MEMORANDUM

Date: February 26, 2021
To: Chehalis River Basin Flood Control Zone District, Betsy Dillin
From: Kleinschmidt Team
Re: Mitigation Capacity and Species Benefits

Introduction

The purpose of this Technical Memorandum is to provide updated mitigation related information on two important areas related to the Draft Environmental Impact Statement findings of the Flood Retention Expandable (FRE) Facility project for the Chehalis Basin. The first section of the memorandum addresses mitigation capacity on the landscape and the second section is focused on potential per-species benefits from the mitigation actions presented in the July 2020 Draft Mitigation Opportunities Report (Kleinschmidt 2020).

Capacity to Mitigate Additional Impacts

This section of the memorandum considers the capacity of the mitigation opportunities study area to provide additional compensatory aquatic habitat mitigation if future impact assessments indicate mitigation needs that exceed the functional improvement from opportunities and actions identified in the July 2020 Draft Mitigation Opportunities Report (Kleinschmidt 2020).

The work presented in this memorandum and in the July 2020 Draft Mitigation Opportunities Report represents one component of the process of evaluating whether sufficient mitigation opportunity exists within the upper Chehalis Basin. This work focuses on estimated quantities of defined habitat types for both impacts and mitigation at a coarse level of detail consistent with the impact descriptions published in the SEPA DEIS (Ecology 2020). This work was performed to provide a basis for a preliminary assessment of mitigation opportunities and potential costs. The mitigation action types used for this analysis serve as a coarse resolution proxy for a future more detailed analysis of impacts and mitigation evaluated based on ecological functions and aquatic species and life stages that are impacted or benefited.

In addition to a direct comparison of habitat quantities between impacts and mitigation, evaluation of mitigation sufficiency will need to consider the spatial and temporal context of the watershed, population dynamics and trends for affected aquatic species, limiting factors for species productivity and survival, and the cumulative effects of the project combined with other actions that affect aquatic species and their habitats. Regulatory agencies will make the determination of mitigation sufficiency and efficacy in consultation with tribes. This information is provided by the District to support early coordination with agencies and tribes regarding mitigation opportunities.

The July 2020 Draft Mitigation Opportunities Report (Kleinschmidt 2020) described a pool of 355 aquatic and terrestrial habitat mitigation sites that were identified in the initial feasibility assessment. Section 4.4 of the July 2020 draft report noted that total length of stream and river channel potentially available for compensatory mitigation for some action types may be considerably more extensive than shown. The extent of mitigation site availability is re-examined herein to document the expanded capacity of identified mitigation opportunities that would be available to address potential impacts to aquatic species not yet determined.

An additional 49 sites have been identified since the July 2020 draft report. At these additional candidate sites, there are 93 potential mitigation actions that may be applied. Many (n=34) of the additional sites are located on the upper mainstem Chehalis River between Pe Ell (Stowe Cr. confluence) and the South Fork Chehalis River. Nine of the new sites are located between the FRE site and Pe Ell and six are within the estimated FRE 10-year event inundation zone. Figure 1 is a revised version of Figure 3 from the July 2020 Draft Mitigation Opportunities Report showing aquatic habitat candidate site pool locations summed by sub-watershed.

Table 5 in the Draft Mitigation Opportunities Report presented a comparison estimated mitigation needs to a snapshot of the available sites identified at that time. Mitigation sites for action types such as riparian buffer expansion, instream modification, gravel retention jams, and off-channel modification sites had been primarily identified only in conjunction with other action types, or as examples of their type, magnitude, and extent of suitable landscape settings. For particular mitigation action types (e.g., riparian buffer expansion, instream modification, gravel retention jams, upland conservation/enhancement), the potential pool of additional sites within the geographic focus area for on-site and off-site mitigation is extensive and unlikely to be limited by availability on the landscape within the range of distribution of anadromous salmonid and lamprey in the upper Chehalis Basin. This will enable the addition, removal, shrinking, or expansion of those types of proposed sites as needed to match impacts. These adjustments can be made during the mitigation planning and design processes based on refinement of project impact analyses, predicted functional maturity timeframes, and degree of certainty of site performance. Such adjustments could also be made in an adaptive management fashion based on monitoring of post-construction project effects and mitigation site performance.

Figure 1: Updated aquatic habitat candidate site pool locations summed by sub-watershed (Revised Figure 3 from July 2020 Draft Mitigation Opportunities Report, updated to include additional sites).

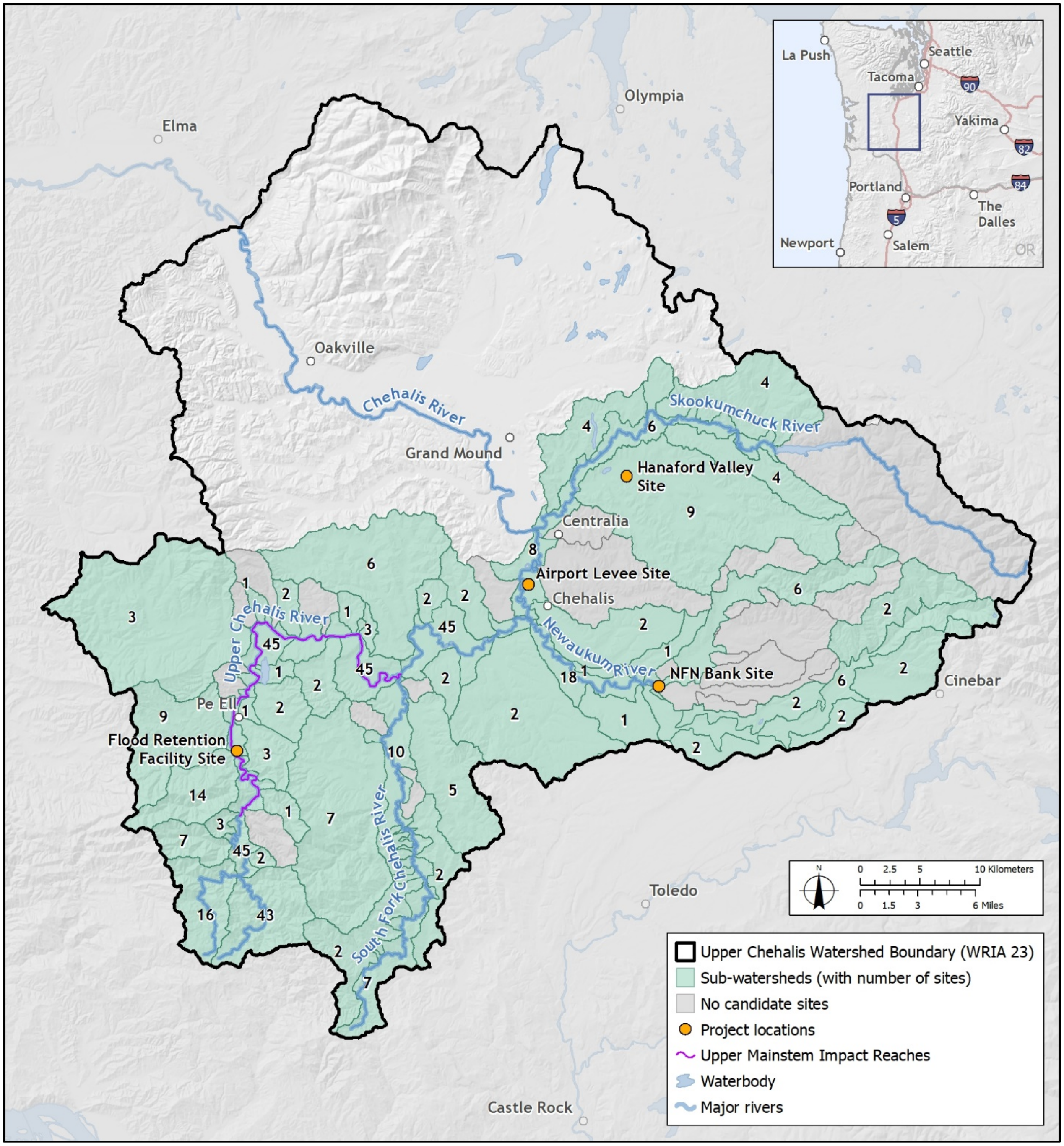


Table 1 is an update of Table 5 in the July 2020 Draft Mitigation Opportunities Report. Estimated mitigation need is verbatim from that report and is subject to revision according to ongoing effects analyses. As in the July 2020 draft report, "identified availability" is not intended to be a comprehensive sum of total availability of suitable sites in the study area. Notes for each mitigation action type outline the maximum theoretical extent of land available for each within their criteria. Additional selection methods are discussed below.

Table 1. Revised comparison of Estimated Mitigation Needs to Opportunities by Action Type

MITIGATION ACTION TYPES	ESTIMATED NEED (JULY 2020)	ESTIMATED AVAILABILITY (JULY 2020)	ADDITIONAL IDENTIFIED AVAILABILTY (FEBRUARY 2021)	NOTES
Riparian Buffer Expansion	17 miles	53 miles	5.6 miles (17 added sites)	Mainstem and tributary sites are available. May include complete reforestation, expanded forested widths, and/or management of existing full-width riparian forest in perpetuity for riparian function. Maximum theoretical extent of potential length would include all channels capable of supporting riparian vegetation in the study area that are not of optimal width, native vegetation community, and/or conservation status.
Hyporheic Exchange Enhancements	9,000 ft	28,500 ft	2700 ft (9 added sites)	Availability is controlled by valley form.
Cold-water Retention Structures	1,000 ft	18,000 ft	1250 ft (5 added sites)	Availability is controlled by hillslope topography and geology.
Instream Modifications	17,500 ft	89,000 ft	23,500 ft (47 added sites)	Maximum theoretical extent of potential length would include all fish-bearing channels in the study area that do not conform to all preference criteria of target species.
Off-channel Modifications	8,000 ft	220,000 ft	4000 ft (2 added sites)	Availability is controlled by valley form.
Gravel Retention Jams	13,500 ft	18,000 ft	10,800 ft (12 added sites)	Maximum theoretical extent of potential length would include all identified spawning reaches in the study area that do not conform to all preference criteria of target species.
Fish Passage	5 barriers	23 barriers	n/a	Availability is controlled by number of existing/inventoried barriers. Some private road crossing barriers may be missing from inventories. Additional opportunities may also include funding second-tier State of WA agency-owned or other barriers.
Wetland Enhancement	1 location (3 acres)	34 locations	1 added site	Availability is controlled by valley form, soils, and hydrology. See Wetland Mitigation Assessment.

MITIGATION ACTION TYPES	ESTIMATED NEED (JULY 2020)	ESTIMATED AVAILABILITY (JULY 2020)	ADDITIONAL IDENTIFIED AVAILABILTY (FEBRUARY 2021)	NOTES
Upland Conservation and Enhancement	2 locations (50 acres each)	10 locations (variable size >50 acres)	n/a	Maximum theoretical extent of potential area would encompass nearly all non-urban lands in the study area except those already in conservation land use type.

Selection Methods for Added Candidate Mitigation Sites

Mitigation action descriptions, site selection criteria, and average site size assumptions for the 49 additional unique sites discussed here were identical to those used in the July 2020 Draft Mitigation Opportunities Report. As in the July 2020 draft report, sub-watersheds mapped in Figure 1 are the same as used in the EDT model (McConnaha et al., 2017). Sites were selected with consideration of equipment and material accessibility.

For this effort, emphasis was placed on identifying additional sites that may be suitable for Hyporheic Exchange Enhancements (n=9), Off-channel Modifications (n=2), and Gravel Retention Jams (n=12). Twenty-five additional sites focused on Instream Modifications and one Riparian Expansion site were also added. Reflecting an emphasis on sites that may provide multiple functional benefits to multiple species and lifestages, 32 of the newly identified sites were identified as having potential for two or more mitigation action types. For each newly identified candidate site, one or more secondary potential mitigation actions (e.g., Riparian Expansion, Cold Water Retention, Instream Modification elements) were assigned where site conditions and morphology provided the opportunity. In this manner, 93 potential mitigation actions were identified that could be applied to the 49 added candidate sites.

Summed additional lengths for each mitigation action type were derived by multiplying the number of identified sites by the per-site extent assumptions in Table 2. These same assumptions were used for the July 2020 draft report.

"Identified availability" numbers are intended to be illustrative, not comprehensive: they represent only mitigation opportunities identified to date. In most cases, the process of identifying opportunities was paused for an action type when it was determined that the pool was of a sufficient magnitude to substantially exceed the estimated effects of the proposed project. For identified mitigation opportunities, the potentially available quantities for each mitigation action type exceed the estimated need by a factor ranging from 3.4 to 35 times the estimated need. These sums are not intended to provide a comprehensive inventory of total availability of suitable sites in the study area. As discussed in Table 1, within specified constraints, additional sites of each type are likely available beyond the pool identified to-date in the July 2020 Draft Mitigation Opportunities Report and in this memorandum. The theoretical maximum extents of land or channel available for each mitigation action type outlined in

Table 1 are based on the geological, biological, and land use variables that control the occurrence of areas that fit the criteria for each action type. For example, as described in Appendix B of the Draft Mitigation Opportunities Report, hyporheic exchange of the type and magnitude envisioned for enhancement occurs in specific valley forms that host alluvial channels with suitable planform geometry and adjacent terraces. Similarly, candidate locations for off-channel habitat modifications could only be sited in relatively unconfined channels in valley bottoms wide enough to possess floodplains, but without critical infrastructure. The siting of cold-water retention structures or alcoves designed to slow mixing of relatively colder local inflows is also determined by valley form: they could be sited where groundwater seeps join perennial fish-bearing channels (mostly found higher in the study area in steeper, more constrained channels) and at the downstream end of hyporheic enhancement sites (found at lower elevations in the study area) to capture hyporheic outflows for the creation of local temperature refugia.

Table 2. Assumed Typical Site Quantities for Each Mitigation Action Type (verbatim from Table 4 in July 2020 Draft Mitigation Opportunities Report)

MITIGATION ACTION TYPE	DESCRIPTION	QUANTITY FOR A TYPICAL SITE	UNIT OF EXTENT
Riparian Buffer Expansion	Reforestation of riparian buffers along channel margins	0.33	Length (miles)
Hyporheic Exchange Enhancements	Hyporheic exchange enhancements at selected riverbends	300	Length (feet)
Groundwater Retention Structures	Structures, side channels, or alcoves that intercept groundwater and form cool water pockets for thermal refugia	250	Length (feet)
Instream Modifications	Construction of habitat features within the perennial wetted channel for several purposes	500	Length (feet)
Off-channel Modifications	Off-channel habitat enhancements including side channel and floodplain actions	2000	Length (feet)
Gravel Retention Jams	Large wood and rock structures that provide roughness to retain salmonid spawning gravels.	900	Length (feet)
Fish Passage	Fish passage improvements including replacing fish passage barrier culverts with passable crossings.	1	Each
Wetland Enhancement	Enhancement, restoration, or expansion of wetlands to benefit wildlife species.	2	Area (acre)

MITIGATION ACTION TYPE	DESCRIPTION	QUANTITY FOR A TYPICAL SITE	UNIT OF EXTENT
Upland Conservation and Enhancement	Conservation and enhancement of specific habitats matching the requirements of focal wildlife species.	10	Area (acre)

Potential Per-Species Benefits from Mitigation Actions

This section provides a framework to cross-reference potential ecological function benefits of each mitigation action type with life stages of five target aquatic species. Table 3 summarizes these benefit types for spring-run Chinook Salmon, fall-run Chinook Salmon, Coho Salmon, Steelhead, and Pacific Lamprey. Life history characteristics of Chehalis Basin fish species were derived from the summaries in Appendix K of the NEPA DEIS (USACE 2020). This memorandum presumes that mitigation planning and design will be conducted using a process-based rather than form-based approach to select actions that match site potential and maximize long-term functioning to support fish population resilience. To ensure that mitigation projects function as intended and benefit the selected target species and lifestages, watershed position, reach and site geomorphology, hydrology, hydraulics, human constraints, and biological factors must shape mitigation planning and the specifics of each design.

The five target species considered here have overlapping habitat requirements and geographic distributions, but they differ in ways that may affect how their populations respond to habitat mitigation actions. These differences will lead to varying benefits depending on mitigation action type, location, and technical specifications. For example, spring Chinook adults' earlier freshwater entrance and longer holding periods make them particularly susceptible to pre-spawn mortality associated with summertime high water temperatures. Mitigation actions that lead to local and/or overall improvements to water temperature conditions at and downstream of spawning reaches could therefore offer relatively greater benefits to spring Chinook populations compared to species with later adult arrival in the Chehalis River. The spatial distribution of life stages also varies: coho and steelhead spawning extends higher in the basin than does Chinook (Ronne et al. 2020). The relative distribution of benefits may, in part, be managed via mitigation siting and design if emphasis on particular species or life stages is desired. The differentiating factors that will guide selection of which local habitat-forming processes (e.g., pool scour, substrate sorting, sediment transport, solar inputs, nutrient retention, surface-groundwater exchange, bank erosion, etc.) to manipulate are rooted in the distinct selective pressures that shaped the evolution of each species or stock. Compared to Chehalis Basin spring Chinook, the following general types of differences in life history and habitat needs are assumed:

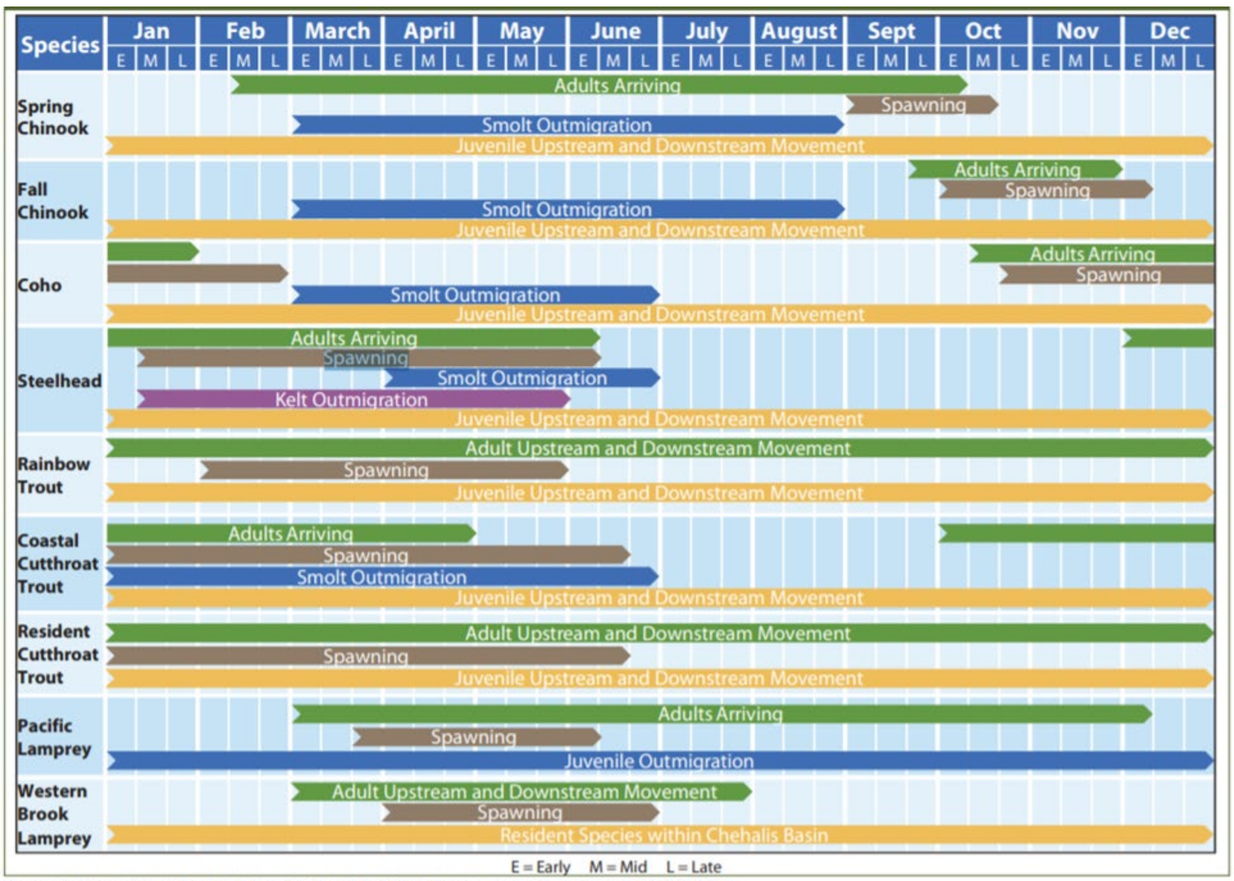
- Fall Chinook: Later adult migration, shorter holding, and later spawning timing; different spawning and rearing distribution
- Coho: Later adult migration, shorter holding, and later/longer spawning timing; different spawning and rearing distribution; smaller spawning substrate preference range; lower rearing

velocities; higher winter use of off-channel rearing habitats; shorter juvenile outmigration period; different fish passage criteria: slightly lower burst speeds and jumping abilities

- Steelhead: Later adult migration and holding timing; later and longer spawning timing; different spawning and rearing distribution; smaller spawning substrate preference range; more diverse juvenile rearing strategies (timing and locations); kelt (post-spawn adult) downstream migration; different fish passage criteria: higher burst speeds and jumping abilities
- Pacific lamprey: Longer adult migration and holding periods; earlier spawning timing; different spawning and rearing distribution; smaller spawning substrate preference range; need for fine sediments for larval rearing; no natal fidelity; continuous juvenile outmigration; different fish passage criteria (no jumps or sharp angles, but can climb vertical wetted surfaces)

Figure 2 is a fish periodicity chart from the Draft SEPA EIS that illustrates timing differences between the target fish species.

Figure 2 Anticipated migration periods of selected fish species and life stages (Figure E-4 from 2020 SEPA DEIS).



Source: Data from Wydoski and Whitney 2003 and Holt 2019; figure adapted from Figure 2-1 in CBS 2018b.

Mitigation site selection will be guided, in part, by known population limiting factors and habitat-forming processes that are likely to be affected by the FRE project. Geomorphological potential and constraints will also guide the process of matching actions to sites. Mitigation actions will be designed according to their location in regard to the life stages that use (or could use) the reach and the associated habitat processes that will support the site's suitability for those life stages. As an example, for a site on the upper mainstem Chehalis River above Doty, the design may emphasize processes that capture, retain, and sort spawning gravels and provide rearing habitat with suitable depth, complexity, and velocities across a range of seasonal flows. A site in the middle reaches of the upper mainstem Chehalis River may emphasize floodplain reconnection and hyporheic enhancement to provide increased forage, high flow refuge, off-channel overwintering habitat, nutrient flux, adult holding water, and temperature moderation. A site on the South Fork may emphasize the creation of seasonal non-natal rearing opportunities and riparian enhancements to reduce summer thermal load contribution and support other habitat improvements.

While some mitigation concepts will be designed specific to species and life stage needs, most mitigation concepts and locations discussed in the July 2020 Draft Mitigation Opportunities Assessment could benefit any of the five target species to some degree due to overlapping spatial distributions and habitat requirements. Table 4 and Table 5 summarize, per target species and life stage, which of the functional benefit types summarized in Table 3 would be expected to be derived from elements of two of the conceptual examples in the Mitigation Opportunities Assessment, demonstrating the application of a variety of mitigation action types across multiple sites within a reach. Those conceptual examples were for hypothetical reaches (based on actual locations within the study area), so Table 4 and Table 5 assume the presence of each of the life stages of the five target species within each reach, with habitat use partitioned in time and space. Actual benefits to fish species will depend on selected locations and designs: actions may benefit species and lifestages unequally. An upper river mitigation site offering enhanced summer rearing habitat could benefit juvenile coho and steelhead more than Chinook due to the ocean-type juvenile Chinook migration strategy observed in the Chehalis by Winkowski et al. (2018), but the same mitigation actions applied further downstream could bias benefits toward Chinook. Mitigation site size and complexity will also influence benefits: smaller sites are more likely to precisely target and benefit a narrower range of species and lifestages per location, but larger sites that are located within overlapping species ranges and designed with diverse and complex habitat features that function across a range of seasonal flow stages will benefit a wider range of species and lifestages. During later mitigation planning and design processes, Table 3 may be refined to indicate selection of targeted limiting factors (e.g., summer rearing habitat and temperature, per Winkowski et al. [2018]), and the checkmarks in Table 4 and Table 5 may be replaced with more detailed site-specific descriptions or quantifications of applicable functional benefits per species and life stage.

Table 3: Potential functional benefits assigned to mitigation action type per target species and life stage.

SPECIES	LIFE STAGE	ACTION TYPES							
		RIPARIAN BUFFER EXPANSION	HYPORHEIC EXCHANGE ENHANCEMENTS	COLD WATER RETENTION STRUCTURES	INSTREAM MODIFICATIONS	OFF-CHANNEL MODIFICATIONS	GRAVEL RETENTION JAMS	FISH PASSAGE	WETLAND ENHANCEMENT
SPRING CHINOOK	Adult migration and holding	Shade to reduce warming; water quality filtration; LWD recruitment for cover and holding pool structure and cover.	Local temperature refuge and buffering	Local temperature refuge	Increased holding pool depth and cover		Increased holding pool depth and cover	Increased access to holding and spawning habitats	Water quality filtration; temperature buffering; reduced PSM risk
	Spawning	Where excess bank or riparian soil erosion is occurring, revegetation may reduce erosion that leads to gravel embeddedness; increased overhanging cover.	Increased quantity or quality of attractive spawning habitat		Increased suitable spawning area; increased substrate sorting; increased cover. Where excess bank or riparian soil erosion is occurring, wood structures may reduce erosion that leads to embeddedness.		Increased suitable spawning area; increased substrate sorting	Increased access to spawning habitat	Floodplain wetlands capture and retain fine sediments that can otherwise lead to gravel embeddedness.
	Incubation	Where excess bank or riparian soil erosion is occurring, revegetation may reduce erosion that leads to egg suffocation.	Moderation of incubation temperatures		Localized reduction of redd scour by increasing hydraulic roughness. Where excess bank or riparian soil erosion is occurring, wood structures may	Reach-scale reduction of redd scour by reducing scour forces at high flows	Localized reduction of redd scour		Floodplain wetlands capture and retain fine sediments that can otherwise lead to egg suffocation.

SPECIES	LIFE STAGE	ACTION TYPES							
		RIPARIAN BUFFER EXPANSION	HYPORHEIC EXCHANGE ENHANCEMENTS	COLD WATER RETENTION STRUCTURES	INSTREAM MODIFICATIONS	OFF-CHANNEL MODIFICATIONS	GRAVEL RETENTION JAMS	FISH PASSAGE	WETLAND ENHANCEMENT
					reduce erosion that leads to egg suffocation.				
	Rearing	Shade to reduce warming; water quality filtration; CPOM nutrient inputs; invertebrate forage; LWD recruitment for hiding and water velocity heterogeneity	Local temperature refuge and buffering	Local temperature refuge	LWD for cover and water velocity heterogeneity; substrate sorting; pool formation	Low-velocity rearing and refuge	LWD for cover and water velocity heterogeneity; substrate sorting; pool formation	Access to non-natal rearing habitats	Water quality filtration; temperature buffering; invertebrate forage if in floodplain
	Outmigration				Refuge from predation	Refuge from predation	Refuge from predation	Access to non-natal rearing habitats	Water quality filtration; invertebrate forage if in floodplain
FALL CHINOOK	Adult migration and holding	Shade to reduce warming; water quality filtration; LWD recruitment for cover and holding pool structure and cover	Local temperature refuge and buffering	Local temperature refuge	Increased holding pool depth and cover		Increased holding pool depth and cover	Increased access to holding and spawning habitats	Water quality filtration; temperature buffering; reduced PSM risk
	Spawning	Where excess bank or riparian soil erosion is occurring, revegetation may reduce erosion that	Increased quantity or quality of attractive spawning habitat		Increased suitable spawning area; increased substrate sorting; increased cover. Where excess bank or riparian soil		Increased suitable spawning area; increased substrate sorting	Increased access to spawning habitat	Floodplain wetlands capture and retain fine sediments that can otherwise lead to gravel embeddedness.

SPECIES	LIFE STAGE	ACTION TYPES							
		RIPARIAN BUFFER EXPANSION	HYPORHEIC EXCHANGE ENHANCEMENTS	COLD WATER RETENTION STRUCTURES	INSTREAM MODIFICATIONS	OFF-CHANNEL MODIFICATIONS	GRAVEL RETENTION JAMS	FISH PASSAGE	WETLAND ENHANCEMENT
		leads to gravel embeddedness; increased overhanging cover.			erosion is occurring, wood structures may reduce erosion that leads to embeddedness.				
	Incubation	Where excess bank or riparian soil erosion is occurring, revegetation may reduce erosion that leads to egg suffocation.	Moderation of incubation temperatures		Localized reduction of redd scour by increasing hydraulic roughness. Where excess bank or riparian soil erosion is occurring, wood structures may reduce erosion that leads to egg suffocation.	Reach-scale reduction of redd scour by reducing scour forces at high flows	Localized reduction of redd scour		Floodplain wetlands capture and retain fine sediments that can otherwise lead to egg suffocation.
	Rearing	Shade to reduce warming; water quality filtration; CPOM nutrient inputs; invertebrate forage; LWD recruitment for hiding and water velocity heterogeneity	Local temperature refuge and buffering	Local temperature refuge	LWD for cover and water velocity heterogeneity; substrate sorting; pool formation	Low-velocity rearing and refuge	LWD for cover and water velocity heterogeneity; substrate sorting; pool formation	Access to non-natal rearing habitats	Water quality filtration; temperature buffering; invertebrate forage if in floodplain
	Outmigration				Refuge from predation	Refuge from predation	Refuge from predation	Access to non-natal rearing habitats	Water quality filtration; invertebrate forage if in floodplain
COHO	Adult migration and holding	Shade to reduce warming;	Local temperature refuge and buffering	Local temperature refuge	Increased holding pool depth and cover		Increased holding pool depth and cover	Increased access to holding and	Water quality filtration; temperature

SPECIES	LIFE STAGE	ACTION TYPES							
		RIPARIAN BUFFER EXPANSION	HYPORHEIC EXCHANGE ENHANCEMENTS	COLD WATER RETENTION STRUCTURES	INSTREAM MODIFICATIONS	OFF-CHANNEL MODIFICATIONS	GRAVEL RETENTION JAMS	FISH PASSAGE	WETLAND ENHANCEMENT
		water quality filtration; LWD recruitment for cover and holding pool structure						spawning habitats	buffering; reduced PSM risk
	Spawning	Where excess bank or riparian soil erosion is occurring, revegetation may reduce erosion that leads to gravel embeddedness.			Increased suitable spawning area; increased substrate sorting. Where excess bank or riparian soil erosion is occurring, wood structures may reduce erosion that leads to embeddedness.		Increased suitable spawning area; increased substrate sorting	Increased access to spawning habitat	Floodplain wetlands capture and retain fine sediments that can otherwise lead to gravel embeddedness.
	Incubation	Where excess bank or riparian soil erosion is occurring, revegetation may reduce erosion that leads to egg suffocation.			Localized reduction of redd scour by increasing hydraulic roughness. Where excess bank or riparian soil erosion is occurring, wood structures may reduce erosion that leads to egg suffocation.	Reach-scale reduction of redd scour by reducing scour forces at high flows	Localized reduction of redd scour		Floodplain wetlands capture and retain fine sediments that can otherwise lead to egg suffocation.
	Rearing	Shade to reduce warming; water quality filtration; CPOM nutrient inputs;	Local temperature refuge and buffering	Local temperature refuge	LWD for cover and water velocity heterogeneity; substrate sorting; pool formation	Low-velocity rearing and refuge	LWD for cover and water velocity heterogeneity; substrate sorting; pool formation	Access to non-natal rearing habitats	Water quality filtration; temperature buffering; invertebrate forage if in floodplain

SPECIES	LIFE STAGE	ACTION TYPES							
		RIPARIAN BUFFER EXPANSION	HYPORHEIC EXCHANGE ENHANCEMENTS	COLD WATER RETENTION STRUCTURES	INSTREAM MODIFICATIONS	OFF-CHANNEL MODIFICATIONS	GRAVEL RETENTION JAMS	FISH PASSAGE	WETLAND ENHANCEMENT
		invertebrate forage; LWD recruitment for hiding and water velocity heterogeneity							
	Outmigration				Refuge from predation	Refuge from predation	Refuge from predation	Access to non-natal rearing habitats	Water quality filtration; invertebrate forage if in floodplain
STEELHEAD	Adult migration and holding; kelt migration	Shade to reduce warming; water quality filtration; LWD recruitment for cover and holding pool structure	Local temperature refuge and buffering	Local temperature refuge	Increased holding pool depth and cover		Increased holding pool depth and cover	Increased access to holding and spawning habitats	Water quality filtration; temperature buffering; reduced PSM risk and lower kelt mortality from stormwater contaminants
	Spawning	Where excess bank or riparian soil erosion is occurring, revegetation may reduce erosion that leads to gravel embeddednes s.			Increased suitable spawning area; increased substrate sorting. Where excess bank or riparian soil erosion is occurring, wood structures may reduce erosion that leads to embeddedness.		Increased suitable spawning area; increased substrate sorting	Increased access to spawning habitat	Floodplain wetlands capture and retain fine sediments that can otherwise lead to gravel embeddedness.
	Incubation	Where excess bank or riparian soil erosion is occurring, revegetation may reduce			Localized reduction of redd scour by increasing hydraulic roughness. Where excess bank or riparian soil	Reach-scale reduction of redd scour by reducing scour forces at high flows	Localized reduction of redd scour		Floodplain wetlands capture and retain fine sediments that can otherwise lead to egg suffocation.

SPECIES	LIFE STAGE	ACTION TYPES							
		RIPARIAN BUFFER EXPANSION	HYPORHEIC EXCHANGE ENHANCEMENTS	COLD WATER RETENTION STRUCTURES	INSTREAM MODIFICATIONS	OFF-CHANNEL MODIFICATIONS	GRAVEL RETENTION JAMS	FISH PASSAGE	WETLAND ENHANCEMENT
		erosion that leads to egg suffocation.			erosion is occurring, wood structures may reduce erosion that leads to egg suffocation.				
	Rearing	Shade to reduce warming; water quality filtration; CPOM nutrient inputs; invertebrate forage; LWD recruitment for hiding and water velocity heterogeneity	Local temperature refuge and buffering	Local temperature refuge	LWD for cover and water velocity heterogeneity; substrate sorting; pool formation	Low-velocity rearing and refuge	LWD for cover and water velocity heterogeneity; substrate sorting; pool formation	Access to non-natal rearing habitats	Water quality filtration; temperature buffering; invertebrate forage if in floodplain
	Outmigration				Refuge from predation	Refuge from predation	Refuge from predation	Access to non-natal rearing habitats	Water quality filtration; invertebrate forage if in floodplain
PACIFIC LAMPREY	Adult migration and holding	Shade to reduce warming; water quality filtration; LWD recruitment for cover and holding pool structure	Local temperature refuge and buffering	Local temperature refuge	Increased holding pool depth and cover		Increased holding pool depth and cover	Increased access to holding and spawning habitats	Water quality filtration; temperature buffering
	Spawning	Where excess bank or riparian soil erosion is occurring, revegetation			Increased suitable spawning area; increased substrate sorting.		Increased suitable spawning area; increased substrate sorting	Increased access to spawning habitat	Floodplain wetlands capture and retain fine sediments that can otherwise

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		may reduce erosion that leads to gravel embeddedness.			Where excess bank or riparian soil erosion is occurring, wood structures may reduce erosion that leads to embeddedness.				lead to gravel embeddedness.
	Incubation	Where excess bank or riparian soil erosion is occurring, revegetation may reduce erosion that leads to egg suffocation.			Localized reduction of redd scour by increasing hydraulic roughness. Where excess bank or riparian soil erosion is occurring, wood structures may reduce erosion that leads to egg suffocation.	Reach-scale reduction of redd scour by reducing scour forces at high flows	Localized reduction of redd scour		Floodplain wetlands capture and retain fine sediments that can otherwise lead to egg suffocation.
	Rearing	Shade to reduce warming; water quality filtration; CPOM nutrient inputs; LWD recruitment for hiding and water velocity heterogeneity	Local temperature refuge and buffering	Local temperature refuge	LWD for cover and water velocity heterogeneity; substrate sorting; pool formation	Increased rearing habitat and capacity due to local fine sediment accumulation for larva burrowing	LWD for cover and water velocity heterogeneity; substrate sorting; pool formation		Water quality filtration; temperature buffering
	Outmigration				Refuge from predation	Refuge from predation	Refuge from predation		Water quality filtration

Table 4: Potential functional benefits of conceptual examples per target species and life stage for Example Conceptual Design Group #2, a hypothetical location on the mainstem Chehalis River from the July 2020 Draft Mitigation Opportunities Assessment.

SPECIES	LIFE STAGE	ACTION TYPES: EXAMPLE CONCEPTUAL DESIGN GROUP #2 (MAINSTEM CHEHALIS RIVER)							
		RIPARIAN BUFFER EXPANSION	HYPORHEIC EXCHANGE ENHANCEMENTS	COLD WATER RETENTION STRUCTURES	INSTREAM MODIFICATIONS	OFF-CHANNEL MODIFICATIONS	GRAVEL RETENTION JAMS	FISH PASSAGE	WETLAND ENHANCEMENT
		Riparian reforestation and protection	*Hyporheic forcing structures and bank treatments*	*Groundwater refugia creation* *Alcove creation and expansion*	*Large wood installations*	*Floodplain reconnection* *Paleo channel enhancement*	*Large wood structures*		*Floodplain wetlands enhancement, creation, and/or reconnection*
SPRING CHINOOK	Adult migration and holding	+	+	+	+		+	+	+
	Spawning				+		+	+	
	Incubation				+	+	+		
	Rearing	+	+	+	+	+	+	+	+
	Outmigration				+	+	+	+	+
FALL CHINOOK	Adult migration and holding	+	+	+	+		+	+	+
	Spawning				+		+	+	
	Incubation				+	+	+		
	Rearing	+	+	+	+	+	+	+	+
	Outmigration				+	+	+	+	+
COHO	Adult migration and holding	+	+	+	+		+	+	+
	Spawning				+		+	+	
	Incubation				+	+	+		
	Rearing	+	+	+	+	+	+	+	+
	Outmigration				+	+	+	+	+
STEELHEAD	Adult migration and holding	+	+	+	+		+	+	+
	Spawning				+		+	+	
	Incubation				+	+	+		

SPECIES	LIFE STAGE	ACTION TYPES: EXAMPLE CONCEPTUAL DESIGN GROUP #2 (MAINSTEM CHEHALIS RIVER)							
		RIPARIAN BUFFER EXPANSION	HYPORHEIC EXCHANGE ENHANCEMENTS	COLD WATER RETENTION STRUCTURES	INSTREAM MODIFICATIONS	OFF-CHANNEL MODIFICATIONS	GRAVEL RETENTION JAMS	FISH PASSAG E	WETLAND ENHANCEMENT
	Rearing	+	+	+	+	+	+	+	+
	Outmigration				+	+	+	+	+
PACIFIC LAMPREY	Adult migration and holding	+	+	+	+		+	+	+
	Spawning				+		+	+	
	Incubation				+	+	+		
	Rearing	+	+	+	+	+	+		+
	Outmigration				+	+	+		+

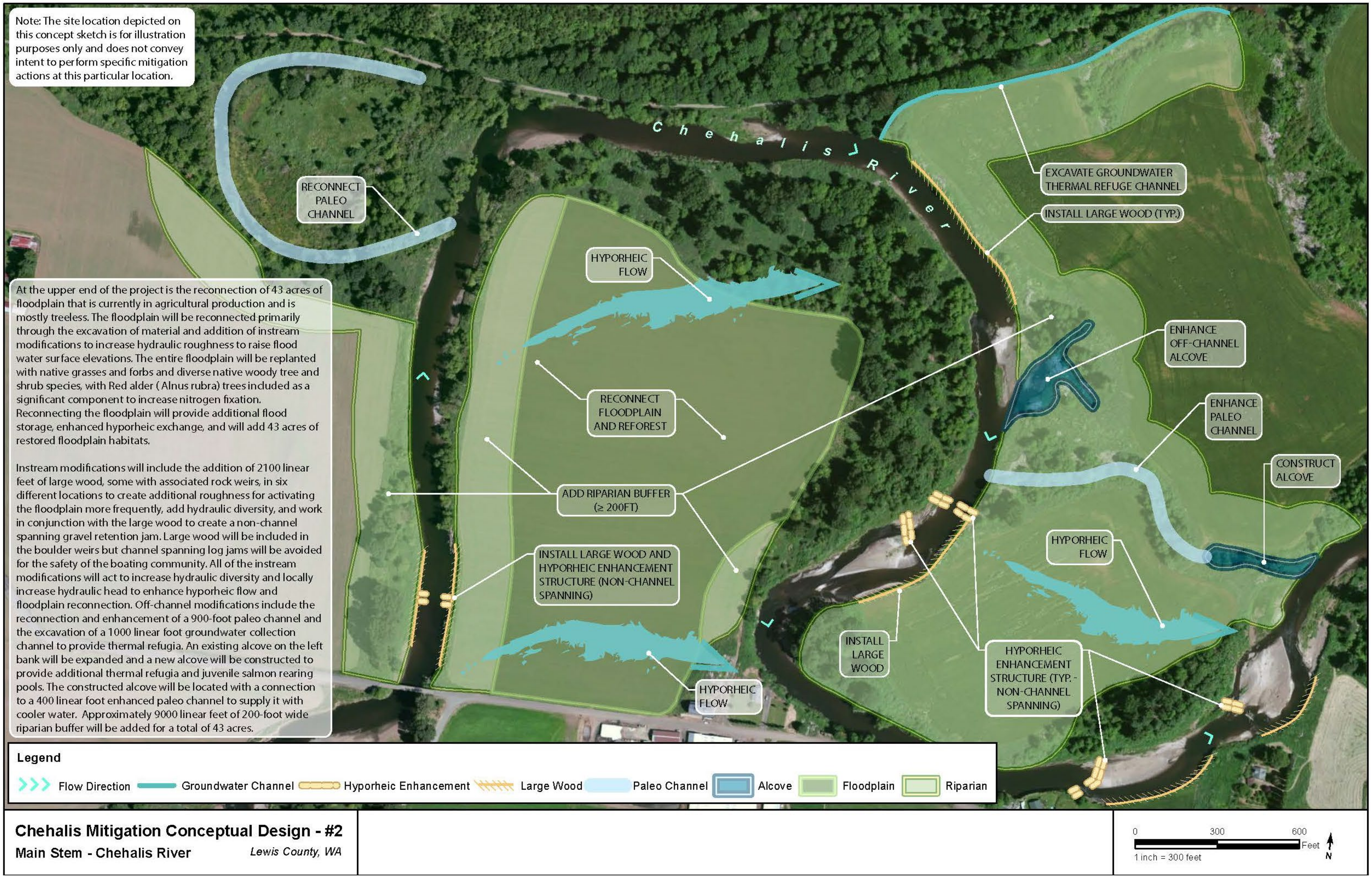

Note: The site location depicted on this concept sketch is for illustration purposes only and does not convey intent to perform specific mitigation actions at this particular location.
Chehalis River
RECONNECT PALEO CHANNEL
HYPORHEIC FLOW
EXCAVATE GROUNDWATER THERMAL REFUGE CHANNEL
INSTALL LARGE WOOD (TYP.)
ENHANCE OFF-CHANNEL ALCOVE
ENHANCE PALEO CHANNEL
CONSTRUCT ALCOVE
RECONNECT FLOODPLAIN AND REFOREST
ADD RIPARIAN BUFFER (≥ 200FT)
INSTALL LARGE WOOD AND HYPORHEIC ENHANCEMENT STRUCTURE (NON-CHANNEL SPANNING)
HYPORHEIC FLOW
INSTALL LARGE WOOD
HYPORHEIC ENHANCEMENT STRUCTURE (TYP. - NON-CHANNEL SPANNING)
HYPORHEIC FLOW
At the upper end of the project is the reconnection of 43 acres of floodplain that is currently in agricultural production and is mostly treeless. The floodplain will be reconnected primarily through the excavation of material and addition of instream modifications to increase hydraulic roughness to raise flood water surface elevations. The entire floodplain will be replanted with native grasses and forbs and diverse native woody tree and shrub species, with Red alder (Alnus rubra) trees included as a significant component to increase nitrogen fixation. Reconnecting the floodplain will provide additional flood storage, enhanced hyporheic exchange, and will add 43 acres of restored floodplain habitats.
Instream modifications will include the addition of 2100 linear feet of large wood, some with associated rock weirs, in six different locations to create additional roughness for activating the floodplain more frequently, add hydraulic diversity, and work in conjunction with the large wood to create a non-channel spanning gravel retention jam. Large wood will be included in the boulder weirs but channel spanning log jams will be avoided for the safety of the boating community. All of the instream modifications will act to increase hydraulic diversity and locally increase hydraulic head to enhance hyporheic flow and floodplain reconnection. Off-channel modifications include the reconnection and enhancement of a 900-foot paleo channel and the excavation of a 1000 linear foot groundwater collection channel to provide thermal refugia. An existing alcove on the left bank will be expanded and a new alcove will be constructed to provide additional thermal refugia and juvenile salmon rearing pools. The constructed alcove will be located with a connection to a 400 linear foot enhanced paleo channel to supply it with cooler water. Approximately 9000 linear feet of 200-foot wide riparian buffer will be added for a total of 43 acres.
Legend
Flow Direction
Groundwater Channel
Hyporheic Enhancement
Large Wood
Paleo Channel
Alcove
Floodplain
Riparian
Chehalis Mitigation Conceptual Design - #2
Main Stem - Chehalis River
Lewis County, WA
0
300
600
Feet
1 inch = 300 feet
N

Table 5: Potential functional benefits of conceptual examples per target species and life stage for Example Conceptual Design Group #5, a hypothetical location on the South Fork Chehalis River from July 2020 Draft Mitigation Opportunities Assessment.

SPECIES	LIFE STAGE	ACTION TYPES: EXAMPLE CONCEPTUAL DESIGN GROUP #5 (SOUTH FORK CHEHALIS RIVER)							
		Riparian Buffer Expansion	Hyporheic Exchange Enhancements	Cold Water Retention Structures	Instream Modifications	Off-channel Modifications	Gravel Retention Jams	Fish Passage	**WETLAND ENHANCEMENT**
		Riparian reforestation and protection	*Hyporheic forcing structures and bank treatments*	*BDA structures at hyporheic return locations*	*Large wood installations for habitat and bank erosion protection*	*Floodplain reconnection* *Paleo channel enhancement, reconnection, and excavation*	*Large wood structures*		*Floodplain wetlands enhancement, creation, and/or reconnection*
SPRING CHINOOK	Adult migration and holding	+	+	+	+		+	+	+
	Spawning	+			+		+	+	
	Incubation				+	+	+		
	Rearing	+	+	+	+	+	+	+	+
	Outmigration				+	+	+	+	+
FALL CHINOOK	Adult migration and holding	+	+	+	+		+	+	+
	Spawning	+			+		+	+	
	Incubation				+	+	+		
	Rearing	+	+	+	+	+	+	+	+
	Outmigration				+	+	+	+	+
COHO	Adult migration and holding	+	+	+	+		+	+	+
	Spawning	+			+		+	+	
	Incubation				+	+	+		
	Rearing	+	+	+	+	+	+	+	+
	Outmigration				+	+	+	+	+
STEELHEAD	Adult migration and holding	+	+	+	+		+	+	+

SPECIES	**LIFE STAGE**	**ACTION TYPES: EXAMPLE CONCEPTUAL DESIGN GROUP #5 (SOUTH FORK CHEHALIS RIVER)**							
		Riparian Buffer Expansion	Hyporheic Exchange Enhancements	Cold Water Retention Structures	Instream Modifications	Off-channel Modifications	Gravel Retention Jams	Fish Passage	**WETLAND ENHANCEMENT**
		Riparian reforestation and protection	*Hyporheic forcing structures and bank treatments*	*BDA structures at hyporheic return locations*	*Large wood installations for habitat and bank erosion protection*	*Floodplain reconnection* *Paleo channel enhancement, reconnection, and excavation*	*Large wood structures*		*Floodplain wetlands enhancement, creation, and/or reconnection*
	Spawning	+			+		+	+	
	Incubation				+	+	+		
	Rearing	+	+	+	+	+	+	+	+
	Outmigration				+	+	+	+	+
PACIFIC LAMPREY	Adult migration and holding	+	+	+	+		+	+	+
	Spawning	+			+		+	+	
	Incubation				+	+	+		
	Rearing	+	+	+	+	+	+		+
	Outmigration				+	+	+		+

Conceptual Design Group #5 is located on the South Fork Chehalis River upstream of the confluence with Stillman Creek. This reach of the South Fork contains active and fallow agricultural fields such that much of the channel has no riparian trees/shrubs.

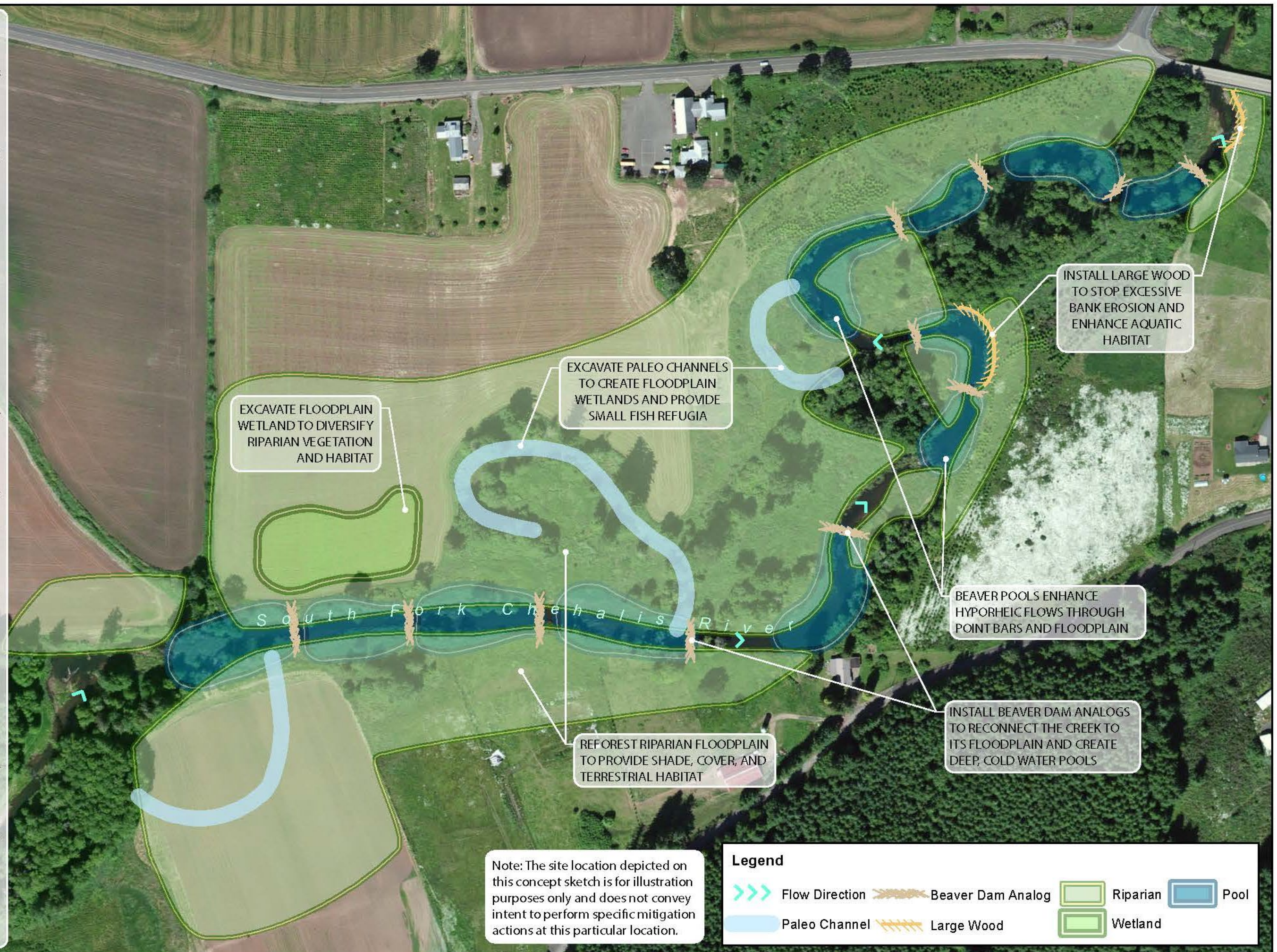
The design calls for the installation of 11 beaver dam analogs (BDA's) to increase hydraulic head to enhance hyporheic flow; reconnect the floodplain; create deep, cold water pools; and diversify riparian hydrology/vegetation. While the BDA's are intended to increase frequent floodflow access to the floodplain, they would be located and installed such that they will not adversely impact structures or other properties. Because the BDA's will most likely not be installed to top of bank, It might be advantageous to excavate some of the river banks to create more hydrologic diversity around the proposed "beaver ponds".

Other instream modifications include the installation of about 350 linear feet of large wood toe stabilization on two areas of severely eroding banks. The large wood toe is completely underwater to increase roughness and thus reduce velocities of high flows at the toe of bank where shear stresses are highest and it provides fish habitat in the pool.

There are two paleo channels on this site that can be excavated to reconnect them to the river as well as deepen and widen them. This will create backwater refugia for small fish as well as floodplain wetlands for hydrologic and vegetative diversity. The agricultural fields next to the straightened reach of river provide the opportunity to create a backwater, oxbow wetland that mimics a paleo channel. This proposed floodplain feature will provide the same ecological benefits as the enhanced paleo channels.

On the opposite side of the river in the straightened reach the agricultural field provides the opportunity to create a broad, floodplain wetland. About two acres of wetland could be created by excavating about 6000 cubic yards from the floodplain. This would diversify the hydrology and riparian plant community. And it may be advantageous to connect this wetland to the proposed "beaver pond".

Riparian buffer will be added along the entire reach of river in the project area as well as around the enhanced paleo channels and floodplain wetland. The riparian buffer plantings will be tailored to the new hydrologic conditions and will include large patches of willows around the ponds to entice beavers. Approximately 4000 linear feet of 100-foot to 300-foot wide riparian buffer will be added, for a total of 36 acres. Added riparian buffer will reduce thermal inputs to the river when the trees reach maturity as well as terrestrial habitat and carbon source for aquatic insects.



Chehalis Mitigation Conceptual Design - #5
South Fork - Chehalis River *Lewis County, WA*

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