SKOKOMISH RIVER BASIN
MASON COUNTY, WASHINGTON
ECOSYSTEM RESTORATION

APPENDIX F

ECOSYSTEM OUTPUTS MODEL

Integrated Feasibility Report and Environmental Impact Statement

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SKOKOMISH RIVER ECOSYSTEM RESTORATION PROJECT ENVIRONMENTAL BENEFITS ANALYSIS

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SKOKOMISH RIVER ECOSYSTEM RESTORATION PROJECT ENVIRONMENTAL BENEFITS ANALYSIS

1 INTRODUCTION

The U.S. Army Corps of Engineers, Seattle District (Corps) is conducting a General Investigation (GI) to propose alternative plans for aquatic ecosystem restoration in the Skokomish River Basin, Mason County, Washington. That process follows a prescribed series of steps to formulate and evaluate specific proposed measures, and involves working with various local entities and other state and Federal agencies. Ecosystem restoration of the Skokomish River includes multiple potential actions that are intended to improve the condition and function of the river system, with an emphasis on factors that limit anadromous fish reproduction, refuge, and rearing habitat. The proposed restoration measures range from site-specific engineering actions to altering basic ecosystem processes. There are multiple possible combinations of these measures, and it is the responsibility of the Corps to identify the most efficient configuration as the recommended restoration plan. For the Corps' ecosystem restoration mission, the assessment of project alternatives is directed toward quantifying complex environmental benefits. Ideally, the process of assessing alternatives should be sufficiently broad-based that it captures the major ecological implications of proposed project actions, while being easily understood, and producing outputs that can be used in the context of standard planning and decision-making procedures.

The purpose of the Environmental Benefits Analysis described here is to provide quantification of the potential ecological improvement of proposed restoration actions so that the actions can be compared to each other, and to compare alternative suites of actions in the cost effectiveness and incremental cost analysis. This assessment method is structured to address the objectives and limitations of the Skokomish River as defined in the Section 905(b) Water Resources Development Act Analysis Report and as identified in subsequent follow-up planning meetings for this project. It is consistent with guidelines set by the Corps (USACE 1999; ER 1165-2-501).

1.1 STUDY AREA

The study area for the Skokomish River GI is approximately 11 square miles and is limited to the Lower Skokomish River Valley, the floodplain and channel of the lower mainstem and lower South Fork of the Skokomish (divided into five study reaches), and a major tributary, Vance Creek (Figure 1). It specifically excludes the North Fork and areas upstream of the lower valley due to various constraints, but recognizes that many of the problems that afflict the lower river originate elsewhere in the system. The 905(b) report identifies a variety of agencies and other entities (e.g. US Forest Service [USFS] or Tacoma Public Utilities [TPU]) that may have restoration projects underway throughout the watershed to address some of those issues, and specifies that the Corps will coordinate with them.

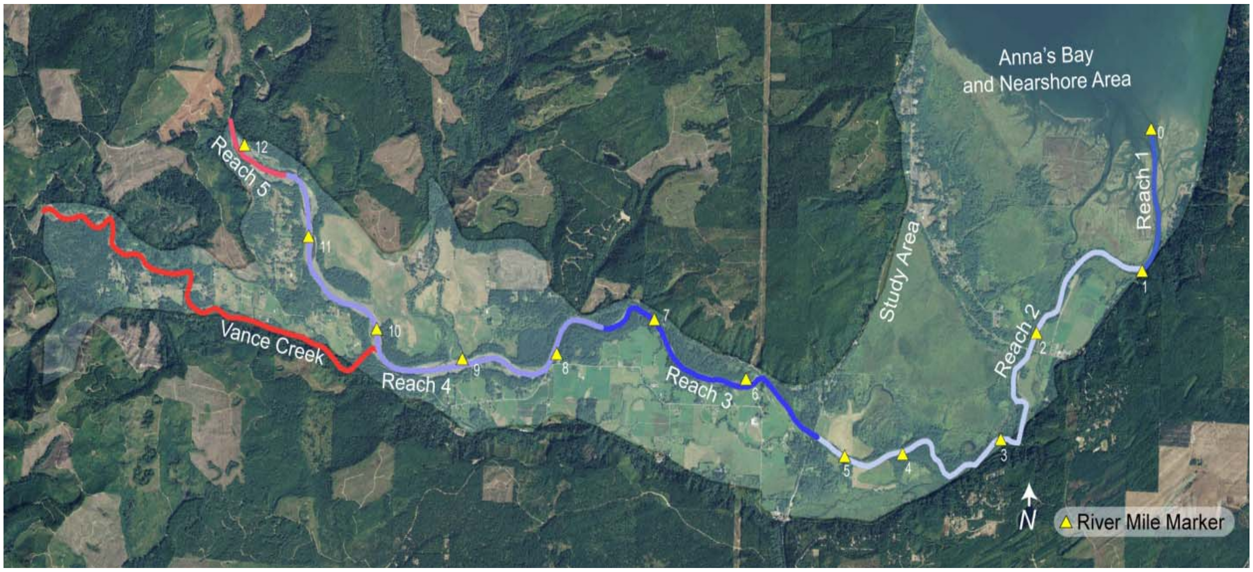


Figure 1. Study Area and Assessment Reaches

1.2 PROBLEM IDENTIFICATION

The Skokomish River Basin was the subject of extensive field investigations beginning more than a decade ago. The Washington Department of Fish and Wildlife and Point No Point Treaty Council conducted habitat assessments focusing on Hood Canal summer chum salmon recovery planning (WDFW and PNPTC 2000), and Correa (2003) described the condition of the area in terms of factors limiting the availability and condition of habitat for all species in the Salmonidae family that are present in the Skokomish basin (Chinook, chum, coho, pink, steelhead, sea run and resident cutthroat, rainbow trout, and bull trout). A more recent study (Peters et al. 2011) revisited the basin and provided a comprehensive characterization of aquatic and riparian habitat conditions. These reports noted that each salmonid species differs in the timing of critical life history events and the way it uses various habitats, but that all of the anadromous fish in the system have the same basic requirements:

- Adequate water quality and appropriate water temperatures;
- Balanced sediment budget;
- Stable spawning gravels;
- Pools and instream structure including large boulders and logs;
- A functional riparian zone;
- Connected freshwater migratory and refuge habitats; and
- A complex of healthy estuarine and nearshore habitats to allow transition from freshwater to seawater.

All of these critical factors were found to be compromised or lacking to some extent. Much of the degradation originates from excess sediments in the channel system, changes in flows, and disconnection of the floodplain and off-channel wetlands by levees.

During the problem identification phase of the feasibility study, the frequent fish stranding that occurs during overbank flows of the Skokomish River was named as a high priority issue. The flood frequency of overbank flow has increased to a return interval of more than once per season, often as many as four times in one winter. The high flow events coincide with the fall migration of Chinook, coho, and steelhead, as well as the incubation of eggs and alevin stage in the redds. The flooding causes adult fish to become stranded in the fields adjacent to the river. For fish that have been able to spawn in the river, the late winter and early spring floods scour the redds causing mortality of incubating eggs, and strand juvenile fish in the fields.

Change in disturbance regime has been identified as an anthropogenic stressor to many salmon populations (Waples et al. 2009). For example, over the past 80 years in the Stillaguamish River, the discharge that had a return interval of 10 to 20 years has become a one- to two-year event (Waples et al. 2008). Seiler et al. (2002) found a strong correlation between high discharge and low egg-to-migrant fry survival. Naturally occurring high flows cause a certain rate of mortality, but viable salmon populations have the resilience to rebuild after loss during rare events. However, the increased frequency from anthropogenic causes may now be too frequent for the salmonid populations to be able to adapt (Waples et al. 2009).

The sedimentation rate in the Skokomish River has exceeded the river's ability to transport sand and gravel, which has led to reduced channel capacity. The river's discharge capacity is now only approximately 25% of the two-year return interval discharge. Flood frequency is multiple times per winter. This flood frequency regime causes such frequent and substantial mortality to the annual returns of migrating salmon that the populations may no longer have the abundance to withstand such losses.

Another characteristic of the Skokomish River is that the variety of habitat types has been significantly reduced mainly by the removal of large wood decades ago, and the filling of pools due to wood removal and excessive sedimentation. This reduction in habitat diversity leads to reduced resilience of the river's salmon populations (Waples et al. 2009).

Table 1. Habitat factors affecting salmonid habitat in Hood Canal Rivers with supporting information. AM is adult migration, S is spawning, I is incubation, R is rearing (WDFW and PNPTC 2000).

Habitat Factors	Impacts to Channel Processes and Summer Chum	Life History Stages	Supporting Literature
Winter high flow	Redd scour through increased sediment transport	I	McNeil 1964, Tripp and Poulin 1986, Thorne and Ames 1987, Nawa and Frissell 1993, Chamberlain et al. 1991, Schuett-Hames et al. 1994, Montgomery et al. 1996
Summer low flow	Prevention or delay of upstream passage, reduction of available spawning area	AM, S	Chamberlain et al. 1991, Johnson et al. 1997
Water temperature	Elevated temperatures impede adult passage, cause direct mortality, and accelerate development during incubation leading to diminished survival in subsequent life stages	AM, SI, I	Beschta et al. 1987, Holtby and Scrivener 1989, Bjornn and Reiser 1991, PNPTC 1998 unpublished data
Dissolved oxygen	Low dissolved oxygen results in direct egg suffocation and diminished survival of subsequent life stages	I	Mason 1969, Koski 1975, Bams and Lam 1983, Chapman 1988, Bjornn and Reiser 1991, Peterson and Quinn 1994b
Fine sediment	Suffocation of developing embryos, entombment of fry in the gravel bed, compaction and cementing of spawning beds	S, I	Koski 1975 and 1981, Chapman 1988, Salo 1991, McHenry et al. 1994, Peterson and Quinn 1994a
Coarse sediment	Channel aggradation leads to egg/fry entombment, redd dislocation	S, I	Madej 1978, Tripp and Poulin 1986
Large woody debris (LWD)	Low levels may increase redd scour, contribute to channel instability, and limit availability of adult holding pools and rearing capacity	AM, S, I, R	Bilby 1984, Sedell and Froggatt 1984, Dolloff 1986, Lisle 1986a and 1986b, Bisson et al. 1987, Bilby and Ward 1989, Montgomery et al. 1995
Channel condition	Reduced holding pool quality and availability renders adults vulnerable to predation/harassment; reduced channel complexity increases frequency and severity of redd scour; limited rearing	AM, S, I, R	Osborn and Ralph 1994, Beschta et al. 1995, Spence et al. 1996
Loss of side channels	Limits adult holding areas, and confines spawning to main channel areas where redds are prone to scour, limits rearing habitat	AM, S, I, R	Sedell and Luchessa 1982, Sedell and Froggatt 1984, Hirshi and Reed 1998
Channel instability	Increased substrate mobility resulting in redd scour/entombment or de-watering of redds	AM, S, I	Nawa and Frissell 1993, Osborn and Ralph 1994, Beschta et al. 1995

Habitat Factors	Impacts to Channel Processes and Summer Chum	Life History Stages	Supporting Literature
Riparian Condition (species composition, age, and extent)	Removal and modification of native riparian forests increases water temperatures, reduces stability of floodplain landforms, and reduces LWD recruitment to stream channels (see above)	AM, S, I	Bisson et al. 1987, FEMAT 1993, Beschta 1995
Floodplain and wetland loss	Concentrates flood flows in main channel, increases peak flow volumes, and results in increased redd scour; loss of wetlands reduce summer low flow volumes (see above)	AM, S, I	Henegar and Harmon 1971, Spence et al. 1996
Fish passage and Access	In-channel structures obstruct or impede adult passage; tidegates/dikes limit juvenile access to rearing and feeding habitats	AM, R	Evans and Johnson 1980, Toews and Brownlee 1981, Furniss et al. 1991

1.3 RESTORATION MEASURES

Initial planning documents (project objectives, constraints, and measures) focus on reversing habitat degradation for the most sensitive species in the Salmonidae family, which is in fact an ecosystem restoration perspective in that the anadromous fish species of the Pacific Northwest depend on essentially all components of their native ecosystem, including patterns of stream flow and sediment deposition, riparian forest distribution and structure, properly functioning wetlands, and the spatial arrangement and interconnectedness of aquatic as well as terrestrial habitats. A comprehensive restoration plan for species in the Salmonidae family, as keystone species, effectively restores habitat and nutrient input for a broad suite of over 130 other native plant and animal species (Cederholm et al. 2000). Restoration planning centered on habitat for the Salmonidae family reinstitutes dynamic processes that tend to maintain ecosystem characteristics, and increases primary production and carbon export. The rationale for employing restoration measures and their corresponding assessment metrics that focus on restoring habitat for the many species of the Salmonidae family is that all watersheds in the Pacific Northwest ecoregion are home to these fish that serve as an indicator of the overall health of not only the aquatic environment where they dwell, but also the connected riparian, wetland, and upland habitats. The assessment approach presented here adopts that perspective and frames restoration measures in terms of their effects on salmonids.

Systemic problems that originate outside of the study area are being addressed using a watershed approach by other entities such as USFS and TPU in areas that are closely tied to their respective missions and in areas where they are the principal land managers. For instance, sedimentation is a significant issue in the South Fork of the Skokomish River Basin. Much of this land ownership is with the USFS and a private company, Green Diamond Timber Company (formerly Simpson Lumber). Green Diamond is addressing sedimentation issues through inclusion of larger riparian buffer areas and limiting the amount of new logging roads through a Habitat Conservation Plan that was developed in cooperation with the Washington State Department of Natural Resources (WDNR). The USFS has developed a restoration plan for the upper basin that includes decommissioning roads, revegetation, replacement of culverts and construction of engineered log jams to trap sediment within the main channel. The study area for the Skokomish GI is downstream of these areas; the Corps recognizes that any restoration activities need to be coordinated with these other watershed improvements.

Most of the restoration measures that have been developed by the Corps and various stakeholders for possible inclusion in this effort are commonly used approaches to multispecies habitat restoration in the region (Beechie et al. 2008, Roni et al. 2008). Reconnection of isolated habitats and floodplains, floodplain and riparian reforestation, and instream habitat improvements are frequently recommended, and are among the proposed measures for Skokomish River restoration. In addition to these typical restoration measures, the Corps has proposed excavating a significant quantity of riverbed substrate to increase flood flow capacity, which would also serve to open blocked tributary mouths. Therefore, the assessment system described here is focused on a specific suite of physical manipulations within the defined study area as they are expected to affect the distribution, availability, and quality of habitats used by anadromous fish for reproduction, refuge, and rearing. Some measures are intended to address immediate critical problems, such as removing barriers to migration, even though channel movement or sediment redistribution may undo the intended effects eventually. These are referred to as the “Base Options” in this document because they are considered the first and most important actions to undertake to address immediate needs. Still other measures, such as reconnecting forested floodplain areas, can be expected to have immediate and permanent effects. These secondary measures are referred to as "Increments" as they will be added on to the Base Options. Measures that involve planting trees will accrue benefits gradually as the planted vegetation matures, but the effects will be permanent, and will eventually replace lost stream processes by contributing large wood to the channel and reestablishing channel dynamics, thus making future direct interventions to improve passage less necessary. When all of these measures are implemented as a coordinated effort across the study area, they constitute a comprehensive ecosystem restoration approach that will benefit a broad suite of terrestrial and aquatic plant and animal species. This process-based restoration serves to restore the typical ecosystem structures of Pacific Northwest river valleys, which in turn supports the valued ecosystem functions and services.

1.4 MODEL APPROACH

None of the models that are Corps-certified or approved for use for assessing restoration effectiveness is appropriate for use in the case of the Skokomish GI study. The Habitat Evaluation Procedures (HEP) (U.S. Fish and Wildlife Service 1980) have been employed in traditional planning studies for decades, but the models available for any species in the Salmonidae family are complex and require highly specific and intensive data collection (e.g., McMahon 1983) that is well beyond the scope of a multi-project planning study. Terrell et al. (1982) acknowledged this limitation and suggested ways to simplify the process, but did not significantly reduce the need for an elaborate and prolonged field data collection program. More to the point, however, the Habitat Suitability Index (HSI) models for salmonid species are highly focused on site-specific in-stream conditions, particularly those affecting spawning. Habitat requirements for the Salmonidae family make a good surrogate for overall ecosystem health only when they reflect the full range of anadromous fish habitat requirements, including off-channel habitats, food web interactions, and spatial relationships among habitats. Clearly, the available HSI models were not developed with that perspective in mind.

A recently proposed restoration prioritization approach, the Biodiversity Security Index (Cole 2010), addresses Corps planning requirements by focusing on the relative scarcity or vulnerability of affected plant and animal species. In the case of the Skokomish GI study, where various federally protected species are affected, this approach would certainly show a strong justification for implementing a restoration effort when compared to other ecosystem restoration proposals elsewhere in the nation where few or no rare species are involved. However, it will not usefully discriminate among any of the project alternatives likely to be proposed for the Skokomish, all of which will positively affect the same group of highly vulnerable species.

Another approach to assessing ecosystem health and recovery is to focus on fundamental processes, such as primary production. Several measures proposed for the Skokomish River include re-establishment of native vegetation across agricultural lands or early-successional communities, which often contain a large component of non-native species. This has beneficial effects not only on a broad suite of fish and wildlife species within the project area, but also on the health of the Puget Sound and marine ecosystems beyond, which receive organic carbon produced in the basin via export by the river. The elevated functionality per unit area of restoration can be directly represented by the differences in primary productivity between native and non-native plant communities. Where pasture (temperate grassland) is restored to palustrine forest or to emergent wetland, and where weedy, non-forested riparian areas (scrub-shrub) are restored to native riparian or palustrine forest, primary productivity can be expected to double or triple (Whittaker 1975). Thus, the restoration effectiveness of those actions can be expressed as the change in productivity multiplied by the area (acres) restored. However, this approach does not adequately capture the other roles played by these native systems in providing critical in-stream refuge habitats, shading and cooling stream systems, initiating and maintaining sediment dynamics, and other elements of a truly ecosystem-based restoration approach. Nor is it applicable to the assessment of restoration measures that do not much affect primary production but address other objectives, such as creation of pool habitats for fish. For the purposes of this project, it is desirable to use reasonably comparable metrics to assess the effects of all of the various proposed restoration measures, which are aimed at holistic ecosystem restoration.

The approach described here is designed to integrate some of the features and advantages of the methods described above without incorporating some of the disadvantages. It takes into consideration the habitat needs of particular sensitive species, the basic productivity and structure of Pacific Northwest native communities, and the fundamental dynamics of stream ecosystems by grouping restoration actions in ways that reflect key ecosystem attributes, such as the connections between aquatic and terrestrial systems. The selected attributes are assessed in a series of stream reaches, which allows recognition of variation in the extent and types of restoration required in different parts of the ecosystem. The response metrics can be considered at various levels of summation, including across all reaches for a particular set of measures, or across all assessment criteria, or both. In this way, the assessment system can be used to identify whether a particular set of measures or alternatives are weaker or stronger than another with respect to any particular critical habitat components, or to identify key spatial gaps in a restoration plan, while also providing the kind of simplified comprehensive “habitat units” that traditionally feed into the Corps planning process.

A major strength of this approach is that it is based on studies and resource inventories in the Skokomish basin and the region that document the past effectiveness of the proposed restoration measures, provide metrics for evaluating the assessment variables, and provide baseline data that can be used to estimate the effectiveness of project alternatives relative to the existing condition. Another advantage is that the basic steps and logic of the approach have a long history of use in the USACE planning process, including ecosystem restoration applications.

1.5 ASSESSMENT METHOD OVERVIEW

This assessment procedure involves comparing the calculated benefits of proposed project alternatives (future with-project) to the future without-project conditions, using information about the baseline condition as a starting point. The period of analysis (i.e. the project life) is 50 years following construction. This assessment method to quantify project benefits has been tailored to the specific types of management measures that have emerged from the plan formulation process. There are several components to the approach:

- Identify the key limiting factors associated with the stream reaches of the study area illustrated in Figure 1.
- Identify assessment metrics to measure success at addressing key limiting factors.

- Identify specific restoration measures and project sites, the areas affected, and applicable limiting factor(s) to evaluate the sites.
- Determine which projects are combinable or mutually exclusive for combining projects into alternative plans.
- Evaluate the existing habitat quality and future without-project habitat quality over the period of analysis (average annual without-project habitat quality), and estimate the average annual with-project habitat quality over the period of analysis for each of the assessment metrics. The difference between the average annual habitat quality with-project and without-project is the average annual habitat quality benefit for each assessment metric.
- Given the impacts of sedimentation on significantly reduced river capacity and frequent fish stranding, determine relative benefits to address either capacity and/or summer low flow conditions.
- Calculate the average annual habitat units (AAHUs) for each project as a function of the change in habitat quality (or average annual habitat benefit) and the area affected.
- Evaluate specific proposed combinations of projects using the gain in AAHUs associated with each project to identify cost-effective ecosystem restoration alternatives that address the complex life history requirements of anadromous species throughout the study area.

These components are described in the following sections.

2 ESTABLISHING EXISTING AND FUTURE WITHOUT-PROJECT AND WITH-PROJECT CONDITIONS AND PRINCIPAL LIMITING FACTORS WITH ASSESSMENT METRICS

Figure 1 illustrates the locations of five mainstem and South Fork Skokomish stream reaches and the tributary Vance Creek. The stream reaches correspond to those established for a comprehensive geomorphological study conducted by the Bureau of Reclamation (Bountry et al. 2009) and can be generally correlated with reach designations used in Correa (2003) and in Peters et al. (2011). Each of these reaches or areas can be characterized in terms of lacking key habitat requirements (including connectivity) that affect various aspects of anadromous fish life stage requirements as identified in the previous comprehensive studies (WDFW and PNPTC 2000, Correa 2003, Peters et al. 2011). For the purpose of this Environmental Benefits Analysis, we have focused on five assessment metrics that have been identified as indicators of limiting factors as discussed below. The assessment metrics included in this report were selected due to 1) their priority among components of the ecosystem that need restoration, 2) their general rating as being in poor condition compared to metrics that were not selected for measurement, and 3) the availability of empirical information on their existing condition. The existing condition information and projections of future conditions form the basis of our future without-project condition, to which proposed actions in the basin are compared to determine if they could have a measurable change to the environment. Table 2 provides a summary of the assessed ecosystem attributes, the types of restoration measures proposed to address deficiencies, the metrics employed to evaluate them, the applicable portions of the study area, and selected pertinent references.

Channel Habitat Quality: This assessment criterion is measured as the total area of channel with complex habitats (LWD, pools, side channels) and with sufficient depth to allow fish migration during the late summer, when flows in the Skokomish River are typically at their lowest point (Skokomish Indian Tribe and WDFW 2010). Proposed measures to address deficiencies in this factor involve direct removal and/or trapping of excess sediments in the system to create pool habitat, and construction of Engineered Log Jams (ELJs) or anchoring large logs with rootwads in various configurations. The ELJs and anchored logs are expected to initiate and maintain channel dynamics that will be self-sustaining. In addition to creating deeper channels, pools, islands, side channels, and other habitat features for some distance downstream, channel migration initiated by ELJs will recruit additional woody material from the banks, which in turn will form new logjams to replace the engineered structures as they deteriorate. Restored channel habitat is considered to include all channel areas likely to be affected by any of these restoration actions, including areas affected by restored channel dynamics well downstream of the sites where specific measures are applied. Channel area is calculated as the total affected channel length multiplied by the average channel bankfull width as scaled from satellite images.

Floodplain Habitat Quality: Natural floodplain features are important components of the fish habitat that serves to represent overall ecosystem health. Floodplain features are typically structurally complex with aquatic connectivity among these features that include abandoned channels, pools, small tributaries and distributaries, oxbows, side channels, and the wetlands and forested areas that export invertebrates and organic material as well as provide direct refuge habitat during high flows. A fully functional riverine system would normally have a mix of these conditions in varying proportions along its length. Conversion of floodplain to urban and agricultural uses tends to eliminate or degrade the access to and quality of these aquatic features. Proposed restoration measures in this category focus on restoring degraded habitats and reconnecting habitats rendered inaccessible due to sedimentation, levees, and similar obstructions. Restored floodplain habitat is defined by the area of reconnected forest and wetlands, reforested floodplain, and restored aquatic habitats within floodplains including their associated buffer zones.

Mainstem River Channel Capacity: Historically, rivers around the Puget Sound basin typically experience overbank flooding once every 1.5 to two years. The many species of the Salmonidae family present in this ecosystem have evolved with this disturbance regime. Excessive aggradation has caused more frequent overbank flooding that has been shown to be harmful to multiple life stages of these fish. A properly functioning hydrologic regime would exhibit the less frequent flooding such that the anadromous fish could successfully spawn within the riverbed and the offspring could survive to migrate downstream to the estuary. Restored channel capacity is defined as achieving at least a 1.33-year return interval to attempt to achieve more than one generation of successful spawning and rearing, and preferably the two-year flow capacity so that multiple generations of fish can begin to rebuild their stocks.

Table 2. Limiting Factors and Associated Assessment Metrics

Limiting Factor	Assessment Metric	Applicable Restoration Measures	Applicability	Reference
Channel Habitat	Pools	Sediment removal and trapping; placement of structures to maintain channel dynamics, scour channels and maintain in-stream habitat complexity	Reaches 2,3,4, 5, Vance Creek	Bountry et al., 2009; Bjornn and Reiser, 1991; Smith, 1973; Stover and Montgomery, 2001
	Woody Debris			
Floodplain Habitat	Riparian Cover	Opening of side channels and tributaries; providing access to existing floodplain forests and wetlands; levee removal; floodplain and riparian reforestation	Reaches 2,3,4,5, Vance Creek	Bountry et al., 2009; Buffington et al., 2002; House and Boehne, 1985; MacDonald and Keller, 1987; McMahon, 1983.
	Connectivity			
Channel Capacity	Flow Capacity	Sediment removal; providing flood storage capacity; providing fish access to large wetlands	Reaches 1,2,3,4	Bountry et al. 2009; Seiler et al. 2002; Beamer et al. 2005

2.1 ESTABLISHING BASELINE CONDITIONS

The starting point for quantifying benefits of restoration actions is to determine the baseline conditions of the study area. For environmental benefits evaluations, it is important to evaluate environmental parameters that are measurable and that change with the proposed alternatives. While it is difficult and costly to measure all parameters that could change with restoration work, it is important to capture a few key indicators that can serve as a proxy for the host of environmental changes that could be expected. This analysis focuses on three limiting factors as those key indicators: floodplain habitat with the parameters of riparian cover and habitat connectivity, main channel habitat with the parameters of large woody debris (LWD) and pool habitat, and in-channel flood flow capacity with the parameter of survival of species in the Salmonidae family from egg stage to migrant fry stage.

2.1.1 HABITAT QUALITY ASSESSMENTS OF THE SKOKOMISH RIVER GI STUDY AREA

Following is a review of available references used to determine the quality ratings of the five assessment metrics of riparian zone, LWD, pool frequency, floodplain connectivity, and channel capacity for features of the Skokomish River GI reaches. Specific selections from the reports were used to establish baseline conditions to be able to compare future with- and without-project conditions, and to quantify the Average Annual Habitat Units.

Three primary reports provide assessments of baseline conditions for the Skokomish watershed (see: WDFW and PNPTC 2000, Correa 2003, and Peters et al. 2011). The first two reports were used in developing conservation plans for restoration of summer run chum salmon and for watershed restoration planning in the Hood Canal while Peters et al. (2011) was a habitat assessment study conducted specifically for the Skokomish GI. Table 3 is a summary of the qualitative ratings by habitat factor for the Skokomish River; the results from all reports are discussed by factor below. These reports were used for the habitat quality scores for the first four assessment metrics listed in Table 2 and described in detail in section 2.1.2.

The channel capacity assessment metric was developed through use of a Bureau of Reclamation report on the geomorphology of the Skokomish River (Bountry 2009), and two reports on the effects of channel aggradation in other rivers in the Pacific Northwest. These describe the negative effects of excessive sedimentation and how decades of channel aggradation can decrease survival rate of salmonid eggs to the migrant fry stage (Seiler 2002, Beamer 2005). This is described further in section 2.1.2.5.

Table 3. General rating of impacts to habitat factors and associated habitat quality equivalents in the Skokomish watershed (including all tributaries) affecting chum salmon from WDFW and PNPTC (2000; Table 3.17).

Habitat Factor	Specific Factor	Impact	Habitat Quality Equivalent
Flow	Winter	High	Poor
	Summer	High	Poor
Water Quality	Temperature	Low	Good
	Nutrients/DO	Low	Good
Sediment	Aggradation	High	Poor
Channel Complexity	LWD	High	Poor
	Channel Condition	High	Poor
	Loss of side channel	High	Poor
	Channel instability	High	Poor
Riparian Condition	Species Composition	High	Poor
	Age	High	Poor
	Extent	Moderate	Fair
Floodplain Loss	Floodplain Loss	High	Poor

The WDFW and PNPTC (2000, including 2000a, 2000b, 2000c) report was completed for summer chum salmon recovery planning in Hood Canal; Appendix 3.6 of that report provides watershed descriptions in the basin based on impacts to habitat within those watersheds. Chapter 3.4 is a qualitative description of freshwater habitat conditions in watersheds of Hood Canal and how those conditions were developed, while Appendix 3.7 has specific watershed conditions for the Skokomish River. The report provides a ranking of impacts to habitats critical to various life stages of chum salmon and those impacts are rated low, moderate, and high. Correa (2003) includes a similar habitat rating matrix (Table 16 of that report) that includes a rating system for various habitat characteristics with a range of poor, fair, and good, and areas without data (data gaps), which used various data sources and interpretation by the author or other agency biologists to identify each condition. Additionally, the USFWS completed their own monitoring and evaluation of the Skokomish River and tributaries specifically for the GI but also discussed previous work. The USFWS report (Peters et al. 2011) refers to Correa (2003) in their characterization of the Skokomish River habitat features of interest to the benefits analysis, and used the impact rating established by Correa (2003) to provide the basis for the poor (high impact), fair (moderate impact) and good (low impact) habitat quality rankings.

Peters et al. (2011) described four main effects or threats to juvenile salmon habitat in the Skokomish watershed as the result of the changes in physical process throughout the watershed including 1) habitat availability, 2) habitat connectivity, 3) habitat stability, and 4) habitat quality. The methods used and the locations of study sites for selected habitat features are described in Appendices. The USFWS used standard measurements for habitat conditions, and they created their quality rankings based on Correa (2003). The Correa (2003) report summarizes work from WDFW and PNPTC (2000) with additional input from other agency biologists, but with little mention as to how the results were derived. The WDFW and PNPTC report with various appendices was reviewed to identify information not found in other sources, including an assessment summary of impacts for the Skokomish Watershed habitat conditions (Appendix 3.6), and methods used to gather data for the riparian assessment and other freshwater habitats of the Skokomish found in Appendices 3.7 and 3.8 of that report.

Chapter 3.4 in WDFW and PNPTC (2000) is the freshwater habitat assessment; the methods are described as a compilation of field knowledge of watershed conditions in Hood Canal watersheds to identify factors that were determinants of quality of summer chum habitat. Habitat factors included winter high flow and summer low flow, temperature, nutrient loading, fine and coarse sediment, LWD presence, channel condition, loss of side channels, channel instability, riparian forest size, extent and species composition, floodplain wetland loss, and fish access and passage. These habitat factors were used to determine habitat quality for the following life stages: freshwater migration, spawning, incubation, rearing, and saltwater migration. For each watershed, the biologists as a group rated the condition of each habitat factor according to the severity of impact (none, low, moderate, and high) and identified habitat-related factors for decline (Appendix Report 3.6). Data were used, when available, to rate habitat quality against that found in relatively undegraded basins. Information gaps were filled with the habitat biologists' field knowledge of each basin. Ratings for riparian condition were based on the results of the riparian assessment (Appendix Report 3.7). Appendix Report 3.8 includes a summary of freshwater habitat data and how the data were rated. Background information for the ratings and watershed narratives included State of Washington Timber Fish and Wildlife ambient monitoring data; completed state and Federal (USFS) watershed analyses; and temperature, sediment, and stream discharge data.

2.1.2 References for Quality Ratings of Ecosystem Conditions

The five assessment metrics selected for this model were chosen based on their priority need for restoration in the GI study area. Ecosystem components that are often used as metrics such as water quality and quantity are either rated as good (water quality) or are not a component that the Corps can change as part of the proposed project (water quantity). Table 4 summarizes the baseline conditions as compiled from the major source documents described above in section 2.1.1, as well as the target conditions to be achieved through engineering and design of the proposed project sites.

Table 4. Assessment metrics with parameters measured for baseline condition assessment and target conditions for restoration.

Assessment Metric	Parameters	Baseline Condition (Overall)	Target Condition
Pool Habitat[1]	Number of pools greater than 1-meter depth, good cover, and cool water	Less than 35% of surface area is pool habitat	Pool to riffle ratio of 1:1, or 40-60% surface area in pools
Large Woody Debris[2]	Pieces of LWD per meter of channel length	Less than 0.2 pieces of LWD per meter	75th percentile of natural conditions; 0.6 LWD pieces per meter
Riparian Cover[3]	Species composition, average stand diameter, density, width	High impact (poor) conditions for 62% of the mainstem and 32% of Vance Creek; riparian buffers less than 66 feet wide; 30-70% canopy cover	150-foot riparian buffer width, with 100% canopy cover
Floodplain Connectivity/ Access[4]	Percentage of aquatic habitat remaining connected to the mainstem	General floodplain access has less than 50% connection; certain sites have no connection	100% connection
Channel Capacity[5]	Frequency of overbank flow at specific discharge return interval; fish survival	Overbank flows typically four times per year; correlation between aggradation and reduced egg-to-migrant survival with likely 33% reduction in Skokomish	Two-year flow capacity within bankfull width

[1] Peters et al. (2011)
[2] Peters et al. (2011) and Fox et al. (2003)
[3] WDFW and PNPTC (2000a)
[4] Correa (2003)
[5] Beamer et al. (2005)

2.1.2.1 *Pool Conditions*

Observations made during a July 1998 float trip from the lower end of the South Fork Skokomish River canyon (South Fork RM 3.0) downstream to mainstem Skokomish River RM 4.0 (total distance of nine miles) revealed a lack of pools, long glides, and riffles and a scarcity of wood, particularly large wood and jams (WDFW and PNPTC 2000). Habitat surveys conducted in 1994 in the lower three miles of Vance Creek found 39% pools and a range of 1.5 to 2.6 channel widths between each pool (Skokomish DNR and PNPTC 1994). Because the surveys were conducted when the stream was dry, the data may be skewed (Keith Dublanica, personal communication 1998, cited in WDFW and PNPTC 2000).

Reviewing the description of the mainstem, the Correa report was found to reference the WDFW and PNPTC (2000) report, which relied on that single float trip in 1998 between RM 4 and 9; this showed a general lack of pools upstream of RM 4. The lower four miles of the mainstem were not monitored as part of any previous study so it appears that USFWS (Peters et al. 2011) assumed that reach to be the same as above RM 4. The same table did provide poor pool condition rankings for Hunter, Weaver, and Vance Creeks, good rating for Richert Springs, and data gap for Purdy Creek. Correa (2003) states that an interagency technical advisory group (TAG) rated streams (with no empirical data collected) as follows: 1) Purdy Creek and Hunter Creek can be characterized as one long pool with low habitat quality; 2) Hunter Creek is dredged periodically and acts as one long pool; and 3) Vance Creek was surveyed for pools in 1994 but ratings may be skewed, and the pool quality is reduced to gravel pockets except in a lower stream section with numerous deep pools with adequate cover. Figure 20 in Peters et al. (2011) provides a classification of pool quality in the same reaches with mainstem and tributaries again shown as poor quality. Pool quality was classified as the number of pools greater than 1-meter depth, good cover, and cool water; poor quality as no deep pools; fair with some deep pools; and good with sufficient deep walls. Correa (2003) states, “pool quality is unknown” for the entire lower Skokomish. Site visits conducted by the study team resulted in a consensus that there is a severe lack of pools, and all pools located were deemed poor quality according to the parameters described above.

Peters et al. (2011) created their Figure 19, which shows pool condition defined by percent pool habitat throughout the mainstem, South Fork Skokomish, and several tributaries based on qualitative criteria of poor, fair, and good that they state is modified from Correa (2003). The lower Skokomish and tributaries are shown in the figure as having a poor percentage of pool habitats. Correa (2003) includes a summary table showing all values for pools (percent pools, pool frequency) as “data gaps” with no rating for the mainstem. The quality rankings identified percent pools as poor at less than 35% surface area as pool habitat, 35-50% surface area is fair, and greater than 50% surface area as pool habitat as good.

Peters et al. (2011) described that in their study they measured four metrics to evaluate pool quality, including average thalweg depth, maximum thalweg depth, average residual pool depth, and maximum residual pool depth. They describe that the four metrics allow for comparisons of pool depths to overall reach depths. Overall, they found that deep-water habitats commonly associated with pools made up between 25% and 44% of the habitat. However, deep-water habitats were absent or in low abundance in several study reaches. In addition, deep-water habitats, which are very important habitats during the winter, were in lowest abundance during that period. Based on WDNR watershed analysis indices (WDNR 1997), the habitat quality rating for percent pool (using percent deepwater as percent pools) would be poor for nine of 21 summer sites, fair for six sites, and good for the other six sites. For winter sites, 20 of 23 sites would be rated as poor, two sites would be rated as fair, and one site would be good. The percentage of deep-water habitats tended to be greater in the stream estuary ecotone, tributaries, and the North Fork Skokomish than in the South Fork Skokomish during the summer and greatest in tributaries and the North Fork during the winter (Figure 21 in Peters et al. 2011).

Overall, the percent of the habitat that consists of pools to provide summer and winter rearing habitat for juvenile salmonids is rated as poor in most areas of the Skokomish River. Based on the available data from Peters et al. (2011) for the mainstem and best professional judgment from the TAG for the tributaries, it appears that mainstem and tributary study reaches should be considered as poor quality. Additionally, Skokomish GI technical team members have walked sections of the mainstem river and viewed tributary conditions on multiple site visits with the same general conclusions that there is a severe lack of pools in the mainstem and the pool habitat in tributaries is generally poor quality.

No empirical data collection was conducted for the purpose of this ecosystem benefits model; therefore, a simple metric that does not require extensive fieldwork is needed for this decision-making tool. The simplest metric for calculating pool habitat condition is to estimate the percent surface area that is pool habitat. It has long been held that a pool to riffle ratio of 1:1, or 40 to 60% surface area in pools is considered desirable for salmon spawning and rearing reaches (Needham 1969). All of these ratings indicate a linear relationship between percent surface area in pools and the categorized quality ratings. The pools metric in this model mimics the Habitat Suitability Index for Chinook salmon (Raleigh et al. 1986). The assumption is that even with no pools, there is still water present, and therefore no zero score is possible; likewise, with 100% pool, essentially a lake, there is still usable habitat area. Achieving anywhere within the range of 40 to 60% surface area in pools achieves a score of 1 (Figure 2).

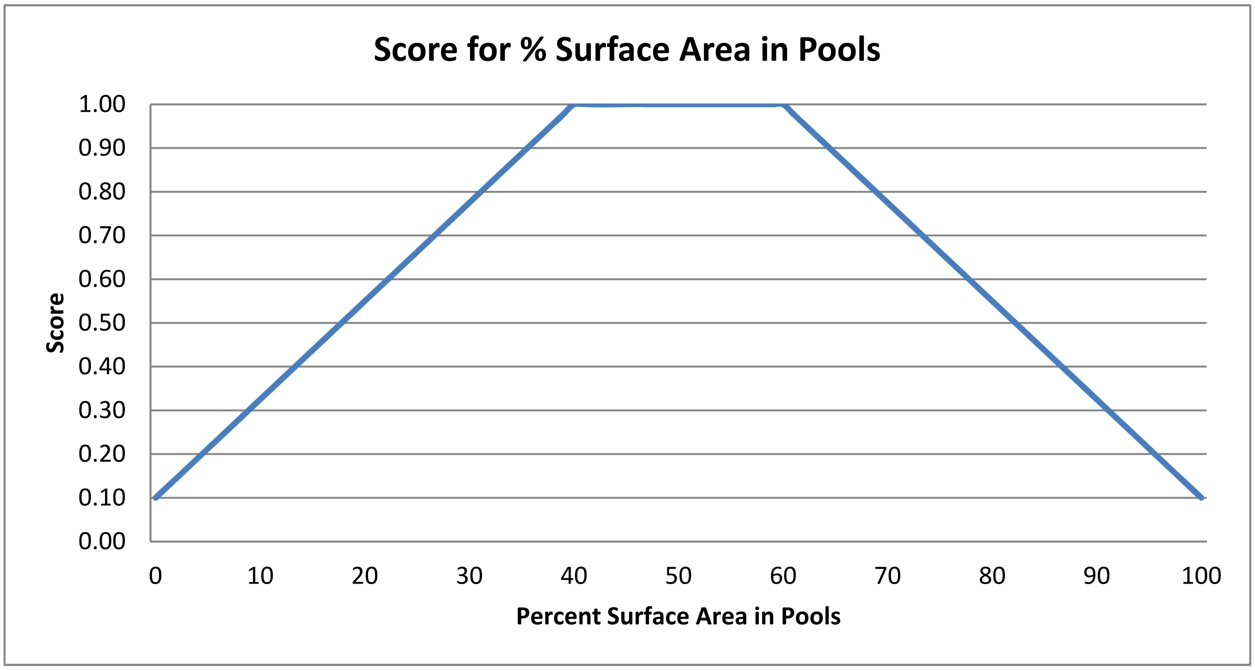


Figure 2. Line graph representing metric score for percent surface area of stream that is in pools.

2.1.2.2 *Large Woody Debris*

Several studies have assessed large wood levels within the Skokomish Basin and have identified reaches where wood levels are below the established standard for undisturbed streams in the Pacific Northwest. Reductions in large wood input to the river channel occur as the active channel width increases. According to WDFW and PNPTC (2000), despite the history of studies in the Skokomish basin, there is little data available on instream habitat for the mainstem and major tributaries to the lower river, although wood loading has been characterized previously as poor in most channel segments (Skokomish DNR and PNPTC 1994; USFS 1995; Simpson Timber Co. and WDNR 1997). Habitat surveys conducted in 1994 in the lower three miles of Vance Creek showed LWD counts ranged from 0.02 to 0.15 pieces of LWD per meter with much of the wood perched above the wetted perimeter, stranded on exposed gravel terraces (Skokomish DNR and PNPTC 1994). Standardized monitoring data has not been collected for the mainstem of the Skokomish River with data limited to observations from a single float trip in 1998, which indicated a scarcity of wood, particularly large wood and logjams (WDFW and PNPTC 2000).

Peters et al. (2011) measured woody debris metrics and attempted to compare those measurements with Fox et al. (2003), who developed recommended large wood quantities and volumes for western Washington rivers (Table 8 in Peters et al. 2011). They determined that large wood was limited in many sites of lower Vance Creek, the South Fork Skokomish, and the mainstem. The number of large debris piles (LDP) per bankfull width was very low for all sites sampled. In particular, the Vance Creek site in this study had no LDP during either summer or winter surveys. Peters et al. (2011) indicated that relative to other fish habitat cover elements, fine wood and vegetative cover were the most common cover elements available in the reaches evaluated, and large wood and large wood debris piles were present at intermediate levels to other cover elements. They did not state how their measurements were broken into quality rankings of low, fair, and good, or how their measurement of LDP could be compared with the work by Fox et al. (2003), who did not use such a metric.

Peters et al. (2011) referenced Correa (2003) in creating their Figure 17, which shows classification levels of LWD, and stating that habitat conditions are poor relative to LWD in the mainstem Skokomish, and Hunter, Weaver, and Vance creeks with the information summarized in the figure. In review of Correa (2003) for the Skokomish GI, it was noted above there has been little or no monitoring of the mainstem and many of the streams, so the rating factor is based on best professional judgment from the author or cooperating biologists (i.e., Purdy Creek has plentiful LWD in the wetland, and upstream of the hatchery, with no wood in ditched areas, [Marty Ereth, pers. comm., 2003]). The quality ratings for LWD were identified as pieces of LWD per meter of channel length with poor defined as less than 0.2, fair 0.2 to 0.4, and good more than 0.4 pieces/m of channel length. These ratings are used for guidance in scoring the LWD assessment metric for this model. Based on Correa's (2003) ratings, the value of LWD in the stream has a linear relationship to the ecosystem benefits score (Figure 3).

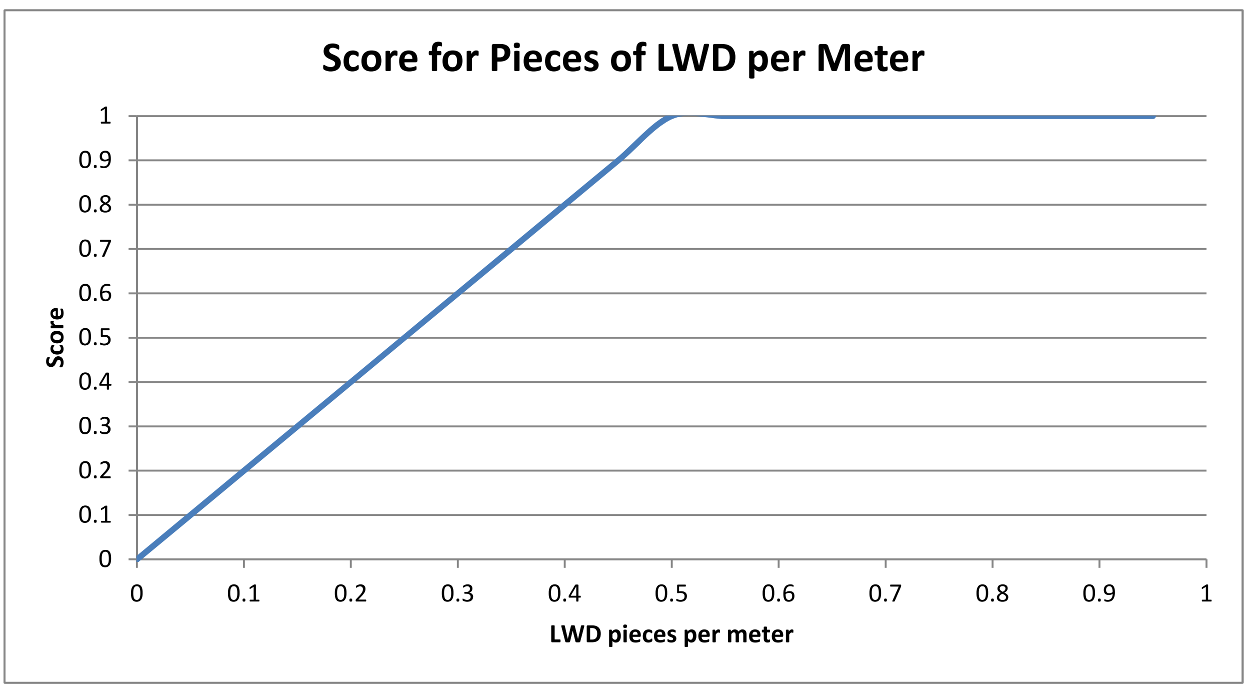


Figure 3. Line graph representing metric score for pieces of large woody debris per meter of channel.

As there are no specific descriptions of quality factors for LWD from USFWS, all reaches in the Skokomish GI benefits analysis should be considered as in poor condition as rated in the other reports unless specifically identified otherwise. Site visits by Corps staff confirmed the conditions are as described in Skokomish DNR and PNPTC (1994) in that there are relatively few pieces and most are perched atop gravel bars and sills, too high to provide in-stream complexity or slower velocity refuge. Riparian plantings implemented for this project would eventually provide recruitment material for in-channel LWD, but this would not be expected to occur until after the 50-year study period. Upstream supply is out of Corps control, but LWD installed as part of the Corps project is expected to accumulate and trap more material. Benefits are only scored for what the Corps plans to install, not for an unpredictable quantity of recruitment. Design guidance provided to the engineers recommends targeting the 75th percentile of natural conditions according to Fox and Bolton (2007); this will result in approximately 0.6 LWD pieces per meter for a score of 1in the future with-project condition.

2.1.2.3 *Riparian Conditions*

In WDFW and PNPTC (2000), Appendix 3.7 describes the methods used to identify impacts to riparian areas in Hood Canal rivers and streams; this level of analysis is not available for LWD, floodplain connectivity, or pool condition. As part of the analysis of habitat limiting factors, aerial photo interpretation was employed to evaluate the condition of riparian forests along summer chum streams in Hood Canal and the eastern Strait of Juan de Fuca. For each segment, the forested riparian buffer width, average stand diameter, species composition, and stand density were noted and the dominant, stream-adjacent land use recorded. They modified the methodology outlined under the Washington State Watershed Analysis Riparian Module to consider both riparian conditions and dominant land use within 200 feet of stream channels. The quality rankings used to evaluate riparian areas are summarized in Table 3.7.1 taken directly from the WDFW and PNPTC (2000) report shown below in Table 5.

WDFW and PNPTC (2000a) describes the Skokomish River (RM 0 to 9) as meeting high impact conditions (poor conditions) for 62% of the mainstem as it is covered by agricultural fields, sparsely vegetated, and/or has a forested riparian buffer less than 66 feet wide. The Vance Creek riparian forest is in better condition overall with 32% as sparsely vegetated or less than 66 feet wide. The majority of Purdy Creek flows through a large intact wetland system, except for the hatchery area above Hwy 101.

Table 5. Summary of riparian assessment impact categories. Riparian buffer density was added to riparian buffer extent to calculate that rating (WDFW and PNPTC 2000, Table 3.7.1).

Riparian assessment category	Low Impact	Moderate Impact	High Impact
Species composition	Conifer dominated (>70% of the canopy)	Mixed conifer/deciduous (both < 70%)	Deciduous dominated (>70% of the canopy) or no tree cover
Average stand diameter	>20 in dbh[1]	12-20 in dbh	<12 in dbh
Density	<33% ground exposure	33-80% ground exposure	>80% ground exposure
Width	>132 ft wide forested buffer	66-132 ft wide forested buffer	<66 ft wide forested buffer

[1] dbh, diameter at breast height

Peters et al. (2011) refer to past studies (e.g. Correa 2003) and data collected during their own study that riparian vegetation appears to be degraded within the Skokomish Basin, with the greatest degradation occurring in the lower Skokomish watershed and in mainstem channels relative to tributaries. Correa (2003) provides a habitat rating matrix (Table 16 in that report) that includes a rating system for riparian vegetation (criteria were riparian composition, buffer width, and channel type) for poor, fair, and good, and areas without data (data gaps) that used various data sources and interpretation by the author or other agency biologists to identify a condition. The figure USFWS created (Figure 11 in Peters et al. 2011) appears to have used scores from Table 16 and shows all parts of the mainstem in poor condition as were Weaver Creek, Hunter creek, and the lower South Fork Skokomish (RM 0 to 3). Purdy Creek was classified as poor to good, while Richert Springs was classified as fair to good. In reviewing Correa, the riparian habitat condition described repeats the WDFW and PNPTC (2000) description but includes that Vance Creek had a data gap for riparian conditions. Based on Correa and WDFW and PNPTC reports, the overall riparian condition should be considered poor with greater than 60% of the mainstem having little canopy cover, a narrow buffer, and limited LWD recruitment.

Using USFWS data collected for the GI (Peters et al. 2011), riparian vegetation conditions in the mainstem were described as severely degraded but healthy in other locations. It appears they rated riparian conditions based on percent canopy cover along the bank and in the middle of the channel as measured by their study team. They described that the conditions were based on mature riparian vegetation cover, and that riparian conditions along the banks were most degraded (less than 30% cover) in the Skokomish mainstem from Highway 101 to the confluence with Vance Creek (RM 4.5 to 9.0), in the upper South Fork and in Hunter Creek. Mature riparian cover varied in Vance Creek, McTaggert Creek, and North Fork, and was generally over 70% canopy cover in the lower mainstem below Highway 101 (RM 0 to 4.5). However, in the lower mainstem, riparian cover in the mid-channel islands was less than 30%. An analysis of the rating systems and ranking of habitats found in Peters et al. (2011), WDFW and PNPTC (2000), and Correa (2003), suggest a linear relationship between percent canopy cover and a benefit metric score (Figure 4).

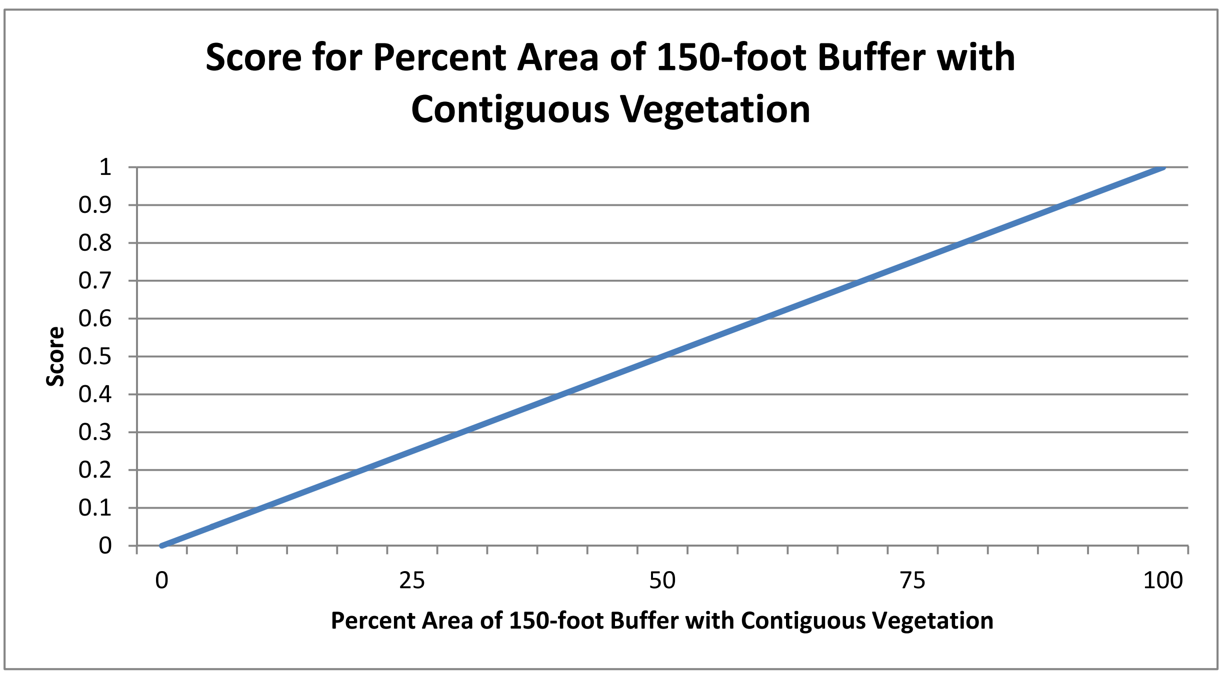


Figure 4. Line graph representing metric score for percent area of 150-foot buffer with continuous vegetation.

The Corps used the following method to calculate the riparian condition metric for existing conditions, and future with-project conditions. Assumptions are that there is a linear relationship between percent canopy cover and the ecosystem benefits score, a target buffer width should be 150 feet for wetlands and stream channels, and that an appropriately detailed assessment can be achieved through aerial photography analysis with calculations in GIS software. The steps are as follows:

1) Identified the seven sites for riparian buffer analysis
2) Created 150-foot individual buffers around each of the sites to be analyzed
3) Within the 150-foot buffer starting at the line representing the project site footprint and extending outward, all contiguous vegetation was identified using one-foot resolution orthophotography that was flown on 22 April 2011. This was done by heads-up-digitizing feature classes that delineated only the contiguous naturally vegetated areas of each site. Natural vegetation versus un-natural vegetation or non-vegetated features were discerned by classifying un-natural as houses, roads, agricultural areas, disturbed ground, fence lines, clear property boundaries, and the border of tree and shrub canopy cover. Grass in residential areas was not counted as natural canopy cover.
4) Calculated the percent area of contiguous vegetation that borders the project footprint by dividing the area of contiguous vegetation by the total buffer area.

The total potential range of this metric is 0 to 100%; the actual calculated percentages for existing conditions are 6 to 81% among the seven project sites that were analyzed. Future without-project conditions are assumed to be the same as existing conditions because land use is not expected to change, and no significant developments are planned for the project sites. To calculate the future with-project conditions, the same steps were applied as listed above with an exception for the assumption that all grass would be planted and all houses, roads, and other unplantable surfaces remained the same. For two of the sites in agricultural fields, it was assumed that the plantable buffer would be constrained at 75 feet instead of 150 due to potential landowner concerns with land use conversion away from agriculture to wetland.

2.1.2.4 *Floodplain Connectivity/Access*

As described in WDFW and PNPTC (2000) and Peters et al. (2011), the majority of the mainstem Skokomish and portions of the South Fork and Vance Creek have been diked and /or channelized, reducing channel complexity and sinuosity, eliminating important side channels, simplifying the remaining habitat, and disconnecting these streams floodplain sloughs and side channels. The mainstem below the confluence is low gradient and has an extensive floodplain. However, the river has been hydraulically disconnected from this floodplain in many areas by levees, bank armoring, channelization, and excessive sedimentation and aggradation (Bountry et al. 2009).

According to Peters et al. (2011; Figure 10, detailed table in Appendix B), loss of floodplain connectivity appears to be worse in the lower watershed than the upper watershed. Further, they reference Correa (2003) to show that habitats in the mainstem Skokomish, the South Fork Skokomish from RM 9.0 to RM 12.0, and Hunter, Weaver, and Vance Creeks are the most degraded, in terms of floodplain connectivity. The mainstem Skokomish River has a hydraulic barrier when a reach goes dry in the summer and an artificial barrier when fish are stranded on the other side of Skokomish Valley Road during winter flooding. In the follow-up review of Correa (2003) for the Skokomish GI benefits analysis, Table 16 in that report shows floodplain access has 50% or more disconnection. The table shows connectivity as good in Purdy Creek and Richert Springs, but more than 50% disconnected in Hunter, Weaver, and Vance Creeks. The report simply describes the majority of the lower mainstem as diked and/or channelized, which disconnected the important side channels and wetlands. Correa (2003, with the data source from

WDFW and PNPTC 2000) described tributary conditions including that 1) Purdy Creek flows through a large intake wetland, although portions of the wetland are isolated by roads, 2) Weaver Creek and Hunter Creek are incised cutting off lower stream sections from the floodplain; and 3) the majority of Vance Creek has been diked and/or channelized, which has eliminated access to important side channels and wetland habitats.

Peters et al. (2011) measured several habitat metrics of the lower Skokomish and noted the severe loss of side channels, mainstem islands, and limited connection of the river to the floodplain, but did not provide an overall ranking for the quality of floodplain connectivity in the mainstem and major tributaries that could be applied to the Skokomish GI benefits analysis. Correa (2003) provided a rating of floodplain connectivity based on what percentage of aquatic habitat in the floodplain has become disconnected. The ratings of percent of aquatic habitat remaining connected to the mainstem in which less than 50% connected warrants a rating of poor, 50 to 90% connected is rated as fair, and 90% or better earns a rating of good indicate a generally linear relationship between percent connectivity and benefits score (Figure 5). The Correa (2003) ranking using the WDFW and PNPTC (2000) data source is used in the assessment of baseline conditions for the Skokomish GI as these reports provide ratings for some of the individual tributaries where projects will occur, or broader river reaches in which the sites lie. To score each project site, either its individual assessment was used, or the general rating from its river reach was used. Connectivity for inlets and outlets described as good in the habitat assessment documents are assumed to be available year round except for in especially dry summers as may occur at intervals greater than two years. For the future with-project score, we assume that project design and construction will result in a site having hydraulic connection year round, again except for unusually dry summer conditions.

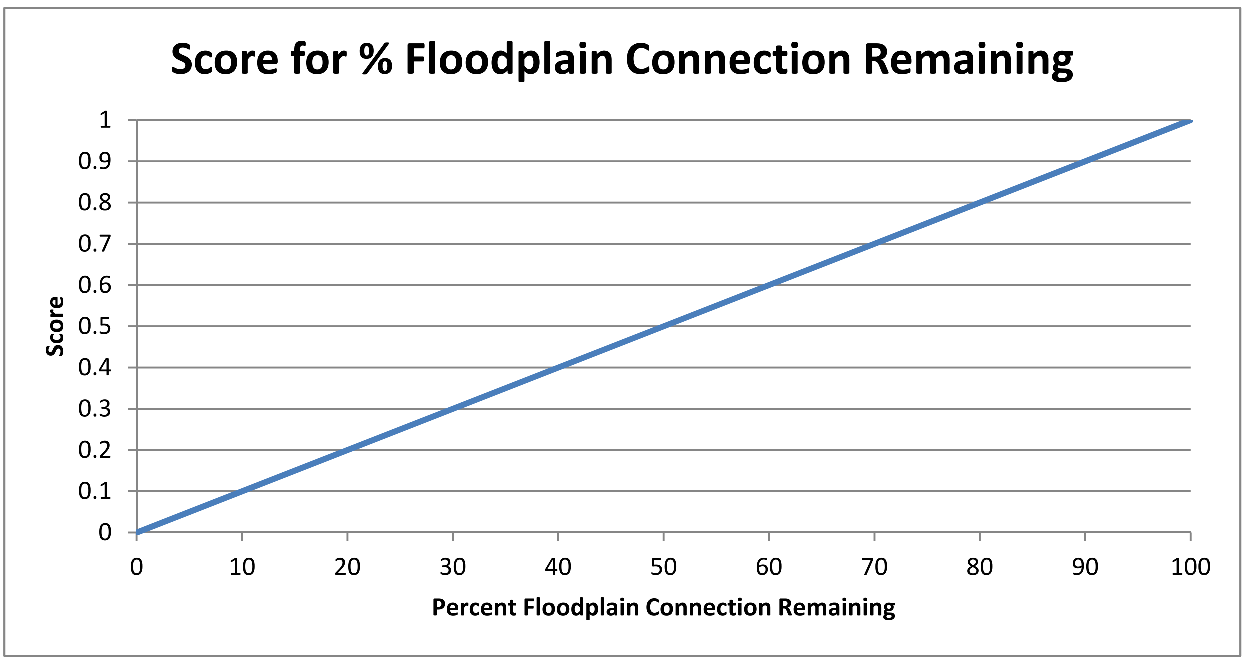


Figure 5. Line graph representing metric score for percent of site or reach with floodplain aquatic habitat connection to mainstem river.

The proposed project sites are completely disconnected, but will become 100% connected after construction. For scoring any other sites, one would assess either the total area of possible connection for wetlands and levee setbacks, or the inlet and outlet for side channels and estimate the percent that has year-round connection along the length of the site or through inlets and outlets as appropriate to the site.

2.1.2.5 *Mainstem River Channel Capacity*

Increased sediment supply and reduced channel capacity negatively affect several anadromous fish life stages. Excess sediment supply in river channels is associated with instability of substrate, which causes scour of redds (eggs in nests) or sediment deposition reducing egg-to-fry survival; it also reduces available rearing and refuge habitat for recently emerged fry and young juveniles. In the Skokomish, the lack of channel capacity for even the one-year return interval discharge causes displacement of fry and juveniles during overbank flows in which they become stranded in floodplain areas without access to return to the river. Those that remain in the channel have little refuge habitat and are therefore forced downstream to the lower river and estuary where they become vulnerable to predators or are unable to survive in saltwater as they have not yet smolted (changed physiology for saltwater life stage). The lack of channel capacity and increased sediment supply result in several impacts to adult salmonids from stranding in floodplain areas. Every year in the Skokomish River, some proportion of the adult salmon runs stray into floodplain areas during overbank flow, and these fish have no return channel to the river (Figure 6). The impacts from this are that the adults may become stranded in floodplain areas where they die before spawning, or they are forced to spawn in areas that become dewatered killing the eggs, or the offspring that do survive in isolated ponds are unable to return to the river to rear.

Figure 6. ESA-listed adult salmon become stranded when overbank flows coincide with spawning migrations.

In natural conditions, rivers of the Puget Sound region see overbank flooding every 1.5 to two years; however, flood frequency in the Skokomish has increased to a return interval of more than once per season. During the problem identification phase of the Skokomish GI, the frequent fish stranding that occurs during overbank flows of the Skokomish River was named as a high priority issue.

The purpose of the channel capacity assessment metric is to quantify benefits of each of the four base options for restoration, because the benefits of these are different from the areas of improved quality as measured by the other four assessment metrics. The benefits are that 1) anadromous fish on their spawning migration would be able to access upstream habitat at the time they arrive, 2) the redds would be less likely to be scoured out due to the gravel instability caused by excessive sediment, and 3) eggs can survive better to the migrant fry life stage.

The scoring for this assessment metric is based on what is deemed natural conditions in Puget Sound area rivers (Figure 7). As stated earlier, rivers around the Puget Sound region typically flood every 1.5 to two years. This is also supported by the substantially improved rate of survival for salmon from the egg to migrant fry stage for which we have data, as well as the assumption that preventing fish stranding mortality will aid in population recovery. These benefits are assumed to have a linear relationship with the improvement in capacity.

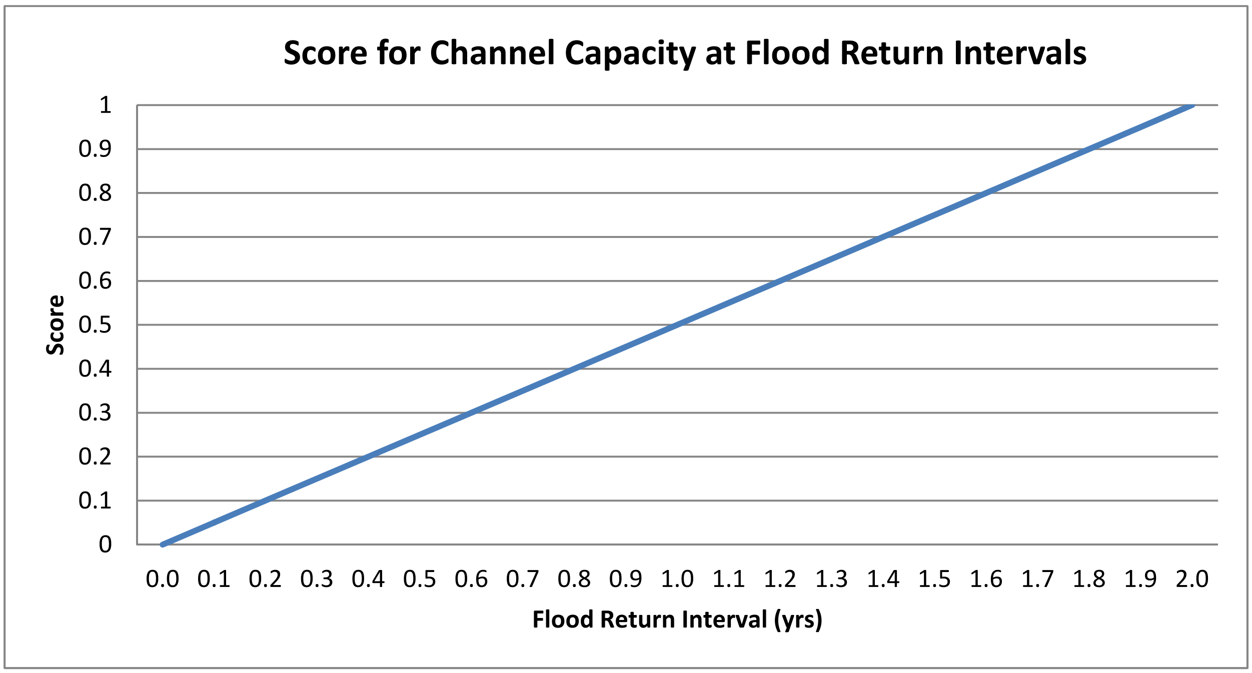


Figure 7. Line graph representing metric score for achieving channel capacity that contains increasing quantities of river flow.

We are assuming the action of removing excess sediment from the channel in combination with the other proposed restoration actions and work by others will restore the Skokomish River mainstem for several decades to a semblance of a functioning river channel. Sediment removal will provide an immediate improvement by increasing the channel capacity while the other proposed project actions will provide increasing benefits as the ecosystem responds to the enhancement features or structure removals, which will improve river and floodplain processes. Targeting a specific flow capacity is recognized as an appropriate goal and the two-year flow, corresponding to typical bankfull width as well as the dominant flow, is often recommended as the target (Copeland and Hall 1998, Millar and MacVicar 1998).

According to Shields et al. (2003), the approach of restoring a river channel to a specific return interval discharge, often corresponding to a two-year return interval as a bankfull discharge, is appropriate when applied to situations with relatively stationary hydrologic conditions. Since the Skokomish floodplain does not have rapidly developing human infrastructure, but is relatively stable as low development and widespread agricultural use, we assume the approach of returning the river to a specific flood flow capacity is appropriately applied.

Supporting information on Salmonid Life Stage of Egg to Fry Survival

The egg-to-migrant fry survival issue supports the target condition of achieving the two-year flow capacity in the mainstem river channel. Data from the Skagit and North Fork Stillaguamish Rivers show that egg-to-migrant fry survival is strongly influenced by peak flow during the egg incubation period and that impairments to watershed processes will decrease egg-to-migrant fry survival of Chinook salmon (Beamer et al. 2005). Seiler et al. (2003) have correlated high discharge with low egg-to-migrant survival with an R^2 value of 0.82. A comparison between functional (natural conditions) and impaired (aggraded) conditions for egg-to-fry-migrant survival is shown in Figure 8 (from Beamer et al. 2005). Although the Skokomish River is in worse condition than other Puget Sound rivers for flood frequency, we believe the reported values are appropriate for the benefits analysis.

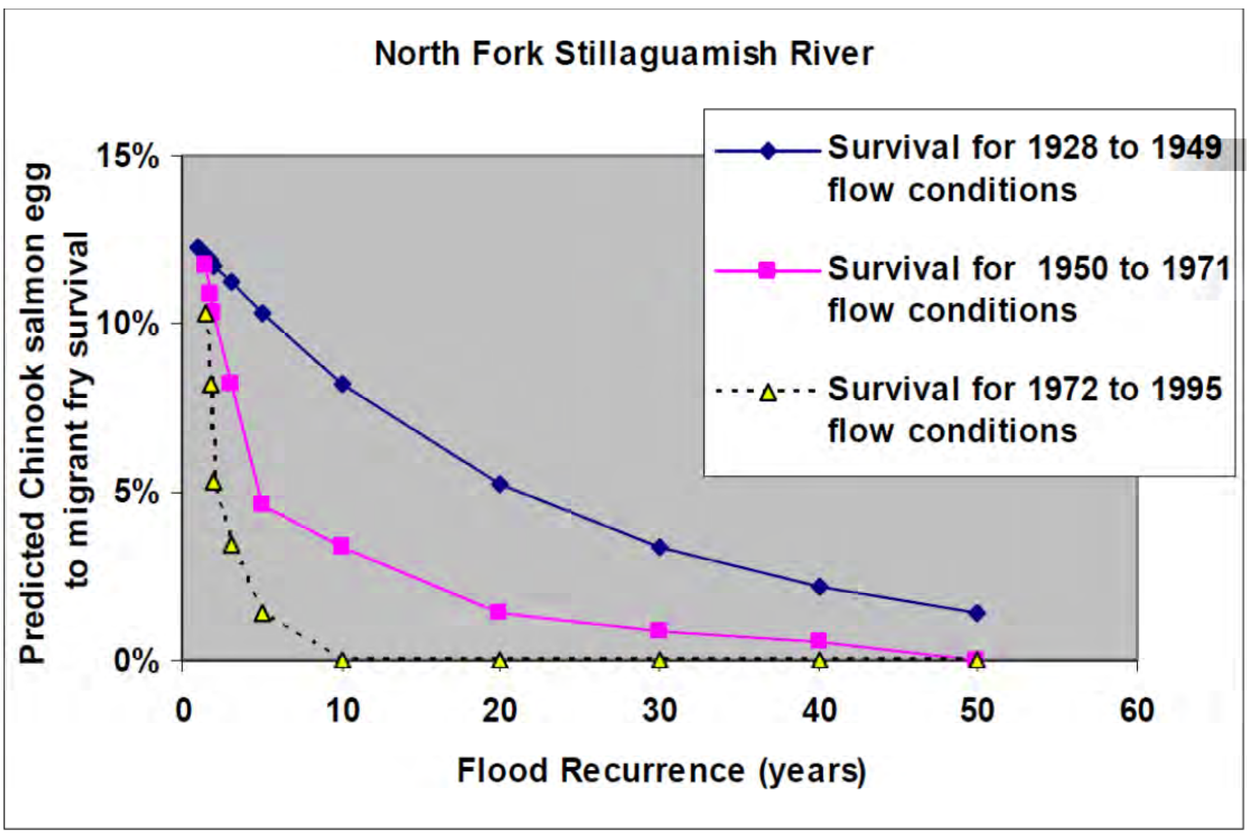


Figure 8. Estimated egg-to-migrant fry survival for the North Fork Stillaguamish River used as a surrogate for Skokomish River chum and Chinook salmon (from Beamer et al. 2005).

Skokomish Chinook salmon spawn in an area over 10 miles long from river mile (RM) 2.2 to RM 12.7; Fall Chum salmon spawn from RM 0 up to RM 11.5 (WDFW 2012).We compared the channel capacity assessment metric to potential increase in egg-to-fry survival using numeric values from Figure 8. While the egg-to-fry survival calculations are not used for the assessment metric, the evidence of improved survival supports the use of channel capacity as a metric and supports the linear relationship between the capacity and the benefits score.

2.2 DETERMINE THE ESTIMATED IMPROVEMENT IN HABITAT QUALITY ASSOCIATED WITH EACH PROJECT

Gains in habitat units associated with projects and specific measures are calculated as Average Annual Habitat Units (AAHUs). They are based on projected changes in habitat quality and affected area, which requires that baseline, future without-project, and future with-project conditions be described quantitatively. This is usually accomplished with an index of habitat quality, where a value of 0.0 indicates that no suitable habitat is available, and an index of 1.0 represents optimum habitat conditions. For the purposes of this environmental benefits analysis, no single index of quality is available or appropriate because of the multiple limiting factors of concern and their varying importance in different parts of the ecosystem. Therefore, multiple indicators have been selected to represent the baseline habitat quality (the existing condition and projected change in habitat quality 50 years into the future over the period of analysis) and to estimate future with-project habitat quality.

As described in section 2.1.1, the indicators used to characterize channel and floodplain habitat quality are derived from the summary data presented in three habitat assessment reports. Figure 9 reproduces an example figure reporting the rating assigned for floodplain connectivity throughout the Skokomish River basin. The study area for this Environmental Benefits Analysis is outlined on that map. Some of the habitat quality ratings are established at the reach scale rather than at the individual project scale. In the example (Figure 9), all of the mainstem, South Fork, and Vance Creek channels are rated “poor” with regard to floodplain connectivity, meaning there is less than 50% connection between the mainstem river and the aquatic habitats in the floodplain.

Each river reach defined in Bountry (2009) and shown in Figure 9 below has roughly the same quality of habitat, so any proposed project increment that is not individually described starts with the same score as the whole reach. All future with-project and future without-project scores are based on the reports as described in section 2.1.2. Personal reconnaissance by project team members verified that the quality ratings for the proposed project sites are not substantially different from the general reach ratings, nor have conditions changed significantly except for the reach that now goes dry during summer low flow. Assessing the habitat quality for each project site would require individual site assessments of significant fieldwork effort, and would very likely result in the same assessment as the previous baseline reports.

The indicators selected to characterize baseline habitat quality are not intended to fully describe conditions in the study area, but rather to represent key elements of habitat structure and dynamics. Additionally, these metrics are ecosystem components that can be affected directly by management measures implementable by the Corps. The assumption is that the condition of those key elements will reflect overall ecosystem structure and function, and that they serve as reasonable surrogates for a broad suite of possible habitat measurements, many of which would be beyond the scope of a planning-level environmental benefits assessment. The indicators used and their scaling and applicability are described below.

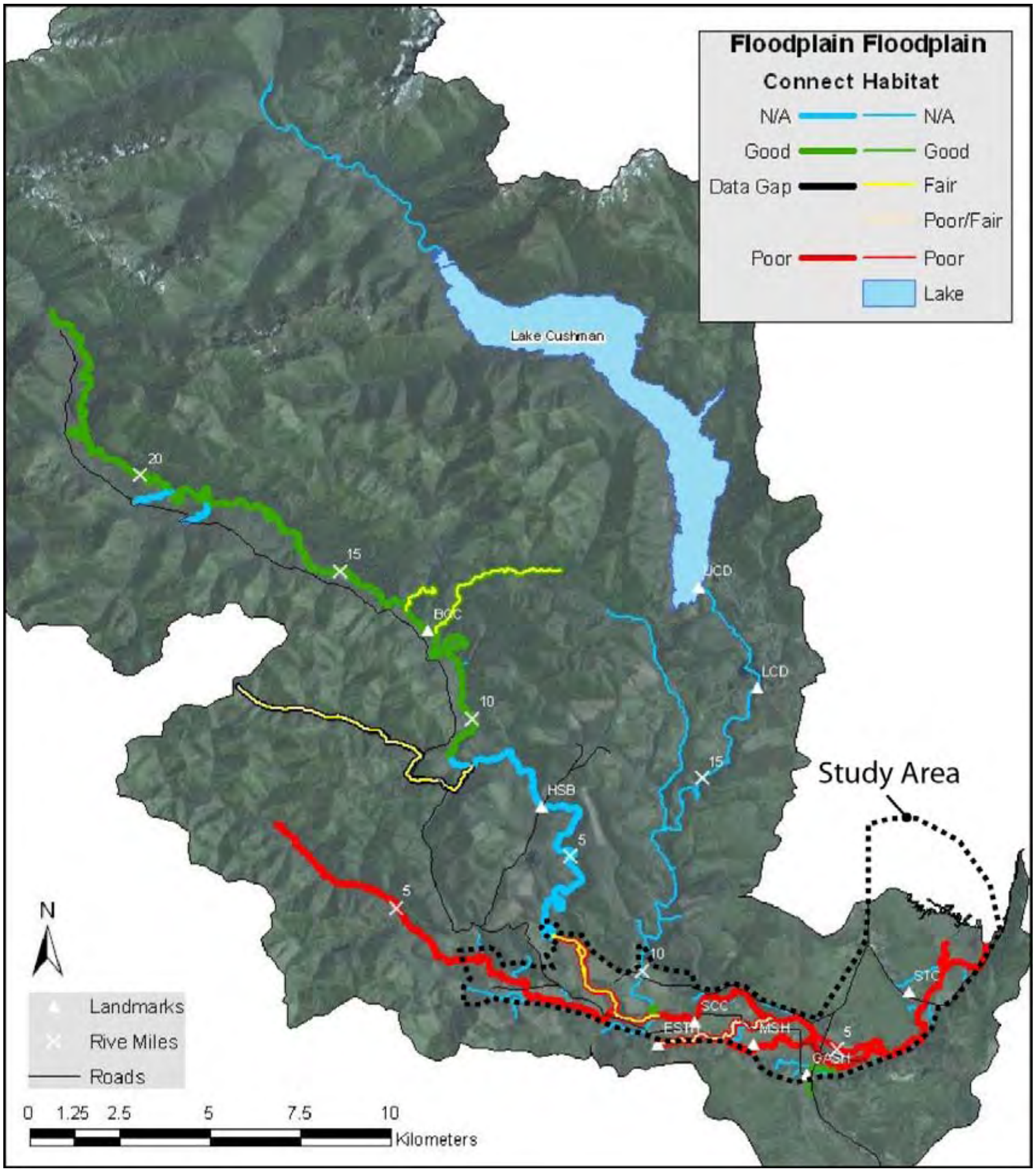


Figure 9. Excerpt from Peters et al. (2011) showing characterization of baseline conditions for floodplain connectivity in the Skokomish basin. GI study area outline added for reference.

Each of the five assessment metrics described in sections 2.1.1 to 2.1.5 use curves to represent the existing and future without-project condition, and future with-project curve. They are projected 50 years into the future over the period of analysis. To estimate the quality achieved at different points in the 50-year period of analysis, it was not possible to rate the individual project sites according to the precise measurement of each assessment metric as this information was not available through the general reach-scale habitat assessments provided in the baseline conditions reports. Each future with-project curve takes into consideration how long a given habitat feature will take to achieve benefits, with a continuous linear function of habitat gain/loss from one notable point in time to the next (i.e. habitat quality is interpolated between these noted points). Habitat quality scores are averaged over the period of analysis to estimate a future without-project (FWOP) and future with-project (FWP) average annual habitat quality index (HQI) score. The difference between the future without-project and future with-project HQI scores is taken as the average annual HQI benefit. Average annual habitat units (AAHUs) are estimated as the product of the affected acreage and the average annual HQI score. This average annual HQI benefit is multiplied by the affected acreage to estimate AAHUs for a given project as shown below.

Average Annual Habitat Units (AAHUs) = Affected Acreage x Average Annual HQI Score

The average annual benefit for a project alternative is the difference in AAHUs from the FWP and FWOP condition for the project's assessment area, as shown below.

Benefits of with project for assessment area (in AAHU) = AAHU (with project) – AAHU (without project)

2.2.1 Pool Habitat

All riverine life stages of the many salmonid species benefit from abundant pool habitat. Juveniles use pools for a significant portion of their time for feeding and rearing, while adults rest in pools during their arduous upstream migration to spawning grounds. As described in section 1.3 regarding baseline conditions of the Skokomish River, the severe lack of pools is unanimously rated as poor among all entities that have analyzed the river habitat. While the habitat quality rating expresses percent surface area in pools for large reaches of river, the purpose of each assessment metric is to score the change at specific project sites. Therefore, this assessment metric aims to calculate the improvement of percent surface area in pools achieved within each project site's footprint. Each project will be designed to optimize habitat quality. Sediment transport is a very active process in this river with no indication that any reach of the substrate is embedded; therefore, pools are expected to begin developing immediately after construction and especially during the first high water event after construction.

The assumptions for the future without-project time curve are the following:

- we assume that the existing conditions of approximately five percent surface area in pools will remain the same without any manual intervention for improvement
- continued aggradation will likely reduce pool depth, but LWD in the upper watershed may move into the study area and be a countervailing effect. The pools are formed by local hydraulic effects and are not likely to be reduced by the overall deposition trend.
- the severe and obvious lack of pools in the mainstem river is about as poor of habitat as possible; the two large pools identified by study team members appear relatively stable, so we assume conditions are not likely to significantly worsen.

The assumptions that went into the shape of the future with-project time curve are the following:

- based on the supporting literature used to determine the baseline conditions, the mainstem river has only about 5% surface area in pools, so the starting score is 0.21 for any in-channel projects
- floodplain projects have either no pools, or they are characterized as one large pool with no riffle habitat (0% or 100%), therefore their starting score is 0.1;
- pools would be excavated during construction. The target is 40 to 60%; we assume each site will have 30% surface area in pools within 5 years after construction for a score of 0.78;

- habitat-forming processes occur during two-year to 10-year flood events (Knighton 1998), so we assume that at least one of these will occur in the first 10 years and that this will cause the pool habitat to achieve the target of 40% surface area for a score of 1.0 at 10 years;
- pools around LWD will be formed by localized hydraulics; because this is a localized effect, and sediment movement is dynamic in this river, these pools are not prone to as much in-filling from the aggradation effects seen in other areas of the river. Benefits of the new pool habitat will be significant and should be stable for the remainder of the period of analysis, assuming a moderate effort at post-project maintenance.

Figure 10 displays the time curves for the pool assessment metric. These time curves were used to estimate the average annual FWOP and FWP HQI, and the average annual HQI benefit for pools as shown in Table 6.

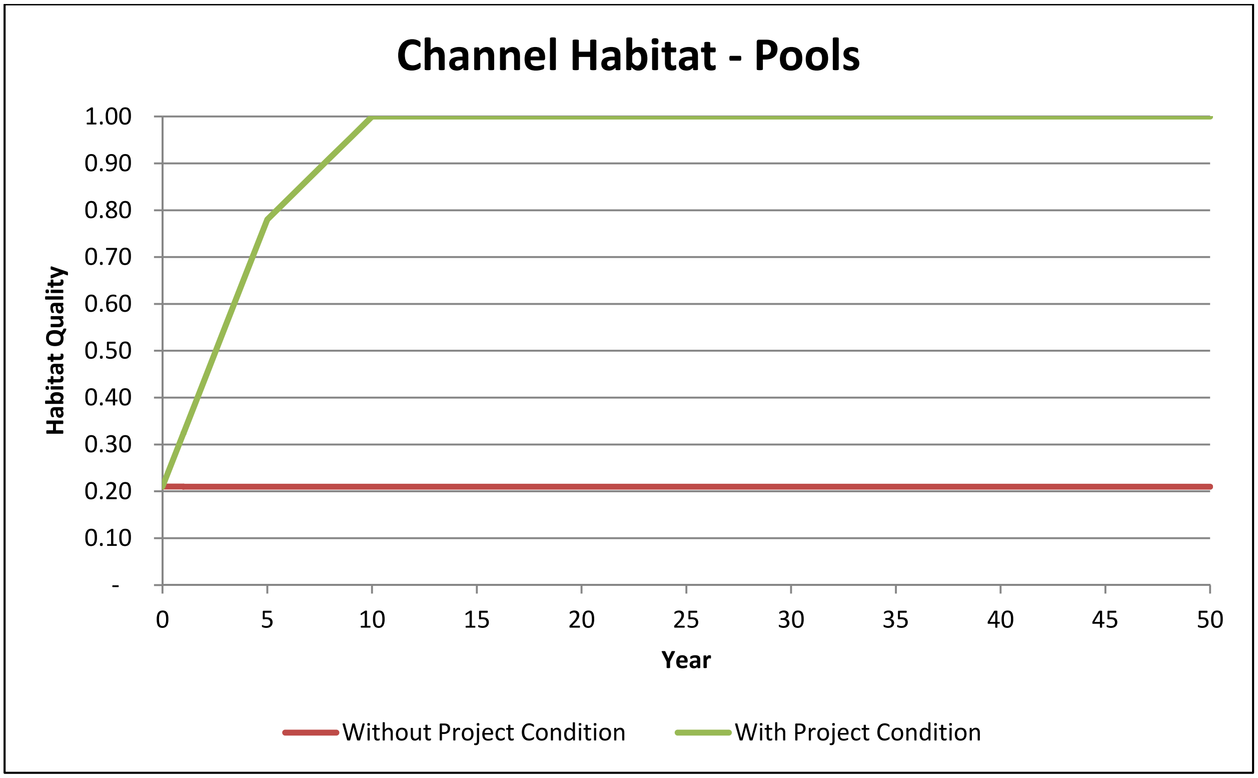


Figure 10. Channel Habitat – Pools: Habitat Quality Index Over Time for Without- and With-Project Conditions

Table 6. Pools Habitat Quality Index Scores for Existing, Without and With Project Conditions, and Average Annual Benefit With Project

Habitat Quality Index Scores - Pools	Score (0-1.0)
Existing Condition	0.21
Average Annual Without Project (Baseline) Condition	0.21
Average Annual With Project Condition	0.93
Average Annual Benefit With Project	0.72

The computations for the without and with project average annual habitat quality scores, and above graph and table are contained in the worksheet ‘Channel – Pools HQI’. The values in this table populate the values in the summary table in the ‘Assessment Metric HQI’ worksheet (see Table 11 in section 2.3).

2.2.2 LARGE WOODY DEBRIS

Large woody debris (LWD) in the active and wetted area of a river channel benefits all life stages of salmonids, but perhaps more so for juveniles as it provides refuge from high velocity flows, cover from predators, rearing area in pools, and surfaces for aquatic insects that become prey items for the juvenile fish. LWD also serves to stabilize substrate and stream banks to prevent too much erosion or instability during the spawning and egg incubation phases. Redd scour from unstable substrate and redd suffocation from bank erosion can be reduced with increased LWD.

Literature on baseline conditions indicates that the quantity of LWD within the wetted channel or low on banks is poor with a count of only 0.06 pieces of LWD per meter. Although there are large logs with root wads present in the riverbed, they are perched high on the gravel bars formed by the excessive sediment in the system.

The assumptions for the future without-project condition time curve are the following:

- LWD is pushed to the channel margins during the numerous floods each year, the logs along the riverbed margins will remain out of reach of average river flows,
- the rate of input from upstream sources will remain the same for the next 50 years as it has been for the past 20 years, which may be biased toward underestimating since forest practices have been improving over the past 20 years and older trees allowed to stand within a buffer zone may be recruited at a higher rate over the next 50 years

The assumptions for the future with-project time curve are the following:

- poor baseline conditions warrant a starting score of 0.1 for 0.06 pieces of LWD per meter;
- construction measures would add the recommended number of key pieces per river mile (Fox and Bolton 2007);
- since LWD exerts its influence nearly immediately, we assume that pieces placed during construction added to material already present in the channel will be actively providing benefits within the first 5 years after construction, for a score of 0.8;
- benefits of bank and substrate stabilization and pool expansion around root wads will continue to accrue at a relatively stable rate. After the 5-year point, we assume that LWD available in the aquatic habitat have recruited additional woody debris and that the restored reaches have accumulated at least the target of .6 pieces per meter for a score of 1.0 by the 10-year mark.
- pool formation around LWD will occur with the first high water flows after construction. Pools around LWD will be formed by local hydraulics and are therefore not as prone to aggradation effects as reaches of the river that have been lacking LWD. We expect the LWD and pools to be self-maintaining for the 50-year study period.

Figure 11 displays the time curves for the LWD assessment metric. These time curves were used to estimate the average annual FWOP and FWP HQI and the average annual HQI benefit for LWD as shown in Table 7.

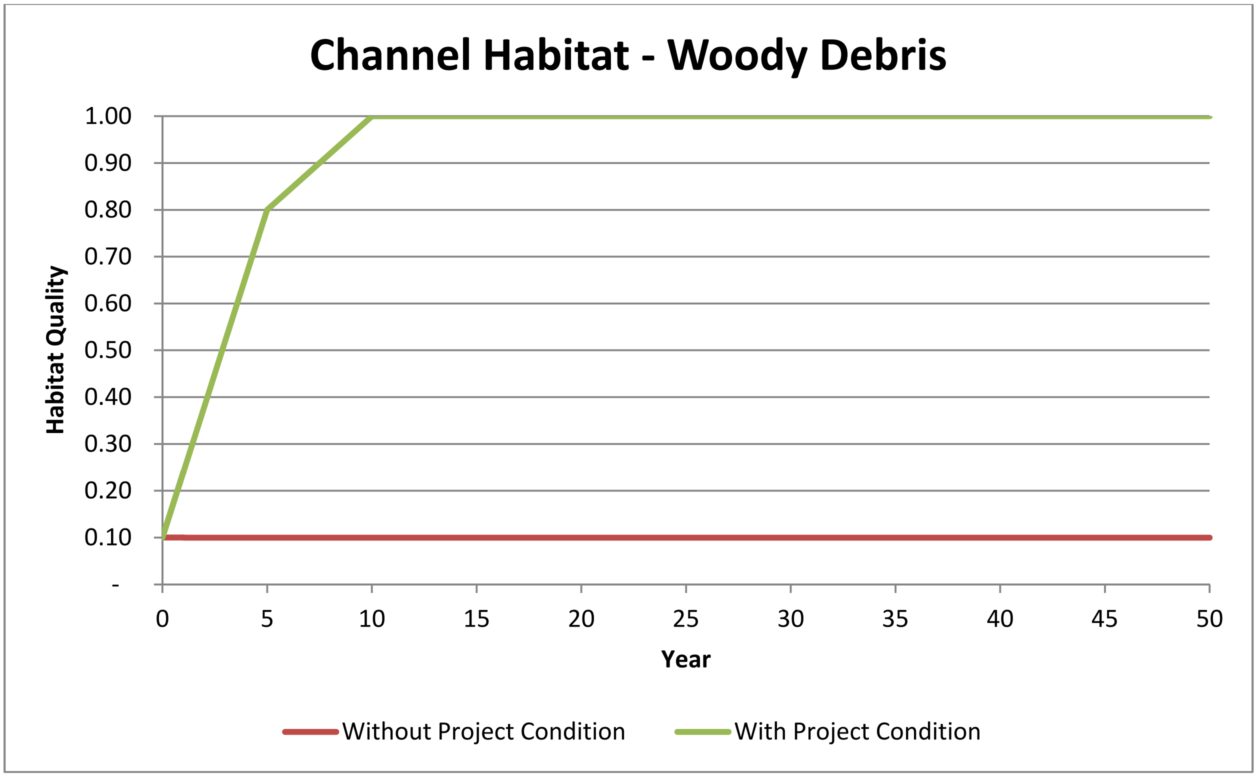


Figure 11. Channel Habitat – Woody Debris: Habitat Quality Index over Time for Without- and With-Project Conditions

Table 7. Woody Debris Habitat Quality Index Scores for Existing, Without and With Project Conditions, and Average Annual Benefit with Project

Habitat Quality Index Scores – Woody Debris	Score (0-1.0)
Existing Condition	0.10
Average Annual Without Project (Baseline) Condition	0.10
Average Annual With Project Condition	0.93
Average Annual Benefit With Project	0.83

The computations for the without and with project average annual habitat quality scores, and above graph and table are contained in the worksheet ‘Channel Habitat – Woody Debris’. The values in this table populate the values in the summary table in the ‘Assessment Metric HQI’ worksheet (see Table 11 in section 2.3).

2.2.3 Riparian Cover

Condition of the riparian zone vegetation is important for overall health of all river ecology and therefore all riverine life stages of salmonids. The recent Skokomish habitat assessments (WDFW and PNPTC 2000, Correa 2003, Peters et al. 2011) use species composition, buffer width, ground coverage, and age, with a resulting rating of the lower mainstem river as poor. Some areas are described as severely degraded while other areas with wide buffers and a high percentage of canopy cover are rated as healthy.

As described in Section 2.1.2.3, the Corps conducted a spatial analysis of the proposed project sites using ArcGIS for the existing conditions and future with-project conditions. Figure 12 shows the existing conditions with the percent of each 150-foot riparian buffer that has contiguous vegetation. Figure 13 shows the future with-project areas that would be planted during construction; we assume achieving 100% canopy cover within all areas that would be planted. Not all areas within the 150-foot buffer of each project can be planted. Areas that are roads, houses, or otherwise non-plantable are assumed to remain in that condition. For the two sites that occur in agricultural fields, we assumed buffer size would be limited to 75 feet surrounding the project footprint as these are on private property and landowner willingness to convert agriculture to wetland is unknown at this time.

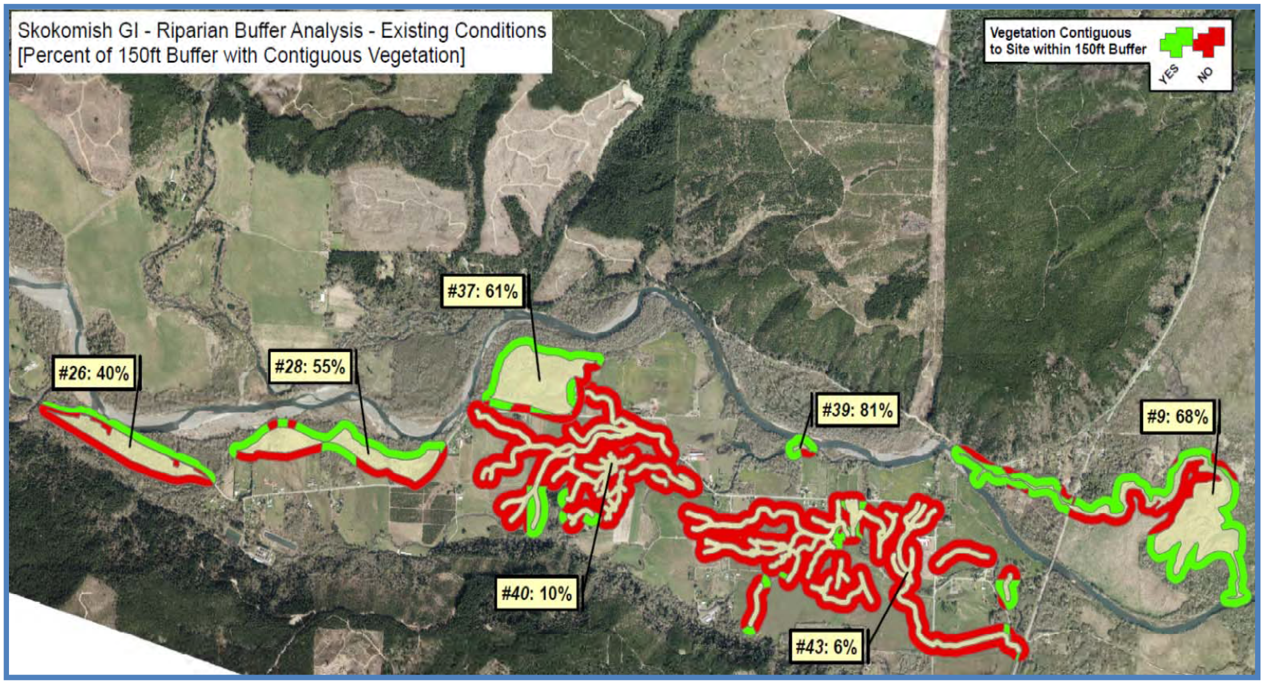


Figure 12. Existing conditions of 150-foot riparian buffer at proposed project sites.

The assumptions for the future without-project condition time curve are the following:

- present land uses would remain the same at each project site, so each site uses the existing conditions score as derived from the spatial analysis
- the present density of canopy cover as viewed in the aerial photographs has reached its full maturity and is not likely to become significantly more dense over the next 50 years, which may be biased toward overestimating present vegetation and underestimating future vegetation.

The assumptions for the future with-project condition are the following:

- the starting score for the time curve is derived from the spatial analysis for existing conditions;
- construction measures that open stream channels for fish access to forested and shrubby wetland areas provide immediate benefits associated with healthy riparian zones as fish access is restored;
- new plantings will be implemented across as much of the plantable area as possible at a density of four to six feet on center for shrubs and 10 to 12 feet on center for trees. Sites are near the river, so recruitment of cottonwoods and alders is expected.
- plantings would have approximately 10% canopy cover immediately after construction, around 80% canopy cover at five years after construction, and are expected to have 100% canopy cover at 10 years after construction.

Figures 14-20 display the time curves for the riparian assessment metric for each of the assessment areas with floodplain habitat limiting factors. These time curves were used to estimate the average annual FWOP and FWP HQI, and the average annual HQI benefit for pools as shown in Table 8.

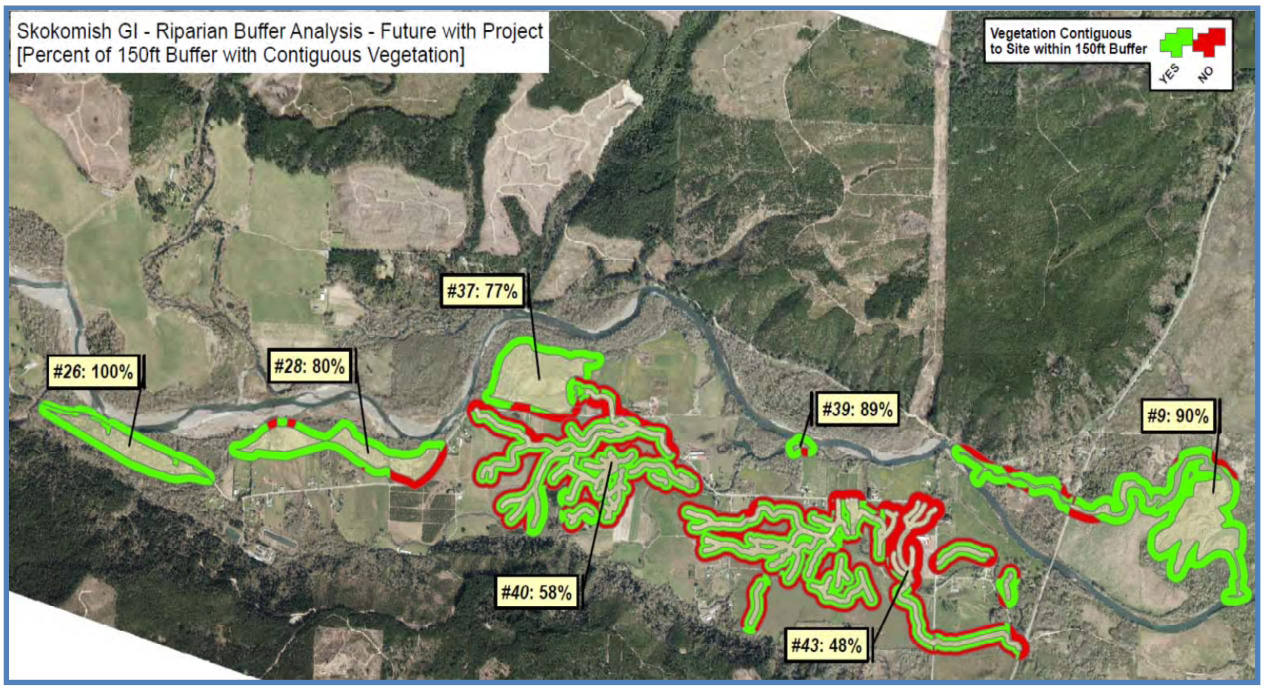


Figure 13. Future with-project conditions of 150-foot riparian buffer at proposed project sites.

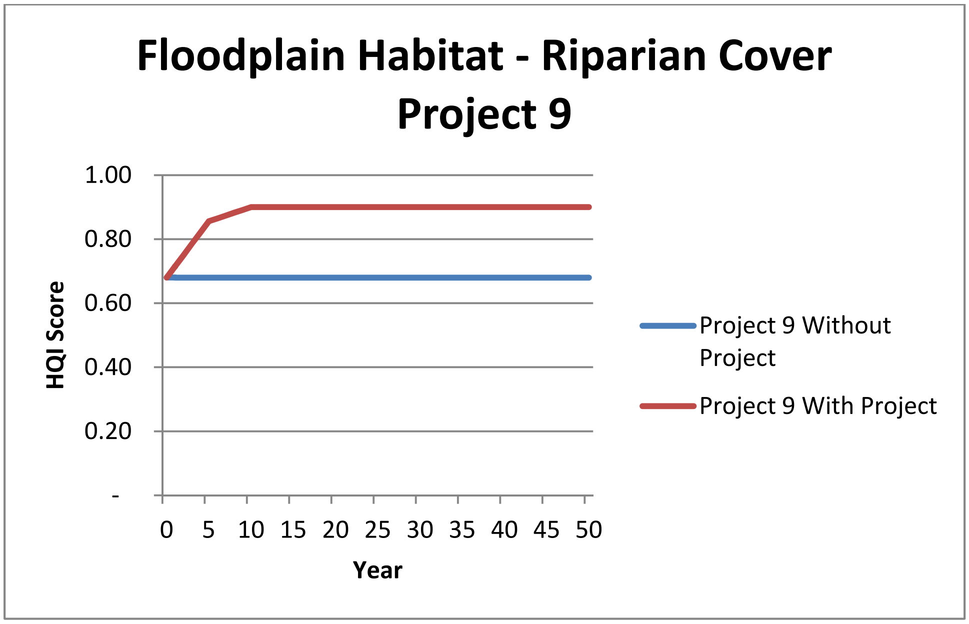


Figure 14. Floodplain Habitat – Riparian Cover: Habitat Quality Index Over Time for Without and With Project Conditions by Project Assessment Area, Project ID 9

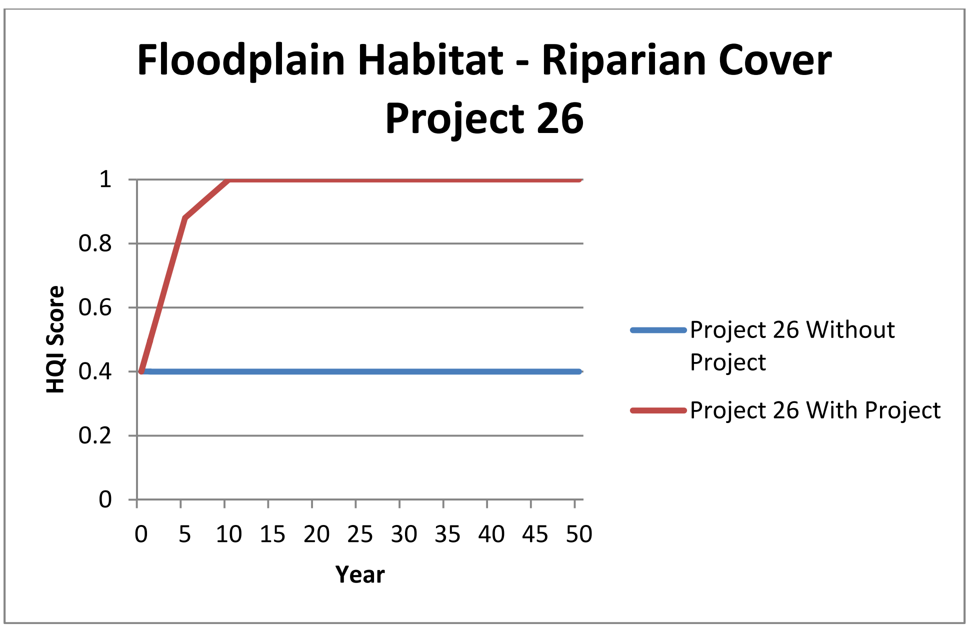


Figure 15. Floodplain Habitat – Riparian Cover: Habitat Quality Index Over Time for Without and With Project Conditions by Project Assessment Area, Project ID 26

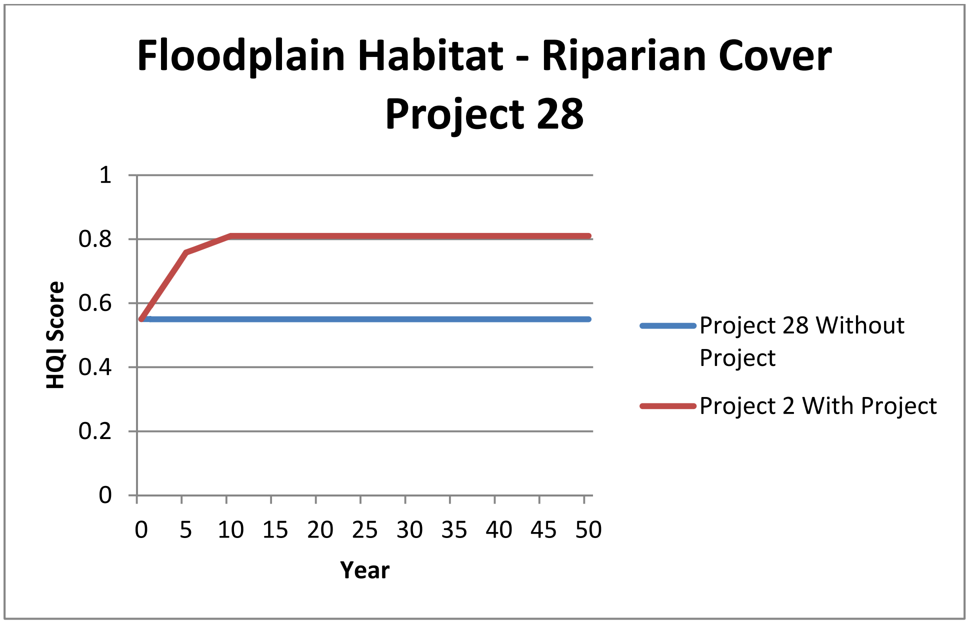


Figure 16. Floodplain Habitat – Riparian Cover: Habitat Quality Index Over Time for Without and With Project Conditions by Project Assessment Area, Project ID 28

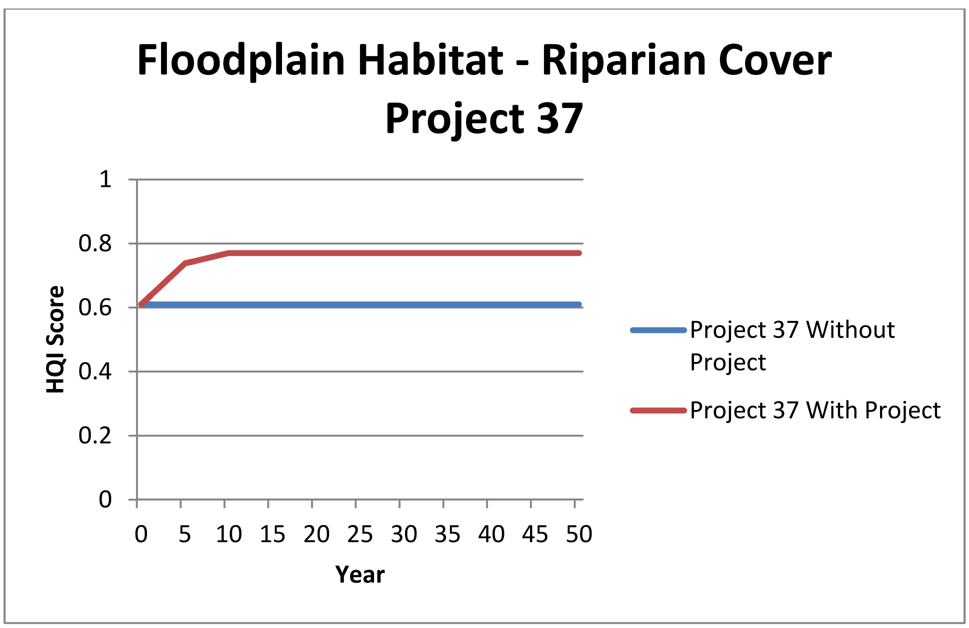


Figure 17. Floodplain Habitat – Riparian Cover: Habitat Quality Index Over Time for Without and With Project Conditions by Project Assessment Area, Project ID 37

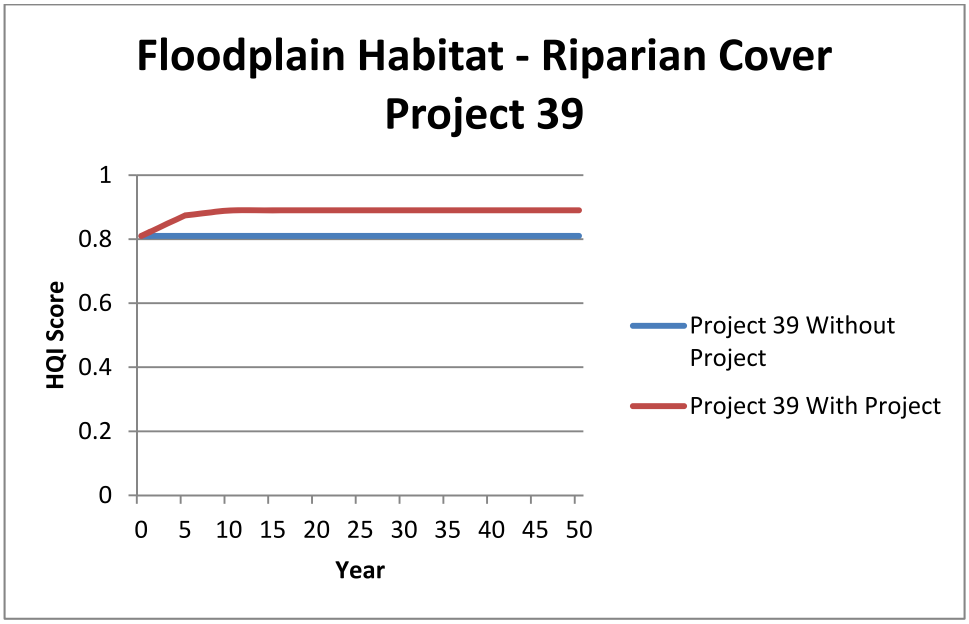


Figure 18. Floodplain Habitat – Riparian Cover: Habitat Quality Index Over Time for Without and With Project Conditions by Project Assessment Area, Project ID 39

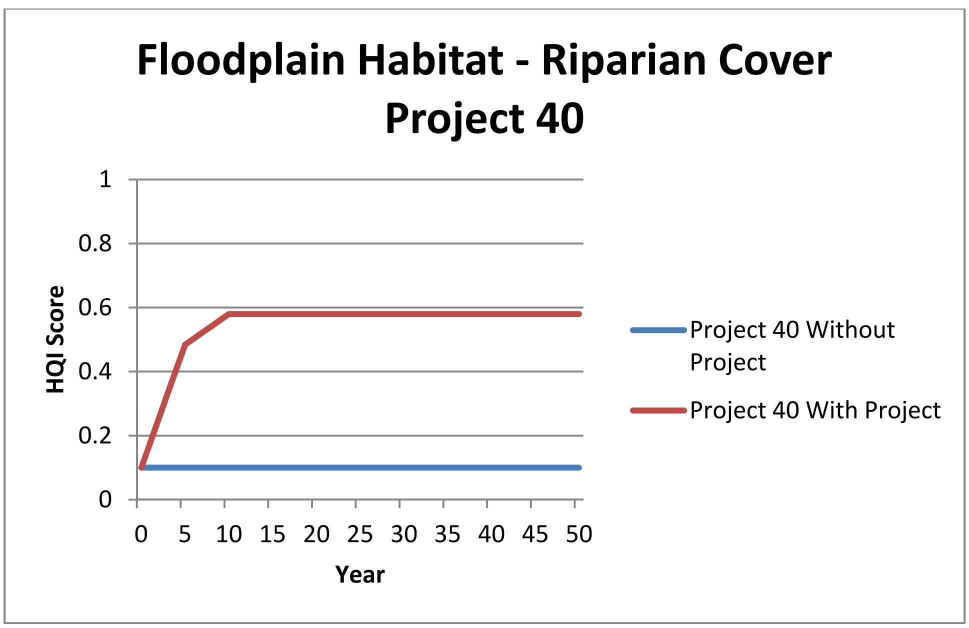


Figure 19. Floodplain Habitat – Riparian Cover: Habitat Quality Index Over Time for Without and With Project Conditions by Project Assessment Area, Project ID 40

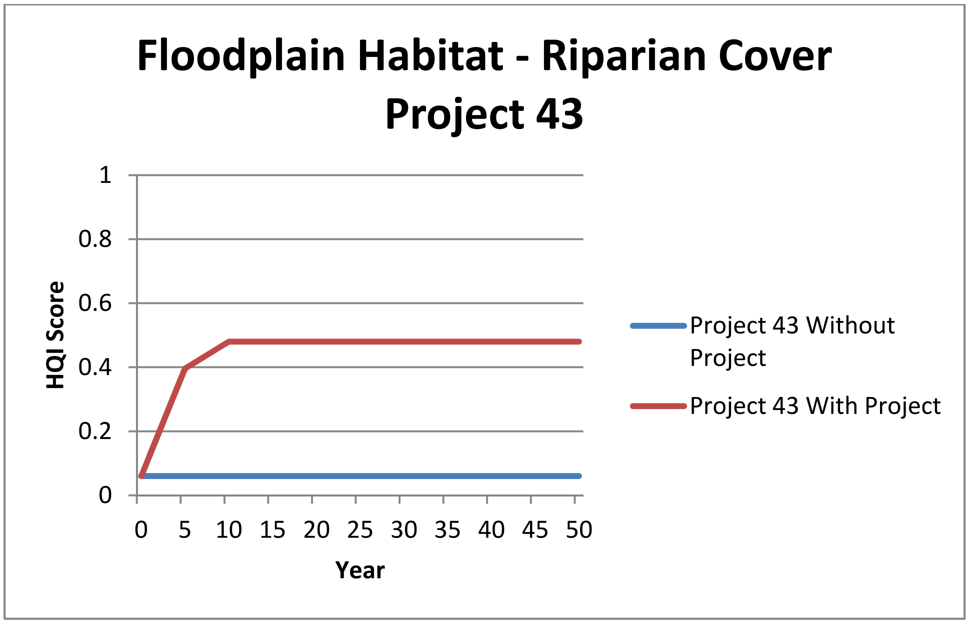


Figure 20. Floodplain Habitat – Riparian Cover: Habitat Quality Index Over Time for Without and With Project Conditions by Project Assessment Area, Project ID 43

Table 8. Riparian Cover Habitat Quality Index Scores for Existing, Without and With Project Conditions, and Average Annual Benefit With Project by Project Assessment Area

Habitat Quality Index Scores – Riparian Cover	Project ID						
	9	26	28	37	39	40	43
Existing Condition	0.68	0.40	0.55	0.61	0.81	0.10	0.06
Average Annual Without Project (Baseline) Condition	0.68	0.40	0.55	0.61	0.81	0.10	0.06
Average Annual With Project Condition	0.88	0.95	0.79	0.76	0.88	0.54	0.45
Average Annual Benefit With Project	0.20	0.55	0.24	0.15	0.07	0.44	0.39

The computations for the without and with project average annual habitat quality scores, and above graph and table are contained in the worksheet 'Floodplain – Riparian Cover'. The values in this table populate the values in the summary table in the 'Assessment Metric HQI' worksheet (see Table 11 in section 2.3).

2.2.4 Floodplain Connectivity

Loss of connections between tributaries, wetlands, off-channel ponds, and secondary side channels have resulted in a rating of poor for habitat conditions in the low-gradient mainstem Skokomish floodplain area. This affects all riverine life stages of salmonids due to the reduction of available spawning, incubation, rearing, and over-wintering habitats. This disconnection is caused partly by diking and draining, as well as the excessive sedimentation that has cut off the mouths of tributaries such that fish passage is blocked.

The assumptions for the future without-project condition time curve are the following:

- Correa (2003) recorded that each of this study's proposed floodplain restoration sites is disconnected,
- reconnaissance through some of the study team's site visits verified that creek mouths may be blocked during summer low flow
- this condition is expected to continue as sediment continues to accumulate and block channels, and because the present land uses are expected to endure.

The assumptions for the future with-project are the following:

- existing conditions documentation states that the specific proposed project sites are disconnected for fish access from the mainstem river, so the starting point for the time curve is a score of 0;
- construction measures will include removing blockages at tributary mouths, opening fish passage and flowing channels through wetlands, ponds, and secondary side channels, and setting back levees providing immediate access and benefits
- we assume that within five years after the re-connection occurs during construction, the habitat will be 100% connected for a score of 1 because of high water events positively affecting the new connected habitat and the ancillary benefits accruing within five years of the re-connection.

Figure 21 displays the time curves for the connectivity assessment metric. These time curves were used to estimate the average annual FWOP and FWP HQI, and the average annual HQI benefit for connectivity as shown in Table 9.

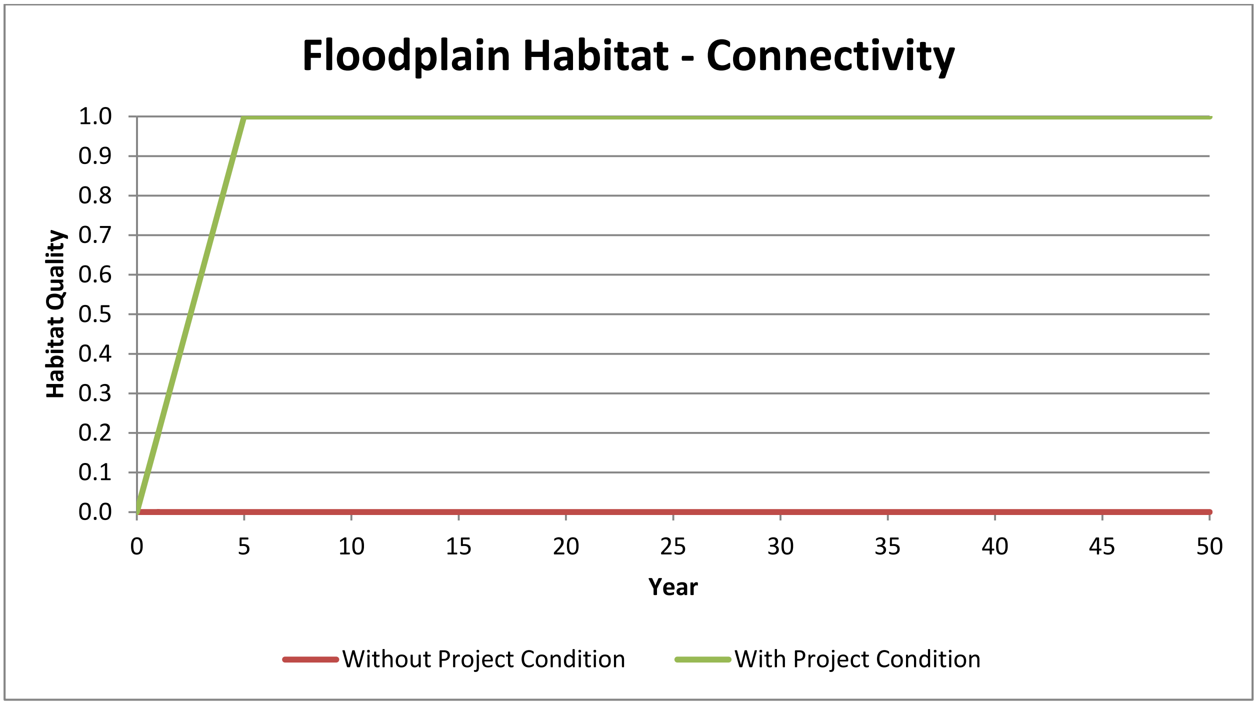


Figure 21. Floodplain Habitat – Connectivity: Habitat Quality Index over Time for Without and With Project Conditions

Table 9. Connectivity Habitat Quality Index Scores for Existing, Without and With Project Conditions, and Average Annual Benefit With Project

Habitat Quality Index Scores - Connectivity	Score (0-1.0)
Existing Condition	0
Average Annual Without Project (Baseline) Condition	0
Average Annual With Project Condition	0.94
Average Annual Benefit With Project	0.94

The computations for the without and with project average annual habitat quality scores, and above graph and table are contained in the worksheet 'Floodplain – Connectivity'. The values in this table populate the values in the summary table in the 'Assessment Metric HQI' worksheet (see Table 11 in section 2.3).

2.2.5 Channel Capacity

Based on the information presented in section 2.1.2.5 regarding potential benefits to salmon from reducing flood frequency, this assessment metric was developed to show relative benefits of one base alternative plan to another. The two-year flood recurrence interval was considered for this analysis because this capacity could have many benefits on the fish populations due to reduced fish stranding.

Another reason for selecting the two-year flow capacity is based on written records of flooding in the Skokomish valley summarized in a USACE report on flooding and sediment baseline conditions (USACE 2011). According to local records, flooding occurred annually in the early part of the 1900s at flows of roughly 13,000 cubic feet per second. Significant logging had already occurred along the South Fork Skokomish with bed elevation decreasing there while aggradation was occurring during the same period downstream from there in the mainstem (Stover and Montgomery 2001). As documented in Stover and Montgomery (2001), review of aerial photographs and meticulously kept U.S. Geological Survey (USGS) records reveals potential causes of changes in channel width and bed elevation over their study years of the 1930s to the 1990s. These USGS records show periods of significant aggradation paired with evidence of specific land use management activities. The target capacity of 17,000 cfs corresponds to approximately a two-year flood return interval, and is likely the approximate capacity that the river contained prior to significant human manipulation of the surrounding watershed. Furthermore, the typical return interval at which low gradient, pool-riffle Puget Sound area rivers experience bankfull discharge in natural conditions is the 1.5 to two-year return interval (Buffington et al. 2003); therefore, this seems to be a reasonable target.

Not all base alternatives achieve two-year capacity, rather they address capacity on a smaller scale, or they only address summer low flow concerns near the confluence where flow goes subsurface in the summer and fish are not able to access habitat upstream. Other capacities were considered but not evaluated due to the cost prohibitive nature of the sediment removal for greater capacities and disruptions to any existing habitat in the Skokomish River.

The Skokomish River typically floods an average of four times each winter, so the flood return interval is 0.25. This corresponds to a score of 0.125 (rounded to 0.13 in Table 10 below) according to the metric devised for benefits calculation. At the current rate of aggradation, frequency of flooding is expected to worsen to a condition in which the river is almost constantly avulsing.

Table 10. Flow Capacity Habitat Quality Index Scores for Existing, Without and With Project Conditions, and Average Annual Benefit with Project

Base #	Existing Habitat Quality Index Score	Average Future Without-Project (FWOP) Habitat Quality Index Score	Average Future With-Project (FWP) Habitat Quality Index Score	Average Change in HQI from FWOP to FWP
1 and 5	0.13	0.03	1.00	0.97
2 and 3	0.13	0.03	0.50	0.47

The average future without-project score is anticipated to be lower than the existing conditions as sediment continues to accumulate and the problems identified with channel capacity become worse. The assumptions for the projection of future without-project are based on the following information:

- Channel aggradation would continue with a sediment input rate of approximately 30,000 to 40,000 cubic yards per year
- Aggradation is expected to cause a major channel avulsion within the next 20 years. The most likely location for an avulsion is near the old North Fork confluence. The river could divert either to the north or to south sides at this location. A diversion to the south would send the river on a five-mile path across agricultural fields to rejoin the existing channel near RM 3. An avulsion is also possible near RM 3.5, where the river could be diverted into the wetland on the north side of the river.

- The wide, shallow river channel will continue to provide poor pool and riffle conditions necessary for spawning.
- Unstable riverbed conditions will continue to disturb spawning sites by scouring redds and reducing the survival of emergent fry.
- Future sediment deposits may have a smaller grain size distribution that includes an increasing amount of fines, reducing the suitability for salmon spawning.

2.3 Summary of Limiting Factor Assessment Metric Habitat Quality for Existing, FWOP, and FWP Conditions

Table 11 summarizes the existing, FWOP, and FWP HQI scores, and the average annual HQI benefit for each of the limiting factors. This table is contained in the 'Assessment Metric HQI' worksheet and is populated from computations of the individual assessment metric worksheets ('Channel Habitat – Pools', Channel Habitat – 'Woody Debris', 'Floodplain – Riparian Cover', and 'Floodplain – Connectivity'. This table is used to lookup average annual HQI benefit scores for benefit evaluation computations in the 'CEICA INPUT DATA' worksheet of the model.

Table 11. Average annual habitat quality index ratings assigned to channel and floodplain limiting factors for existing, future without-project and future with-project conditions, and net difference (average annual HQI benefit).

Limiting Factor	Assessment Metric	Base	Project ID	Existing Habitat Quality Index (HQI) Score	Average Annual FWOP HQI	Average Annual FWP HQI	Average Annual HQI Benefit
Channel Habitat	Pools	all	N/A	0.21	0.21	0.93	0.72
	Woody Debris	all	N/A	0.10	0.10	0.93	0.83
Floodplain Habitat	Riparian Cover	all	9	0.68	0.68	0.88	0.20
		all	26	0.40	0.40	0.95	0.55
		all	28	0.55	0.55	0.79	0.24
		all	37	0.61	0.61	0.76	0.15
		all	39	0.81	0.81	0.88	0.07
		all	40	0.10	0.10	0.54	0.44
		all	43	0.06	0.06	0.45	0.39
	Connectivity	all	N/A	0.00	0.00	0.94	0.94
Channel Capacity	Flow Capacity	1	N/A	0.13	0.03	1.00	0.97
		2	N/A	0.13	0.03	0.50	0.47
		3	N/A	0.13	0.03	0.50	0.47
		5	N/A	0.13	0.03	1.00	0.97

3 IDENTIFY PROJECTS, THE AREAS AFFECTED, AND LIMITING FACTORS ADDRESSED

An initial array of alternatives has been formulated based on initial data collection and best professional judgment including input from Mason County, the Skokomish Tribe, and local, state, and Federal agencies. The study team identified over 25 management measures (features or activities that can be implemented at a specific geographic site) as possibly implementable in the study area. Management measures include large-scale sediment removal, construction of setback levees, placement of large woody debris, side channel restoration, and riparian plantings. Each measure was qualitatively assessed and a determination was made as to whether it should move forward in the formulation of alternative plans.

After preliminary screening, 19 management measures were carried forward to the next plan formulation step: identification of potential restoration sites. The study team identified approximately 60 potential sites where one or more measures could be implemented to address the unique problems of the study area. Sites were selected based on locations of severe degradation within the study area; the team used best professional judgment to determine what measure(s) would function at each site for intended benefits.

To guide alternatives formulation, the study team identified the study's highest priorities. If these priorities are not met, the study will fail to address the most severe biological needs of the system. The study has six priorities:

1. Increase channel capacity
2. Address river reach that runs dry during summer months
3. Reduce sediment accumulation
4. Reconnect side channels and tributaries
5. Restore floodplain riparian buffer zone
6. Improve habitat complexity and functionality

The initial array of alternatives was formulated based on initial data collection and best professional judgment. The study team identified which of the approximately 60 potential restoration sites address the highest study priorities. This exercise led to the development of alternatives that include a "base" measure. The "bases" are key measures at specific sites or reaches of the river that address the highest priorities of the study area (increasing channel capacity, improving sediment transport, and addressing summer low flow; ultimately keeping fish in the river to spawn, rear, and migrate). The bases are large projects with no separable elements; they are also mutually exclusive from other bases. Developing alternatives around these base measures ensures the critical needs of the study area are addressed. An alternative cannot be considered complete, acceptable, or effective unless one of these bases is included. The base alternatives include two large-scale sediment removal options that reach across multiple river reaches plus two smaller-scale restoration projects within specific reaches of the river.

Increments will be added to the focused array of four base alternatives to capture supplementary benefits associated with restoration of additional channel and floodplain habitat features. Potential increments considered for addition to the base plans were selected from the list of 19 proposed management measures and 60 potential restoration sites using best professional judgment. These increments are generally smaller and can be added to whichever base option becomes the preferred alternative. The first increment added to base plans includes placement of LWD. This measure was identified to be the first critical habitat feature that should be included in a recommended plan in addition to the base; LWD helps establish pools, trap excessive sediment, improves stream habitat complexity, and serves as a substrate for aquatic invertebrates that salmon rely on as a food source. Next, additional in-channel increments were considered to address the highest study priorities (increasing channel capacity, improving sediment transport, addressing summer low flow connectivity). Finally, additional floodplain increments were considered as lower priority restoration features. Potential floodplain increments include removal of blockages at the mouths of tributaries, restoration of side channel habitat, creation of new side channels, and levee setbacks.

Of the approximately 60 potential restoration sites, eight sites were identified by the study team as high priority in-channel or floodplain increments that would optimize the environmental benefits for an alternative plan. A cost-effectiveness/incremental cost analysis (CE/ICA) will determine the appropriate number and scale of cost effective increments. The combinability of projects to base plans is further described in Chapter 4 along with the overall CE/ICA framework for the study.

Table 12 includes key information about the base alternatives in blue and the additional channel and floodplain increments in green including project name, description, reach or reaches affected, limiting factor addressed, and affected acreage (acres calculated using GIS). Figure 22 shows a map of the study area with all of the projects being carried forward in the environmental benefits analysis at this point in the plan formulation process. Finally, Figures 23 through 26 show conceptual drawings of the four proposed base plans: Bases 1, 2, 3, and 5, respectively.

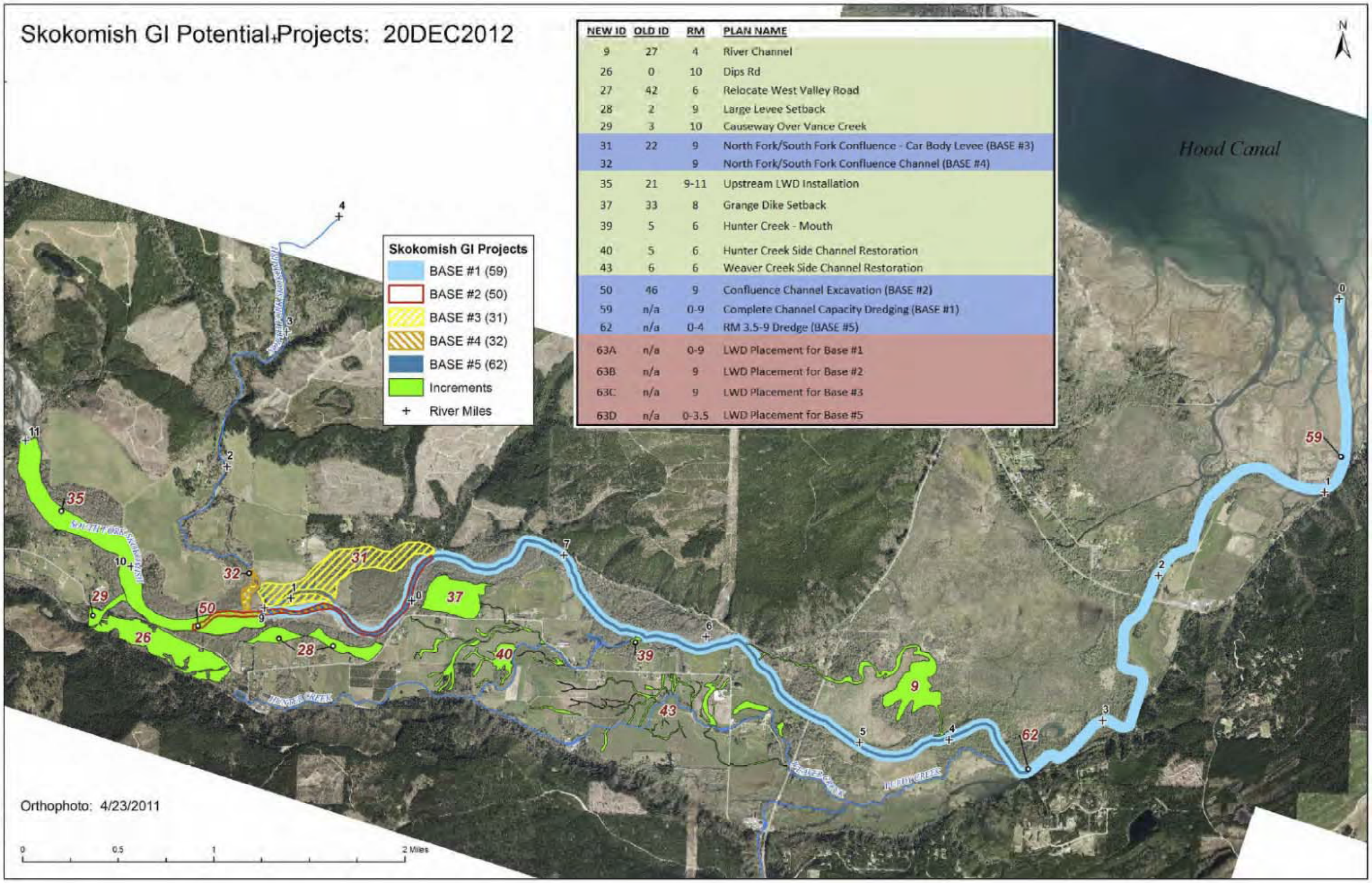
At the time that this model was under development, the project team was using local site names to refer to each site where measures could be implemented and scored for comparison. During the project's feasibility-level design phase, site names were formalized in the Final Feasibility Report and Environmental Impact Statement; therefore, some site names have changed, but none were added.

Table 12. Potential restoration projects including notes regarding their design. The assessment metrics (limiting factors addressed), affected areas and reaches are identified. Where a single project spans more than one reach, the affected acreage is allocated accordingly.

NEW ID	RM	PLAN NAME	SITE PROBLEM OR NEED	PLAN DESCRIPTION	ASSESSMENT AREA LIMITING FACTOR(S)	GIS ACRES	AFFECTED REACH(ES)
"BASE" ALTERNATIVES							
59	0-9	BASE #1 Complete Channel Capacity Dredging with LWD	Aggradation reduces fish access and migration. Limited LWD in river system.	Dredge from RM 0 to RM 9 (complete mainstem dredge). Place several pieces of LWD or ELJs in the main channel to provide additional fish habitat.	Channel capacity and in-channel habitat	219	0-4
50	9	BASE #2 Confluence Channel Excavation with LWD	Subsurface flow; limited connectivity to upper reaches due to aggradation. Limited LWD in river system.	Dredging and installation of ELJ or a fish weir near the confluence. Place several pieces of LWD or ELJs in the main channel near the original confluence or near RM 1 of the North Fork. LWD placement would provide additional fish habitat.	Channel capacity and in-channel habitat	26	4
31	9	BASE #3 North Fork/South Fork Confluence - Car Body Levee Removal with LWD	Car body levees act as an unnatural buffer and limits habitat connectivity to side channels and riparian zones. Limited LWD in river system.	Remove car body levee & reconnect channel on North Fork (allow flows to naturally divert to North Fork). Place several pieces of LWD or ELJs in the North Fork Channel near the original confluence (vicinity of RM 1 of the North Fork).	Channel capacity and in-channel habitat	68	4
62	3.5-9	BASE #5 RM 3.5-9 Dredge with LWD	Aggradation reduces fish access and migration. Limited LWD in river system.	Dredge from RM 3.5 to RM 9. Place several pieces of LWD or ELJs in the main channel to provide additional fish habitat.	Channel capacity and in-channel habitat	132	2-4

NEW ID	RM	PLAN NAME	SITE PROBLEM OR NEED	PLAN DESCRIPTION	ASSESSMENT AREA LIMITING FACTOR(S)	GIS ACRES	AFFECTED REACH(ES)
ADDITIONAL INCREMENTS TO BASE ALTERNATIVES							
9	4	River Channel	Rearing and migration opportunities are significantly limited in a remnant river channel with a poor connection to the mainstem.	Improve the hydraulic connection of an existing abandoned channel to make it more accessible for fish habitat. This improvement would occur at both the upstream and downstream ends of the channel. The channel would provide slower velocity habitat and higher flow connection; will not carry river flows year round. Because there is existing riparian vegetation in the channel, limited LWD placement or plantings would occur if necessary and be focused near the agricultural field in the area. The channel would rejoin the old oxbow at the downstream end of the site.	Floodplain habitat	45	2 / 3
26	10	Dips Rd	West Valley Road acts as a physical barrier to riparian habitat connectivity.	Relocate a small area of West Valley Road near the Dips to the West Valley Wall. Remove road surface, scarify roadbed, breach embankments at select locations where the roadbed is higher than the ground elevation, and remove riprap to create a higher-functioning riparian habitat and reconnected riparian zone.	Floodplain habitat	17	4
28	9	Large Levee Setback	The connection to riparian habitats is restricted by a levee near the mainstem bank.	Setback levee to provide access to additional riparian habitats including an overwintering pool. Assume existing levee breach will remain open (do not repair this area).	Floodplain habitat	23	4
35	11	Upstream LWD Installation	Spawning, rearing, and refuge habitats (including pools) are limited in RM 9 to 11 due to a lack of LWD in the upstream reaches of the Skokomish River.	Place LWD structures to create pools and provide cover.	In-channel habitat	107	4 / 5
37	8	Grange Dike Setback	The connection to riparian habitats is restricted by the Grange Dike near the mainstem bank.	Set levee back to provide access to additional riparian habitat including a pool.	Floodplain habitat	34	4 / 3
39	6	Hunter Creek - Mouth	There is a poor connection between the mouth of Hunter Creek and the mainstem.	Small-scale excavation at the mouth of Hunter Creek to provide year-round access between the Creek and mainstem river.	Floodplain habitat	0.5	3

NEW ID	RM	PLAN NAME	SITE PROBLEM OR NEED	PLAN DESCRIPTION	ASSESSMENT AREA LIMITING FACTOR(S)	GIS ACRES	AFFECTED REACH(ES)
40	6	Hunter Creek Side Channel Restoration	Fish stranding commonly occurs at this site due to limited side channels off Hunter Creek; spawning and rearing opportunities are significantly limited in Hunter Creek.	Excavate remnant channels (identified by LIDAR) to provide improved side channel habitat including refuge for juvenile fish during high flows. Riparian buffer plantings would also occur at this site.	Floodplain habitat	29	3
43	6	Weaver Creek Side Channel Restoration	A lack of juvenile salmonid rearing habitat & stranded fish during high flow events.	Limited excavation of remnant channels (identified by LIDAR) to provide improved side channel habitat including refuge for juvenile fish during high flows. Riparian buffer plantings would also occur at this site.	In-channel habitat	25	3



NEW ID	OLD ID	RM	PLAN NAME
9	27	4	River Channel
26	0	10	Dips Rd
27	42	6	Relocate West Valley Road
28	2	9	Large Levee Setback
29	3	10	Causeway Over Vance Creek
31	22	9	North Fork/South Fork Confluence - Car Body Levee (BASE #3)
32		9	North Fork/South Fork Confluence Channel (BASE #4)
35	21	9-11	Upstream LWD Installation
37	33	8	Grange Dike Setback
39	5	6	Hunter Creek - Mouth
40	5	6	Hunter Creek Side Channel Restoration
43	6	6	Weaver Creek Side Channel Restoration
50	46	9	Confluence Channel Excavation (BASE #2)
59	n/a	0-9	Complete Channel Capacity Dredging (BASE #1)
62	n/a	0-4	RM 3.5-9 Dredge (BASE #5)
63A	n/a	0-9	LWD Placement for Base #1
63B	n/a	9	LWD Placement for Base #2
63C	n/a	9	LWD Placement for Base #3
63D	n/a	0-3.5	LWD Placement for Base #5

Figure 22. Skokomish GI screened base plans and incremental projects

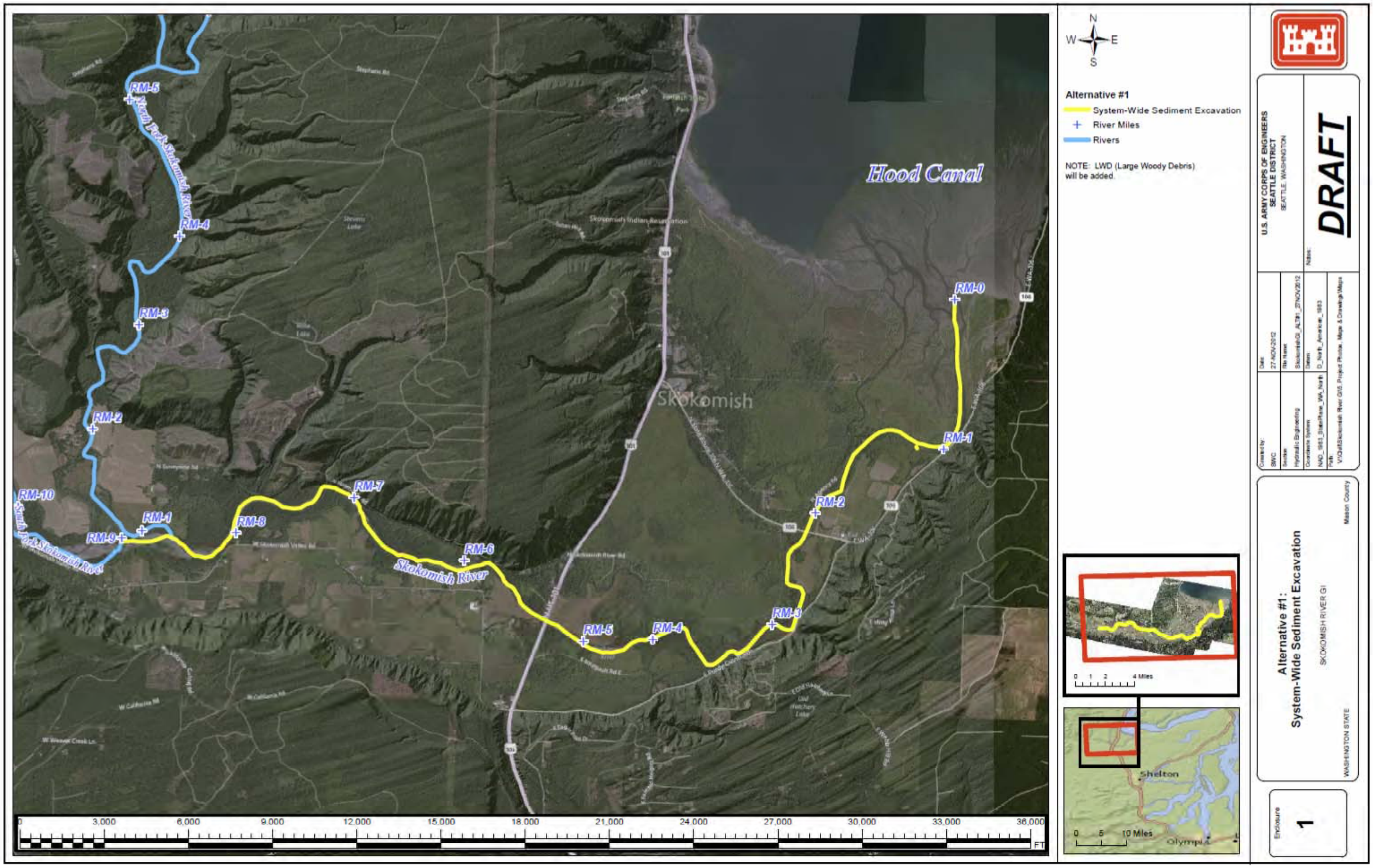


Figure 23. Base Alternative #1 - System-Wide Sediment Excavation from River Mile 0 to 9 and LWD

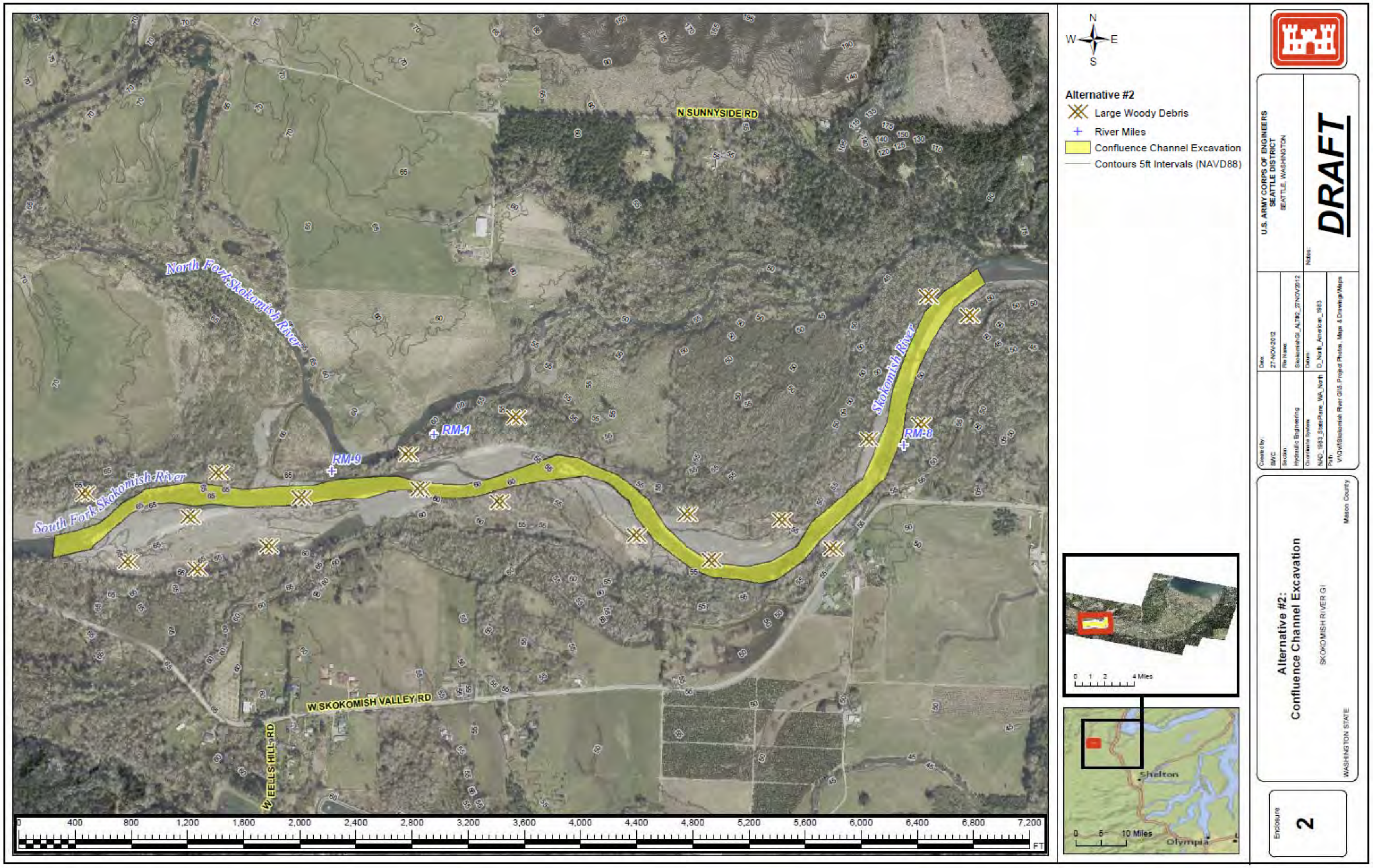


Figure 24. Base Alternative #2 - North Fork Confluence Channel Excavation and LWD

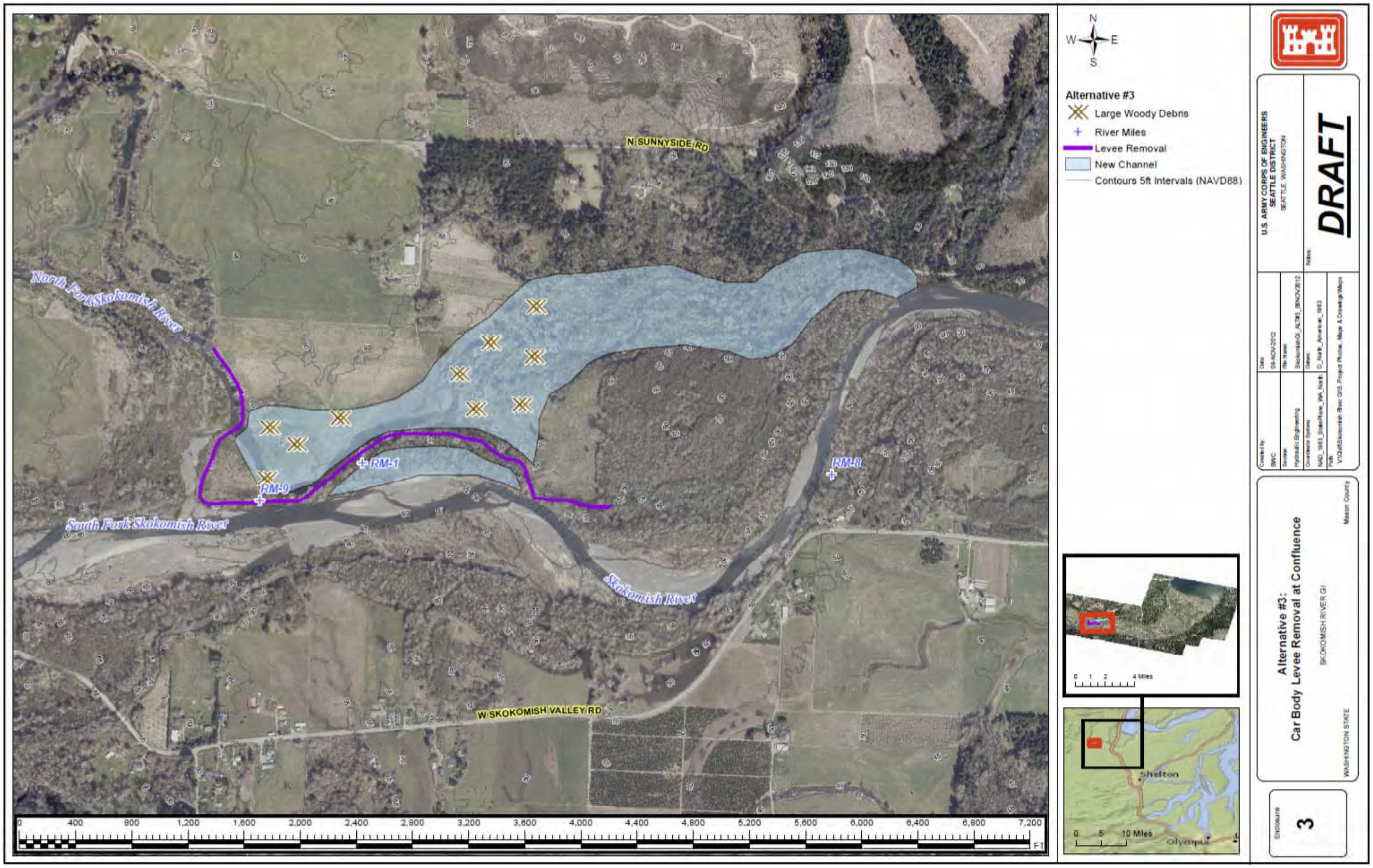


Figure 25. Base Alternative #3 - North Fork Confluence Car Body Levee Removal and LWD

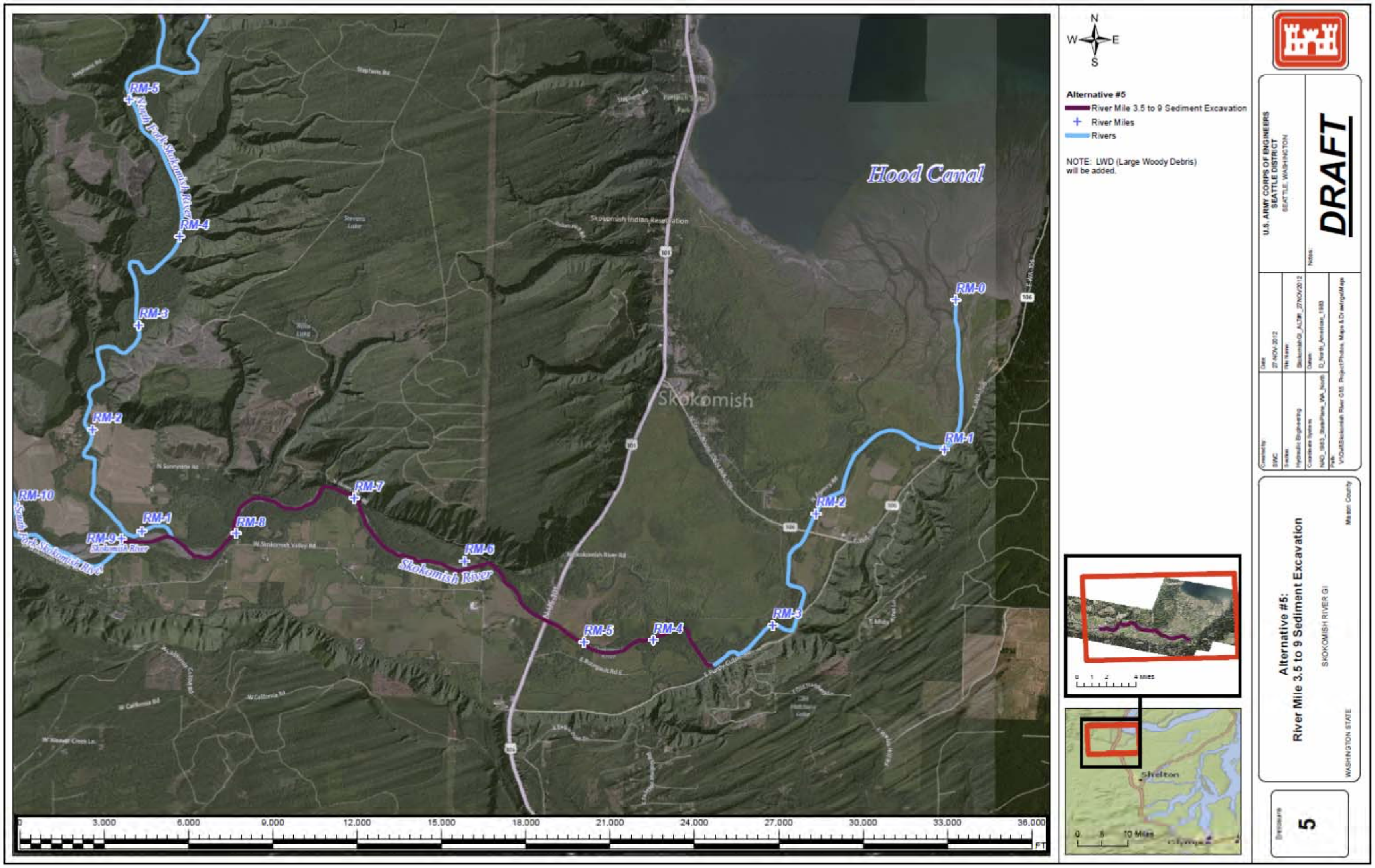


Figure 26. Base Alternative #5 - Sediment Excavation from River Mile 3.5 to 9 and LWD

4 EVALUATE SPECIFIC PROPOSED COMBINATIONS OF PROJECTS

An exercise was done to determine which projects are combinable and which are mutually exclusive. No two base plans are combinable and are therefore mutually exclusive. The capacity dredging with large woody debris base alternatives (Projects 59, 50, 31, and 62) are the first increments for any one alternative plan. In IWR Planning Suite, there will be a rule that each incremental project is dependent on one of the base alternatives and no two base alternatives are combinable.

AAHUs are computed for an assessment area by multiplying the HQI given the applicable limiting factor(s) and the affected acres as follows:

$$AAHU = HQI \; x \; Affected \; Area$$

Table 13 summarizes the combinability of increments to base plans, denoted with a 'Y' for combinable and 'N' for not combinable. This table is included in the Environmental Benefits Analysis spreadsheet model in the worksheet titled 'CombinabilityBasePlans' and informed the project increments in Table 14. The increments are included in the worksheet 'IncrementstoBases' in the Environmental Benefits Analysis spreadsheet model. Habitat benefits for each of these project increments are evaluated in the worksheet 'CE ICA INPUT DATA'.

For each proposed restoration action, it was first determined whether the project assessment area for that action would result in measureable change to the channel capacity, in-channel habitat, or floodplain habitat limiting factors. After determining applicable limiting factor(s) for a project assessment area, the without project and with project habitat quality index scores for relevant assessment metrics were estimated. For example, a project that would address in-channel habitat only would be evaluated using the in-channel habitat assessment metrics for LWD and percent surface area in pools.

Many of the proposed projects have multiple types of benefits and may include LWD and pool formation even though they are considered a floodplain connection project. The rationale for not scoring a project on all four assessment metrics that represent the floodplain and in-channel limiting factors is that most of the projects will not include all four components or contribute to enhancing all of the habitat features represented by all four assessment metrics. In general, the side channel projects are scored as benefiting connectivity, and the levee setback projects are score as contributing to riparian habitat. The LWD installation is scored under the in-channel habitat limiting factor; as an in-channel measure, it will not contribute to floodplain connectivity. Additionally, the effort applied to calculating the relative area of effect of more than two different components does not provide a commensurate level of precision in scoring, nor is this level of precision necessary to compare the projects.

The channel capacity limiting factor with its assessment metric of flow capacity is reserved for application to the base options. The rationale for this is that the incremental projects do not accomplish flow capacity because of their small size compared to the volume of floodwater or because of their location being different from where the problematic flooding occurs.

Table 13. Combinability of Incremental Projects with Base Alternatives

Project Number	Project Name	Base #1	Base #2	Base #3	Base #5
59	BASE #1 Complete Channel Capacity Dredging (RM 0-9) with LWD	Y	N	N	N
50	BASE #2 Confluence Channel Excavation with LWD	N	Y	N	N
31	BASE #3 North Fork/South Fork Confluence - Car Body Levee Removal with LWD	N	N	Y	N
62	BASE #5 RM 3.5-9 Dredge with LWD	N	N	N	Y
9	River Channel	Y	Y	Y	Y
26	Dips Road	Y	Y	Y	Y
28	Large Levee Setback	Y	Y	Y	Y
35	Upstream LWD Installation	Y	Y	Y	Y
37	Grange Dike	Y	Y	Y	Y
39	Hunter Creek Mouth	N	Y	Y	N
40	Hunter Creek Side Channel Habitat Reconnection	Y	Y	Y	Y
43	Weaver Creek Side Channel	Y	Y	Y	Y

Table 14. Project Increments Assigned to Base Alternatives Based on Combinability

Project Number	Base # Assignment	Project Number/ Base	Project Name	Affected Reach(es)	Affected Acres	Limiting Factor
59	1	K1	BASE #1 Complete Channel Capacity Dredging (RM 0-9) with LWD	0-4	219	Channel Capacity and In-Channel Habitat
50	2	L1	BASE #2 Confluence Channel Excavation with LWD	4	26	Channel Capacity and In-Channel Habitat
31	3	M1	BASE #3 North Fork/South Fork Confluence - Car Body Levee Removal with LWD	4	68	Channel Capacity and In-Channel Habitat
62	5	N1	BASE #5 RM 3.5-9 Dredge with LWD	2-4	132	Channel Capacity and In-Channel Habitat
9	all	B1	River Channel	2-3	45	Floodplain Habitat
26	all	C1	Dips Road	4	17	Floodplain Habitat
28	all	D1	Large Levee Setback	4	23	Floodplain Habitat
35	all	F1	Upstream LWD Installation	4-5	107	In-Channel Habitat
37	all	G1	Grange Dike	3-4	34	Floodplain Habitat
39	2 and 3	H1	Hunter Creek Mouth	3	0.5	Floodplain Habitat
40	all	I1	Hunter Creek Side Channel Habitat Reconnection	3	29	Floodplain Habitat
43	all	J1	Weaver Creek Side Channel	3	25	In-Channel Habitat

The following flow diagram in Figure 27 shows the assessment metrics (labeled V1 to V5), limiting factors and three paths to compute habitat quality index depending on which of the limiting factors apply for a given assessment area.

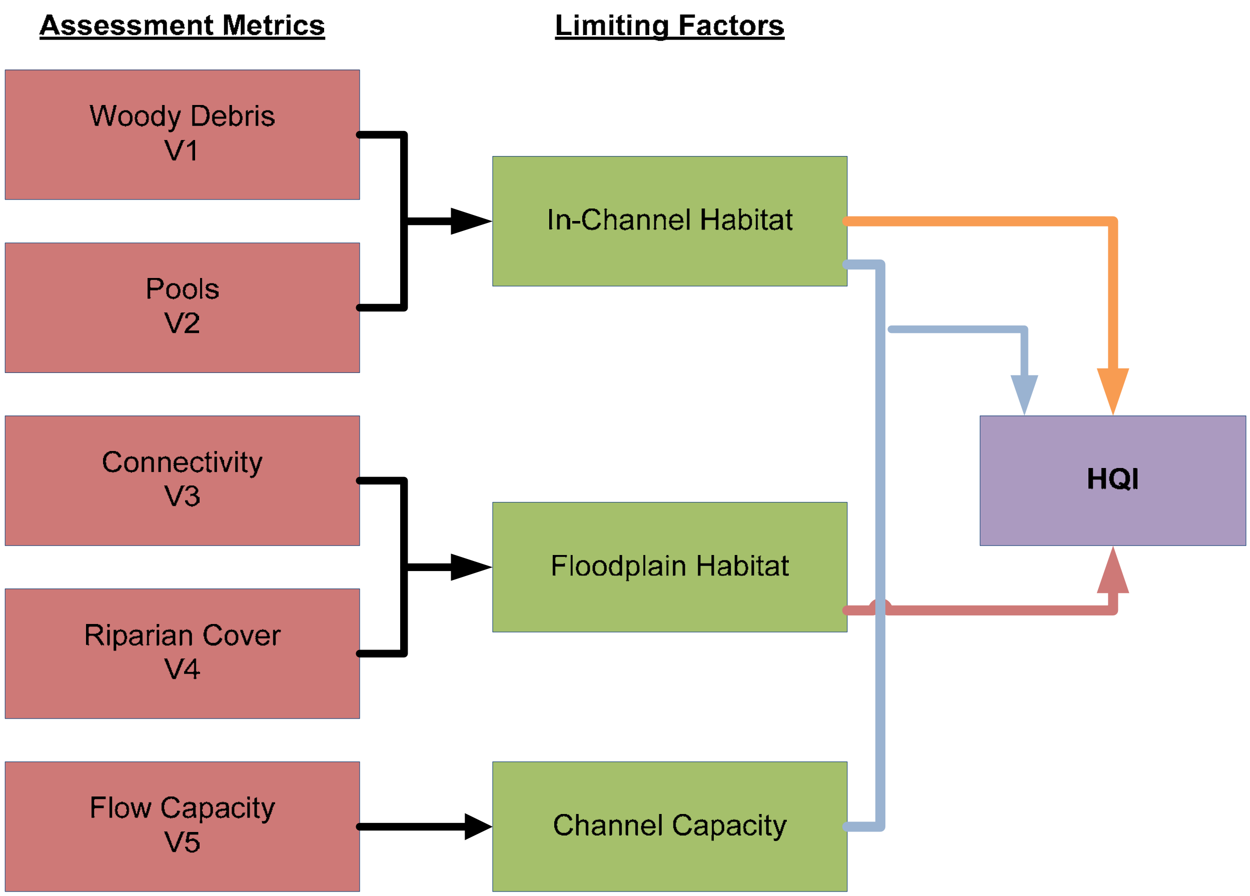


Figure 27. Flow diagram of HQI computation based on assessment area limiting factor(s) and assessment metrics

HQI is equal to one of three equations depending on the limiting factor(s) that apply to a given assessment area:

- $HQI = \frac{V1+V2+V5}{3}$ for assessment areas which evaluate both channel capacity and in-channel habitat limiting factors;
- $HQI = \frac{V1+V2}{2}$ for assessment areas which evaluate the in-channel habitat limiting factor only; and
- $HQI = \frac{V3+V4}{2}$ for assessment areas that evaluate the floodplain habitat limiting factor only.

AAHUs are computed for an assessment area by multiplying the HQI given the applicable limiting factor(s) and the affected acres as follows:

$$AAHU = HQI \ x \ Affected \ Area$$

Tables 15 to 17 show the evaluation of assessment areas by limiting factor(s) proposed project increments address. Table 15 includes computation of AAHUs for project increments that evaluate channel capacity and in-channel habitat limiting factors; Table 16 evaluates project increments for the floodplain habitat limiting factor only, and Table 17 evaluates project increments for the in-channel habitat limiting factor only. For each assessment area, three evaluations are presented. The first line is the evaluation of the without project condition for the assessment areas and is denoted by a letter followed by 0. It is scored based on the applicable limiting factor(s) and HQI is computed using the applicable HQI equation. The second line is for the project increment (with-project action) and is denoted with the same project letter followed by 1. It evaluates the habitat quality associated with the proposed action and is scored using the same assessment metrics used in the without project condition. Lastly, the third line presents the benefits of the proposed action. The benefits are taken as the change in HQI score multiplied by the affected area of the project.

$$Benefits\ (in\ AAHU) = Change\ in\ HQI\ Score\ (With\ Project - Without\ Project)\ x\ Affected\ Area$$

Table 15. HQI scoring and AAHU's for assessment areas with channel capacity and in-channel habitat limiting factors

						QI Scores for Applicable Variables						
Project Number	**Base # Assignment**	**Project Number/Base**	**Affected Reach(es)**	**Primary Reach Affected**	**Affected Acres**	**V1 - Woody Debris**	**V2 - Pools**	**V3 - Connectivity**	**V4 - Riparian Cover**	**V5 - Capacity**	**HQI**	**AAHU (Affected Acres * HQI)**
Limiting Factors for Assessment Area = Channel Capacity and In-Channel Habitat HQI = (V1 + V2 + V5)/3												
59	1	K0	0-4	N/A	219	0.10	0.21	N/A	N/A	0.03	0.11	24.5
59	1	K1	0-4	N/A	219	0.93	0.93	N/A	N/A	1.00	0.95	208.7
59	***1***	***K1***	***0-4***	***N/A***	***219***	***0.83***	***0.72***	***N/A***	***N/A***	***0.97***	***0.84***	***184.2***
50	2	L0	4	N/A	26	0.10	0.21	N/A	N/A	0.03	0.11	*2.9*
50	2	L1	4	N/A	26	0.93	0.93	N/A	N/A	0.50	0.79	20.4
50	***2***	***L1***	***4***	***N/A***	***26***	***0.83***	***0.72***	***N/A***	***N/A***	***0.47***	***0.67***	***17.5***
31	3	M0	4	N/A	68	0.10	0.21	N/A	N/A	0.03	0.11	*7.6*
31	3	M1	4	N/A	68	0.93	0.93	N/A	N/A	0.50	0.79	*53.5*
31	***3***	***M1***	***4***	***N/A***	***68***	***0.83***	***0.72***	***N/A***	***N/A***	***0.47***	***0.67***	***45.9***
62	5	N0	2-4	N/A	132	0.10	0.21	N/A	N/A	0.03	0.11	*14.8*
62	5	N1	2-4	N/A	132	0.93	0.93	N/A	N/A	1.00	0.95	*125.8*
62	***5***	***N1***	***2-4***	***N/A***	***132***	***0.83***	***0.72***	***N/A***	***N/A***	***0.97***	***0.84***	***111.0***

Table 16. HQI scoring and AAHU's for assessment areas with floodplain habitat limiting factors

						QI Scores for Applicable Variables						
Project Number	Base # Assignment	Project Number/Base	Affected Reach(es)	Primary Reach Affected	Affected Acres	V1 - Woody Debris	V2 - Pools	V3 - Connectivity	V4 - Riparian Cover	V5 - Capacity	HQI	AAHU (Affected Acres * HQI)
Limiting Factors for Assessment Area = Floodplain Habitat HQI = (V3 + V4) / 2												
9	all	B0	2-3	3	45	N/A	N/A	-	0.68	N/A	0.34	15.3
9	all	B1	2-3	3	45	N/A	N/A	0.94	0.88	N/A	0.91	41.0
9	***all***	***B1***	***2-3***	***3***	***45***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.57***	***25.7***
26	all	C0	4	4	17	N/A	N/A	-	0.40	N/A	0.20	3.4
26	all	C1	4	4	17	N/A	N/A	0.94	0.95	N/A	0.95	16.1
26	***all***	***C1***	***4***	***4***	***17***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.75***	***12.7***
28	all	D0	4	4	23	N/A	N/A	-	0.55	N/A	0.28	6.3
28	all	D1	4	4	23	N/A	N/A	0.94	0.79	N/A	0.87	19.9
28	***all***	***D1***	***4***	***4***	***23***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.59***	***13.6***
37	all	G0	3-4	4	34	N/A	N/A	-	0.61	N/A	0.31	10.4
37	all	G1	3-4	4	34	N/A	N/A	0.94	0.76	N/A	0.85	28.9
37	***all***	***G1***	***3-4***	***4***	***34***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.54***	***18.5***
39	2 and 3	H0	3	3	0.5	N/A	N/A	-	0.81	N/A	0.41	0.2
39	2 and 3	H1	3	3	0.5	N/A	N/A	0.94	0.88	N/A	0.91	0.5
39	***2 and 3***	***H1***	***3***	***3***	***0.5***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.51***	***0.3***
40	all	I0	3	3	29	N/A	N/A	-	0.10	N/A	0.05	1.5
40	all	I1	3	3	29	N/A	N/A	0.94	0.54	N/A	0.74	21.5
40	***all***	***I1***	***3***	***3***	***29***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.69***	***20.1***

Table 17. HQI scoring and AAHU's for assessment areas with in-channel habitat limiting factors

						QI Scores for Applicable Variables						
Project Number	**Base # Assignment**	**Project Number/Base**	**Affected Reach(es)**	**Primary Reach Affected**	**Affected Acres**	**V1 - Woody Debris**	**V2 - Pools**	**V3 - Connectivity**	**V4 - Riparian Cover**	**V5 - Capacity**	**HQI**	**AAHU (Affected Acres * HQI)**
Limiting Factors for Assessment Area = In-Channel Habitat HQI = (V1 + V2) / 2												
9	all	B0	2-3	3	45	N/A	N/A	-	0.68	N/A	0.34	16.6
9	all	B1	2-3	3	45	N/A	N/A	0.94	0.88	N/A	0.91	99.5
9	***all***	***B1***	***2-3***	***3***	***45***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.57***	***82.9***
26	all	C0	4	4	17	N/A	N/A	-	0.40	N/A	0.20	3.9
26	all	C1	4	4	17	N/A	N/A	0.94	0.95	N/A	0.95	23.2
26	***all***	***C1***	***4***	***4***	***17***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.75***	***19.4***

5 SUMMARIZED CE/ICA INPUT DATA FOR IWR-PLANNING SUITE

For the purposes of comparing and evaluating alternatives, the AAHUs will be used in IWR-Planning Suite to evaluate the cost effectiveness and incremental cost of the base alternatives in combinations with the additional incremental projects. Total AAHU for incremental projects are equal to the difference in AAHU's for the without-project condition and the with-project condition for a given assessment area. Table 18 summarizes the benefits for each project increment to be used for the cost effectiveness and incremental cost analysis (CE/ICA) in IWR-Planning Suite.

Table 18. Summary of project increment benefits for CE/ICA in IWR-Planning Suite

Project Number	Base # Assignment	Project Number/Base	Project Name	Limiting Factor	Affected Reach(es)	Affected Acres	HQI	AAHU (Affected Acres * HQI)
59	1	K1	BASE #1 Complete Channel Capacity Dredging (RM 0-9) with LWD	Channel Capacity and In-Channel Habitat	0-4	219	0.84	184.2
50	2	L1	BASE #2 Confluence Channel Excavation with LWD	Channel Capacity and In-Channel Habitat	4	26	0.67	17.5
31	3	M1	BASE #3 North Fork/South Fork Confluence - Car Body Levee Removal with LWD	Channel Capacity and In-Channel Habitat	4	68	0.67	45.9
62	5	N1	BASE #5 RM 3.5-9 Dredge with LWD	Channel Capacity and In-Channel Habitat	2-4	132	0.84	111.0
9	all	B1	River Channel	Floodplain Habitat	2-3	45	0.57	25.7
26	all	C1	Dips Road	Floodplain Habitat	4	17	0.75	12.7
28	all	D1	Large Levee Setback	Floodplain Habitat	4	23	0.59	13.6
35	all	F1	Upstream LWD Installation	In-Channel Habitat	4-5	107	0.77	82.9
37	all	G1	Grange Dike	Floodplain Habitat	3-4	34	0.54	18.5
39	2 and 3	H1	Hunter Creek Mouth	Floodplain Habitat	3	0.5	0.51	0.3
40	all	I1	Hunter Creek Side Channel Habitat Reconnection	Floodplain Habitat	3	29	0.69	20.1
43	all	J1	Weaver Creek Side Channel	In-Channel Habitat	3	25	0.77	19.4

6 HOW CE/ICA INPUT DATA WILL BE USED IN IWR PLAN FOR CE/ICA ANALYSIS

It is intended that the AAHU will be used in IWR Planning Suite, certified version 2.0.6.0. Conceptual level costs are being developed for each of the incremental projects and their annualized costs will be used in the model for the cost component. Alternatives will be evaluated using the annualized construction first costs and annual operations and maintenance (O&M) costs, and the total average annual cost, which considers life cycle costs of the project.

It is anticipated that the base plans will have a large cost range and the suite of alternatives generated will show large jumps in incremental cost from one base to another. Total project cost and habitat improvement will be considered in the identification of alternatives to carry forward analysis under the National Environmental Policy Act. It may be worthwhile to carry forward a single alternative plan for each of the base alternatives that reasonably meet both sponsor cost share capability and priority habitat needs in the basin.

7 SENSITIVITY ANALYSIS

A sensitivity analysis of the habitat outputs (AAHUs) was performed to consider different weighting of the assessment metrics for the three HQI equations. Lack of channel capacity is a priority problem in the Skokomish study area and is only addressed to some extent with the base alternatives. Both the channel capacity and in-channel habitat limiting factors apply to the computation of HQI scores for the four base alternatives using the following equation:

$$HQI = \frac{V1 + V2 + V5}{3}$$

If we were to prioritize the channel capacity and weight flow capacity (V5) higher than the other two in-channel habitat assessment metrics (woody debris or V1, and pools or V2) such that flow capacity is twice as important as both V1 and V2, the HQI equation for channel capacity and in-channel habitat limiting factors would be modified as follows:

$$HQI = \frac{V1 + V2 + (2 \times V5)}{4}$$

Table 19 presents the change in HQI scores that result from weighting flow capacity twice as important as woody debris and pools for the four base alternatives. Overall change in the benefit evaluations result in a change of -7.4% to +4.0% for each affected acre. Because the scale, costs, and benefits for each of the base alternatives are greatly different, the minor changes in overall habitat quality associated with weighting capacity higher than the other two metrics would have no affect on the cost effectiveness and incremental cost analysis for these base alternatives.

Table 19. Sensitivity analysis: Weighting flow capacity (V5) twice as great as woody debris (V1) and pools (V2) for HQI computations of channel capacity and in-channel habitat limiting factors

Scenario	HQI	Scenario	HQI	Scenario	HQI	Scenario	HQI
Base 1, equal weighting of metrics	0.84	Base 2, equal weighting of metrics	0.67	Base 3, equal weighting of metrics	0.67	Base 5, equal weighting of metrics	0.84
Base 1, capacity weighted 2x	0.87	Base 2, capacity weighted 2x	0.62	Base 3, capacity weighted 2x	0.62	Base 5, capacity weighted 2x	0.87
Change in Base 1 HQI	+0.03	Change in Base 2 HQI	-0.05	Change in Base 3 HQI	-0.05	Change in Base 5 HQI	+0.03
% Change in AAHU	+4.0%	% Change in AAHU	-7.4%	% Change in AAHU	-7.4%	% Change in AAHU	+4.0%

For assessment areas that only evaluate one of the limiting factors, in-channel habitat or floodplain habitat, a sensitivity analysis on the HQI score was performed to consider weighting of one the assessment metrics to be two times more important than the other assessment metric. The equations used for the computation of in-channel habitat (woody debris or V1, and pools or V2) and floodplain habitat (connectivity or V3, and riparian habitat or V4) considered equal weighting of each of the metrics with the following equations:

- $HQI = \frac{V1+V2}{2}$ for in-channel habitat, and
- $HQI = \frac{V3+V4}{2}$ for floodplain habitat.

Weighing one assessment metric twice as great as the other assessment metric modifies these two equations as follows:

- $HQI = \frac{(2 \times V1)+V2}{3}$ for in-channel habitat where V1 is twice as great as V2;
- $HQI = \frac{V1+(2 \times V2)}{3}$ for in-channel habitat where V2 is twice as great as V1;
- $HQI = \frac{(2 \times V3)+V4}{3}$ for floodplain habitat where V3 is twice as great as V4; and
- $HQI = \frac{V3+(2 \times V4)}{3}$ for floodplain habitat where V4 is twice as great as V3.

Table 20 presents the HQI computations for project increments that address either in-channel habitat or floodplain habitat limiting factors for each of the weightings and compare the changes to HQI computations where assessment metrics are equally weighted. Overall change in the benefit evaluations result in a change of -28.5% to +28.5% for each affected acre. The project increments for these assessment areas are of much smaller scale than the base alternatives and would not affect the cost effectiveness and incremental cost analysis of the bases, but may result in minor changes to the overall cost effectiveness of the additional project increments in combination with the base alternatives.

Table 20. Sensitivity analysis: Weighting one assessment metric twice as great as other assessment metric for HQI computations of in-channel or floodplain habitat limiting factors

Project ID	V1 = V2	V1 = 2 x V2	V2 = 2 x V1	Project ID	V3 = V4	V3 = 2 x V4	V4 = 2 x V3
F1	0.77	0.79	0.76	B1	0.57	0.70	0.45
J1	0.77	0.79	0.76	C1	0.75	0.81	0.68
				D1	0.59	0.71	0.47
				G1	0.54	0.68	0.41
				H1	0.51	0.65	0.36
				I1	0.69	0.77	0.61

Because the overall sensitivity to the weighting of metrics is likely to have minor effects on the cost effectiveness and incremental cost analysis, and because there is no basis found in literature to weight the measures, the team will perform the analysis assuming equal weighting of the metrics for each of the three HQI equations.

8 MODEL UNCERTAINTIES AND LIMITATIONS

With any attempt to quantify ecosystem benefits of restoration, the method will have inherent uncertainties and limitations. We have identified several in the process of developing this ecosystem benefits model. They are summarized as follows:

1) Amount of benefits not quantified

    a. We use the Salmonidae family as a “keystone species,” and as the most important ESA-listed species, for calculating habitat benefits. This assumes the majority of benefits are quantified through the metrics focused on salmonid habitat needs. The model has only five different assessment metrics, so this leaves entire categories of salmon habitat benefits unquantified.

    b. We assume that other benefits will accrue for avian, mammal, insect, and bivalve species; however, the model does not include direct predictive measurements, so there is some unknown quantity of benefits for these other biota. This is identified as one of the limitations of this model in that it is not a comprehensive accounting of all classes of biota that are expected to experience benefits.

    c. The biggest limitation of this model is that combining the unrelated qualities represented by the capacity metric versus the in-channel and floodplain metrics, then taking the average of these metrics, reduces the value of providing the critical population survival component afforded by the channel capacity measure. The results severely underestimate the value of the two alternatives that provide increased channel capacity that would reduce annual fish mortality from stranding outside the channel.

2) Benefits beyond the project footprint

    a. Successful restoration is expected to enhance salmon habitat and thereby help to increase their populations, which occupy and traverse through areas well outside of the project footprint. Salmon are a prey item for many other species, and influence structure and function throughout their spawning range, as well as provide marine derived nutrients back to the land-based, freshwater ecosystem. This model uses project footprint as the area component, which is smaller than the total area of influence of the anticipated increase in biological benefits as salmon move upstream and downstream from the project areas.

    b. Another limitation of this model is that it does not calculate the potential change in process and structure upstream and downstream from the project footprint that may accrue due to placement of LWD or removal of significant quantities of sediment. Risk and uncertainty of these actions are analyzed in the Draft Feasibility Report/Environmental Impact Statement and other project documents to ensure human safety and minimized environmental impacts; however, the benefits calculation is limited to the project footprint due to uncertainty of scope of benefits outside of the immediate project area.

3) Project design and implementation results

    a. We assume that significant sediment removal from the aggraded river to the two-year flood flow capacity will have significant short-term impacts, such as turbidity during construction, but will significantly reduce the overbank flooding that causes adult and juvenile salmonids to become stranded in the agricultural fields. The model bases benefits on the concept that this will increase the survival rate of the egg-to-migrant fry life stage. Since there have been no before-after-control-impact studies to quantify this increase in survival rate, we have a large degree of uncertainty regarding the quantification of this expected improvement in the Skokomish River.

    b. Design guidance was provided from the project fish biologist to the design engineers regarding appropriate and target quantities of LWD placement. We assume that adding LWD to the river to achieve the target based on best available science in the most recent literature on LWD loading in Pacific Northwest streams will achieve the desired effects (see: Fox et al. 2003, Fox and Bolton 2007). LWD that is anchored during construction is expected to recruit and trap other woody debris that travels downstream from the forested upper watershed. One of the limitations of this model is that there is no quantification of benefits from the growing mass of LWD recruited post construction due to uncertainty of rate and quantities.

    c. The most likely scenario for operations and maintenance of the project is to implement a recurring dredging program. This is assumed the most efficient and least environmentally damaging, compared to other options such as a sediment trap, because a regular dredging program would only remove what deposits. A sediment trap would induce deposition and require dredging every year. A trap may fill during a large flood and then bypass sediment for the rest of the year. A sediment trap is a continuous operation (trapping or removing) and may be an obstruction to fish passage. Compared to a sediment trap, periodic dredging would occur much less frequently, only when needed. For Base Options 1 and 5, a multi-year dredging plan could be implemented, rotating the dredging location. Current estimates are that dredging every 20 years could maintain capacity between the 1.33 to two-year flood return intervals for the larger dredging alternatives. For the Base Option that dredges at the North Fork confluence, dredging every 10 years would be required to maintain capacity because the confluence area is shallower than other reaches of the river.

4) Predictability of inputs from the upper watershed above the study area

    a. Water: We have large uncertainty regarding the flood flows that will occur during and after construction. We can only calculate the probability of any flow level based on history of exceedances, but cannot predict what will occur during and after construction.

b. LWD: The upper watershed of the Skokomish basin has large logjams and is largely forested across most of the landscape. LWD inputs into the study area are difficult to predict, but may be improving as landscape management of commercial forestry practices improves.

c. Sediment: The Corps estimates that the bedload inflow from the upper watershed is approximately 30,000 to 40,000 cubic yards per year. The primary source is natural erosion with some contribution from landslides that may occur due to present or past timber harvests on steep slopes or logging roads that cause erosion and sedimentation. The contributions from forestry practices are assumed to be decreasing as roads are being decommissioned on public lands and more erosion prevention measures are used in public and private timber harvests. However, the primary source is a natural occurrence and the rate cannot be precisely predicted for any given year, only in averages and trends.

5) Operational modifications at Cushman Dam on the North Fork Skokomish River

a. Seattle District is familiar with the provisions of the relicensing agreement and will continue to coordinate with the settlement parties as alternative plans are developed. The settlement agreement places no legal restrictions or responsibilities on the Corps.

b. The settlement agreement has established monthly base flows that are being implemented by the operating project; flushing flows are not being implemented at this time due to a lack of channel capacity to carry the flows (flushing flows would induce flooding downstream of the dam).

c. Operation of upstream reservoirs has been taken into consideration during the alternatives formulation process; the without project condition and future without project includes the current and likely future flow regimes from Cushman Dam. Future flow modifications from Cushman Dam could increase flows in the North Fork (e.g., implementation of North Fork flushing flows), though the impacts of these flows would minimally affect the alternatives proposed under the GI. The recommended plan may allow for the future implementation of flushing flows but the Corps will not formulate, evaluate, or select a plan based on this effect. Dam flows from the North Fork enter the study area at RM 7.5, while the study area extends upstream to RM 12.

6) Habitat development after construction

a. Each metric has assumptions stated for the temporal scale of how benefits will accrue after construction. These are based on literature, best professional judgment, and Corps staff's personal observations of similar projects.

b. Primary uncertainty lies within the prediction of stability of the riverbed after significant quantities of sediment are removed. There is no metric to score for more or less stability.

c. Quantity and velocity of water will affect development of habitat after construction, so this ties back to the inability to predict when and what level of high flow events will occur after construction.

7) Predicting future with-project and future without-project

    a. Uncertainties regarding predicting the future have largely been covered previously in this chapter. One of the limitations specific to the scores for future without project is that using the relationship derived from historical data to predict the future assumes that there are certain steady-state conditions among the complex ecosystem processes, structures, and functions. We assume that the degrading habitat will continue to degrade at the same rate, or that it is already as bad as it can get and therefore the score for the future without-project is the same as the existing conditions.

    b. Predicting the future with-project scores relies on the assumption that the project will function as designed and therefore deserves the score it is given according to the metric. There is unquantifiable uncertainty in this outcome, but a Monitoring and Adaptive Management Plan will be designed to maximize benefits.

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Appendix A: Skokomish Environmental Benefits Analysis Spreadsheet – A Guide to the Worksheets and Computations

The intent of this appendix is to support the documentation of the main model documentation report and provide a guide to the worksheets contained within the Skokomish Environmental Benefits Analysis Spreadsheet. Tables and information contained within the worksheet are provided here, along with the formulas used to derive environmental outputs for project increments considered for the Skokomish River General Investigation at this time. Each Section corresponds to a single worksheet within the model, which also corresponds to the ID's in Section 1, Table of Contents.

Background to the assessment metrics, valuations, and equations are contained in the main report. The functions used within the model are directly related to the information provided in the main report. Much of the information contained within the spreadsheet was derived from team input and no computations were required. The table found in the 'CE ICA INPUT DATA' worksheet contains the majority of the computations that will feed the cost effectiveness and incremental cost analyses (CE/ICA) for the study.

1 TABLE OF CONTENTS

A table of contents worksheet is included to provide links to the individual worksheets within the model. A total of 12 worksheets are included and are summarized as follows.

ID	Worksheet	Content Description
1	Table of Contents	This tab describes the contents of each of the worksheets included in the Skokomish Environmental Benefits Analysis (EBA) Spreadsheet Model. The EBA Model is used to derive the environmental outputs needed to evaluate alternatives in IWR-Planning Suite for cost effectiveness and incremental analysis. The procedures, environmental basis for the outputs, and the plan formulation are described in the model certification document that accompanies this report.
2	INPUT DATA	These are the project increments/measures identified by the project development team (PDT) to address degraded habitat in the lower Skokomish River Basin. Included are the project number, project name, affected reach or reaches, a primary affected reach, affected acreage, and a designation of which limiting factors apply to the assessment area. This project data is carried forward in the development of average annual habitat units and is included in several other worksheets including 'CombinabilityBasePlans', 'IncrementstoBases', and 'CE ICA INPUT DATA'.

ID	Worksheet	Content Description
3	CombinabilityBasePlans	The PDT conducted an exercise to identify combinability of projects and measures to the bases. No two incremental projects are mutually exclusive, and all other project increments are combinable with exception of the four base alternatives.
4	IncrementstoBases	This worksheet carries forward the project information from the 'INPUT DATA' worksheet and the project relationships from the 'CombinabilityBasePlans' worksheet to show all of the possible incremental projects and the bases they may be combined with. Projects are denoted by a letter and number for CE/ICA in IWR-Planning Suite.
5	Assessment Metric HQI	The assessment metric existing, future without-project, and future with-project condition, and average annual HQI benefit scores (or change from the without project condition to the with project condition) are summarized here. The existing, future without-project, and future with-project scores are derived in worksheets for each of the assessment metrics ('Channel – Pools HQI', 'Channel - Woody Debris HQI', 'Floodplain - Riparian Cover HQI', and 'Floodplain – Connectivity HQI'). These HQI scores are used for computation of average annual habitat units in the 'CE/ICA INPUT DATA' worksheet.
6	Capacity HQI	This worksheet documents the computations of the existing, future without-project, and future with-project HQI scores by assessing change in habitat quality for the flow capacity assessment metric over the study period for each of the base alternatives.
7	Channel – Pools HQI	This worksheet documents the computations of the existing future without-project, and future with-project HQI scores by assessing change in habitat quality for the pool assessment metric over time. Habitat changes were noted at appropriate points in time, and HQI scores were linearly interpolated between these points. The without and with project HQI scores average the HQI values over a 50-year time horizon. The benefit or change in habitat quality is the difference between the average annuals HQI scores for the future without-project and future with-project conditions.
8	Channel - Woody Debris HQI	This worksheet documents the computations of the existing, future without-project, and future with-project HQI scores by assessing change in habitat quality for the woody debris assessment metric over time. Habitat changes were noted at appropriate points in time, and HQI scores were linearly interpolated between these points. The without and with project HQI scores average the HQI values over a 50-year time horizon. The benefit or change in habitat quality is the difference between the average annuals HQI scores for the future without-project and future with-project conditions.

ID	Worksheet	Content Description
9	Floodplain - Riparian Cover HQI	This worksheet documents the computations of the existing, future without-project, and future with-project HQI scores by assessing change in habitat quality for the riparian cover assessment metric over the study period for each of the assessment areas. Habitat changes were noted at appropriate points in time, and HQI scores were linearly interpolated between these points. The without and with project HQI scores average the HQI values over a 50-year time horizon. The benefit or change in habitat quality is the difference between the average annuals HQI scores for the future without-project and future with-project conditions.
10	Floodplain – Connectivity HQI	This worksheet documents the computations of the existing, future without-project, and future with-project HQI scores by assessing change in habitat quality for the connectivity assessment metric over time. Habitat changes were noted at appropriate points in time, and HQI scores were linearly interpolated between these points. The without and with project HQI scores average the HQI values over a 50-year time horizon. The benefit or change in habitat quality is the difference between the average annuals HQI scores for the future without-project and future with-project conditions.
11	CE ICA INPUT DATA	This worksheet contains the computations of AAHU by assessment area and net benefits for each of the project increments. The benefits will be used for cost effectiveness and incremental cost analyses (CE/ICA) analysis in IWR-Planning Suite.
12	CE ICA Sensitivity Analysis	This worksheet presents a sensitivity analysis of the change in HQI and AAHU when one assessment metric is weighted greater than the other one or two assessment metrics for the three HQI equations.

2 'INPUT DATA' WORKSHEET

These are the project increments/measures identified by the study team to address degraded habitat in the lower Skokomish River Basin. Items included are the project number, project name, affected reach or reaches, a primary affected reach, affected acreage, and applicable limiting factor(s) for the assessment area. This project data is carried forward in the development of average annual habitat units and is included in several other worksheets including 'CombinabilityBasePlans', 'IncrementstoBases', and 'CE ICA INPUT DATA'. This table is included as Table 14 in the main model documentation report.

3 'COMBINABILITYBASEPLANS' WORKSHEET

The PDT went through an exercise to identify combinability of projects/measures to the bases. No two incremental projects are mutually exclusive, and thus all incremental projects combinable with a base were also combinable with one another. This table is included as Table 13 in the main model documentation report.

AAHUs are computed for an assessment area by multiplying the HQI given the applicable limiting factor(s) and the affected acres as follows:

$$AAHU = HQI\ x\ Affected\ Area$$

4 ‘INCREMENTSTOBASES’ WORKSHEET

This worksheet carries forward the project information from the 'INPUT DATA' worksheet and the project relationships from the 'CombinabilityBasePlans' worksheet to show all of the possible increments of projects and the bases to which they may be assigned. This was a planning exercise and no formulas are included in this worksheet. This table is included as Table 13 in the main model documentation report.

5 ‘ASSESSMENT METRIC HQI’ WORKSHEET

The assessment metric existing, future without-project and future with-project condition, and average annual HQI benefit (or change from the without project condition to the with project condition) are summarized here. The existing, future without-project, and future with-project scores are derived in worksheets for each of the assessment metrics (‘Capacity HQI’, 'Channel – Pools HQI', 'Channel - Woody Debris HQI', 'Floodplain - Riparian Cover HQI', and 'Floodplain – Connectivity HQI'). The formulas or locations for each of the values are provided to the right in the following table.

Row /Column	B	C	D	E	F	G	H	I	F	G	H	I
4	Limiting Factor	Assessment Metric	Base	Project ID	Existing Habitat Quality Index Score	Average Future Without-Project (FWOP) Habitat Quality Index Score	Average Future With-Project (FWP) Habitat Quality Index Score	Average Benefit (change in HQI from FWOP to FWP, or FWOP HQI - FWP HQI)	Existing Habitat Quality Index Score	Average Future Without-Project (FWOP) Habitat Quality Index Score	Average Future With-Project (FWP) Habitat Quality Index Score	Average Benefit (change in HQI from FWOP to FWP, or FWOP HQI - FWP HQI)
5												
6	Channel Habitat	Pools	all	N/A	0.21	0.21	0.93	0.72	='Channel - Pools HQI'!B6	='Channel - Pools HQI'!B58	='Channel - Pools HQI'!C58	=H6-G6
7		Woody Debris	all	N/A	0.10	0.10	0.93	0.83	='Channel - Woody Debris HQI'!B6	='Channel - Woody Debris HQI'!B58	='Channel - Woody Debris HQI'!C58	=H7-G7
8	Floodplain Habitat	Riparian Cover	all	9	0.68	0.68	0.88	0.20	='Floodplain - Riparian Cover HQI'!B7	='Floodplain - Riparian Cover HQI'!B59	='Floodplain - Riparian Cover HQI'!C59	=H8-G8
9			all	26	0.40	0.40	0.95	0.55	='Floodplain - Riparian Cover HQI'!D7	='Floodplain - Riparian Cover HQI'!D59	='Floodplain - Riparian Cover HQI'!E59	=H9-G9
10			all	28	0.55	0.55	0.79	0.24	='Floodplain - Riparian Cover HQI'!F7	='Floodplain - Riparian Cover HQI'!F59	='Floodplain - Riparian Cover HQI'!G59	=H10-G10
11			all	37	0.61	0.61	0.76	0.15	='Floodplain - Riparian Cover HQI'!H7	='Floodplain - Riparian Cover HQI'!H59	='Floodplain - Riparian Cover HQI'!I59	=H11-G11
12			all	39	0.81	0.81	0.88	0.07	='Floodplain - Riparian Cover HQI'!J7	='Floodplain - Riparian Cover HQI'!J59	='Floodplain - Riparian Cover HQI'!K59	=H12-G12

Row /Column	B	C	D	E	F	G	H	I	*F*	*G*	*H*	*I*
4	Limiting Factor	Assessment Metric	Base	Project ID	Existing Habitat Quality Index Score	Average Future Without-Project (FWOP) Habitat Quality Index Score	Average Future With-Project (FWP) Habitat Quality Index Score	Average Benefit (change in HQI from FWOP to FWP, or FWOP HQI - FWP HQI)	*Existing Habitat Quality Index Score*	*Average Future Without-Project (FWOP) Habitat Quality Index Score*	*Average Future With-Project (FWP) Habitat Quality Index Score*	*Average Benefit (change in HQI from FWOP to FWP, or FWOP HQI - FWP HQI)*
13			all	40	0.10	0.10	0.54	0.44	*='Floodplain - Riparian Cover HQI'!L7*	*='Floodplain - Riparian Cover HQI'!L59*	*='Floodplain - Riparian Cover HQI'!M59*	*=H13-G13*
14			all	43	0.06	0.06	0.45	0.39	*='Floodplain - Riparian Cover HQI'!N7*	*='Floodplain - Riparian Cover HQI'!N59*	*='Floodplain - Riparian Cover HQI'!O59*	*=H14-G14*
15		Connectivity	all	N/A	0.00	0.00	0.94	0.94	*='Floodplain - Connectivity HQI'!B6*	*='Floodplain - Connectivity HQI'!B58*	*='Floodplain - Connectivity HQI'!C58*	*=H15-G15*
16	Channel Capacity	Flow Capacity	1	N/A	0.17	0.17	1.00	0.83	*='Capacity HQI'!E6*	*='Capacity HQI'!F6*	*='Capacity HQI'!G6*	*=H16-G16*
17		Flow Capacity	2	N/A	0.17	0.17	0.50	0.33	*='Capacity HQI'!E7*	*='Capacity HQI'!F7*	*='Capacity HQI'!G7*	*=H17-G17*
18		Flow Capacity	3	N/A	0.17	0.17	0.50	0.33	*='Capacity HQI'!E8*	*='Capacity HQI'!F8*	*='Capacity HQI'!G8*	*=H18-G18*
19		Flow Capacity	5	N/A	0.17	0.17	1.00	0.83	*='Capacity HQI'!E9*	*='Capacity HQI'!F9*	*='Capacity HQI'!G9*	*=H19-G19*

6 'CAPACITY HQI' WORKSHEET

This worksheet documents the computations of the existing, future without- and future with-project HQI scores by assessing change in habitat quality for the flow capacity assessment metric over time. This is assessed by base alternative. Habitat changes were noted at appropriate points in time, and HQI scores were linearly interpolated between these points. The without and with project HQI scores average the HQI values over a 50-year time horizon. The benefit or change in habitat quality is the difference between the average annuals HQI scores for the future without- and future with-project conditions.

All base alternatives have an existing condition aggraded score of less than the one-year score, with flood recurrence at approximately four times per year in the existing condition and approaching no flood capacity by year 20 in the without project condition. With restoration, Bases 1 and 5 will provide approximately two-year flow capacity with a score equal to 1; Bases 2 and 3 will provide approximately one-year capacity with a score equal to 0.5. These values are displayed in the table below and are populated in the 'Assessment Metric HQI' worksheet.

Row / Column	B	C	D	E	F	G	H	*E*	*F*	*G*	*H*
4	Limiting Factor	Assessment Metric	Base	Existing Habitat Quality Index Score	Average Future Without-Project (FWOP) Habitat Quality Index Score	Average Future With-Project (FWP) Habitat Quality Index Score	Average Change in HQI from FWOP to FWP	*Existing Habitat Quality Index Score*	*Average Future Without-Project (FWOP) Habitat Quality Index Score*	*Average Future With-Project (FWP) Habitat Quality Index Score*	*Average Change in HQI from FWOP to FWP*
6	Channel Capacity	Flow Capacity	1	0.13	0.03	1.00	0.97	*=$B$40*	*=$B$92*	*=1/1*	*=G6-F6*
7	Channel Capacity	Flow Capacity	2	0.13	0.03	0.50	0.47	*=$B$40*	*=$B$92*	*=1/2*	*=G7-F7*
8	Channel Capacity	Flow Capacity	3	0.13	0.03	0.50	0.47	*=$B$40*	*=$B$92*	*=1/2*	*=G8-F8*
9	Channel Capacity	Flow Capacity	5	0.13	0.03	1.00	0.97	*=$B$40*	*=$B$92*	*=1/1*	*=G9-F9*

Row/Column	A	B	C	*B*	*C*
35	**WORKSHEET**				
36	**Quality index scores over the period of analysis**				
37	**Limiting Factor**	**Channel Capacity**			
38	**Assessment Metric**	**Flow Capacity**			
39	**Year**	**Without Project Condition**	**Slope**	***Without Project Condition***	***With Project Condition***
40	0	**0.13**		**=1/8**	
41	1	0.12	-0.6%	=B40+$C$41	=(B60-B40)/(A60-A40)
42	2	0.11		=B41+$C$41	

Row/Column	A	B	C	*B*	*C*
35	**WORKSHEET**				
36	**Quality index scores over the period of analysis**				
37	**Limiting Factor**	**Channel Capacity**			
38	**Assessment Metric**	**Flow Capacity**			
39	**Year**	**Without Project Condition**	**Slope**	***Without Project Condition***	***With Project Condition***
43	3	0.11		=B42+$C$41	
44	4	0.10		=B43+$C$41	
45	5	0.09		=B44+$C$41	
46	6	0.09		=B45+$C$41	
47	7	0.08		=B46+$C$41	
48	8	0.08		=B47+$C$41	
49	9	0.07		=B48+$C$41	
50	10	0.06		=B49+$C$41	
51	11	0.06		=B50+$C$41	
52	12	0.05		=B51+$C$41	
53	13	0.04		=B52+$C$41	
54	14	0.04		=B53+$C$41	
55	15	0.03		=B54+$C$41	
56	16	0.03		=B55+$C$41	
57	17	0.02		=B56+$C$41	
58	18	0.01		=B57+$C$41	
59	19	0.01		=B58+$C$41	
60	20	-		**0**	
61	21	-		0	
62	22	-		0	
63	23	-		0	
64	24	-		0	
65	25	-		0	
66	26	-		0	
67	27	-		0	
68	28	-		0	
69	29	-		0	
70	30	-		0	
71	31	-		0	
72	32	-		0	
73	33	-		0	
74	34	-		0	
75	35	-		0	
76	36	-		0	
77	37	-		0	
78	38	-		0	
79	39	-		0	
80	40	-		0	
81	41	-		0	
82	42	-		0	
83	43	-		0	
84	44	-		0	
85	45	-		0	
86	46	-		0	
87	47	-		0	
88	48	-		0	
89	49	-		0	
90	50	-		0	
91		**Without project condition**		**Without project condition**	
92	Average	0.03		=AVERAGE(B40:B90)	

7 'CHANNEL – POOLS HQI' WORKSHEET

This worksheet documents the computations of the existing, future without-project, and future with-project HQI scores by assessing change in habitat quality for the pool assessment metric over time. Habitat changes were noted at appropriate points in time, and HQI scores were linearly interpolated between these points. The without- and with-project HQI scores average the HQI values over a 50-year time horizon. The benefit or change in habitat quality is the difference between the average annual HQI scores for the future without- and future with-project conditions. A graph is generated that plots the HQI values for the future without- and future with-project time curves over the period of analysis. Column D has equations to compute the slope (rise) between two known points. Formulas for each of the cells are contained in the columns to the right. More information about the habitat quality scoring and time curves for the future without- and with project HQI scores can be found within in the main report.

Row/ Column	A	B	C	D	*B*	*C*	*D*
1	**WORKSHEET**						
2	**Quality index scores over the period of analysis**						
3	**Limiting Factor**	**Channel Habitat**					
4	**Assessment Metric**	**Pools**					
5	**Year**	**Without Project Condition**	**With Project Condition**	**Slope**	***Without Project Condition***	***With Project Condition***	***Slope***
6	0	**0.21**	**0.21**		**0.21**	**0.21**	
7	1	0.21	0.32		0.21	=C6+$D$9	
8	2	0.21	0.44		0.21	=C7+$D$9	
9	3	0.21	0.55	11.40%	0.21	=C8+$D$9	=(C11-C6)/(5-0)
10	4	0.21	0.67		0.21	=C9+$D$9	
11	5	0.21	**0.78**		0.21	**0.78**	
12	6	0.21	0.82	4.40%	0.21	=C11+$D$12	=(C16-C11)/(A16-A11)
13	7	0.21	0.87		0.21	=C12+$D$12	
14	8	0.21	0.91		0.21	=C13+$D$12	
15	9	0.21	0.96		0.21	=C14+$D$12	
16	10	0.21	**1.00**		0.21	**1**	
17	11	0.21	1.00		0.21	1	
18	12	0.21	1.00		0.21	1	
19	13	0.21	1.00		0.21	1	
20	14	0.21	1.00		0.21	1	
21	15	0.21	1.00		0.21	1	
22	16	0.21	1.00		0.21	1	
23	17	0.21	1.00		0.21	1	
24	18	0.21	1.00		0.21	1	
25	19	0.21	1.00		0.21	1	
26	20	0.21	1.00		0.21	1	
27	21	0.21	1.00		0.21	1	
28	22	0.21	1.00		0.21	1	
29	23	0.21	1.00		0.21	1	
30	24	0.21	1.00		0.21	1	
31	25	0.21	1.00		0.21	1	
32	26	0.21	1.00		0.21	1	
33	27	0.21	1.00		0.21	1	
34	28	0.21	1.00		0.21	1	

Row/Column	A	B	C	D	*B*	*C*	*D*
1	**WORKSHEET**						
2	**Quality index scores over the period of analysis**						
3	**Limiting Factor**	**Channel Habitat**					
4	**Assessment Metric**	**Pools**					
5	**Year**	**Without Project Condition**	**With Project Condition**	**Slope**	***Without Project Condition***	***With Project Condition***	***Slope***
35	29	0.21	1.00		0.21	1	
36	30	0.21	1.00		0.21	1	
37	31	0.21	1.00		0.21	1	
38	32	0.21	1.00		0.21	1	
39	33	0.21	1.00		0.21	1	
40	34	0.21	1.00		0.21	1	
41	35	0.21	1.00		0.21	1	
42	36	0.21	1.00		0.21	1	
43	37	0.21	1.00		0.21	1	
44	38	0.21	1.00		0.21	1	
45	39	0.21	1.00		0.21	1	
46	40	0.21	1.00		0.21	1	
47	41	0.21	1.00		0.21	1	
48	42	0.21	1.00		0.21	1	
49	43	0.21	1.00		0.21	1	
50	44	0.21	1.00		0.21	1	
51	45	0.21	1.00		0.21	1	
52	46	0.21	1.00		0.21	1	
53	47	0.21	1.00		0.21	1	
54	48	0.21	1.00		0.21	1	
55	49	0.21	1.00		0.21	1	
56	50	0.21	1.00		0.21	1	
57		**Without project condition**	**With Project Condition**		**Without project condition**	**With Project Condition**	**Without project condition**
58	Average	0.21	0.93		=AVERAGE(B6:B56)	=AVERAGE(C6:C56)	=AVERAGE(B6:B56)
59	Average change (benefit)		0.72			=C58-B58	

8 'CHANNEL – WOODY DEBRIS HQI' WORKSHEET

This worksheet documents the computations of the existing, future without-project, and future with-project HQI scores by assessing change in habitat quality for the woody debris assessment metric over time. Habitat changes were noted at appropriate points in time, and HQI scores were linearly interpolated between these points. The without- and with-project HQI scores average the HQI values over a 50-year time horizon. The benefit or change in habitat quality is the difference between the average annual HQI scores for the future without- and future with-project conditions. A graph is generated that plots the HQI values for the future without- and future with-project time curves over the period of analysis. Column D has equations to compute the slope (rise) between two known points. Formulas for each of the cells are contained in the columns to the right. More information about the habitat quality scoring and time curves for the future without- and with-project HQI scores can be found within in the main report.

Row/Column	A	B	C	D	*B*	*C*	*D*
1	**WORKSHEET**						
2	**Quality index scores over the period of analysis**						
3	**Limiting Factor**	**Channel Habitat**					
4	**Assessment Metric**	**Woody Debris**					
5	**Year**	**Without Project Condition**	**With Project Condition**	**Slope**	***Without Project Condition***	***With Project Condition***	***Slope***
6	0	**0.10**	**0.10**		**0.1**	**0.1**	
7	1	0.10	0.24	14%	0.1	=C6+$D$7	=(C11-C6)/(A11-A6)
8	2	0.10	0.38		0.1	=C7+$D$7	
9	3	0.10	0.52		0.1	=C8+$D$7	
10	4	0.10	0.66		0.1	=C9+$D$7	
11	5	0.10	**0.80**		0.1	**0.8**	
12	6	0.10	0.84	4%	0.1	=C11+$D$12	=(C16-C11)/(A16-A11)
13	7	0.10	0.88		0.1	=C12+$D$12	
14	8	0.10	0.92		0.1	=C13+$D$12	
15	9	0.10	0.96		0.1	=C14+$D$12	
16	10	0.10	**1.00**		0.1	**1**	
17	11	0.10	1.00		0.1	=IF(C16+$D$7>1,1,C16+$D$7)	
18	12	0.10	1.00		0.1	=IF(C17+$D$7>1,1,C17+$D$7)	
19	13	0.10	1.00		0.1	=IF(C18+$D$7>1,1,C18+$D$7)	
20	14	0.10	1.00		0.1	=IF(C19+$D$7>1,1,C19+$D$7)	
21	15	0.10	1.00		0.1	=IF(C20+$D$7>1,1,C20+$D$7)	
22	16	0.10	1.00		0.1	=IF(C21+$D$7>1,1,C21+$D$7)	
23	17	0.10	1.00		0.1	=IF(C22+$D$7>1,1,C22+$D$7)	
24	18	0.10	1.00		0.1	=IF(C23+$D$7>1,1,C23+$D$7)	
25	19	0.10	1.00		0.1	=IF(C24+$D$7>1,1,C24+$D$7)	
26	20	0.10	1.00		0.1	=IF(C25+$D$7>1,1,C25+$D$7)	
27	21	0.10	1.00		0.1	=IF(C26+$D$7>1,1,C26+$D$7)	
28	22	0.10	1.00		0.1	=IF(C27+$D$7>1,1,C27+$D$7)	
29	23	0.10	1.00		0.1	=IF(C28+$D$7>1,1,C28+$D$7)	
30	24	0.10	1.00		0.1	=IF(C29+$D$7>1,1,C29+$D$7)	
31	25	0.10	1.00		0.1	=IF(C30+$D$7>1,1,C30+$D$7)	
32	26	0.10	1.00		0.1	=IF(C31+$D$7>1,1,C31+$D$7)	
33	27	0.10	1.00		0.1	=IF(C32+$D$7>1,1,C32+$D$7)	
34	28	0.10	1.00		0.1	=IF(C33+$D$7>1,1,C33+$D$7)	
35	29	0.10	1.00		0.1	=IF(C34+$D$7>1,1,C34+$D$7)	
36	30	0.10	1.00		0.1	=IF(C35+$D$7>1,1,C35+$D$7)	
37	31	0.10	1.00		0.1	=IF(C36+$D$7>1,1,C36+$D$7)	
38	32	0.10	1.00		0.1	=IF(C37+$D$7>1,1,C37+$D$7)	
39	33	0.10	1.00		0.1	=IF(C38+$D$7>1,1,C38+$D$7)	
40	34	0.10	1.00		0.1	=IF(C39+$D$7>1,1,C39+$D$7)	
41	35	0.10	1.00		0.1	=IF(C40+$D$7>1,1,C40+$D$7)	
42	36	0.10	1.00		0.1	=IF(C41+$D$7>1,1,C41+$D$7)	
43	37	0.10	1.00		0.1	=IF(C42+$D$7>1,1,C42+$D$7)	
44	38	0.10	1.00		0.1	=IF(C43+$D$7>1,1,C43+$D$7)	
45	39	0.10	1.00		0.1	=IF(C44+$D$7>1,1,C44+$D$7)	
46	40	0.10	1.00		0.1	=IF(C45+$D$7>1,1,C45+$D$7)	
47	41	0.10	1.00		0.1	=IF(C46+$D$7>1,1,C46+$D$7)	
48	42	0.10	1.00		0.1	=IF(C47+$D$7>1,1,C47+$D$7)	
49	43	0.10	1.00		0.1	=IF(C48+$D$7>1,1,C48+$D$7)	
50	44	0.10	1.00		0.1	=IF(C49+$D$7>1,1,C49+$D$7)	
51	45	0.10	1.00		0.1	=IF(C50+$D$7>1,1,C50+$D$7)	
52	46	0.10	1.00		0.1	=IF(C51+$D$7>1,1,C51+$D$7)	
53	47	0.10	1.00		0.1	=IF(C52+$D$7>1,1,C52+$D$7)	
54	48	0.10	1.00		0.1	=IF(C53+$D$7>1,1,C53+$D$7)	

Row/Column	A	B	C	D	*B*	*C*	*D*
1	**WORKSHEET**						
2	**Quality index scores over the period of analysis**						
3	**Limiting Factor**	**Channel Habitat**					
4	**Assessment Metric**	**Woody Debris**					
5	**Year**	**Without Project Condition**	**With Project Condition**	**Slope**	***Without Project Condition***	***With Project Condition***	***Slope***
55	49	0.10	1.00		0.1	=IF(C54+$D$7>1,1,C54+$D$7)	
56	50	**0.10**	1.00		**0.1**	=IF(C55+$D$7>1,1,C55+$D$7)	
57							
58	Average	0.10	0.93		=AVERAGE(B6:B56)	=AVERAGE(C6:C56)	
59	Average change (benefit)		0.83			=C58-B58	

9 'FLOODPLAIN – RIPARIAN COVER HQI' WORKSHEET

This worksheet documents the computations of the existing, future without- and future with-project HQI scores by assessing change in habitat quality for the riparian cover assessment metric over time. Habitat quality is assessed by assessment area for each of the project increments. Habitat changes were noted at appropriate points in time, and HQI scores were linearly interpolated between these points. The without- and with-project HQI scores average the HQI values over a 50-year time horizon. The benefit or change in habitat quality is the difference between the average annual HQI scores for the future without- and future with-project conditions. A graph is generated that plots the HQI values for the future without- and future with-project time curves for each of the assessment areas over the period of analysis. Formulas for each of the cells are contained in the second table. More information about the habitat quality scoring and time curves for the future without- and with-project HQI scores can be found within in the main report.

Row / Column	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	**WORKSHEET**														
2	**Quality index scores over the period of analysis**														
3	**Limiting Factor**	**Floodplain Habitat**													
4	**Assessment Metric**	**Riparian Cover**													
5	**Project Assessment Area**	**9**	**9**	**26**	**26**	**28**	**28**	**37**	**37**	**39**	**39**	**40**	**40**	**43**	**43**
6	**Year**	**Project 9 Without Project**	**Project 9 With Project**	**Project 26 Without Project**	**Project 26 With Project**	**Project 28 Without Project**	**Project 28 With Project**	**Project 37 Without Project**	**Project 37 With Project**	**Project 39 Without Project**	**Project 39 With Project**	**Project 40 Without Project**	**Project 40 With Project**	**Project 43 Without Project**	**Project 43 With Project**
7	**0**	**0.68**	**0.68**	**0.4**	**0.4**	**0.55**	**0.55**	**0.61**	**0.61**	**0.81**	**0.81**	**0.1**	**0.1**	**0.06**	**0.06**
8	**1**	0.68	0.72	0.4	0.50	0.55	0.59	0.61	0.64	0.81	0.82	0.1	0.18	0.06	0.13
9	**2**	0.68	0.75	0.4	0.59	0.55	0.63	0.61	0.66	0.81	0.84	0.1	0.25	0.06	0.19
10	**3**	0.68	0.79	0.4	0.69	0.55	0.67	0.61	0.69	0.81	0.85	0.1	0.33	0.06	0.26
11	**4**	0.68	0.82	0.4	0.78	0.55	0.72	0.61	0.71	0.81	0.86	0.1	0.41	0.06	0.33
12	**5**	0.68	**0.86**	0.4	**0.88**	0.55	**0.76**	0.61	**0.74**	0.81	**0.87**	0.1	**0.48**	0.06	**0.40**
13	**6**	0.68	0.86	0.4	0.90	0.55	0.77	0.61	0.74	0.81	0.88	0.1	0.50	0.06	0.41
14	**7**	0.68	0.87	0.4	0.93	0.55	0.78	0.61	0.75	0.81	0.88	0.1	0.52	0.06	0.43
15	**8**	0.68	0.88	0.4	0.95	0.55	0.79	0.61	0.76	0.81	0.88	0.1	0.54	0.06	0.45
16	**9**	0.68	0.89	0.4	0.98	0.55	0.80	0.61	0.76	0.81	0.89	0.1	0.56	0.06	0.46
17	**10**	0.68	**0.90**	0.4	**1**	0.55	**0.81**	0.61	**0.77**	0.81	**0.89**	0.1	**0.58**	0.06	**0.48**
18	**11**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
19	**12**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
20	**13**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
21	**14**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
22	**15**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
23	**16**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
24	**17**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
25	**18**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
26	**19**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
27	**20**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
28	**21**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
29	**22**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
30	**23**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
31	**24**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
32	**25**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
33	**26**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
34	**27**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
35	**28**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
36	**29**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
37	**30**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
38	**31**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
39	**32**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
40	**33**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
41	**34**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
42	**35**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
43	**36**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
44	**37**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
45	**38**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
46	**39**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
47	**40**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
48	**41**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
49	**42**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
50	**43**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
51	**44**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
52	**45**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
53	**46**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48

Row / Column	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	**WORKSHEET**														
2	**Quality index scores over the period of analysis**														
3	**Limiting Factor**	**Floodplain Habitat**													
4	**Assessment Metric**	**Riparian Cover**													
5	**Project Assessment Area**	**9**	**9**	**26**	**26**	**28**	**28**	**37**	**37**	**39**	**39**	**40**	**40**	**43**	**43**
6	**Year**	**Project 9 Without Project**	**Project 9 With Project**	**Project 26 Without Project**	**Project 26 With Project**	**Project 28 Without Project**	**Project 28 With Project**	**Project 37 Without Project**	**Project 37 With Project**	**Project 39 Without Project**	**Project 39 With Project**	**Project 40 Without Project**	**Project 40 With Project**	**Project 43 Without Project**	**Project 43 With Project**
54	**47**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
55	**48**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
56	**49**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
57	**50**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
58		**9 WOP**	**9 WP**	**26 WOP**	**26 WP**	**28 WOP**	**29 WP**	**37 WOP**	**37 WP**	**39 WOP**	**39 WP**	**40 WOP**	**40 WP**	**43 WOP**	**43 WP**
59	**Average**	0.68	0.88	0.40	0.95	0.55	0.79	0.61	0.76	0.81	0.88	0.10	0.54	0.06	0.45
60	**Average change (benefit)**		0.20		0.55		0.24		0.15		0.07		0.44		0.39

Row / Column	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	**WORKSHEET**														
2	**Quality index scores over the period of analysis**														
3	**Limiting Factor**	**Floodplain Habitat**													
4	**Assessment Metric**	**Riparian Cover**													
5	**Project Assessment Area**	**9**	**9**	**26**	**26**	**28**	**28**	**37**	**37**	**39**	**39**	**40**	**40**	**43**	**43**
6	**Year**	**Project 9 Without Project**	**Project 9 With Project**	**Project 26 Without Project**	**Project 26 With Project**	**Project 28 Without Project**	**Project 28 With Project**	**Project 37 Without Project**	**Project 37 With Project**	**Project 39 Without Project**	**Project 39 With Project**	**Project 40 Without Project**	**Project 40 With Project**	**Project 43 Without Project**	**Project 43 With Project**
7	**0**	**0.68**	**0.68**	**0.4**	**0.4**	**0.55**	**0.55**	**0.61**	**0.61**	**0.81**	**0.81**	**0.1**	**0.1**	**0.06**	**0.06**
8	**1**	0.68	=C7+((C$12-C$7)/($A$12-$A$7))	0.4	=E7+((E$12-E$7)/($A$12-$A$7))	0.55	=G7+((G$12-G$7)/($A$12-$A$7))	0.61	=I7+((I$12-I$7)/($A$12-$A$7))	0.81	=K7+((K$12-K$7)/($A$12-$A$7))	0.1	=M7+((M$12-M$7)/($A$12-$A$7))	0.06	=O7+((O$12-O$7)/($A$12-$A$7))
9	**2**	0.68	=C8+((C$12-C$7)/($A$12-$A$7))	0.4	=E8+((E$12-E$7)/($A$12-$A$7))	0.55	=G8+((G$12-G$7)/($A$12-$A$7))	0.61	=I8+((I$12-I$7)/($A$12-$A$7))	0.81	=K8+((K$12-K$7)/($A$12-$A$7))	0.1	=M8+((M$12-M$7)/($A$12-$A$7))	0.06	=O8+((O$12-O$7)/($A$12-$A$7))
10	**3**	0.68	=C9+((C$12-C$7)/($A$12-$A$7))	0.4	=E9+((E$12-E$7)/($A$12-$A$7))	0.55	=G9+((G$12-G$7)/($A$12-$A$7))	0.61	=I9+((I$12-I$7)/($A$12-$A$7))	0.81	=K9+((K$12-K$7)/($A$12-$A$7))	0.1	=M9+((M$12-M$7)/($A$12-$A$7))	0.06	=O9+((O$12-O$7)/($A$12-$A$7))
11	**4**	0.68	=C10+((C$12-C$7)/($A$12-$A$7))	0.4	=E10+((E$12-E$7)/($A$12-$A$7))	0.55	=G10+((G$12-G$7)/($A$12-$A$7))	0.61	=I10+((I$12-I$7)/($A$12-$A$7))	0.81	=K10+((K$12-K$7)/($A$12-$A$7))	0.1	=M10+((M$12-M$7)/($A$12-$A$7))	0.06	=O10+((O$12-O$7)/($A$12-$A$7))
12	**5**	0.68	**=0.8*(C17-C7)+C7**	0.4	**=0.8*(E17-E7)+E7**	0.55	**=0.8*(G17-G7)+G7**	0.61	**=0.8*(I17-I7)+I7**	0.81	**=0.8*(K17-K7)+K7**	0.1	**=0.8*(M17-M7)+M7**	0.06	**=0.8*(O17-O7)+O7**
13	**6**	0.68	=C12+((C$17-C$12)/($A$17-$A$12))	0.4	=E12+((E$17-E$12)/($A$17-$A$12))	0.55	=G12+((G$17-G$12)/($A$17-$A$12))	0.61	=I12+((I$17-I$12)/($A$17-$A$12))	0.81	=K12+((K$17-K$12)/($A$17-$A$12))	0.1	=M12+((M$17-M$12)/($A$17-$A$12))	0.06	=O12+((O$17-O$12)/($A$17-$A$12))
14	**7**	0.68	=C13+((C$17-C$12)/(A	0.4	=E13+((E$17-E$12)/(A	0.55	=G13+((G$17-G$12)/(A	0.61	=I13+((I$17-I$12)/(A	0.81	=K13+((K$17-K$12)/(A	0.1	=M13+((M$17-M$12)/($A	0.06	=O13+((O$17-O$12)/(A

Row / Column	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	**WORKSHEET**														
2	**Quality index scores over the period of analysis**														
3	**Limiting Factor**	**Floodplain Habitat**													
4	**Assessment Metric**	**Riparian Cover**													
5	**Project Assessment Area**	**9**	**9**	**26**	**26**	**28**	**28**	**37**	**37**	**39**	**39**	**40**	**40**	**43**	**43**
6	**Year**	**Project 9 Without Project**	**Project 9 With Project**	**Project 26 Without Project**	**Project 26 With Project**	**Project 28 Without Project**	**Project 28 With Project**	**Project 37 Without Project**	**Project 37 With Project**	**Project 39 Without Project**	**Project 39 With Project**	**Project 40 Without Project**	**Project 40 With Project**	**Project 43 Without Project**	**Project 43 With Project**
			17-$A$12))		17-$A$12))		17-$A$12))		17-$A$12))		17-$A$12))		$17-$A$12))		17-$A$12))
15	**8**	0.68	=C14+((C$17-C$12)/($A$17-$A$12))	0.4	=E14+((E$17-E$12)/($A$17-$A$12))	0.55	=G14+((G$17-G$12)/($A$17-$A$12))	0.61	=I14+((I$17-I$12)/($A$17-$A$12))	0.81	=K14+((K$17-K$12)/($A$17-$A$12))	0.1	=M14+((M$17-M$12)/($A$17-$A$12))	0.06	=O14+((O$17-O$12)/($A$17-$A$12))
16	**9**	0.68	=C15+((C$17-C$12)/($A$17-$A$12))	0.4	=E15+((E$17-E$12)/($A$17-$A$12))	0.55	=G15+((G$17-G$12)/($A$17-$A$12))	0.61	=I15+((I$17-I$12)/($A$17-$A$12))	0.81	=K15+((K$17-K$12)/($A$17-$A$12))	0.1	=M15+((M$17-M$12)/($A$17-$A$12))	0.06	=O15+((O$17-O$12)/($A$17-$A$12))
17	**10**	0.68	**0.9**	0.4	**1**	0.55	**0.81**	0.61	**0.77**	0.81	**0.89**	0.1	**0.58**	0.06	**0.48**
18	**11**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
19	**12**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
20	**13**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
21	**14**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
22	**15**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
23	**16**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
24	**17**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
25	**18**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
26	**19**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
27	**20**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
28	**21**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
29	**22**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
30	**23**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
31	**24**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
32	**25**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
33	**26**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
34	**27**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
35	**28**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
36	**29**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
37	**30**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
38	**31**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
39	**32**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
40	**33**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
41	**34**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
42	**35**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
43	**36**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
44	**37**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
45	**38**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
46	**39**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
47	**40**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
48	**41**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
49	**42**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
50	**43**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
51	**44**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
52	**45**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48

Row / Column	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	**WORKSHEET**														
2	**Quality index scores over the period of analysis**														
3	**Limiting Factor**	**Floodplain Habitat**													
4	**Assessment Metric**	**Riparian Cover**													
5	**Project Assessment Area**	**9**	**9**	**26**	**26**	**28**	**28**	**37**	**37**	**39**	**39**	**40**	**40**	**43**	**43**
6	**Year**	**Project 9 Without Project**	**Project 9 With Project**	**Project 26 Without Project**	**Project 26 With Project**	**Project 28 Without Project**	**Project 28 With Project**	**Project 37 Without Project**	**Project 37 With Project**	**Project 39 Without Project**	**Project 39 With Project**	**Project 40 Without Project**	**Project 40 With Project**	**Project 43 Without Project**	**Project 43 With Project**
53	**46**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
54	**47**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
55	**48**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
56	**49**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
57	**50**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
58		**9 WOP**	**9 WP**	**26 WOP**	**26 WP**	**28 WOP**	**28 WP**	**37 WOP**	**37 WP**	**39 WOP**	**39 WP**	**40 WOP**	**40 WP**	**43 WOP**	**43 WP**
59	**Average**	0.68	=AVERAGE(C7:C57)	=AVERAGE(D7:D57)	=AVERAGE(E7:E57)	=AVERAGE(F7:F57)	=AVERAGE(G7:G57)	=AVERAGE(H7:H57)	=AVERAGE(I7:I57)	=AVERAGE(J7:J57)	=AVERAGE(K7:K57)	=AVERAGE(L7:L57)	=AVERAGE(M7:M57)	=AVERAGE(N7:N57)	=AVERAGE(O7:O57)
60	**Average change (benefit)**		=C59-B59		=E59-D59		=G59-F59		=I59-H59		=K59-J59		=M59-L59		=O59-N59

10 ‘FLOODPLAIN – CONNECTIVITY HQI’ WORKSHEET

This worksheet documents the computations of the existing, future without-project and future with-project HQI scores by assessing change in habitat quality for the connectivity assessment metric over time. Habitat changes were noted at appropriate points in time, and HQI scores were linearly interpolated between these points. The without- and with-project HQI scores average the HQI values over a 50-year time horizon. The benefit or change in habitat quality is the difference between the average annual HQI scores for the future without- and future with-project conditions. A graph is generated that plots the HQI values for the future without-project and future with-project time curves over the period of analysis. Column D has equations to compute the slope (rise) between two known points. Formulas for each of the cells are contained in the columns to the right. More information about the habitat quality scoring and time curves for the future without- and with-project HQI scores can be found within in the main report.

Row/Column	A	B	C	D	*B*	*C*	*D*
1	**WORKSHEET**						
2	**Quality index scores over the period of analysis**						
3	**Limiting Factor**	**Floodplain Habitat**					
4	**Assessment Metric**	**Connectivity**					
5	**Year**	**Without Project Condition**	**With Project Condition**	**Slope**	***Without Project Condition***	***With Project Condition***	***Slope***
6	0	-	-		*0*	*0*	
7	1	-	0.20	0.20	*0*	*=C6+$D$7*	*=(C11-C6)/(A11-A6)*
8	2	-	0.40		*0*	*=C7+$D$7*	
9	3	-	0.60		*0*	*=C8+$D$7*	
10	4	-	0.80		*0*	*=C9+$D$7*	
11	5	-	**1.00**		*0*	*1*	
12	6	-	1.00		*0*	*1*	
13	7	-	1.00		*0*	*1*	
14	8	-	1.00		*0*	*1*	
15	9	-	1.00		*0*	*1*	
16	10	-	1.00		*0*	*1*	
17	11	-	1.00		*0*	*1*	
18	12	-	1.00		*0*	*1*	
19	13	-	1.00		*0*	*1*	
20	14	-	1.00		*0*	*1*	
21	15	-	1.00		*0*	*1*	
22	16	-	1.00		*0*	*1*	
23	17	-	1.00		*0*	*1*	
24	18	-	1.00		*0*	*1*	
25	19	-	1.00		*0*	*1*	
26	20	-	1.00		*0*	*1*	
27	21	-	1.00		*0*	*1*	
28	22	-	1.00		*0*	*1*	
29	23	-	1.00		*0*	*1*	
30	24	-	1.00		*0*	*1*	
31	25	-	1.00		*0*	*1*	
32	26	-	1.00		*0*	*1*	
33	27	-	1.00		*0*	*1*	
34	28	-	1.00		*0*	*1*	
35	29	-	1.00		*0*	*1*	
36	30	-	1.00		*0*	*1*	
37	31	-	1.00		*0*	*1*	

Row/Column	A	B	C	D	*B*	*C*	*D*
1	**WORKSHEET**						
2	**Quality index scores over the period of analysis**						
3	**Limiting Factor**	**Floodplain Habitat**					
4	**Assessment Metric**	**Connectivity**					
5	**Year**	**Without Project Condition**	**With Project Condition**	**Slope**	***Without Project Condition***	***With Project Condition***	***Slope***
38	32	-	1.00		*0*	*1*	
39	33	-	1.00		*0*	*1*	
40	34	-	1.00		*0*	*1*	
41	35	-	1.00		*0*	*1*	
42	36	-	1.00		*0*	*1*	
43	37	-	1.00		*0*	*1*	
44	38	-	1.00		*0*	*1*	
45	39	-	1.00		*0*	*1*	
46	40	-	1.00		*0*	*1*	
47	41	-	1.00		*0*	*1*	
48	42	-	1.00		*0*	*1*	
49	43	-	1.00		*0*	*1*	
50	44	-	1.00		*0*	*1*	
51	45	-	1.00		*0*	*1*	
52	46	-	1.00		*0*	*1*	
53	47	-	1.00		*0*	*1*	
54	48	-	1.00		*0*	*1*	
55	49	-	1.00		*0*	*1*	
56	50	-	1.00		*0*	*1*	
57							
58	Average	-	0.94		*=AVERAGE(B6:B56)*	*=AVERAGE(C6:C56)*	
59	Average change (benefit)		0.94			*=C58-B58*	

11 'CE ICA INPUT DATA' WORKSHEET

This worksheet summarizes scoring for without and with project conditions for each of the assessment areas, with computation of average annual habitat units (AAHUs) for the without project condition listed in the first row, computation of with project AAHUs in the second row, and the difference (or benefit, with – without project) displayed in the third row. The difference, or benefits, for each of the assessed projects will be used for cost effectiveness and incremental cost analysis (CE/ICA) in IWR-Planning Suite.

Projects are listed by applicable limiting factors. The first four projects, or base alternatives, address capacity and in-channel habitat and the average habitat quality index (HQI) score is computed by taking the average of V1 (woody debris), V2 (pools) and V5 (capacity), or (V1+V2+V5)/3. Six incremental projects address floodplain habitat and the average annual HQI score is computed by taking the average of V3 and V4, or (V3+V4)/2. Finally, two projects address in-channel habitat only and the average annual HQI score is computed by taking the average of V1 and V2, or (V1+V2)/2.

The first table shows the values for each of the assessed projects. The second table includes the formulas for scoring assessment metrics, computation of average annual HQI scores, and AAHUs.

Row/ Column	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
2									QI Scores for Applicable Variables						
3	**Project Number**	**Base # Assignment**	**Project Number/Base**	**Project Name**	**Assessment Area Limiting Factor(s)**	**Affected Reach(es)**	**Primary Reach Affected**	**Affected Acres**	**V1 - Woody Debris**	**V2 - Pools**	**V3 - Connectivity**	**V4 - Riparian Cover**	**V5 - Capacity**	**HQI**	**AAHU (Affected Acres * HQI)**
4				**Limiting Factors Assessed for Assessment Area = Channel Capacity and In-Channel Habitat (HQI = (V1+V2+V5)/3)**											
5	59	1	K0	BASE #1 Assessment Area Base/FWOP Condition	Channel Capacity and In-Channel Habitat	0-4	N/A	219	0.10	0.21	N/A	N/A	0.17	0.16	24.5
6	59	1	K1	BASE #1 Complete Channel Capacity Dredging (RM 0-9) + LWD	Channel Capacity and In-Channel Habitat	0-4	N/A	219	0.93	0.93	N/A	N/A	1.00	0.95	208.7
7	***59***	***1***	***K1***	***Benefit (With-Without)***	***Channel Capacity and In-Channel Habitat***	***0-4***	***N/A***	***219***	***0.83***	***0.72***	***N/A***	***N/A***	***0.83***	***0.79***	***184.2***
8	50	2	L0	BASE # 2 Assessment Area Base/FWOP Condition	Channel Capacity and In-Channel Habitat	4	N/A	26	0.10	0.21	N/A	N/A	0.17	0.16	*2.9*
9	50	2	L1	BASE #2 Confluence Channel Excavation + LWD	Channel Capacity and In-Channel Habitat	4	N/A	26	0.93	0.93	N/A	N/A	0.50	0.79	20.4
10	***50***	***2***	***L1***	***Benefit (With-Without)***	***Channel Capacity and In-Channel Habitat***	***4***	***N/A***	***26***	***0.83***	***0.72***	***N/A***	***N/A***	***0.33***	***0.63***	***17.5***
11	31	3	M0	BASE #3 Assessment Area Base/FWOP Condition	Channel Capacity and In-Channel Habitat	4	N/A	68	0.10	0.21	N/A	N/A	0.17	0.16	*7.6*
12	31	3	M1	BASE #3 North Fork/South Fork Confluence - Car Body Levee Removal + LWD	Channel Capacity and In-Channel Habitat	4	N/A	68	0.93	0.93	N/A	N/A	0.50	0.79	*53.5*
13	***31***	***3***	***M1***	***Benefit (With-Without)***	***Channel Capacity and In-Channel Habitat***	***4***	***N/A***	***68***	***0.83***	***0.72***	***N/A***	***N/A***	***0.33***	***0.63***	***45.9***
14	62	5	N0	BASE #5 Assessment Area Base/FWOP Condition	Channel Capacity and In-Channel Habitat	2-4	N/A	132	0.10	0.21	N/A	N/A	0.17	0.16	*14.8*
15	62	5	N1	BASE #5 RM 3.5-9 Dredge + LWD	Channel Capacity and In-Channel Habitat	2-4	N/A	132	0.93	0.93	N/A	N/A	1.00	0.95	*125.8*
16	***62***	***5***	***N1***	***Benefit (With-Without)***	***Channel Capacity and In-Channel Habitat***	***2-4***	***N/A***	***132***	***0.83***	***0.72***	***N/A***	***N/A***	***0.83***	***0.79***	***111.0***
17				**Limiting Factors Assessed for Assessment Area = Floodplain Habitat (HQI = (V3+V4)/2)**											
18	9	all	B0	River Channel Assessment Area Base/FWOP Condition	Floodplain Habitat	2-3	3	45	N/A	N/A	-	0.68	N/A	0.34	15.3
19	9	all	B1	River Channel	Floodplain Habitat	2-3	3	45	N/A	N/A	0.94	0.88	N/A	0.91	41.0
20	***9***	***all***	***B1***	***Benefit (With-Without)***	***Floodplain Habitat***	***2-3***	***3***	***45***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.57***	***25.7***
21	26	all	C0	Dips Road Assessment Area Base/FWOP Condition	Floodplain Habitat	4	4	17	N/A	N/A	-	0.40	N/A	0.20	3.4
22	26	all	C1	Dips Road	Floodplain Habitat	4	4	17	N/A	N/A	0.94	0.95	N/A	0.95	16.1
23	***26***	***all***	***C1***	***Benefit (With-Without)***	***Floodplain Habitat***	***4***	***4***	***17***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.75***	***12.7***
24	28	all	D0	Large Levee Setback Assessment Area Base/FWOP Condition	Floodplain Habitat	4	4	23	N/A	N/A	-	0.55	N/A	0.28	6.3
25	28	all	D1	Large Levee Setback	Floodplain Habitat	4	4	23	N/A	N/A	0.94	0.79	N/A	0.87	19.9
26	***28***	***all***	***D1***	***Benefit (With-Without)***	***Floodplain Habitat***	***4***	***4***	***23***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.59***	***13.6***
27	37	all	G0	Grange Dike Assessment Area Base/FWOP Condition	Floodplain Habitat	3-4	4	34	N/A	N/A	-	0.61	N/A	0.31	10.4
28	37	all	G1	Grange Dike	Floodplain Habitat	3-4	4	34	N/A	N/A	0.94	0.76	N/A	0.85	28.9
29	***37***	***all***	***G1***	***Benefit (With-Without)***	***Floodplain Habitat***	***3-4***	***4***	***34***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.54***	***18.5***
30	39	2 and 3	H0	Hunter Creek Mouth Assessment Area Base/FWOP Condition	Floodplain Habitat	3	3	0.5	N/A	N/A	-	0.81	N/A	0.41	0.2
31	39	2 and 3	H1	Hunter Creek Mouth	Floodplain Habitat	3	3	0.5	N/A	N/A	0.94	0.88	N/A	0.91	0.5
32	***39***	***2 and 3***	***H1***	***Benefit (With-Without)***	***Floodplain Habitat***	***3***	***3***	***0.5***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.51***	***0.3***
33	40	all	I0	Hunter Creek Assessment Area Base/FWOP Condition	Floodplain Habitat	3	3	29	N/A	N/A	-	0.10	N/A	0.05	1.5
34	40	all	I1	Hunter Creek Side Channel Habitat Reconnection	Floodplain Habitat	3	3	29	N/A	N/A	0.94	0.54	N/A	0.74	21.5
35	***40***	***all***	***I1***	***Benefit (With-Without)***	***Floodplain Habitat***	***3***	***3***	***29***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.69***	***20.1***
36				**Limiting Factors Assessed for Assessment Area = In-Channel Habitat (HQI = (V1+V2)/2)**											
37	35	all	F0	Upstream LWD Assessment Area Base/FWOP Condition	In-Channel Habitat	4-5	5	107	0.10	0.21	N/A	N/A	N/A	0.16	16.6
38	35	all	F1	Upstream LWD Installation	In-Channel Habitat	4-5	5	107	0.93	0.93	N/A	N/A	N/A	0.93	99.5
39	***35***	***all***	***F1***	***Benefit (With-Without)***	***In-Channel Habitat***	***4-5***	***5***	***107***	***0.83***	***0.72***	***N/A***	***N/A***	***N/A***	***0.77***	***82.9***
40	43	all	J0	Weaver Creek Assessment Area Base/FWOP Condition	In-Channel Habitat	3	3	25	0.10	0.21	N/A	N/A	N/A	0.16	3.9
41	43	all	J1	Weaver Creek Side Channel	In-Channel Habitat	3	3	25	0.93	0.93	N/A	N/A	N/A	0.93	23.2
42	***43***	***all***	***J1***	***Benefit (With-Without)***	***In-Channel Habitat***	***3***	***3***	***25***	***0.83***	***0.72***	***N/A***	***N/A***	***N/A***	***0.77***	***19.4***

	B	C	D	E	F	I	J	K	L	M	N	O	P
3	Project Number	Base # Assignment	Project Number/Base	Project Name	Assessment Area Limiting Factor(s)	Affected Acres	V1 – Woody Debris	V2 - Pools	V3 - Connectivity	V4 - Riparian Cover	V5 - Capacity	HQI	AAHU (Affected Acres * HQI)
4				**Limiting Factors Assessed for Assessment Area = Channel Capacity and In-Channel Habitat (HQI = (V1+V2+V5)/3)**									
5	59	1	K0	BASE #1 Assessment Area Base/FWOP Condition	Channel Capacity and In-Channel Habitat	219	=IF(OR(F5="In-Channel Habitat",F5="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$7,"N/A")	=IF(OR(F5="In-Channel Habitat",F5="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$6,"N/A")	=IF(F5="Floodplain Habitat",'Assessment Metric HQI'!$G$15,"N/A")	=IF(F5="Floodplain Habitat",VLOOKUP(B5,'Assessment Metric HQI'!$E$8:$H$14,3),"N/A")	=IF(F5="Channel Capacity and In-Channel Habitat",VLOOKUP(C5,'Assessment Metric HQI'!$D$16:$I$19,4),"N/A")	=IF(F5="Channel Capacity and In-Channel Habitat",(J5+K5+N5)/3,IF(F5="In-Channel Habitat",(J5+K5)/2,IF(F5="Floodplain Habitat",(L5+M5)/2)))	=O5*I5
6	59	1	K1	BASE #1 Complete Channel Capacity Dredging (RM 0-9) + LWD	Channel Capacity and In-Channel Habitat	219	=IF(OR(F6="In-Channel Habitat",F6="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$7,"N/A")	=IF(OR(F6="In-Channel Habitat",F6="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$6,"N/A")	=IF(F6="Floodplain Habitat",'Assessment Metric HQI'!$H$15,"N/A")	=IF(F6="Floodplain Habitat",VLOOKUP(B6,'Assessment Metric HQI'!$E$8:$H$14,4),"N/A")	=IF(F6="Channel Capacity and In-Channel Habitat",VLOOKUP(C6,'Assessment Metric HQI'!$D$16:$I$19,5),"N/A")	=IF(F6="Channel Capacity and In-Channel Habitat",(J6+K6+N6)/3,IF(F6="In-Channel Habitat",(J6+K6)/2,IF(F6="Floodplain Habitat",(L6+M6)/2)))	=O6*I6
7	***59***	***1***	***K1***	***Benefit (With-Without)***	***Channel Capacity and In-Channel Habitat***	***219***	***=IF(OR(F7="In-Channel Habitat",F7="Channel Capacity and In-Channel Habitat"),J6-J5,"N/A")***	***=IF(OR(F7="In-Channel Habitat",F7="Channel Capacity and In-Channel Habitat"),K6-K5,"N/A")***	***=IF(F7="Floodplain Habitat",L6-L5,"N/A")***	***=IF(F7="Floodplain Habitat",L6-L5,"N/A")***	***=IF(F7="Channel Capacity and In-Channel Habitat",N6-N5,"N/A")***	***=O6-O5***	***=O7*I7***
8	50	2	L0	BASE # 2 Assessment Area Base/FWOP Condition	Channel Capacity and In-Channel Habitat	26	=IF(OR(F8="In-Channel Habitat",F8="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$7,"N/A")	=IF(OR(F8="In-Channel Habitat",F8="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$6,"N/A")	=IF(F8="Floodplain Habitat",'Assessment Metric HQI'!$G$15,"N/A")	=IF(F8="Floodplain Habitat",VLOOKUP(B8,'Assessment Metric HQI'!$E$8:$H$14,3),"N/A")	=IF(F8="Channel Capacity and In-Channel Habitat",VLOOKUP(C8,'Assessment Metric HQI'!$D$16:$I$19,4),"N/A")	=IF(F8="Channel Capacity and In-Channel Habitat",(J8+K8+N8)/3,IF(F8="In-Channel Habitat",(J8+K8)/2,IF(F8="Floodplain Habitat",(L8+M8)/2)))	*=O8*I8*
9	50	2	L1	BASE #2 Confluence Channel Excavation + LWD	Channel Capacity and In-Channel Habitat	26	=IF(OR(F9="In-Channel Habitat",F9="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$7,"N/A")	=IF(OR(F9="In-Channel Habitat",F9="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$6,"N/A")	=IF(F9="Floodplain Habitat",'Assessment Metric HQI'!$H$15,"N/A")	=IF(F9="Floodplain Habitat",VLOOKUP(B9,'Assessment Metric HQI'!$E$8:$H$14,4),"N/A")	=IF(F9="Channel Capacity and In-Channel Habitat",VLOOKUP(C9,'Assessment Metric HQI'!$D$16:$I$19,5),"N/A")	=IF(F9="Channel Capacity and In-Channel Habitat",(J9+K9+N9)/3,IF(F9="In-Channel Habitat",(J9+K9)/2,IF(F9="Floodplain Habitat",(L9+M9)/2)))	=O9*I9
10	***50***	***2***	***L1***	***Benefit (With-Without)***	***Channel Capacity and In-Channel Habitat***	***26***	***=IF(OR(F10="In-Channel Habitat",F10="Channel Capacity and In-Channel Habitat"),J9-J8,"N/A")***	***=IF(OR(F10="In-Channel Habitat",F10="Channel Capacity and In-Channel Habitat"),K9-K8,"N/A")***	***=IF(F10="Floodplain Habitat",L9-L8,"N/A")***	***=IF(F10="Floodplain Habitat",L9-L8,"N/A")***	***=IF(F10="Channel Capacity and In-Channel Habitat",N9-N8,"N/A")***	***=O9-O8***	***=O10*I10***
11	31	3	M0	BASE #3 Assessment Area Base/FWOP Condition	Channel Capacity and In-Channel Habitat	68	=IF(OR(F11="In-Channel Habitat",F11="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$7,"N/A")	=IF(OR(F11="In-Channel Habitat",F11="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$6,"N/A")	=IF(F11="Floodplain Habitat",'Assessment Metric HQI'!$G$15,"N/A")	=IF(F11="Floodplain Habitat",VLOOKUP(B11,'Assessment Metric HQI'!$E$8:$H$14,3),"N/A")	=IF(F11="Channel Capacity and In-Channel Habitat",VLOOKUP(C11,'Assessment Metric HQI'!$D$16:$I$19,4),"N/A")	=IF(F11="Channel Capacity and In-Channel Habitat",(J11+K11+N11)/3,IF(F11="In-Channel Habitat",(J11+K11)/2,IF(F11="Floodplain Habitat",(L11+M11)/2)))	*=O11*I11*
12	31	3	M1	BASE #3 North Fork/South Fork Confluence - Car Body Levee Removal + LWD	Channel Capacity and In-Channel Habitat	68	=IF(OR(F12="In-Channel Habitat",F12="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$7,"N/A")	=IF(OR(F12="In-Channel Habitat",F12="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$6,"N/A")	=IF(F12="Floodplain Habitat",'Assessment Metric HQI'!$H$15,"N/A")	=IF(F12="Floodplain Habitat",VLOOKUP(B12,'Assessment Metric HQI'!$E$8:$H$14,4),"N/A")	=IF(F12="Channel Capacity and In-Channel Habitat",VLOOKUP(C12,'Assessment Metric HQI'!$D$16:$I$19,5),"N/A")	=IF(F12="Channel Capacity and In-Channel Habitat",(J12+K12+N12)/3,IF(F12="In-Channel Habitat",(J12+K12)/2,IF(F12="Floodplain Habitat",(L12+M12)/2)))	*=O12*I12*
13	***31***	***3***	***M1***	***Benefit (With-Without)***	***Channel Capacity and In-Channel Habitat***	***68***	***=IF(OR(F13="In-Channel Habitat",F13="Channel Capacity and In-Channel Habitat"),J12-J11,"N/A")***	***=IF(OR(F13="In-Channel Habitat",F13="Channel Capacity and In-Channel Habitat"),K12-K11,"N/A")***	***=IF(F13="Floodplain Habitat",L12-L11,"N/A")***	***=IF(F13="Floodplain Habitat",L12-L11,"N/A")***	***=IF(F13="Channel Capacity and In-Channel Habitat",N12-N11,"N/A")***	***=O12-O11***	***=O13*I13***
14	62	5	N0	BASE #5 Assessment Area Base/FWOP Condition	Channel Capacity and In-Channel Habitat	132	=IF(OR(F14="In-Channel Habitat",F14="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$7,"N/A")	=IF(OR(F14="In-Channel Habitat",F14="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$6,"N/A")	=IF(F14="Floodplain Habitat",'Assessment Metric HQI'!$G$15,"N/A")	=IF(F14="Floodplain Habitat",VLOOKUP(B14,'Assessment Metric HQI'!$E$8:$H$14,3),"N/A")	=IF(F14="Channel Capacity and In-Channel Habitat",VLOOKUP(C14,'Assessment Metric HQI'!$D$16:$I$19,4),"N/A")	=IF(F14="Channel Capacity and In-Channel Habitat",(J14+K14+N14)/3,IF(F14="In-Channel Habitat",(J14+K14)/2,IF(F14="Floodplain Habitat",(L14+M14)/2)))	*=O14*I14*
15	62	5	N1	BASE #5 RM 3.5-9 Dredge + LWD	Channel Capacity and In-Channel Habitat	132	=IF(OR(F15="In-Channel Habitat",F15="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$7,"N/A")	=IF(OR(F15="In-Channel Habitat",F15="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$6,"N/A")	=IF(F15="Floodplain Habitat",'Assessment Metric HQI'!$H$15,"N/A")	=IF(F15="Floodplain Habitat",VLOOKUP(B15,'Assessment Metric HQI'!$E$8:$H$14,4),"N/A")	=IF(F15="Channel Capacity and In-Channel Habitat",VLOOKUP(C15,'Assessment Metric HQI'!$D$16:$I$19,5),"N/A")	=IF(F15="Channel Capacity and In-Channel Habitat",(J15+K15+N15)/3,IF(F15="In-Channel Habitat",(J15+K15)/2,IF(F15="Floodplain Habitat",(L15+M15)/2)))	*=O15*I15*
16	***62***	***5***	***N1***	***Benefit (With-Without)***	***Channel Capacity and In-Channel Habitat***	***132***	***=IF(OR(F16="In-Channel Habitat",F16="Channel Capacity and In-Channel Habitat"),J15-J14,"N/A")***	***=IF(OR(F16="In-Channel Habitat",F16="Channel Capacity and In-Channel Habitat"),K15-K14,"N/A")***	***=IF(F16="Floodplain Habitat",L15-L14,"N/A")***	***=IF(F16="Floodplain Habitat",L15-L14,"N/A")***	***=IF(F16="Channel Capacity and In-Channel Habitat",N15-N14,"N/A")***	***=O15-O14***	***=O16*I16***
17				**Limiting Factors Assessed for Assessment Area = Floodplain Habitat (HQI = (V3+V4)/2)**									
18	9	all	B0	River Channel Assessment Area Base/FWOP Condition	Floodplain Habitat	45	=IF(OR(F18="In-Channel Habitat",F18="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$7,"N/A")	=IF(OR(F18="In-Channel Habitat",F18="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$6,"N/A")	=IF(F18="Floodplain Habitat",'Assessment Metric HQI'!$G$15,"N/A")	=IF(F18="Floodplain Habitat",VLOOKUP(B18,'Assessment Metric HQI'!$E$8:$H$14,3),"N/A")	=IF(F18="Channel Capacity and In-Channel Habitat",VLOOKUP(C18,'Assessment Metric HQI'!$D$16:$I$19,4),"N/A")	=IF(F18="Channel Capacity and In-Channel Habitat",(J18+K18+N18)/3,IF(F18="In-Channel Habitat",(J18+K18)/2,IF(F18="Floodplain Habitat",(L18+M18)/2)))	=O18*I18
19	9	all	B1	River Channel	Floodplain Habitat	45	=IF(OR(F19="In-Channel Habitat",F19="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$7,"N/A")	=IF(OR(F19="In-Channel Habitat",F19="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$6,"N/A")	=IF(F19="Floodplain Habitat",'Assessment Metric HQI'!$H$15,"N/A")	=IF(F19="Floodplain Habitat",VLOOKUP(B19,'Assessment Metric HQI'!$E$8:$H$14,4),"N/A")	=IF(F19="Channel Capacity and In-Channel Habitat",VLOOKUP(C19,'Assessment Metric HQI'!$D$16:$I$19,5),"N/A")	=IF(F19="Channel Capacity and In-Channel Habitat",(J19+K19+N19)/3,IF(F19="In-Channel Habitat",(J19+K19)/2,IF(F19="Floodplain Habitat",(L19+M19)/2)))	=O19*I19
20	***9***	***all***	***B1***	***Benefit (With-Without)***	***Floodplain Habitat***	***45***	***=IF(OR(F20="In-Channel Habitat",F20="Channel Capacity and In-Channel Habitat"),J19-J18,"N/A")***	***=IF(OR(F20="In-Channel Habitat",F20="Channel Capacity and In-Channel Habitat"),K19-K18,"N/A")***	***=IF(F20="Floodplain Habitat",L19-L18,"N/A")***	***=IF(F20="Floodplain Habitat",L19-L18,"N/A")***	***=IF(F20="Channel Capacity and In-Channel Habitat",N19-N18,"N/A")***	***=O19-O18***	***=O20*I20***
21	26	all	C0	Dips Road Assessment Area Base/FWOP Condition	Floodplain Habitat	17	=IF(OR(F21="In-Channel Habitat",F21="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$7,"N/A")	=IF(OR(F21="In-Channel Habitat",F21="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$6,"N/A")	=IF(F21="Floodplain Habitat",'Assessment Metric HQI'!$G$15,"N/A")	=IF(F21="Floodplain Habitat",VLOOKUP(B21,'Assessment Metric HQI'!$E$8:$H$14,3),"N/A")	=IF(F21="Channel Capacity and In-Channel Habitat",VLOOKUP(C21,'Assessment Metric HQI'!$D$16:$I$19,4),"N/A")	=IF(F21="Channel Capacity and In-Channel Habitat",(J21+K21+N21)/3,IF(F21="In-Channel Habitat",(J21+K21)/2,IF(F21="Floodplain Habitat",(L21+M21)/2)))	=O21*I21
22	26	all	C1	Dips Road	Floodplain Habitat	17	=IF(OR(F22="In-Channel Habitat",F22="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$7,"N/A")	=IF(OR(F22="In-Channel Habitat",F22="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$6,"N/A")	=IF(F22="Floodplain Habitat",'Assessment Metric HQI'!$H$15,"N/A")	=IF(F22="Floodplain Habitat",VLOOKUP(B22,'Assessment Metric HQI'!$E$8:$H$14,4),"N/A")	=IF(F22="Channel Capacity and In-Channel Habitat",VLOOKUP(C22,'Assessment Metric HQI'!$D$16:$I$19,5),"N/A")	=IF(F22="Channel Capacity and In-Channel Habitat",(J22+K22+N22)/3,IF(F22="In-Channel Habitat",(J22+K22)/2,IF(F22="Floodplain Habitat",(L22+M22)/2)))	=O22*I22

	B	C	D	E	F	I	J	K	L	M	N	O	P
3	Project Number	Base # Assignment	Project Number/Base	Project Name	Assessment Area Limiting Factor(s)	Affected Acres	V1 – Woody Debris	V2 - Pools	V3 - Connectivity	V4 - Riparian Cover	V5 - Capacity	HQI	AAHU (Affected Acres * HQI)
23	26	all	C1	Benefit (With-Without)	Floodplain Habitat	17	=IF(OR(F23="In-Channel Habitat",F23="Channel Capacity and In-Channel Habitat"),J22-J21,"N/A")	=IF(OR(F23="In-Channel Habitat",F23="Channel Capacity and In-Channel Habitat"),K22-K21,"N/A")	=IF(F23="Floodplain Habitat",L22-L21,"N/A")	=IF(F23="Floodplain Habitat",L22-L21,"N/A")	=IF(F23="Channel Capacity and In-Channel Habitat",N22-N21,"N/A")	=O22-O21	=O23*I23
24	28	all	D0	Large Levee Setback Assessment Area Base/FWOP Condition	Floodplain Habitat	23	=IF(OR(F24="In-Channel Habitat",F24="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$7,"N/A")	=IF(OR(F24="In-Channel Habitat",F24="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$6,"N/A")	=IF(F24="Floodplain Habitat",'Assessment Metric HQI'!$G$15,"N/A")	=IF(F24="Floodplain Habitat",VLOOKUP(B24,'Assessment Metric HQI'!$E$8:$H$14,3),"N/A")	=IF(F24="Channel Capacity and In-Channel Habitat",VLOOKUP(C24,'Assessment Metric HQI'!$D$16:$I$19,4),"N/A")	=IF(F24="Channel Capacity and In-Channel Habitat",(J24+K24+N24)/3,IF(F24="In-Channel Habitat",(J24+K24)/2,IF(F24="Floodplain Habitat",(L24+M24)/2)))	=O24*I24
25	28	all	D1	Large Levee Setback	Floodplain Habitat	23	=IF(OR(F25="In-Channel Habitat",F25="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$7,"N/A")	=IF(OR(F25="In-Channel Habitat",F25="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$6,"N/A")	=IF(F25="Floodplain Habitat",'Assessment Metric HQI'!$H$15,"N/A")	=IF(F25="Floodplain Habitat",VLOOKUP(B25,'Assessment Metric HQI'!$E$8:$H$14,4),"N/A")	=IF(F25="Channel Capacity and In-Channel Habitat",VLOOKUP(C25,'Assessment Metric HQI'!$D$16:$I$19,5),"N/A")	=IF(F25="Channel Capacity and In-Channel Habitat",(J25+K25+N25)/3,IF(F25="In-Channel Habitat",(J25+K25)/2,IF(F25="Floodplain Habitat",(L25+M25)/2)))	=O25*I25
26	28	all	D1	Benefit (With-Without)	Floodplain Habitat	23	=IF(OR(F26="In-Channel Habitat",F26="Channel Capacity and In-Channel Habitat"),J25-J24,"N/A")	=IF(OR(F26="In-Channel Habitat",F26="Channel Capacity and In-Channel Habitat"),K25-K24,"N/A")	=IF(F26="Floodplain Habitat",L25-L24,"N/A")	=IF(F26="Floodplain Habitat",L25-L24,"N/A")	=IF(F26="Channel Capacity and In-Channel Habitat",N25-N24,"N/A")	=O25-O24	=O26*I26
27	37	all	G0	Grange Dike Assessment Area Base/FWOP Condition	Floodplain Habitat	34	=IF(OR(F27="In-Channel Habitat",F27="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$7,"N/A")	=IF(OR(F27="In-Channel Habitat",F27="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$6,"N/A")	=IF(F27="Floodplain Habitat",'Assessment Metric HQI'!$G$15,"N/A")	=IF(F27="Floodplain Habitat",VLOOKUP(B27,'Assessment Metric HQI'!$E$8:$H$14,3),"N/A")	=IF(F27="Channel Capacity and In-Channel Habitat",VLOOKUP(C27,'Assessment Metric HQI'!$D$16:$I$19,4),"N/A")	=IF(F27="Channel Capacity and In-Channel Habitat",(J27+K27+N27)/3,IF(F27="In-Channel Habitat",(J27+K27)/2,IF(F27="Floodplain Habitat",(L27+M27)/2)))	=O27*I27
28	37	all	G1	Grange Dike	Floodplain Habitat	34	=IF(OR(F28="In-Channel Habitat",F28="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$7,"N/A")	=IF(OR(F28="In-Channel Habitat",F28="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$6,"N/A")	=IF(F28="Floodplain Habitat",'Assessment Metric HQI'!$H$15,"N/A")	=IF(F28="Floodplain Habitat",VLOOKUP(B28,'Assessment Metric HQI'!$E$8:$H$14,4),"N/A")	=IF(F28="Channel Capacity and In-Channel Habitat",VLOOKUP(C28,'Assessment Metric HQI'!$D$16:$I$19,5),"N/A")	=IF(F28="Channel Capacity and In-Channel Habitat",(J28+K28+N28)/3,IF(F28="In-Channel Habitat",(J28+K28)/2,IF(F28="Floodplain Habitat",(L28+M28)/2)))	=O28*I28
29	37	all	G1	Benefit (With-Without)	Floodplain Habitat	34	=IF(OR(F29="In-Channel Habitat",F29="Channel Capacity and In-Channel Habitat"),J28-J27,"N/A")	=IF(OR(F29="In-Channel Habitat",F29="Channel Capacity and In-Channel Habitat"),K28-K27,"N/A")	=IF(F29="Floodplain Habitat",L28-L27,"N/A")	=IF(F29="Floodplain Habitat",L28-L27,"N/A")	=IF(F29="Channel Capacity and In-Channel Habitat",N28-N27,"N/A")	=O28-O27	=O29*I29
30	39	2 and 3	H0	Hunter Creek Mouth Assessment Area Base/FWOP Condition	Floodplain Habitat	0.5	=IF(OR(F30="In-Channel Habitat",F30="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$7,"N/A")	=IF(OR(F30="In-Channel Habitat",F30="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$6,"N/A")	=IF(F30="Floodplain Habitat",'Assessment Metric HQI'!$G$15,"N/A")	=IF(F30="Floodplain Habitat",VLOOKUP(B30,'Assessment Metric HQI'!$E$8:$H$14,3),"N/A")	=IF(F30="Channel Capacity and In-Channel Habitat",VLOOKUP(C30,'Assessment Metric HQI'!$D$16:$I$19,4),"N/A")	=IF(F30="Channel Capacity and In-Channel Habitat",(J30+K30+N30)/3,IF(F30="In-Channel Habitat",(J30+K30)/2,IF(F30="Floodplain Habitat",(L30+M30)/2)))	=O30*I30
31	39	2 and 3	H1	Hunter Creek Mouth	Floodplain Habitat	0.5	=IF(OR(F31="In-Channel Habitat",F31="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$7,"N/A")	=IF(OR(F31="In-Channel Habitat",F31="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$6,"N/A")	=IF(F31="Floodplain Habitat",'Assessment Metric HQI'!$H$15,"N/A")	=IF(F31="Floodplain Habitat",VLOOKUP(B31,'Assessment Metric HQI'!$E$8:$H$14,4),"N/A")	=IF(F31="Channel Capacity and In-Channel Habitat",VLOOKUP(C31,'Assessment Metric HQI'!$D$16:$I$19,5),"N/A")	=IF(F31="Channel Capacity and In-Channel Habitat",(J31+K31+N31)/3,IF(F31="In-Channel Habitat",(J31+K31)/2,IF(F31="Floodplain Habitat",(L31+M31)/2)))	=O31*I31
32	39	2 and 3	H1	Benefit (With-Without)	Floodplain Habitat	0.5	=IF(OR(F32="In-Channel Habitat",F32="Channel Capacity and In-Channel Habitat"),J31-J30,"N/A")	=IF(OR(F32="In-Channel Habitat",F32="Channel Capacity and In-Channel Habitat"),K31-K30,"N/A")	=IF(F32="Floodplain Habitat",L31-L30,"N/A")	=IF(F32="Floodplain Habitat",L31-L30,"N/A")	=IF(F32="Channel Capacity and In-Channel Habitat",N31-N30,"N/A")	=O31-O30	=O32*I32
33	40	all	I0	Hunter Creek Assessment Area Base/FWOP Condition	Floodplain Habitat	29	=IF(OR(F33="In-Channel Habitat",F33="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$7,"N/A")	=IF(OR(F33="In-Channel Habitat",F33="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$6,"N/A")	=IF(F33="Floodplain Habitat",'Assessment Metric HQI'!$G$15,"N/A")	=IF(F33="Floodplain Habitat",VLOOKUP(B33,'Assessment Metric HQI'!$E$8:$H$14,3),"N/A")	=IF(F33="Channel Capacity and In-Channel Habitat",VLOOKUP(C33,'Assessment Metric HQI'!$D$16:$I$19,4),"N/A")	=IF(F33="Channel Capacity and In-Channel Habitat",(J33+K33+N33)/3,IF(F33="In-Channel Habitat",(J33+K33)/2,IF(F33="Floodplain Habitat",(L33+M33)/2)))	=O33*I33
34	40	all	I1	Hunter Creek Side Channel Habitat Reconnection	Floodplain Habitat	29	=IF(OR(F34="In-Channel Habitat",F34="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$7,"N/A")	=IF(OR(F34="In-Channel Habitat",F34="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$6,"N/A")	=IF(F34="Floodplain Habitat",'Assessment Metric HQI'!$H$15,"N/A")	=IF(F34="Floodplain Habitat",VLOOKUP(B34,'Assessment Metric HQI'!$E$8:$H$14,4),"N/A")	=IF(F34="Channel Capacity and In-Channel Habitat",VLOOKUP(C34,'Assessment Metric HQI'!$D$16:$I$19,5),"N/A")	=IF(F34="Channel Capacity and In-Channel Habitat",(J34+K34+N34)/3,IF(F34="In-Channel Habitat",(J34+K34)/2,IF(F34="Floodplain Habitat",(L34+M34)/2)))	=O34*I34
35	40	all	I1	Benefit (With-Without)	Floodplain Habitat	29	=IF(OR(F35="In-Channel Habitat",F35="Channel Capacity and In-Channel Habitat"),J34-J33,"N/A")	=IF(OR(F35="In-Channel Habitat",F35="Channel Capacity and In-Channel Habitat"),K34-K33,"N/A")	=IF(F35="Floodplain Habitat",L34-L33,"N/A")	=IF(F35="Floodplain Habitat",L34-L33,"N/A")	=IF(F35="Channel Capacity and In-Channel Habitat",N34-N33,"N/A")	=O34-O33	=O35*I35
36				Limiting Factors Assessed for Assessment Area = In-Channel Habitat (HQI = (V1+V2)/2)									
37	35	all	F0	Upstream LWD Assessment Area Base/FWOP Condition	In-Channel Habitat	107	=IF(OR(F37="In-Channel Habitat",F37="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$7,"N/A")	=IF(OR(F37="In-Channel Habitat",F37="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$6,"N/A")	=IF(F37="Floodplain Habitat",'Assessment Metric HQI'!$G$15,"N/A")	=IF(F37="Floodplain Habitat",VLOOKUP(B37,'Assessment Metric HQI'!$E$8:$H$14,3),"N/A")	=IF(F37="Channel Capacity and In-Channel Habitat",VLOOKUP(C37,'Assessment Metric HQI'!$D$16:$I$19,4),"N/A")	=IF(F37="Channel Capacity and In-Channel Habitat",(J37+K37+N37)/3,IF(F37="In-Channel Habitat",(J37+K37)/2,IF(F37="Floodplain Habitat",(L37+M37)/2)))	=O37*I37
38	35	all	F1	Upstream LWD Installation	In-Channel Habitat	107	=IF(OR(F38="In-Channel Habitat",F38="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$7,"N/A")	=IF(OR(F38="In-Channel Habitat",F38="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$6,"N/A")	=IF(F38="Floodplain Habitat",'Assessment Metric HQI'!$H$15,"N/A")	=IF(F38="Floodplain Habitat",VLOOKUP(B38,'Assessment Metric HQI'!$E$8:$H$14,4),"N/A")	=IF(F38="Channel Capacity and In-Channel Habitat",VLOOKUP(C38,'Assessment Metric HQI'!$D$16:$I$19,5),"N/A")	=IF(F38="Channel Capacity and In-Channel Habitat",(J38+K38+N38)/3,IF(F38="In-Channel Habitat",(J38+K38)/2,IF(F38="Floodplain Habitat",(L38+M38)/2)))	=O38*I38
39	35	all	F1	Benefit (With-Without)	In-Channel Habitat	107	=IF(OR(F39="In-Channel Habitat",F39="Channel Capacity and In-Channel Habitat"),J38-J37,"N/A")	=IF(OR(F39="In-Channel Habitat",F39="Channel Capacity and In-Channel Habitat"),K38-K37,"N/A")	=IF(F39="Floodplain Habitat",L38-L37,"N/A")	=IF(F39="Floodplain Habitat",L38-L37,"N/A")	=IF(F39="Channel Capacity and In-Channel Habitat",N38-N37,"N/A")	=O38-O37	=O39*I39
40	43	all	J0	Weaver Creek Assessment Area Base/FWOP Condition	In-Channel Habitat	25	=IF(OR(F40="In-Channel Habitat",F40="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$7,"N/A")	=IF(OR(F40="In-Channel Habitat",F40="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$6,"N/A")	=IF(F40="Floodplain Habitat",'Assessment Metric HQI'!$G$15,"N/A")	=IF(F40="Floodplain Habitat",VLOOKUP(B40,'Assessment Metric HQI'!$E$8:$H$14,3),"N/A")	=IF(F40="Channel Capacity and In-Channel Habitat",VLOOKUP(C40,'Assessment Metric HQI'!$D$16:$I$19,4),"N/A")	=IF(F40="Channel Capacity and In-Channel Habitat",(J40+K40+N40)/3,IF(F40="In-Channel Habitat",(J40+K40)/2,IF(F40="Floodplain Habitat",(L40+M40)/2)))	=O40*I40

	B	C	D	E	F	I	J	K	L	M	N	O	P
3	**Project Number**	**Base # Assignment**	**Project Number/Base**	**Project Name**	**Assessment Area Limiting Factor(s)**	**Affected Acres**	**V1 – Woody Debris**	**V2 - Pools**	**V3 - Connectivity**	**V4 - Riparian Cover**	**V5 - Capacity**	**HQI**	**AAHU (Affected Acres * HQI)**
41	43	all	J1	Weaver Creek Side Channel	In-Channel Habitat	25	=IF(OR(F41="In-Channel Habitat",F41="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$7,"N/A")	=IF(OR(F41="In-Channel Habitat",F41="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$6,"N/A")	=IF(F41="Floodplain Habitat",'Assessment Metric HQI'!$H$15,"N/A")	=IF(F41="Floodplain Habitat",VLOOKUP(B41,'Assessment Metric HQI'!$E$8:$H$14,4),"N/A")	=IF(F41="Channel Capacity and In-Channel Habitat",VLOOKUP(C41,'Assessment Metric HQI'!$D$16:$I$19,5),"N/A")	=IF(F41="Channel Capacity and In-Channel Habitat",(J41+K41+N41)/3,IF(F41="In-Channel Habitat",(J41+K41)/2,IF(F41="Floodplain Habitat",(L41+M41)/2)))	=O41*I41
42	***43***	***all***	***J1***	***Benefit (With-Without)***	***In-Channel Habitat***	***25***	***=IF(OR(F42="In-Channel Habitat",F42="Channel Capacity and In-Channel Habitat"),J41-J40,"N/A")***	***=IF(OR(F42="In-Channel Habitat",F42="Channel Capacity and In-Channel Habitat"),K41-K40,"N/A")***	***=IF(F42="Floodplain Habitat",L41-L40,"N/A")***	***=IF(F42="Floodplain Habitat",L41-L40,"N/A")***	***=IF(F42="Channel Capacity and In-Channel Habitat",N41-N40,"N/A")***	***=O41-O40***	***=O42*I42***

12 CE ICA SENSITIVITY ANALYSIS

This worksheet presents the sensitivity analysis from Section 8 of the main report. It evaluates the changes in HQI scores and overall AAHU benefits with weighting of one variable for each of the three HQI equations. The following weight changes to HQI equations were evaluated:

- $HQI = \frac{V1+V2+(2\times V5)}{4}$ for channel capacity and in-channel habitat where V5 (capacity) is twice as great as V1 (woody debris) and V2 (pools);
- $HQI = \frac{(2\times V1)+V2}{3}$ for in-channel habitat where V1 is twice as great as V2;
- $HQI = \frac{V1+(2\times V2)}{3}$ for in-channel habitat where V2 is twice as great as V1;
- $HQI = \frac{(2\times V3)+V4}{3}$ for floodplain habitat where V3 (connectivity) is twice as great as V4 (riparian cover); and
- $HQI = \frac{V3+(2\times V4)}{3}$ for floodplain habitat where V4 is twice as great as V3.

HQI scores and AAHUs for the weighting of metrics in the equations above are presented in columns Q through Y and are compared to the equal weighting of metrics for the three equations that will be used for evaluating the cost effectiveness and incremental cost analysis of project increments.