Flood Plain Reconnection Feasibility Study

Puyallup, Carbon, White Rivers
Pierce County, Washington

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Prepared for:
Puyallup River and Chambers Creek Lead Entity Technical Advisory
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- Tom Nelson Pierce County
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- Patrick Reynolds Mucklesoot Indian Tribe
- Carl Ward Washington State Department of Transportation
- Hans Berge King County
- Doug Wiedemeirer Washington Department of Fish and Wildlife
- Karen Chang U.S. Fish Service
- Sherrie Duncan Ridolfi
- Tyler Patterson Tacoma Water
INTRODUCTION

This report presents the results of a re-evaluation of Pierce County’s Levee Setback Feasibility Analysis for 32 sites on the Puyallup, Carbon and White Rivers as Pierce County, shown on Figure 1, the Vicinity Map. The original analysis was conducted from 2005 through 2008 and focused primarily on evaluating the feasibility and benefits of levee setbacks with respect to the flood hazard reduction and improvements in channel forming processes, which have been constrained since the levees were originally constructed. This re-evaluation focuses on identifying and ranking the original 32 sites with respect to existing habitat.

PROJECT GOALS AND UNDERSTANDING

Natural Systems Design (NSD) was contracted by Pierce County Water Programs Division to re-evaluate the data collected for the original 32 sites described in the 2008 study. The primary goal is to identify, prioritize and rank the original 32 sites for existing readily available fish habitat. Implicit in this primary goal are several objectives, which are listed below:

- Re-evaluate the original 32 sites; make no changes to original site boundaries and add no new sites to the 2008 site catalogue.
- Use the 2008 analyses to the extent possible, and conduct no new analyses. Pierce County staff indicated that the 2008 data base could be updated with readily available information such as recent aerial photographs, LiDAR, and observed changes in site use and development.
- Visit the 32 sites to document and qualitatively assess the existing habitat for quality and immediate benefit following a levee setback.
- Revise the 2008 prioritization workbook to better describe floodplain reconnection, existing habitat and other physical conditions supporting habitat.
- Based on the results of the re-evaluation, identify future needs and next steps that will help achieve Pierce County’s long term goals regarding habitat restoration and flood hazard management for the lower Puyallup River basin.

PROJECT BACKGROUND

The Puyallup River watershed includes 3 major basins, the Puyallup, Carbon and White River basins. The Puyallup River is the primary drainage channel for the watershed, with the Carbon and White rivers being tributaries to it. In total, the three river systems drain approximately 900 square miles encompassing the north and west flanks of Mt Rainier and a large section of the Puget lowland.

The lower portion of the basin was cleared by early settlers in the mid- to late- 1800s. By the early 1900s the lower Puyallup (Sumner to Commencement Bay), was straightened and leveed to increase the floodplain area available for agriculture and grazing, and for flood protection.

During this time period, the White River basin was not part of the Puyallup River watershed. Instead the White River flowed northwest to join with the Green River in Kent, WA. In 1914 the White River was mechanically diverted to the Puyallup River via a new channel alignment through the Stuck Valley in Pierce County. This action was mostly an attempt to reduce Green River flooding in
Kent and Renton. Since its diversion, the White River channel has been adjusting to the new alignment, as well as changes forced on natural processes by the construction of the Mud Mountain Dam, and increasingly developed environment offered by the construction of levees. The modifications exerted on the river in the first half of the 1900s resulted in several conditions that have had profound influence on the evolution of hydraulic and geomorphic channel and floodplain characteristics. First, the White River in Pierce County is very young; the channel form typically lacks complexity and the lower portion of it near Sumner is so deeply incised that it fully contains the 100 year regulated flow. Second, the Mud Mountain Dam has profound influence on high stage flows in the lower White, effectively disconnecting White River floodplains from the main stem at all but the most upstream portions of the Pierce County channel sections. As such, flood plain interactions formerly occurring in the lower White have been largely precluded from important historic salmon habitat.

In stark contrast to White River history and conditions, the Puyallup and Carbon Rivers have been in their respective valleys and channels for thousands of years and, until leved, where well-adjusted to the discharge of water and sediment coming off the uplands. Levees were constructed from the 1920s to the mid-1960s through the middle portion of the Puyallup River, and much of the Carbon River (up to the canyon section located upstream from South Prairie Creek) was also leved. A complete history and timeline table is available for review in a report entitled ‘Channel Migration Zone Analysis for the Puyallup Carbon and White Rivers in Pierce County’ (GeoEngineers, 2003). Construction of the levees accomplished several results that are regarded today as negative outcomes: 1) the width of the leved corridor is generally 30 to 40 percent less than pre-levee active channel widths, substantially decreasing flood conveyance and storage capacities of the Puyallup and Carbon Rivers, 2) the levee corridors cut off and left abandoned numerous channel bends which straightened the channel and increased channel gradients and flow velocities, thus altered sediment transport capacity, 3) the levees disconnected the river from its floodplains, eliminating valuable off-channel and floodplain habitat and decreasing flood storage capacity, and 4) the narrow confinement of the leved corridor substantially modified fluvial channel forming processes resulting in simplification of channel geometry and damaged in-channel habitat.

In the early 2000s, Pierce County staff and management were aware of and sought to mitigate some of the adverse impacts caused by the presence of the existing levees. One of the long term efforts undertaken by Pierce County Department of Surface Water Management included evaluating the feasibility of setting back existing levees to reconnect rivers with their floodplains. The Levee Setback Feasibility Study was initiated in 2005 and completed in 2008.

**2008 LEVEE FEASIBILITY STUDY**

**Approach**

The 2008 Feasibility Study evaluated 32 sites located long the Puyallup, Carbon and White Rivers in Pierce County. The feasibility of setting back levees from their existing alignments was examined from several perspectives: 1) flood storage, 2) fluvial geomorphic processes, 3) habitat, 4) project costs, and 5) land availability.
Evaluated sites were prioritized and ranked based primarily on floodplain reconnection, flood storage and favorable channel responses to levee setbacks. Existing and potential future salmonid habitat was an important consideration of the prioritization ranking process, but was treated more indirectly, based on the premise that floodplain reconnection and the reclaiming of dynamic channel forming process would increase and improve in- and off-channel habitat.

The 32 sites included in the 2008 study were obtained from two existing catalogues compiled by the Puyallup Indian Tribe and from the Pierce County Floodplain Management Plan, as well as a few sites suggested by the Technical Advisory Committee assembled specifically for the project. No other sites were added to the project catalogues over the course of the project, and no reconnaissance was conducted in search of new candidate sites.

The approach to prioritizing the sites consisted of describing project goals in terms of objectives that could be quantified in such a way that the sites could be compared and prioritized. The project goals were defined as:

1) Increase flood plain reconnection and flood storage.

2) Improve geomorphic process and function.

3) Improve habitat diversity.

The descriptive information was organized under the three Goals in one or more sub-headings (Objectives) designed to help describe the site. The 2008 study also considered Project Costs and Land Availability in the site prioritization strategy.

The Objectives associated with each Goal are outlined below:

**Goal 1. Increase Floodplain Connectivity and Flood Storage.**

**Objectives**

1.1 Maximize area of floodplain inundation at high frequency events

1.2 Maximize storage volume at low frequency events

1.3 Minimize actions necessary to accomplish the goal

1.4 Protection offered by new levee alignment

**Goal 2. Reestablish Short and Long-Term Geomorphic Processes and Function.**

**Objectives**

2.1 Promote channel migration within the mapped severe and/or moderate migration potential areas
2.2 Promote increased channel complexity and multi-channel (braided) reaches

2.3 Promote more natural sediment conveyance and storage processes

2.4 Promote natural LWD recruitment and pool formation

2.5 Minimize potential adverse flooding and/or erosion impacts on local or downstream infrastructure or channel conditions.

2.6 Improve connectivity to tributaries, potential wetlands or springs, and existing side channels.

**Goal 3. Maximize Aquatic Habitat Diversity and Use.**

**Objective**

3.1 Maximize aquatic habitat diversity and use.

**Project Cost.**

**Land Availability.**

Each site was evaluated and described in terms of the objectives, Project Costs and Land Availability, as outlined above.

**2008 Prioritization Workbook**

The prioritization workbook was developed to record and store data and observations describing the physical characteristics of the 32 setback sites. The results for each site were entered in a Prioritization Workbook, which consisted of a Summary Page and a series of linked pages, each page dedicated to a specific objective.

**Assessed Values and Normalized Goal Scores.**

The results of analyses and calculations for each Objective (for each individual site) were entered on the appropriate page and an assessed value, from 0 to 4, was assigned to the results. Assignment of the assessed value was based on either the percentile of a site score relative to the scores of all sites for that Objective, or by a ‘sliding rule’ approach based on the desirability or importance of the condition being evaluated. The total Goal Scores and Assessed Values of all sites for all Objectives, and the Project Costs and Land Availability categories, were pulled onto the Summary Page and the Assessed Values for each site were summed.

**Weighting Function.**

The original prioritization workbook includes a “Weighing Function” that was applied from the Workbook summary page to either increase the scores of Goals or specific Objective Assessment Values within a goal (relative to other goals and objectives); it could also be used to “Turn off” a goal or objective. Weighting factors were applied and the resulting “Weighted Priority Values” were ranked with respect to each river system (Puyallup, Carbon and White).
Normalized Results

Because many of the Objectives comprising Goals 1 and 2 are based on the size or surface area of the site, and because of the effects of the Mud Mountain Dam on the White River, site scores for Goals 1 and Goal 2 were normalized with respect to all 32 sites. This action was taken largely to neutralize the advantages of the very largest sites over the smallest sites, and to ‘level the playing field’ for Sites on the White River, which is young compared to the Puyallup and Carbon. Please see the 2008 Feasibility Report for a detailed description of the Workbook, scoring methods and ranking strategies.

2014 RE-EVALUATION

Re-evaluation of the original 32 sites was conducted with respect to potential fish habitat. The objectives of the re-evaluation set out in the ‘Project Goals and Understanding’ section of the report specify that, to the extent possible, the 2008 data sets were to be used. The 2008 data sets and analyses developed for, and resulting from, the 2008 study included the following:

- LiDAR dated 2005 and digital GIS map layers
- Time series aerial photographs from 1932 to 2005
- Channel Migration Zone maps and digitized channel traces (GeoEngineers, 2003)
- HEC-RAS Model for Flood Insurance Study of the Puyallup, Carbon, White Rivers (NHC, 2005)
- Prioritization Workbook (2008)
- The Feasibility Study and Site Catalogue (2008)

RE-EVALUATION APPROACH

Several data sets were updated for the 2014 Re-evaluation to provide the project team with the most current site conditions, including the 2010 LiDAR and post-2005 aerial photographs, both of which were added to the 2008 GIS data base.

Updated data sets for each site were then reviewed and evaluated for potential habitat. The 2010 LiDAR and 2012 air photo were used to identify old abandoned channels not previously visible from the 2005 LiDAR, and to look for changes in site conditions, land use and development. Review of recent aerial photos showed that several sites have been modified by the encroachment of urban development since 2008. The aerial photos also show channel responses from the January 2009 flood event. In particular, the 2009 event caused substantial changes in river width where levees were breached, or in some places, completely blown out.

The 2010 LiDAR was also used to qualitatively assess topography across each site as an indicator of a site’s flood plain, an whether it is equal with, or lower than, the top of the adjacent levee. Sites with ‘higher’ elevations were considered to require more restoration and/or remedial measures to fully utilize the site. These sites were given lower importance for site visits than the ‘low’ ground sites.
Some sites with 'higher' topography were not visited due to lack of allocated field time.

The site visits provided valuable information regarding the overall condition of the site, presence or absence of existing habitat or other desirable floodplain features, quality of the habitat, and the ability to provide immediate benefit to fish upon removal of the existing levee. Mitigation measures for protecting existing habitat following levee removal were discussed at the time of the site visit, although that information was not included in the prioritization approach.

Observations and information obtained from the site visits were applied to the prioritization workbook Objective pages.

2014 PRIORITIZATION WORKBOOK OBJECTIVES

Metrics and scoring strategies used to define 2008 Objectives were modified as needed; first, to focus the results of 2008 analyses more squarely on habitat, and second, to describe observed habitat conditions made during the 2014 site visits. Following is a list of changes made to the 2008 Objectives and descriptors. Please see the 2008 Levee Setback Feasibility Report for a detailed description of the Workbook, scoring and ranking strategies.

Objective 1.1 (Maximize area of floodplain inundation at high frequency events)

The 2008 study used the estimated floodplain area inundated during both the 2-yr and 5-yr storm events as a measure of floodplain reconnection potential. The estimate was based on the results of a HEC-RAS hydraulic model defined for the un-leveed condition.

The 2014 study focused primarily on reconnecting the floodplain with the main stem river channel as a means of engaging habitat. Therefore, only the area inundated during the 2-yr flow event was used for this re-evaluation.

For this objective, high assessed value scores indicate that a large portion of the site is inundated during a 2-yr storm event. Individual site scores were assigned based on the quartile within which a site’s total volume fell, with 4 assigned to the highest quartile and 1 assigned to the lowest quartile.

Objective 1.2 (Maximize storage volume at low frequency events).

The 2008 project used the estimated maximum flood storage volumes over the duration of three storm events, the 25, 50, and 100-yr storms. This metric was taken as a measure of flood volumes that could be restored to the floodplains, thus reducing local and downstream flood hazards, and as an indicator of the magnitude of aquatic habitat that could be accessed and/or created during substantial flood events following the removal of the levees.

Given the importance of the benefits described above (increasing flood-state habitat and reducing local flood hazard) this objective was retained for the 2014 re-evaluation. The original, unmodified 2008 calculations and resulting scores were used in the 2014 prioritization strategy.
Scores for this objective are based on combined flood volumes calculated for the 25, 50, and 100-year storm events. Individual site scores were assigned based on the quartile within which a site’s total volume falls, with 4 assigned to the highest quartile and 1 assigned to the lowest quartile.

**Objective 1.3 (Minimize actions necessary to accomplish the goal).**

The 2008 study assigned values from 0 to 4 to sites depending on the need for, and approximate amounts of, excavation required to re-connect existing floodplain features with a main stem channel. The assignment of values was based on a series of 4 Categories developed to describe the presence or absence of existing floodplain features, their locations with respect to zones of frequent inundation and channel migration potential, and the estimate volume of soil excavated from the floodplain.

This objective was modified in the 2014 project; Categories A, B, C and D were redefined and 2 more (E and F) were added to better describe the range of possible feature Categories. Also, because the conditions of many sites have changed since 2008, excavated volumes estimated to reconnect features to the main stem channel were omitted from the 2014 prioritization analysis.

A high score for this objective corresponds to sites expected to experience immediate or short-term habitat creation simply by removing levees or revetments. The feature Categories and their associated assessed values are given below:

- **Category A** - Sites with 2-yr inundation, existing suitable floodplain features, and/or with active channel migration zones requiring no excavation; Assessed value = 4

- **Category B** - Sites with 2-yr inundation and existing suitable floodplain features but requiring some excavation to connect low-lying areas and features. Assessed value = 3.

- **Category C** - Sites with 2-yr inundation, minor or no floodplain features, but levee removal would likely result in the river moving into site or forming new secondary or side channels. Assessed value = 3.

- **Category D** - Sites with no 2-yr inundation and completely disconnected floodplain features that would require major excavation. Assessed value = 2.

- **Category E** - Sites with minor 2-yr inundation and no existing floodplain features, but would likely be eroded by main stem channel creating new channel and floodplain habitat. Assessed value = 1.

- **Category F** - sites with little to no 2-yr inundation and no floodplain features. Assessed value = 0.

**Objective 1.4, (Habitat value relative to new levee alignment).**

In the 2008 study this objective, entitled ‘Level of Flood Protection’, addressed the ability of levees adjacent to the proposed setback site to provide flood protection. The objective was assessed by posing 6 questions that focused on previously documented (as of 2007/2008) damages to adjacent levees, as well as the frequency of flooding at all adjacent properties, and levee damage repair costs.
This information was used to help define the level of protection the new levees would need to provide along adjacent properties.

The 2014 prioritization substantially modified this objective. The original 6 questions were omitted and replaced by a single question that looks only at where the setback proposed in 2008 is situated relative to the lateral extent of the 100 yr. flood within and adjacent to the site. This change shifts the emphasis of the Objective away from the cost of improving new levee protections, more towards the benefits of a set-back in terms of reducing levee costs and acknowledging the amount of habitat that would be gained from the set-back. For example, a new levee that is setback to the extreme edge of the 100-yr floodplain may not be needed at all or could be built to a much lower elevation and thus cost less, than a levee that or cuts through the 100-yr floodplain and, consequently, need to be built to a higher elevation. The same consideration holds for potential habitat; setting back the levee to the edge of the 100 yr floodplain offers more area for potential habitat development than if set back only partway through the 100 year floodplain.

A high score for this objective is given to sites where all or a large portion of the disconnected 100-yr flood zone is contained by the setback alignment, possibly resulting in a small levee structure or no structure at all. The scoring method applied to the location of the new levee relative to the extent of the 100-yr flood plain is given below:

- Levee placement along the landward edge of the 100-yr flood zone. Assessed value = 4
- Most of the Levee follows the edge of the 100-yr, but less than one-third the levee length does not. Assessed value = 3
- A section of the levee follows edge of the 100-yr but one half or more of the levee length does not. Assessed value = 2
- Entire length of the levee is located inside the 100-year flood zone. Assessed value = 1

Objective 2.1, (Promote channel migration within the mapped severe and/or moderate migration potential areas)

The 2008 study used the 2003 CMZ map overlain on setback sites to determine how much of the site lay with severe and moderate migration hazard areas. The metrics used to define this objective were retained unmodified for use in the 2014 prioritization project. For this objective, the assessed value score for each site was assigned based on the surface area lying within the mapped severe, moderate, or low migration potential areas (MPAs). The distribution of points is provided below:

- 100 percent of the site lies completely within the severe MPA = 4.
- 80% of the site lies within the severe MPA = 3.
- 100 percent of the site lies within either the moderate or the severe MPAs = 2.
- 100 percent of the site lies within either the low, moderate or the severe MPAs = 1.
- 10 percent or more of the site lies outside of the low, moderate or severe MPA = 0.
No Channel Migration Study was completed for the site = NA.

Objectives 2.2, 2.3, 2.4 and 2.5

In the 2008 study Objectives 2.2, 2.3, 2.4 and 2.5 focused specifically on main stem channel conditions immediately upstream, downstream and adjacent to each site. These Objectives, repeated below with their titles, were included to address potential main stem channel responses resulting from setting back a levee.

2.2 Promote increased channel complexity and multi-channel (braided) reaches
2.3 Promote more natural sediment conveyance and storage processes
2.4 Promote natural LWD recruitment and pool formation
2.5 Minimize potential adverse flooding and/or erosion impacts on local or downstream infrastructure or channel conditions.

The 2014 study omits these objectives because of the many in-channel changes that occurred in response to the January 2009 storm event, and since then. The in-channel changes ranged from substantial channel widening, particularly in areas where levees were blown out, and higher than typical sediment deposition, which likely caused aggradation along many channel sections. These changes require verifying and/or modifying in-channel portions of HEC-RAS cross sections used in the 2008 study, which could not be accommodated under the current work scope.

Objective 2.6 (Presence of existing floodplain features/tidal influence)

The 2008 study used this objective (formerly entitled ‘Improve connectivity to tributaries, potential wetlands or springs, and existing side channels’) to give credit to sites bearing specific types of existing flood plain features that would benefit fish habitat. The existing features acknowledged in this objective are: tributary channels that extend through the site, wetlands, side channels (former river channels cut off from the main stem by the levee), and springs.

The 2014 study retained the floodplain features/characteristics used in 2008, and added one more; sites located within the area of tidal influence. This last characteristic was added to acknowledge the importance of estuarine conditions to salmonid species, and to identify and reward sites situated within this important area.

Assessment scores for this Objective are based on the number and types of features/characteristics existing within a site. The scoring method is given below:

• Tributary = If yes, the name of the tributary is listed. Yes = 1.
• Wetland = Yes indicates that some portion of a wetland exists within the site. Yes = 0.5
• Side Channel = Yes indicates that a former main stem or high flow channel feature remains within
site boundaries. Yes = 1.

- Spring = Yes indicates that spring water emerges from within site boundaries. Yes = 0.5
- Tidal influence = Yes indicates the site is located in an area that is influence by the tides. Yes = 3

**Objective 3.1 (Presence of existing suitable habitat)**

The data used in 2008 came from Pierce County’s EDT model. Model results were applied to each of the sites, however, no field reconnaissance or model verification work was conducted at the time of the study.

The 2014 study omitted the 2008 metrics developed from the EDT model and replaced it with a simple scoring system based on site visit observations regarding existing habitat quality. The possible habitat value scores range from 0 (Lowest Quality Existing Habitat) to 4 (Highest Quality Existing Habitat). Habitat value scores were discussed in the field, assigned to the sites by the consulting team, and then discussed at a meeting with Pierce County Biologist Tom Nelson. The scoring method applied to this Objective is given below:

- No existing habitat or Lowest Quality Existing Habitat = 0
- Medium Range Existing Habitat = 1-3
- Highest Quality Existing Habitat = 4

**Cluster Score**

In addition to changes and modifications to 2008 objectives discussed above, a new Goal category was added to give credit to individual sites that are naturally grouped together. Scores for site groupings, called the cluster score, were added to reward sites for residing in close proximity to others. This new category speaks to the importance and benefits of reconnecting floodplains with their rivers over longer linear distances (adjacent sites on the same side of the river), and wider floodplain sections (sites located on opposing sides of the river. Both conditions offer greater flood hazard reduction and channel forming process benefits than can typically be accomplished with a single isolated site, even when the site is very large.

The scoring method applied to this objective was to award a subject site with 1 point for each adjacent site. The highest score (4) indicates that four sites are clustered around the subject site, and the lowest score (0) indicates that no other sites are located adjacent to the subject site.

**PRIORITIZATION AND RANKING APPROACH**

**Workbook Summary Page**

Prioritization and Overall ranking is performed on the Workbook Summary Page, which was substantially modified from the 2008 version. Both the original (2008) and modified (2014)
workbooks are provided in Appendix A. The changes most important to prioritizing the sites for habitat benefit are outlined below.

**Ranking**

The 2008 study prioritized sites with respect to river systems, which resulted in three distinct sets of ranked sites, one each for the Puyallup, Carbon and White river. The 2014 re-evaluation prioritized each site relative to all 32 sites regardless of river system (the Overall Rank), as a means of identifying those sites containing the most readily available quality habitat, as well as those in greatest need of restoration. At the request of the Lead Entities Advisory Group, the sites were also prioritized by river system (System Rank).
Normalization Approach

The 2008 study normalized the total Goal and individual Objective evaluations prior to ranking the sites. The 2008 normalization approach is discussed in a preceding section of this report. Normalization was NOT applied to any of the 2014 results. All 2014 calculation results, and the allocation of assessment value points, were left untouched.

Weighting Factors

A weighting factor (formerly referred to as the Weighting Function) was applied to all Objectives and the Cluster category. This factor is intended to used to emphasize or diminish assessed value scores for any Objective or the Cluster score, across all sites. Weighting factors applied in the 2014 study are given below:

- Cluster Score = 0.5
- Objective 1.1 (Maximize area of floodplain inundation at high frequency events) = 1.0
- Objective 1.2 (Maximize storage volume at low frequency events) = 0.75
- Objective 1.3 (Minimize actions necessary to accomplish the goal) = 1.0
- Objective 1.4 (Protection offered by new levee alignment) = 0.75
- Objective 2.1 (Promote channel migration within mapped severe and/or moderate migration potential areas) = 0.5
- Objective 2.6 (Presence of existing floodplain features/tidal influence) = 1.0
- Objective 3.1 (Presence of existing potential habitat conditions) = 1.0

The above Weighting Factors are applied to Objectives and Cluster scores shown on the Workbook Summary Page (brought forward from individual objective pages). The ‘weighted’ scores for each Objective are calculated, summed across each site, and posted in the Priority Value column. The selection of individual Objective Weighting Factors was based on the relevance and importance of specific types of site features and/or characteristics to habitat. For example, Objective 1.1 (Floodplain reconnection) is considered very important to habitat and was given a maximum Weighting Factor of 1.0. It is important to note here that County practitioners can modify the values of Weighting Factors to suite future needs; very important Objectives can be set to a value of “1”, and less important Objectives can be set some fraction of “1” (0.50, 0.75).

Overall Rank

The Overall Rank of a site is based on the sum of the Assessed Objective Scores multiplied by the assigned Weighting Factors, referred to as the Priority Value, and ranked with respect to all 32 sites. This approach generated duplicate scores, which in turn resulted in duplicate ranking values. For example, the duplicated rank numbers include ranks 7, 14, 23, and 28 (there are sets of sites each with ranks of 7 and 14). All duplicate ranks are defined by the letter (d).
Cost Benefit Rank.

The 2008 study included both total project costs and land availability in the final prioritization strategy. The 2008 project costs included the assessed property value, estimated costs for removing the old levee and constructing a new 100-yr levee along the setback alignment (each based on costs per lineal foot), and design, permitting and monitoring costs.

Project costs were not included in the 2014 study because the County wished to restrict the focus of the re-evaluation to habitat, and avoid biases associated with project costs. While not included in the Overall Ranking, the estimated 2008 project costs still offer substantial information regarding the financial feasibility of any setback project. To make better use of this information, the 2014 ‘Cost/Benefit Rank’ was developed to provide a relative measure of project costs per the habitat benefit gained; it is calculated as the project cost for each set back, divided by the sum of the site’s assessed value score, and ranked with respect to all 32 sites. For most sites, project costs are based on cost estimates evaluated in 2008. However, project costs for some sites already in progress or scheduled for completion, were updated to reflect more current estimates or actual costs. These sites included Calistoga (Site 18), South Fork (Site 14), and Fennel Creek (Site 09). The cost benefit rank includes the use of combined priority value scores for Goals 1, 2, 3 and the new clustering score.

RESULTS OF THE 2014 RE-EVALUATION STUDY

SITE PRIORITIZATION AND RANKING RESULTS

Complete results of the 2014 re-evaluation for existing habitat conditions are presented in the Prioritization Workbook, provided in Appendix A. For convenience and comparison purposes, the Workbook Summary page is shown in Table 1. The Table lists the sites by ascending final overall rank, and Assessed Values. Weighting factors assigned to the Objectives and the Cluster Score are shown above each Objective column and are accounted for in the Assessed Values Column.

Objectives focused on floodplain reconnection (Objective 1.1), the presence of floodplain features offering usable off-channel habitat (Objectives 1.3, 2.6 and 3.1) were assigned the highest weighting factor of 1.0. Flood storage (Objective 1.2) and the location of the setback levee relative to the 100-yr floodplain (Objective 1.4) were each given a weighting value of 0.75. The lowest weighting value, 0.5, was assigned to the Cluster score and the location of the site relative to the mapped Channel Migration Zone. Note that final site prioritization and ranking does not include project costs (see the previous section entitled Prioritization Workbook Changes; Summary Page). Of the sites with ranks from 1 through 10, 6 are located on the Puyallup River, 2 on the Carbon River, and 2 on the White River.
The total assessed value scores for each of the Objectives shown on Table A1 indicates that all Goal 1 Objectives play a dominant role in final site rankings. However, close review of Table 1 also shows that most sites occupying the top ten ranks are heavily favored by high scores in Objective 1.3 (Minimize Actions Necessary to Accomplish the Goal).

Table 2, below, looks at the influence of all Objectives and the Cluster Score on the top 10 ranked sites.

Table 1 Overall Ranking – top ten ranked sites

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Site #</th>
<th>River System</th>
<th>2014 Overall Rank</th>
<th>Priority Value</th>
<th>Cluster Score</th>
<th>Inundation</th>
<th>Maximum Flood Storage</th>
<th>Minimize Floodplain Actions</th>
<th>Minimize Habitat Value relative to New Levee Alignment</th>
<th>Promote Channel Migration</th>
<th>Presence of Existing Floodplain Features / Tidal Influence</th>
<th>Floodplain Features / Tidal Influence</th>
<th>Presence of Existing Suitable Habitat</th>
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Note that in addition to Objective 1.3, Objectives 1.1 and 3.1 greatly influenced the final results. The Cluster Score and Objective 2.6 (Presence of existing floodplain features/tidal influence) played the least important role in the final ranking. Objective 2.6 showed comparatively poorly, largely
because tidal influence was given a high assessed value, but could be assigned to only one site, Site #1.

Sorting the ranked sites with respect to Objective 1.3 (Table 3) shows that with the exception of Site #11 (ranked 6th), the top 10 ranked sites and Sites #25 (Ranked 11), #26 (Ranked 12) and Site 16 (ranked 14) have a high assessed value of 4.

Table 2 Influence of Objective 1.3 on Overall Rank

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<th>Minimize Floodplain Actions 1.3</th>
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<td>190th Ave downstream</td>
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<td>Puyallup</td>
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<td>5</td>
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<td>4</td>
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<td>Right Bank Carbon</td>
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<td>Bridge Street</td>
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A similar exercise looking at the influence of Objective 3.1 is provided in Table 4, below. Most of the top 10 sites have Assessed Values of 3 and 4. The exceptions to this is Site #11 (Ranked 6th), which has an Assessed Values of 2.

Table 3 Influence of Objective 3.1 on Overall Rank

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<th>Site Name</th>
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<td>4</td>
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COST BENEFIT RANK

As described in a preceding section of this report, the ‘Cost Benefit Rank’ was added to the evaluation to provide some measure of the estimated cost of levee setback projects with respect to the total priority value estimated for a site. This rank can be used to identify those projects offering the best value within a selected range of Overall Rankings. The results of this evaluation are provided below in Table 5.

Table 4 Comparison of Overall and Cost Benefit Ranks

<table>
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* Costs based on current estimates or actual costs for project in-progress
Table 5  Comparison of Overall Rank, Cluster and Objective 1.1, 1.3, 3.1 Scores

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Site #</th>
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CLUSTERED SITES

Re-evaluation results displayed on Table 1 indicate that the Cluster Score is not a strong influence on the site ranking. However, setting back the levees of closely grouped sites clearly offers opportunities for achieving all Goals and Objectives that individual sites cannot provide. The greatest overall benefit is that of increasing the length and/or width of the active channel. This is particularly important for achieving (or restoring) dynamic reach-scale channel forming processes and flood storage, especially where the width of the natural active channel corridor has been substantially reduced along the Puyallup and Carbon Rivers.

Clustered sites that have merited high values in Objectives 1.1, 1.3, and 3.1 offer a very high potential for gaining immediate habitat benefit following a levee setback. Table 6, below, shows a comparison of sites, first with respect to high cluster scores, and then to Objective 1.1, 1.3 and 3.1.

Sites with the highest combined scores (Cluster, and Objectives 1.1, 1.3, 3.1) include:

- Site #10: 116th Reconnection (Ranked 1st) Combined score = 15
- Site #13: Upper Puyallup Confluence (Ranked 2nd) Combined score = 14
- Site #12: McCutcheon Rd & 128th (Ranked 7th) Combined score = 14
- Site #19: 190th Ave Downstream (Ranked 3rd) Combined score = 14
- Site #11: Canyon Falls Creek (Ranked 6th) Combined score = 13
- Site #15: Horse Haven (Ranked 4th) Combined score = 13
- Site #32: Countyline (Ranked 5th) Combined score = 13

Clustered site benefits associated with flood plain reconnection and flood storage are particularly obvious when viewed on reach-scale maps overlain with the FEMA 100-year floodplain and 1931-1998 Historic Migration Zone boundaries. The Historic Migration Zone is referred to in this report as the Historic Channel Occupation Tract (HCOT) after terminology used in Pierce County's channel migration zone mapping (GeoEngineers 2003). These maps are provided in Appendix B of this report.

The HCOT boundaries, shown in blue on the maps, are generally consistent with the active channel width prior to the construction of levees. The active channel is observable from 1931, 1940, and in some areas the 1965 aerial photographs. Note that the HCOT does not extend downstream from the confluence of the Puyallup and White Rivers because CMZ mapping did not extend beyond that point; this section of the Puyallup River has been leveed and severely confined since the 1920s. The HCOT provides a visual reference to the active channel width that was lost to the levees. The HCOT is typically underlain by alluvium and is highly susceptible to rapid erosion and channel migration. In this regard, it is part of the severe migration hazard area, and is accounted for in Objective 2.1.

The compilation of the HCOT, FEMA floodplain and Electron Mudflow presents a compelling
picture of the effectiveness of setting back levees across clustered sites. Note that in most areas, the 100-yr floodplain is bounded by low terraces cut previously by the river. Recent field studies, and the use of LiDAR in geologic mapping, indicate that terraces on the Puyallup River and lower Carbon are composed of Electron Mudflow deposits eroded by migrating channels well prior to levee construction. Areas on the Appendix B maps where the FEMA floodplain and Electron Mudflow deposits overlap are most likely the result of idiosyncrasies associated with the registration of different coordinate systems, and field mapping tools and techniques available in the 1950s and 60s.

Clustered sites that contain a large portion of HCOT area, and encompass all or most of the FEMA flood are poised to offer huge benefits regarding floodplain reconnection, flood storage, and natural recovery of dynamic channel forming processes. The latter of these, recovery of channel forming processes is a key contributor to the development of in-channel complexity and habitat; it is most easily encouraged by widening the currently confined channel to give riverine processes more space to function. Consequently, setting back levees along sites located opposite one another should be a high priority.

Based on visual review of the Appendix B maps, the following 3 clusters offer valuable reach-scale benefits:

- 9, 10, 11, 12, 13, and 21.
- 15, 16, and 17.
- 31 and 32.

The first, and largest group (sites 9, 10, 11, 12, 13, and 21) clearly offers the greatest opportunity for achieving both short- and long-term habitat and flood hazard reduction goals. Combined, this cluster extends roughly 10,000 feet along the channel center line, and would increase the width of the floodplain to about 2,000 feet. As shown on the Appendix B map page (Site 9-13, 21), upstream and downstream sites are separated by the 128th Street alignment and bridge crossing, both of which are likely underlain by Electron Mudflow deposits. The presence of the Electron Mudflow on both banks appears to form a natural pinch-point, or constriction, on the river, based on the topography of the terrace (Electron) underlying both bridge approaches, and the shape of the HCOT, which only dates back to 1931. This information suggests that, if the levees are set back at Sites, 10, 11, 12, and 13, the existing river banks would still form a constriction to the Puyallup River and interfere with channel forming processes and floodplain function. However, based on geomorphic analyses performed on this section of the Puyallup River for a variety of studies (CMZ analysis, 2003, Flood Hazard Management Plan, 2012), the constriction is not geologically controlled and has been maintained by the bridge and its associated protective structures.

During high flows, constrictions such as the 128th Street Bridge typically generate artificially high velocities and lack critical refugia for fish. They can also create flooding problems upstream and incision through the constriction if not sufficiently sized to accommodate high flows. Further incision and channelization caused by revetments and levees can amplify flooding downstream by increasing the celerity or speed of flood waves that would otherwise be slowed down if allowed to spread across the natural floodplain.
Historic channelization at some constrictions such as the 128th St bridge give the incorrect perception that the river channel has been relatively stable through time. However, numerous meander scars in that section of the Puyallup River valley show that the river had been very dynamic prior to being developed. Five hundred years ago the Electron Mudflow inundated the Puyallup Valley, and created a low relief to nearly level surface of mud and sand extending from hillside to hillside. Following the Mudflow, the river immediately began to cut a new channel and, due to the low surface gradient and abundant supply of sediment coming from upstream and locally eroding banks, developed meanders that migrated back and forth to form the existing floodplain.

In the time between the Mudflow and European settlement (about 400 years) the 225-275 ft wide river channel had created a floodplain bounded by scalled terraces (composed of Mudflow deposits) where the meandering river had cut into the mudflow. The floodplain ranged in width from about 500 ft to over 2600 ft. Had the bridge not been built, river meanders would have continued to migrate across and down the valley, widening the floodplain and smoothing out its perimeter. Had another century passed before development began the floodplain would certainly be much wider at the crossing. Setting back the levees and revetments in the project sites on either side of the bridge (sites 10-13) would reconnect the river to floodplain areas about 2200 ft wide.
Each site alone offers high value benefits to fish and flood reduction, but together this group of sites offers the greatest large scale benefits of any individual or clustered set of sites evaluated in this study. Widening the crossing would improve connectivity between the sites so that the cluster of 4 sites can function more as one integrated site.

CONCLUSIONS AND RECOMMENDATIONS

The goal of this project is to re-evaluate the original 32 sites for existing future habitat following the removal of levees, and to identify those sites containing the most readily available habitat. As with the 2008 study, the 2014 re-evaluation ranks the sites based on direct comparison of cumulative Objective scores. The sites are given both an Overall Rank (sites ranked relative to all 32 sites) and a System Rank (sites ranked relative other sites in a particular river system).

In as much as the final product is an overall ranking of the 32 sites, from 1 to 32, the intent of the overall ranking is not to promote or apply a ‘top down’ selection process when choosing sites for levee removal. The resulting overall ranking is meant only to identify sites prioritized under a narrow site selection criteria and should not necessarily drive the order in which sites are restored. Other criteria important to consider for prioritizing restoration sites include:

• **Risk of lost opportunity due to land conversion to other uses.** Since 2008, restoration opportunities for several of the above referenced 32 sites have already been lost due to development. Once structures are placed on a property, the acquisition typically becomes much more expensive and funds do not extend far towards restoration. It can be challenging and costly to acquire developed properties, and cumulatively, parcel fragmentation can encumber restoration on a river-reach scale. Unless properties are publically owned or zoned in a manner that restricts structures or other more permanent forms of development, there is a substantial risk that a site will be lost to another use. Therefore, properties at risk of this type of loss may justify a higher priority to secure in some manner, with a conceptual plan for restoration attached to help justify the acquisition.

• **Habitat needs of species of concern.** Each sub-basin within WRIA 10 may have important species that require more immediate attention in order to protect and provide critical habitats. In some cases, restoration opportunities may be difficult to find or may require a greater cost to implement; however, without proactive efforts to restore these habitats, the targeted species may further decline or eventually be lost entirely. Therefore, it may be prudent to place a higher priority on projects that currently have a lower rank in order to proactively restore critically needed habitat for these species.

CONCLUSIONS

Re-evaluation of the feasibility approach and ranking strategy substantially changed the priority ranks of the 32 sites as compared against the 2008 results. Table 7, below, provides 2014 and 2008 results in terms of Overall Ranks and River System Ranks. Note that, similar to the 2014 results, the conversion of 2008 System ranks to Overall ranks resulted in duplicate ranks.
Table 6: Comparison of Overall and System Ranks: 2008 and 2014

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Table 7 shows that the Overall ranking of most sites changed very substantially. The ranks of eleven sites changed from 0 to 5 places, eight sites changed from 6 to 10 places and thirteen sites changed more than 11 places. The changes are due in large part to the general 2014 approach of not normalizing any of the raw Goal 1 and 2 scores, and not including omitting Project Costs and Land Availability scores, which greatly influenced the 2008 prioritization results. Other factors contributing to the changes in ranking priority include 1) addition of the Cluster score, which was not used in 2008, 2) the revision of several objectives to focus more specifically on existing habitat,
and 3) revisions to the application of weighting factors assigned to individual Objectives. Having made this last point, it is important to note that the intent of the weighting factors is to give Workbook users the option of increasing and/or decreasing the influence of various Objectives used in the Evaluation.

A consequence of using weighting factors is that site ranks can vary depending on the weighing factors assigned by the user. Based on trial runs applying different weighting factors on the Cluster and Objectives scores, the ranks of some sites changed from 1 to 4 slots, depending on the amount the weighting factor is changed. For comparison, site ranks based on no Weighting factors are shown in Appendix Table 2.

Over the course of the re-evaluation, a few sites surfaced as being very strong candidates both respect to providing immediate habitat benefit and flood reduction. These sites include:

Site #10 (116th Reconnection – Rank 1)
Site #13 (Upper Puyallup Confluence – Rank 2)
Site #15 (Horse Haven – Rank 4)
Site #19 (190th Ave. Downstream – Rank 3)

Given the weighting factors used in this study, these 4 sites occupy the top 4 ranks and are all clustered with at least 1 other site. In addition, all but Site #10 (116th Reconnection – Rank 1) are among the top 10 Cost Benefit Ranks, rendering them excellent overall choices.

Strong consideration should also be given to the clustered site groups discussed earlier. The most beneficial group with regard to overall habitat and flood reduction is the group containing Sites 9, 10, 11, 12, 13 and 21. Combined, this cluster could help return a reach-scale section of the Puyallup, and the confluence of the Carbon and Puyallup, to its pre-leveed condition and would make large strides toward substantially reducing the existing flood hazard in both the immediate vicinity and downstream of these sites. The multiple benefits gained by treating these sites simultaneously or in increments, clearly exceeds the benefits gained from any individual site. Treatment of this site cluster is strongly recommended.

In addition to the sites discussed above, two other sites merit special consideration. They are Site #1 (Union Pacific) on the Puyallup, and Site #23 (High School) on the Carbon River. Both sites, which both place in the upper middle portion of the final ranking, could otherwise be overlooked: Union Pacific is ranked 13th, and High School is ranked 18th. While neither of these sites contain existing, readily available habitat or floodplain features that could be used without substantial restoration, both hold natural habitat value that far exceed the cost of mitigating their deficiencies.

The Union Pacific Site is on the right bank roughly 3 miles upstream from the river outlet into Commencement Bay. Although the site is not located in the estuary itself, it is in a tidally influenced portion of the channel. This environment, which is crucial to returning salmonid runs and many other wildlife species, is in extremely short supply in the Lower Puyallup basin due to dense development of the Port of Tacoma shoreline. Setting back the levee for habitat at this site will
require considerable restoration effort and cost. It is, however, the only site of the original 32 that can provide such environmental benefit to the Puyallup Basin fishery.

The habitat benefit offered by the Union Pacific Site can be increased substantially by also setting back the levee at Clear Creek, which is located directly across the river on the left bank. Clear Creek was not included in the original 32 sites evaluated in 2008 feasibility study. Subsequently, there is no hydraulic/flood plain inundation data to draw from. However, this site would likely have fallen into the top 10 or 15 sites because of its presence within a tidally influenced zone, the presence of the creek and low topography, and other beneficial floodplain features observed from 2010 LiDAR coverage. This site can be viewed on Appendix B maps.

**The High School site** (Site #23) is located in a tightly constrained portion of the Carbon River. At this site the right channel edge is pinned in place by a large steep-faced bluff composed of glacial soils. The left bank is confined by the levee, which when built, cut of roughly half the former width of the active channel. Site #23 is situated about 2,500 feet downstream from the Bridge Street site (Site #24 and ranked 7th), which is adjacent to a highly productive holding and spawning area (personal communication, Russ Ladley: Puyallup Tribe). Setting back the levees at this site would give the river some much needed space if reconnected to the floodplain, initiate dynamic channel forming processes, and add to exiting in-channel habitat currently in use in the vicinity of site 24.
RECOMMENDATIONS REGARDING FUTURE NEEDS

Over the course of this Re-Evaluation and, based on the insight allowed by new and improved technology, expanded data bases and fresh perspectives, several “next steps” emerged as necessary to achieve Pierce County’s habitat restoration and flood hazard reduction goals. These steps, or future needs, are briefly outlined below for consideration:

- First and most important is to evaluate conditions in areas lying outside the existing 32 sites, with the intent of identifying new setback sites. This action is particularly important in creating a consistent river corridor through as much of the Puyallup, Carbon and White River valleys as possible.

- Identify restoration opportunities specifically on the lower White River. As stated earlier in this report, the geomorphic history and current hydrologic conditions (as influenced by the Mud Mountain Dam) are starkly different from the Puyallup and Carbon River systems, both in terms of floodplain utilization / flood storage and favorable geomorphic floodplain features. One result of these differences is that White River sites tend to compare poorly against Puyallup and Carbon River sites. Identifying new sites critical to improving White River riverine processes and protecting / creating floodplain and aquatic habitat would be highly beneficial for priority species such as White River Spring Chinook. Such habitats in the lower White River are currently in short supply, and the few remaining area are at high risk of loss by industrial development.

- Measure and calculate the combined / cumulative footprint and effect of the identified setback projects at both reach- and lower watershed scales. This information can be used to assess the percent of total river length that could be recovered, as well as the percent of the total river floodplain (i.e., 100 yr) recovered for future funding applications.

- Include in future updates an Objective to identify favorable channel and floodplain areas at ‘risk of being developed’.

- Identify bottlenecks, or constrictions, likely to be exposed following the removal of levees from clustered sites. Potential constrictions, such as the 128th Street bridge crossing should be carefully evaluated for potential impacts to habitat and flood hazards. Additional studies may be required to determine the feasibility of re-routing roads, and designing longer bridge spans where there is undeveloped land.

- Identify potential areas/reaches hostile to fish during high flows, and determine distances between, or the frequency of, setback sites offering habitat for refugia along river.

- Identify bank modification methods and different approaches to bank/levee protection that would improve river habitat where levees can’t be set back; identify actions that complement the larger scale setback projects.

- If ecologic uplift, particularly for salmon is the primary goal, identify secondary goals that can be achieved with setback projects, specifically recreation (public access, boat ramps, trails, play fields, etc.) and agriculture.
- Develop a hydraulic routing model for the three river system that can account for added floodplain, channel length, and roughness to quantify habitat and flood benefits more accurately. The model should be sufficiently robust to address how these projects and in-stream restoration (logjams) decrease downstream flood peaks. The model could be set in an imaginary landscape roughly similar to Puyallup. The benefits of such a model would be to show the effects of 1) the percentage of the floodplain reconnected, 2) increased channel sinuosity, 3) changes in channel form (single stem to anabranching), and 4) increase in channel roughness.

LIMITATIONS

We have prepared this report for Pierce County and The Puyallup River and Chambers Creek Lead Entity Technical Advisory Board. Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices for geomorphology in this area at the time this report was prepared. The conclusions, recommendations, and opinions presented in this report are based on our professional knowledge, judgment and experience. No warranty or other conditions, expressed or implied, should be understood.

We appreciate this opportunity to be of service to Puyallup River and Chambers Creek Lead Entity Technical Advisory Board for this project and look forward to continuing to work with you. Please call if you have any questions regarding this report, or if you need additional information.

Sincerely,

Natural Systems Design, Inc.

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Senior Geomorphologist

Tim Abbe, PhD, PEG, PHG  
Principle Geomorphologist
Attachments:

- Site Vicinity Map
- Appendix A – Maps A1 and A2
- Appendix B - Sites Mapbook - Sites 1 – 32
- Appendix C - Grouped Sites Mapbook – 11 maps
- Appendix D – 2014 Workbook
- Appendix E – 2008 Workbook