3.66**
2	1		14	20	34	
2	2			13	13	
2	3			16	16	
2	**Total**		**14**	**49**	**63**	**10.31**
3	1		8	10	18	
3	2			8	8	
3	3			19	19	
3	**Total**		**8**	**37**	**45**	**6.55**
4	1		5	10	15	
4	2			2	2	
4	3			13	13	
4	**Total**		**5**	**25**	**30**	**5.95**
5	1	3	3	6	12	
5	2			5	5	
5	3			3	3	
5	**Total**	**3**	**3**	**14**	**20**	**1.96**
6	1	8	3	12	23	

Table 7. Proposed Design Elements by Reach and Priority Tier for the Project Reach

		Elements (count)				Floodplain Roughness (acres)
Reach	Priority Tier	Boulder Rib	Large Jam	Small Jam	Total Elements	Total
6	2			5	5	
6	3			5	5	
6	**Total**	**8**	**3**	**22**	**33**	**0.9**
7	1	15	1	4	20	
7	2	4		2	6	
7	3			2	2	
7	**Total**	**19**	**1**	**8**	**28**	**0.35**
8	1	1	6	15	22	
8	2			5	5	
8	3			4	4	
8	**Total**	**1**	**6**	**24**	**31**	**0.88**
	Grand Total	**31**	**44**	**205**	**280**	**30.56**

3.2.1 Tier 1 Priorities

3.2.1.1 Spring Reconnection

Install porous rock mattresses or culverts at locations where the existing roadway disconnects the natural flow path of groundwater springs. In locations where subsurface flows have been intercepted by the road grade, thus resulting in overland spring seep flows immediately adjacent on the uphill side of the road, a permeable rock mattress is suitable for installation at the road crossing to allow the water to be conveyed subsurface through the roadbed, to reduce thermal warming, improve water temperature, and reduce sediment loading. An aquatic organism passage culvert is recommended for applications where there are concentrated surface flows and favorable habitat conditions present on the upstream side of the road interception. Appendix B discusses the springs reconnection proposed treatment applications in detail.

3.2.1.2 Levee Setback

Relocate the pushup levee from the current location in the channel/floodplain to a new location adjacent to the roadway to maximize the valley bottom area available to the river. Levee setbacks are appropriate in areas where the levee is necessary to protect infrastructure, but the current location of the levee increases downstream flood risk or greatly reduces recovery potential in the reach.

3.2.1.3 Stabilize Secondary Channel Junctions

Use engineered large wood and/or rock structures at locations where secondary channels split off from the main stem channel. The primary goal of these structures is to increase stability at channel junctions to limit whole-sale channel changes and extensive bed scour during the next large flood event. Secondarily, these structures may be used to preferentially direct flows toward either channel at the junction. Key locations include the upstream end of islands and bars, and where flood channels have recently developed. These structures should be at least partially buried in the streambed to increase efficacy and stability.

3.2.1.4 Habitat Structures Within the Main Stem

Add large wood and/or rock structures throughout the main stem channel to provide improved salmonid habitat. Structures are expected to trap and sort sediment, create and maintain pools and riffles, and provide water velocity and predation refuge for salmonids. Some structures will be placed to enhance existing habitat, while others will be distributed systematically throughout homogenous plane-bed sections to create new habitat as they interact with high flows. Ballasted wood structures are most suitable for unconfined and partly confined reaches, whereas rock structures are best suited for confined reaches.

3.2.2 Tier 2 Priorities

3.2.2.1 Levee Modification

Remove or alter the pushup levee in the channel/floodplain. Some pushup levees are unnecessary as they hinder (rather than help) the river and increase flood risk downstream. These levees should be removed if there is no infrastructure to protect them, and would allow for greater energy dissipation from flood events. Likewise, portions of levees may be perforated at key locations to allow for floodplain or secondary channel connection.

3.2.2.2 Habitat Structures Within Side Channels

Add large wood structures throughout perennial side channels to enhance and create salmonid habitat. Structures are smaller than those placed in the main stem, but they provide similar benefits.

3.2.2.3 Increase Floodplain Roughness

Add large wood structures and/or riparian plantings within the valley bottom to increase floodplain roughness and kick-start riparian recovery. The primary locations for this treatment include areas where topsoil has eroded, leaving exposed cobble/gravel sheets. Increasing roughness is expected to: improve fine sediment retention on the floodplain; improve survival of riparian plantings and naturally recruited vegetation; and increase resiliency of flood channels. Low-tech structures, such as PALS, may be suitable for these areas.

3.2.3 Tier 3 Priorities

3.2.3.1 Levee Abandonment

Take no action to remove or alter the pushup levee, and allow the river to work with the material, as placed.

3.2.3.2 Habitat Structures Within Flood Channels

Add large wood structures to flood channels to improve high flow velocity refuge for salmonids, trap and sort sediment during floods, direct flood flows in preferential directions, and increase resiliency to future flood events. These structures are like those placed within side channels, but unless primary flow paths change, they will only be functional during flood events.

4. Recommended Restoration Monitoring Considerations

With baseline pre-Project data (field, LiDAR, and drone imagery), well-defined goals and objectives, and a potential restoration of more than 5 miles of river, the Project is ideally suited for efficient implementation and effectiveness monitoring. Cramer recently developed an implementation and effectiveness monitoring plan for the BPA Action Effectiveness Monitoring program and the Washington Salmon Recovery Funding Board (SRFB), specifically for evaluating large floodplain restoration projects like the Project (Roni et al. 2020). This approach and methodology, which are based on reviewing and testing the latest methods (Roni et al. 2019), are designed to efficiently evaluate overall physical and biological responses, as well as success of design elements using a combination of the latest remote sensing techniques (for example, green LiDAR and aerial imagery) and rapid field surveys.

The methodology requires pre-Project surveys (LiDAR plus traditional habitat surveys), as-built conditions, and flow-based post-treatment monitoring. It uses a simple before- and after-design with post-treatment data collection only after adequate flows have occurred, to create measurable changes. Thus, it can leverage the green LiDAR and field surveys already collected by WWBWC followed by similar postrestoration surveys. It also uses a combination of hydraulic and habitat suitability modeling to quantify changes in suitable spawning and rearing habitat at base, bankfull, and other flows. This approach provides quantifiable proof of physical habitat and biological improvement over time directly tied to specific Project design elements and actions; therefore, the design team recommends using a similar approach to evaluate and adaptively manage the Project.

Like any successful implementation and effectiveness monitoring program, the plan needs to have clear questions based on the goals, the Smart, Measurable, Attainable, Relevant, Timebound (SMART) objectives, and the scale of the Project and monitoring. These should be developed as part of the conceptual, preliminary, and final design process. Based on the goals, objectives, and conceptual design, the monitoring plan should include questions to determine whether the Project has effectively:

- Increased the frequency, duration, and volume of flow on the floodplain (LiDAR and hydraulic model)
- Raised groundwater levels to establish and increase riparian vegetation growth and survival (LiDAR, aerial imagery, and groundwater wells, if desired)
- Decreased channel shear stress, reduced scour, and increased sediment deposition and vegetation establishment (hydraulic model, LiDAR, and Digital Elevation Model of difference)
- Increased the connectivity of side channels at low and high flows (LiDAR and hydraulic model)
- Protected and enhanced the connectivity of springs within the off-channel and main stem (LiDAR, aerial imagery, and field data)
- Increased the diversity and complexity of habitat both within the channel and on the floodplain (LiDAR and rapid field survey)
- Improved water temperature and turbidity (field data and dataloggers)
- Increased the quality and quantity of suitable juvenile and adult salmon rearing habitat and invertebrate habitat (LiDAR and hydraulic and habitat suitability modeling)
- Increased the diversity of riparian and wetland habitat (LiDAR and aerial imagery)

Key metrics for most of these questions can be selected from ongoing BPA and SRFB monitoring (Roni et al. 2019, 2020). Quantifiable targets to evaluate physical and biological response and effectiveness of key design elements (for example, large wood structures, side channel connectivity, and levees) will be developed during the preliminary or final design phase. With the exception of temperature, many of these questions and their associated metrics can be assessed with remote sensing, including green LiDAR, aerial imagery, hydraulic modeling, and compared during pre-Project, as-built, and post-Project phases. Simple temperature loggers, ground water wells, and water quality monitoring can be added, depending upon the level of resolution and specific targets set during the final design phase. The final components of the monitoring approach will be analysis and reporting and development of an adaptive management approach that is consistent with WWBWC and landowner goals, should the monitoring indicate deviations from Project SMART objectives and targets.

5. Anticipated Future Design Tasks

Following review and endorsement of this Concept Design Report by the landowners, BPA, and WWBWC, the design team is prepared to help WWBWC advance this concept design toward permitting and final design. The design team proposes the following steps for consideration by BPA and WWBWC:

- Prepare for and conduct one private landowner meeting to present and discuss the conceptual design presented herein.
- Following 1-month reviews of the conceptual design by the WWBWC, landowners, and BPA, and acceptance of the proposed design approach and tiered priorities, prepare the detailed design and construction documents for the Tier 1 priority actions with interim milestone deliverable packages at 60% and 90% complete levels.
- Refine the hydraulic model and perform 2D hydraulic modeling of the Tier 1 priority actions to characterize the projected implementation responses and inform the detailed design.
- Perform sediment transport analysis.
- Perform a site-specific wetland delineation survey and report to satisfy state and federal requirements.
- Develop construction cost estimates for the Tier 1 priority actions delineated by the reach from downstream to upstream.

6. References

Chow, V. T. 1959. *Open-Channel Hydraulics*. McGraw Hill Book Company, Inc.

Fox, M., and S. Bolton. 2007. "A Regional and Geomorphic Reference for Quantities and Volumes of Instream Wood in Unmanaged Forested Basins of Washington State." *North American Journal of Fisheries Management*. Vol. 27, No. 1. pp. 342–359.

Moore, K., K. Jones, J. Dambacher, C. Stein, et al. 2017. *Aquatic Inventories Project, Conservation and Recovery Program*. Version 27.1. Corvallis, Oregon: Oregon Department of Fish and Wildlife. May

Oregon Department of Environmental Quality (DEQ). 2005. *Walla Walla Subbasin Stream Temperature Total Maximum Daily Load and Water Quality Management Plan*. August.

Roni, P., C. Clark, K. Ross, R. Camp, M. Krall, J. Hall, and R. Brown. 2020. *Using remote sensing and other techniques to assess and monitor large floodplain and riparian restoration projects*. Olympia, Washington: Recreation and Conservation Office.

Roni, P., J. E. Hall, S. M. Drenner, and D. Arterburn. 2019. "Monitoring the effectiveness of floodplain habitat restoration: A review of methods and recommendations for future monitoring." *Wiley Interdisciplinary Reviews: Water*. Vol. 6, No.4.

Selong, J.H., T.E. McMahon, A.V. Zale, and F.T. Barrows. 2001. "Effect of temperature on growth and survival of bull trout, with application of an improved method for determining thermal tolerance in fishes." *Transactions of the American Fisheries Society*. Vol. 130. pp.1026-1037.

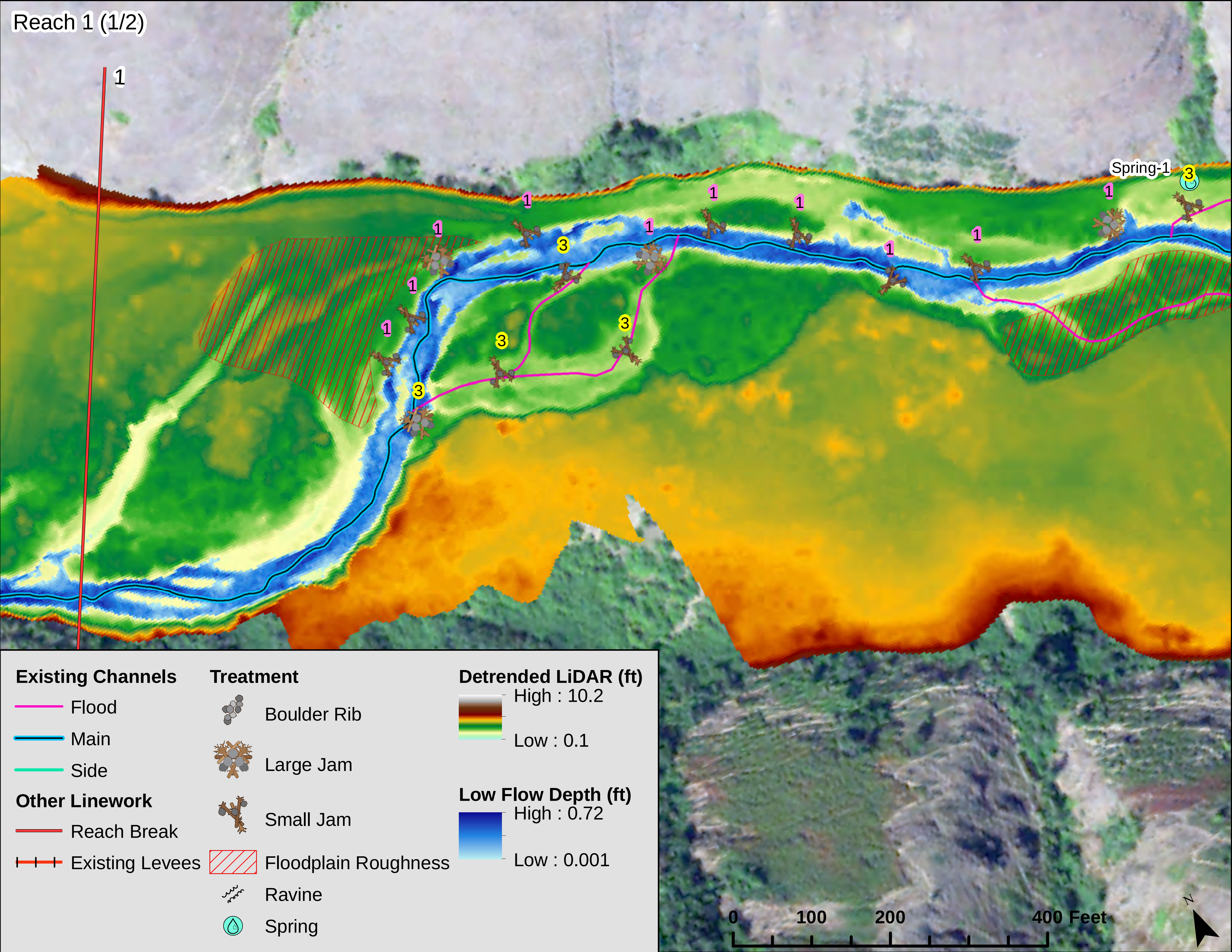
U.S. Army Corps of Engineers (USACE). 1994. *Channel Stability Assessment for Flood Control Projects*. Engineering Manual 1110-2-1418. https://www.publications.usace.army.mil/Portals/76/Publications/EngineerManuals/em_1110-2-1418.pdf.

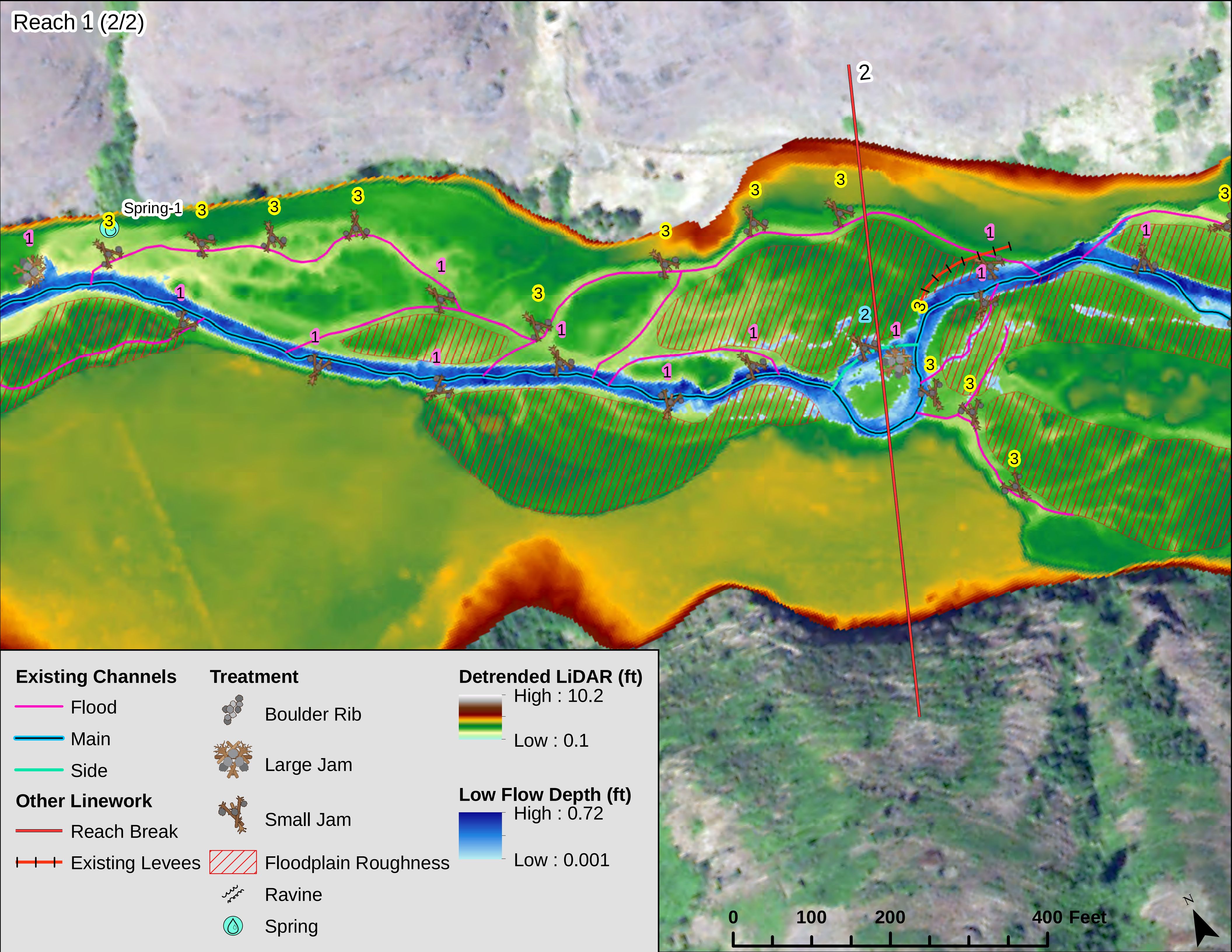
U.S. Army Corps of Engineers (USACE). 2016. *HEC-RAS River Analysis System User's Manual*. Davis, California: U.S. Army Corps of Engineers Hydrologic Engineering Center.

Walla Walla Basin Watershed Council (WWBWC). 2021. *Walla Walla River Habitat Assessment Summary*. May.

Walla Walla Watershed Planning Unit (WWWPU) and Walla Walla Basin Watershed Council (WWBWC). 2004. *Walla Walla Subbasin Plan*. Prepared for Northwest Power and Conservation Council.

Appendix A
Conceptual Design Concept Maps


Reach 1 (1/2)
1
Spring-1
1
3
Existing Channels
Flood
Main
Side
Other Linework
Reach Break
Existing Levees
Treatment
Boulder Rib
Large Jam
Small Jam
Floodplain Roughness
Ravine
Spring
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
Low Flow Depth (ft)
High : 0.72
Low : 0.001
0
100
200
400 Feet
N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Existing Channels
Flood
Main
Side
Other Linework
Reach Break
Existing Levees
Treatment
Boulder Rib
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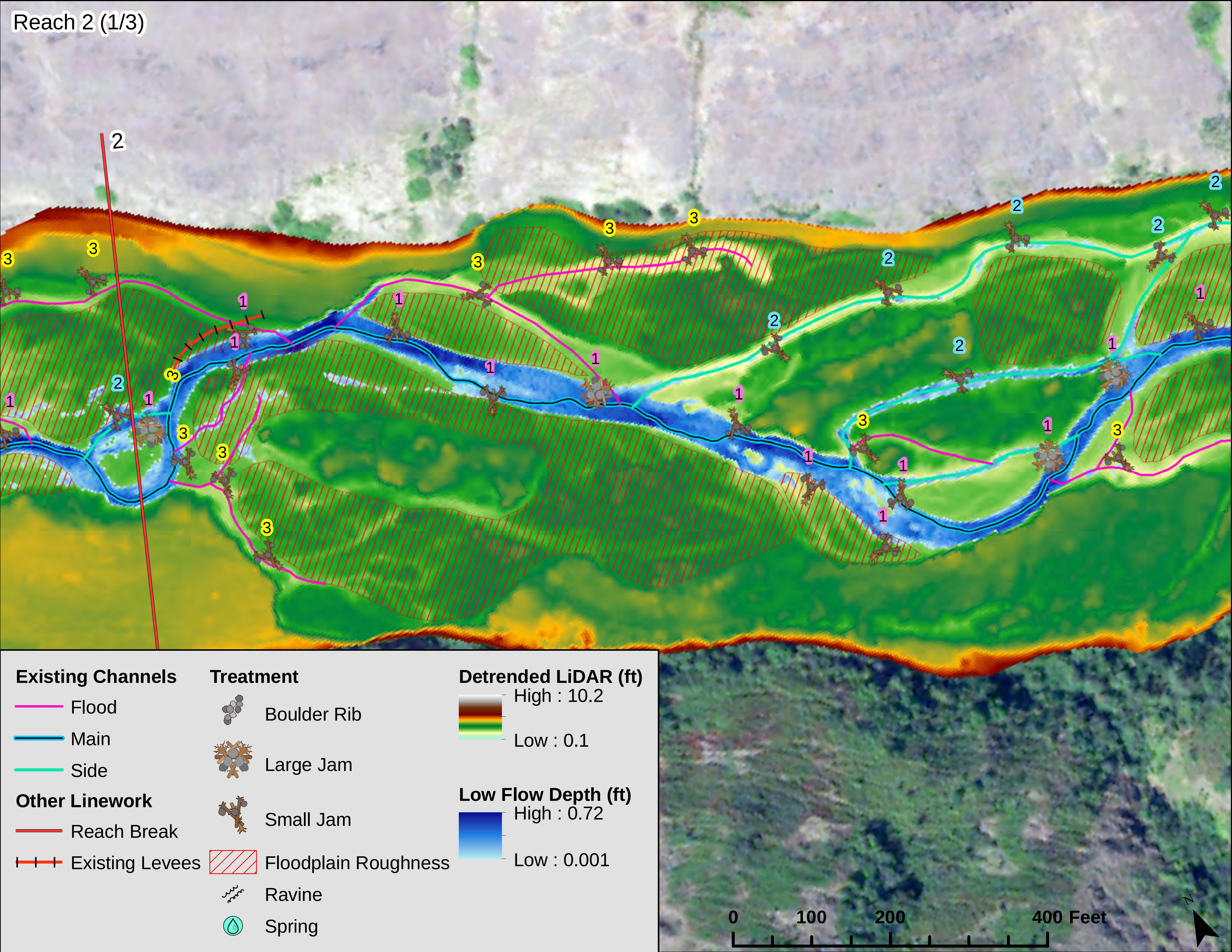
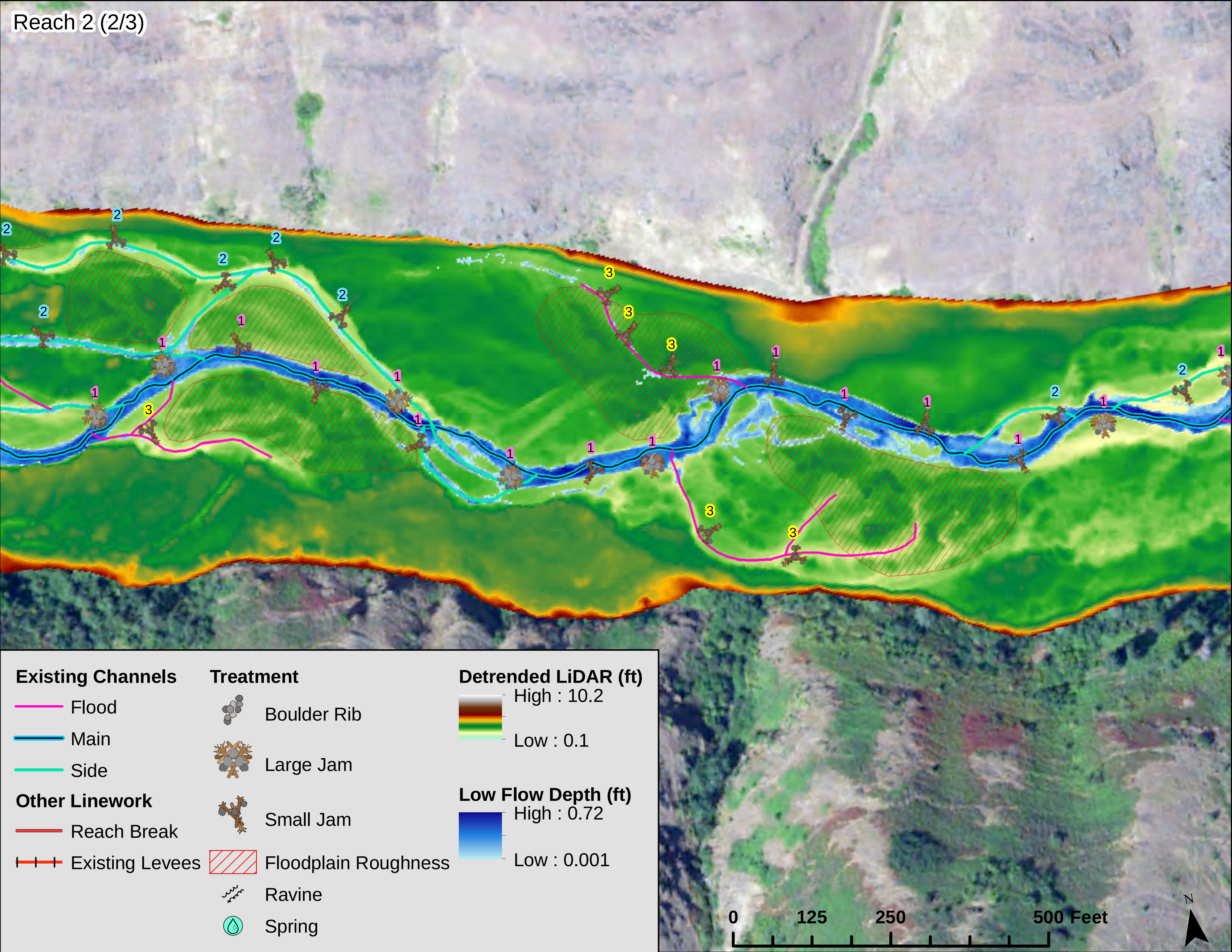
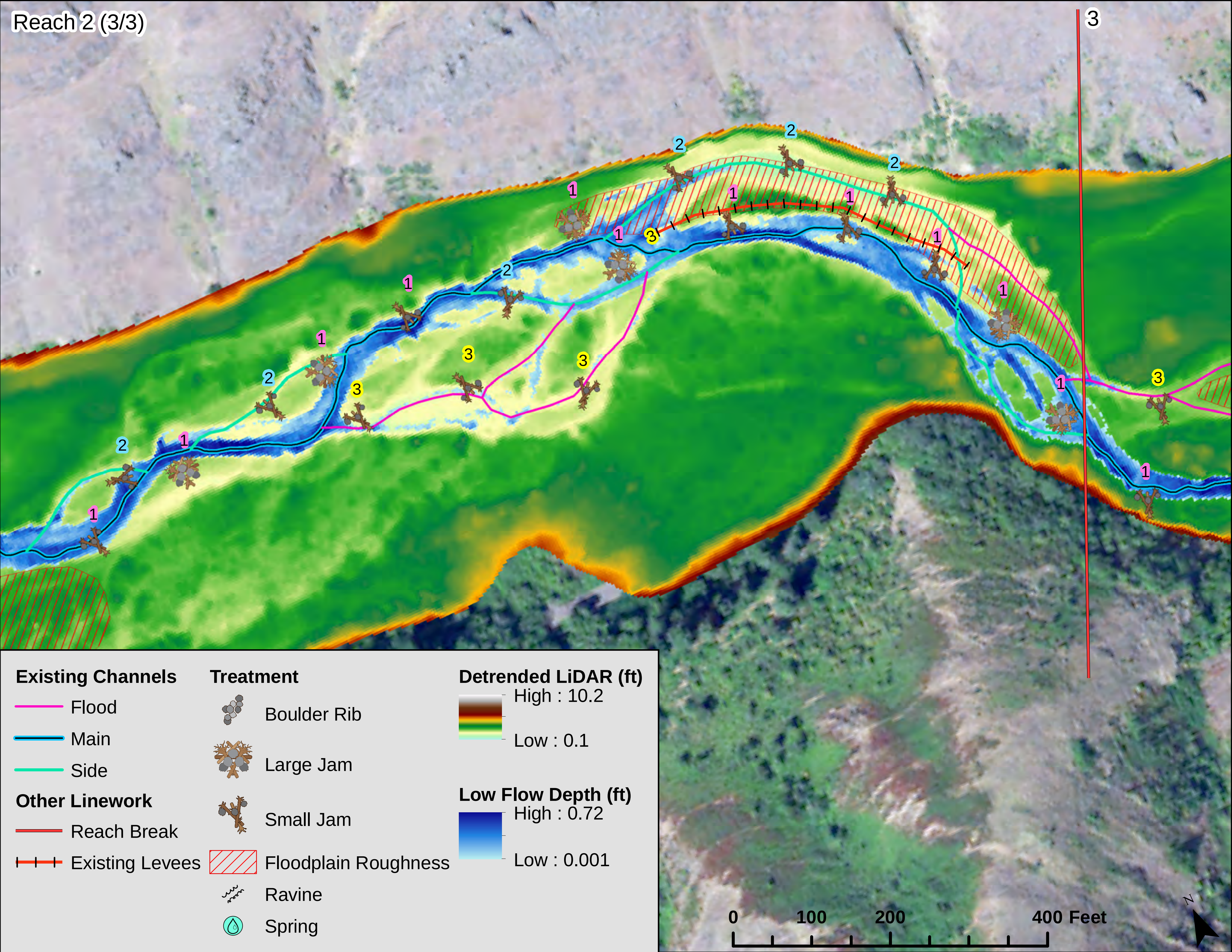
Small Jam
Floodplain Roughness
Ravine
Spring
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
Low Flow Depth (ft)
High : 0.72
Low : 0.001
0
100
200
400 Feet
N



Reach 2 (1/3)
2
Existing Channels
Flood
Main
Side
Other Linework
Reach Break
Existing Levees
Treatment
Boulder Rib
Large Jam
Small Jam
Floodplain Roughness
Ravine
Spring
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
Low Flow Depth (ft)
High : 0.72
Low : 0.001
0 100 200 400 Feet
N


Reach 2 (2/3)
Existing Channels
Flood
Main
Side
Other Linework
Reach Break
Existing Levees
Treatment
Boulder Rib
Large Jam
Small Jam
Floodplain Roughness
Ravine
Spring
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
Low Flow Depth (ft)
High : 0.72
Low : 0.001
0
125
250
500 Feet
N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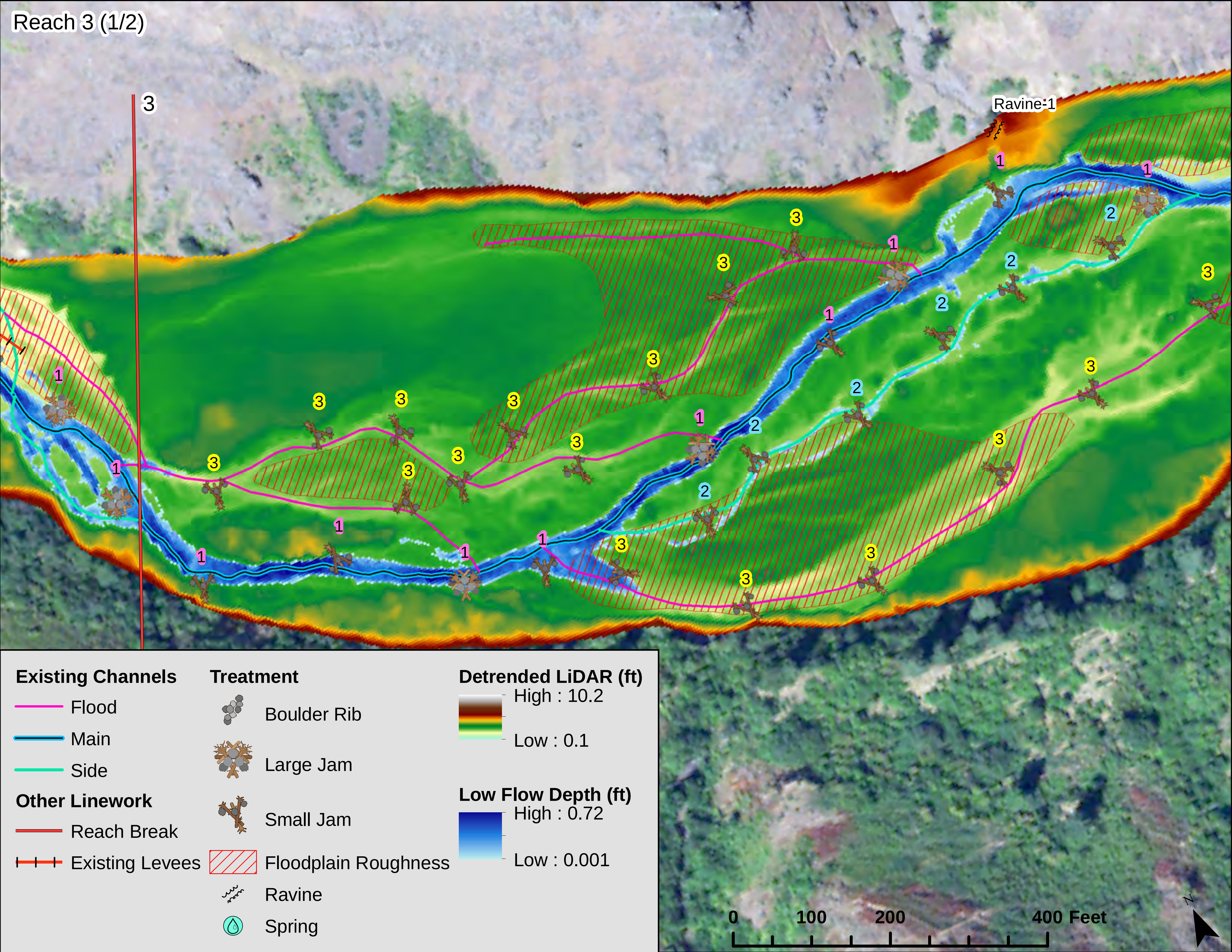
Existing Channels
Flood
Main
Side
Other Linework
Reach Break
Existing Levees
Treatment
Boulder Rib
Large Jam
Small Jam
Floodplain Roughness
Ravine
Spring
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
Low Flow Depth (ft)
High : 0.72
Low : 0.001
0
100
200
400 Feet
N


Reach 3 (1/2)
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Ravine-1
Existing Channels
Flood
Main
Side
Other Linework
Reach Break
Existing Levees
Treatment
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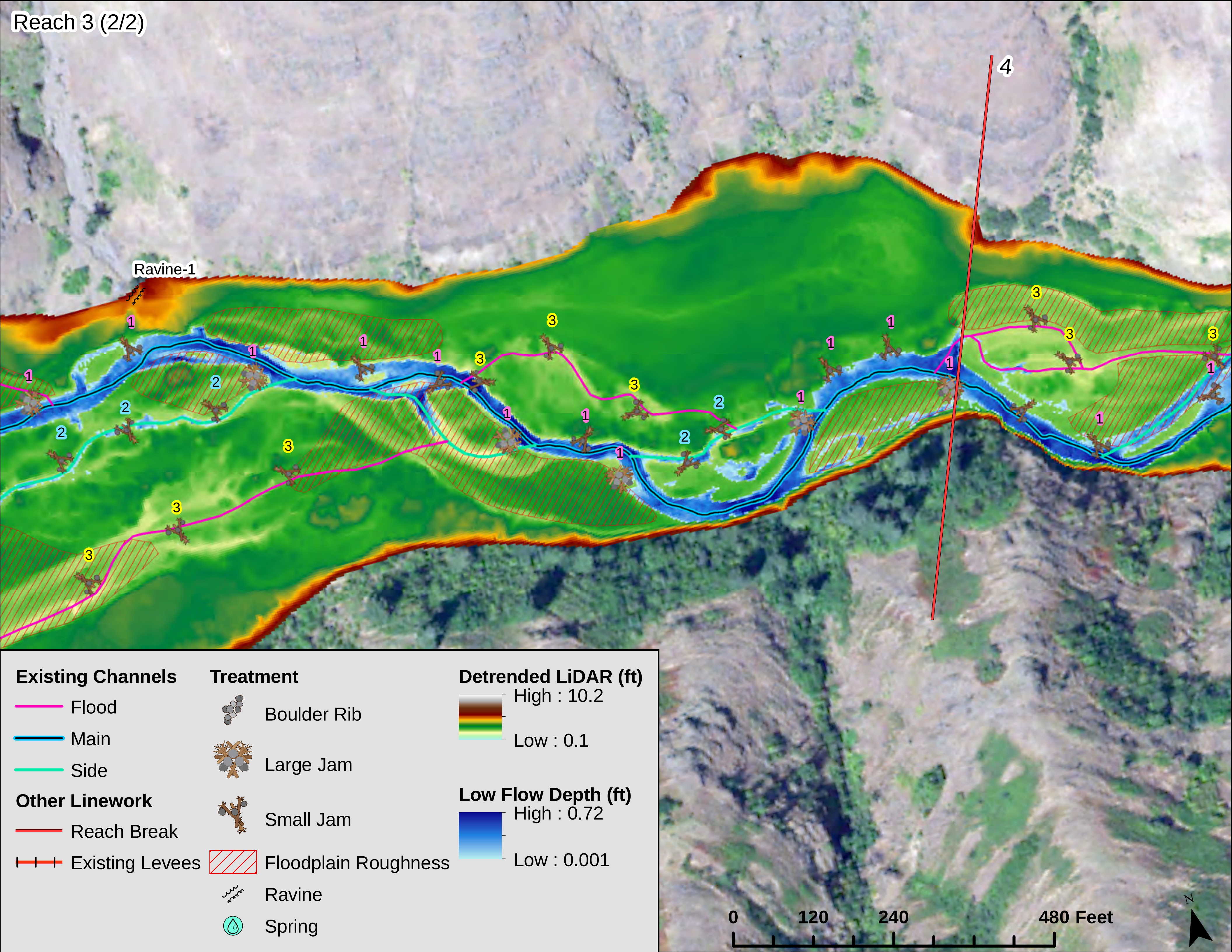
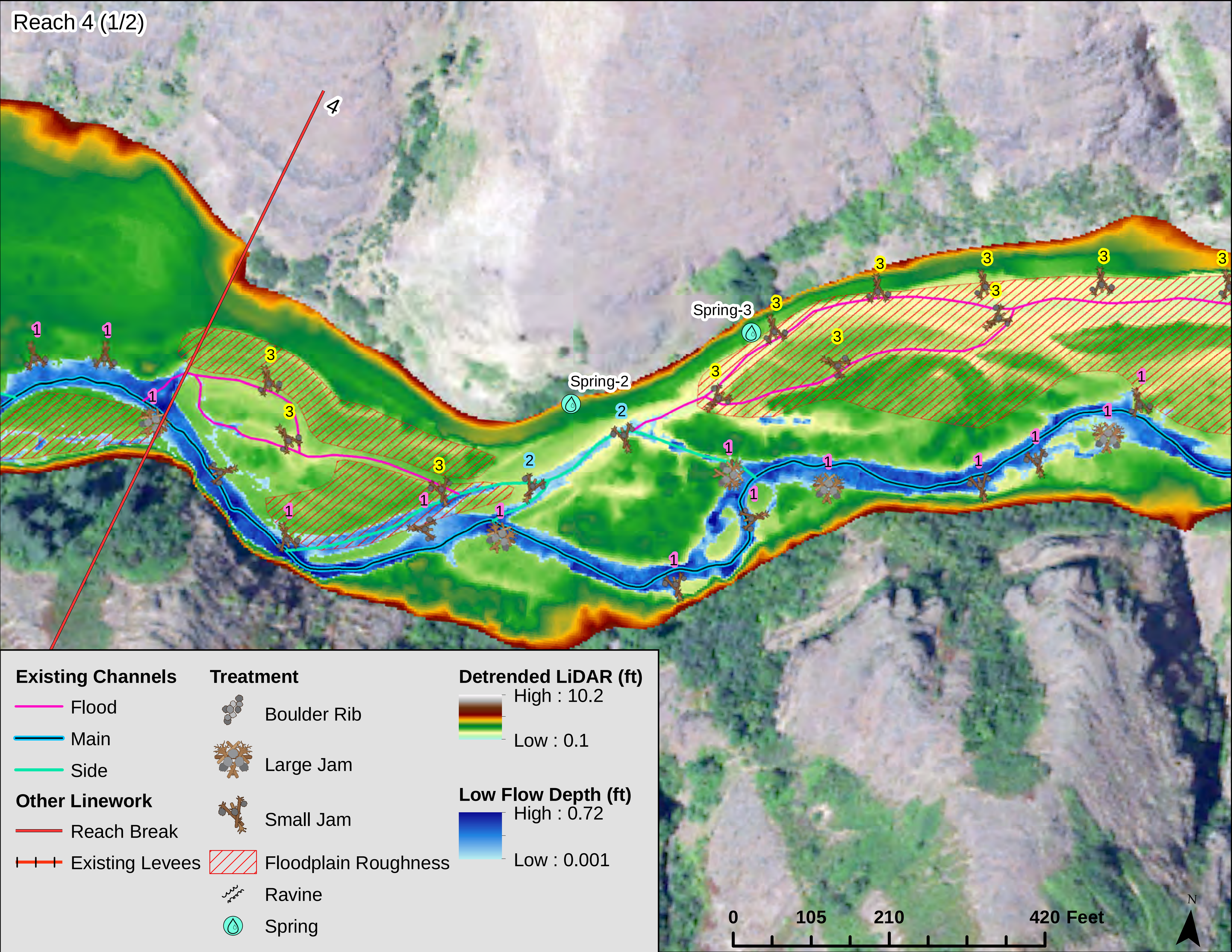
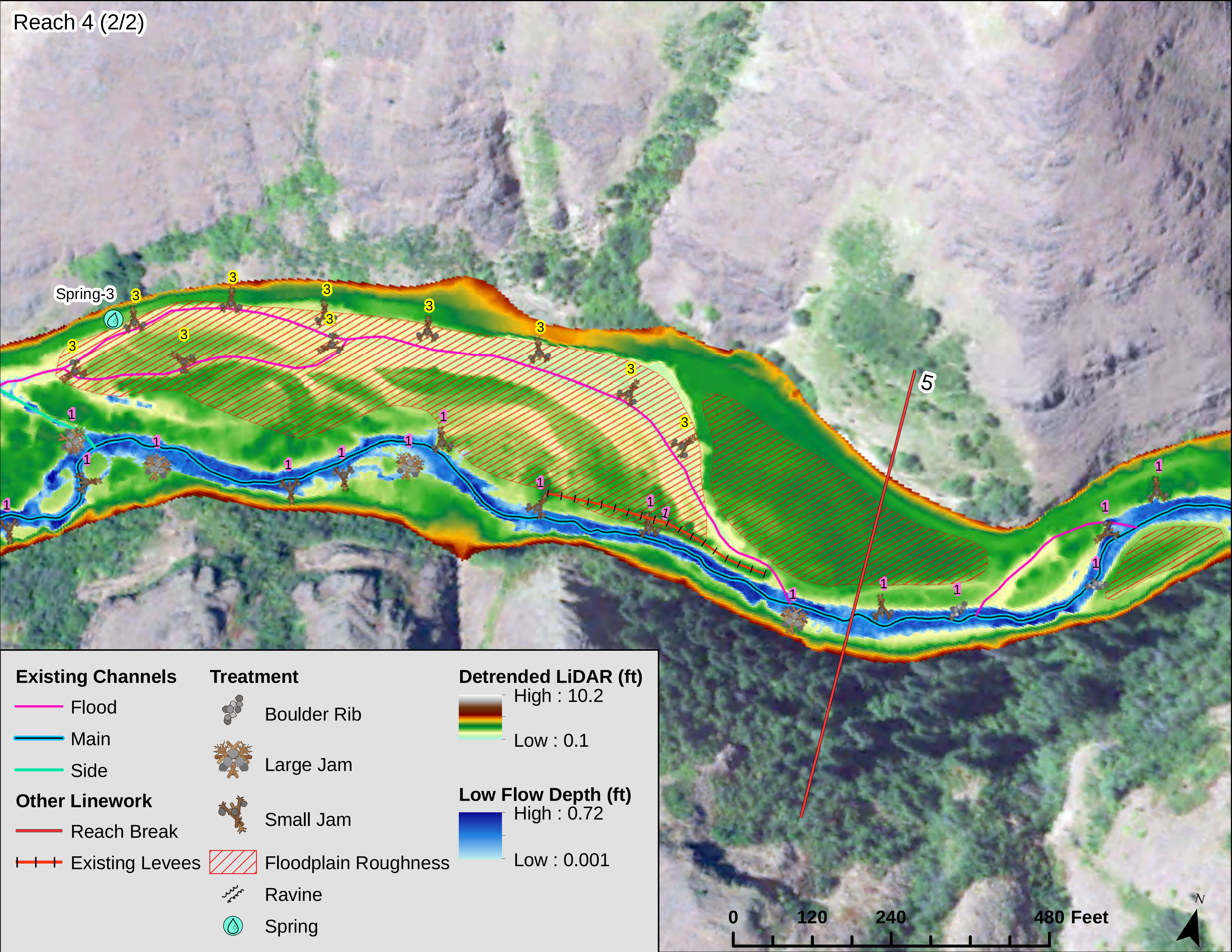
Large Jam
Small Jam
Floodplain Roughness
Ravine
Spring
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
Low Flow Depth (ft)
High : 0.72
Low : 0.001
0
100
200
400 Feet
N



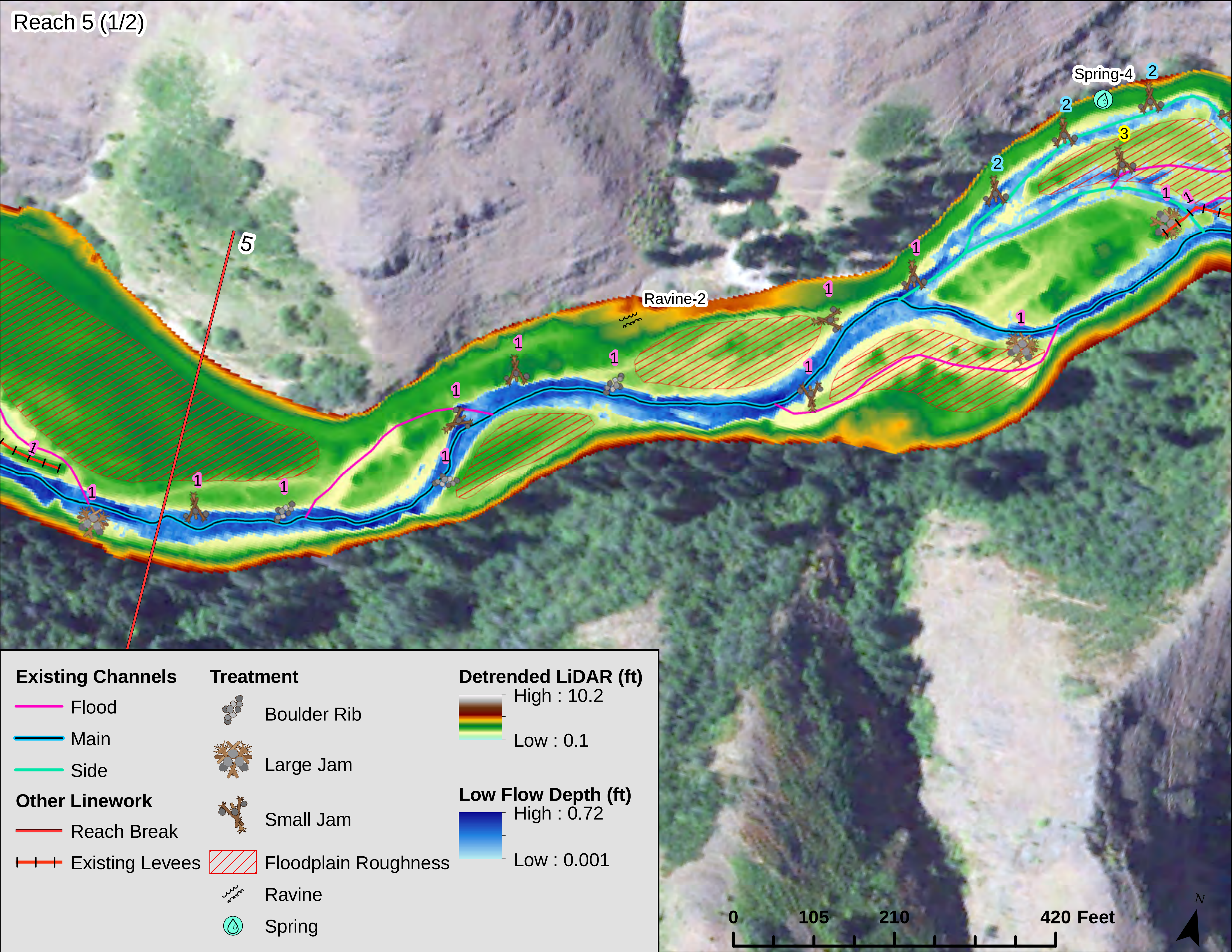
Reach 3 (2/2)
4
Ravine-1
Existing Channels
Flood
Main
Side
Other Linework
Reach Break
Existing Levees
Treatment
Boulder Rib
Large Jam
Small Jam
Floodplain Roughness
Ravine
Spring
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
Low Flow Depth (ft)
High : 0.72
Low : 0.001
0
120
240
480 Feet
N

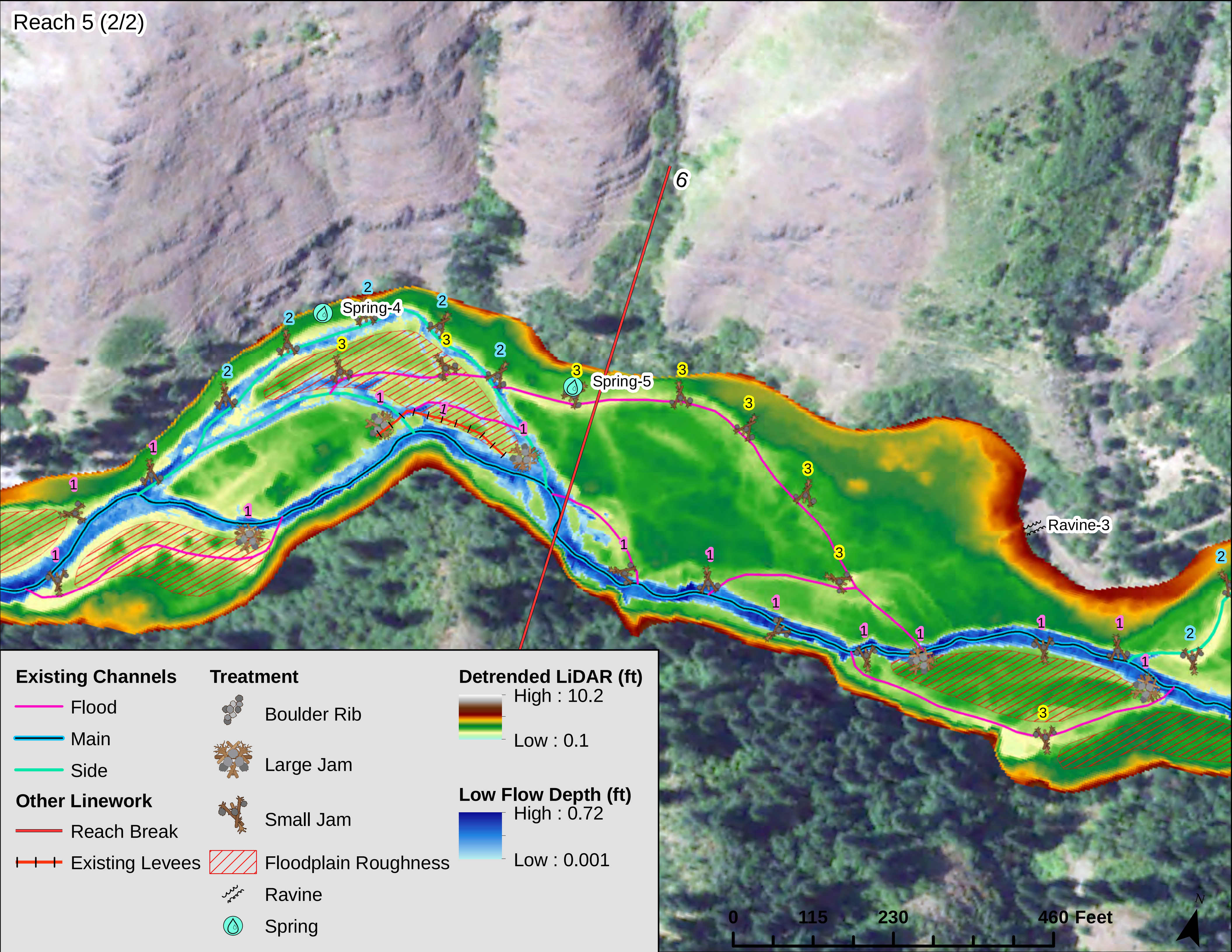


Reach 4 (1/2)
4
Spring-2
Spring-3
1
2
3
Existing Channels
Flood
Main
Side
Other Linework
Reach Break
Existing Levees
Treatment
Boulder Rib
Large Jam
Small Jam
Floodplain Roughness
Ravine
Spring
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
Low Flow Depth (ft)
High : 0.72
Low : 0.001
0
105
210
420 Feet
N

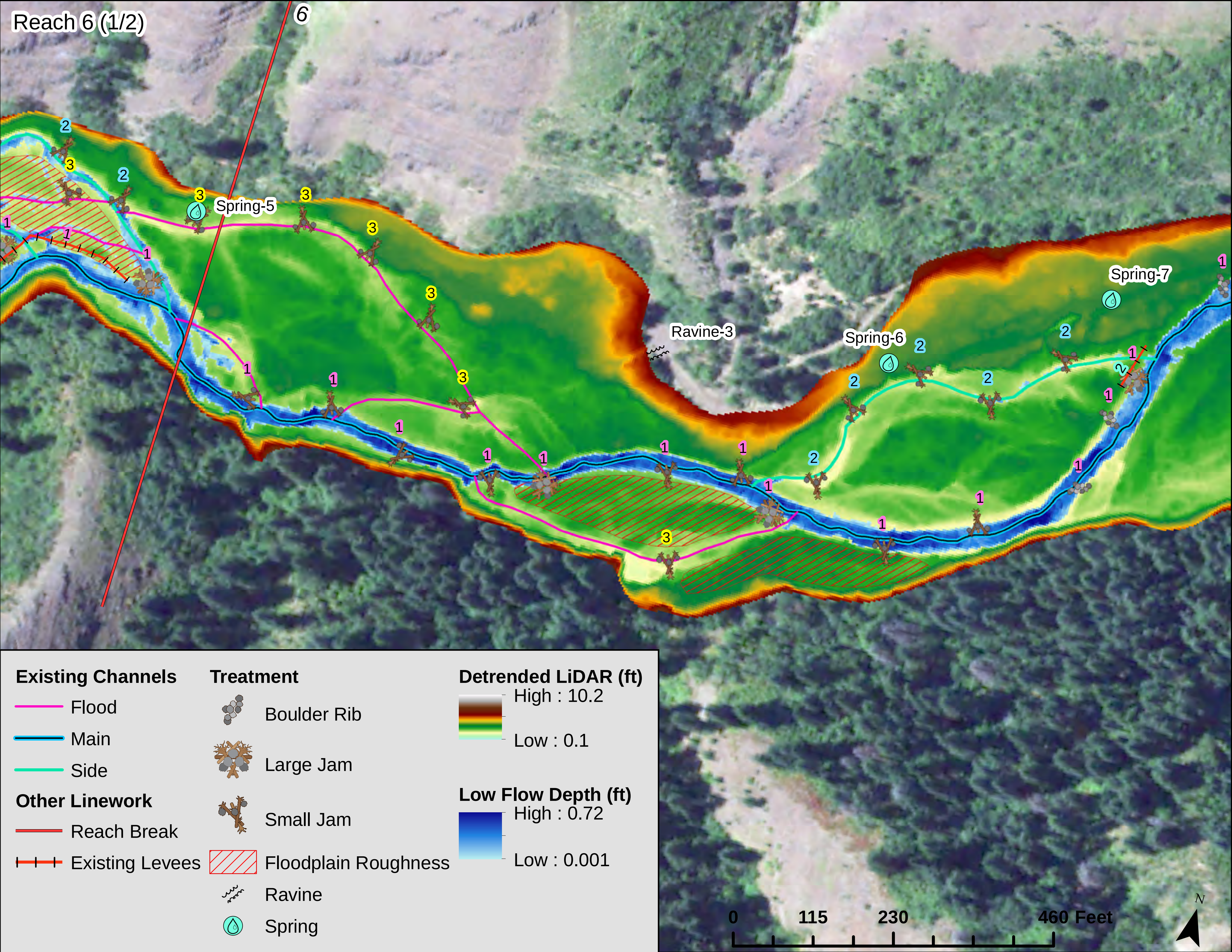


Reach 4 (2/2)
Spring-3
5
Existing Channels
Flood
Main
Side
Other Linework
Reach Break
Existing Levees
Treatment
Boulder Rib
Large Jam
Small Jam
Floodplain Roughness
Ravine
Spring
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
Low Flow Depth (ft)
High : 0.72
Low : 0.001
0 120 240 480 Feet
N

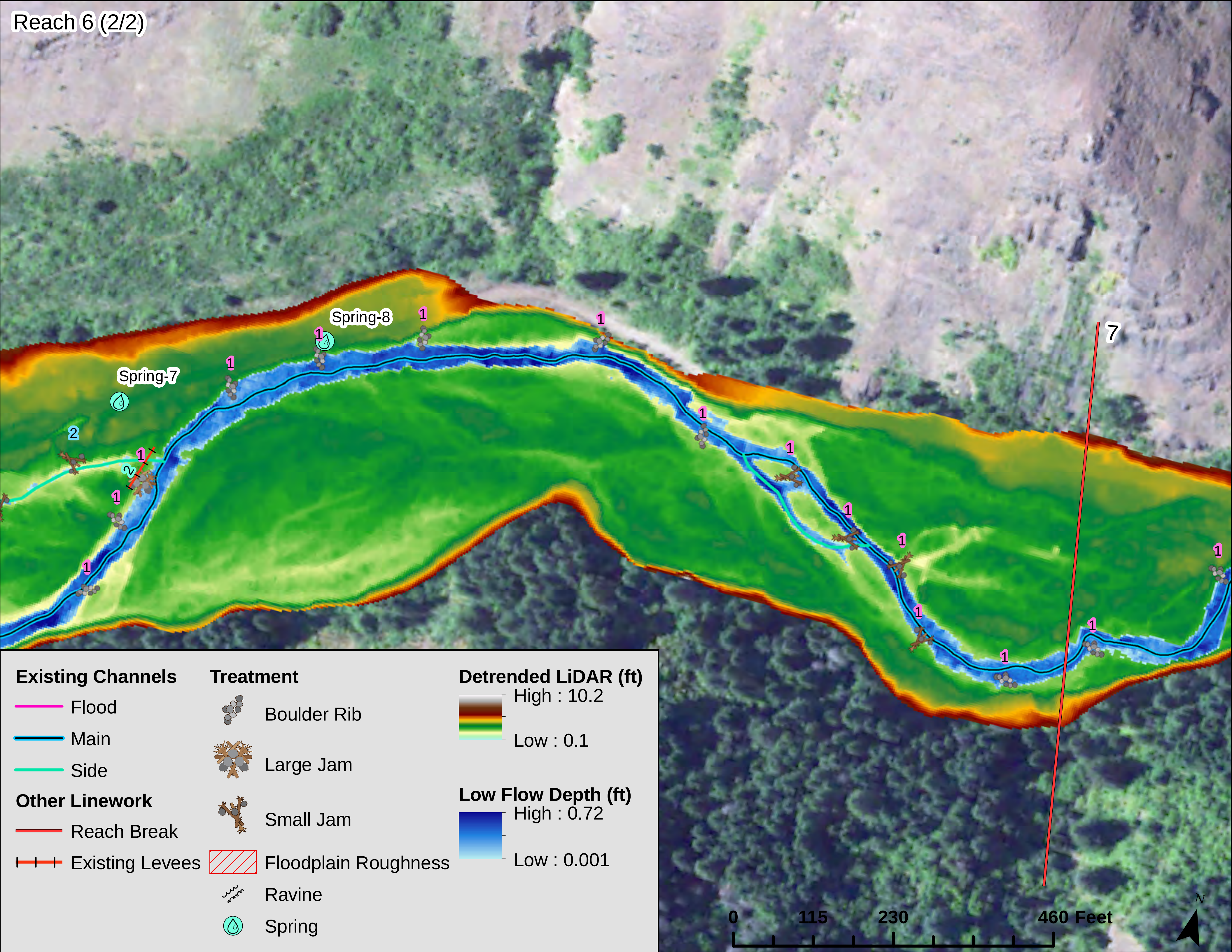

Reach 5 (1/2)
5
Ravine-2
Spring-4
Existing Channels
Flood
Main
Side
Other Linework
Reach Break
Existing Levees
Treatment
Boulder Rib
Large Jam
Small Jam
Floodplain Roughness
Ravine
Spring
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
Low Flow Depth (ft)
High : 0.72
Low : 0.001
0
105
210
420 Feet
N



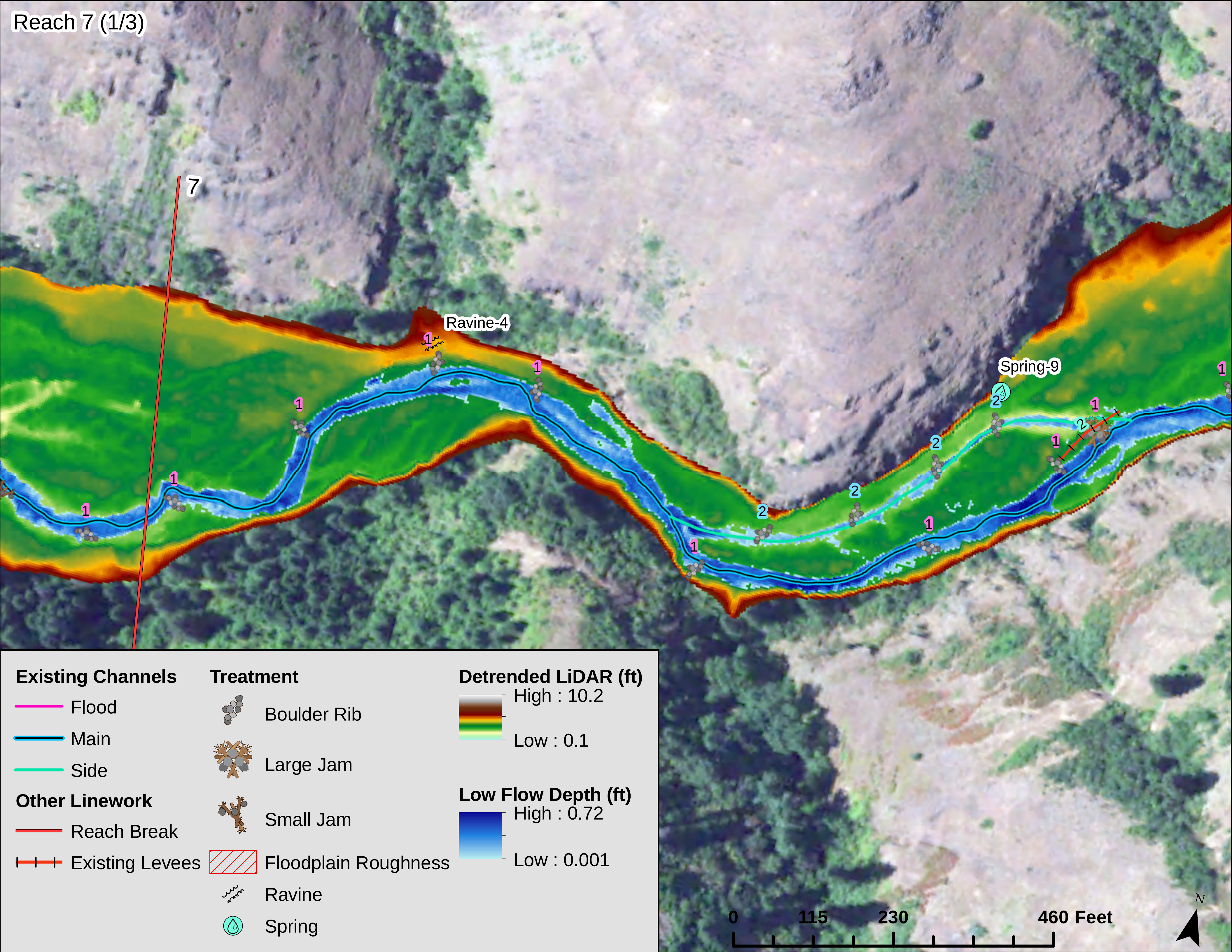
Reach 5 (2/2)
6
Spring-4
Spring-5
Ravine-3
Existing Channels
Flood
Main
Side
Other Linework
Reach Break
Existing Levees
Treatment
Boulder Rib
Large Jam
Small Jam
Floodplain Roughness
Ravine
Spring
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
Low Flow Depth (ft)
High : 0.72
Low : 0.001
0
115
230
460 Feet
N

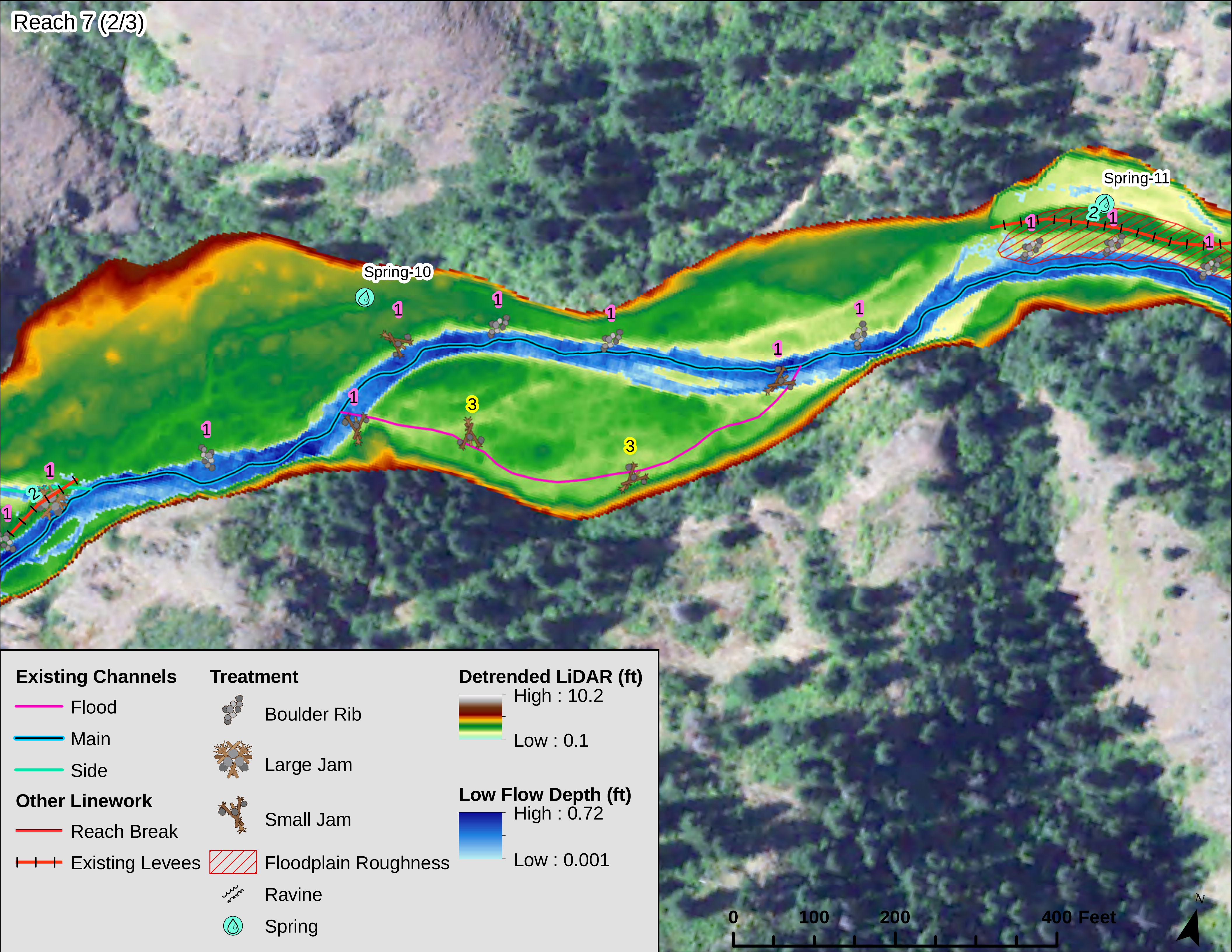


Reach 6 (1/2)
6
Spring-5
Ravine-3
Spring-6
Spring-7
Existing Channels
Flood
Main
Side
Other Linework
Reach Break
Existing Levees
Treatment
Boulder Rib
Large Jam
Small Jam
Floodplain Roughness
Ravine
Spring
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
Low Flow Depth (ft)
High : 0.72
Low : 0.001
0
115
230
460 Feet
N

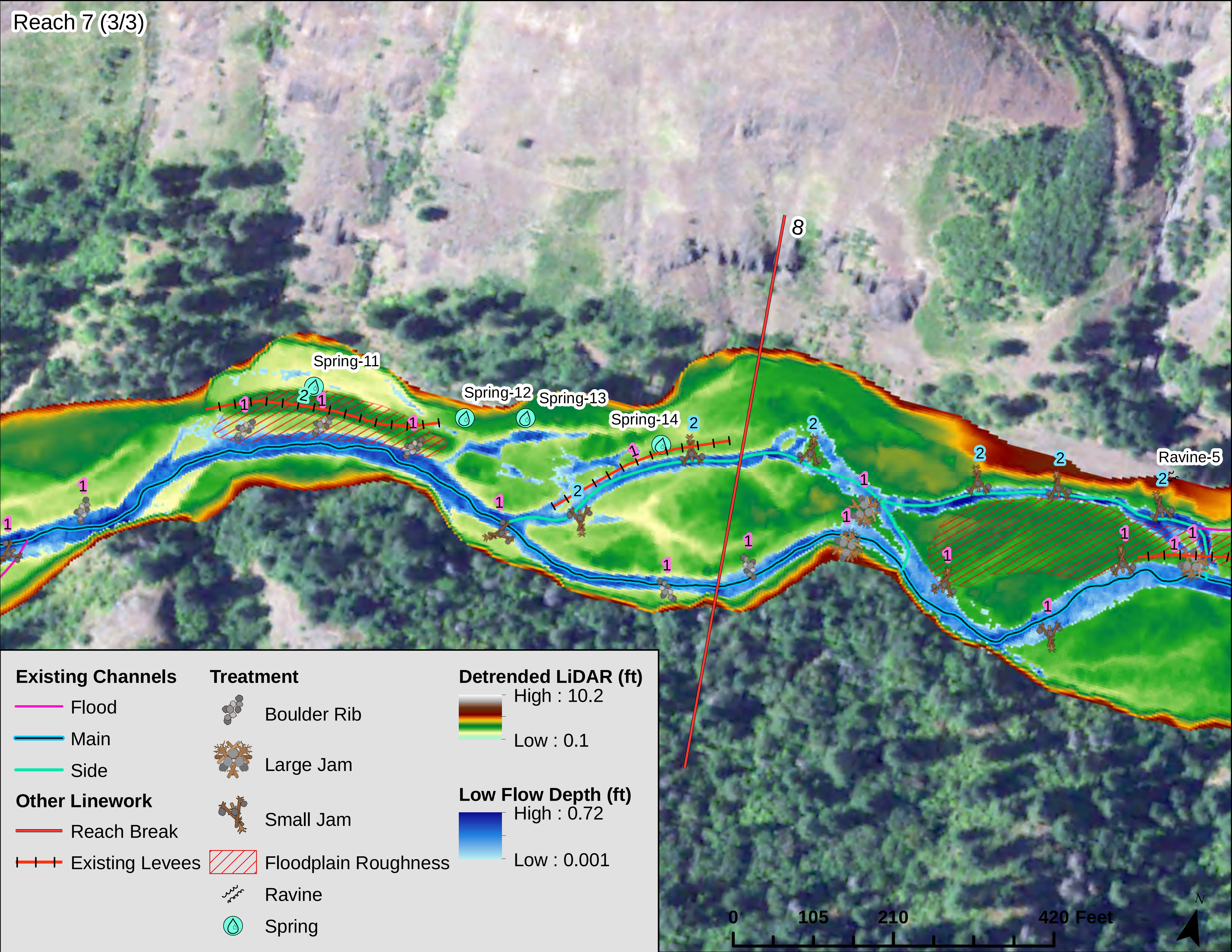


Reach 6 (2/2)
Spring-7
Spring-8
7
Existing Channels
Flood
Main
Side
Other Linework
Reach Break
Existing Levees
Treatment
Boulder Rib
Large Jam
Small Jam
Floodplain Roughness
Ravine
Spring
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
Low Flow Depth (ft)
High : 0.72
Low : 0.001
0
115
230
460 Feet
N

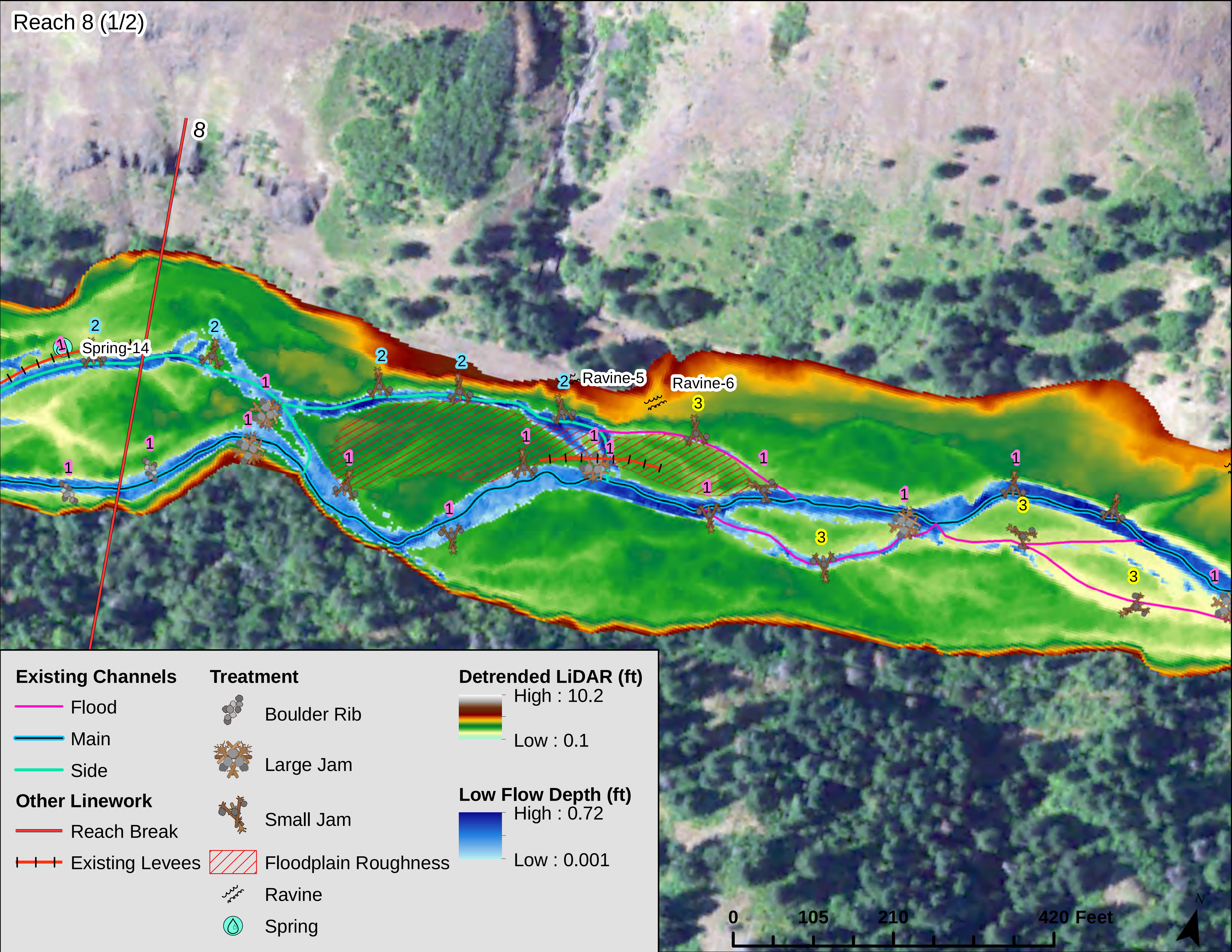

Reach 7 (1/3)
7
Ravine-4
Spring-9
1
2
Existing Channels
Flood
Main
Side
Other Linework
Reach Break
Existing Levees
Treatment
Boulder Rib
Large Jam
Small Jam
Floodplain Roughness
Ravine
Spring
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
Low Flow Depth (ft)
High : 0.72
Low : 0.001
0
115
230
460 Feet
N



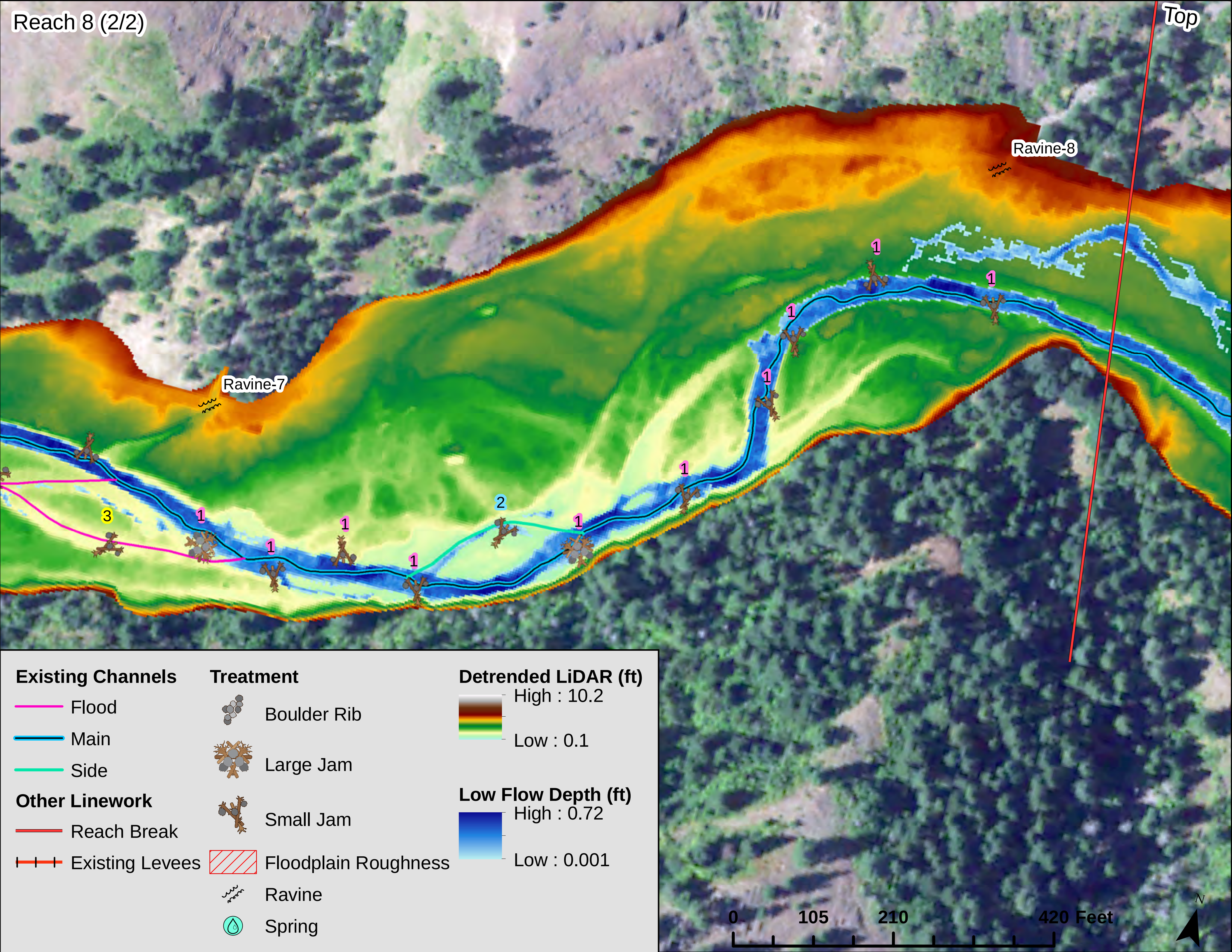
Reach 7 (2/3)
Spring-10
Spring-11
1
2
3
Existing Channels
Flood
Main
Side
Other Linework
Reach Break
Existing Levees
Treatment
Boulder Rib
Large Jam
Small Jam
Floodplain Roughness
Ravine
Spring
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
Low Flow Depth (ft)
High : 0.72
Low : 0.001
0
100
200
400 Feet
N



Reach 7 (3/3)
8
Spring-11
Spring-12
Spring-13
Spring-14
Ravine-5
Existing Channels
Flood
Main
Side
Other Linework
Reach Break
Existing Levees
Treatment
Boulder Rib
Large Jam
Small Jam
Floodplain Roughness
Ravine
Spring
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
Low Flow Depth (ft)
High : 0.72
Low : 0.001
0 105 210 420 Feet
N



Reach 8 (1/2)
8
Spring-14
Ravine-5
Ravine-6
Existing Channels
Flood
Main
Side
Other Linework
Reach Break
Existing Levees
Treatment
Boulder Rib
Large Jam
Small Jam
Floodplain Roughness
Ravine
Spring
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
Low Flow Depth (ft)
High : 0.72
Low : 0.001
0
105
210
420 Feet
N



Reach 8 (2/2)
Top
Ravine-8
Ravine-7
1
2
3
Existing Channels
Flood
Main
Side
Other Linework
Reach Break
Existing Levees
Treatment
Boulder Rib
Large Jam
Small Jam
Floodplain Roughness
Ravine
Spring
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
Low Flow Depth (ft)
High : 0.72
Low : 0.001
0
105
210
420 Feet
N

Appendix B
Springs Reconnection Memo

Jacobs

Memorandum

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REGISTERED PROFESSIONAL ENGINEER
95101PE
Digital Signature
OREGON
JULY 11, 2019
PERRIN A. ROBINSON
EXPIRES: 12/31/2022

Subject	**Concept Design**
Project Name	North Fork (NF) Walla Walla River Sam's-Rea Property Springs Reconnection
Attention	Eric Hoverson, Walla Walla Basin Watershed Council (WWBWC)
From	Perrin Robinson, Jacobs
Date	October 19, 2021
Copies to	Troy Baker, WWBWC

1. Background

Flood events occurred in the NF Walla Walla River in February and May 2020, that severely impacted the river and floodplain. In addition, emergency repair measures were implemented by private landowners to repair access roads, irrigation systems, and other land re-establishment work. WWBWC identified a stretch of river along the NF Walla Walla River, located approximately 10 miles upstream from Milton-Freewater, Oregon, as an initial focus area for river and floodplain restoration efforts. The Walla Walla River Sam's-Rea Design Project (the Project) boundaries encompass a 5.2-mile stretch, extending from the end of the paved NF Walla Walla Road and locked gate upstream to Little Meadow Creek, and large properties owned by the Sam's and Rea's families. WWBWC approached the Sam's and Rea's family members and the families have been receptive to the restoration work proposed by WWBWC. Jacobs is currently engaged in developing a conceptual river restoration design for this Project reach as part of a separate task order.

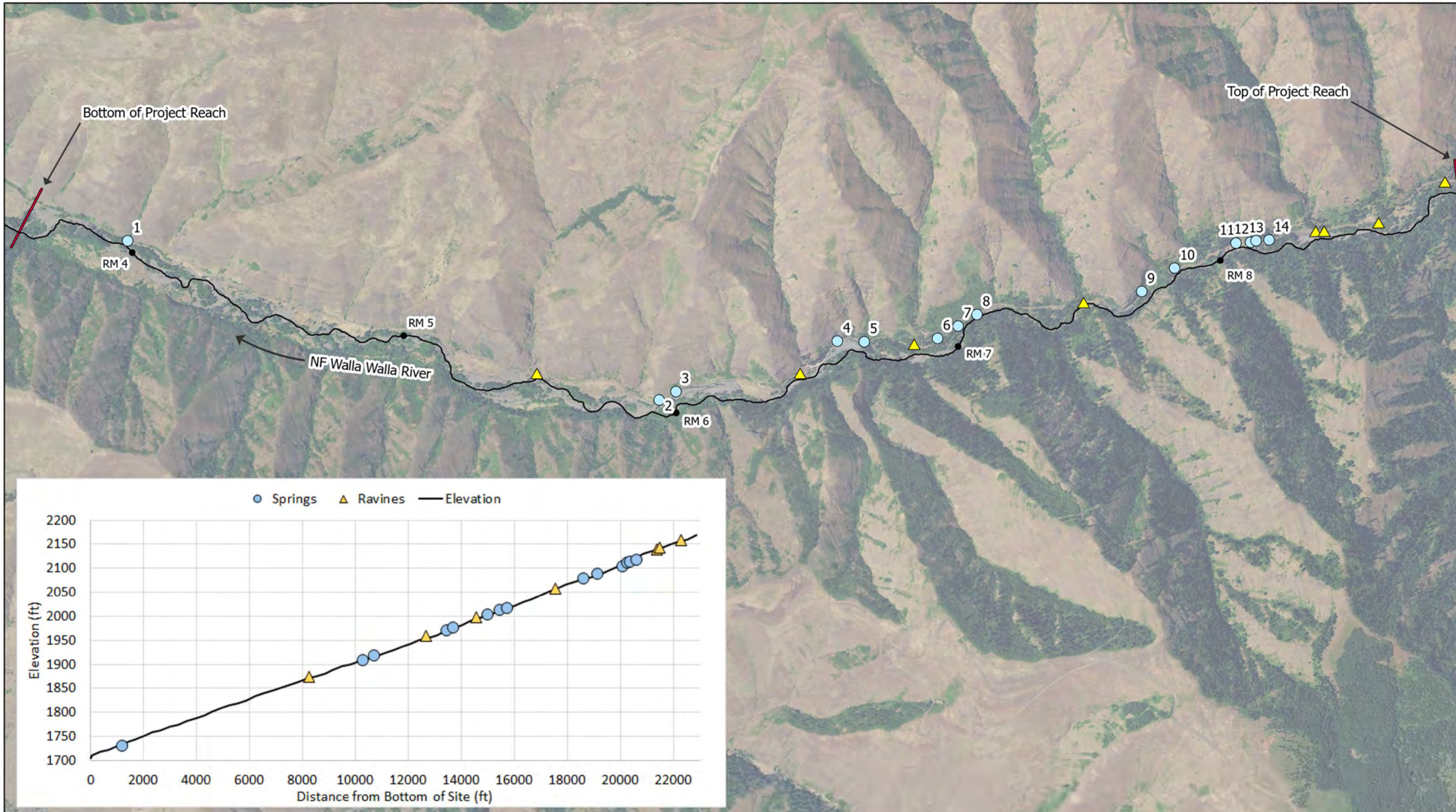
Within this 5.2-mile stretch of river, 14 natural springs adjacent to the NF Walla Walla River have been identified that provide contributory flows to the NF Walla Walla River. At most of these locations, subsurface flow is currently intercepted by an existing road that parallels the NF Walla Walla River through the Project reach and provides vehicular access to properties located further upstream from the Sam's and Rea's properties. Rather than providing clean, cold groundwater inputs to the NF Walla Walla River, the subsurface water ponds on the uphill (north) side of the roadway and flows over the roadway surface at the nearest low point, reducing water quality (increased temperature and sediment) and expediting road degradation. Figure 1 shows the location of the springs within the Project reach of the NF Walla Walla River.

In addition, there are eight ephemeral ravine drainages contributory to the NF Walla Walla River within this stretch of river that have been intersected by the existing access road. While beyond the scope of this technical memorandum (TM), grading and drainage modifications and improvements to the access road for conveyance of the periodic flows from these ravines are components of the overall river restoration objectives to facilitate construction equipment access and reduce the impacts caused by roadway washouts.

Based on water monitoring conducted by the Oregon Department of Environmental Quality (DEQ), the NF Walla Walla River, a tributary of the Walla Walla River in the Walla Walla Subbasin (Hydrologic Unit Code No. 17070102), is listed as an impaired waterway for temperature standards established by Oregon code OAR 340-041-0028, per the state list, developed in accordance with Section 303(d) of the federal Clean Water Act (Oregon DEQ 2005). Temperature impairment for the NF Walla Walla River is caused by solar radiation and can be improved through increased shading and cold-water inputs from groundwater sources. Water temperature monitoring data for the NF Walla Walla River is provided on the WWBWC website for monitoring station S-104 (WWBWC 2020).

2. Purpose

To address the 303(d) temperature listing of the NF Walla Walla River and improve overall salmonid habitat water quality, WWBWC has prioritized the protection and reconnection of the springs within the Project reach in conjunction with the overall river restoration project. The goal of protection and reconnection of the springs is to maintain and/or improve the temperature of the groundwater springs and allow for improved connectivity with the NF Walla Walla River for improved cold-water inputs and sediment-loading reduction. This TM has been prepared to describe the current conditions, identify the proposed reconnection treatments to be utilized, and assign the proposed treatments to the individual spring locations, based on the spring characteristics, to establish the concept design for the spring reconnections.



LEGEND

- Springs
- Ravines
- NF Walla Walla River
- Project Reach Boundaries

N W E S

0 0.1 0.2 0.3 0.4 0.5
Miles

FIGURE 1
Sam's-Rea Project Reach Springs Location Map
North Fork Wall Walla River Sam's-Rea Design
Proposed Conceptual Springs Treatment Applications

Jacobs
CRAMER FISH SCIENCES

3. Current Conditions

WWBWC performed a field inventory of the springs within the 5.2-mile Project reach on August 31, 2021, to assign a numbering system, identify their locations, and record the water temperature as it flowed over the road. Table 3-1 provides the spring inventory data collection.

Table 3-1. Existing Spring Inventory Data

Spring No.	Spring Name	Latitude	Longitude	Elevation[a] (feet amsl)	Temperature (°C)	Notes
1	Green Gate	45.89072	-118.23495	1,694	14	50 meters up from Green Gate.
2	Sulfur Bedrock	45.88497	-118.20583	1,893	22	--
3	Double Cross	45.88530	-118.20492	1,904	15	--
4	Western Fence	45.88731	-118.19615	1,953	16	--
5	Corner Bend	45.88730	-118.19468	1,958	16	--
6	Sedge Outlet	45.88747	-118.19069	1,989	24	Lowest of the trilogy network.
7	Sedge Oasis	45.88795	-118.18958	1,990	26	Middle of the trilogy network.
8	Sedge Headwater	4588840	-118.18856	2,024	22	Lowest of the trilogy network.
9	Blackberry	45.88937	-118.17960	2,063	13	Rock climbing hillslope.
10	Smartweed	45.89028	-118.17783	2,083	17	--
11	Blue Lagoon	45.89127	-118.17450	2,098	23	--
12	Sulfur Soil	45.89131	-118.17371	2,110	19	--
13	Tara Rock	45.89137	-118.17341	2,123	20	--
14	Bedrock Bump	45.89141	-118.17270	2,117	14	--

Source: WWBWC, 2021.

Notes:

°C = degree(s) Celsius
amsl = above mean seal level

Additionally, a follow-on site visit was conducted by staff from WWBWC, Bonneville Power Administration (BPA), and Jacobs on September 10, 2021 to:

- Perform visual observations of the springs.
- Determine the importance of reconnecting each spring in terms of water quality and fish habitat benefits.
- Discuss applicable treatment and its purpose for each spring.

Attachment 1 provides photographs of current conditions for each of the 14 springs taken during the August and September site visits. Table 3-2 provides a brief description of each spring's characteristics, based on the visual observations made during the September site visit.

Table 3-2. Existing Spring Characterization

Spring No.	Description
1	Originates from the upper hillslope and provides cold water input to the NF Walla Walla River. Water ponding is present on the existing road and water flows towards the river's side channel, located approximately 100 feet away. No fish habitat is provided in the spring flow path and no fish rearing ponding is present upstream of the road.
2	A warm water seep from the hillside, caused by road interception of groundwater. No fish habitat is provided in the spring flow path and no fish rearing ponding is present upstream of the road.
3	A cold-water seep from the hillside, immediately adjacent to the road, caused by road interception of groundwater. Water flows over the road to enter the river side channel, located approximately 20 feet from the edge of roadbed. No fish habitat is provided in the spring flow path and no fish rearing ponding is present upstream of the road.
4	A cold-water seep from the hillside, immediately adjacent to the road, caused by road interception of groundwater. Water flows along the roadway in a wheel rut for ~ 150 feet and, ultimately, into a river side channel, located immediately adjacent to the road. No fish habitat is provided in the spring flow path and no fish rearing ponding is present upstream of the road.
5	A cold-water seep adjacent to the road, caused by road interception of groundwater. Water flows along the edge of the road through grassy vegetation and along the road in a wheel rut to a relative low point in the road, where the water flows across the road and over land to a river flood channel. No fish habitat is provided in the spring flow path and no fish rearing ponding is present upstream of the road.
6	Seep that originates in a vegetated lowland area adjacent to the road. Water pools and warms in the road and trickles out into a river side channel. No fish habitat is provided in the spring flow path and no fish rearing ponding is present upstream of the road.
7	Seep that originates in a vegetated lowland area adjacent to the road. Spring water flows through the vegetated area frequented by grazing cattle and, ultimately, pools in the roadway, where the water warms prior to flowing into a river side channel. No fish habitat is provided in the spring flow path and no fish rearing ponding is present upstream of the road.
8	Seep that originates in a vegetated lowland area adjacent to the road. Spring water flows through the vegetated area frequented by grazing cattle and, ultimately, pools in the roadway, where the water warms prior to flowing into the river main channel. No fish habitat is provided in the spring flow path and no fish rearing ponding is present upstream of the road.
9	A cold-water spring that originates in the hillside, caused by road interception of groundwater. Water flows through blackberry vegetation, across the road, and into a river side channel. No fish habitat is provided in the spring flow path and no fish rearing ponding is present upstream of the road.
10	A cold-water spring that originates from the hillside, caused by road interception of groundwater. Water flows under tree canopy and through ground vegetation prior to pooling in the road and conveying over land through vegetation to the river main channel. No fish habitat is provided in the spring flow path and no fish rearing ponding is present upstream of the road.
11	A series of apparent springs that are present in the rock face adjacent to, and contributory to, ponded water as a result of a roadway embankment levee constructed postflood for site access. The ponded water seeps through the roadway embankment and flows into the main channel.

Table 3-2. Existing Spring Characterization

Spring No.	Description
	There is potential for direct connectivity to the main channel for the back channel, pooled fish habit area.
12	A hillside seep caused by road interception of groundwater that flows onto roadway and is conveyed in a wheel rut to the upper pooled area of Spring 11.
13	A hillside seep caused by road interception of groundwater that flows onto roadway and is conveyed along the road in wheel ruts. Water migrates to the upper pooled area of Spring 11.
14	A cold-water spring that emerges from the hillside and pools on the upstream side of the road. Water trickles across the road, pools in the wheel ruts, and flows into a roadside swale that conveys the water to a river side channel. Fish habitat is present in the roadside swale and pooled area upstream of the road crossing.

Note:

~ = approximately

4. Treatment Options

Many treatment options are available to address water conveyance at roadway crossings, depending on the roadway geometry, topographical elevations, hydrologic conditions (including surface flow or subsurface flow and the quantity and timing of discharge), and the design criteria. Some treatment options simply convey water from the upstream side of the road crossing to the downstream side, while other options are available when addressing aquatic organism passage (AOP) and flow conveyance. There are multiple reference materials that address the available treatment options and their applicability and design. The following sections provide brief summaries of common stream-road crossing options that could be utilized to reconnect the natural spring flows to the NF Walla Walla River.

4.1 Porous Rock Mattress

Porous rock mattresses (for example, French mattresses) are typically utilized in areas where the roadway fill is less permeable than the surrounding soils, and the roadway prism intercepts the natural subsurface flow path of groundwater or shallow surface flow, causing surface ponding on the uphill side of the road. They allow the water to flow through highly permeable roadbed substrate while maintaining the structural integrity of the roadbed for vehicular traffic. Additionally, this treatment is applicable where installing cross drains and culverts would be difficult due to the surrounding grades and vegetation. Porous rock mattresses also allow the water to be shielded from the warming effects of the sun while flowing subsurface below the roadbed, improving downstream water quality and reducing roadway erosion. Figures 2 and 3 provide graphical illustrations of porous rock installations.

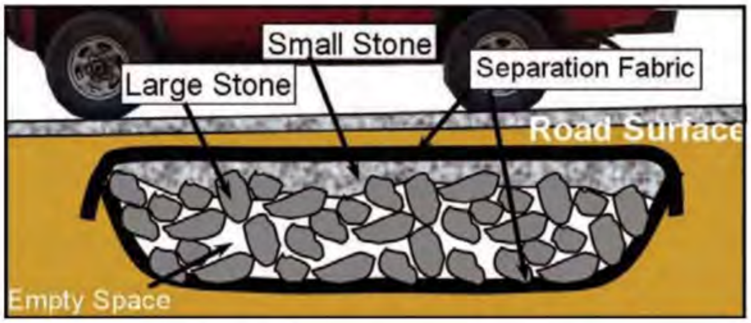


Figure 2. Porous Rock Mattress – Graphical Side View
Source: USFS, 2012.

Figure 3. Porous Rock Mattress – Side View of Actual Installation
Source: USFS, 2012.

4.2 Culverts

Culverts are a traditional means of conveying surface water at a road crossing. Culverts are typically installed where concentrated surface water flows occur in natural drainage paths at road crossings (cross-culvert) and developed impervious catchment areas, such as roadway gutters and parking lot low points. The science and engineering associated with the design of properly functioning cross-culverts continues to evolve and mature, particularly relating to the design of stream simulation AOP culverts. A circular cross-culvert placed on-grade has historically been the go-to approach to providing water conveyance for lower flow surface water applications, but this application has many downsides that emerge over time for many installations where the culvert is hydraulically undersized or the geomorphic conditions do not support this application. Additionally, on-grade circular cross-culverts are not applicable in settings where AOP is a principal design criterion. Bridge spans are suitable for consideration for higher flow applications, but have not been contemplated for the Project reach springs reconnection given the low-flow conditions present for the identified natural springs.

Within the category of culverts, several options are available for application for lower flow surface water sites, similar to the Project spring flows that emerge as a result of the road grade interceptions. These options include open-bottom arch pipes, three-sided box culverts, and embedded culverts. With embedded culverts, there are several variations to consider. The following sections summarize the available culvert options that are applicable to the Project, to convey surface water spring flows and to provide AOP, where deemed applicable.

4.2.1 Open-bottom Arch Pipe

The open-bottom arch culvert is a common application for stream-road crossings that allows for adequate channel spans and natural channel bottom stream simulations for AOP. Open-bottom arch culverts are constructed using galvanized steel, aluminum, or steel-reinforced materials, depending on the application conditions. Concrete footings are typically constructed as a connection foundation for the open-bottom arch culvert. Care (through engineering analysis) must be taken to ensure that the footings are not undermined by scour, which could compromise the open-bottom arch culvert system that supports the overlying roadbed. Figure 4 shows a typical open-bottom arch pipe application.

Figure 4. Open-bottom Arch Pipe Example
Source: USFS, 2008.

4.2.2 Three-sided Box Culvert

A three-sided box culvert is another bottomless option for stream-road crossings that provides stream spanning flexibility while accommodating AOP considerations for a long-term solution. This option can be constructed using steel-reinforced concrete, galvanized steel, or aluminum materials. Figure 5 shows a three-sided box culvert installation example.

Figure 5. Three-sided Box Culvert Example
Source: Maine Audubon, 2018.

4.2.3 Embedded Culvert

Embedded culverts consist of box culverts, arch pipes, and round pipes. Embedded culverts allow for substrate to be placed in the invert area of the culverts, but do not allow for the fluctuations of natural geomorphic processes that open-bottom structures provide. The embedded culverts have a fixed bottom that limit the natural scour and deposition of substrate. The embedded culvert must span the stream, which limits round pipes to low-flow applications. Materials limit the lifespan of the embedded culvert relative to the exposed bottom portion of the culvert that are subject to submersion and corrosion. Figures 6 and 7 depict examples of embedded culverts.

Figure 6. Embedded Box Culvert
Source: Maine Audubon, 2018.

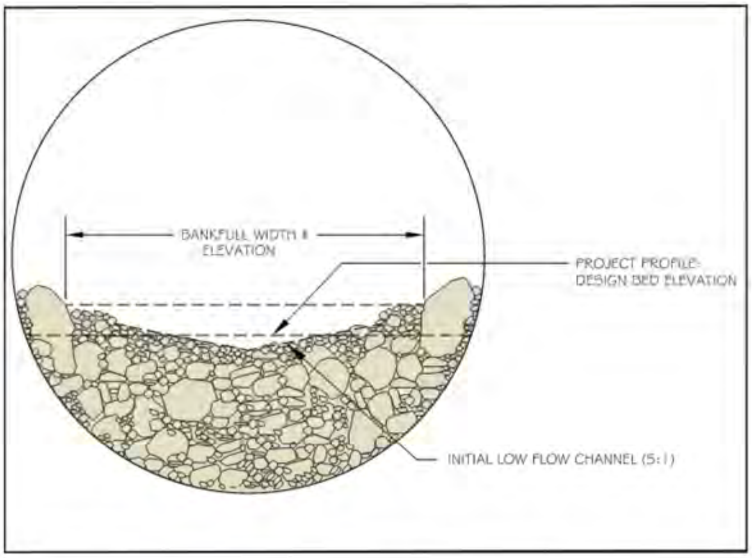


Figure 7. Embedded Round Pipe Section
Source: USFS, 2008.

4.3 Low-water Ford

4.3.1 At-grade Ford

A low-water ford is installed at or near streambed elevations and can be surfaced with rock, concrete, or other materials. This treatment option is typically installed in ephemeral or low baseflow channels and where the channel is broad and shallow. Figure 8 depicts a typical low-water ford application.

Figure 8. Low-water Ford Example
Source: USFS, 2012.

4.3.2 Gabion Ford Crossing

A gabion ford crossing is another type of low-water crossing with a different type of construction than on-grade installation. The gabion ford crossing allows for a drop in elevation on the downstream end of the crossing and is therefore not conducive for applications where AOP considerations are a factor. Figure 9 shows a typical gabion ford crossing.

Figure 9. Gabion Ford Crossing
Source: USFS, 2012.

5. Proposed Treatment Applications

A goal of the broader Sam's-Rea NF Walla Walla River restoration project is to increase the aquatic organism habitat complexity and refuge opportunities within the reach. Reconnection of the naturally occurring springs to the NF Walla Walla River that have been disconnected because of construction of the access road is a priority of the overall river restoration to aid in the overarching goal by providing cold water inputs and spring habitat AOP access, where feasible. The treatment options have been presented and there are a few that merit application to address natural spring reconnections to the NF Walla Walla River, given the existing conditions present at the spring locations.

In determining the proposed treatments, the conditions present at each of the springs (Table 2) and the applicability of the treatment relative to the reconnection goals were considered. In locations where groundwater flows have been intercepted by the road grade, thus resulting in overland spring seep flows immediately adjacent on the uphill side of the road, a permeable rock mattress is suitable for installation at the road crossing to allow the water to be conveyed subsurface through the roadbed to reduce thermal warming, improve water temperature, and reduce sediment loading. An AOP culvert is recommended for applications where there are concentrated surface flows and favorable habitat conditions present on the upstream side of the road interception. A low-ford crossing could be utilized at locations where intermittent surface water flows are encountered, road grades relative to the uphill topography is conducive, and AOP is not a consideration.

Table 5-1 provides a summary of the conceptual design applications proposed for each spring and the rationale for the application. Attachment 2 provides graphical mapping of the proposed conceptual design application by spring location within the Project reach.

Table 5-1. Conceptual Spring Reconnection Treatment Application

Spring No.	Treatment Application	Selection Rationale
1	Porous rock mattress perpendicular to the roadway	Provides a direct conveyance path that eliminates road ponding and warming effects; stabilizes the roadway for river restoration construction access.
2	Porous rock mattress perpendicular to the roadway	Provides a direct conveyance path that eliminates road ponding and warming effects; stabilizes the roadway for river restoration construction access.
3	Porous rock mattress perpendicular to the roadway	Provides a direct conveyance path that eliminates road ponding and warming effects; stabilizes the roadway for river restoration construction access.
4	Porous rock mattress perpendicular to the roadway	Provides a direct conveyance path that eliminates road ponding and warming effects; stabilizes the roadway for river restoration construction access.
5	Porous rock mattress perpendicular to the roadway at a low point with impervious buildup on the upstream side of the road to concentrate flow to the porous rock mattress	Maintains a vegetated flow path adjacent to the upstream side of the road to the road low point for conveyance that eliminates ponding and warming effects; stabilizes the roadway for river restoration construction access.
6	Porous rock mattress perpendicular to the roadway	Provides a direct conveyance path that eliminates road ponding and warming effects; stabilizes the roadway for river restoration construction access.
7	No treatment	Protection from cattle grazing is recommended for the vegetated area associated with Spring 7; opportunity to establish spring water flow connectivity to the Spring 6 area for roadway conveyance.
8	No treatment	Protection from cattle grazing is recommended for the vegetated area associated with Spring 8; opportunity to establish spring water flow connectivity to and through Spring 7 to the Spring 6 area for roadway conveyance.
9	Porous rock mattress perpendicular to the roadway	Provides a direct conveyance path that eliminates road ponding and warming effects; stabilizes the roadway for river restoration construction access.
10	Porous rock mattress perpendicular to the roadway	Provides a direct conveyance path that eliminates road ponding and warming effects; stabilizes the roadway for river restoration construction access.
11	Open-bottom arch pipe culvert with upstream water surface elevation control	Allows for AOP for refuge and rearing access to habitable upstream area
12	Linear porous rock mattress paralleling the upstream side of the road (tied into Spring 13 treatment) with a deeper rock gallery towards the connection with the Spring 11 ponded area	Allows spring water to be conveyed subsurface to eliminate overland conveyance and warming; a deeper rock gallery promotes cooling of spring water for input into the water ponding area associated with Spring 11 and, ultimately, the river

Table 5-1. Conceptual Spring Reconnection Treatment Application

Spring No.	Treatment Application	Selection Rationale
		via the proposed open-bottom arch culvert for AOP connection to the river.
13	Linear porous rock mattress paralleling the upstream side of the road	Allows spring water to be conveyed subsurface to eliminate overland conveyance and warming; directs flow to the water ponding area associated with Spring 11 and the proposed open-bottom arch culvert for AOP connection to the river.
14	Open-bottom arch pipe culvert with upstream water surface elevation control	Allows for AOP for refuge and rearing access to the habitable upstream area.

6. Recommended Next Steps

Following review and endorsement of the proposed spring reconnection treatment applications by landowners, BPA, and WWBWC, design and construction bid packages will need to be prepared. To support development of the design, topographic ground survey data collection will be required at a few specific locations to be identified by Jacobs as part of future work. Jacobs anticipates that follow-on design and construction bid package preparation will be initiated in December 2021, and completed by late spring or early summer 2022, for implementation during late summer or fall 2022, as an early construction package.

7. References

Maine Audubon. 2018. *How to Create Stream Smart Crossings*. http://www.maineaudubon.org/wp-content/uploads/2018/03/3_TechnicalGuidance_2018_FINAL_AA.pdf.

Oregon Department of Environmental Quality (DEQ). 2005. *Walla Walla Subbasin Stream Temperature Total Maximum Daily Load and Water Quality Management Plan*. August.

U.S. Forest Service (USFS). 2012. *Environmentally Sensitive Road Maintenance Practices for Dirt and Gravel Roads*. April.

U.S. Forest Service (USFS).2008. *Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings*. August.

Walla Walla Basin Watershed Council (WWBWC). 2020. *S104 North Fork Walla Walla River*. http://wwbwc.org/s104-north-fork-walla-walla-river.html.

Walla Walla Basin Watershed Council (WWBWC). 2021. Existing Spring Inventory Data. Collected by E. Hoverson and T. Patton. August 31.

Attachment 1
Photographs of Current Conditions

Spring 1

Spring 2

Spring 3

Spring 4


Spring 5


Spring 6

Spring 7

Spring 8

Spring 9

Spring 10

Spring 11

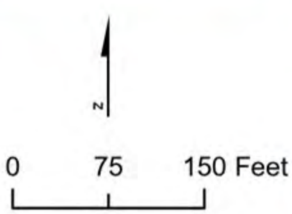
Spring 12

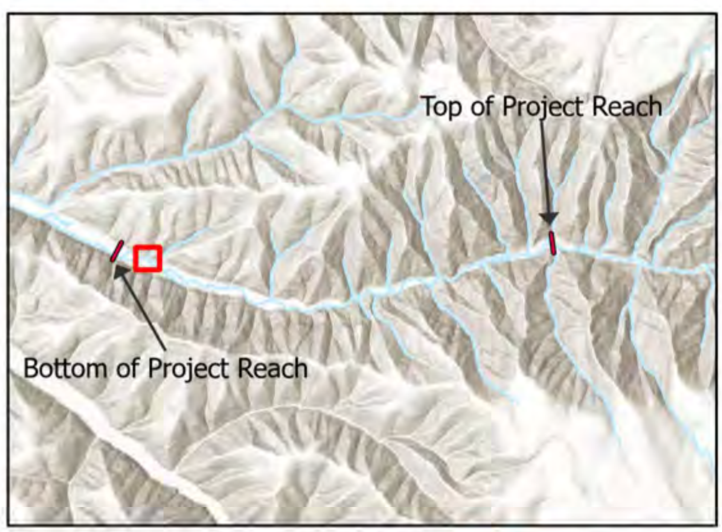
Spring 13

Spring 14

Attachment 2
Proposed Conceptual Spring Treatment Application Maps

LEGEND
Area of Potential Effect (APE)
Proposed Treatment at Roadway
Culvert
Porous Rock Mattress
No Treatment





ATTACHMENT 2.1
Spring 1
North Fork Walla Walla River Sam's-Rea Design
Proposed Conceptual Springs Treatment Applications

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LEGEND

Area of Potential Effect (APE)

Proposed Treatment at Roadway

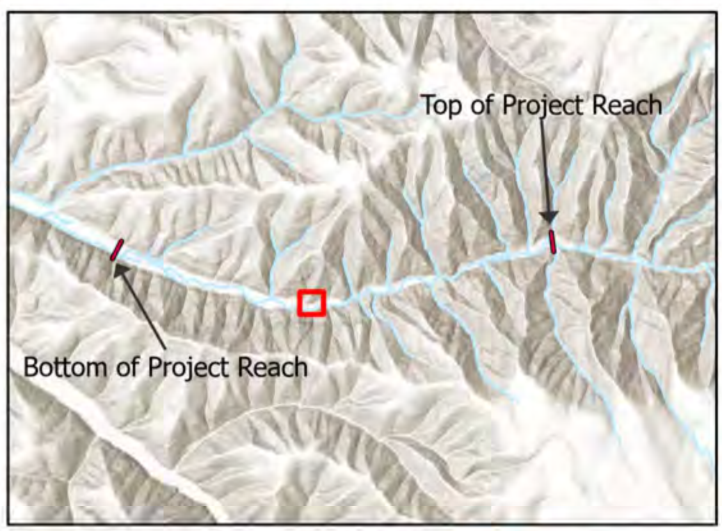
Culvert

Porous Rock Mattress

No Treatment

N

0 75 150 Feet



ATTACHMENT 2.2
Springs 2 and 3
North Fork Walla Walla River Sam's-Rea Design
Proposed Conceptual Springs Treatment Applications

Jacobs

CRAMER FISH SCIENCES

LEGEND

Area of Potential Effect (APE)

Proposed Treatment at Roadway

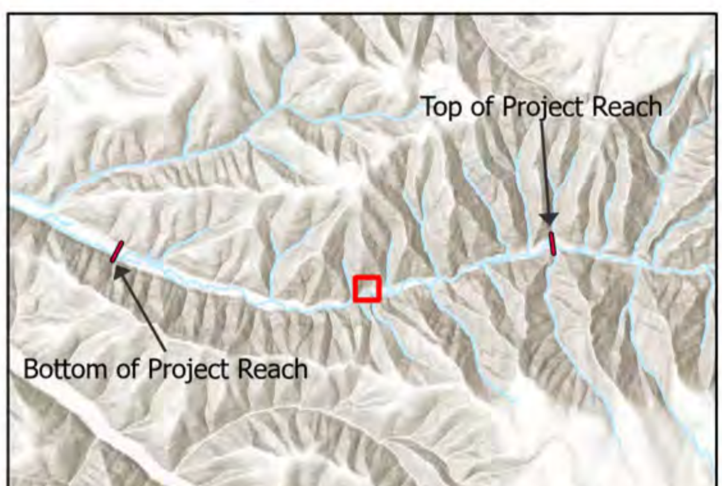
Culvert

Porous Rock Mattress

No Treatment

N

0 75 150 Feet



ATTACHMENT 2.3
Springs 4 and 5
North Fork Walla Walla River Sam's-Rea Design
Proposed Conceptual Springs Treatment Applications

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LEGEND

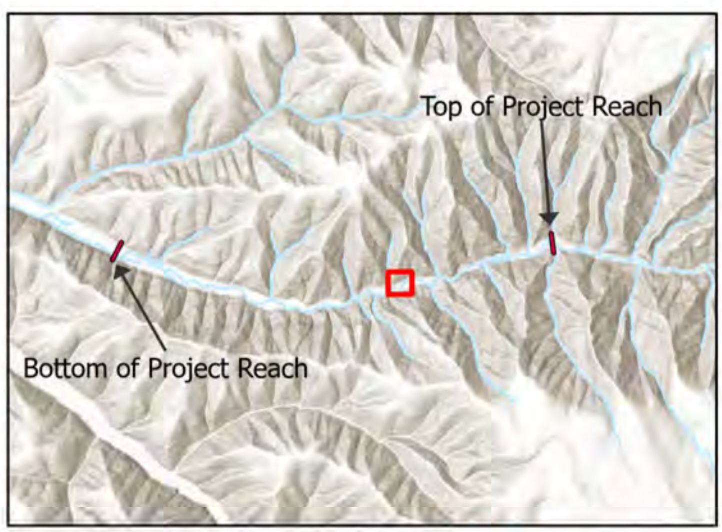
Area of Potential Effect (APE)

Proposed Treatment at Roadway

- Culvert
- Porous Rock Mattress
- No Treatment

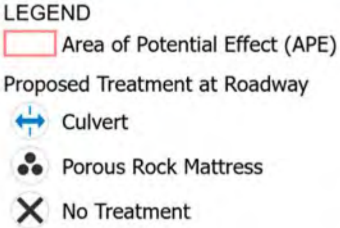
N

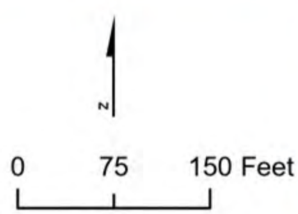
0 75 150 Feet

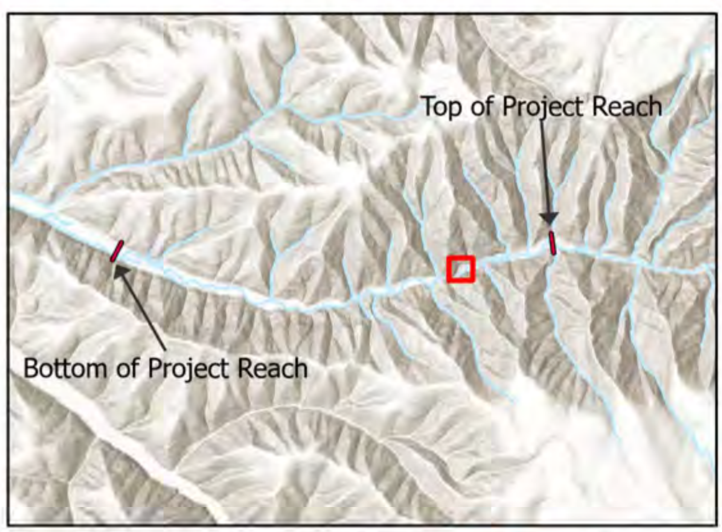


ATTACHMENT 2.4
Springs 6 through 8
North Fork Walla Walla River Sam's-Rea Design
Proposed Conceptual Springs Treatment Applications

LEGEND







ATTACHMENT 2.5
Springs 9 and 10
North Fork Walla Walla River Sam's-Rea Design
Proposed Conceptual Springs Treatment Applications

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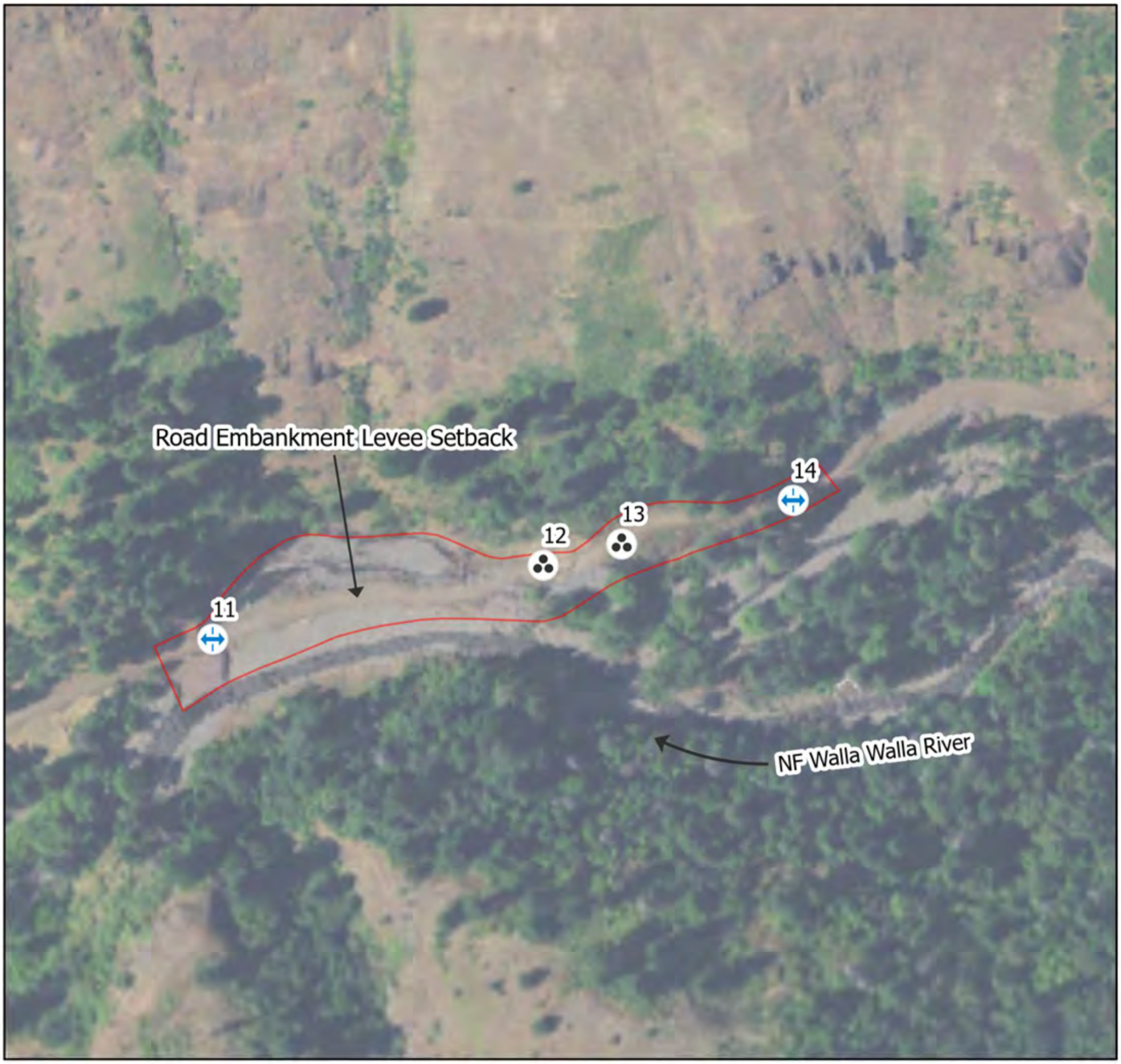


LEGEND

Area of Potential Effect (APE)

Proposed Treatment at Roadway

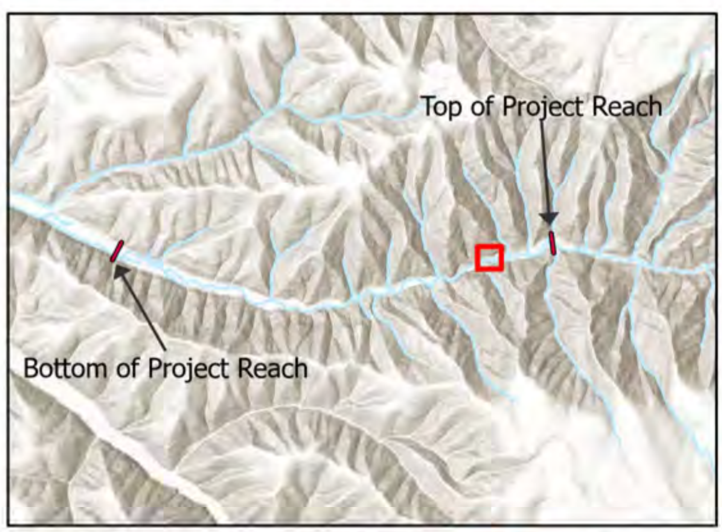
Culvert

Porous Rock Mattress

No Treatment

N

0 75 150 Feet



ATTACHMENT 2.6
Springs 11 through 14
North Fork Walla Walla River Sam's-Rea Design
Proposed Conceptual Springs Treatment Applications

Jacobs CRAMER FISH SCIENCES

Appendix C
Hydrologic Analysis

Jacobs

Memorandum

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Subject	**North Fork Walla Walla River Hydrology**
Project Name	Walla Walla Basin Watershed Council North Fork (NF) Walla Walla River Sam's-Rea Design Project (the Project)
Attention	Walla Walla Basin Watershed Council
From	Robert Zabrowski, EIT
Date	September 28, 2021
Copies to	File

1. Introduction

The Project is located on the NF Walla Walla River, approximately 10 miles upstream from Milton-Freewater, Oregon. The Project boundaries encompass a 4-mile stretch from the end of the paved NF Walla Walla Road and locked gate to Little Meadow Creek. The Project reach (Figure 1), encompasses several expansive tracts owned by the Sam’s and Rea families. The desired outcome of the Project is a restoration condition that consists of a properly functioning, complex, and self-sustaining river system with reconnected floodplain featuring vibrant, productive riparian features. The overall Project construction has been scheduled to occur within the July-September 2023-2027 instream work periods. This technical memorandum (TM) summarizes the hydrologic analysis of the NF Walla Walla River performed to inform the hydraulic modeling and conceptual design (15%) effort.

2. Hydrologic Analysis

The NF Walla Walla River is located in Umatilla County, Oregon, and is one of the major tributaries to the Walla Walla River. Its drainage area covers approximately 45 square miles (Figure 1). The hydrology of this basin has been analyzed to better understand the magnitude of large floods and the low flow conditions that occur in the NF Walla Walla River. This flow information is a direct input to the existing conditions hydraulic model described in the conceptual design report. Specifically, the 95% exceedance and 2-year flow rates have been estimated to evaluate channel-floodplain interactions and habitat connectivity/complexity, and the 100-year flood event has been estimated to assess flood risk to the roadway and other infrastructure. Additionally, large flood estimates may be used in future design phases to evaluate structural stability for specific design elements.

2.1 Watershed Description

The Walla Walla River Basin has a predominantly dry, continental climate, but some marine characteristics are evident (Harrison et al. 1964). Climate in the Walla Walla River Basin is heavily influenced by elevation and varies from semiarid (less than 10 inches of annual precipitation) in the western lowlands that lie in the rain shadow of the Cascade Mountains, to cool and wet (40 to 60 inches of annual precipitation) at higher elevations (Walla Walla Watershed Planning Unit and Walla Walla Basin Watershed Council 2004). Winter precipitation often falls as snow in higher elevations and is stored as snowpack until warmer temperatures initialize runoff in the spring and early summer months. The NF Walla Walla River flows for 18.8 miles from its headwaters in the coniferous forested, western slopes of the Blue Mountains in northeast Oregon through volcanic canyons to a predominately cottonwood river valley before eventually reaching its confluence with the South Fork Walla Walla River to form the mainstem Walla Walla River. In the middle portion of the watershed, the valley bottom widens and the stream gradient decreases. This transition corresponds to a shift in land use from forested, less disturbed reaches to that of agricultural pastureland. In the lower portion of the watershed, orchards, vineyards, and other agricultural uses predominate.

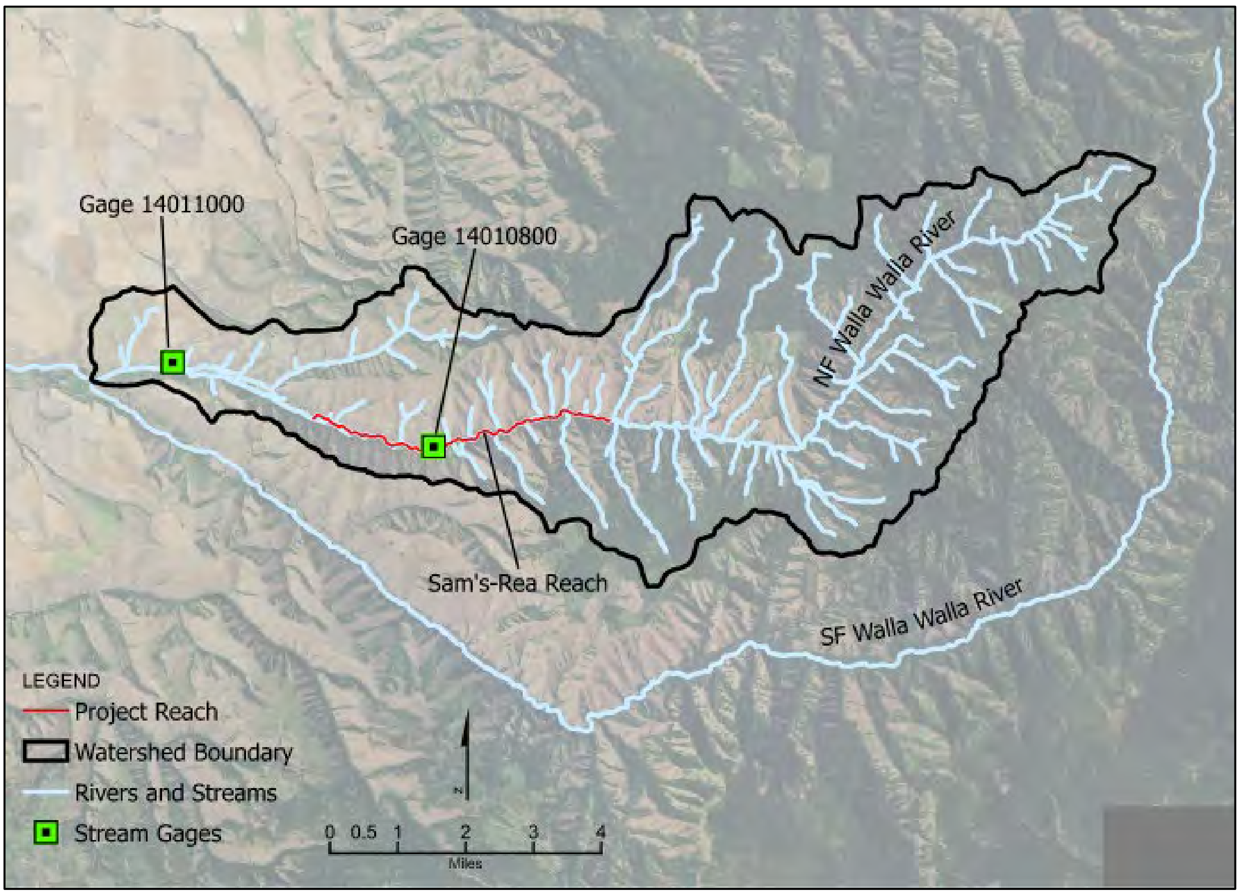


Figure 1. North Fork Walla Walla River Watershed Map

2.2 Flood History

The Oregon Water Resources Department (OWRD) operates a stream gaging station (Station ID 14010800) on the NF Walla Walla River, where 45 annual peak flow measurements were collected between 1970 and 2019. This gaging station is situated within the 4-mile Sam's-Rea reach. Additionally, a historic U.S. Geological Survey (USGS) stream gaging station (Station ID 14011000) was operated between 1933 and 1969, downstream from the Project site, near the confluence with the South Fork Walla Walla River. Figure 1 shows the location of these stream gages.

The NF Walla Walla River experienced significant flood events in February and May 2020, and there were natural and anthropogenic alterations of the stream channel from these events. Natural alterations included bank erosion, channel migration, and avulsion, as well as the movement and deposition of sediment and large woody debris in the channel and on the floodplain. Anthropogenic alterations included the construction of push-up levees throughout the Project reach to channelize the river and keep the flow away from the roadway and other infrastructure. Although these levees are intended to reduce flood damages, they reduce natural floodplain function and exacerbate downstream flooding. Gage 14010800 was damaged during the 2020 flooding, and the peak flow rate was not recorded. Following the high-water episodes, emergency repair work was conducted for the roadway throughout the Project reach, and the gage station was repaired by OWRD. The historic downstream gage record indicates that the basin experienced smaller flood events in 1947 and 1965.

2.3 Flood Frequency Relationship

Flood events of a magnitude that is expected to be equaled or exceeded in any given year during a 2-, 10-, 50-, and 100-year period are often used for floodplain management and river engineering applications. These events, termed the 2-, 10-, 50-, and 100-year floods have a 50, 10, 2, and 1% chance, respectively, of being equaled or exceeded during any given year. Estimates of the magnitude of these flood events can be obtained through a variety of statistical techniques. The most recent guidance from USGS is that flood flow frequency estimates should be computed using Bulletin 17C procedures (USGS 2019).

A flood frequency analysis was performed for the NF Walla Walla River using the annual peak discharge data collected at OWRD gage station 14010800. Jacobs decided that gage 14011000 should not be utilized for this analysis, as this dataset encompasses a larger tributary area and different basin characteristics than gage 14010800. The period of record for these two datasets does not overlap, so a correlational relationship could not be established and an attempt to combine the two streamflow datasets was not made. The period of record for gage 14010800 was sufficient to provide flood frequency estimates with reasonable confidence limits. The Hydrologic Engineering Center's Statistical Software Package (HEC-SSP) was used to perform the flood frequency analysis following Bulletin 17C procedures. Bulletin 17C procedures estimate peak flow statistics by fitting a log-Pearson type III distribution to records of annual peak flows and applying two additional statistical methods: 1) the Expected Moments Algorithm to help describe uncertainty in annual peak flows, and to better represent missing and historical record; and 2) the generalized Multiple Grubbs Beck Test to screen out potentially influential low outliers, and to better fit the upper end of the peak flow distribution. In addition to the annual peak flow data, inputs for this analysis included a generalized skew coefficient and perception thresholds for the years in the period of record without peak flow data. For this analysis, the Pacific Northwest regional skew coefficient of -0.07 was applicable with a corresponding mean standard error 0.18 (USGS 2017), and a weighted skew coefficient was computed using the regional skew coefficient and station skew coefficients from the stream gage records. No additional information was available to refine the perception thresholds for the years without peak flow data, so the default threshold values were used for those years. Table 1-1 summarizes the peak discharge estimates for specific flood events, and the computed flood frequency curve is shown in Figure 2. The input and output data for the HEC-SSP analysis are provided in Attachment 1.

Table 1-1. Peak Flow Statistics for the North Fork Walla Walla River Gage 14010800

Return Period (years)	Peak Discharge (cfs) for NF Walla Walla River (OWRD 14010800)	Confidence Limits (cfs)	
		0.05	**0.95**
2	479	545	422
5	728	856	636
10	910	1117	782
50	1358	1908	1106
100	1567	2352	1241
200	1788	2875	1375
500	2102	3710	1550

Source: USGS, 2019.

Note:

cfs = cubic feet per second

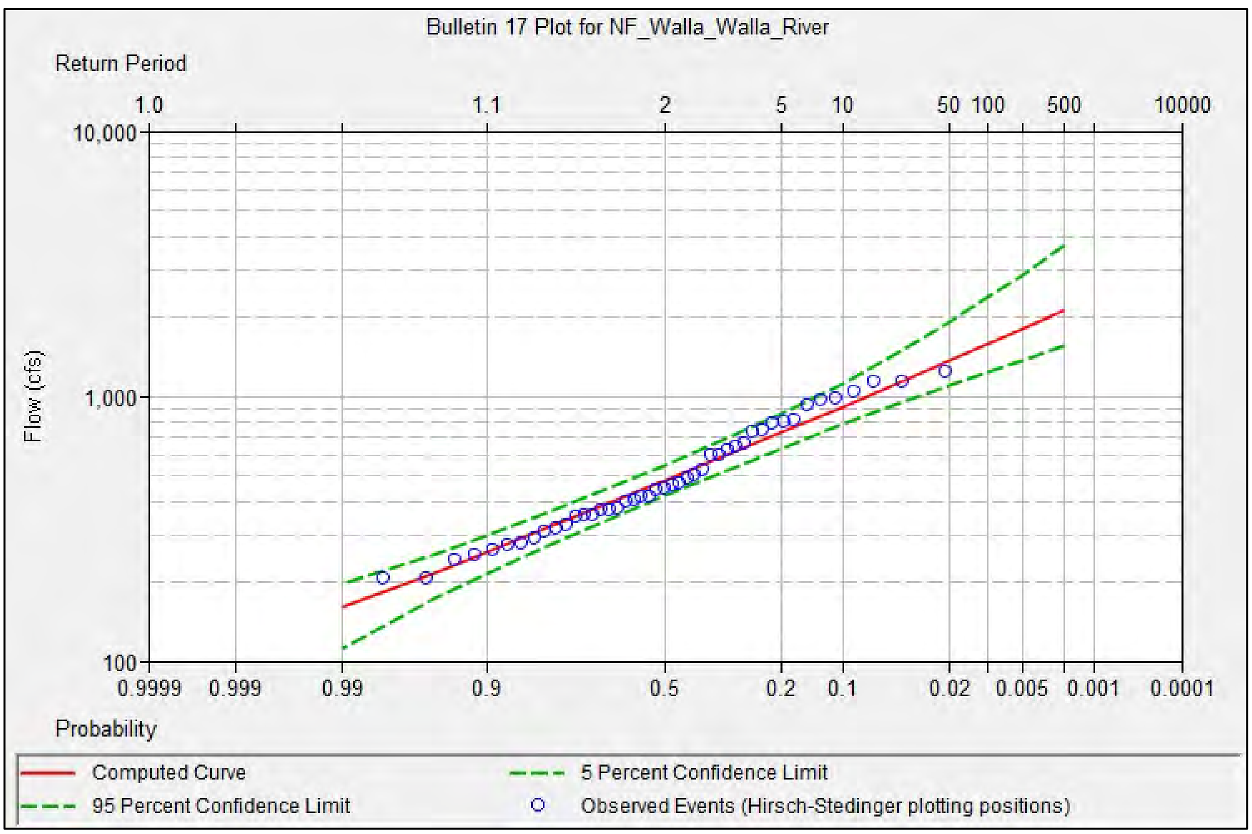


Figure 2. Flood Frequency Curve from Bulletin 17C Analysis for the North Fork Walla Walla River Gage 14010800

2.4 Flow Duration Analysis

In addition to peak flow measurements, mean daily discharge data have been collected at OWRD Station 14010800 since October 1, 1969. A flow duration analysis was performed with this data to determine the daily mean flow values that have been exceeded for various percentages of the total period of record. For example, a 5% exceedance probability represents a high flow that has been exceeded only 5% percent of all days of the flow record. As Figure 3 shows, the median daily flow measured at the gage was 23 cfs, the 95% exceedance flow was 6 cfs, and the minimum recorded flow was 3.43 cfs.

Figure 3. Daily Flow Duration Curve for the North Fork Walla Walla River Gage 14010800

3. Summary

This TM summarizes the hydrologic analyses for the Sam's-Rea Project reach on the NF Walla Walla River, including a peak flow frequency analysis and a flow duration analysis. These hydrologic results, specifically the 95% exceedance, 2-year, and 100-year flow estimates, have been used as direct inputs to the existing conditions hydraulic model described in the conceptual design report.

4. References

Harrison, E. T., N. C. Donaldson, F. R. McCreary, A. O. Ness, and S. Krashevski. 1964. *Soil Survey of Walla Walla County, Washington*. Prepared for the Soil Conservation Service, U.S. Department of Agriculture.

U.S. Geological Survey (USGS). 2017. *Magnitude, Frequency, and Trends of Floods at Gaged and Ungaged Sites in Washington, Based on Data through Water Year 2014*.

U.S. Geological Survey (USGS). 2019. “Guidelines for Determining Flood Flow Frequency, Bulletin 17C.” Chapter 5 of Section B, Surface Water. *Book 4, Hydrologic Analysis and Interpretation*. Version 1.1. May.

Walla Walla Watershed Planning Unit and Walla Walla Basin Watershed Council. 2004. *Walla Walla Subbasin Plan*. Prepared for Northwest Power and Conservation Council.

Attachment 1
HEC-SSP Flood Frequency Analysis Input and Output Data

File: NF_Walla_Walla_River.rpt, Page: 1

Bulletin 17C (Java) Frequency Analysis
14 Sep 2021 12:26 PM

--- Input Data ---
Analysis Name: NF_Walla_Walla_River
Description:
Data Set Name: NF Walla Walla River-FLOW-PEAK
DSS File Name: \\BOIFPP01\Proj\WallaWallaBasin\W3Y00602_NFWWR_Sams-Rea_Restore\Hydrology\Peak Flow Analysis\HEC-SSP\
DSS Pathname: /NF Walla Walla River//FLOW-PEAK/01jan1900/IR-CENTURY//
Report File Name: \\BOIFPP01\Proj\WallaWallaBasin\W3Y00602_NFWWR_Sams-Rea_Restore\Hydrology\Peak Flow Analysis\HEC-SS
XML File Name: \\BOIFPP01\Proj\WallaWallaBasin\W3Y00602_NFWWR_Sams-Rea_Restore\Hydrology\Peak Flow Analysis\HEC-SSP\
Start Date:
End Date:
Skew Option: Use Weighted Skew
Regional Skew: -0.07
Regional Skew MSE: 0.18
Plotting Position Type: Hirsch-Stedinger
Upper Confidence Level: 0.05
Lower Confidence Level: 0.95
Display ordinate values using 1 digits in fraction part of value
--- End of Input Data ---
<< EMA Representation of Data >>
NF Walla Walla River-FLOW-PEAK

		Value		Threshold		
Year	Peak	Low	High	Low	High	Type
1970	500.0	500.0	500.0	1.0E-99	1.0E99	Syst
1971	782.0	782.0	782.0	1.0E-99	1.0E99	Syst
1972	810.0	810.0	810.0	1.0E-99	1.0E99	Syst
1973	250.0	250.0	250.0	1.0E-99	1.0E99	Syst
1974	458.0	458.0	458.0	1.0E-99	1.0E99	Syst
1975	1,040.0	1,040.0	1,040.0	1.0E-99	1.0E99	Syst
1976	795.0	795.0	795.0	1.0E-99	1.0E99	Syst
1977	278.0	278.0	278.0	1.0E-99	1.0E99	Syst
1978	644.0	644.0	644.0	1.0E-99	1.0E99	Syst
1979	371.0	371.0	371.0	1.0E-99	1.0E99	Syst
1980	240.0	240.0	240.0	1.0E-99	1.0E99	Syst
1981	624.0	624.0	624.0	1.0E-99	1.0E99	Syst
1982	745.0	745.0	745.0	1.0E-99	1.0E99	Syst
1983	528.0	528.0	528.0	1.0E-99	1.0E99	Syst
1984	600.0	600.0	600.0	1.0E-99	1.0E99	Syst
1985	377.0	377.0	377.0	1.0E-99	1.0E99	Syst
1986	1,240.0	1,240.0	1,240.0	1.0E-99	1.0E99	Syst
1987	204.0	204.0	204.0	1.0E-99	1.0E99	Syst
1988	204.0	204.0	204.0	1.0E-99	1.0E99	Syst
1989	263.0	263.0	263.0	1.0E-99	1.0E99	Syst
1990	400.0	400.0	400.0	1.0E-99	1.0E99	Syst
1991	597.0	597.0	597.0	1.0E-99	1.0E99	Syst
1992	350.0	350.0	350.0	1.0E-99	1.0E99	Syst
1993	732.0	732.0	732.0	1.0E-99	1.0E99	Syst
1994	354.0	354.0	354.0	1.0E-99	1.0E99	Syst
1995	324.0	324.0	324.0	1.0E-99	1.0E99	Syst
1999	315.0	315.0	315.0	1.0E-99	1.0E99	Syst
2000	419.0	419.0	419.0	1.0E-99	1.0E99	Syst
2001	307.0	307.0	307.0	1.0E-99	1.0E99	Syst
2002	414.0	414.0	414.0	1.0E-99	1.0E99	Syst
2003	958.0	958.0	958.0	1.0E-99	1.0E99	Syst
2004	975.0	975.0	975.0	1.0E-99	1.0E99	Syst
2005	291.0	291.0	291.0	1.0E-99	1.0E99	Syst

2006	441.0	441.0	441.0	1.0E-99	1.0E99	Syst
2007	273.0	273.0	273.0	1.0E-99	1.0E99	Syst
2008	373.0	373.0	373.0	1.0E-99	1.0E99	Syst
2009	466.0	466.0	466.0	1.0E-99	1.0E99	Syst
2010	448.0	448.0	448.0	1.0E-99	1.0E99	Syst
2012	407.0	407.0	407.0	1.0E-99	1.0E99	Syst
2014	485.0	485.0	485.0	1.0E-99	1.0E99	Syst
2015	929.0	929.0	929.0	1.0E-99	1.0E99	Syst
2016	353.0	353.0	353.0	1.0E-99	1.0E99	Syst
2017	663.0	663.0	663.0	1.0E-99	1.0E99	Syst
2018	1,130.0	1,130.0	1,130.0	1.0E-99	1.0E99	Syst
2019	1,130.0	1,130.0	1,130.0	1.0E-99	1.0E99	Syst

Fitted log10 Moments	Mean	Variance	Std Dev	Skew
EMA at-site data w/o regional info	2.683830	0.045467	0.213230	0.216379
EMA w/ regional info and B17b MSE(G)	2.683830	0.045467	0.213230	0.096911
EMA w/ regional info and specified MSE(G)	2.683830	0.045467	0.213230	0.096911

EMA Estimate of MSE[G at-site]	0.128837
MSE[G at-site systematic]	0.128837
Equivalent Record Length [G at-site]	45.000000
Equivalent Record Length [Syst+Hist-LowOutl]	45.000000
Grubbs-Beck Critical Value	0.000000

--- Final Results ---

<< Plotting Positions >>

NF Walla Walla River-FLOW-PEAK

Events Analyzed		Ordered Events			
	FLOW		Water	FLOW	H-S
Day Mon Year	CFS	Rank	Year	CFS	Plot Pos
18 Jan 1970	500.0	1	1986	1,240.0	2.17
18 Jan 1971	782.0	2	2019	1,130.0	4.35
12 Mar 1972	810.0	3	2018	1,130.0	6.52
15 Jan 1973	250.0	4	1975	1,040.0	8.70
14 Jan 1974	458.0	5	2004	975.0	10.87
24 Jan 1975	1,040.0	6	2003	958.0	13.04
06 Dec 1975	795.0	7	2015	929.0	15.22
06 Apr 1977	278.0	8	1972	810.0	17.39
01 Dec 1977	644.0	9	1976	795.0	19.57
06 Mar 1979	371.0	10	1971	782.0	21.74
12 Jan 1980	240.0	11	1982	745.0	23.91
15 Feb 1981	624.0	12	1993	732.0	26.09
20 Feb 1982	745.0	13	2017	663.0	28.26
06 Jan 1983	528.0	14	1978	644.0	30.43
23 Jan 1984	600.0	15	1981	624.0	32.61
09 Apr 1985	377.0	16	1984	600.0	34.78
22 Feb 1986	1,240.0	17	1991	597.0	36.96
12 Mar 1987	204.0	18	1983	528.0	39.13
20 Apr 1988	204.0	19	1970	500.0	41.30
09 Mar 1989	263.0	20	2014	485.0	43.48
27 Apr 1990	400.0	21	2009	466.0	45.65
18 May 1991	597.0	22	1974	458.0	47.83
06 Dec 1991	350.0	23	2010	448.0	50.00
03 May 1993	732.0	24	2006	441.0	52.17
02 Jan 1994	354.0	25	2000	419.0	54.35
31 Jan 1995	324.0	26	2002	414.0	56.52
01 Jan 1996	---	27	2012	407.0	58.70
01 Jan 1997	---	28	1990	400.0	60.87

01 Jan 1998	---	29	1985	377.0	63.04
29 Dec 1998	315.0	30	2008	373.0	65.22
30 May 2000	419.0	31	1979	371.0	67.39
29 Apr 2001	307.0	32	1994	354.0	69.57
13 Apr 2002	414.0	33	2016	353.0	71.74
31 Jan 2003	958.0	34	1992	350.0	73.91
28 Jan 2004	975.0	35	1995	324.0	76.09
24 Nov 2004	291.0	36	1999	315.0	78.26
05 Apr 2006	441.0	37	2001	307.0	80.43
14 Dec 2006	273.0	38	2005	291.0	82.61
16 May 2008	373.0	39	1977	278.0	84.78
05 May 2009	466.0	40	2007	273.0	86.96
02 Jun 2010	448.0	41	1989	263.0	89.13
01 Jan 2011	---	42	1973	250.0	91.30
25 Apr 2012	407.0	43	1980	240.0	93.48
01 Jan 2013	---	44	1988	204.0	95.65
09 Mar 2014	485.0	45	1987	204.0	97.83
09 Feb 2015	929.0	46	2013	---	---
14 Feb 2016	353.0	47	2011	---	---
15 Mar 2017	663.0	48	1998	---	---
03 Feb 2018	1,130.0	49	1997	---	---
01 Jan 2019	1,130.0	50	1996	---	---

* Low outlier plotting positions are computed using Median parameters.

<< Frequency Curve >>

NF Walla Walla River-FLOW-PEAK

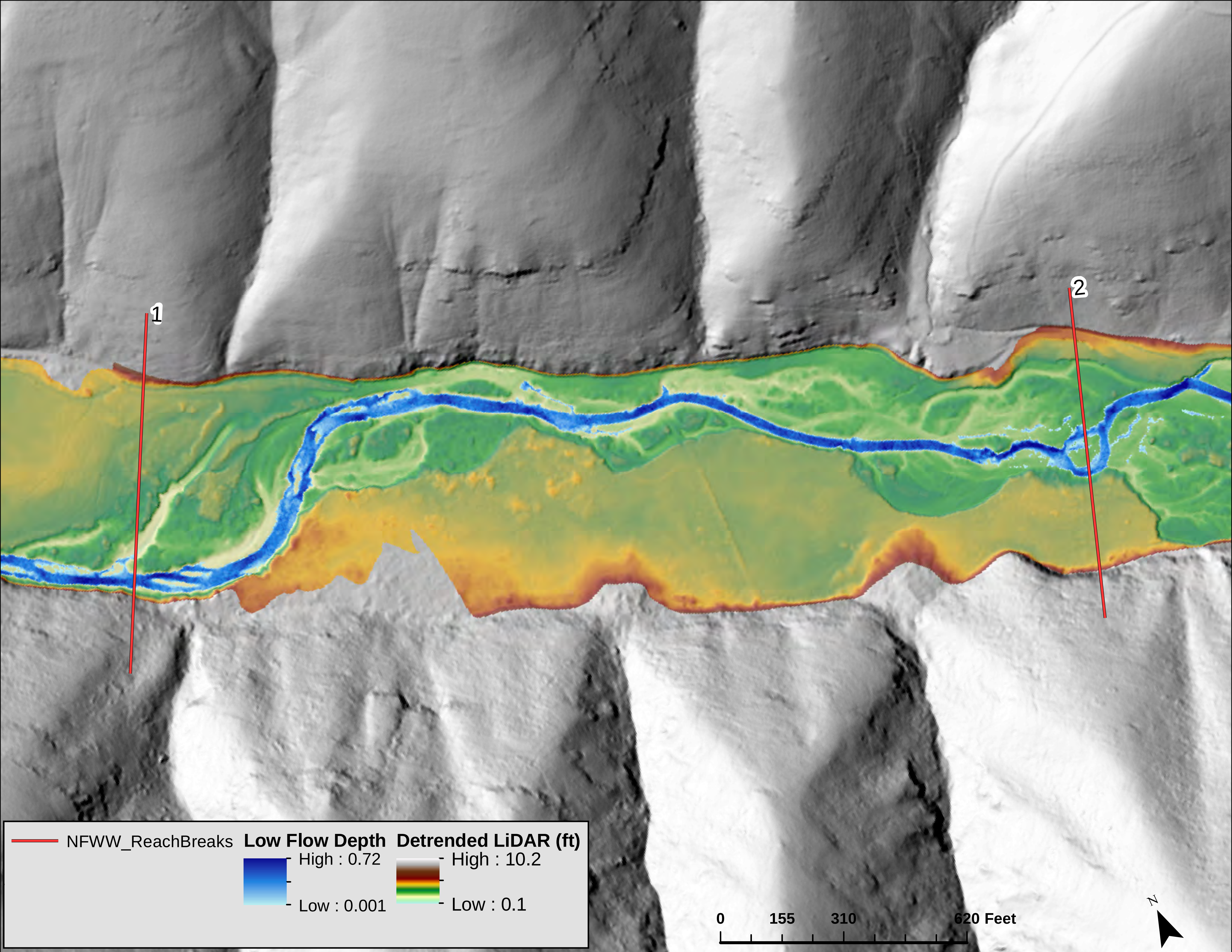
Computed Curve FLOW, CFS	Variance Log(EMA)	Percent Chance Exceedance	Confidence Limits 0.05 FLOW, CFS	Confidence Limits 0.95 FLOW, CFS
2,102.2	0.01077	0.200	3,710.0	1,550.0
1,788.4	0.00779	0.500	2,875.2	1,374.7
1,566.8	0.00593	1.000	2,352.3	1,240.9
1,357.5	0.00438	2.000	1,907.7	1,105.8
1,097.3	0.00283	5.000	1,421.1	923.8
910.4	0.00199	10.000	1,116.9	782.4
728.1	0.00144	20.000	855.8	635.8
479.1	0.00110	50.000	545.1	421.8
318.7	0.00129	80.000	363.2	274.4
258.7	0.00170	90.000	298.2	215.0
218.3	0.00234	95.000	255.9	173.4
159.6	0.00476	99.000	197.4	112.2

<< Multiple Grubbs-Beck Test P-Values >>

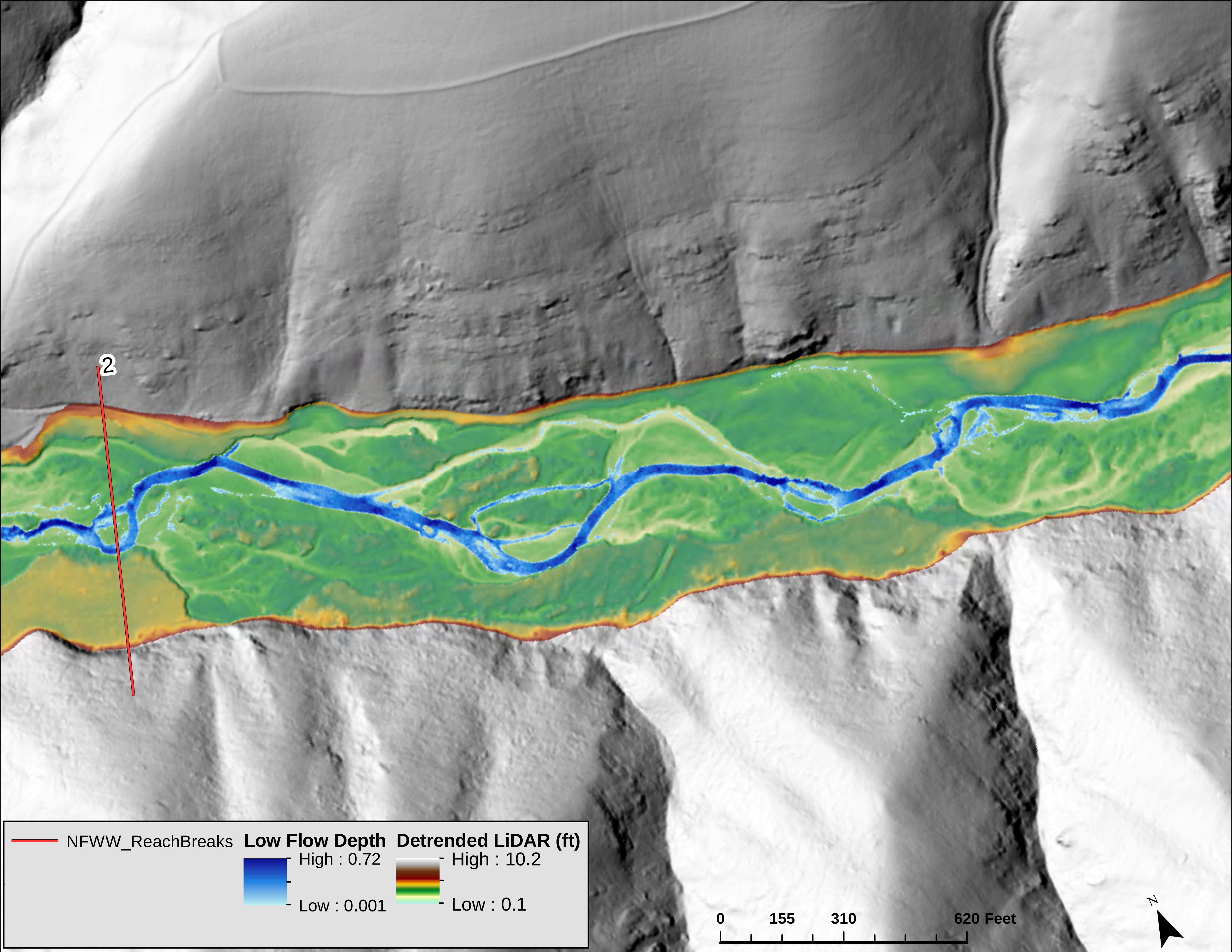
NF Walla Walla River-FLOW-PEAK

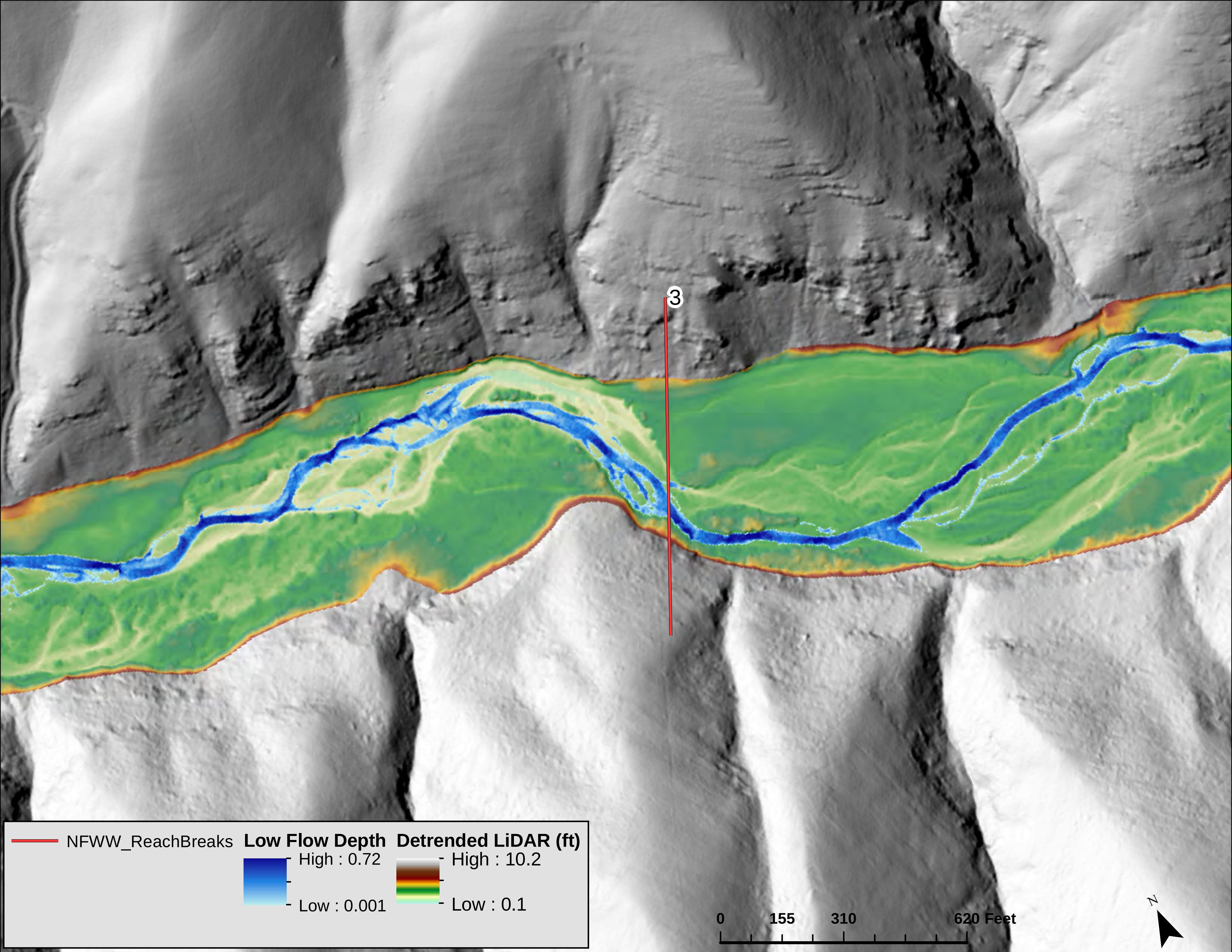
Number Of Low Outliers	P-Values
1	9.128E-1
2	6.474E-1
3	8.466E-1
4	7.824E-1
5	7.659E-1
6	7.199E-1
7	5.948E-1
8	5.994E-1
9	6.622E-1
10	6.021E-1
11	5.564E-1

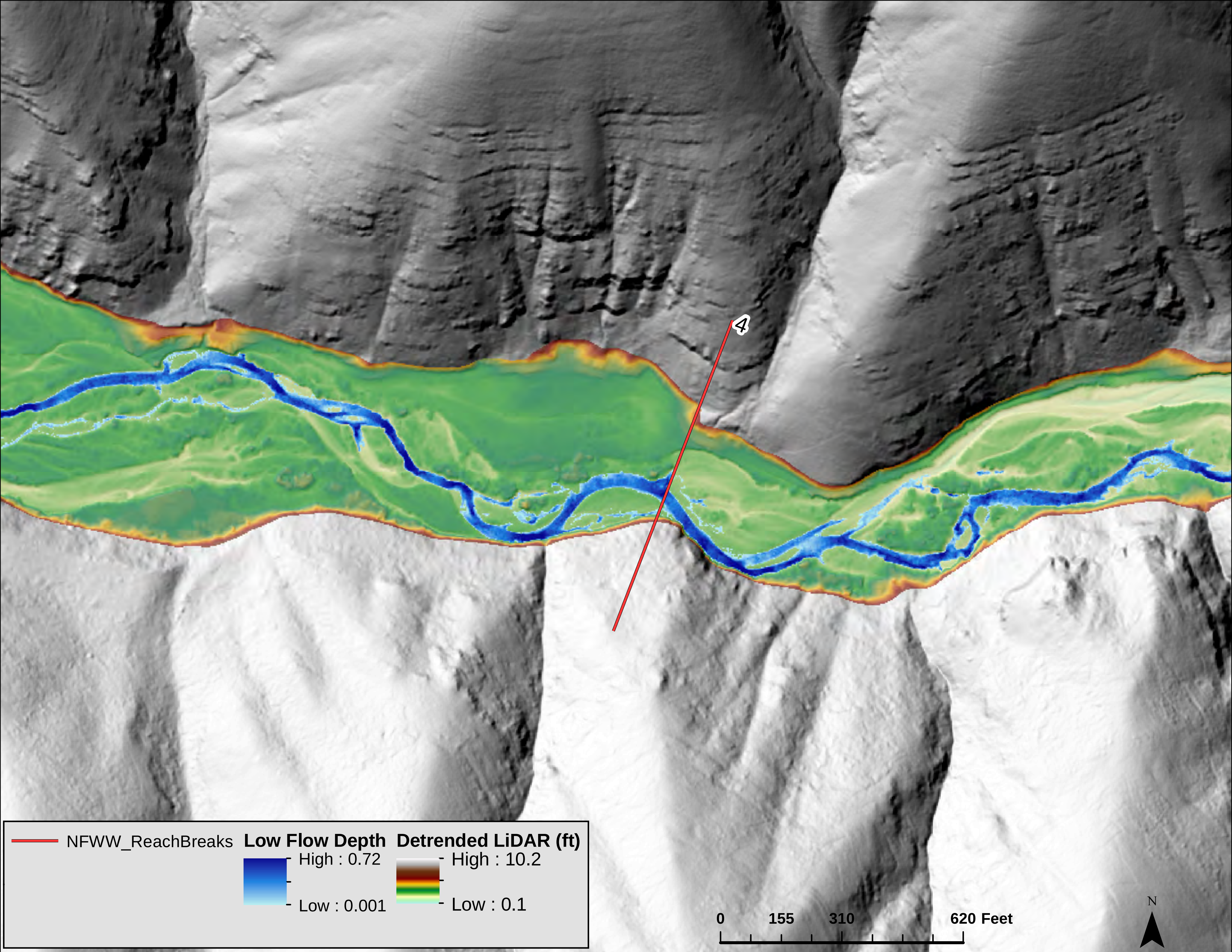
Appendix D
HEC-RAS Hydraulic Model Results

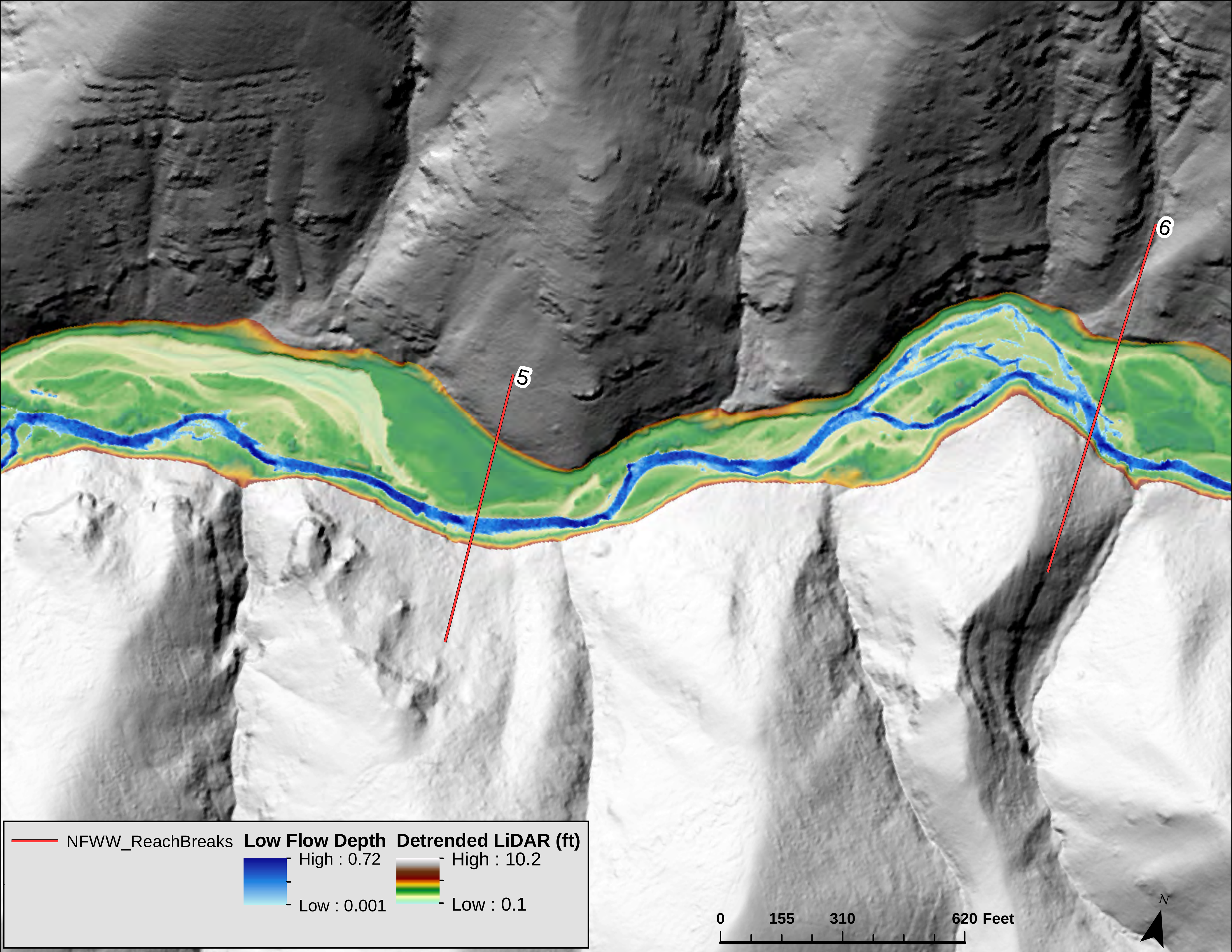


1
2
NFWW_ReachBreaks
Low Flow Depth
High : 0.72
Low : 0.001
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
0
155
310
620 Feet
N

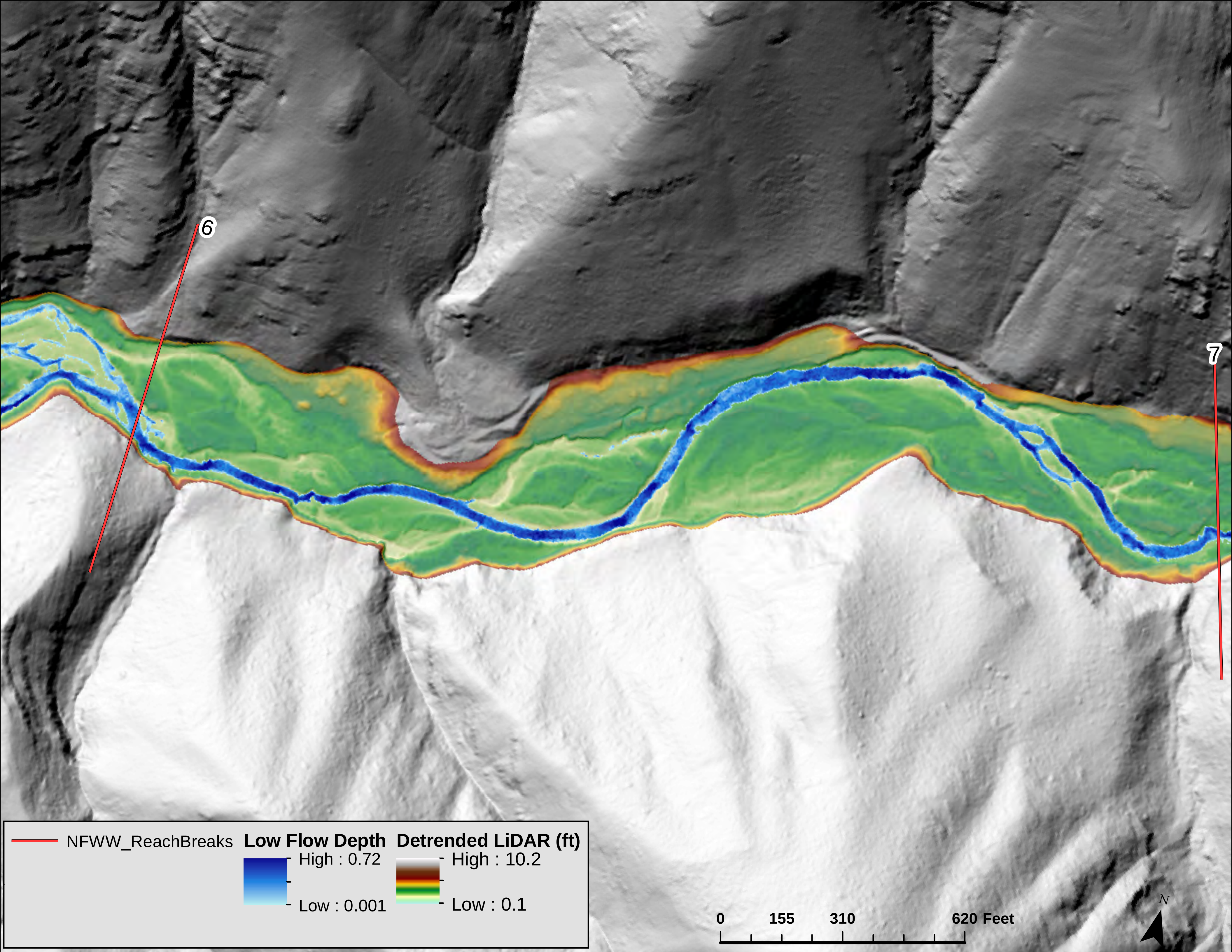

2
NFWW_ReachBreaks
Low Flow Depth
High : 0.72
Low : 0.001
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
0
155
310
620 Feet
N

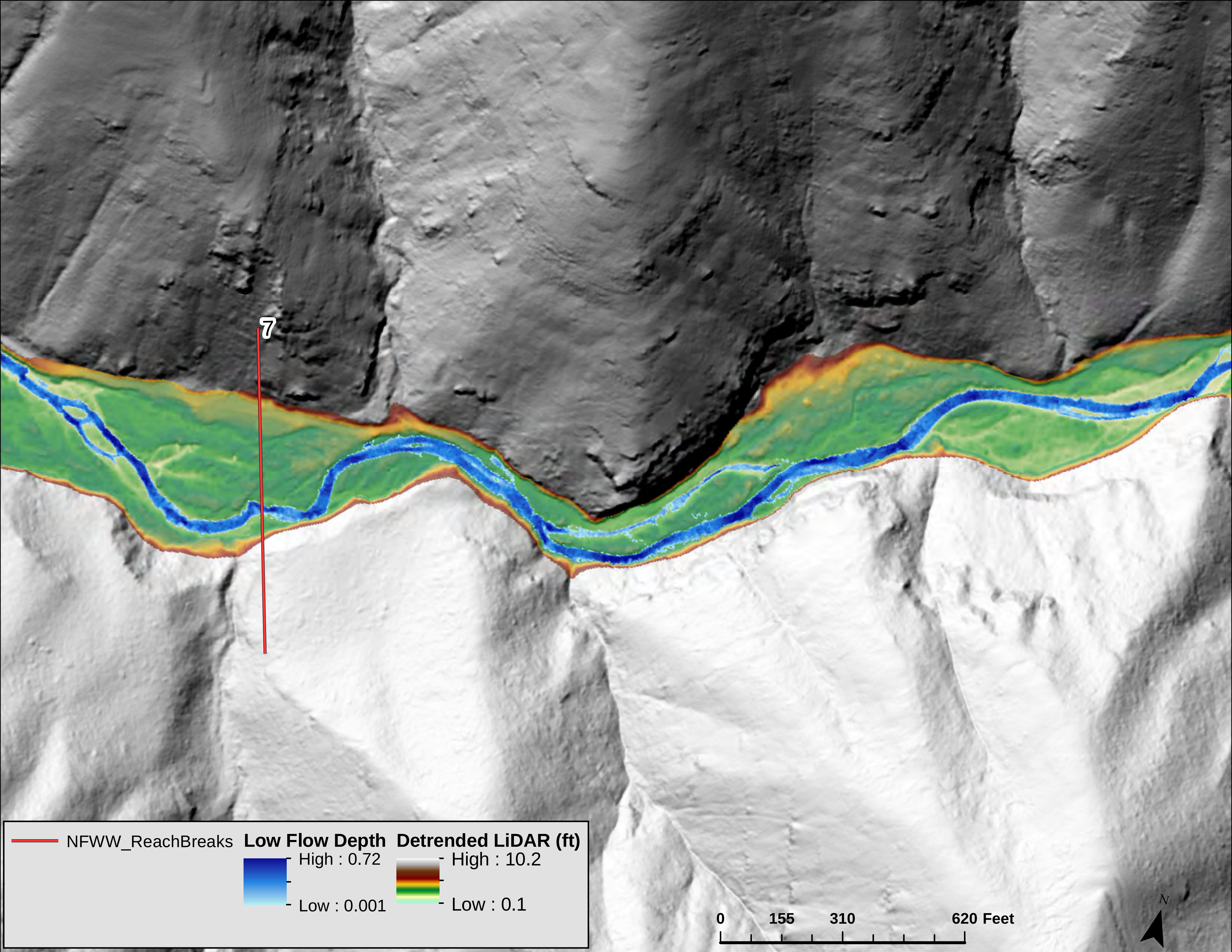

3
NFWW_ReachBreaks
Low Flow Depth
High : 0.72
Low : 0.001
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
0
155
310
620 Feet
N

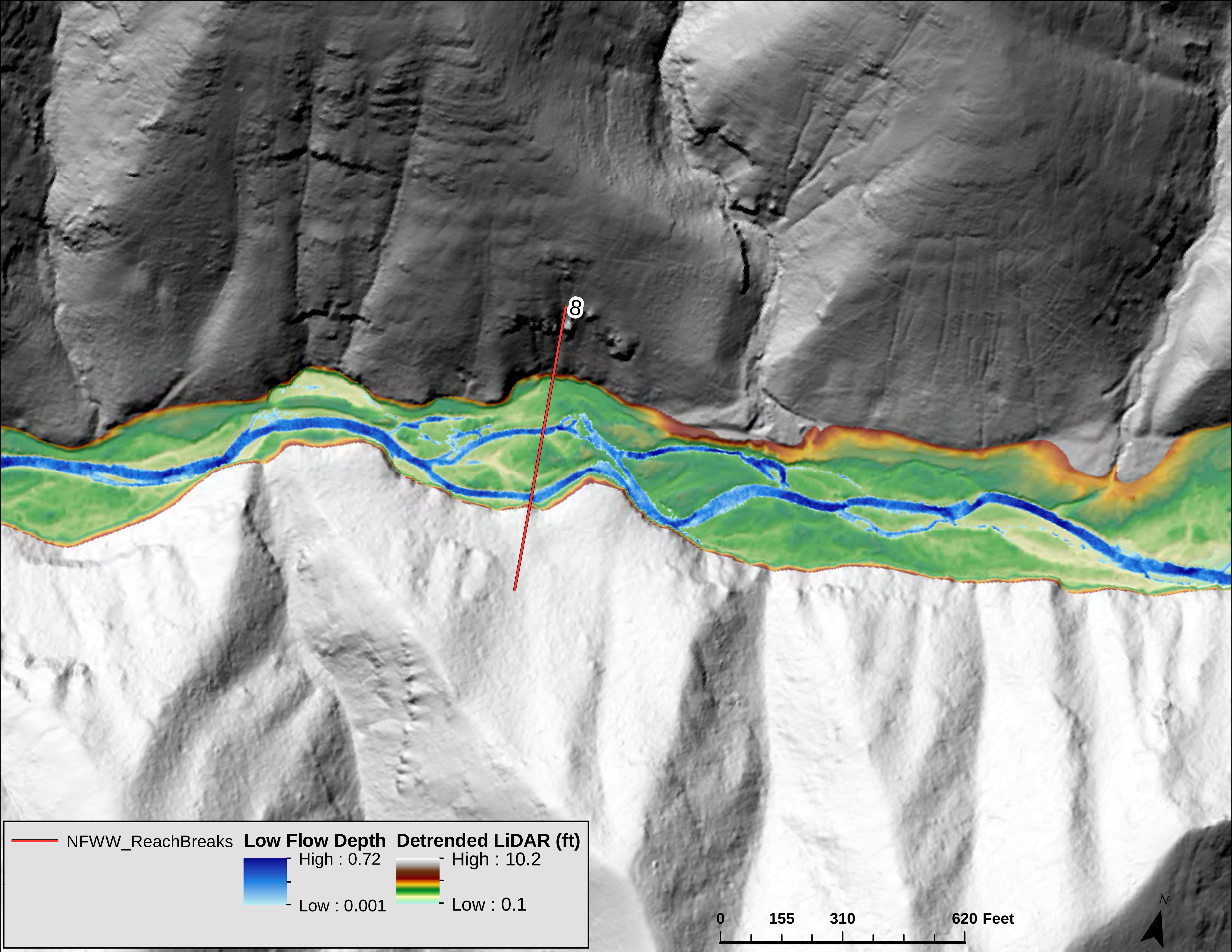

4
NFWW_ReachBreaks
Low Flow Depth
High : 0.72
Low : 0.001
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
0
155
310
620 Feet
N

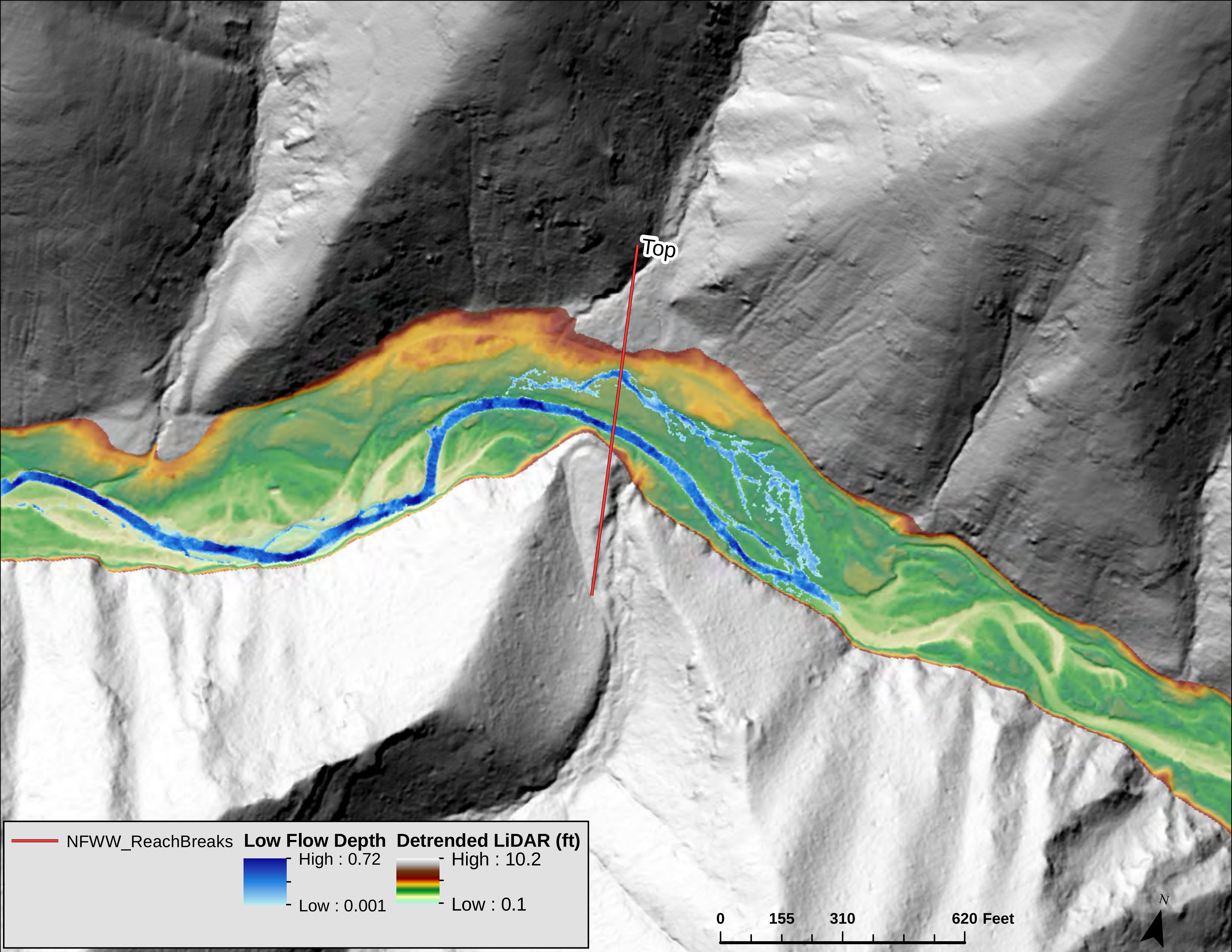


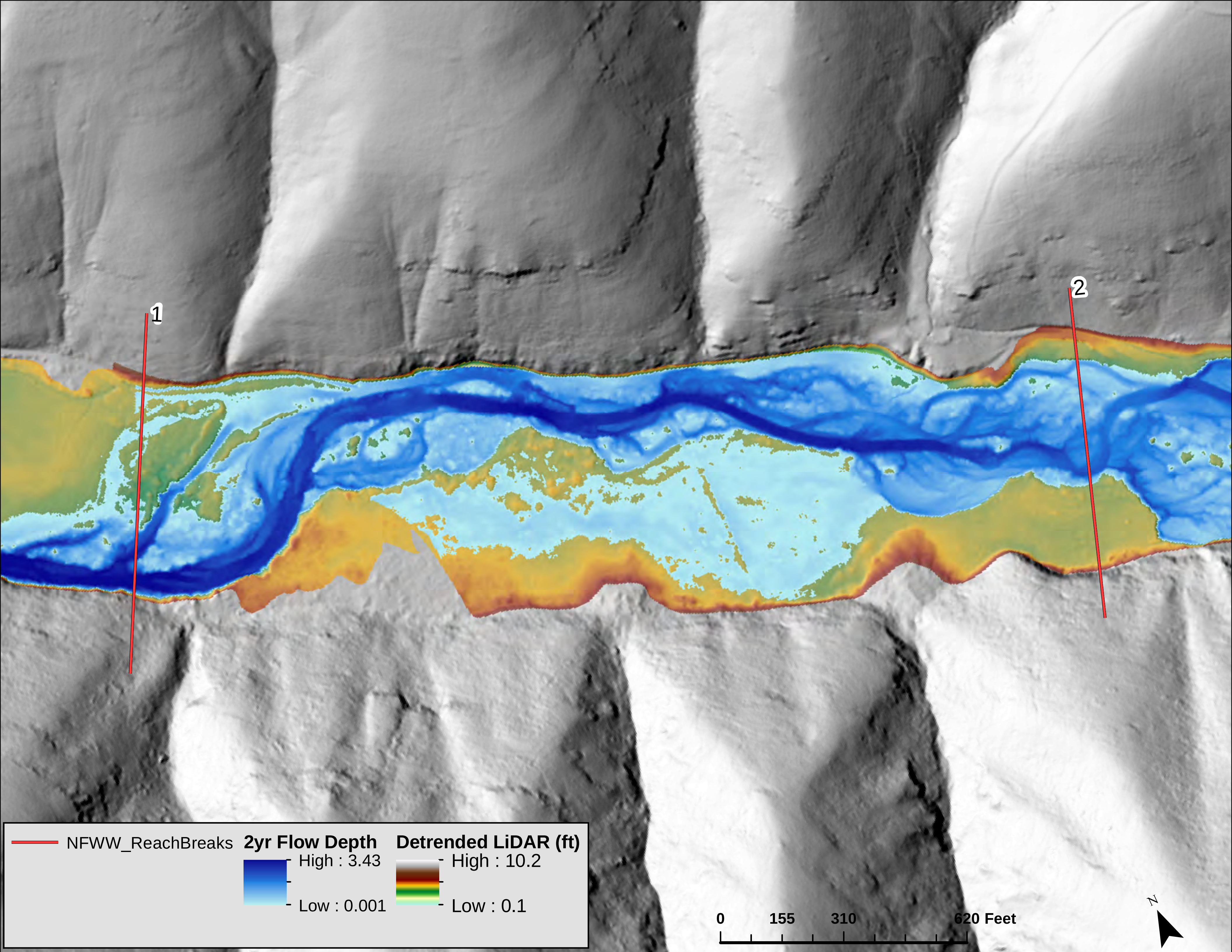
5
6
NFWW_ReachBreaks
Low Flow Depth
High : 0.72
Low : 0.001
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
0
155
310
620 Feet
N


6
7
NFWW_ReachBreaks
Low Flow Depth
High : 0.72
Low : 0.001
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
0
155
310
620 Feet
N

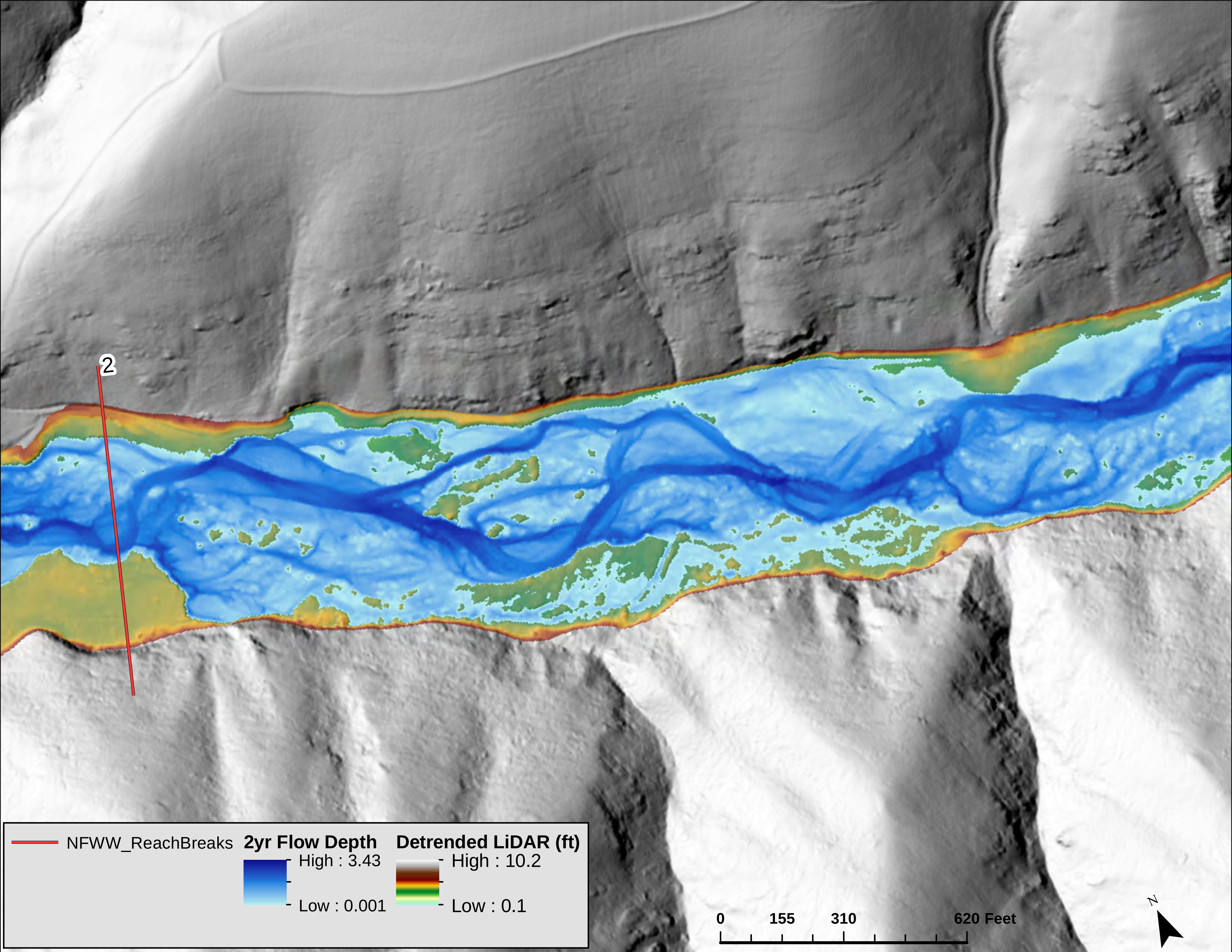

7
NFWW_ReachBreaks
Low Flow Depth
High : 0.72
Low : 0.001
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
0
155
310
620 Feet
N


8
NFWW_ReachBreaks
Low Flow Depth
High : 0.72
Low : 0.001
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
0
155
310
620 Feet
N

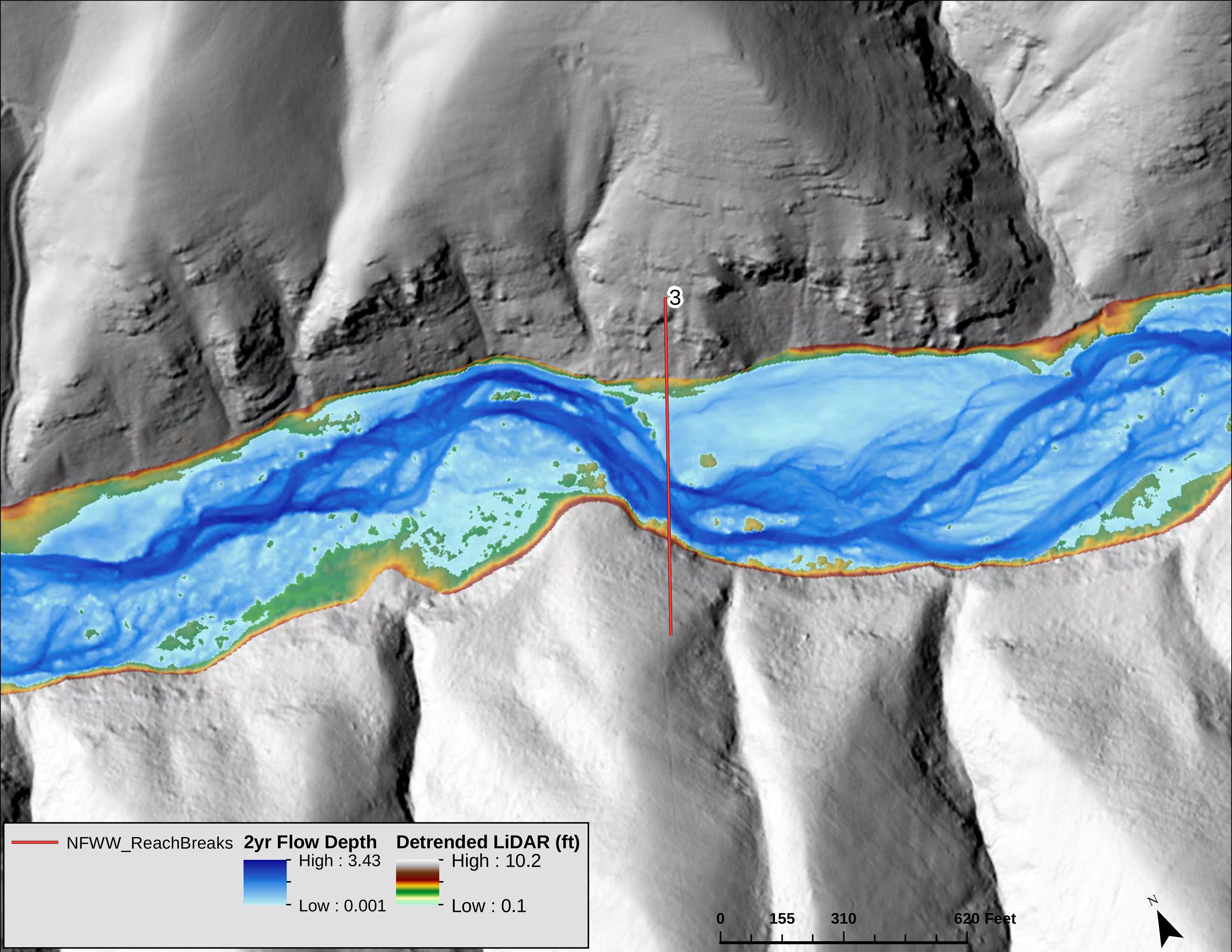

Top
NFWW_ReachBreaks
Low Flow Depth
High : 0.72
Low : 0.001
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
0
155
310
620 Feet
N



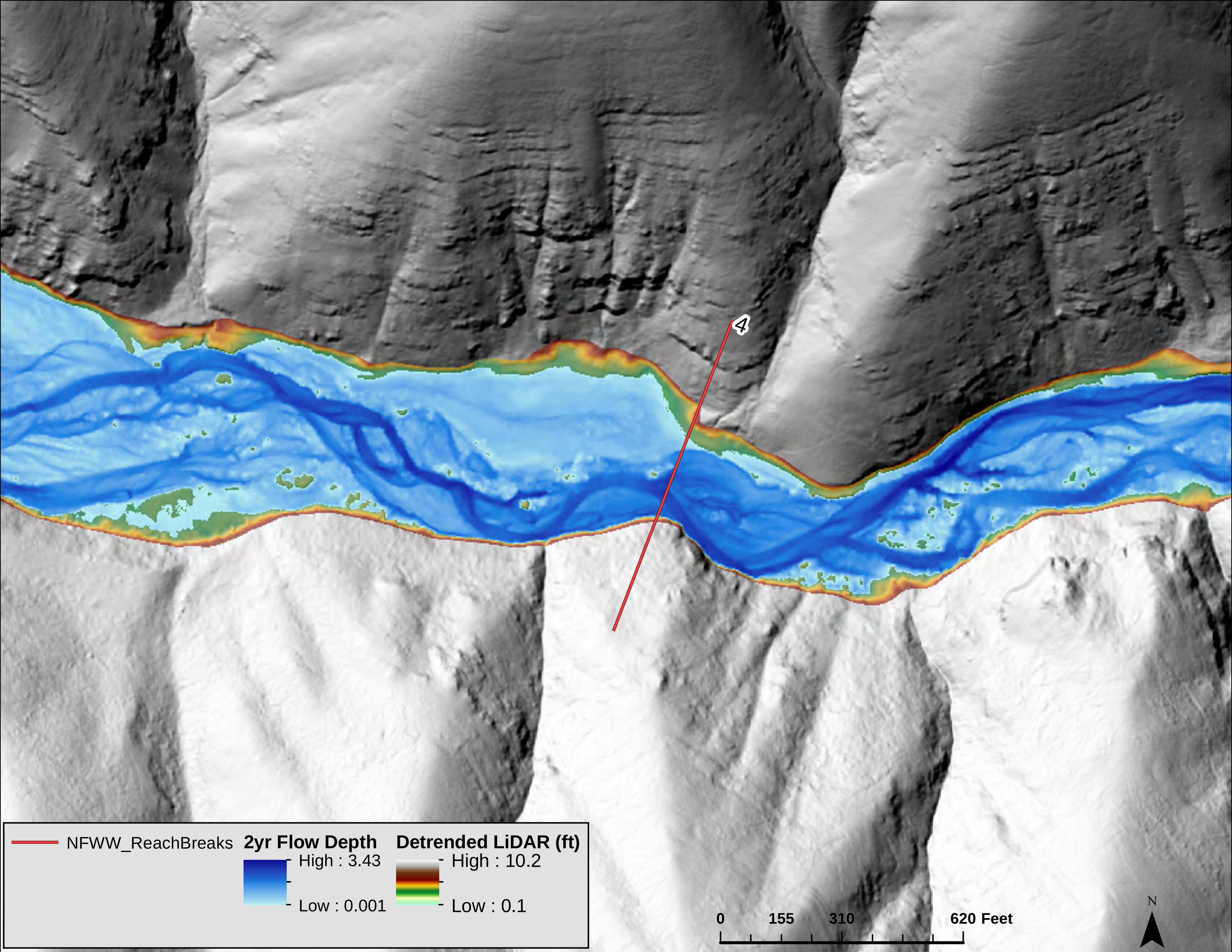
1
2
NFWW_ReachBreaks
2yr Flow Depth
High : 3.43
Low : 0.001
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
0
155
310
620 Feet
N



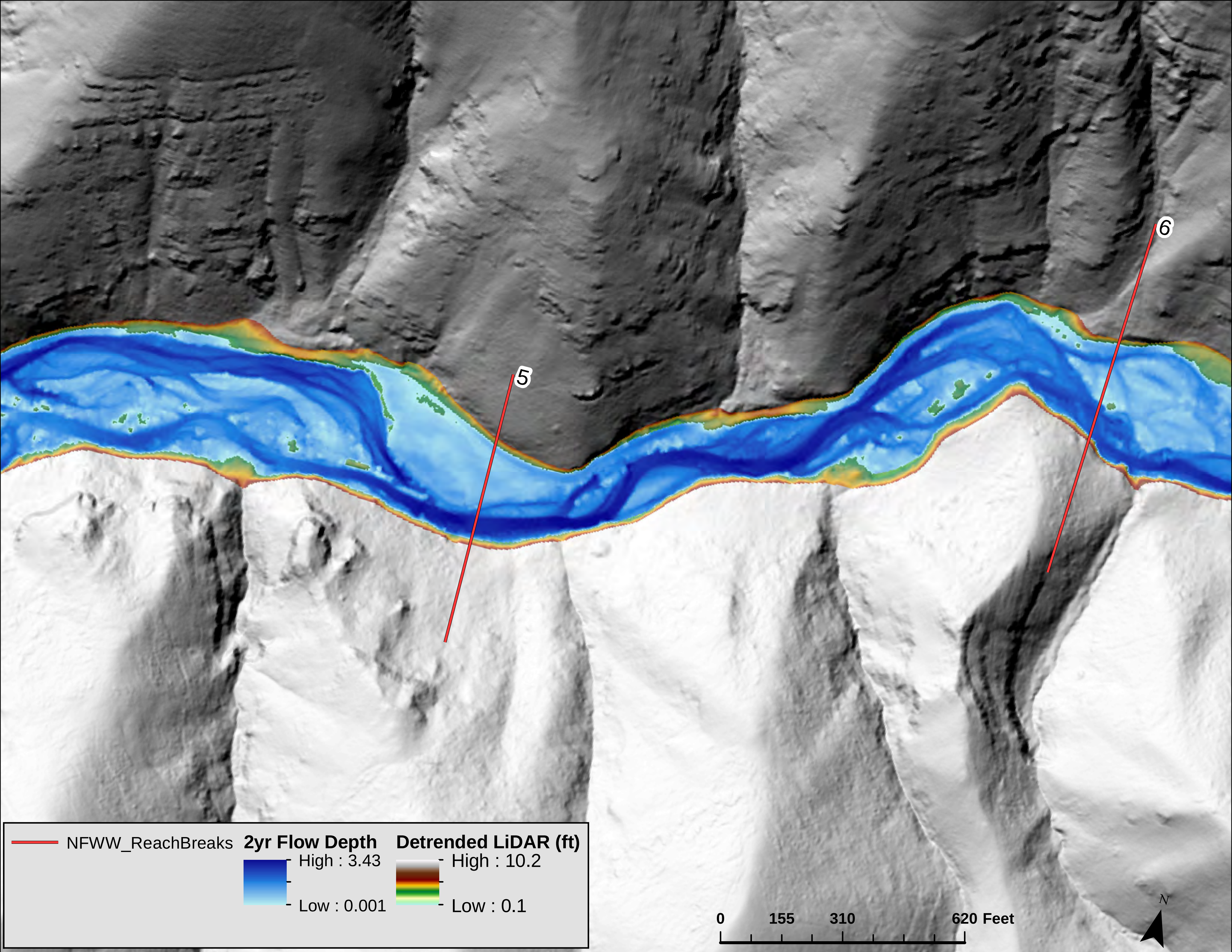
2
NFWW_ReachBreaks
2yr Flow Depth
High : 3.43
Low : 0.001
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
0
155
310
620 Feet
N

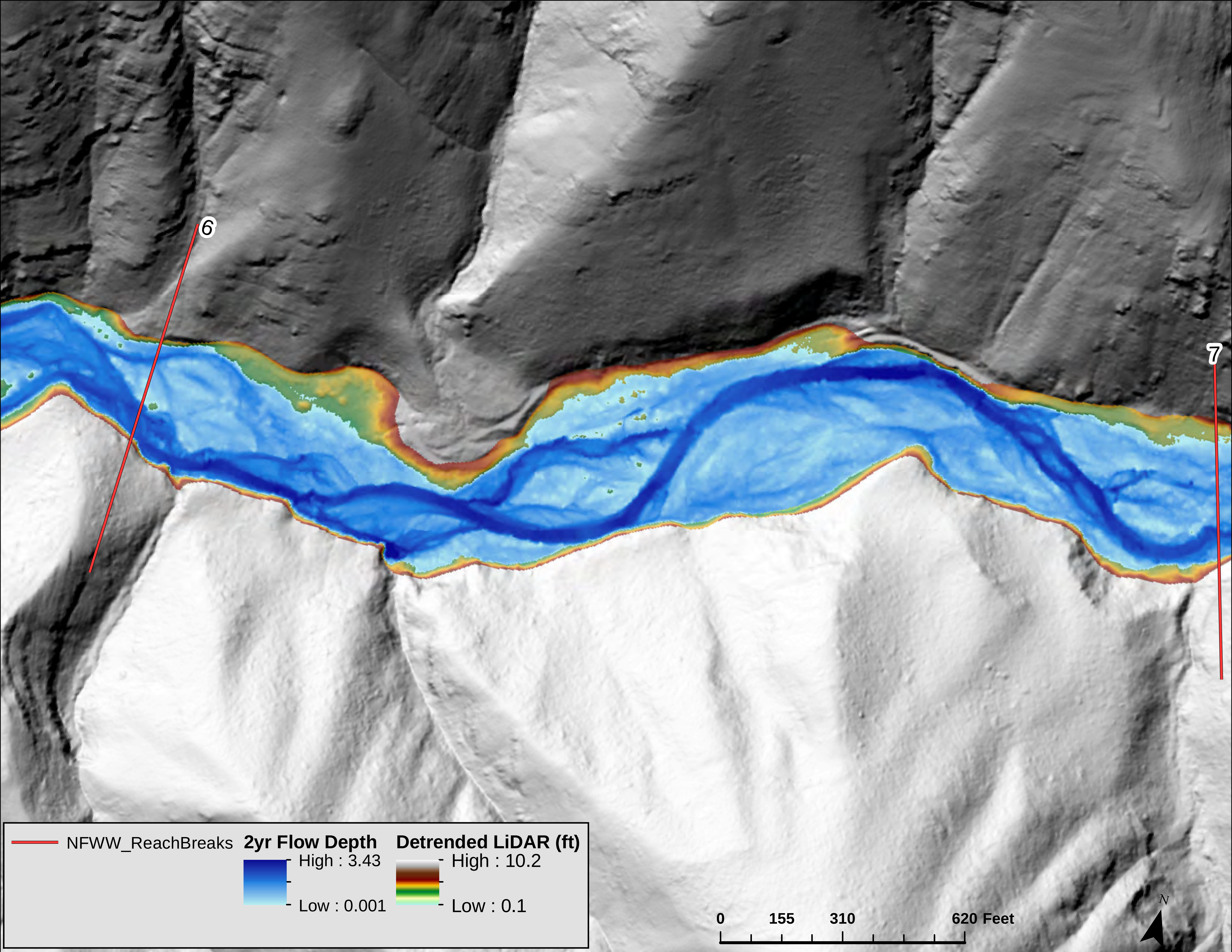


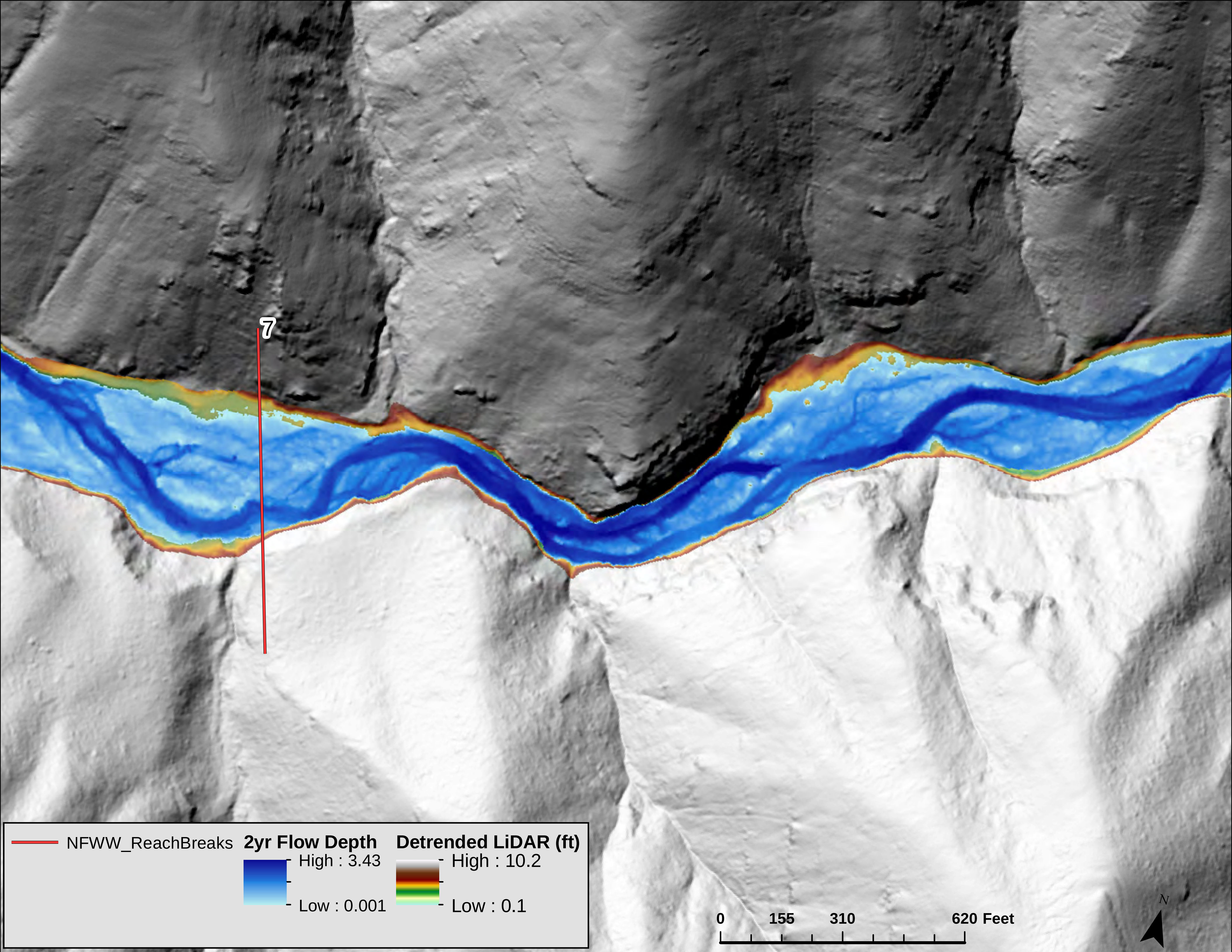
3
NFWW_ReachBreaks
2yr Flow Depth
High : 3.43
Low : 0.001
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
0
155
310
620 Feet
N

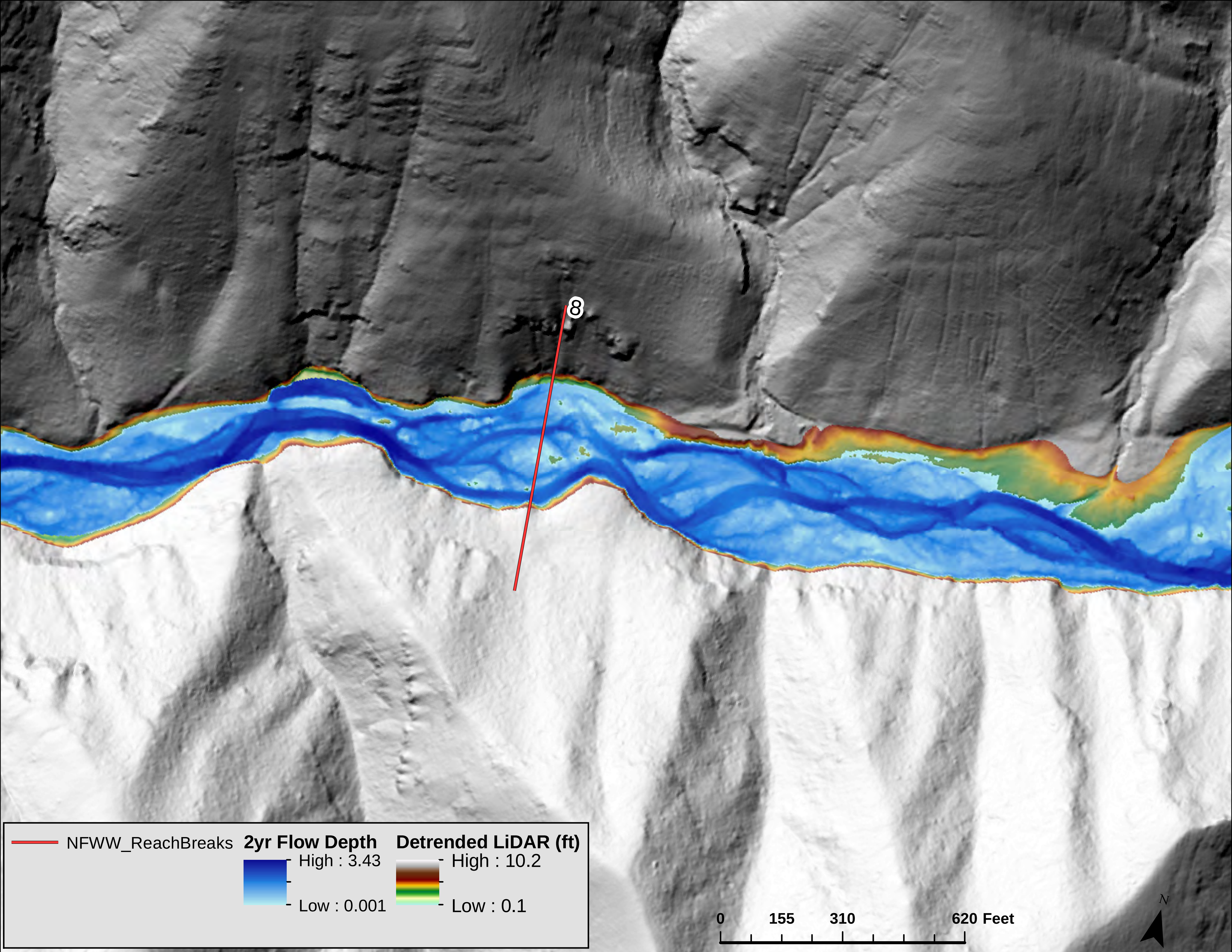


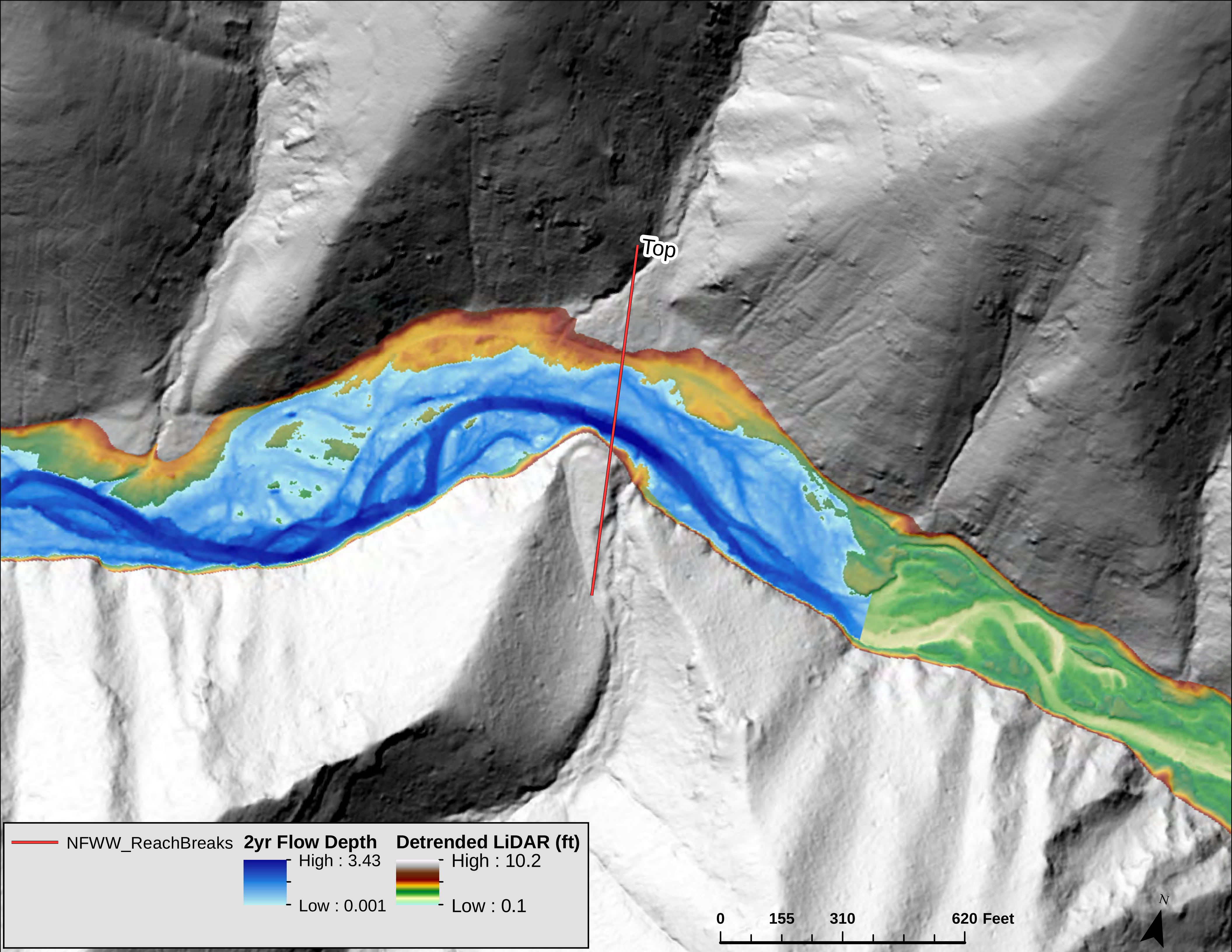
4
NFWW_ReachBreaks
2yr Flow Depth
High : 3.43
Low : 0.001
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
0
155
310
620 Feet
N

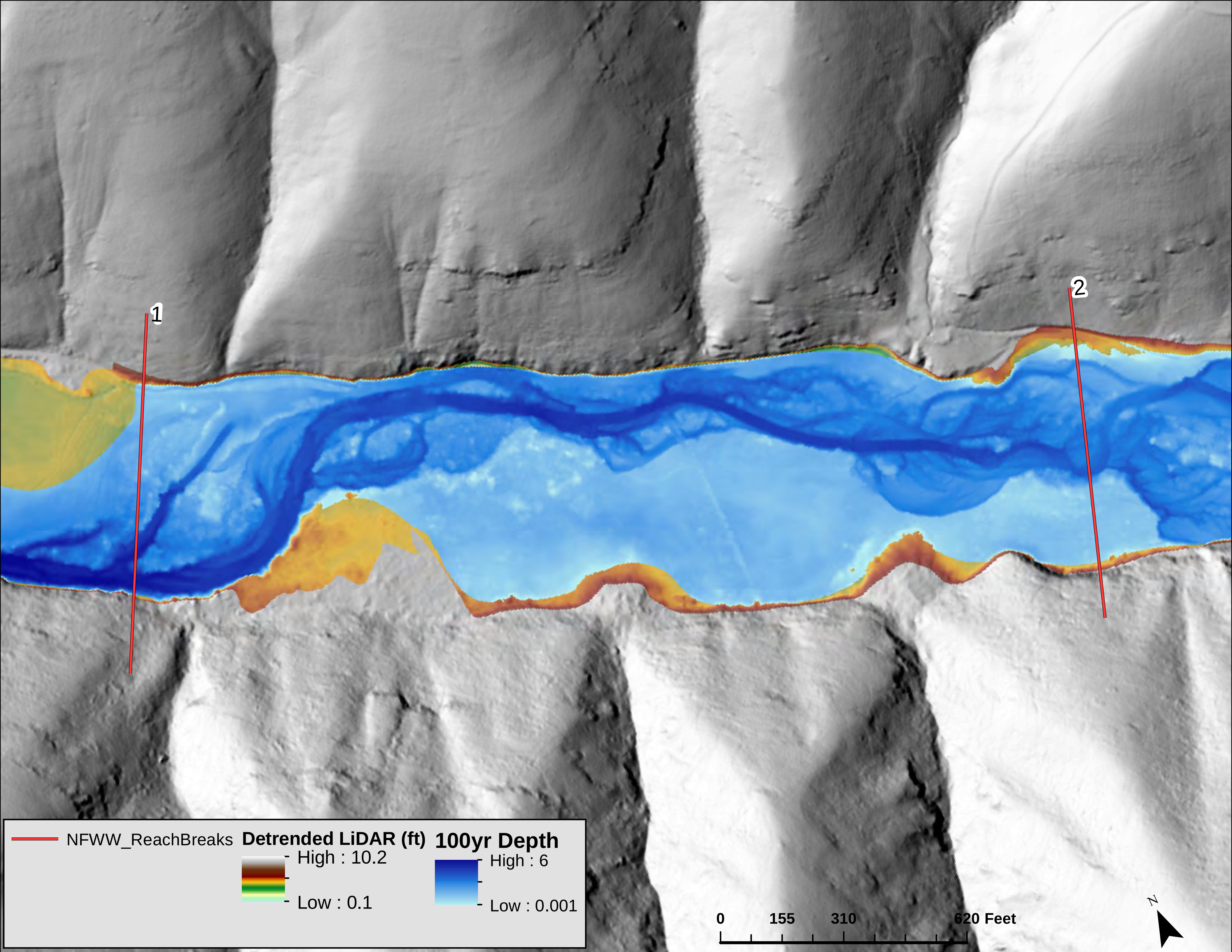

5
6
NFWW_ReachBreaks
2yr Flow Depth
High : 3.43
Low : 0.001
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
0
155
310
620 Feet
N


6
7
NFWW_ReachBreaks
2yr Flow Depth
High : 3.43
Low : 0.001
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
0
155
310
620 Feet
N

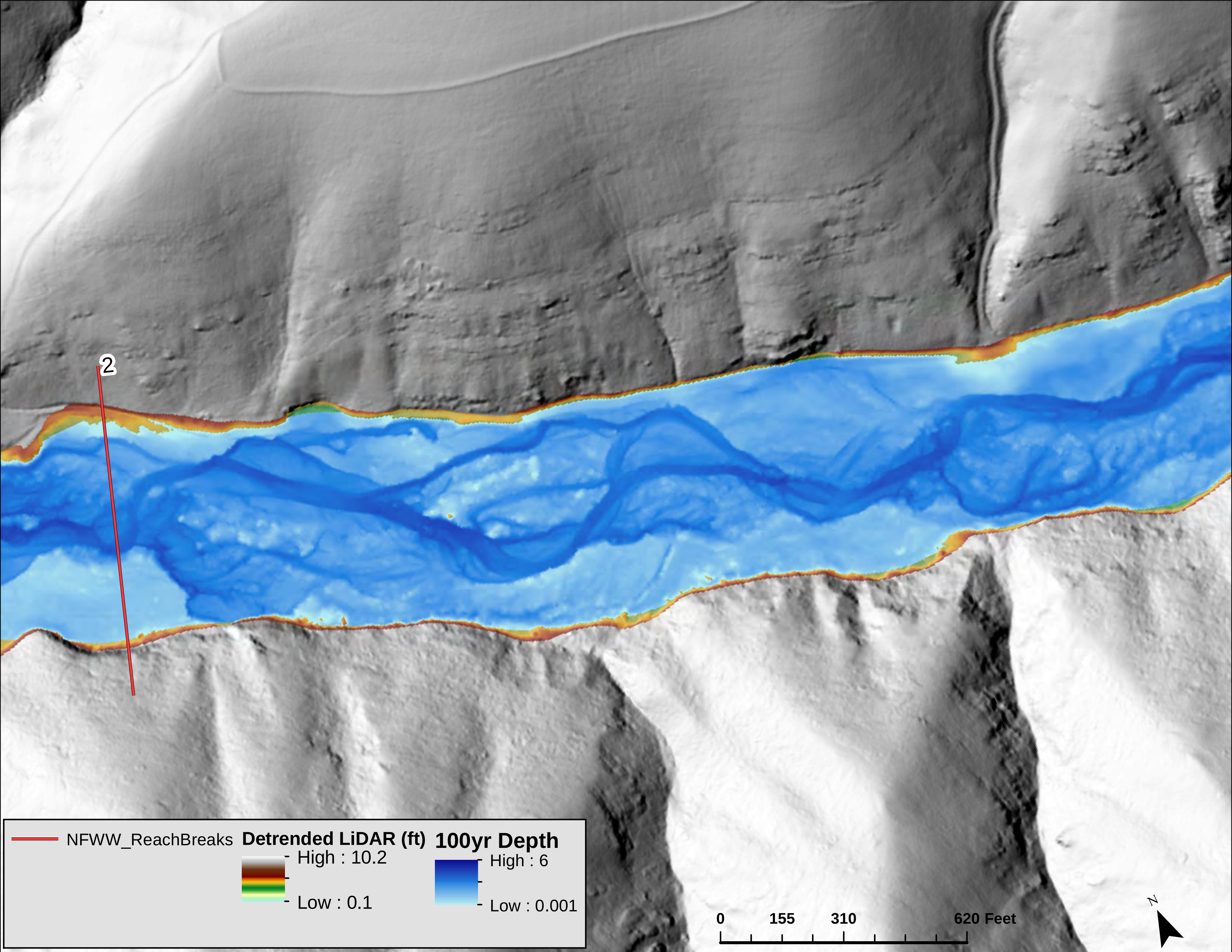

7
NFWW_ReachBreaks
2yr Flow Depth
High : 3.43
Low : 0.001
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
0
155
310
620 Feet
N


8
NFWW_ReachBreaks
2yr Flow Depth
High : 3.43
Low : 0.001
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
0
155
310
620 Feet
N

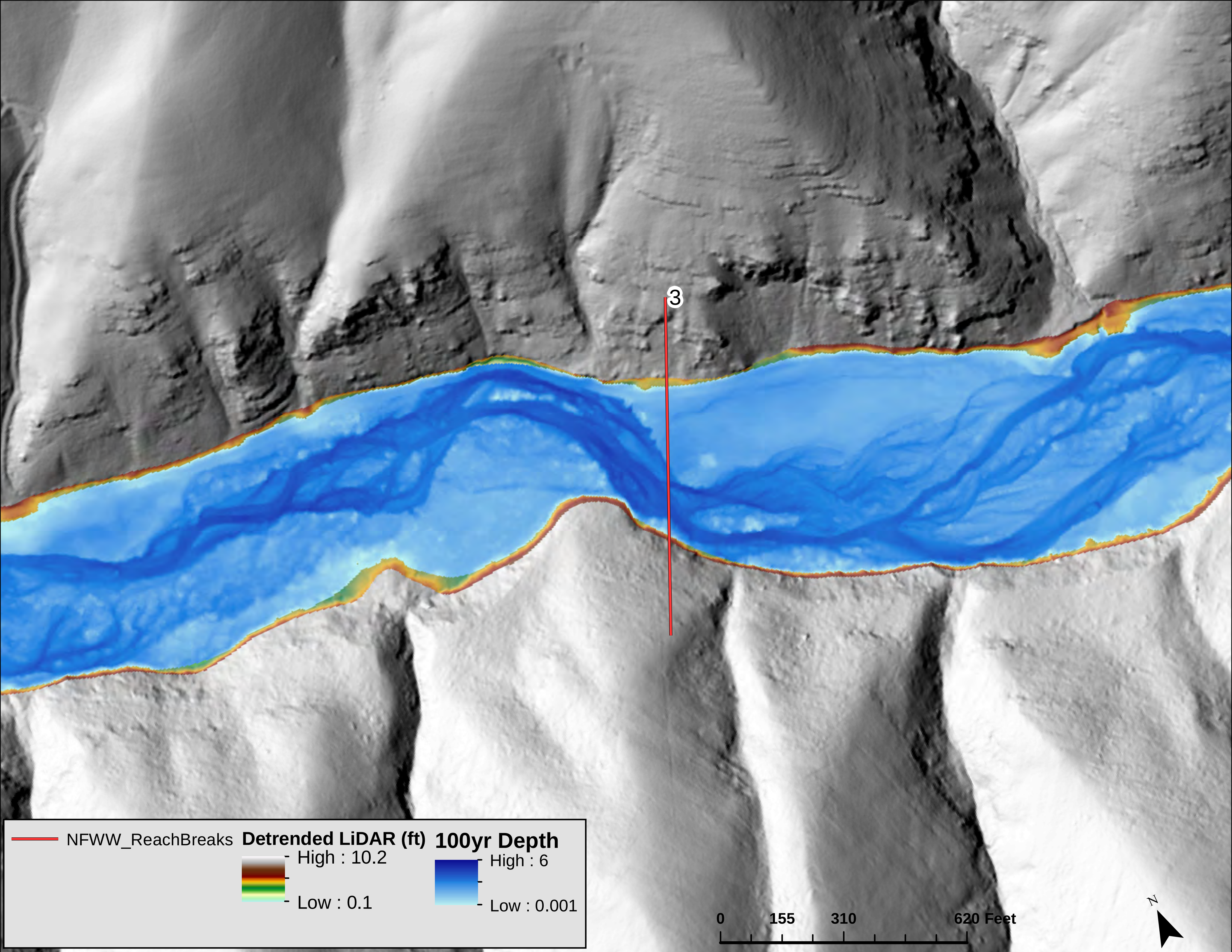

Top
NFWW_ReachBreaks
2yr Flow Depth
High : 3.43
Low : 0.001
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
0
155
310
620 Feet
N

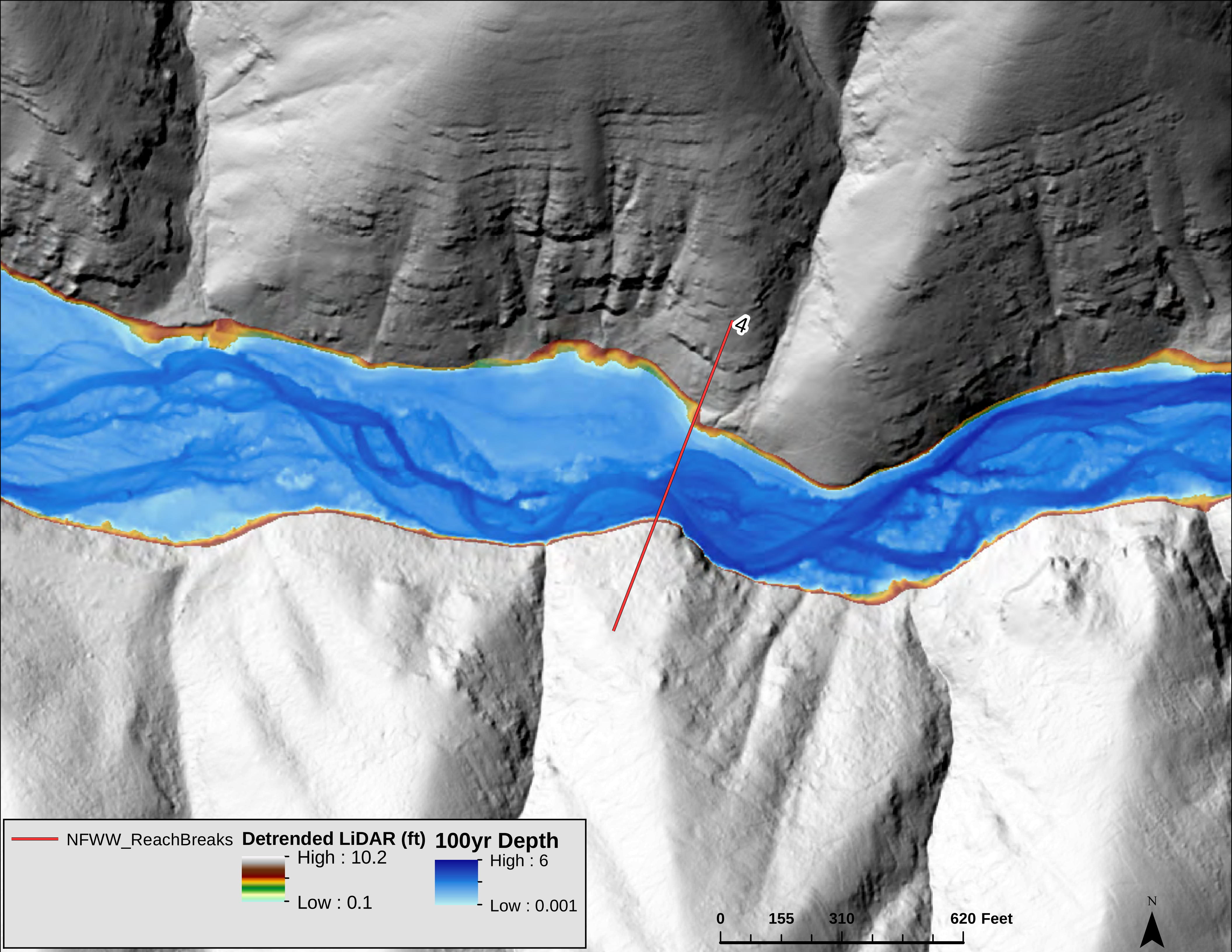


1
2
NFWW_ReachBreaks
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
100yr Depth
High : 6
Low : 0.001
0
155
310
620 Feet
N

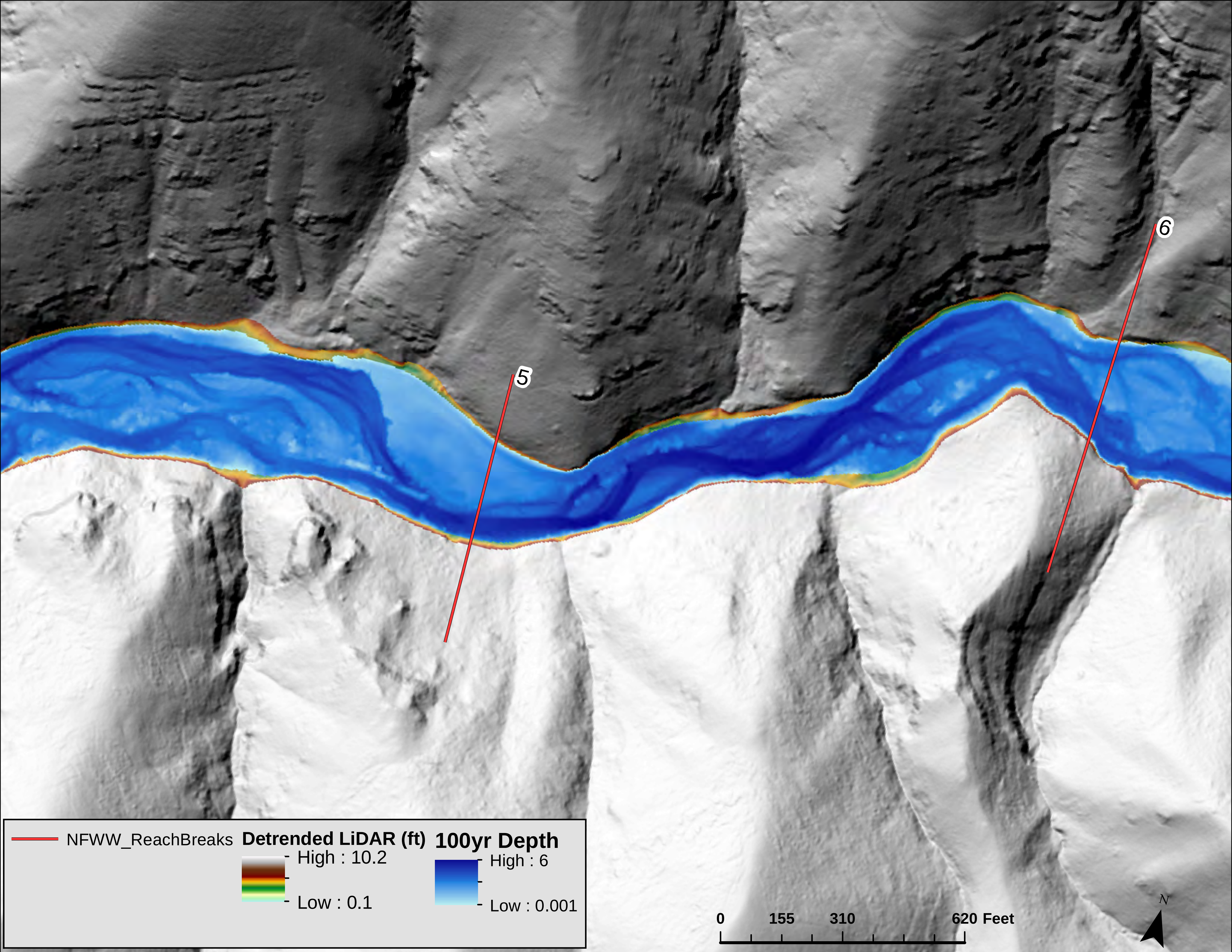


2
NFWW_ReachBreaks
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
100yr Depth
High : 6
Low : 0.001
0
155
310
620 Feet
N

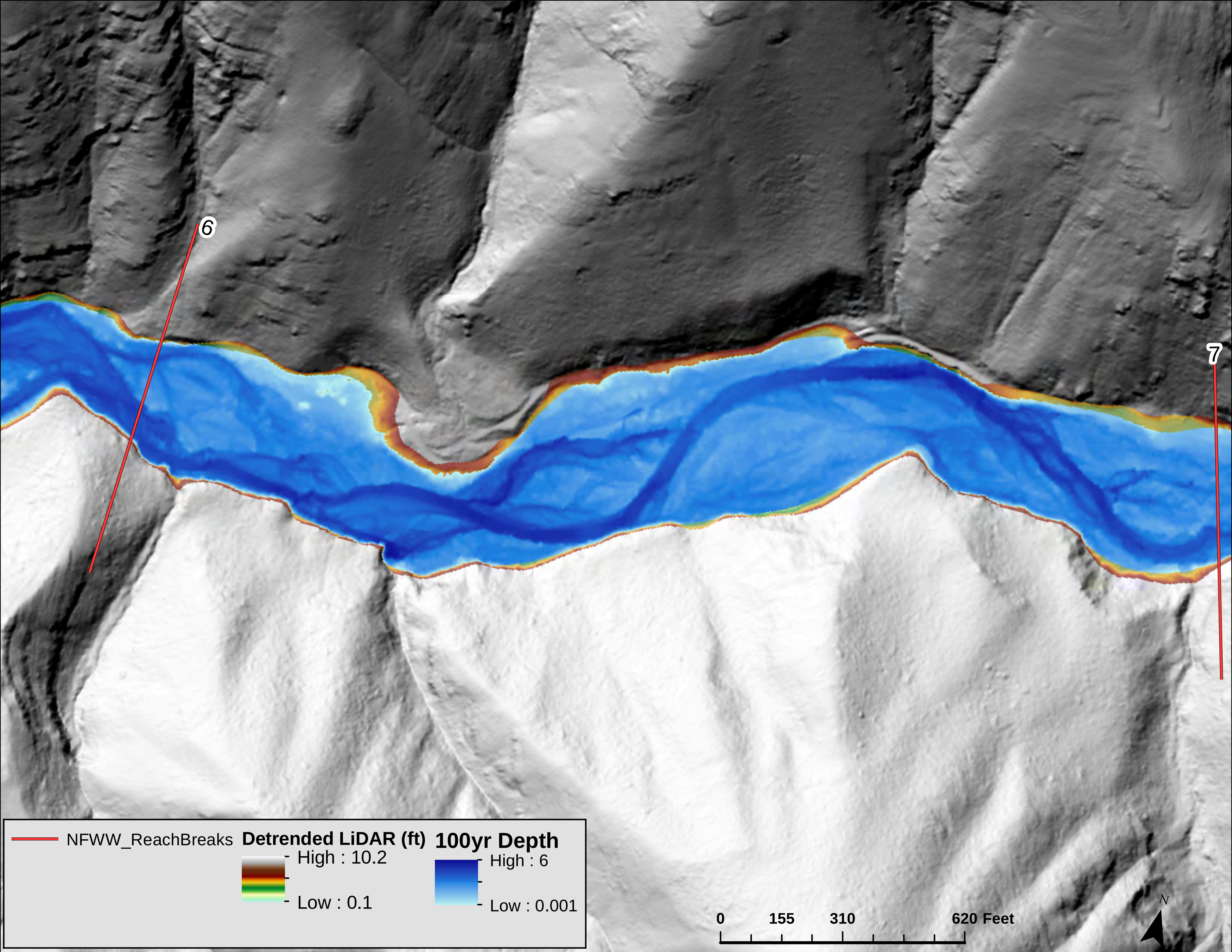

3
NFWW_ReachBreaks
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
100yr Depth
High : 6
Low : 0.001
0
155
310
620 Feet
N

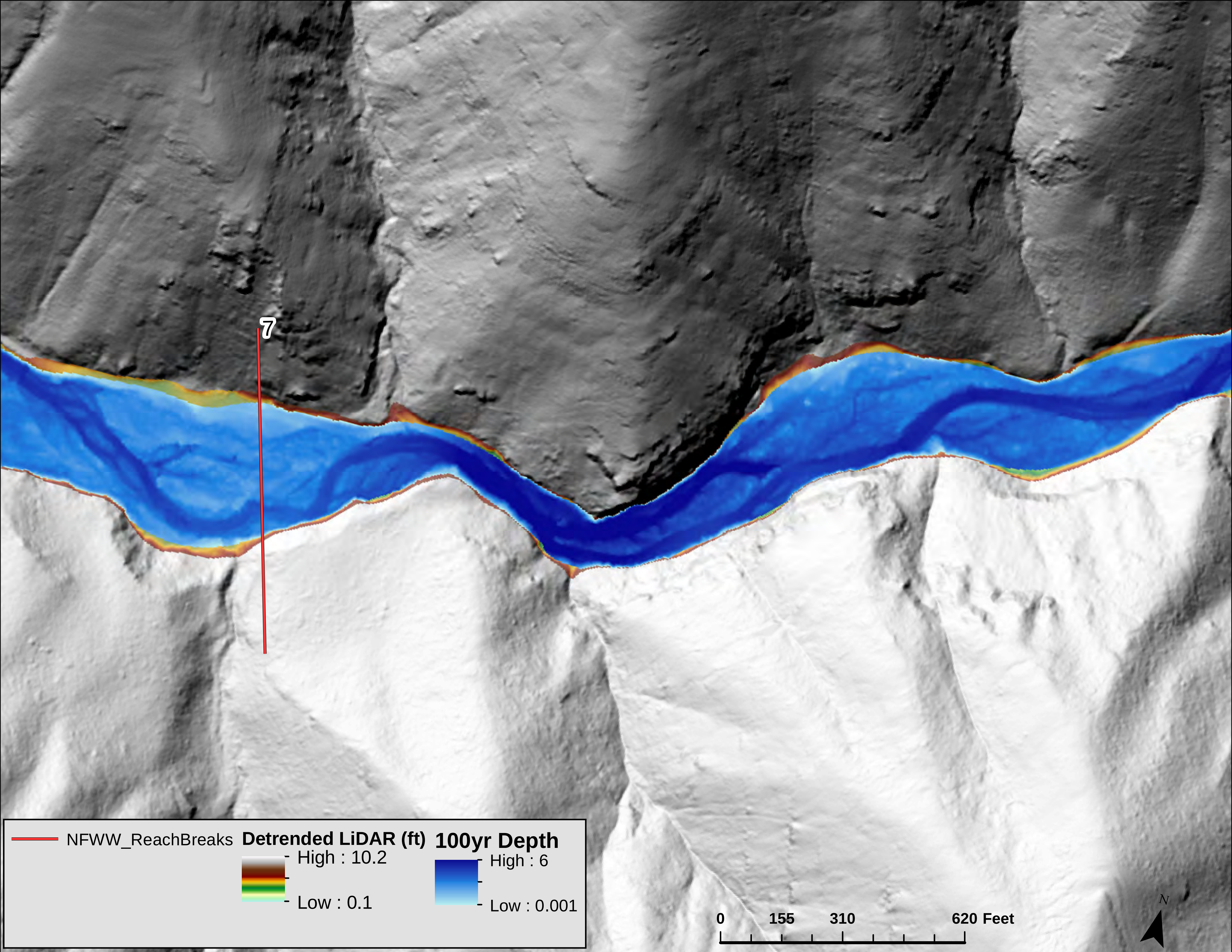


4
NFWW_ReachBreaks
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
100yr Depth
High : 6
Low : 0.001
0
155
310
620 Feet
N

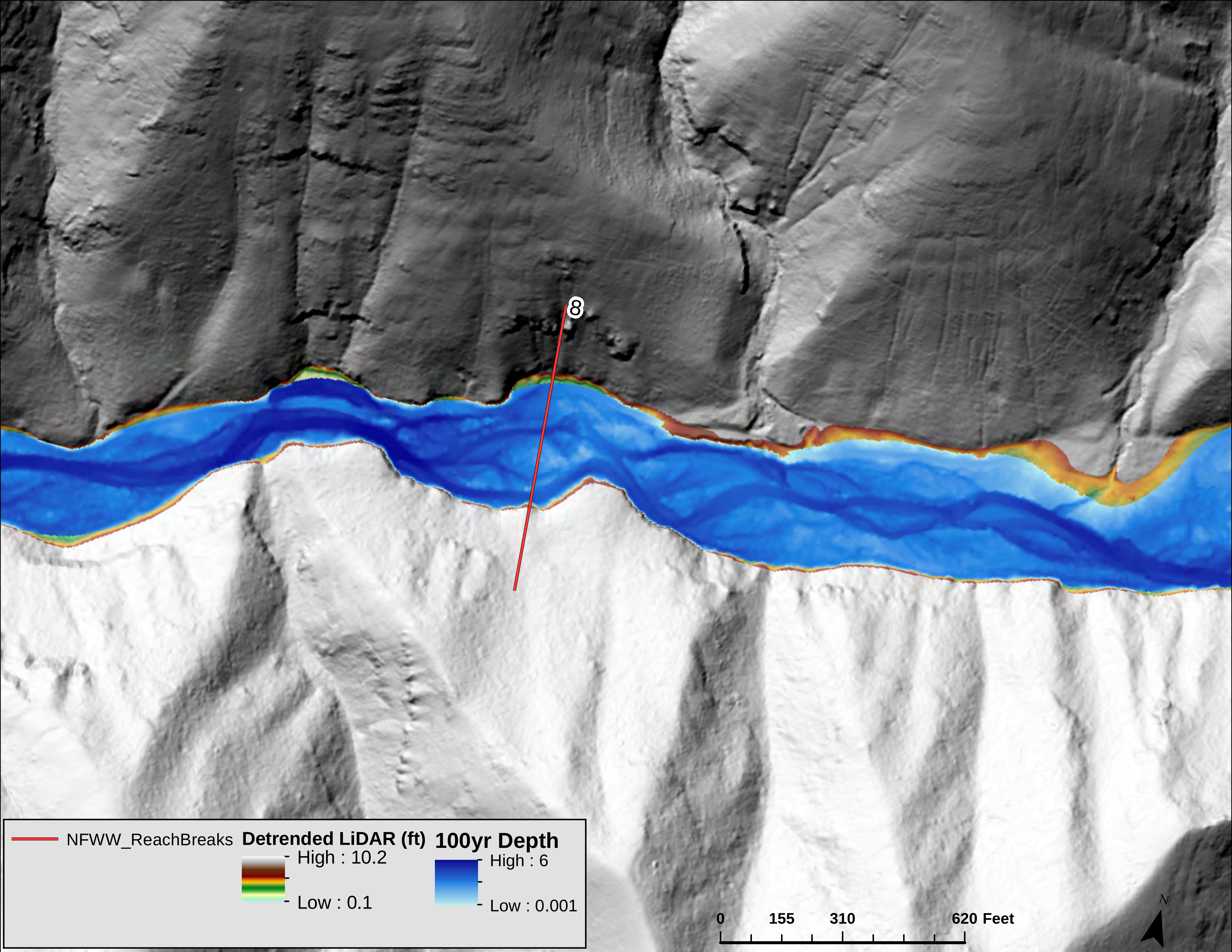


5
6
NFWW_ReachBreaks
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
100yr Depth
High : 6
Low : 0.001
0
155
310
620 Feet
N

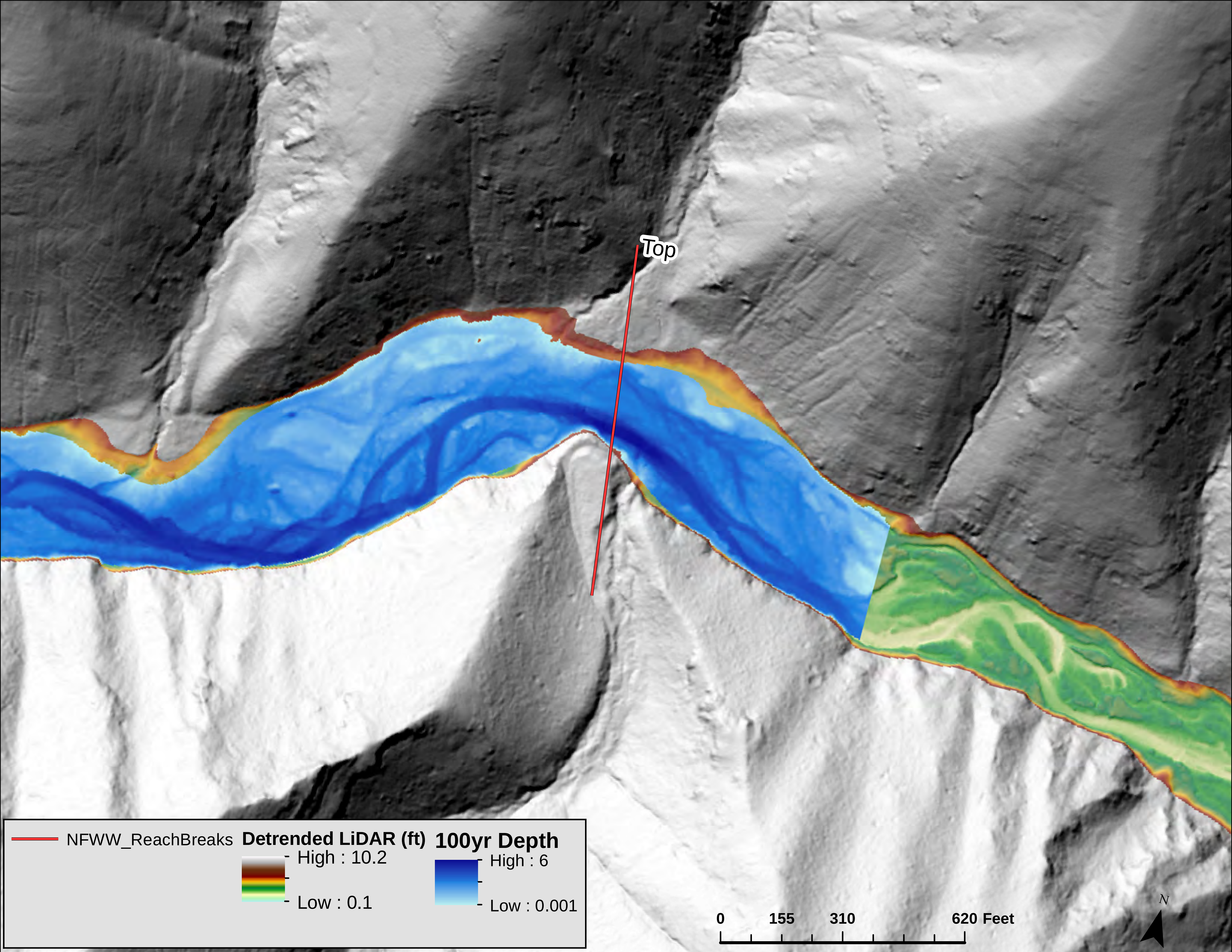

6
7
NFWW_ReachBreaks
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
100yr Depth
High : 6
Low : 0.001
0
155
310
620 Feet
N



7
NFWW_ReachBreaks
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
100yr Depth
High : 6
Low : 0.001
0
155
310
620 Feet
N



8
NFWW_ReachBreaks
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
100yr Depth
High : 6
Low : 0.001
0
155
310
620 Feet
N


Top
NFWW_ReachBreaks
Detrended LiDAR (ft)
High : 10.2
Low : 0.1
100yr Depth
High : 6
Low : 0.001
0
155
310
620 Feet
N