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LOW – TECH PROCESS – BASED RESTORATION

PROJECT IMPLEMENTATION AND MONITORING PROTOCOL

Sponsored by:

OREGON WATERSHED ENHANCEMENT BOARD

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SUMMARY

The following document outlines a set of attributes and survey methods that can be used to support the design, management, and monitoring of process based riverscape restoration projects. The approach draws heavily on the conceptualization of low-tech process-based restoration (LT-PBR) practices presented by Wheaton et al. (2019) and operationalizes those ideas through development of a unified framework for consistently documenting and presenting restoration information throughout a project lifespan. The protocol has been developed with the following intent:

- Present an accessible and flexible set of design attributes and monitoring survey protocols that can be consistently applied to the design, implementation, and monitoring of LT-PBR projects.
- Develop a flexible data collection and management solution that encourages adoption of the survey protocols by a diverse set of restoration practitioners and that supports common tasks in proposal development, permit acquisition, and fulfillment of land management agency monitoring and reporting requirements.
- Advance the science and art of LT-PBR practices by encouraging the adoption of a standardized design, monitoring, and approach for the calculation and interpretation of summary metrics that describe project outcomes and effectiveness.

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1 Introduction

This protocol was developed in response to a growing trend within stream and riparian restoration to utilize structures that mimic the form and function of beaver dams (i.e., beaver dam analogs, BDAs) and woody debris accumulations (i.e., post assisted log structures, PALS). The restoration approach involves the strategic introduction of these structural elements using a design intended to amplify natural hydrologic, geomorphic, and biological processes that accelerate stream recovery trajectories. Fundamentally, the approach follows the tenants of process – based restoration outlined by (Beechie et al. 2010), tenants of ecological restoration proposed by Palmer et al. (2005) and its extension as Low – Tech Process – Based Restoration (LT-PBR) by Wheaton et al. (2019) that emphasized the use of structural treatments that can be built by hand.

The application of LT-PBR gained broad appeal within the aquatic ecosystem restoration community throughout the western US during the early 2000s. Unlike more traditional restoration that relies on engineering plans and heavy construction equipment (i.e., excavators, skid-steer, etc.) to impose channel and floodplain restoration designs, LT-PBR ultimately defers design decisions to the characteristics and limitations set by individual riverscapes. Thus, the approach reduces design and implementation costs and allows natural stream processes to do much of the restoration "work". By minimizing economic and ecological risks associated with stream and riparian restoration design and implementation, LT-PBR seeks to enable the restoration community to address aquatic resource degradation at large spatial scales.

Ultimately, LT-PBR practices are intended to invoke a more resilient riverscape, capable of maintaining a diverse and self-sustaining set of fluvial and riparian processes that benefit aquatic and terrestrial resources and the fish, wildlife, and people that rely on them. As a novel restoration target, the creation of self-sustaining processes presents a new set of challenges; not only for defining and framing restoration objectives, but also for the development of survey protocols and indicator metrics that can be used to gauge project effectiveness and quantify project outcomes. This protocol represents one step toward meeting these challenges. Following the precedence set by LT-PBR practices, the protocol aims to be an accessible and economical tool that facilitates the widespread implementation of river restoration efforts.

1.1 Protocol Scope and Organization

Throughout their lifespan, ecosystem restoration projects are inherently complex; each requiring different phases of planning, prioritization, design, permitting, and coordination of implementation actions. In many cases the selection of monitoring surveys, data collection and summarization procedures, and calculation of metrics that might indicate project progress and/or effectiveness also play a critical role in successful project execution. Given these complexities, this protocol represents an attempt to support a consistent and efficient approach to the design, implementation, monitoring, and reporting of LT-PBR projects and project outcomes.

The protocol consists of three primary components that include 1) a ***PROJECT DESIGN AND IMPLEMENTATION FRAMEWORK*** that outlines project organization and a core set of project design attributes; 2) a series of ***MONITORING SURVEYS*** capable of generating a diversity of metrics describing project outcomes and effectiveness; 3) a ***DATA COLLECTION AND MANAGEMENT*** solution that supports consistent information capture.

TABLE 1. MAJOR COMPONENTS THAT MAKE UP THE LT-PBR IMPLEMENTATION AND MONITORING PROTOCOL AND A DESCRIPTION OF THE PRIMARY FUNCTION, INTENDED USE CASES, AND TARGET USERS SPECIFIC TO EACH COMPONENT.

COMPONENT	**DESIGN AND IMPLEMENTATION**	**MONITORING SURVEY PROTOCOLS**	**DATA COLLECTION AND MANAGEMENT**
FUNCTION	Project organization using core set of attributes describing design, objectives, and structure specification.	Series of monitoring surveys capable of generating a diversity of metrics describing ecological outcomes and project effectiveness.	Complete data collection and management solution supporting consistent information capture.
APPLICATION	Iterative process intended to be edited and updated with new information throughout the lifespan of a project.	Repeat monitoring surveys at discrete survey events	Used throughout design development, implementation, field data collection, or report preparation.
TARGET USERS	Requires understanding of the restoration design. Project managers, restoration designers, or construction foreman.	Accessible to individuals with a reasonable understanding of fluvial dynamics and taxonomy. Summer research technician or a community volunteer.	All protocol users at appropriate application.

1.1.1 RESTORATION PRIORITIZATION AND PLANNING

Prioritization (i.e., where to implement restoration) and planning (i.e., appropriateness of restoration actions) are critical steps in any restoration project that are largely beyond the scope of this protocol. Rather, this protocol is intended to explicitly support the management, implementation, and monitoring of low-tech process-based restoration projects, and assumes that areas targeted for restoration actions have been prioritized by regional land and habitat management planning documents or watershed assessments plans. An abundance of resources exist that can assist with restoration project planning, some of which have an explicit focus on process – based restoration actions, including:

- ***Chapter 3: Planning for Low-Tech Process-Based Restoration*** in the Low – Tech Process – Based Restoration of Riverscapes Design Manual (Wheaton et al. 2019) offers a focused treatment of processed – based restoration planning considerations with an emphasis on the use of hand – built artificial structures.

- ***River Restoration Analysis Tool (RiverRAT)*** developed by NOAA Fisheries provides a comprehensive framework for considering the risks and impacts associated with riverine habitat restoration largely within the context of salmon and trout habitat.

1.1.2 Project Design and Implementation

The Project Design approach presented in section 3 presents a framework and core set of attributes used to capture and convey project components including the documentation of objectives, implementation timelines, structure design, construction, and maintenance specification. Unlike many stream habitat or riparian condition survey protocols, the project design component of this protocol acts as an iterative project management solution that will be edited and updated throughout the lifespan of a project. For example, the framework can be used during initial inception to generate preliminary material and cost estimates and can also be used during opportunistic field visits to develop maintenance plans, collect repeat photos, or document concerns with fish passage. Unlike the Monitoring Survey Protocols described in section 4, the project management protocol is primarily aimed at users with a thorough understanding of the restoration design and context for restoration objectives. This would include those individuals carrying the title of project manager, restoration designer, or construction manager, and that are tasked with long-term project oversight.

1.1.3 Monitoring Surveys Protocols

Obviously, a single protocol does not exist that would be capable of capturing the diversity of ecological and practical outcomes that might be initiated as a result of stream and riparian restoration actions. However, the monitoring surveys included within this protocol have been designed to generate a series of metrics indicative of restoration outcomes that include:

- ***Structure Survey*** – A field survey designed to document the characteristics, dynamics, and distribution of natural and artificial structural elements (i.e., beaver dams and woody debris jams), and generate metrics describing structure function and potential risks (e.g., fish passage concerns).

- ***Channel Survey*** – A field survey designed to document the characteristics, dynamics, and distribution of geomorphic habitat units and generate metrics describing process – based restoration effectiveness and in-channel habitat quantity and quality (i.e., complexity).

- ***Remote Riverscape Survey*** – A desktop workflow designed to quantify valley bottom dynamics and composition, including vegetation community composition, floodplain connectivity, and habitat quantity from aerial imagery.

The monitoring surveys, described in greater detail within section 4 - Monitoring Survey Protocols, are included within the protocol as optional project components. The surveys are optional in that practitioners need only implement those survey protocols that align with their project objectives, or where capacity of the coordinating agency can support monitoring activities. However, when implemented together the monitoring survey metrics provide multiple lines of evidence that can be used to describe restoration effectiveness and progress toward project objectives.

Unlike the project management protocol components, the monitoring surveys do not require an in-depth knowledge of the project design or detailed context for restoration objectives. The surveys are intended to be accessible to those individuals with a reasonable understanding of fluvial dynamics and taxonomy such as a summer research technician or a community volunteer.

1.1.4 Data Collection and Management Application

The protocol framework is designed with a complementary database application capable of supporting the collection, management, export, and summarization of project management and monitoring survey information (Figure 1). In its current iteration the database has been built in Filemaker Pro, as this platform delivers a number of features that allow rapid development of a rich data collection and management application, including:

- ***Multi-platform support*** – A single database file can be used across Mac and Windows operating systems and used in the field on iPad and iPhone mobile devices.
- ***Offline support*** – Full data access in remote locations lacking data connectivity.
- ***Photo capture and storage*** – Field capture of photos directly into mobile devices and desktop photo import and export.
- ***Coordinate capture*** – Field capture of latitude and longitude using GPS enabled mobile devices.
- ***Custom mapping*** – Geographic visualization of project and restoration structures location data from within the application.
- ***Rich data export*** – Data export in common tabular formats (i.e., .csv, .xlsx), and generation and export of standardized PDF reports.

A series of instructional videos covering the operation and features of the database application should also be considered an important component of this protocol.

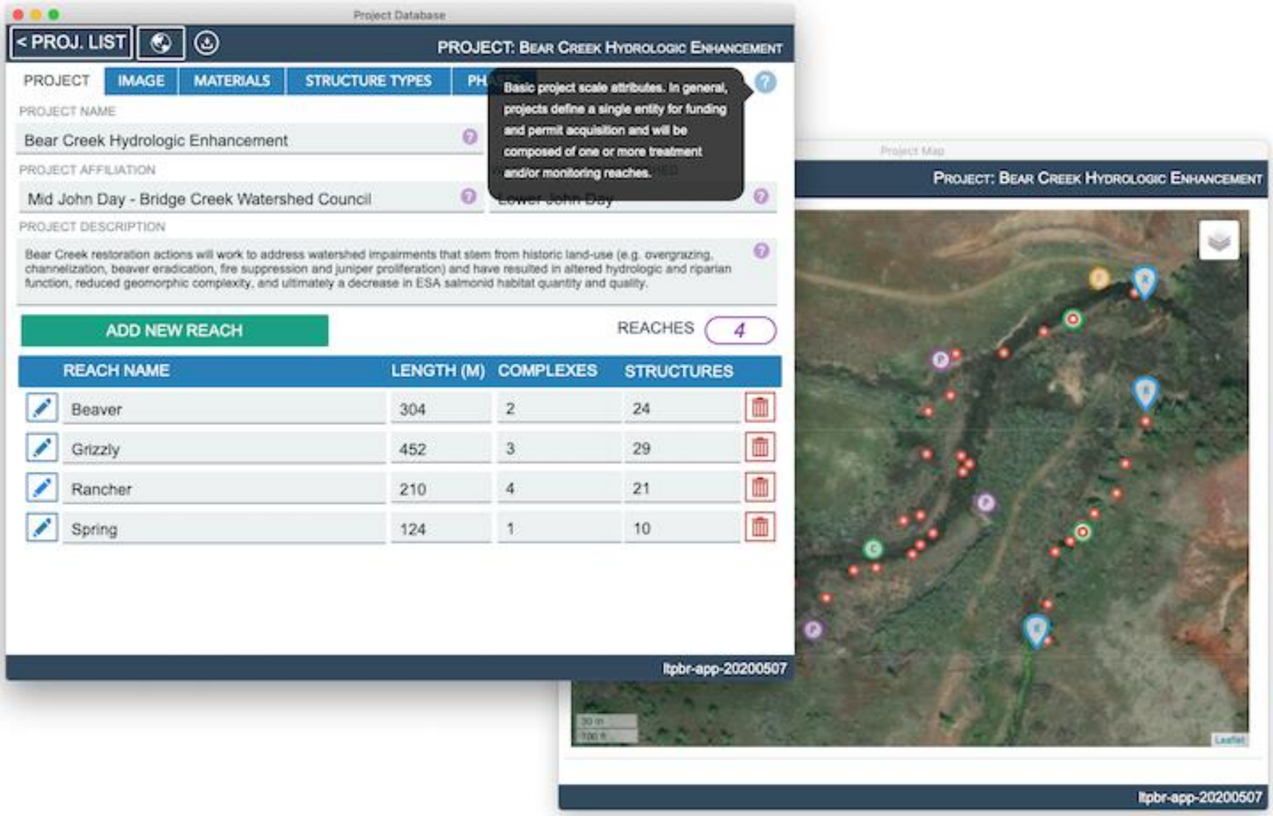

Figure 1. Example of the project management database application (v 1.0.0). The application is designed for use on desktop computers as well as mobile devices (i.e., iPhone and iPad) and facilitates data capture, management, summarization, and reporting.

1.2 LT-PBR Project Organization

This protocol organizes LT-PBR project information according to a scale-dependent spatial hierarchy, which allows design, maintenance, and monitoring information to be specified and summarized at a spatial resolution that is both practical and efficient. From large to small, the spatial organization framework consists of:

- ***Projects*** – a set of restoration actions covered under a specific set of permits and/or funding sources. Projects consist of one or more restoration treatment reaches (Figure 3).
- ***Reaches*** – linear segments of the river network delineated to serve as the primary unit of management within a restoration project. A single reach will ideally share typical valley and/or channel characteristics (i.e., valley bottom width, level of incision, valley gradient, ecosystem impairment) and restoration objectives (Figure 3). Reaches generally will contain multiple structure complexes.

- ***Complexes*** – a cluster or group of restoration structures (i.e., wood structures and/or beaver dam analogs) designed to work together to mimic and/or promote specific processes in support of local objectives (Figure 2). The term comes from the concept of a beaver dam complex consisting of a mosaic of beaver dams and ponds capable of rearranging entire valley bottoms.

- ***Structures*** – the smallest spatial unit of an LT-PBR project refers to structural elements introduced to the riverscape designed to mimic the form and function of beaver dams (i.e., BDAs) and woody debris accumulations (i.e., PALS).

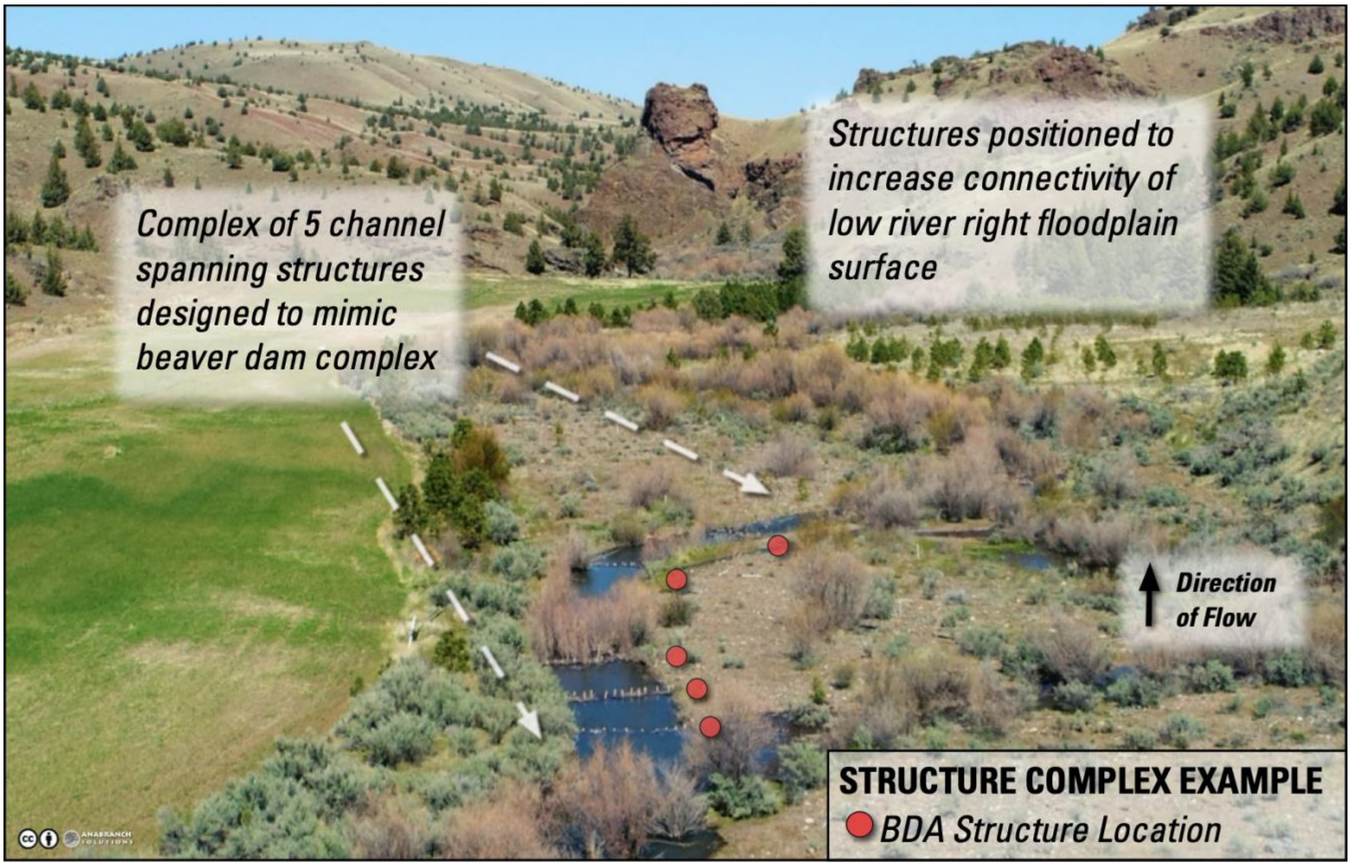

Figure 2. Example of a structure complex of 5 beaver dam analogs (BDA) designed to work in concert to achieve a specific geomorphic or hydrologic objective.

FIGURE 3. EXAMPLE OF A PROCESS-BASED RESTORATION PROJECT DESIGN CONSISTING OF MULTIPLE TREATMENT REACHES DELINEATED ACCORDING TO VALLEY AND FLOODPLAIN CHARACTERISTICS THAT DETERMINED RESTORATION POTENTIAL AND OBJECTIVES. EACH REACH ALSO CONTAINS SEVERAL STRUCTURE COMPLEXES PROJECT IMPLEMENTATION CONSISTED OF AN INITIAL PILOT THAT WAS FOLLOWED BY 3 ADDITIONAL PHASES OF STRUCTURE ADDITIONS, MODIFICATIONS, AND ENHANCEMENTS IMPLEMENTED ANNUALLY.

1.3 LT-PBR Structural Elements

LT-PBR restoration can employ a variety of structure types built to a diversity of shapes, sizes, and specifications depending on local channel dimensions, material availability, and objectives. However, the structural elements that naturally occur within functioning riverscapes provide a useful template for the classification of structure form and function that includes 1) PALS that mimic woody debris accumulations (Figure 4), and BDA structures that mimic beaver dams (Figure 5).

1.3.1 Post Assisted Log Structures (PALS)

Post assisted log structures (PALS) are a general classification of LT-PBR structure. PALS are generally designed to mimic the form and function of woody debris accumulations and are anchored in position using posts driven into the stream channel (Figure 4). Large PALS can be constructed of many small woody debris elements, allowing them to be constructed by hand while providing a function similar to that of large woody debris pieces that would otherwise require heavy equipment for placement. In general, PALS differ from BDA structures in that they are not constructed to induce immediate ponding of flow, but rather to mimic natural wood accumulations that typically form as bank-attached, mid-channel, or channel spanning structures.

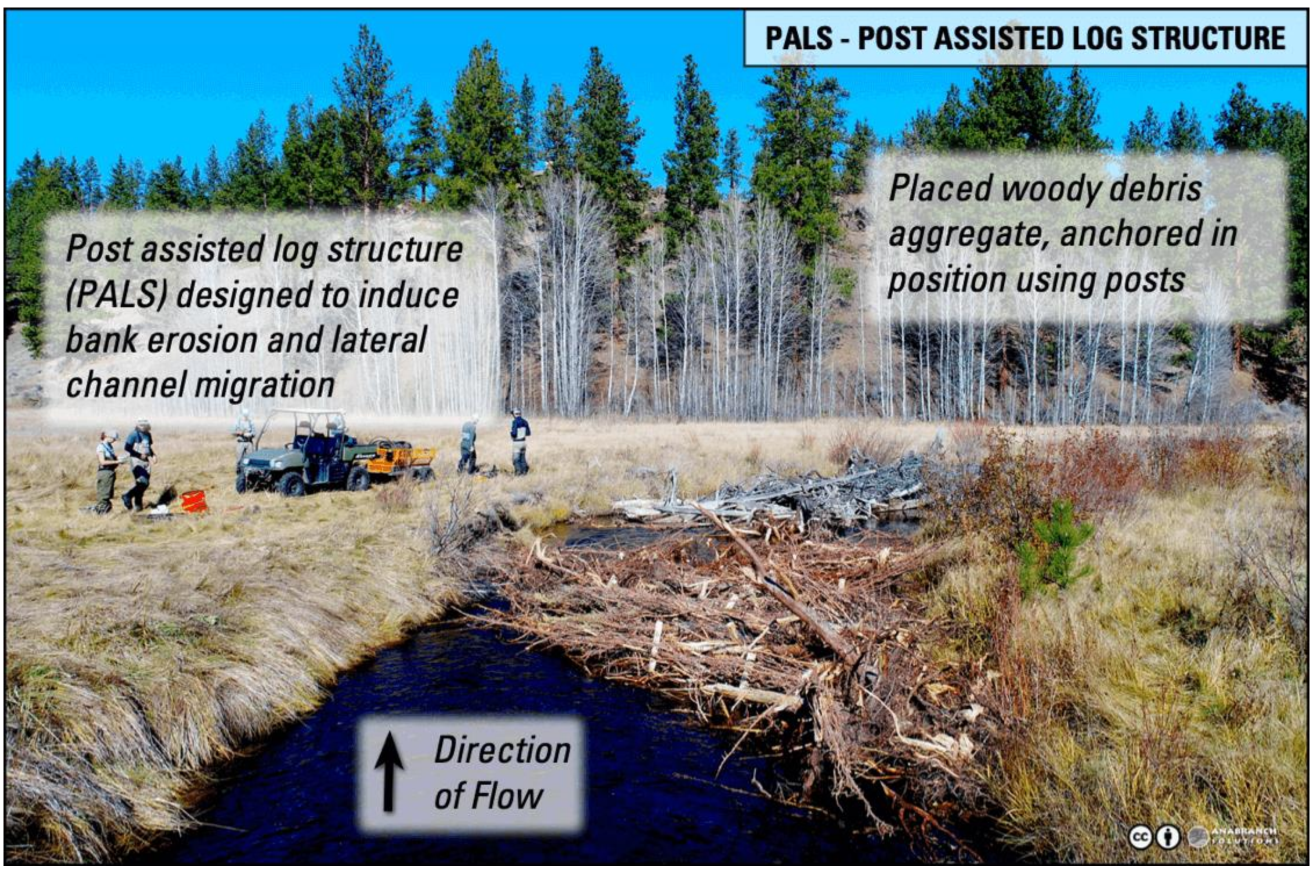

Figure 4. Looking downstream at a post assisted log structure (PALS) spanning 90% of the active channel and designed to mimic a woody debris accumulation (i.e., bank-attached debris jam).

1.3.2 BEAVER DAM ANALOGS (BDAS)

Beaver dam analogs (BDAs) are hand-built structures that mimic the form and function of natural beaver dams. The term 'beaver dam analog' was coined by Pollock et al. (2014) though examples of mimicking and encouraging beaver dam building extends back circa 1930 (see Kraebel and Pillsbury 1934). Similar to natural beaver dams, BDA are differentiated from PALS in that they are generally constructed using additional fill material (i.e., sediment, cobble) that promote immediate ponding even during low-flow periods.

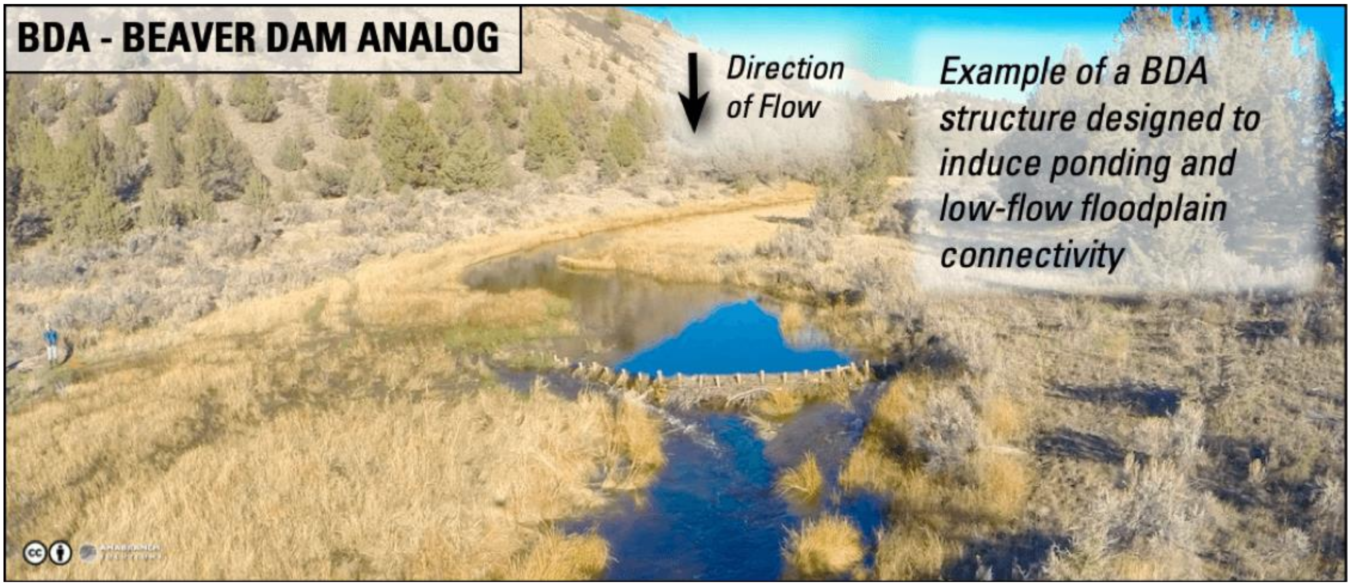

FIGURE 5. EXAMPLE OF A TYPICAL BDA STRUCTURE. UNLIKE PALS, BDAS ARE CHANNEL SPANNING AND BUILT USING SEDIMENT, COBBLE, AND OTHER FILL MATERIAL TO ALLOW PONDING OF FLOW EVEN DURING LOW-FLOW PERIODS.

2 PROTOCOL CONVENTIONS

Section 3 - Project Design and section 4 - Monitoring Survey Protocols contain the majority of information necessary to implement this protocol, and a number of conventions have been incorporated into these sections to improve the consistency and utility of the overall document. Some discussion of common terminology, as well as conventions regarding the units of measure used in different section of the protocol also warrant discussion and clarification.

2.1 FORMATTING CONVENTIONS

A number of formatting conventions are used within the document to improve its overall readability, utility, and differentiate protocol components including:

ATTRIBUTES – Attributes represent pieces of information supplied by protocol users and represent data. The attribute formatting will be followed by its definition.

ATTRIBUTE VALUES – Attribute values represent a fixed list of values or choices specific to an attribute.

This italic highlighted formatting is used to provide additional insight or recommendations supplied by the authors that may not be essential to the protocol, but often provides advice on project design, the implementation of a monitoring approach, or presents other background information that is based on experience.

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This boxed formatting is used to supply information that is specific to the operation of
the database application. For example, this information may make note of attribute values
that are automatically entered by default by the database application.
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2.2 VALLEY AND CHANNEL ORIENTATION

River-left and right, and valley-left and right are descriptive terms used throughout the design and monitoring survey portions of this protocol (Figure 6). These terms assume that left and right are relative to a protocol user looking in a downstream or down valley direction. The difference between river and valley direction is one of scale in that river-left and right would be relative to the planform of an active channel and banks (which may meander), while valley-left and right is relative to the confining valley walls that form the margins of the valley bottom.

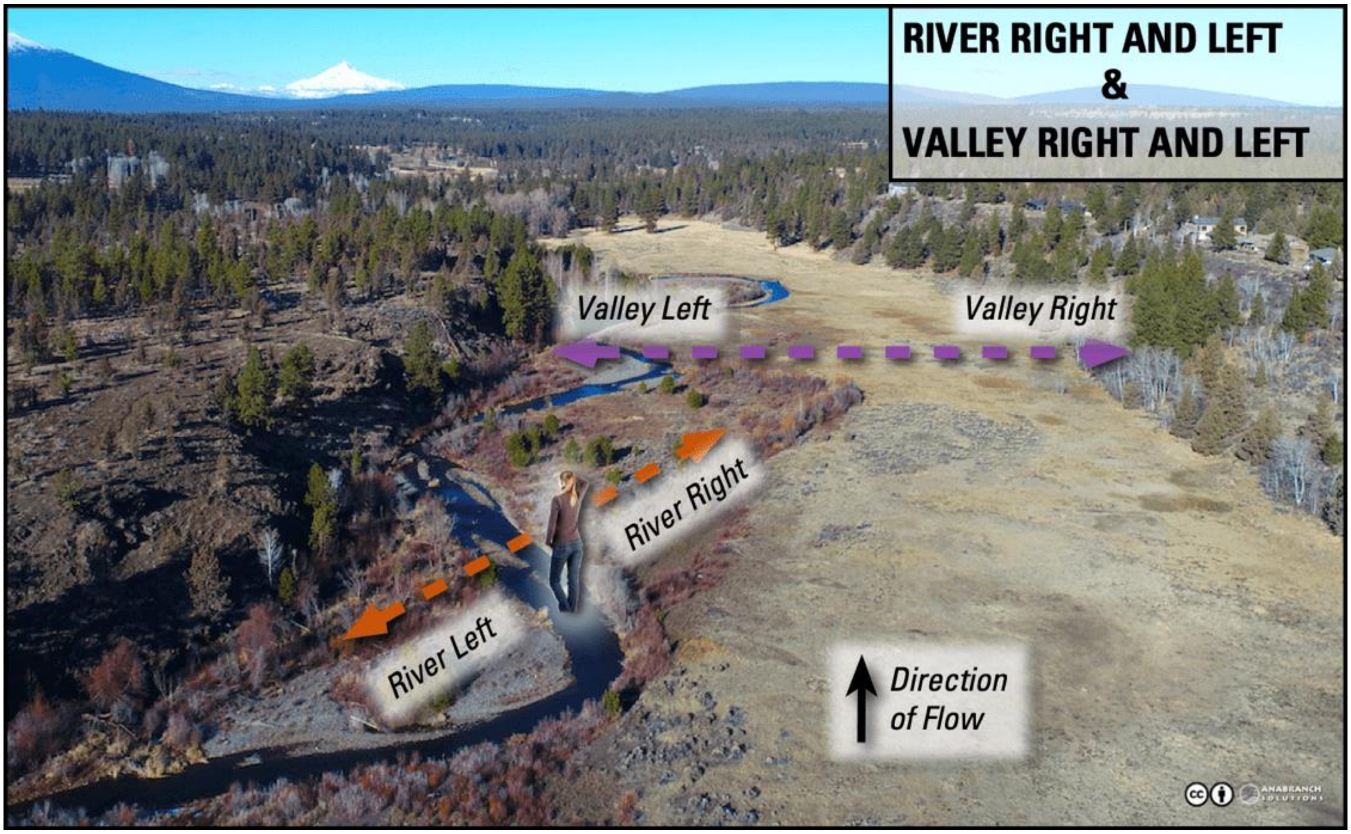

FIGURE 6. DEMONSTRATION OF DIFFERENCE BETWEEN RIVER LEFT AND RIGHT, WHICH WILL FOLLOW THE PLANFORM OF THE CHANNEL, AND VALLEY LEFT AND RIGHT, WHICH WILL FOLLOW THE PLANFORM OF THE CONFINING VALLEY MARGINS.

2.3 FLOW DESCRIPTIONS

Reach monitoring visits (described below within section 3.2.5 - Reach Visit) and monitoring survey events (section 4 - Monitoring Survey Protocols) require an attribute that is descriptive of the relative discharge.

FLOW CONDITION – A visual estimate of the relative discharge at the time of a monitoring event or visit.

> ***DRY*** - All active channel surfaces including pools and impoundments created by natural and artificial beaver dams, are completely lacking surface flow.
>
> ***INTERMITTENT*** – Sections of channel are flowing, and/or some pools or impoundments feature isolated pockets of surface water.
>
> ***BASEFLOW*** – Typical low-flow conditions of perennial streams occurring during mid and late summer/fall; however, flow is continuous within at least one channel throughout the area of interest.
>
> ***MODERATE*** – More surface discharge than baseflow, however the majority of flow is still contained within the active channel (i.e., below a bankfull flow).

TYPICAL FLOOD – Approximating a flood event in which flow begins to overtop banks that form the boundary of the active channel and spill onto floodplain surfaces. Should be considered similar to common definitions for a bankfull flood event with an exceedance interval of approximately 2 years.

LARGE FLOOD – Large flood event occurring infrequently and causing extensive dispersal of flow across active floodplains and potential inundation of disconnected floodplain and/or terrace surfaces.

It is extremely informative to visit restoration reaches during high flow events to allow observation of structure function and observe active floodplains extents. However, many of the field protocol components are best initiated during moderate to baseflow conditions including the structure and channel field survey protocols as well as documentation of structure maintenance requirements.

2.4 Units of Measure and Location Coordinates

For several reasons, both imperial and metric units of measure are used in different portion of the protocol. First, many of the attributes used throughout section 3 - Project Design, including structure dimensions, reach length, and others use imperial units. This is attributable to typical specifications for permitting applications that in many cases expect information to be reported using feet or miles (distance), acres (area), and cubic yards (volume). Conversely, all attribute values described within section 4 - Monitoring Survey Protocols use metric units (i.e., meters) as this is generally more consistent with scientific protocols used to quantify habitat and landscape features. Location coordinates should always use decimal degrees projected on the WGS84 reference ellipsoid (i.e., EPSG:4326).

```
Coordinates manually entered into the database should be recorded to 6 decimal places to
allow sufficient location precision (e.g. 44.654321, -120.654321).
```

3 Project Design and Implementation

The project design and implementation component of the protocol provides an iterative project management solution that will be edited and updated throughout the lifespan of a project. The framework provides a core set of attributes and attribute definitions used to inform the permit application process, document structure implementation and maintenance, and support project report preparation. These protocol components are primarily intended to be used by project managers, restoration designers, construction foreman, and other individuals tasked with long-term project oversight.

3.1 LT-PBR Projects

Defining a project provides a useful entity for grouping a collection of restoration actions implemented under a set of permits and/or funding resources. Projects will generally contain several restoration reaches and potentially control (i.e., no restoration) and/or reference (i.e., restoration target) monitoring reaches. Other low-tech restoration components are also defined with respect to individual projects including:

- ***Materials*** – Vegetative material types and dimensions that will be used in construction of low-tech restoration structures.
- ***Structure Types*** – Low-tech restoration structure types, their characteristics, and construction considerations.
- ***Phases*** – Periods of structure installation and/or maintenance actions within a multi-phased restoration project.

3.1.1 *Project Scale Design Attributes*

PROJECT NAME – A unique name used to identify the project (e.g., "Bridge Creek Incision Recovery").

PROJECT AFFILIATION – Primary organization or entity responsible for project management and implementation.

WATERSHED/SUBWATERSHED – Watershed or subwatershed encompassing the project.

PROJECT DESCRIPTION – Descriptive narrative for the project that may include but is not limited to describing project level goals and objectives, collaborating partners, and restoration implementation and/or monitoring considerations.

3.1.2 Defining Project Materials

Materials utilized to construct low-tech restoration structures are defined for each project, and in most cases refer to woody vegetation material that is harvested on site or transported to the site. Separate material type entries should be created to represent the range of typical vegetative material types and sizes that will be used in structure construction.

If the typical vegetative materials used in construction exhibit considerable size variation create two entries for the typical sizes that might be used (e.g., juniper - large and juniper – small). Also, if only a portion of the materials are available for harvest at the construction site create a separate material type that allows accounting for materials that will need to be transported to the site (e.g., Juniper – imported).

MATERIAL NAME – A descriptive name unique to the material type within the current project (e.g., “large willow”).

AVERAGE LENGTH (FT.) – A typical length for the material type.

AVERAGE DIAMETER (IN.) – Average diameter for the main stem of a typical material.

MATERIAL DESCRIPTION – Narrative description of the material type that may include but is not limited to information related to material source and transport, intended use in structure construction, or other characteristics.

3.1.3 Structure Types – Your Restoration Cookbook

Typical structure types are defined for each project. Structure type definitions serve as recipes with ingredients that include the materials used in structure construction, typical structure dimensions, and intended function. Material estimates for each structure type, estimates of fill material (i.e., cobble and sediment), and post spacing are used to develop material and fill estimates to aid in permit acquisition and restoration implementation.

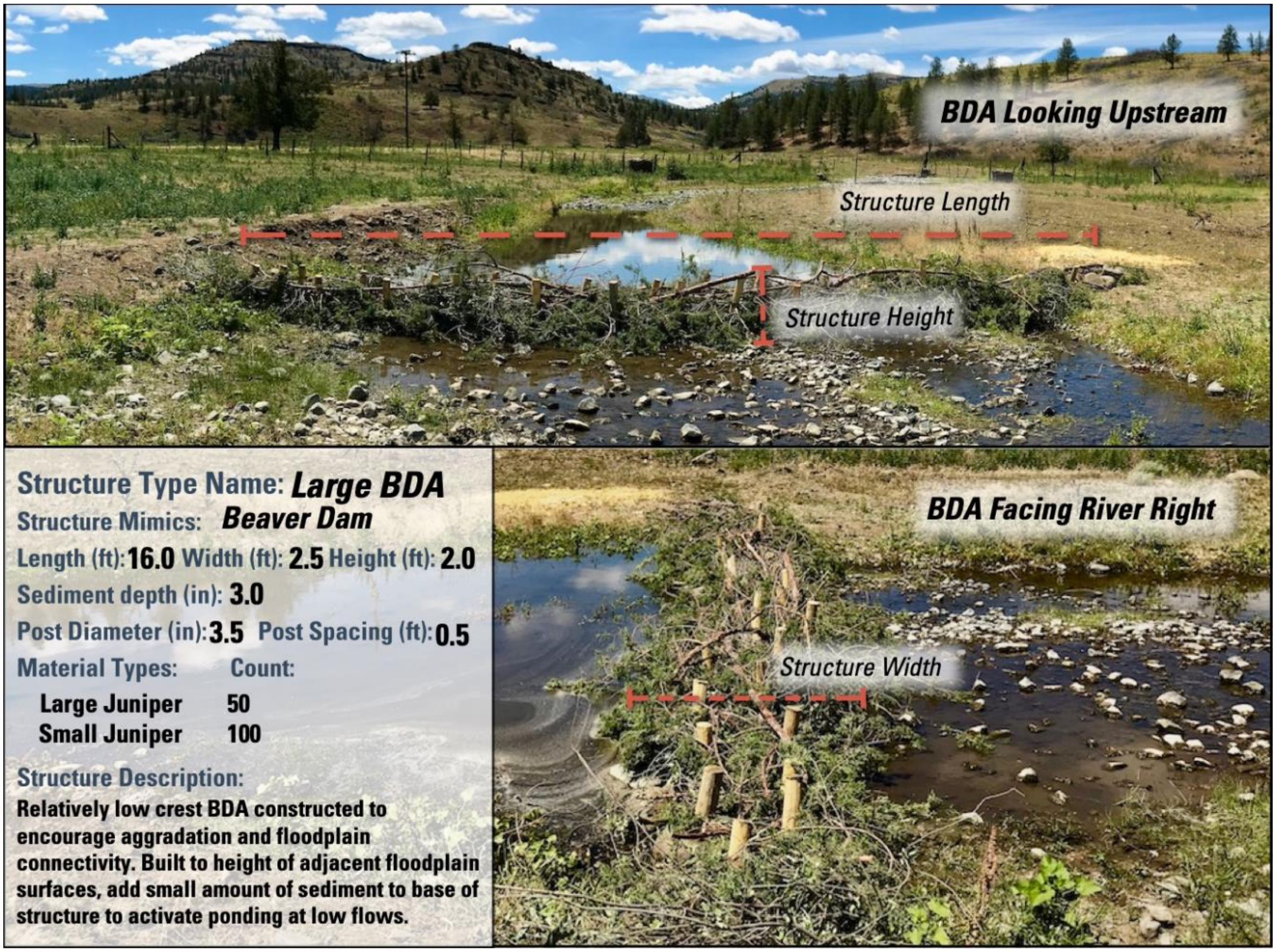

FIGURE 7. TYPICAL DESIGN SPECIFICATION FOR A BDA STRUCTURE SHOWING PRIMARY BDA DESIGN ATTRIBUTES, INCLUDING DIMENSIONS, POST TYPE AND DISTRIBUTION, MATERIAL TYPES AND ABUNDANCES, AND SHORT DESCRIPTION OF FUNCTION AND CONSTRUCTION SPECIFICATIONS.

STRUCTURE TYPE NAME – A unique and descriptive name that can be used to identify the structure type (e.g., Large BDA or Small Wood Jam).

STRUCTURE MIMICS – Naturally occurring structural element that the structure is intended to mimic in form and function.

> ***BEAVER DAM*** – Structure is channel spanning has been designed to mimic the form function of a beaver dam.
>
> ***WOOD ACCUMULATION*** – A more porous structure that may be bank-attached, mid-channel, or channel spanning and has been designed to mimic the form and function of a woody debris jam/accumulation.

STRUCTURE TYPE DESCRIPTION – Written narrative that may describe, but is not limited to structure construction, materials, placement within the channel, intended hydraulic or geomorphic function, and/or considerations for fish passage.

LENGTH (FT.) – Longest dimension of the as-built structure type, this is generally the dimension perpendicular to the direction of flow.

WIDTH (FT.) – Width of the as-built structure, this is generally the dimensions running parallel to the direction of flow.

HEIGHT (FT.) – Vertical distance from the channel or floodplain elevation to the top of fill material for the as-built structure.

SEDIMENT DEPTH (IN.) – Typical depth of sediment (cobbles and/or gravels) that will be added as fill material to the structure during construction. Used in development of a total fill volume estimate based on the dimensions entered for length and width.

POST DIAMETER (IN.) – Estimated diameter of posts used in structure construction. Used to estimate a volume for posts based on the structure height dimension.

POST SPACING (FT.) – Estimated horizontal spacing between posts, used to derive a final post estimate of posts for the structure type.

MATERIAL TYPE – Type of vegetative material used as fill within the structure as previously specified in section 3.1.2. Defining Project Materials. Structures are made up of various types of vegetative fill material.

MATERIAL COUNT – Estimate for the number of pieces of material used in construction of a typical structure type.

3.1.4 Implementation Phases

Implementation phases provide a means to articulate expected periods of structure construction, structure maintenance, and/or enhancement over time.

Many projects might begin with an initial pilot level implementation effort that is often followed by a larger implementation phase, and then several years of maintenance and structure additions.

PHASE NAME – Unique name for the implementation phase (e.g., “pilot”, “Phase 01, or “Complete Design”).

EXPECTED IMPLEMENTATION DATE – Expected date that the phase of implementation will be initiated.

PHASE DESCRIPTION – Written narrative describing the implementation phase that may include but is not limited to information about maintenance actions, expansion to additional treatment reaches, and/or inclusion of new structure types or construction techniques that will be or were implemented.

3.2 Reach Scale Design and Objectives

The concept of a reach is used as the primary unit of management within low-tech restoration projects. Reaches define a linear segment of the riverscape, and a single reach will ideally feature a consistent set of valley and/or channel characteristics (i.e., valley bottom width, level of incision, valley gradient, geomorphic or riparian impairment) and targets for restoration objectives. A number of protocol components are implemented and/or collected with respect to individual reaches, including:

- ***Restoration Objectives*** – Specification of objectives
- ***Repeat photo locations*** – The location of repeat photos used to document restoration outcomes.
- ***Reach Visit*** – High-level, qualitative monitoring approach for documenting progress toward restoration objectives, potential risks, and ecological outcomes.
- ***Surveys*** – Monitoring surveys are implemented at the scale of stream reaches, and many metrics are summarized to describe conditions at the reach scale.

Riverscape restoration plans are often limited by constraints such as road crossings or land ownership. Although reach boundaries are ideally defined by characteristics of the valley, reaches may also be delineated according to the location of human infrastructure, ownership boundaries, or other practical considerations.

3.2.1 *Reach Scale Design Attributes*

REACH NAME – A unique name for the reach, initially establish, that will persist through time to allow for successive measurement comparison.

STREAM NAME – Name of the stream that encompasses the reach. Included as projects may span multiple streams.

START AND STOP LATITUDE AND LONGITUDE – Coordinates for the beginning and end of the reach in decimal degrees.

```
When used on an Apple mobile device equipped with a GPS the database can record latitude
and longitude coordinates by hitting the map marker button. Coordinates in decimal degrees
for specific points can also be displayed by clicking anywhere on the map.
```

When defining your reach boundaries be sure to include up and downstream areas that may be treated in the future as surveying and capturing repeat photos will have the ability to show impacts of the restoration treatments before and after restoration implementation.

REACH LENGTH (M) – Reach length in meters measured along the center of the valley bottom (i.e., area between confining margins (Figure 8). Reach length is used in the calculation of survey metrics generated from data collected as part of the 4. Monitoring Survey Protocols.

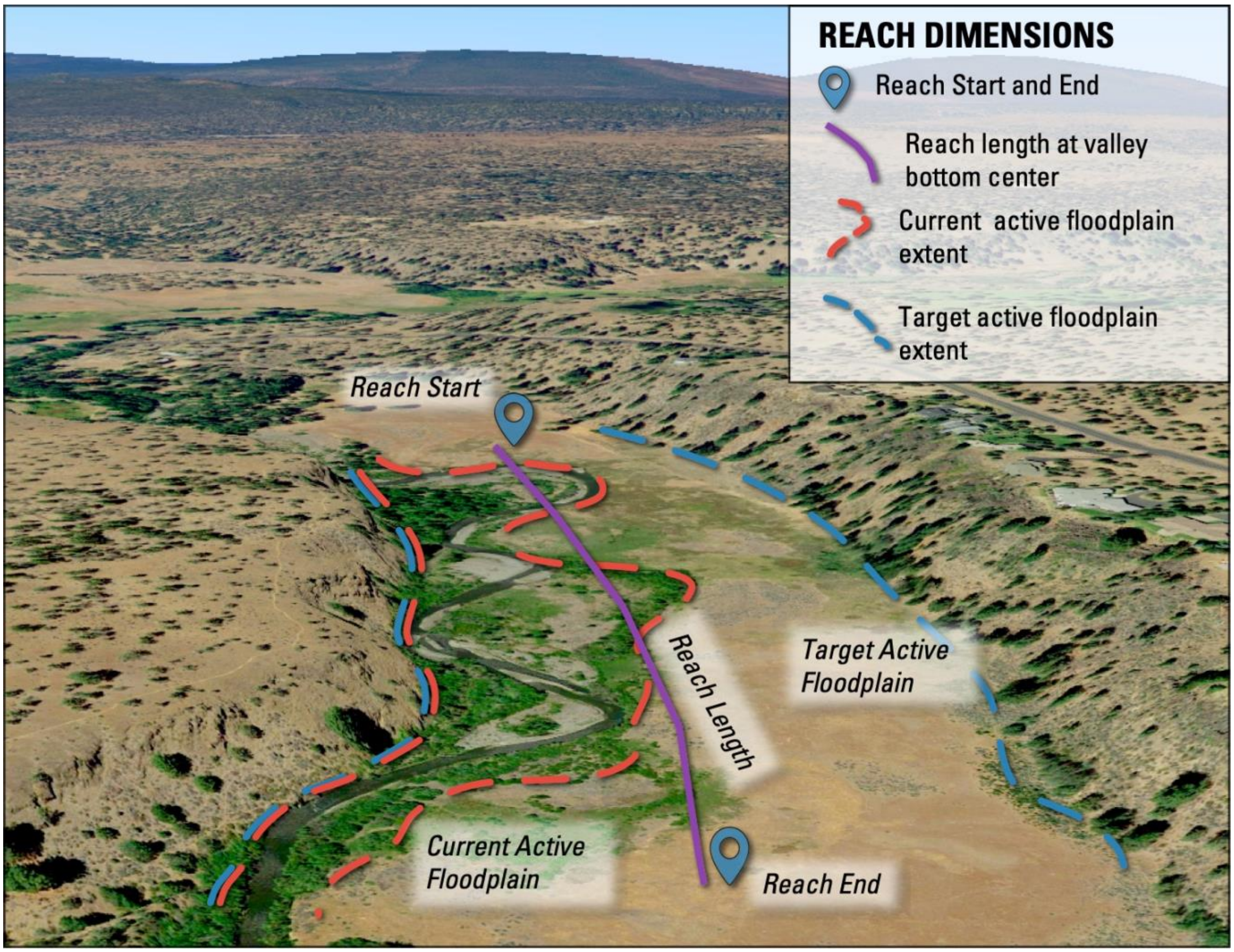

FIGURE 8. EXAMPLE OF VALLEY MARGINS USED TO DEFINE REACH DIMENSIONS. THE BOUNDARIES FOR THE ACTIVE FLOODPLAIN ARE USED TO ESTIMATE A CURRENT AND TARGET ACTIVE FLOODPLAIN WIDTH. THE REACH LENGTH IS MEASURED ALONG THE CENTER OF THE VALLEY BOTTOM.

CURRENT ACTIVE FLOODPLAIN WIDTH (M) – An average or representative width (meters) of the reach active floodplain prior to restoration implementation (i.e., current active floodplain width).

TARGET ACTIVE FLOODPLAIN WIDTH (M) – An average or representative width (meters) of the reach active floodplain that might be achieved through restoration as a result of incision trench widening or increasing floodplain connectivity via channel aggradation and flow obstruction.

Following field reconnaissance, it may be helpful to use a geographic information system (GIS) and aerial imagery or channel topography to measure and verify the reach length and the baseline and target active floodplain width.

REACH DESCRIPTION – A written narrative that might include but is not limited to a description of current and target channel and floodplain conditions, reach – scale restoration objectives, complex and/or structure design or construction considerations, and/or infrastructural risks present within the reach.

3.2.2 Specification of Reach Scale Objectives

Riverscape restoration may be motivated by a diversity of factors ranging from improvement or expansion of habitat for sensitive species, restoration of wetland ecosystem function, or alteration of stream hydrology for agricultural production. Despite this diversity, this protocol encourages users to categorically specify a primary and secondary restoration objective for each reach based on a list of potential objectives. While remaining non-exhaustive, the list attempts to account for objectives that might focus on the evolution and recovery of degraded stream channels (i.e., incision trench widening, channel aggradation), as well as habitat creation and/or expansion for sensitive species (i.e., in-channel habitat quality, riparian vegetation expansion).

While the selection of restoration objectives from a fixed list may not fully articulate objectives for specific projects, it is intended to inform a broader understanding of LT-PBR restoration objectives, and also provide a means to directly link objectives to measurable indicator metrics generated as part of the monitoring surveys (see appendix 7.1 - Reach Scale Objectives and Supporting Summary Metrics). Protocol users are also encouraged to articulate more specific and comprehensive explanations of reach scale restoration objectives as part of the reach description.

PRIMARY AND SECONDARY OBJECTIVES – Used to specify a primary and secondary objective for the reach from a fixed list of reach – scale objectives.

> ***INCISION TRENCH WIDENING AND INSET FLOODPLAIN DEVELOPMENT*** – Widening of incised stream channels through erosion. Implies that there is little possibility to increase connectivity to existing floodplain or disconnected floodplain features. However, widening of the incision trench may offer potential to increase habitat complexity, reduce stream power, and increase the extent of inset floodplain surfaces and riparian vegetation abundance and distribution.
>
> ***CHANNEL AGGRADATION AND FLOOPLAIN CONNECTIVITY*** – Sediment deposition and capture leading to increased channel elevation and floodplain connectivity. Implies that increased floodplain

connectivity, and floodplain expansion onto currently disconnected surfaces are reasonable restoration targets.

INCREASE RIPARIAN VEGETATION ABUNDANCE AND EXTENT – Increase the abundance and extent of riparian vegetation by altering sediment and hydrologic regimes. Often associated with projects implementing vegetation reestablishment (i.e., planting) treatments.

CHANNEL HABITAT QUANTITY AND QUALITY – Increase the quantity and quality of active channel habitat through alteration of channel topography and planform (i.e., channel meanders, multi-threaded channel development), velocity distributions, sediment distribution and diversity, and the addition of structural elements.

BEAVER HABITAT CREATION OR EXPANSION – Create or increase conditions suitable for beaver colonization including pond creation as cover and expansion of riparian vegetation as suitable forage.

3.2.3 REPEAT PHOTOS

Repeat photos provide a compelling description of restoration impacts through time and should be established throughout treatment and control restoration reaches prior to implementation actions.

Strive to establish photo points at locations that have a clear view and capture a large portion of your riverscape. Photos taken in heavy brush or in close proximity to individual structures or other features are usually not informative over time. Establishing a smaller number of quality repeat photo locations is generally more effective than establishing a large number of poor - quality photo points with a narrow or obstructed field of view, say for example at every restoration structure.

FIGURE 9. EXAMPLE OF BEST PRACTICES FOR FRAMING REPEAT PHOTOS THAT WILL BE USEFUL FOR CAPTURING CHANGE OVER TIME AND STRUCTURE FUNCTION.

PHOTO POINT NAME – A descriptive and unique name used to identify the photo point.

PHOTO POINT LATITUDE AND LONGITUDE – Coordinates for the photographer location in decimal degrees.

PHOTO FACING – Orientation of the photographer relative to flow direction within the valley.

UP OR DOWN VALLEY – Photo is oriented looking either up (upstream) or down the valley (downstream).

VALLEY RIGHT OR LEFT **–** Photo is oriented looking at either the right or left valley wall where right and left are defined with respect to facing down the valley (downstream).

PHOTO STANDING – Description of the riverscape surface on which the photographer should be standing to capture the photo. Right and left are defined with respect to the active channel looking down the valley.

UPLAND – Photographer is out of the valley bottom and is positioned on an upland hillslope or terrace feature.

FLOODPLAIN – Photographer is positioned on a floodplain surface (i.e., current or target active floodplain).

BANK – Photographer is positioned on a bank that is adjacent to the active channel.

PRIMARY CHANNEL – Photographer is positioned within the primary channel

NON-PRIMARY CHANNEL – Photographer is standing within a non-primary channel.

ISLAND – Photographer is positioned on an island.

PHOTO POINT DESCRIPTION – A narrative that should at a minimum describe the location and orientation of the repeat photo location to assist others in reproducing the photo. The description can and should also contain information about what the photo seeks to capture (e.g., a specific structure or structure type, disconnected floodplain that may become active, etc).

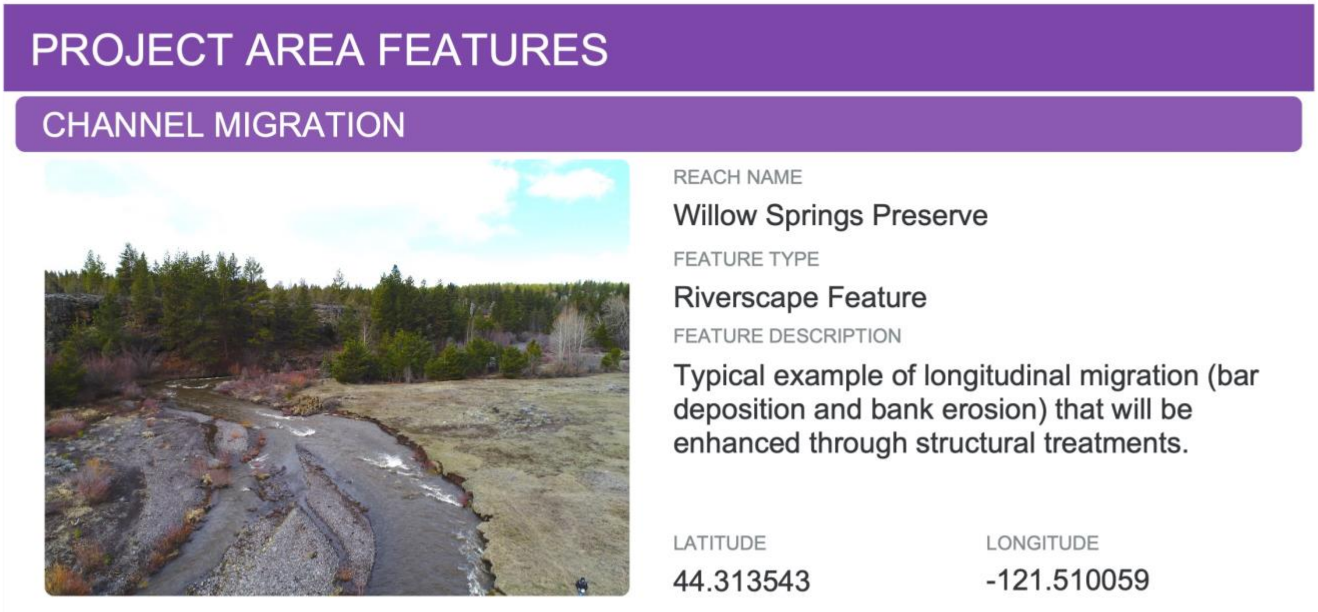

Figure 10. Example of riverscape feature observation as exported from the database application. Riverscape feature observations are used to document the types and locations of riverscape features and human infrastructure that may be important during restoration design development and/or permit acquisition, and may also be useful for qualitatively documenting restoration responses or risks.

3.2.4 Riverscape Features

The features protocol component can be used to document locations, photos, and characteristics of riverscape features that may be relevant to the restoration design, permit preparation, or expectations for restoration outcomes (Figure 10). Examples of feature observations may include, but are by no means limited to:

- The location and types of ***human infrastructure*** (e.g., building, fields in production, irrigation infrastructure) that designs should avoid.
- ***Geomorphic features*** (e.g., channel units, typical floodplain elevations, erosive banks) that may be relevant to the restoration approach and design.
- ***Existing structural elements*** (e.g., natural beaver dams, woody debris jams) that may be used in the design or that may be emulated by artificial structural treatments.

Unlike repeat photos point locations, feature observations not meant to be tracked over time using repeat photo acquisitions. In most cases, the location and types of features will be documented during initial project area scoping and used to inform the restoration design process.

FEATURE NAME – A descriptive and unique name defined by the user that identifies the feature observation.

FEATURE TYPE – A categorical description that can be applied to feature observations.

RIVERSCAPE FEATURE – May be used to describe any feature of the riverscape (e.g., typical floodplains, characteristic vegetation communities, etc.).

STRUCTURE OBSERVATION – May be used to describe observations of structures (i.e., natural and/or artificial beaver dams and wood accumulations), their form, and/or their behavior.

HUMAN INFRASTRUCTURE – Could be used to document the types and locations of human infrastructure within the valley bottom (e.g., houses, irrigation equipment, agricultural fields).

```
Note, while “Natural Feature” and “Human Infrastructure” are suggested the list of
potential feature types within the database application can be edited and further defined
by individual users.
```

FEATURE PHOTO – A photograph of the feature (Figure 10).

FEATURE DESCRIPTION – A written narrative descriptive of the feature observation and its relevance to the restoration project.

FEATURE LATITUDE AND LONGITUDE – Coordinates documenting the feature location in decimal degrees (e.g. 44.654321, -120.654321).

3.2.5 Reach Visit

The reach visit is intended to serve as an opportunistic monitoring event that can be implemented rapidly to document progress toward reach - scale restoration objectives. The reach visit also provides a venue for recording potential ecological or infrastructural risks, observations of restoration structure function, and/or un-anticipated ecological outcomes that may be useful for reporting and provide context for data collected as part of 4 - Monitoring Survey Protocols.

VISIT DATE – Date of the visit to the reach.

VISIT FLOW – Observed flow during the reach visit using descriptions provided in 2.3 - Flow Descriptions.

REACH OBJECTIVE STATUS – Qualitative estimate of progress toward primary and secondary reach scale objectives specified for the reach, as well as those described within the reach description narrative (see 3.2.1. Reach Scale Design Attributes).

NEGATIVE PROGRESS – The restoration treatments have exacerbated existing reach impairments. (e.g., increased channel incision, or reduced available aquatic habitat).

NO PROGRESS – Restoration treatments have neither enhanced nor detracted from progress toward specified reach objectives.

PROGRESS – Restoration treatments are making progress toward specified reach scale objectives; however, target objectives have not been met.

OBJECTIVES MET – Restoration treatments have succeeded in achieving reach objectives.

It is often useful to review objectives specification from the original design prior to recording the progress toward objectives.

REACH VISIT DESCRIPTION – A written narrative describing information related to progress toward objectives, flow conditions, fish passage concerns, or other observations.

VISIT ACTIVE FLOODPLAIN WIDTH (M) – Estimate of an average active floodplain width during the visit based on field evaluation of geomorphic and vegetative indicators or if possible, the acquisition and orthorectification of aerial imagery. Intended to track progress toward the target active floodplain width.

3.3 Structure Complex Design and management

Complexes refer to a cluster or group of restoration structures (i.e., wood structures and/or beaver dam analogs) designed to work together to mimic and/or promote specific processes in support of local objectives. The term comes from the concept of a beaver dam complex consisting of a mosaic of beaver dams and ponds capable of rearranging entire valley bottoms. Complexes provide a sub-reach level scale of observation for defining:

- ***Complex Objectives*** – Restoration objectives at the sub-reach level.
- ***Structure Maintenance*** – Specification of maintenance activities and quantification of maintenance material requirements.

The concept of the structure complex is extremely useful for conveying restoration designs and guiding implementation. However, as part of multi-phased restoration projects where channel and floodplain configurations are being rearranged annually by high flow events, and where new structures are being added opportunistically in order to continue restoration trajectories, the boundaries of structure complexes may become difficult to discern. Thus, erring on the specification of fewer complexes during the initial design process will often results in a more concise LT-PBR project that is easier to manage, accurately document, and maintain over time.

3.3.1 Complex Scale Design Attributes

Few attributes are recorded relative to complex designs, but the information is relevant to the articulation of design intents and structure distributions relative to channel and floodplain features at the sub-reach scale.

COMPLEX NAME – A unique and descriptive name for the complex.

Simple complex names are ideal to delineate complexes. Often attaching a number to the reach name provides enough detail to differentiate complexes. (e.g. "Reach Name-01)".

COMPLEX DESCRIPTION – A short written narrative that may include details specific to the distribution of structures and structure types within the complex, design intent and process based complex objectives, extent of complex influence, and/or configuration of riverscape features that may be influenced by the complex at different flow stages.

COMPLEX LATITUDE AND LONGITUDE – Complex coordinates in decimal degrees for a location near the center of the complex.

ZONE OF INFLUENCE WIDTH AND LENGTH – The complex zone of influence(ZOI) describes the area over which a complex is expected exert hydraulic and/or geomorphic influence in response to a typical flood event. The width (lateral expectation) and length (up to down valley expectation) describe the approximate dimensions of the complex ZOI (Figure 11).

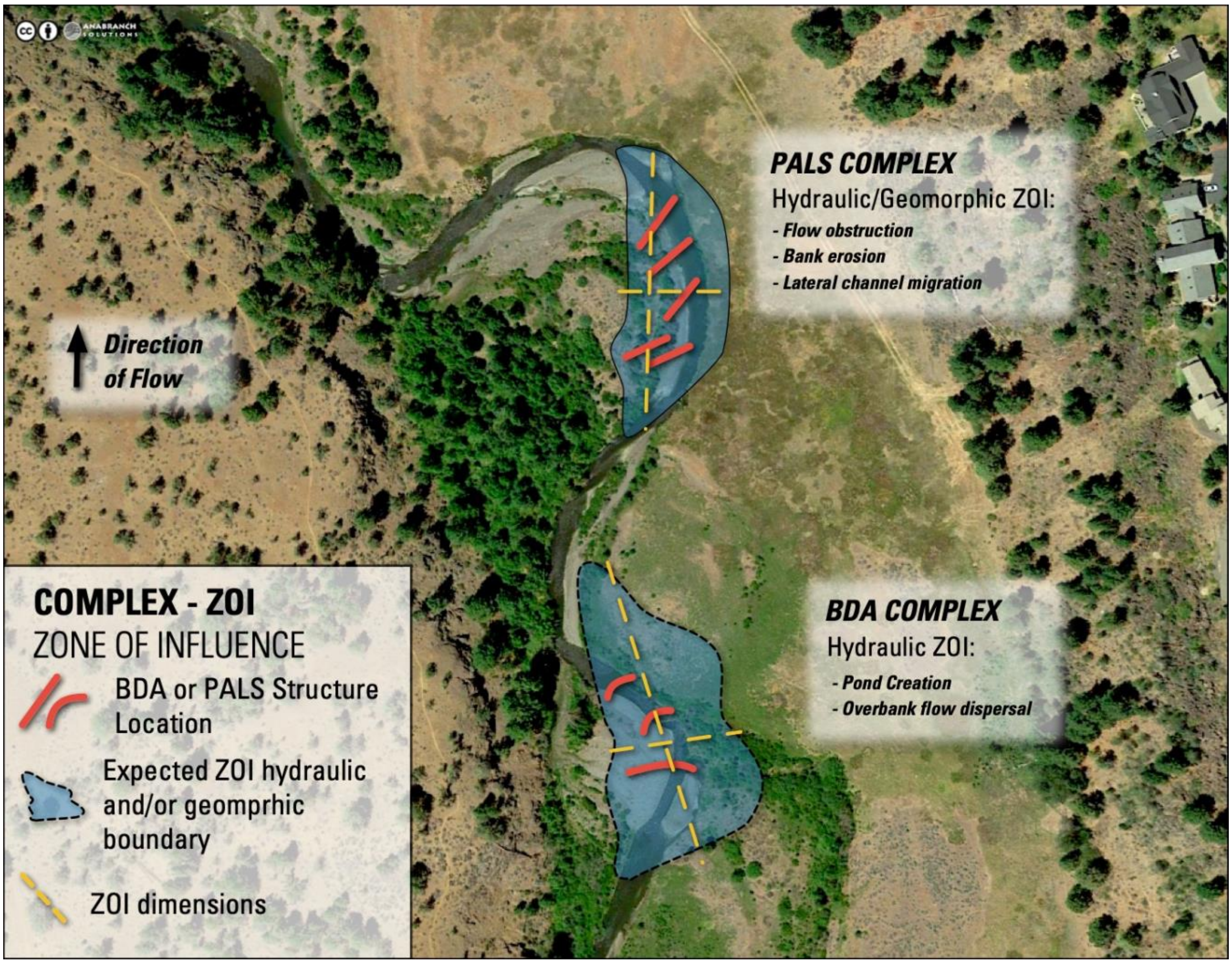

FIGURE 11. OVERHEAD VIEW OF TWO STRUCTURE COMPLEXES DEMONSTRATING EXPECTATIONS FOR HYDRAULIC AND/OR GEOMORPHIC ZONE OF INFLUENCE (ZOI) AND ESTIMATE OF ZOI DIMENSIONS.

Complex ZOI areas can be determined by a number of hydraulic and geomorphic processes created by structural implementation. For example, the hydraulic ZOI for BDA structures may extend upstream to the point which ponding occurs, extend laterally as flow is diverted across floodplain surfaces, and extend downstream to the point at which overbank flow returns to the channel. Geomorphic ZOIs may refer to expectations for incision trench widening or lateral channel migration as a result of terrace erosion.

3.3.2 Complex Maintenance Specification

Maintenance actions include the enhancement, repair, and/or modification of existing restoration structures, and are specified at the complex scale. Specification of maintenance actions includes a narrative of the maintenance activity and an expectation for additional material types and quantity requirements.

It may seem more appropriate to specify maintenance actions with respect to individual structures. However, a focus on maintenance requirements for individual structures becomes tedious and inefficient to manage and implement on all but the smallest of LT-PBR projects. Rather, specification of maintenance at a sub-reach (i.e., complex) scale provides an efficient means to convey maintenance actions and material requirements to implementation crews without the need to locate individual structures or create excessive maintenance records for each structure. Good examples of maintenance specifications at the complex scale include "add additional willow to top of posts for all structures in complex", "add sediment to the base of all undermined structures", or "extend the two most upstream structures laterally onto the river right floodplain ~ 15 ft.".

MAINTENANCE SHORT DESCRIPTION – A short title for the maintenance actions (e.g., "add fill", or "repair breaches").

DATE COMPLETED – The date that the maintenance action was implemented, signifies that the maintenance action has been completed.

MAINTENANCE DESCRIPTION – A written narrative describing the required maintenance action. The maintenance description can include, but is not limited to information describing general areas or structures within the complex that may need maintenance, description of structure characteristics that should be modified, materials that should be used, and/or a description of how maintenance may contribute to meeting complex-scale objectives.

IMPLEMENTATION PHASE – The phase of implementation that the maintenance actions are to be conducted as previously defined in 3.1.4 - Implementation Phases.

POST ESTIMATE – Estimate of the total number of posts that may be required for the maintenance actions.

MATERIAL TYPE – Vegetative material type to be included in maintenance implementation as previously defined in 3.1.2 - Defining Project Materials. Multiple material types can be included in each maintenance action.

MATERIAL COUNT – Estimated number of each material type that may be needed to implement the maintenance action.

3.4 STRUCTURE DESIGN

The majority of structure design considerations (i.e., dimensions, materials, posts) are specified as part of project setup within section 3.1.3 - Structure Types. Thus, structure designs consist of specifying the location, type, and implementation phase associated with structures in each complex.

STRUCTURE TYPE – The type of structure as previously defined in section 3.1.3 - Structure Types.

STRUCTURE COUNT – Number of structures built or to be built of that type.

```
Within the database, structure count can be used to specify multiple structures of a given
type under a single record. This may be sufficient detail for LT-PBR projects that have
large numbers of structures.
```

STRUCTURE ID – A short ID that can be used to uniquely identify the structures or set of structures.

```
The database will assign each new structure record a three-digit numeric ID (e.g., 004).
The ID is useful when identifying structure records from a list or when viewing on a map.
The auto-assigned structure ID can be edited by database users.
```

COMPLEX – The complex name that the structure belongs to.

```
Complex will be auto populated by the data application. However, you can easily reassign a
structure to a different complex using the field dropdown within the structure data entry
interface.
```

STRUCTURE LATITUDE AND LONGITUDE – Coordinates for the structure location, or center point for a set of structures in decimal degrees.

STRUCTURE DESCRIPTION – Verbal narrative that may describe but is not limited to the specific intended function of the structure(s), orientation of the structure with respect to channel and floodplain features, and/or construction considerations.

IMPLEMENTATION PHASE – The phase of implementation under which the structure will be installed as defined in section 3.1.4 - Implementation Phases.

4 Monitoring Survey Protocols

Monitoring surveys include field – based surveys of structure and active channel characteristics and a desktop GIS survey of riverscape features. The survey protocols have been designed to be accessible to any protocol user with an understanding of river behavior and taxonomy. Aside from a familiarity with the expected lateral (target active floodplain) and longitudinal (up to downstream) extent of the survey reach (Figure 8), background knowledge of the restoration design and objectives is not explicitly required.

4.1 Field Based Surveys

Field – based surveys document the distribution and characteristics of structural elements (i.e., beaver dams and woody debris jams) and geomorphic units within the active channel. The survey attributes have been designed to allow derivation of metrics that are relevant to LT-PBR projects effectiveness, potential risks, and aquatic and wetland habitat quantity and quality.

It may be tempting to capture repeat photos, document needed maintenance, or design new structures while conducting the field - based surveys. Don't fall into this trap. The field survey protocol is complex, andonce a new survey has been initiated it is recommended that protocol users devote their full attention to accurately documenting the spatial distribution and characteristics of structural elements and geomorphic features within the reach. Save restoration design and photo point capture for another time when you can give these important tasks the attention they deserve.

4.1.1 Field Survey Event Attributes

Survey event attributes are meant to document the date, flow conditions, and any notes that might be relevant to interpretation of the survey data.

It is strongly recommended that a two-person crew equipped with a 50 m measuring tape and 2 m graduated measuring staff are employed to implement the field - based surveys. The measurement equipment allows accurate measurement of structural element and geomorphic unit dimensions.

REACH NAME – Name of the reach being surveyed.

```
Reach name will be auto populated by the database on event creation. The database also
allows survey events to be reassigned to different reaches.
```

SURVEY DATE – Date the survey event was conducted.

SURVEY START AND STOP COORDINATES – Start and stop coordinates for the survey.

Although redundant with the reach coordinates, recording the start and stop coordinates at each field survey event can be used to verify whether the survey encompassed the entire reach, or be used to survey only a subset of the complete reach length.

SURVEY VALLEY LENGTH (M) – Length of the survey in meters measured along the center of the valley bottom (see Figure 8 for an example).

SURVEY FLOW – Flow conditions during the structure survey using flow descriptors from section 2.3 - Flow Descriptions.

Although it is advisable to observe restoration structure treatments during moderate to high flow events it is often difficult to implement the structural survey and channel unit survey during high flows.

SURVEY NOTES – Written narrative providing any additional information that may be relevant to interpretation of the survey data.

SURVEYED BY – Full name of the individual conducting the survey.

4.1.2 Structural Element Attributes

Attributes common to both dam and jam structure types. Survey all structural elements within the reach that are within the active channel.

OBSERVATION ID – A 3-digit ID used to identify an individual structure observation.

```
The database application will automatically create an observation ID on creation of a new
dam record; however, the value of the ID can also be edited by the user.
```

STRUCTURE SOURCE – Describes whether the structure is natural (dams built by beaver dams or naturally woody debris and accumulations) or artificial (built as a restoration structure).

NATURAL – The structure was built by beavers or is a naturally occurring piece or accumulation of woody debris.

ARTIFICIAL – The structure was built or placed as part of a restoration treatment.

Artificial structures that are being maintained or enhanced by natural beaver activity should still be recorded as "artificial". Maintenance of artificial structures will be clearly documented within the "Beaver Maintenance" attribute below.

STRUCTURE NOTES – Any notes or comments that may be relevant to the structural element or that may increase interpretation of data.

DOMINANT LOW-FLOW TYPE – Dominant flow pathway in relation to the structural element:

OVER – Dam is relatively intact, and flow is primarily spilling over the crest of the dam, or woody debris or accumulation is causing majority of flow to spill over the structure.

AROUND – Structure is causing flow to be diverted around the structure within the active channel or onto adjacent floodplain surfaces.

THROUGH – Structure is porous, and flow is primarily percolating through the structure with little evidence of flow impoundment or altered flow pathways.

UNDER – bed scour has resulted in flow passing under the structure.

TERMINAL – Structure is acting as an impermeable barrier and there is no flow passing downstream of the structure.

DRY – Structure is not in contact with surface flow.

NA – An assessment of the dominant flow pathway is not applicable or relevant at this structure.

LATERAL RESPONSE – Dominant lateral geomorphic or hydraulic response to flood events at the structure.

DISPERSION – During high flow events the structure is causing overbank flow leading to increased floodplain connectivity and/or creation of additional channel braids.

EROSION – During high flow events structure has primarily caused bank, terrace, or hillslope erosion leading to a widening of the active channel or inset floodplain.

NO RESPONSE – Little response has yet to occur in response to flow events.

FIGURE 12. EXAMPLE OF LATERAL GEOMORPHIC AND HYDRAULIC RESPONSES AT A BDA STRUCTURE. THIS STRUCTURE IS EXHIBITING DISPERSION AS OVERBANK FLOW AND END CUTTING SUGGESTING EROSION. IT MAY BE COMMON FOR A SINGLE STRUCTURE TO ELICIT BOTH RESPONSES TO SOME DEGREE, IN WHICH CASE THE SURVEYOR WILL SELECT THE MOST DOMINANT RESPONSE.

ELEVATIONAL RESPONSE – Dominant (i.e., net) geomorphic change to the elevation of the active channel bed in response to high flow events.

DEPOSITIONAL – Structure is causing sediment capture and/or deposition (i.e., bar formation or uniform deposition) leading to an increase to the channel bar elevation.

EROSIONAL – Dominant geomorphic process consists of bed scour, sediment evacuation, and a potential lowering of the channel elevation.

EQUILIBRIUM – Deposition and scour of bed material is approximately equal.

NO RESPONSE – Little evidence of geomorphic change to the channel bed.

BEAVER MAINTENANCE – Evidence and timing of structure maintenance by beaver through addition of vegetation, sediment, cobble, or other materials used to increase the elevation, extent, or decrease structure porosity.

ACTIVE – Structure is actively being maintained by beaver.

OLD – There is evidence of past maintenance by beaver, applicable to natural dams if maintenance is not fresh (active).

NONE – There is no evidence of beaver dam maintenance.

FISH PASSAGE RISK – Visual evaluation of risks to fish passage given the presence of absence of flow pathways, channel geometry, structure porosity, and structure height with respect to flow stage.

NO RISK – Structure porosity and existing flow pathways offer no risk to fish passage, passage is certain at all flows.

LOW FLOW RISK – Low structure porosity, the geometry of the channel, and lack of flow pathways would likely limit fish passage during low – baseflow discharge. Passage is likely at flows above baseflow due to creation of flow pathways through, around, and over the dam.

ALL FLOW RISK – Low dam porosity, high dam height, and lack of diverse flow pathways pose a significant risk to fish passage at low flow and during what would be considered a typical flood.

NA – An assessment of passage is not applicable to this structure.

4.1.3 Dam Specific Attributes

Attributes specific to natural and/or artificial beaver dams.

DAM LENGTH (M) – Length of the dam crest in meters (e.g., 3.5).

MAXIMUM HYDRAULIC HEIGHT (M) – A measurement of dam effectiveness as the ***MAXIMUM*** hydraulic drop (Figure 13) from the water surface upstream to downstream of the dam (e.g., 0.34).

MINIMUM JUMP HEIGHT (M) – Minimum jump height for fish passage around a channel spanning dam structure (e.g., 0.05). The measurement should target the ***MINIMUM*** elevation change for flow pathways that are near vertical (Figure 13). For structures that are breached or causing flow around the structure the minimum jump height should be near 0.

If the structure is in a dry section of channel be sure that the Dominant Flow Type is marked “Dry”. Use “0” for the dam height attributes.

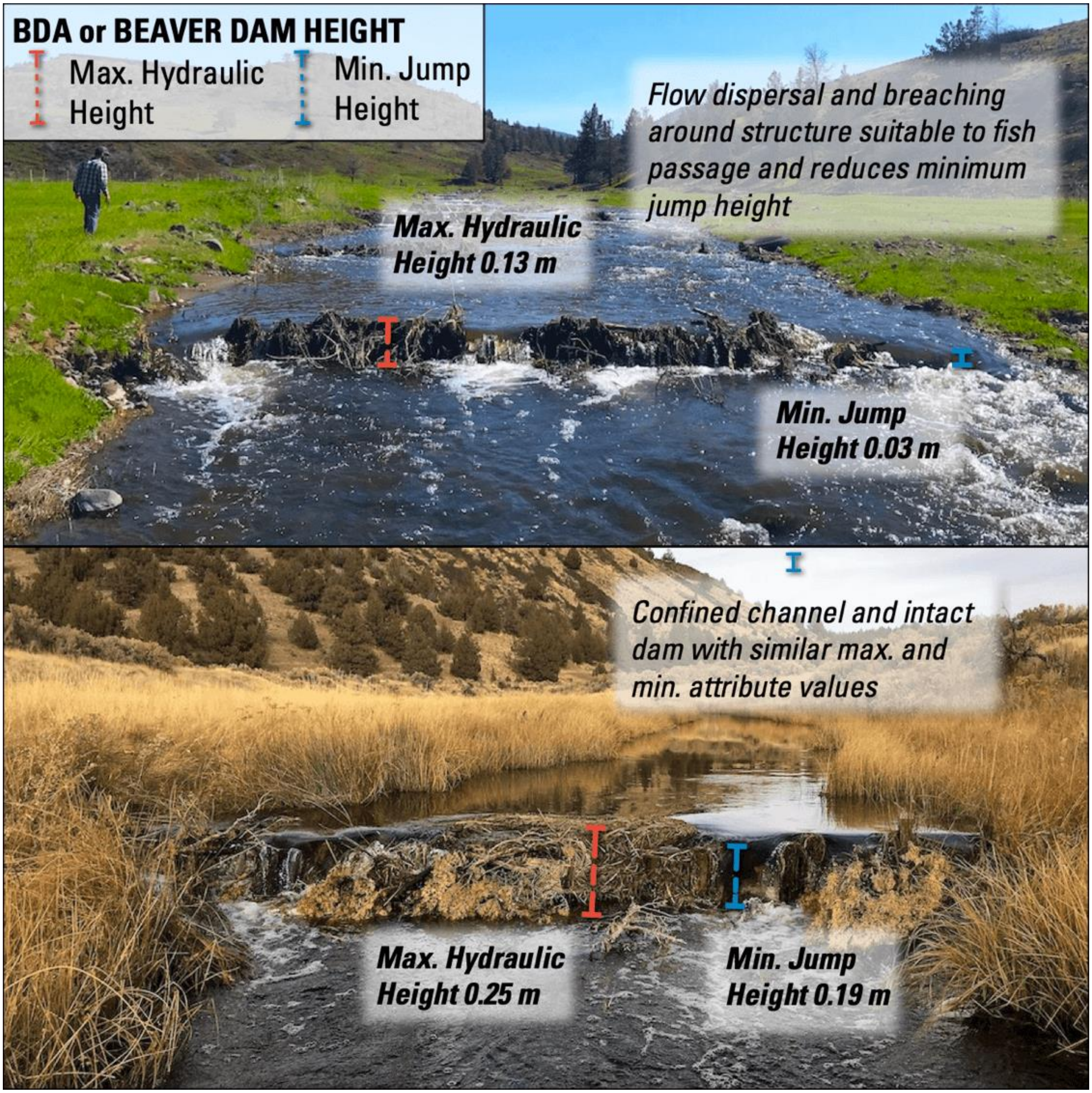

FIGURE 13. EXAMPLES OF BEAVER DAM OR DAM ANALOG MEASUREMENTS OF MAXIMUM HYDRAULIC HEIGHT AND MINIMUM JUMP HEIGHT WITHIN TWO DIFFERENT CHANNEL AND STRUCTURE SETTINGS.

DAM INTEGRITY – Descriptive of the dam structural integrity (Figure 14).

INTACT – Structure shows little evidence of breaching or erosion around the structure, flow is primarily spilling over and/or flowing through the structure.

BREACH – Some evidence of breaching (i.e., vegetative material and/or post loss) and/or erosion of the banks or streambed. Flow is concentrated near the breach, but the structure is still impounding water and reducing the water surface gradient behind the dam.

BLOWN – A large portion of the structure has been damaged and/or lost during high flows. Water surface gradient is consistent with the streambed.

BURRIED – Sediment deposition has essentially buried the structure.

FLOODED – Downstream structural elements (e.g., natural or artificial dams and/or wood jams) have resulted in inundation of the structure.

NA – An assessment of condition is not applicable, possible, or is irrelevant.

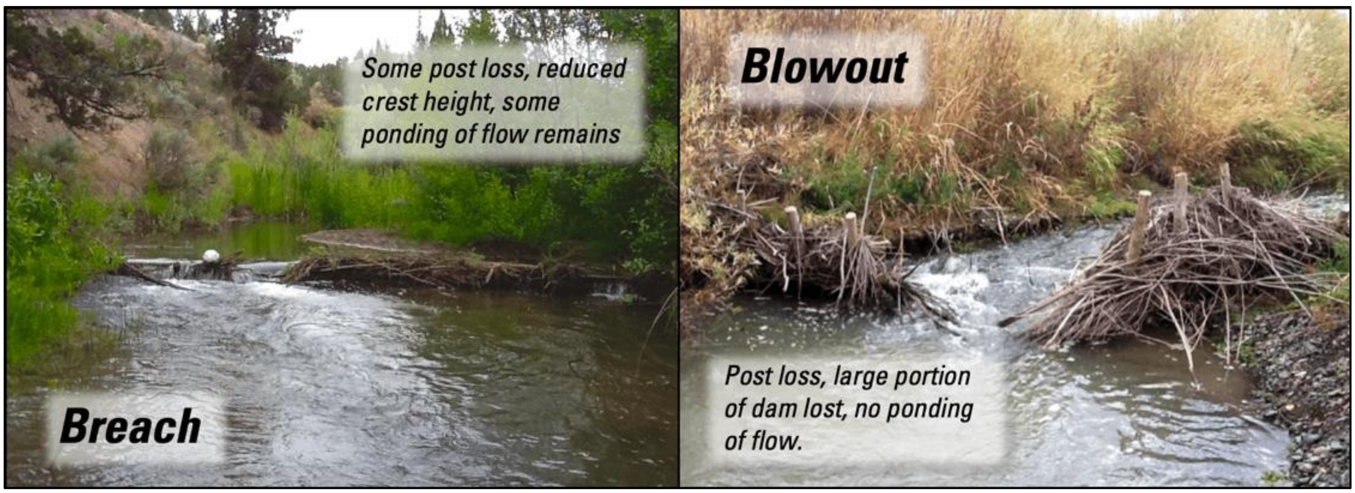

FIGURE 14. EXAMPLE OF ATTRIBUTE VALUES USED TO EVALUATE BDA OR NATURAL BEAVER DAM STRUCTURE INTEGRITY.

4.1.4 JAM SPECIFIC ATTRIBUTES

Structure attributes specific to natural and artificially placed wood and wood accumulations.

ARTIFICIAL JAM CONDITION – An estimate of placed structure stability in response to high flow events. This attribute is not applicable to naturally occurring wood and woody debris.

STABLE – Posts and/or wood placed as part of the structure remain stable in response to high flow events.

UNSTABLE – Posts and/or wood have become dislodged due to flood events and scour in the vicinity of the structure.

BURRIED – Sediment deposition has almost completely buried the structure.

FLOODED – Downstream structural elements (e.g., natural or artificial dams and/or wood jams) have resulted in inundation of the structure.

NATURAL – Should be used to describe the conditions of natural wood accumulations or pieces of woody debris.

NA – An assessment of condition is not applicable, possible, or is irrelevant. Naturally occurring jams and wood pieces will always be marked as NA.

JAM LENGTH AND WIDTH (M) – Lateral dimensions of the woody debris jam, or length of single piece of large woody debris in meters (e.g., 5.6). Jam width should be recorded as the average stem diameter for single pieces of large wood.

JAM HEIGHT (M) – Total elevation height of the jam accumulation, or average diameter for single pieces of large woody debris (e.g., 2.3).

WOOD COUNT – Number of pieces of large wood in the wood accumulation. Should be 1 for single pieces of large wood.

In some systems featuring high wood abundances counting each individual piece will not be feasible. In these cases an estimate of large wood pieces will be sufficient.

FIGURE 15. EXAMPLE OF DIMENSIONS USED IN THE RECORDING OF PALS OR NATURAL WOODY DEBRIS ACCUMULATION LENGTH, WIDTH, AND HEIGHT ULTIMATELY USED TO ESTIMATE A VOLUME OF WOODY DEBRIS ACCUMULATIONS.

4.1.5 GEOMORPHIC UNIT ATTRIBUTES

Attributes describing geomorphic habitat units within the active channel. Typically, all geomorphic units should be delineated (i.e., surveyed) if they have a channel length greater than half of an average active channel width. However, geomorphic units that do not meet this size criteria can and should be delineated when they are representative of significant habitat features or provide evidence of geomorphic processes. Similarly, exceptions to the size criteria should also be made within small stream systems and non-primary channels.

UNIT TYPE – Geomorphic unit types are primarily delineated based on the longitudinal profile of the active channel bed (Figure 16).

CONCAVITY – Bed form concavity (i.e., pools) formed as a result of scour during high flow periods.

CONVEXITY – Bed form convexity (i.e., bars) formed as a result of deposition during high flow events.

PLANAR – Planar bed form (i.e., glides, rapids, runs) that is neither depositional nor erosional during high flow events.

POND – Surface water impoundment caused by a flow obstruction such as a beaver dam or woody debris jam.

NA – Channel unit type is not applicable or cannot be determined at the time of the survey.

STRUCTURE FORCED – Geomorphic unit is formed by sediment scour, deposition, or impoundment of flow caused by a naturally occurring or artificially placed structural element.

ARTIFICIAL STRUCTURE – Unit was forced by an artificially placed restoration structure.

NATURAL STRUCTURE – Unit was forced by natural beaver dam, woody debris, woody debris accumulation, or other naturally occurring structural element.

NOT STRUCTURE FORCED – Unit was not formed as a result of a natural or artificial woody debris jam or beaver dam structure. Note, this classification includes units forced by bars, boulders, bedrock, and/or the planform of the channel.

Bars, boulders, and bedrock may be considered structural elements. However, this "Structure Forced" attribute has an explicit focus on geomorphic units associated with the structural elements most often imitated by LT-PBR projects – namely beaver dams and wood and woody debris accumulations.

UNIT NOTES – Written narrative noting significant characteristics of the unit or information that will improve interpretation of the survey data.

UNIT COORDINATES – Location of the unit in decimal degrees recorded at the downstream end of each unit.

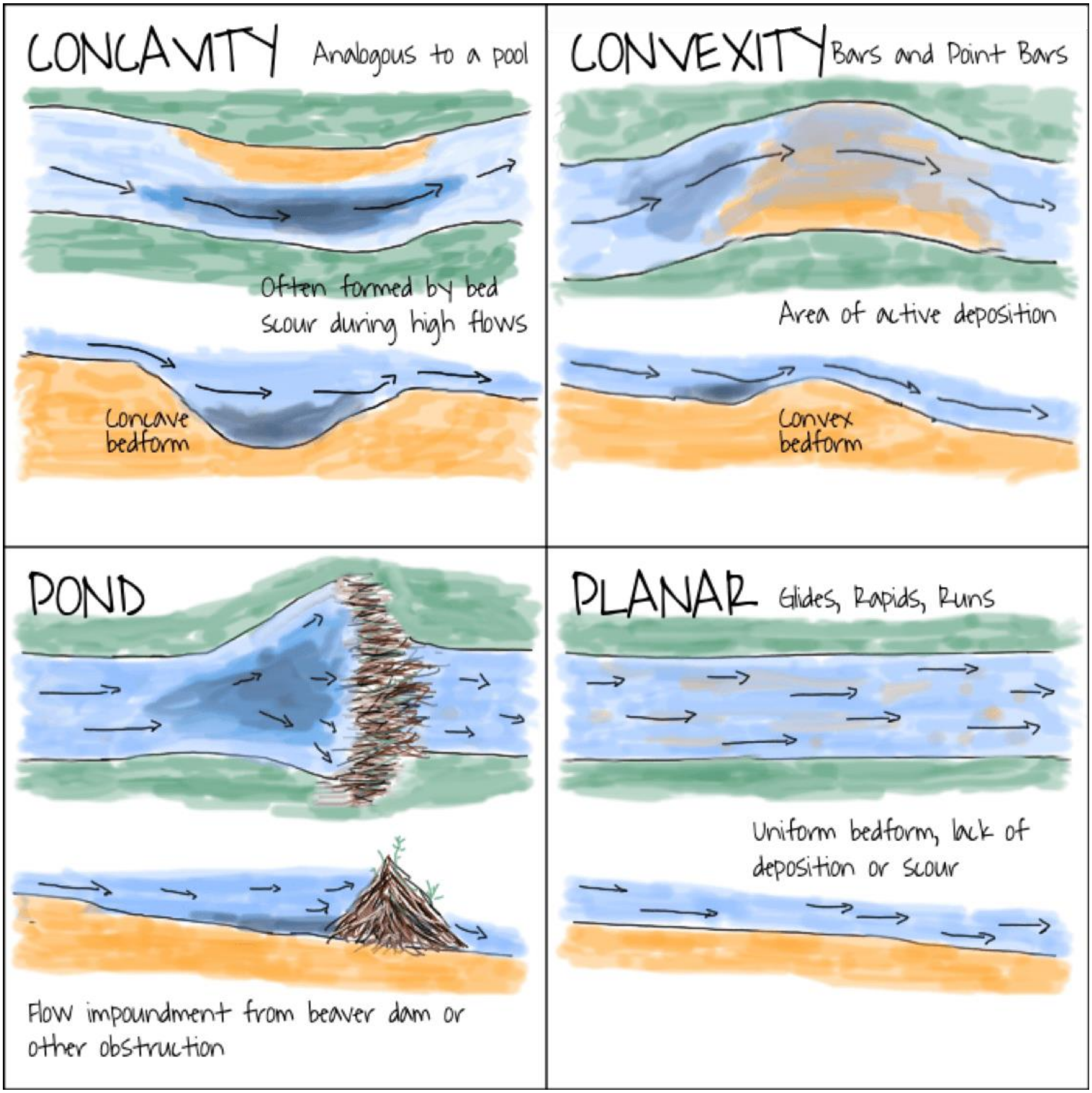

FIGURE 16. REPRESENTATIVE SKETCHES TYPIFYING BEDFORM, PLANFORM, AND FLOW PATHWAYS ASSOCIATED WITH GEOMORPHIC HABITAT UNIT TYPES.

PRIMARY CHANNEL – Describes whether the unit is within the primary or a non-primary active channel.

PRIMARY CHANNEL – The unit is within the active channel that carries the majority of surface flow.

NON-PRIMARY CHANNEL – The unit is not within the active channel carrying the majority of flow (i.e., secondary or tertiary channels).

PRIMARY UNIT – Descriptive of geomorphic unit position and relationship to other geomorphic units within the active channel (Figure 17).

> ***PRIMARY UNIT*** – Geomorphic units that follow the channel thalweg and/or encompass the majority of the active channel at any given point. Primary units should be continuous throughout the geomorphic survey, and the sum of primary unit lengths is used to calculate the total length of primary and non-primary channels within the survey reach.
>
> ***NON-PRIMARY UNIT*** – Non-primary units will never span the entire active channel, generally will not encompass the channel thalweg, and are always adjacent to at least one primary unit.

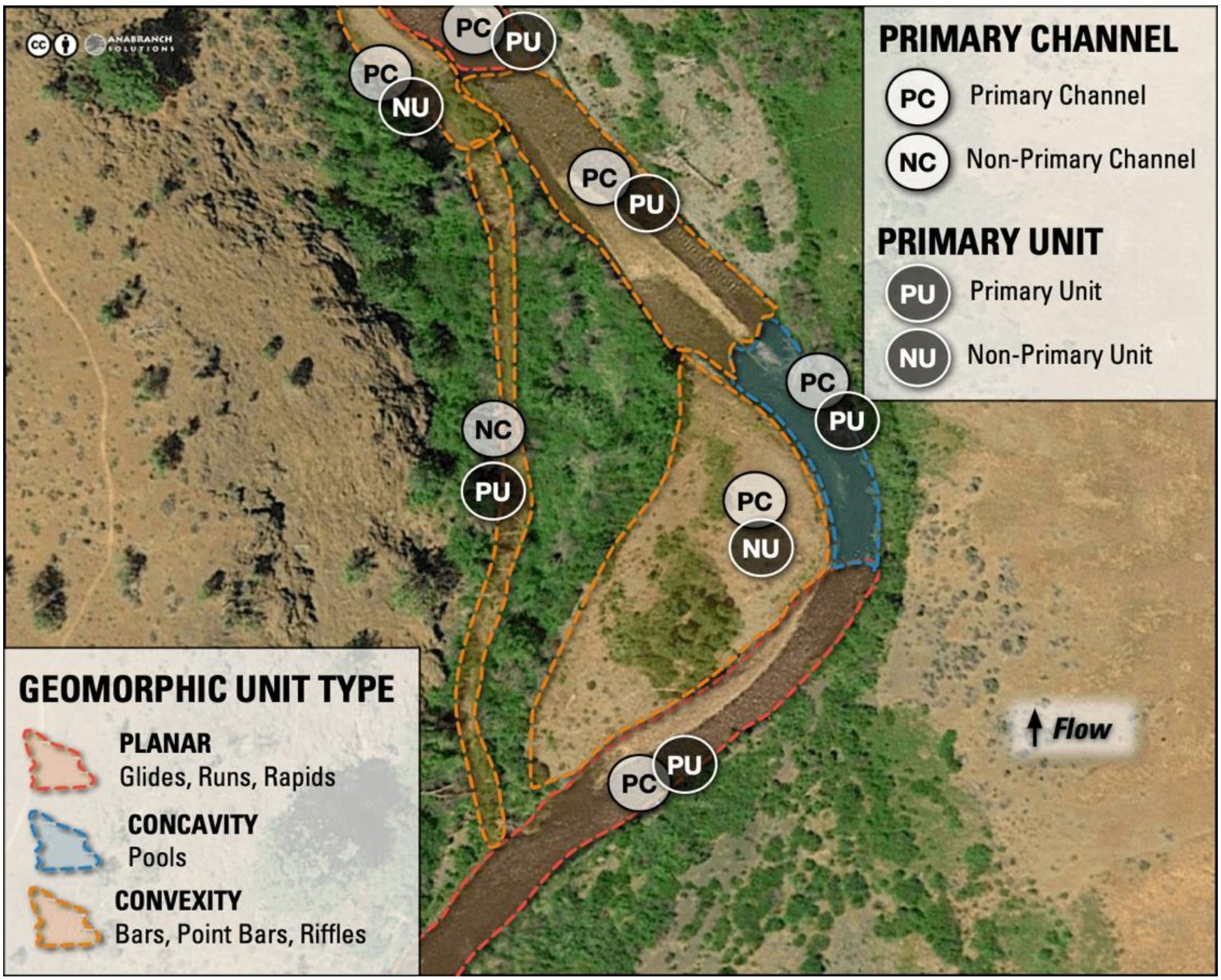

FIGURE 17. OVERHEAD VIEW OF A SURVEY REACH DEMONSTRATING CHANNEL TYPE AND CHANNEL SPANNING SURVEY ATTRIBUTES.

UNIT LENGTH AND WIDTH – Average dimensions for the unit. Length and width should be measured parallel and perpendicular to the direction of flow, respectively. Used to calculate a total area for the geomorphic unit.

PERCENT WETTED – Percent of the unit area currently inundated by surface flow. Ultimately used to calculate a total wetted area for the reach.

Record 0% to indicate that the unit is completely dry (i.e., lacks surface flow).

UNIT DEPTH – An average depth for the geomorphic unit. Maximum depth should be measured for concave unit types (i.e., pools).

Record a depth of 0.00 to indicate a dry unit.

4.2 Remote Riverscape Survey

The remote riverscape survey quantifies restoration impacts through digitization of riverscape features using a desktop geographic information software (GIS) and available georectified repeat imagery. High-resolution aerial imagery acquired using a commercial or professional grade drone is ideal for this survey, however publicly available imagery sources such as those acquired through the United States Department of Agriculture's National Agriculture Imagery Program (NAIP) may also offer sufficient resolution to accurately identify and quantify riverscape features. The process of quantifying riverscape features can be accomplished using a variety of GIS platforms, including desktop GIS software from ESRI (i.e., ***ArcMap***), the free and open source ***QGIS*** program, or Google Earth.

Note, the remote riverscape survey may not be possible in heavily forested systems prohibit identification of riverscape features. However, the majority of the metrics produced by the riverscape survey can also be calculated based on field survey data.

4.2.1 Riverscape Survey Event Attributes

Attributes descriptive of the imagery source and acquisition date.

IMAGERY DATE – Date of imagery acquisition.

IMAGERY SOURCE – Short description of imagery source (e.g., Google Earth, NAIP, Private Drone.

IMAGERY FLOW – Relative stream discharge on the date of imagery acquisition using flow attributes values from section 2.3 - Flow Descriptions.

RIVERSCAPE SURVEY NOTES – Any notes related to the imagery source or processing that may increase the interpretation of the survey data.

GIS FILES – A repository within the database application meant to hold the GIS files (e.g., .shp, .kml) containing the digitized features from the survey. The database is capable of storing the GIS file collection as a compressed directory (e.g., .zip file).

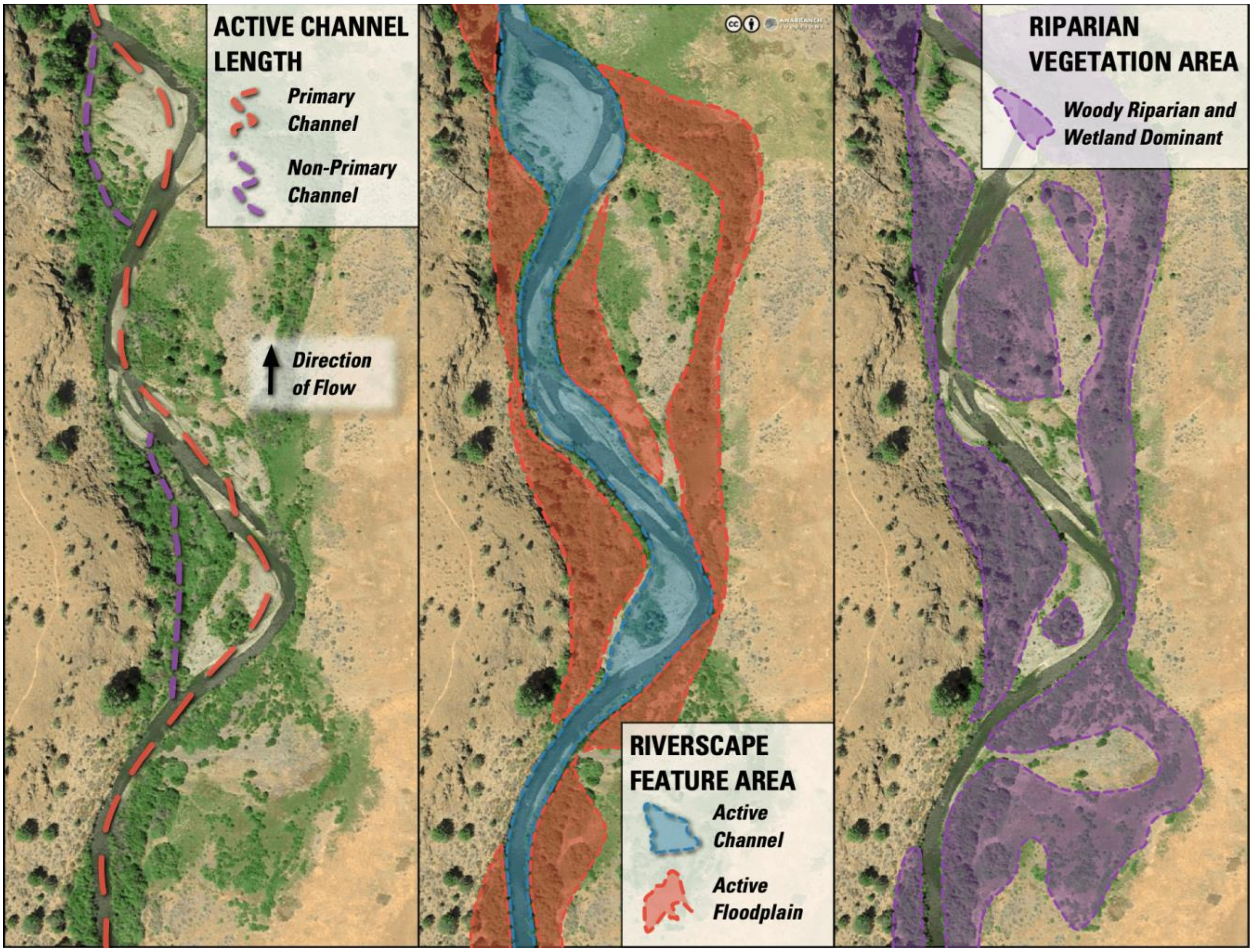

FIGURE 18. EXAMPLE OF DIGITIZED VALLEY BOTTOM FEATURES SHOWING APPROACH TO QUANTIFICATION OF CHANNEL NETWORK LENGTH, ACTIVE CHANNEL AND FLOODPLAIN AREA, AND RIPARIAN VEGETATION EXTENT.

4.2.2 RIVERSCAPE SURVEY FEATURE ATTRIBUTES

The riverscape survey is used to quantify the distribution and extent of riverscape features including the active channel, active floodplain, and riparian vegetation communities.

4.2.2.1 Measures of Active Channel Network Length

Channel lengths should be digitized within a GIS using polyline feature types.

PRIMARY CHANNEL LENGTH (M) – Length of the primary channel in meters following the thalweg. In multi-threaded channels the primary channel is the thread that transports the largest portion of the total stream discharge (e.g., 2454 m).

NON-PRIMARY CHANNEL LENGTH (M) – The sum of the length of all non-primary channel segments within the restoration reach as measured along the channel thalweg (e.g., 2343 m).

WETTED CHANNEL LENGTH (M) – Length of all primary and non-primary active channel segments containing surface flow. If the entire active channel network within the restoration reach is flowing the wetted channel length should be the sum of the primary and non-primary channel lengths.

4.2.2.2 Measures of Riverscape Feature Area

The area of riverscape features should be digitized within a GIS using polygon feature types. Areas should be recorded in square meters (m^2).

ACTIVE CHANNEL AREA (M^2) – Total area of the active channel network within the reach extent.

ACTIVE FLOODPLAIN AREA (M^2) – Total area of the active floodplain within the reach extent.

RIPARIAN VEGETATION AREA (M^2) – Total area of the reach extent that is dominated by riparian and wetland plant communities.

5 References

Beechie, T., Sear, D.A., Olden, J.D., Pess, G.R., Buffington, J.M., Moir, H., Roni, P. and Pollock, M.M., 2010. Process-based principles for river restoration. Bioscience, 60(3): 209-222. DOI: 10.1525/bio.2010.60.3.7

Kraebel C, and Pillsbury A.F. (1934) Guideline for watershed improvement measures: Handbook of erosion control in Mountain Meadows:1-69. US Forest Service, Region 5.

Osterkamp, W.R., 2008. Annotated Definitions of Selected Geomorphic Terms and Related Terms of Hydrology, Sedimentology, Soil Science and Ecology. In: U.S.G. Survey (Editor), Reston, Virginia, pp. 49

Palmer M.A., Bernhardt E.S., Allan J.D., Lake P.S., Alexander G., Brooks S., Carr J., Clayton S., Dahm C.N., Follstad-Shah J., Galat D.L., Loss S.G., Goodwin P., Hart D.D., Hassett B., Jenkinson R., Kondolf G.M., Lave R., Meyer J.L., O'donnell T.K., Pagano, and Sudduth E. (2005) Standards for ecologically successful river restoration. Journal of Applied Ecology 42:208–217. Available at: https://doi.org/10.1111/j.1365-2664.2005.01004.x

Pollock, M.M., Beechie, T.J., Wheaton, J.M., Jordan, C.E., Bouwes, N., Weber, N. and Volk, C., 2014. Using Beaver Dams to Restore Incised Stream Ecosystems. Bioscience, 64(4): 279-290. DOI: 10.1093/biosci/biu036

Skidmore, P.B., Thorne, C.R., Cluer, B.L., Pess, G.R., Castro, J.M., Beechie, T.J. and Shea, C.C., 2011. Science base and tools for evaluating stream engineering, management, and restoration proposals, U.S. Department of Commerce, Seatle, WA. Available at: https://repository.library.noaa.gov/view/noaa/4020.

Wheaton J.M., Bennett S.N., Bouwes, N., Maestas J.D. and Shahverdian S.M. (Editors). 2019. Low-Tech Process-Based Restoration of Riverscapes: Design Manual. Version 1.0. Utah State University Restoration Consortium. Logan, UT. Available at: http://lowtechpbr.restoration.usu.edu/manual

6 Glossary of Protocol Terms

This incomplete glossary is meant to facilitate a consistent terminology for protocol users. Users should recognize that attempts to provide a single *de facto* taxonomy for describing fluvial geomorphic features are too numerous to name. As such, these definitions should only be considered applicable within the scope of this protocol and may conflict with definitions referenced within other fluvial habitat and riparian assessment protocols, texts, and the scientific literature.

A

ACTIVE CHANNEL - A natural or constructed passageway or depression of perceptible linear extent containing continuously or periodically flowing water and sediment. The active channel should be considered any area of the valley bottom where frequent depositional and erosional processes have resulted in lack of vegetative cover and substrates dominated by alluvial material. The active channel also includes all areas of the valley bottom inundated during baseflow discharge (e.g., as a result of ponding by restoration structures and/or natural beaver dams).

ACTIVE FLOODPLAIN – Areas of the valley bottom at an elevation and position relative to the active channel that will be inundated during a typical flood event. Floodplains are likely to show recent signs of inundation such as deposition and/or scour of alluvial material, racking of woody and other organic debris. In the long term, active floodplains are likely to exhibit increased abundances of wetland and riparian vegetation as a function of increased frequency and duration of flow inundation and/or proximity to groundwater.

B

BANKFULL - The stage at which flow starts to leave the channel, overtops its banks and spreads out onto an adjacent floodplain surface. In fluvial-geomorphology, bankfull is the water-surface level at the tops of alluvial- stream banks that corresponds to the level of adjacent flood-plain surfaces, if present. Thus, bankfull stage is the level at which bankfull discharge occurs, the upper limit of channel capacity. As such, the concept of bankfull stage requires an interpretation of site-specific landforms, especially bank. Although bankfull stage can refer to various channel-bank levels, it generally applies to alluvial-stream channels (1) having sizes and shapes adjusted to recent fluxes of water and sediment, (2) that are principal conduits for discharges moving through a length of alluvial bottomland, and (3) that are bounded by flood plains upon which water and sediment spill when the flow rate exceeds that of bankfull discharge. From Osterkamp (2008).

BAR - In-channel sediment of relatively coarse bed material, typically coarse sand through cobbles in size, that is generally deposited during the recession of a high flow and is mostly exposed during periods of low flow; the upper surface of bars of perennial streams is typically equivalent to a stage of about 40-percent flow duration. From Osterkamp (2008).

BED - The bottom surface of a water course, generally of a stream channel, upon which water and sediment move during periods of discharge. From Osterkamp (2008).

C

COMPLEX – Cluster or group of restoration structures (e.g., wood structures or beaver dam analogs) designed to work together to mimic and/or promote specific processes to achieve specific restoration objective(s). The term comes from the concept of a beaver dam complex typically consisting of a primary dam with a lodge and secondary dams extending downstream and/or upstream to extend the foraging range.

CONTROL – Used within the context of experimental restoration design, control reaches are those that will not receive structural treatments but will receive monitoring data acquisition.

D

E

F

FLUVIAL – Of, relating to, or found in a river or stream

G

H

HYDRAULIC - Hydraulics describe the nature of flow consisting of depth (a scalar quantity) and velocity (a vector quantity with direction and magnitude).

I

INCISION – Stream channel in which excessive scour has resulted in a loss of channel elevation and disconnection from historic floodplain surfaces. Incised stream channels are often straight and feature little to no active floodplain surfaces within the incision trench.

INTERMITTENT - Streams that only flow during part of the year (such as in the spring and early summer after snowmelt) or in direct response to precipitation.

J

K

L

LOW – TECH PROCESS – BASED RESTORATION - The practice of using simple, low cost, structural additions (e.g., wood and beaver dams) to promote geomorphic, hydrologic, and vegetative processes intended to restore riverscape function (see Wheaton et al. 2019).

M

MEANDER – A bend in a river or stream channel.

N

O

P

PHASE – A discrete period of restoration implementation that may consist of new structure installation and/or the maintenance or enhancement of existing structures (e.g., many LT-PBR projects will begin with a pilot phase that is followed by additional restoration phases.

PILOT - A small scale or trial restoration project initiated before implementing a large-scale restoration project; often used when first using low-tech restoration in a new area or with a new group of partners.

PLANFORM - Shape and geometric character of a river or stream channel's position in the valley bottom.

Q

R

RIPARIAN - Interface between land and a river or stream. Generally, the 'riparian' zone is the floodplain portion of the valley bottom, which supports vegetation with higher water tolerances and/or needs (i.e., the green parts).

RIVERSCAPE – Streams and riverine landscapes, or "riverscapes" are composed of connected floodplain and channel habitats that together make up the valley bottom. The term riverscape is used to indicate a holistic perspective of the broad scale patterns and processes associated with fluvial systems.

S

T

TARGET ACTIVE FLOODPLAIN – Relative to the current active floodplain, the target active floodplain describes the area of the valley bottom that might be inundated during a **TYPICAL FLOOD**

as a result of a structural restoration intervention, either as a result of augmented hydraulics or through changes to active channel and floodplain morphology.

TERRACE – Valley-contained alluvial surface that represents a former active (abandoned) floodplain.

THALWEG - The line that connects the lowest points in an active channel. Should be the point that the active channel that carries the greatest volume of flow.

TYPICAL FLOOD – A flood event in which flow begins to overtop banks that form the boundary of the active channel and spill onto floodplain surfaces. Should be considered similar to common definitions for a bankfull flood event with an exceedance interval of approximately 2 years.

U

V

VALLEY BOTTOM - Low-lying area between hillslopes containing the stream channel and contemporary floodplain. The valley bottom represents the current maximum possible extent of channel adjustment, active floodplain expansion, and riparian extent.

W

WOODY DEBRIS - Relative expression of wood in a stream channel sufficient in size to be immobile at most flows and to interfere with channel hydraulics. From: Skidmore et al. (2011)

X

Y

Z

ZONE OF INFLUENCE - The area that a structure complex is capable of influencing either hydraulically or geomorphically in response to a typical flood.

7 Appendices

The following appendices provide supplementary protocol information important to its application and utility.

7.1 Reach Scale Objectives and Supporting Summary Metrics

The following tables (i.e., 7.1.1 - 7.1.5) reference a series of indicator metrics that can be used to quantify progress toward reach scale objectives specified during the restoration design process (see 3.2.2 - Specification of Reach Scale Objectives). The tables also list the monitoring survey(s) used to generate metric values, metric calculation, and a brief interpretation of the relationship of the metric to each objective. Ideally, these tables encourage restoration practitioners to establish baseline and target values for indicators of restoration effectiveness that are easily quantifiable, and that can be leveraged during the proposal development and monitoring stages of any LT-PBR restoration project.

```
Note, calculated metrics can be found in the standard Excel exports for "Field Surveys" and
"Riverscape Surveys" within the database application's export interface. Attribute names
used in the Excel exports are listed in the tables below with respect to each metric.
```

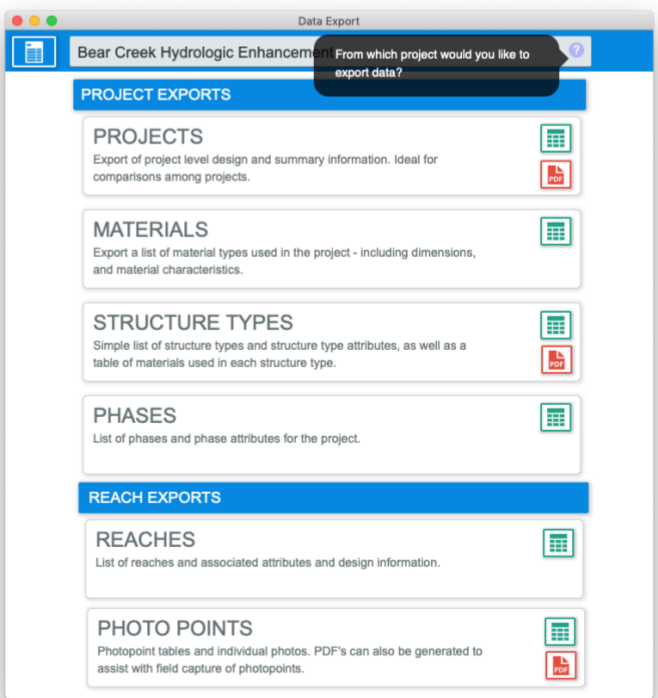

Figure 19. Showing the data export interface from the database application used to export raw data in Excel, repeat photo series, and auto-generated .PDF reports.

7.1.1 Indicators of Incision Trench Widening

METRIC	SURVEY	EXPORT AS	CALCULATION AND INTERPRETATION
% STRUCTURES LATERALLY EROSIVE	Field	calc_LateralErosionPercentTotalStructures	% of total structures causing or that have caused lateral erosion of banks, disconnected floodplain and/or terrace surfaces, or valley walls leading to widening of the active channel or inset floodplain.
% STRUCTURES DEPOSITIONAL	Field	calc_DepositionalPercentTotalStructures	% of all structures that are net aggradational, indicating reduced stream power, increased channel elevation, and potential for inset floodplain development.
PRIMARY CHANNEL LENGTH	Field, Riverscape	calc_ChannelLengthPrimary, PrimaryChannelLength	Sum of primary channel unit lengths following the thalweg. Increasing channel length suggests a widening of the incision trench creating space for channel meanders and a more complex channel planform.
NON-PRIMARY CHANNEL LENGTH	Field, Riverscape	calc_ChannelLengthNonPrimary, NonPrimaryChannelLength	Sum of non-primary unit length measured along the thalweg. The occurrence or increase in non-primary channel length suggests formation of an inset floodplain and more complex channel planform.
ACTIVE CHANNEL AREA	Field, Riverscape	calc_ChannelAreaTotal ActiveChannelArea	In incised channels the area of the active channel is often a direct measure of channel confinement.
ACTIVE FLOODPLAIN AREA	Riverscape	ActiveFloodplainArea	Presence and increase of an inset active floodplain are indicative of widening incision trench.
RIPARIAN VEGETATION AREA	Riverscape	RiparianVegetationArea	The presence and extent of riparian vegetation is evident of inset floodplain development.

7.1.2 Indicators of Floodplain Connectivity and Expansion

METRIC	SURVEY	EXPORT AS	CALCULATION AND INTERPRETATION
% STRUCTURES LATERAL DISPERSAL	Field	calc_LateralErosionPercentTotalStructures	% of total structures causing or that have caused lateral dispersal of flow onto active and/or disconnected floodplain or terrace surfaces indicating increased floodplain connectivity and expansion.
% STRUCTURES DEPOSITIONAL	Field	calc_DepositionalPercentTotalStructures	% of all structures that are net aggradational, indicating increased channel elevation, and potential for inset floodplain development.
PRIMARY CHANNEL LENGTH	Field	calc_ChannelLengthPrimary, PrimaryChannelLength	Increasing channel length through creation of a more complex planform is indicative of a wandering channel with a high degree of floodplain connectivity.
NON-PRIMARY CHANNEL LENGTH	Field, Riverscape	calc_ChannelLengthNonPrimary, NonPrimaryChannelLength	Sum of non-primary unit length measured along the thalweg. The occurrence or increase in non-primary channels throughout floodplain surfaces is indicative of a channel with a high degree of floodplain connectivity.
ACTIVE CHANNEL AREA	Field, Riverscape	calc_ActiveChannelArea ActiveChannelArea	Active channel area will increase as a product of increased primary and non-primary channel length.
ACTIVE FLOODPLAIN AREA	Riverscape	ActiveFloodplainArea	Floodplain area provides a direct measure of floodplain connectivity and expansion.
RIPARIAN VEGETATION AREA	Riverscape	RiparianVegetationArea	Increased floodplain inundation frequency and groundwater elevations contribute to expansion of riparian and wetland vegetation extent.

7.1.3 Indicators of Riparian Vegetation Abundance and Extent

METRIC	SURVEY	EXPORT AS	CALCULATION AND INTERPRETATION
ACTIVE FLOODPLAIN AREA	Riverscape	ActiveFloodplainArea	Increased active floodplain extent creates conditions and often provides the mechanism contributing to riparian vegetation establishment.
RIPARIAN VEGETATION AREA	Riverscape	RiparianVegetationArea	Increased floodplain inundation frequency and groundwater elevations contribute to expansion of riparian and wetland vegetation extent.

7.1.4 Indicators of In-Channel Habitat Quantity and Quality

METRIC	SURVEY	EXPORTED AS	CALCULATION AND INTERPRETATION
POOL FREQUENCY	Field	calc_DensityUnitsPools	Concave unit density (pools / km) based on the survey length measured along the center of the valley bottom. Increased pool frequency is indicative of a dynamic channel and offers critical cover and holding habitat for fish at all life-stages.
POOL DEPTH RANGE	Field	calc_DepthPoolsRange	Range (max. – min.) of depth measurements from cancave units. An increased range of pool depths suggests higher habitat complexity.
BAR FREQUENCY	Field	calc_DensityUnitsBars	Convex unit density (bars / km) based on the survey length measured along the center of the valley bottom. Increased occurrence of bars indicates a more dynamic channel and often provides substrate variation critical to adult spawning salmonids.
POND AREA	Field	calc_WettedAreaPonds	Sum of the wetted area of pond unit types. Pond habitat often creates thermal refugia, drought refugia, and slow-water rearing habitat for many aquatic species.
WOODY DEBRIS FREQUENCY	Field	calc_DensityJams	Woody debris accumulation density per. km scaled to the survey length measured along the center of the valley bottom. Increased woody debris provides cover and flow velocity refugia for many aquatic species.
WETTED CHANNEL AREA	Field	calc_WettedAreaTotal	Sum of unit wetted areas. Wetted channel area provides a measure of habitat quantity that will increase with pond formation, channel lengthening, and non-primary channel creation.

7.1.5 Indicators of Beaver Habitat Creation

METRIC	SURVEY	EXPORTED AS	CALCULATION AND INTERPRETATION
% INTACT DAMS	Field	calc_DamIntegrityPercentIntact	Percent of dam structures surveyed marked “intact”. Intact dams allow pond cover for beaver, increase likelihood of beaver colony establishment, or indicate beaver maintenance of existing dams.
% ARTIFICIAL DAM MAINTENANCE	Field	calc_BeaverMaintDamArtificialPercent	Percent of artificial dam structures being actively maintained by beaver. Beaver maintenance on artificial structures provides direct evidence of beaver occupation.
COUNT NATURAL DAMS	Field	calc_CountDamsNatural	The number of natural dams provides direct evidence of beaver colony establishment.
POND AREA	Field	calc_WettedAreaPonds	Sum of the wetted area of pond unit types. Greater pond area provides cover for beavers and increases the likelihood of beaver colony persistence.
AVERAGE POND DEPTH	Field	calc_DepthPondsMean	Average depth of pond unit types (only considers ponds with depths > 0). Deeper ponds provide cover for beavers and increases the likelihood of beaver colony persistence.
NON-PRIMARY CHANNEL LENGTH	Field, Riverscape	calc_ChannelLengthNonPrimary, NonPrimaryChannelLength	In larger systems non-primary channels often exhibit a lower stream power more suitable to natural dam establishment.
RIPARIAN VEGETATION AREA	Riverscape	RiparianVegetationArea	Expansion of woody riparian and wetland vegetation provides increased forage for beaver.

7.2 LT-PBR Example Protocol Application Workflow

The following provides a short example of how the protocol can be used in all stages of an LT-PBR restoration project workflow from initial project scoping, design, implementation, and monitoring (Figure 20).

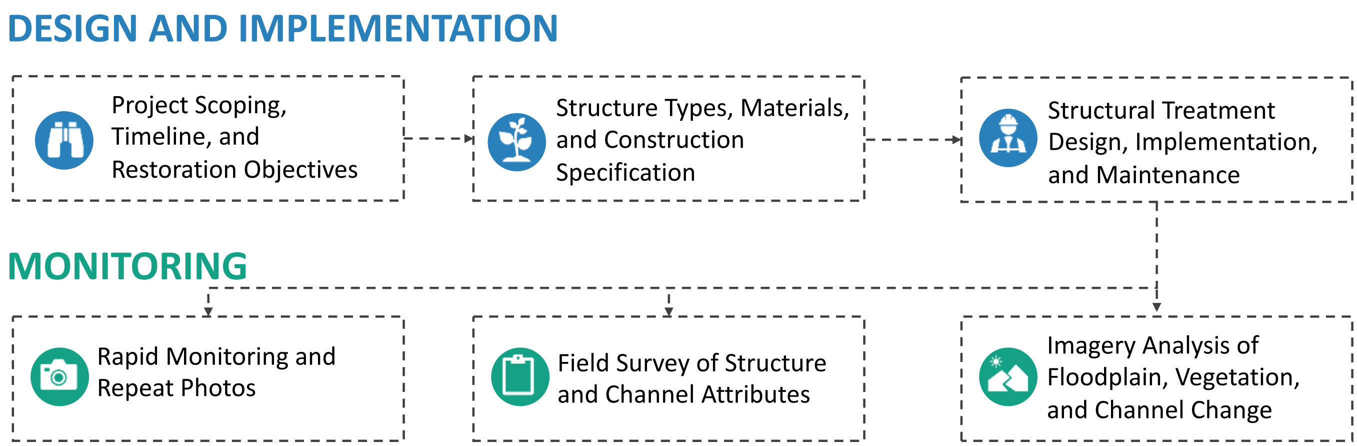

Figure 20. Diagram showing key components of restoration projects that are supported by the LT-PBR project management and monitoring protocol.

Project Scoping, Timeline, and Restoration Objectives

The protocol encourages documentation of high-level project information used during design development and permit acquisition that includes specification of restoration objectives, restoration reach delineation, and project implementation schedules. This type of information can be recorded during desktop interaction with the database application as well as during initial site scoping visits.

- At project inception, high-level information can be documented within the database according to section 3.1.1 - Project Scale Design Attributes. This information will assist with report and permit preparation.
- During an initial field visit, restoration reach boundaries can be documented using the database application according to section 3.2.1 - Reach Scale Design Attributes.
- Locations, photos, and descriptions of riverscape features, human infrastructure, building materials, and other features that might be used to inform a restoration design can be documented in the field according to section 3.2.4 - Riverscape Features.

- Field observations are used to develop restoration objectives and restoration targets specific to each reach as described in sections 3.2.1 - Reach Scale Design Attributes, and 3.2.2 Specification of Reach Scale Objectives.

- Timelines for project implementation (described in section 3.1.4 - Implementation Phases), that may include a pilot treatment and multiple larger treatments are set to be consistent with project objectives.

Structure Types and Materials

Following project scoping, the protocol and database can be used to specify structure types that will be included within the restoration treatment design (Figure 21). The protocol supports designs that include multiple restoration structure types (i.e., recipes) with different construction and functional specifications. Additionally, the protocol allows explicit tracking of the vegetative material types that will be used in restoration structure construction. This information is intended to assist with estimates of material requirement as well as fill volume estimates that may be needed for permit applications.

- Documentation of the types and dimensions of vegetative materials that will be used in structure construction is described in section 3.1.2 - Defining Project Materials. Need to be defined prior to development of structure types.

- Structure types, including their dimensions, post – spacing, construction characteristics, and material quantities can be documented in section 3.1.3 - Structure Types – Your Restoration Cookbook.

STRUCTURE TYPE DESCRIPTIONS

PRIMARY BDA

STRUCTURE MIMICS	TOTAL POSTS	SEDIMENT DEPTH (IN.)
Beaver Dam	6	2

HEIGHT (FT.)	LENGTH (FT.)	WIDTH (FT.)	POST DIAM (IN.)	POST SPACING (FT. / POST)
2.5	12.0	3.0	3	3.0

MATERIAL NAME	QUANTITY
Juniper Branches	100

STRUCTURE TYPE DESCRIPTION

Large BDA generally spanning the length of the primary channel. Posts installed and fill added to elevation just above the active channel height.

FIGURE 21. EXAMPLE OF A STRUCTURE TYPE DESCRIPTION REPORT THAT IS GENERATED AND EXPORTED BY THE DATABASE APPLICATION.

TREATMENT DESIGN, IMPLEMENTATION, AND MAINTENANCE

After development of structure types that are appropriate to the project setting and objectives structures can be distributed throughout treatment reaches according to a restoration design.

- Structure complex and individual structure locations are best specified in the field using the database application running on an iPad. However, preliminary or conceptual designs can be developed on the desktop for planning purposes and then field verified. Specification of structures and structure complexes are described in sections 3.3.1 - Complex Scale Design Attributes and 3.4 - Structure Design.

- Structure maintenance (described in 3.3.2 - Complex Maintenance Specification), which includes enhancements and repairs to existing structures can be documented during site visits following initial implementation. In general, maintenance is best specified in the field using the database application running on an iPad.

PROJECT OVERVIEW

PROJECT COORDINATING ENTITY
Mid John Day - Bridge Creek Watershed

PROJECT WATERSHED
Lower John Day

TREATMENT REACHES	TREATMENT LENGTH (KM)	CONTROL REACHES	CONTROL LENGTH (KM)
4	1.09	0	0.00

TOTAL COMPLEXES	TOTAL STRUCTURES	STRUCTURE TYPES	IMPLEMENTATION PHASES
10	84	6	3

PROJECT DESCRIPTION

Bear Creek restoration actions will work to address watershed impairments that stem from historic land-use (e.g. overgrazing, channelization, beaver eradication, fire suppression and juniper proliferation) and have resulted in altered hydrologic and riparian function, reduced geomorphic complexity, and ultimately a decrease in ESA salmonid habitat quantity and quality.

REACHES

TYPE	REACH NAME	STREAM NAME	REACH LENGTH (KM)	FLOODPLAIN AREA (KM) CURRENT	FLOODPLAIN AREA (KM) TARGET
Treatment	Beaver	Bear Creek	0.30	0.55	1.73
Treatment	Grizzly	Bear Creek	0.45	1.36	3.39
Treatment	Rancher	Bear Creek	0.21	0.25	0.42
Treatment	Spring	Spring Gulch	0.12	0.05	0.10

STRUCTURE TYPES

TYPE NAME	MIMICS
BDA Floodplain	Beaver Dam
PAL	Wood Aggregate
Postless BDA	Beaver Dam
Primary BDA	Beaver Dam
Reinforced Existing	Beaver Dam
Secondary BDA	Beaver Dam

IMPLEMENTATION PHASES

PHASE	DATE	STRUCTURES
Phase-01	Sep 5, 2017	20
Phase-02	Jul 19, 2018	44
Phase-03	Sep 13, 2019	20

BEAR CREEK HYDROLOGIC ENHANCEMENT

Figure 22. Project overview report generated by the database application showing treatment reaches, structure types, and implementation phases.

Rapid Monitoring Visits and Repeat Photos

The protocol provides several ways to rapidly track restoration impacts which includes the monitoring "visit" and repeat photo point establishment. In order to be most effective, monitoring visit observations and repeat photos should be captured prior to and following restoration implementation, and at treatment and control reaches. Photo points and monitoring visits may be sufficient for tracking and reporting on many restoration projects where the capacity for more comprehensive monitoring is not available.

- Rapid monitoring "visits" (described in 3.2.5 - Reach Visit) provides a means to quickly document progress toward restoration objectives, as well as record observations related to restoration responses during any short visit to a restoration monitoring reach.

- Repeat photos can also be captured opportunistically and are not associated with the Monitoring Survey Protocols. Procedures for establishing repeat photo points are found in section 3.2.3 - Repeat Photos. Repeat photos can be captured in the field using the database application running on an iPad.

Field Survey of Structure and Channel Attributes

Field monitoring surveys (described in 4.1 - Field Based Surveys) should be implemented prior to and following restoration implementation and at treatment and control reaches. Field surveys are designed to document structure condition, function, and distribution as well as active channel change and habitat quality and quantity. It is essential that field surveys be conducted in the field using the database application on an iPad.

Imagery Analysis of Riverscape Dynamics

Section 4.2 - Remote Riverscape Survey provides procedures for quantifying changes to the active floodplain, active channel, and riparian vegetation distributions using acquisition of aerial imagery, and/or the availability of contemporary and historic imagery. Again, this monitoring approach should be implemented for time periods prior to and following restoration implementation and at treatment and control monitoring reaches.

7.3 Database Application

This draft of the LT-PBR project implementation and monitoring protocol (version 1) was written to support data management within version 1.0.0 of the fmLTPBR database application. Much of the database application functionality can be accessed free of charge using an iPad or iPhone mobile device running the free Filemaker Go application (note that the interface has been optimized for iPads and may prove unwieldy on iPhones). Using the database application on a mobile device is ideal for field data collection, capturing repeat photos, and many other common project management tasks. Running the database application on a desktop (i.e., Mac or Windows operating systems), which is highly recommended for getting the most out of the protocol and database application, requires purchase of a Filemaker Pro Advanced license. Table 2 lists the hardware and software on which the database application was developed, and that should offer the most seamless user experience both on a desktop and iPad for field data capture.

Table 2. Recommended software and hardware for use with the fmLTPBR database application.

ITEM	DESCRIPTION	SPECIFICATION
IOS MOBILE OPERATING SYSTEM	Mobile operating system for iPad.	iPad OS 13
FILEMAKER GO	Version of FileMaker Go for running the database application on iOS devices.	FileMaker Go 18 for iPad. V 10
IPAD	iPad mobile device with cellular capability and GPS.	9.7" iPad 7th generation with cellular
MACOS DESKTOP OPERATING SYSTEM	Desktop macOS version for running Filemaker Pro Advanced.	macOS Catalina V 10
WINDOWS OPERATING SYSTEM	Windows OS version for running Filemaker Pro Advanced on Windows desktop and tablet* computers.	Windows 10
FILEMAKER PRO	Filemaker Pro version for operation of the database on a desktop platform.	Filemaker Pro 18 Advanced

* Note, that the camera and GPS are unlikely to allow field capture of coordinates and photos using a Windows tablet running Filemaker Pro Advanced. For this reason, an iPad running Filemaker Go is highly recommended for field data capture and review.

May 7th, 2020