STREAM & FLOODPLAIN RESOURCE MANAGEMENT Natural Systems Design P.O BOX 15609 SEATTLE, WASHINGTON 98115

To: **Quinault Indian Nation**

From: Natural Systems Design, Inc.

Date: April 22, 2020

Re: **CASCADE OF FRE FACILITY ECOSYSTEMS EFFECTS TECHNICAL MEMO**

EXECUTIVE SUMMARY

A qualified technical team of senior ecologists, geomorphologists, biologists, hydraulic engineers, and hydrologists reviewed the SEPA Draft Environmental Impact Statement (DEIS), along with related documents prepared to support the proposed Flood Retention Expandable (FRE) facility project (proposed project) being reviewed by the State of Washington's Department of Ecology under that State Environmental Policy Act (SEPA). The team was composed of Kevin Fetherston PhD, PWS; Tim Abbe, PhD, PEG, PHG; Mike Ericsson, MS, PG; Paul Pittman, MS, PEG; Scott Katz, MS; Susan Dickerson, PhD, PG; and Torrey Luiting, MS, PWS. Hydraulic considerations were reviewed by Leif Embertson, PE and Megan Nelson PE, MS. Review of wildlife, fisheries, and forest practices elements of the proposed project was completed by Caprice Fasano, BS; Kristen Phillips, MS; Andrew Annanie, BS, and Lauren Macfarland, MSc.

The team reviewed the DEIS, as well as the Earth, Water, Wetlands, Wildlife, and Fisheries Discipline Reports, the Chehalis Basin Strategy technical analyses including: Chehalis Basin Strategy Geomorphology, Sediment Transport, and Large Woody Debris Report (Watershed GeoDynamics & Anchor 2017), Downstream Floodplain Wetland Analysis (Anchor April 2019), 2018 Chehalis ASRP Instream Amphibian Survey Report (Hayes et al. 2018), Cottonwood Habitat Study (Hough-Snee and Anchor 2019), Geomorphology and Sediment Transport (Watershed GeoDynamics 2019). Particular attention was paid to the hydrology, geomorphology, and climate change technical analyses presented in these documents, and the consequent potential impacts to wetlands, waters, fish and wildlife species, and habitats upstream and downstream of the proposed FRE facility.

The totality of these analyses was examined together to specifically consider the linkages between riverine, riparian, and wetland physical and biologic processes and to assess the degree to which the DEIS accurately identifies and quantifies the direct impacts and the indirect cascade of effects on fish and wildlife that would occur as a result of the construction of the proposed FRE facility and its flood control operations. In particular, this review applies a hierarchical framework that is well-established in the scientific literature (Jorde et al. 2008; Burke et al. 2009; Naiman et al. 2005; Ward and Stanford 1995). The framework is used for linking first-order impacts, which are alterations to the physical drivers of ecosystems (e.g., hydrology), to the cascade of effects to second- and third- order impacts, which are physical and biological responses of the ecosystem, respectively. Lastly, the framework provides a tool to characterize linkages between biological feedbacks (i.e., forth-order impacts) and amplification of ecosystem impacts.

The review team concluded that the following **critical assumptions, omissions, and errors are present in the DEIS and associated discipline reports, which result in a gross underestimation of the potential for ecosystem-scale impacts and for the amplification of impacts over time if the proposed project is approved for construction and operation:**

- The DEIS fails to consider, analyze or characterize the physical and ecologic process linkages inherent in riverine ecosystems and thus **fails to consider the consequent indirect impacts of the cascade of ecosystem effects and the amplification of those effects over time that will result from the proposed project.** The proposed project will result in a cascade of impacts to both existing floodplain/off-channel water bodies and wetlands, as well as a loss of the physical processes that create and sustain the future formation of floodplain wetlands and floodplain/off-channel water bodies, resulting in a significant, unmitigable amplification of impacts over time.
- Impacts related to **upstream reservoir ecosystems are underestimated for the following reasons:**
  - The following first-order impacts related to **upstream reservoir ecosystem** hydrology and sediment supply are individually underestimated in the DEIS.
    - The frequency and duration of reservoir impoundment are underestimated for both current and future climate conditions.
    - The frequency and duration of backwatering events and their associated impacts are not considered or analyzed.
    - Increases in the frequency and magnitude of landslides and hillslope erosion, and therefore sediment delivery, are drastically underestimated.
  - Underestimating impacts to individual first-order processes leads to underestimation of impacts to channel morphology, sediment transport, vegetation, and aquatic habitat within the reservoir area.
  - Compounding impacts that result from the interactions and feedback between processes (both those underestimated and those sufficiently characterized) are not considered and will amplify ecosystem impacts relative to assessments of individual impacts.
- Impacts related to **downstream ecosystems are also underestimated for the following reasons:**
  - The underestimated first-order impacts that drive the cascade of local ecosystem impacts in the upstream reservoir (listed above) are also applicable to **downstream impacts.**
  - In addition to the upstream first-order impacts that are underestimated, the following additional first-order impacts to downstream processes are in error or underestimated in the DEIS:
    - Reductions to groundwater recharge are underestimated based on underestimated frequency of peak flow events that would trigger FRE operation and underestimated recharge rates.
    - The hydrologic connection between groundwater and surface water are inadequately analyzed, resulting in underestimated impacts to floodplain water bodies, wetlands, and baseflow.
    - Reductions to downstream sediment transport and coarse sediment supply are underestimated.
    - Impacts to downstream sediment transport processes are underestimated due to flawed modeling assumptions.
    - The increase in fine sediment supply from increased frequency and magnitude of landslides and hillslope erosion, and thus, downstream impacts of fine sediment to aquatic habitat are underestimated.

        - The determination of minor impacts on downstream floodplain water bodies and wetlands is inconsistent with the DEIS supporting documents, and does not account for well-established linkages between large flood events and the formation and maintenance of floodplain water bodies and wetlands.
    - An underestimation of impacts to individual first-order processes leads to underestimation of impacts to channel morphology, sediment transport, vegetation, and aquatic habitat downstream of the proposed FRE facility.
    - The compounding impacts that result from the interactions and feedback between processes was not considered and will amplify ecosystem impacts relative to assessments of individual impacts.
- Multiple analyses used to quantify second- and third-order effects in the DEIS are flawed:
    - The determination and delineation of the spatial extent of the DEIS impact analysis domain is based upon flawed hydrogeomorphic assumptions regarding the longitudinal extent of impacts due to FRE operations.
        - Modeling results and data presented in the DEIS do not support limiting the spatial extent of moderate to significant impacts on geomorphic processes to areas upstream of the South Fork Chehalis and Newaukum River confluences.
    - The downstream impact assessment to channel and floodplain morphology and hydrologic connectivity (second-order effects) is based upon a flawed hydrogeomorphic modelling analysis.
    - The impact analysis of downstream ecological processes, and plant, fish and wildlife community habitats (third-order effects) is based upon an inadequate modeling approach.
    - Therefore, the analysis of direct and indirect impacts to fish and amphibian habitats is inadequate.
- Because there are demonstrated flaws in the hydraulic and geomorphic modeling approaches, all analyses that depend on those models are inadequate. **Therefore, all impacts to geomorphic processes and those dependent on the conclusions of the geomorphic analyses are under-estimated in the DEIS.**
- The DEIS fails to account for the ways in which climate change projections for lower summer streamflow will be amplified by downstream impacts to floodplain inundation and groundwater recharge; impacts to aquatic habitat will be more severe with the exacerbation of lower summer streamflow and higher summer stream temperatures.
- The DEIS fails to account for the ways in which climate change projections for increased frequency and magnitude of peak flows of all sizes will also affect sediment transport and therefore will exacerbate downstream channel incision and related impacts to habitat-forming processes and habitat quality.

Overall, we find that numerous individual impacts have been underestimated or insufficiently analyzed. Furthermore, we find that no meaningful analysis has considered or acknowledged the interaction of these impaired processes in an ecosystem framework. **Given the well-established interactions between geomorphic, hydrologic, and ecological processes that form and maintain high quality aquatic habitat, the impairment of several of these individual processes will set in motion a much larger "cascade" of impacts. The synchronous alteration to multiple, connected natural processes that sustain aquatic habitat sets up a positive feedback loop in which the overall impact to ecosystems is amplified relative to the alteration of any one process. These indirect impacts are not adequately or appropriately analyzed in the DEIS and its associated discipline reports.**

INTRODUCTION

An expandable flood retention (FRE) facility has been proposed as an alternative to accomplish flood damage reduction on the Chehalis River, Washington. Several alternative concepts were proposed, but the FRE facility has been advanced for environmental review under SEPA. The stated purpose of the facility is to store water in the upper watershed to alleviate flood damage to developed areas of the lower floodplain near the towns of Centralia and Chehalis. It is designed for a 100-year hydrologic event, such as the 1996 flood, but is not designed to retain larger floods such as the 2007 flood. Under the late century scenario analyzed in the DEIS, impounded water will inundate an 847- acre area upstream of the dam episodically and for variable duration when a peak flow occurs that exceeds the threshold for FRE operation. The DEIS states that full reservoir drawdown will require up to 35 days for single reservoir pool filling events.

Although the DEIS identified significant and unavoidable impacts due to FRE facility operations, the DEIS fails to fully characterize long term direct and indirect impacts to: temporary reservoir fish habitat, downstream fish habitat, downstream floodplain wetlands and off-channel water bodies (i.e. secondary channels, slough complexes, ponds and associated wetlands), and fish and amphibian habitat associated with these floodplain habitats. The DEIS fails to adequately characterize and quantify both the spatial and temporal extent of direct and indirect impacts to hydrogeomorphic and ecological processes that are critical to create and sustain habitat within the temporary reservoir area and within downstream in-channel and floodplain habitats.

The following analysis utilizes a process-based hierarchical framework for characterizing the “cascade of effects” that can be expected from the FRE facility operations (Figure 1. Hierarchy of physical and biological impacts caused by dam operations. Modified from Jorde et al. (2008)., Modified from Jorde et al. 2008; Burke et al. 2009). Consistent with best-available-science, this analysis focuses on key linkages between alterations of first order hydrologic, water quality and sediment regimes, second-order geomorphic responses, and third- and fourth-order ecological responses as a result of impacts due to the proposed project. These physical and ecological process linkages are identified and highlighted in this analysis for the both reservoir area and downstream.

We first present the process-based cascade of effects hierarchical concept and then apply the cascade of effects framework to the evaluation of the DEIS and baseline reports impacts analyses and conclusions. Lastly, we review several key analyses in the DEIS and discuss reasons that these analyses and their conclusions are flawed.

Process-based Hierarchical Framework for Characterizing Impacts of Dams–A Cascade of Ecosystem Effects

Construction and operation of dams, and their associated upstream reservoirs, result in both direct and indirect impacts to aquatic and riparian ecosystems (Figure 1). Flood control dam operations have been reported to result in a "cascade of effects," or impacts, both within dam reservoirs and on downstream river and riparian ecosystems (Figure 1. Hierarchy of physical and biological impacts caused by dam operations. Modified from Jorde et al. (2008).; Jorde et al. 2008; Burke et al. 2009; Naiman et al. 2005; Ward and Stanford 1995). First through fourth-order impacts are defined as follows (Figure 1. Hierarchy of physical and biological impacts caused by dam operations. Modified from Jorde et al. (2008).).

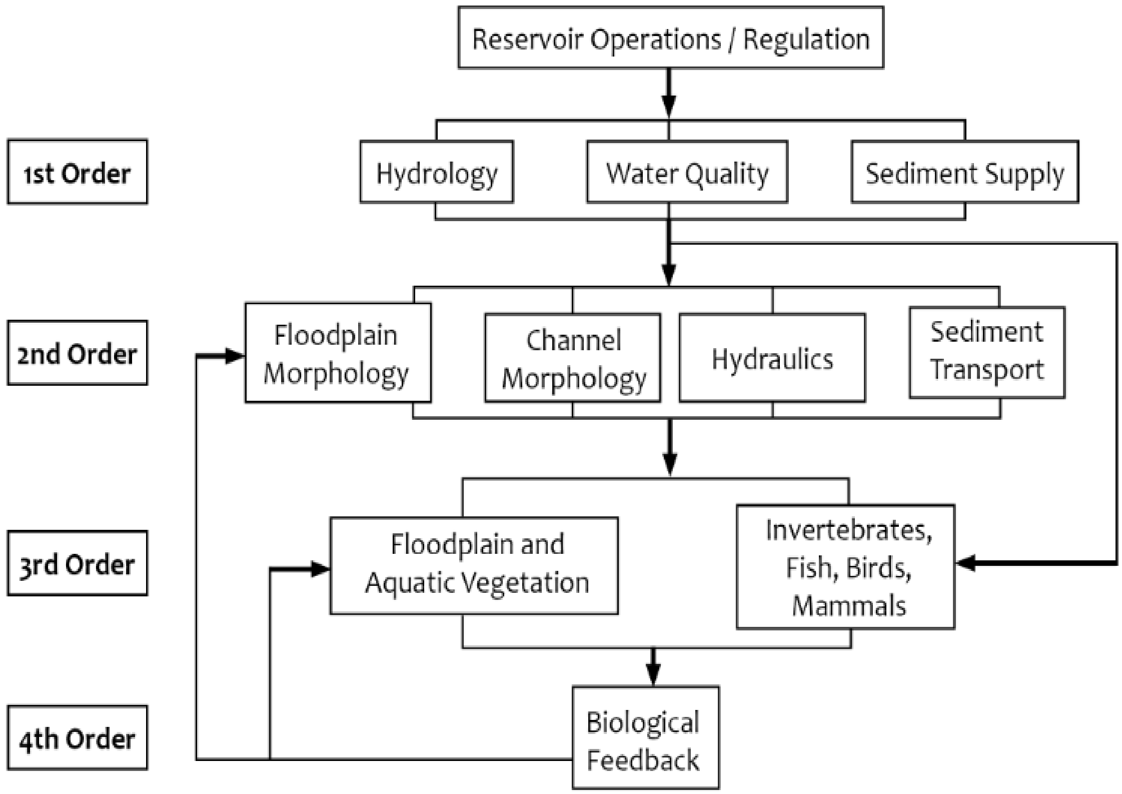


Figure 1. Hierarchy of physical and biological impacts caused by dam operations. Modified from Jorde et al. (2008).

First-order impacts

First-order impacts are changes to primary physical drivers of the fluvial system: hydrology, sediment supply, large wood recruitment, and water quality (Williams and Wolman 1984; Poff et al. 1997; Naiman et al. 2000; Grant et al. 2003). Changes in first-order processes lead to second-order impacts.

Second-order impacts

Second-order impacts are the physical responses that result from changes in first-order processes. Second-order impacts include altered channel hydraulics, sediment transport, and channel and floodplain morphology (Williams and Wolman 1984; Grant et al. 2003; Marren et al. 2014).

Third-order impacts

Third-order impacts are the ecological responses of biological communities and ecosystems to both first- and second-order impacts (Ligon et al. 1995; Naiman et al. 2000; Rood et al. 2005; Merritt et al. 2009). These biological responses reflect the altered physical processes and habitat template.

Fourth-order impacts

Fourth-order impacts are those biogeomorphic feedbacks between ecological responses and physical processes (Naiman et al. 2000; Rood et al. 2005).

A cascade of impacts occurs when a flood control dam – designed to capture and hold back high flows– alters the natural flow, sediment, and wood regimes, creating what is referred to as a first-order impact. Alteration of the natural flow, sediment and wood regimes directly impacts both downstream sediment transport and channel hydraulics, resulting in alteration of channel and floodplain morphology over time, referred to as a second-order impact. Alteration of hydrologic, sediment and wood regimes, and channel and floodplain forming processes, directly and indirectly impact the formation and function of plant, fish and wildlife habitat and then affects the plant and animal populations they support, referred to as a third-order effect. Changes in plant communities, such as vegetation encroachment into a side channel that now has a reduced flow regime, may subsequently cause changes in channel hydraulics, causing channel incision and decoupling channel and floodplain lateral connectivity. This is referred to as a fourth-order effect.

The proposed FRE facility is designed to control downstream flooding, which will impact the primary drivers of the downstream fluvial systems and second- and third-order hydrogeomorphic and ecological processes. All flood control dams affect the primary factors that control the shape, size and overall morphology of a river and its floodplain (Grant et al. 2003), including the hydrologic regime (magnitude, frequency, and duration of flows), sediment supply (volume and size) and the frequency of sediment transport, and supply and transport of large wood. Through alteration of the natural flow, sediment, wood, and disturbance regimes of riverine systems, dams have been demonstrated to affect downstream riparian and floodplain wetland vegetation composition, structure and ecosystem function (Rood et al. 2005; Johnson et al. 2012; Shafroth et al. 2010). The downstream effects of hydrologic and sediment regulation by dams have been shown to result in a cascade of effects throughout the downstream riverine and riparian ecosystems effecting both aquatic and riparian ecosystems, wetlands, plant communities and the fish and wildlife populations they support (Naiman et al. 2000; Nilsson and Berggren 2000). Richards et al. (2002) describe the cascade of effects, and their temporal and spatial cumulative impacts in downstream riparian and aquatic ecosystems as follows:

> “River hydroregulation by dams results in a terrestrialization of the vegetation, associated with a reduced rate of turnover of the fluvial landscape, reduced rates of ecosystem change, reduction of channel and ecosystem dynamics and of the mosaic detail, reduced flood frequency, and loss of habitat and age diversity.”

Rivers and Floodplains–Flood Disturbance and the Shifting Habitat Mosaic

Floodplain habitats are generated by both physical and ecological processes over space and time, including flooding, cut and fill alluviation, channel avulsions, recruitment of large wood and riparian vegetation establishment and succession (Stanford et al. 2005). Channels and floodplains form a shifting habitat mosaic of wetland and upland habitats, side channels and sloughs, depressional ponds and ephemeral water bodies (Stanford et al. 2005). Floodplain ecosystems, and their mosaic of aquatic, wetland and upland habitats, are generated and maintained by overbank floods and related disturbance processes (Ward and Stanford 1995; Hauer et al. 2016).

The Chehalis River and its tributaries are a network of channels and floodplain, a shifting habitat mosaic distributed across the river valley in a temporally dynamic pattern (Hauer et al. 2016). This shifting habitat mosaic is maintained through time by flooding and resulting geomorphic changes across the river channel and floodplains. Natural floods are critical to the generation and maintenance of floodplain and off-channel water bodies and their associated aquatic, wetland and upland habitats supportive of fish, wildlife and native plant communities. Flood control dams, by their objective designs, reduce the frequency, magnitude and duration of floods. With the operation of the FRE facility, thousands of acres of current floodplain (I.e., 3,514-4,679 acres, DEIS Table N-13) would no longer be inundated and would over time experience losses of floodplain water body, wetland and riparian habitats (Richards et al. 2002).

The foundation of the process-based cascade of effects framework is the identification of key linkages between physical and ecological processes, channel and floodplain morphology, and plant, fish, and wildlife habitats and communities. Impact analyses that do not clearly identify and characterize the interconnected web of physical and biotic linkages in aquatic and riparian ecosystems, result in inadequate analysis and incorrect determinations of impacts of process-based impacts from flood control facilities throughout the aquatic and riparian ecosystems.

We present below a number of examples of the cascade of impacts that are either not identified, are in error, or are inadequately characterized in the DEIS. In these examples, we identify significant data gaps, errors, and omissions that present significant inaccuracies regarding the conclusions made concerning the degree and magnitude of impacts of the proposed project.

ANALYSIS

Key to identifying the cascade of effects is the identification and characterization of the physical and ecological processes that generate and maintain aquatic and riparian ecosystems and communities. The DEIS fails to characterize all physical and ecological process linkages and subsequently fails to adequately assess the degree of impacts of the proposed project. Using the cascade of effects framework, we use a holistic ecosystem approach to analyze the linkages between physical and ecological processes and their impacts to habitat-forming processes and to fish and wildlife species. We address the cumulative spatial and temporal aspects of the cascade of effects, both within the FRE facility reservoir area, and downstream of the FRE facility. We provide a critique of several key DEIS analyses and conclusions, and a discussion of the ways in which these data gaps, errors and omissions result in further underestimates of impacts to aquatic and terrestrial habitat.

Upstream Reservoir Cascade of Effects

Changes to first-order processes within the reservoir footprint of the FRE facility will trigger two separate cascades of ecosystem effects: one cascade of local ecosystem effects and one cascade of downstream ecosystem effects. Several key first-order processes will be altered by the construction and operation of the FRE facility. The ways in which first-order impacts will subsequently link to second, third, and forth-order processes are insufficiently analyzed in the DEIS. In addition, the degree of several first-order impacts is underestimated or insufficiently analyzed in the DEIS, and the resulting impacts to second, third, and forth-order processes within the reservoir footprint of the FRE facility are therefore underestimated or uncharacterized.

We review the first-order impacts and then describe the linkages to second, third, and forth-order processes that set up a cascade of local ecosystem effects within the reservoir footprint of the FRE facility.

Alterations to First-Order Processes

The following first-order impacts related to hydrology and sediment supply are <u>individually underestimated in the DEIS:</u>

- The frequency and duration of reservoir impoundment are underestimated for both current and future climate conditions. The analysis of peak flows that trigger FRE operation under current conditions utilized annual flood frequency analysis and does not consider the observed occurrence of years in which multiple, independent peak flows exceed the threshold for FRE operation. Furthermore, the analysis of peak flows under future climate conditions does not reflect a “high-end” climate change scenario and therefore likely underestimates the frequency and duration of FRE operation (See NSD Hydrology White Paper, 2020).
- The frequency and duration of backwatering events and their associated impacts are not considered or analyzed (See NSD Hydrology White Paper, 2020). Backwatering occurs when streamflow is obstructed by a natural flow constriction, channel-spanning blockage, or infrastructure that lacks the conveyance capacity to pass the full volume of discharge downstream.
- Increases in the frequency and magnitude of landslides and hillslope erosion, and therefore sediment delivery to the reservoir footprint, are drastically underestimated. Clearing of native vegetation to create the proposed reservoir and water fluctuations due to flood impoundment will decrease the stability of the surrounding hillslopes and cause a greater degree of landslides and hillslope erosion (see Earth Discipline White Paper, NSD and SaturnaH2O 2020).

In addition, the following first-order impact to large wood loading is acknowledged in the DEIS, and will contribute to the cascade of effects:

- Reductions in large wood recruitment and large wood supply as a result of removing all 'flood intolerant' trees from the slopes and riparian zone of proposed impoundment area are acknowledged. This would remove a primary source of large wood to the river and would impair natural wood recruitment from banks and hillslopes.

Alterations to Second-, Third, and Forth-order Processes

As a result of underestimating several first-order impacts to individual processes, impacts to channel morphology, sediment transport, vegetation community composition, and aquatic habitat are also underestimated. Furthermore, the compounding impacts that result from the interactions and feedback between these processes are not considered and will amplify ecosystem impacts beyond that considered with assessments only individual impacts.

Reservoir Filling Links to Sediment Supply and Vegetation

The operation of the FRE facility and filling of the reservoir will contribute to increased frequency of landslides and will impair establishment of mature riparian vegetation. Both impacts are underestimated since the frequency and duration of FRE operation are underestimated.

The increased frequency of landslides will cause a greater input of both coarse and fine sediment to the reservoir footprint and to the Chehalis River system downstream than under baseline conditions. These large, episodic inputs of sediment will immediately impair aquatic habitat by burying channels and wetlands, and the increased sediment supply will contribute to a shift in morphology toward a braided channel system, which is further discussed below. The DEIS acknowledges that reservoir operations will increase fine sediment inputs, which will impact water quality and salmonid egg survival; however, predictions of fine sediment inputs due to increased landslides and erosion are grossly underestimated in the DEIS (see Earth Discipline White Paper, NSD and SaturnaH2O 2020). In addition, temporary ponding due to backwatering at the low-level outlets, which is stated as extending roughly 300 feet upstream (DEIS, p. P-73), will trigger local deposition of fine sediment due to reduced stream velocities, and will impair downstream transport of coarse sediment.

Vegetation Links Back to Sediment Supply and to Aquatic Habitat

The vegetation community within the proposed reservoir footprint will be impacted by construction and operation of the FRE facility, and the impacts to vegetation will subsequently contribute to landslide frequency, reduced water quality, and loss of large wood recruitment. Figure 2. FRE facility reservoir: Existing conditions, pre-construction management actions, flood retention events, and future conditions illustrated per the information on elevation, water depths, and vegetation zones presented in the DEIS, Appendix 1, Tables 1-3 and 1-4. Figure 3illustrates the clearing of the forests along the river and slopes within the reservoir area and the subsequent effects on soil cohesion and landslide potential. This figure is based on a cross-section of the reservoir area from approximately 460 meters upstream of RM 108. The vegetation community within the reservoir footprint will be converted from a conifer-dominated forest to a willow (*Salix* spp.) dominated scrub-shrub community (DEIS Appendix 1, Figure 1-10 and Table 1-4). On the hillslopes, this conversion will substantially reduce root cohesion, which reduces hillslope stability and contributes to increased landslides and sediment delivery (Montgomery et al. 2000; Earth Discipline White Paper, NSD and SaturnaH2O 2020).

Within riparian areas, the conversion from mature coniferous forest to a willow-dominated scrub-shrub community will affect water quality through the drastic reductions in shading and large wood recruitment. Figure 3 illustrates a 'ring' of similar vegetation impacts around the flood control reservoir at the Keechelus dam on the upper Yakima River, Washington. Riparian forest conversion impacts directly degrade local aquatic habitat quality due to increased water temperatures, reduced in-stream cover, and reduced in-stream organic material (Moore et al. 2006; Tockner et al. 1999). In addition, the reduction in large wood recruitment will indirectly degrade aquatic habitat quality by impairing geomorphic processes that depend on large in-stream wood, such as pool creation and retention of spawning gravels (Montgomery et al. 2003).

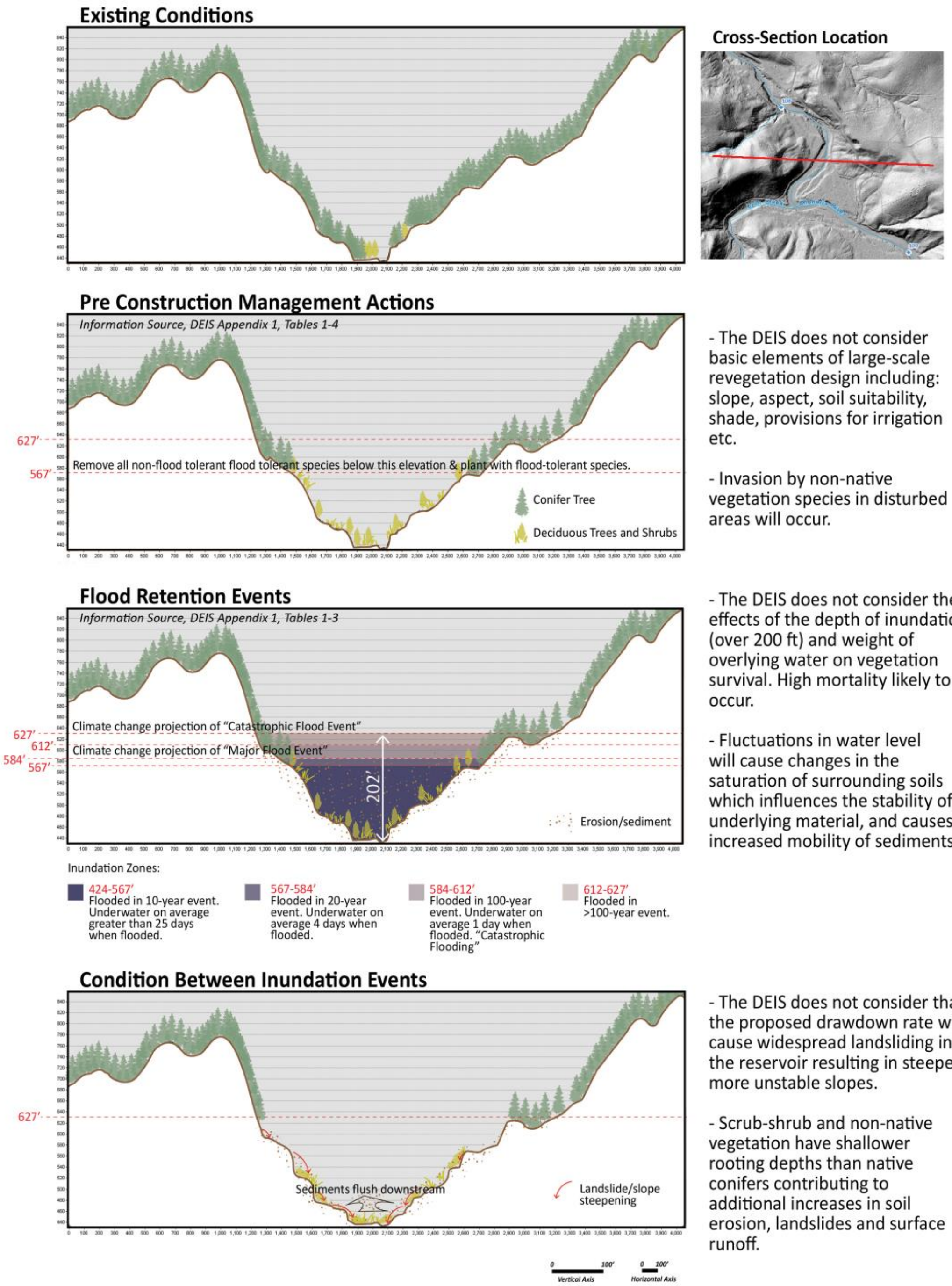
Lastly, the recruitment of large wood is a critical component of establishing "hard points" in a stream, which allow for development of mature riparian forest and the maintenance of complex channel planforms that contribute to aquatic habitat diversity (Collins et al. 2012; Montgomery and Abbe 2006). Without these "hard points" and with the combined influence of increased sediment supply and elimination of mature riparian vegetation, the morphology of the stream within the reservoir footprint is likely to become braided. Braided river systems generally provide less shade and shallower channel morphology, both of which contribute to warmer stream temperatures, than meandering or anabranching streams (Montgomery and Abbe 2006; Beechie et al. 2006). Since braided channels are highly dynamic, this morphology also sets up a positive feedback loop in which the reduction of large wood recruitment triggers braided morphology, which impairs the establishment of mature riparian forest and further maintains braided morphology.

The successful conversion and reestablishment of a new vegetation community on the reservoir hillslopes is also uncertain, given the failure of the DEIS to consider basic elements of large-scale revegetation design or the full effects of inundation. During construction, selective harvest will remove non-flood tolerant species which includes Douglas fir (*Pseudotsuga menziesii*), which is the dominant overstory species under existing conditions (DEIS Appendix 1, p. 1-32; Figure 2. FRE facility reservoir: Existing conditions, pre-construction management actions, flood retention events, and future conditions illustrated per the information on elevation, water depths, and vegetation zones presented in the DEIS, Appendix 1, Tables 1-3 and 1-4. top two panels). The area will then be planted with "flood tolerant species" that are purportedly capable of withstanding "water level fluctuations" (DEIS Appendix 1, p. 1-32; Figure 2 third panel). However, basic consideration for slope, aspect, soil suitability, shade, plant density, and provision for irrigation are omitted in the plan for establishment of 'flood tolerant species' which are described as 'willows, dogwood, and salmonberry'.

> "The Applicant's project description states vegetation would be planted to provide stability; therefore, the analysis assumes that planting of native flood-tolerant shrubs would occur after tree harvesting to minimize bare ground. It is assumed some clearing and grading for construction of temporary access roads within the temporary reservoir inundation area would be required to facilitate tree removal, but this has not been quantified. Vegetation community categories and impact areas within the temporary reservoir maximum inundation extent are shown in Table P-14 and Figures P-13 through P-15. Based on the removal of trees and plantings that would occur during construction, the resulting plant communities would be evergreen forest (Douglas fir dominated) in Zones 3 and 4 (approximately 142 acres) and scrub-shrub (dominated by young willows, dogwood, elderberry, salmonberry) in Zones 1 and 2 (approximately 600 acres total)." (DEIS Appendix P, P. P-63)

The maintenance needed to prevent the 514 acres of logged area from being overrun by early successional, weedy and/or invasive plant species between periods of inundation is ignored, as is the consequence of water level regulation on vegetation community composition (Nilsson et. al. 1997; Hill et. al. 1998). Furthermore, the DEIS focuses on projected tolerance of Pacific Northwest tree and shrub species to the depth and duration of typical riverine surface inundation (I.e. 1 to 25 days inundation at depths of 165 to 202 feet of water, late century major and catastrophic flood reservoir depths respectively [DEIS Exhibit 2-4 and Appendix P, Figure P-17 and Table P-14]) in considering vegetation survival and changes to community composition. The analysis of impacts to vegetation within the reservoir fails to consider the depth of inundation and weight of the impounded water when predicting survival and community composition of vegetation on the slopes or along the river as a result of FRE facility closure. Figure 3 illustrates the type of characteristic zone of periodically impacted vegetation that forms around reservoirs where water levels fluctuate as the reservoir is filled and drained. Lastly, given that the frequency and duration of inundation are underestimated and backwatering is not addressed, the impacts of inundation to contribute to the cycle of repeated loss of native trees, shrubs and perennial understory vegetation within the hillslope and floodplain inundation zone are also underestimated (Figure 2. FRE facility reservoir: Existing conditions, pre-construction management actions, flood retention events, and future conditions illustrated per the information on elevation, water depths, and vegetation zones presented in the DEIS, Appendix 1, Tables 1-3 and 1-4., bottom panel).

If the establishment of a new vegetation community is unsuccessful, the lack of robust woody vegetation and potential dominance of weedy and/or invasive plants would initiate a positive feedback loop in which many of the impacts discussed above are amplified. Hillslope erosion and loss of topsoil would be exacerbated, and the likelihood of establishing a native forested or scrub-shrub plant community further drops (Figure 2. FRE facility reservoir: Existing conditions, pre-construction management actions, flood retention events, and future conditions illustrated per the information on elevation, water depths, and vegetation zones presented in the DEIS, Appendix 1, Tables 1-3 and 1-4., bottom panel). The reduction of streamside shading would be amplified with little to no shade provided and consequent continued increases in water temperature. Recruitment of large wood, or any woody material, further drops, which affects channel-forming processes discussed above and further impairs the establishment of mature riparian forests and forested wetlands.



Existing Conditions

Cross-Section Location

Pre Construction Management Actions

Information Source, DEIS Appendix 1, Tables 1-4

- The DEIS does not consider basic elements of large-scale revegetation design including: slope, aspect, soil suitability, shade, provisions for irrigation etc.

- Invasion by non-native vegetation species in disturbed areas will occur.

Flood Retention Events

Information Source, DEIS Appendix 1, Tables 1-3

- The DEIS does not consider the effects of the depth of inundation (over 200 ft) and weight of overlying water on vegetation survival. High mortality likely to occur.

- Fluctuations in water level will cause changes in the saturation of surrounding soils which influences the stability of underlying material, and causes increased mobility of sediments.

Inundation Zones:

■	424-567'	Flooded in 10-year event. Underwater on average greater than 25 days when flooded.
■	567-584'	Flooded in 20-year event. Underwater on average 4 days when flooded.
■	584-612'	Flooded in 100-year event. Underwater on average 1 day when flooded. "Catastrophic Flooding"
■	612-627'	Flooded in >100-year event.

Condition Between Inundation Events

- The DEIS does not consider that the proposed drawdown rate will cause widespread landsliding in the reservoir resulting in steeper, more unstable slopes.

- Scrub-shrub and non-native vegetation have shallower rooting depths than native conifers contributing to additional increases in soil erosion, landslides and surface runoff.

Figure 2. FRE facility reservoir: Existing conditions, pre-construction management actions, flood retention events, and future conditions illustrated per the information on elevation, water depths, and vegetation zones presented in the DEIS, Appendix 1, Tables 1-3 and 1-4.

Figure 3. Keechelus Dam Reservoir, illustrating 'ring' of impacted vegetation in zone of water level fluctuation. Source: U.S. Bureau of Reclamation: https://www.usbr.gov/projects/index.php?id=294

In addition to the cascade of effects to the local ecosystem, described above, impacts to first-order processes within the reservoir footprint of the FRE facility will combine with impacts downstream of the FRE facility to trigger a cascade of downstream ecosystem effects.

Downstream Cascade of Effects

The construction and operation of the FRE facility will alter first-order processes within FRE facility reservoir area, as well as downstream of the facility; together, these changes in the first-order processes that ultimately drive habitat formation and maintenance will trigger a cascade of downstream ecosystem effects. The hierarchical cascade of effects framework is utilized to illustrate how the impacts of FRE facility operations cascade through downstream riverine and riparian ecosystems, and how those impacts are amplified across the landscape and through time. Chehalis River and FRE facility-specific elements have been incorporated in the cascade of impacts hierarchical framework in Figure 4.

Similar to the analysis of upstream ecosystem effects, the degree to which several key first-order processes will be altered are underestimated or insufficiently analyzed in the DEIS, and the resulting impacts to second, third, and forth-order processes downstream of the FRE facility are therefore underestimated or uncharacterized. Furthermore, the ways in which these first-order impacts will subsequently link to second, third, and forth-order processes are insufficiently analyzed in the DEIS.

Alterations to First-Order Processes

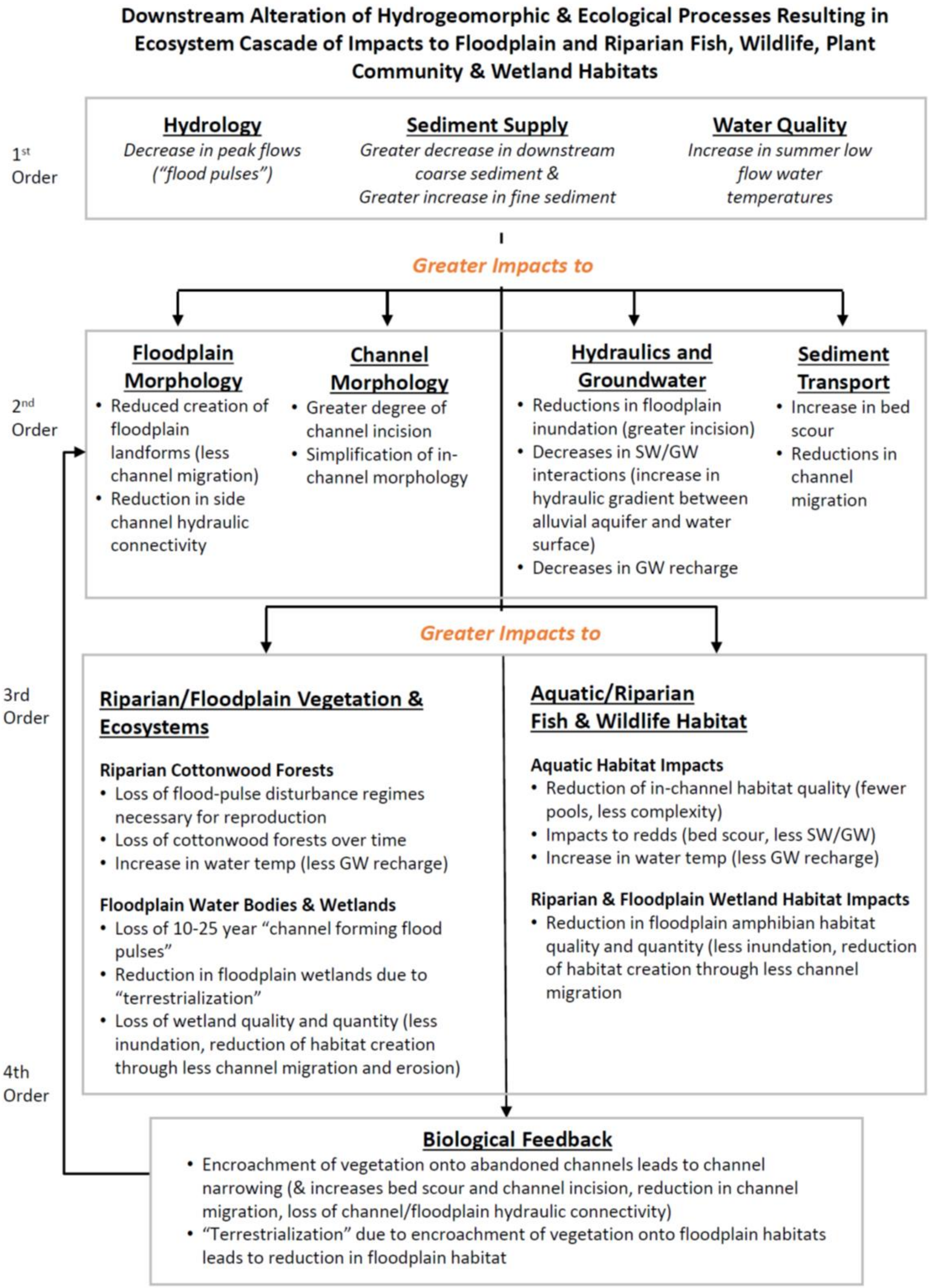
The same first-order impacts that drive the cascade of local ecosystem impacts, described above, are also applicable to downstream impacts, including underestimation in the frequency and duration of reservoir impoundment and in the frequency and magnitude of landslides and therefore sediment supply.

In addition to those impacts, the following first-order impacts related to hydrology, sediment transport, and large wood loading downstream of the FRE facility are individually underestimated in the DEIS:

- Reductions in groundwater recharge are underestimated based on underestimated frequency of peak flow events that would trigger FRE operation and underestimated recharge rates (See NSD Hydrology White Paper, 2020).
- The hydrologic connection between groundwater and surface water are inadequately analyzed, resulting in underestimated impacts related to groundwater storage and contributions to floodplain water bodies, wetlands, and baseflow (See NSD Hydrology White Paper, 2020).
- Reductions to downstream sediment transport and coarse sediment supply are underestimated.
- Reductions in downstream large wood supply are underestimated overall because reductions due to decreases in channel migration caused by decreases in coarse sediment and flow due to the FRE operation are not evaluated. Only the reductions in downstream large wood supply from blocking by the FRE facility are acknowledged.

Alterations to Second-, Third, and Forth-order Processes

As a result of underestimating impacts to these individual first-order processes, impacts to channel morphology, sediment transport, vegetation community composition, and aquatic habitat are also underestimated. Furthermore, the compounding impacts that result from the interactions and feedback between processes is not considered and will amplify ecosystem impacts relative to assessments of individual impacts.



Downstream Alteration of Hydrogeomorphic & Ecological Processes Resulting in Ecosystem Cascade of Impacts to Floodplain and Riparian Fish, Wildlife, Plant Community & Wetland Habitats

1st Order

Hydrology
Decrease in peak flows (“flood pulses”)

Sediment Supply
Greater decrease in downstream coarse sediment & Greater increase in fine sediment

Water Quality
Increase in summer low flow water temperatures

Greater Impacts to

2nd Order

Floodplain Morphology
- Reduced creation of floodplain landforms (less channel migration)
- Reduction in side channel hydraulic connectivity

Channel Morphology
- Greater degree of channel incision
- Simplification of in-channel morphology

Hydraulics and Groundwater
- Reductions in floodplain inundation (greater incision)
- Decreases in SW/GW interactions (increase in hydraulic gradient between alluvial aquifer and water surface)
- Decreases in GW recharge

Sediment Transport
- Increase in bed scour
- Reductions in channel migration

Greater Impacts to

3rd Order

Riparian/Floodplain Vegetation & Ecosystems

Riparian Cottonwood Forests
- Loss of flood-pulse disturbance regimes necessary for reproduction
- Loss of cottonwood forests over time
- Increase in water temp (less GW recharge)

Floodplain Water Bodies & Wetlands
- Loss of 10-25 year “channel forming flood pulses”
- Reduction in floodplain wetlands due to “terrestrialization”
- Loss of wetland quality and quantity (less inundation, reduction of habitat creation through less channel migration and erosion)

Aquatic/Riparian Fish & Wildlife Habitat

Aquatic Habitat Impacts
- Reduction of in-channel habitat quality (fewer pools, less complexity)
- Impacts to redds (bed scour, less SW/GW)
- Increase in water temp (less GW recharge)

Riparian & Floodplain Wetland Habitat Impacts
- Reduction in floodplain amphibian habitat quality and quantity (less inundation, reduction of habitat creation through less channel migration

4th Order

Biological Feedback
- Encroachment of vegetation onto abandoned channels leads to channel narrowing (& increases bed scour and channel incision, reduction in channel migration, loss of channel/floodplain hydraulic connectivity)
- “Terrestrialization” due to encroachment of vegetation onto floodplain habitats leads to reduction in floodplain habitat

Figure 4. Chehalis River and FRE specific hierarchy of physical and biological impacts.

Sediment and Wood Link to Channel Incision

Sediment transport and large wood recruitment and transport processes are fundamental to riverine systems and influence a wide range of physical and biological processes (Schumm 1985; Montgomery et al. 2003; Montgomery and Buffington 1998) and therefore downstream aquatic habitats, habitat-forming processes, and fish and wildlife species (third-order impact). Downstream transport of coarse sediment will be reduced by the presence (i.e., backwatering) and operation (i.e., impoundment) of the FRE facility, which reduces sediment supply downstream. As a result, the channel will cut down vertically (i.e., incise) into the floodplain as the capacity of the river to move sediment exceeds the amount of sediment available to move. Channel incision is driven by increases in the frequency and magnitude of bed scour because more hydraulic force will be applied to the channel bed instead of to transporting coarse sediment that would have otherwise been present (Schumm et al. 1984).

In addition, the DEIS analysis underestimates impacts to downstream sediment transport processes due to flawed modeling assumptions and methods. The flaws in the sediment transport model include omission of the majority of sediment contributed by the 2007 storm, omission of the contribution of increased frequency and magnitude of landslides, lack of calibration, and under-estimated impacts due to the choice of transport equation and bedload proportion (See Flawed Analyses section below for further detail). Therefore, the decrease in coarse sediment downstream of the FRE facility is likely to be greater than is quantified in the DEIS, and the magnitude and longitudinal extent of channel incision will be greater, which will further amplify the third- and forth- order impacts described below.

The magnitude and longitudinal extent of channel incision is a second-order impact, and is critically important to aquatic habitat (third-order impact) as well as setting up a positive feedback loop (fourth-order impact). Channel incision causes a simplification of in-channel morphology and the associated hydraulics (e.g. Cluer and Thorne, 2014) and directly impairs aquatic habitat through increased scour (and subsequent mortality) of salmonid redds. The simplification of in-channel structure will reduce diversity of in-channel aquatic habitat. A reduction in coarse sediment supply is also likely to reduce channel migration, which impairs the formation and maintenance of floodplain landforms such as oxbows and riverine wetlands (Naiman et al. 2005; Ward and Stanford 1995). Furthermore, channel incision vertically disconnects a channel from its floodplain, which results in surface water disconnection of side channels, sloughs, and wetlands and less frequent inundation of floodplain water bodies, decreasing the quality and quantity of aquatic habitat (third-order impact) (Brummer et al. 2006; Cluer and Thorne 2014; Amoros and Bornette 2002). Channel incision also affects groundwater contributions to baseflow, discussed further below.

Lastly, channel incision sets up a positive feedback loop in which vertical down-cutting increases the conveyance capacity of the channel, which allows for more water to be conveyed before flows overtop the banks. With more water “trapped” in the channel, stream power, which represents the erosive potential of moving water, increases leading to higher rates of scour and additional incision (e.g. Cluer and Thorne 2014).

Large Wood Supply Links to Aquatic Habitat Quality

In addition to the indirect effects on habitat quality from channel incision, which are driven by reductions in sediment and large wood supply due to retention by the FRE facility (DEIS Appendix F, Sediment Impact F-v and F-76; Wood Impact F-v and F-79), the reduction in large wood supply will directly and indirectly affect local habitat quality. Reduced in-stream wood results in reduced in-stream cover and reduced in-stream organic material, both of which are critical components of aquatic habitat quality (Moore et al. 2006; Tockner et al. 1999). In addition, the reduction in large wood loading will indirectly degrade aquatic habitat quality by impairing geomorphic processes that depend on large in-stream wood, such as pool creation and retention of spawning gravels (Montgomery et al. 2003).

Fine Sediment Supply Links to Aquatic Habitat Quality

Downstream transport of fine sediment will be increased by the increased upstream supply due to landslides and hillslope erosion, described above. The DEIS also underestimates the increase in fine sediment supply due to landslides and hillslope erosion, and thus, downstream impacts of fine sediment to aquatic habitat are also underestimated (see Earth Discipline White Paper, NSD and SaturnaH2O 2020).

Increased fine sediment degrades both in-channel and floodplain habitats that support fish and riparian-associate amphibian and wildlife species (Jensen et al. 2009). In the channel, the increase in fine sediment will cause greater sedimentation and channel bed fining which will negatively impact salmon redds by decreasing available oxygen (Greig et al. 2005). The increase in the downstream supply of fine sediment will also deposit within floodplain landforms during high flows, affecting floodplain wetlands and riparian forests (third-order impact) (Ewing 1996; Merritt and Cooper 2000).

Flood Retention and Channel Incision Link to Groundwater and In-Stream Habitat

Groundwater recharge and storage will be reduced due to the operation of the FRE facility, which leads to reduced availability for groundwater contributions to baseflow, which results in lower and warmer summer flows (Hunt et al. 2018; Loheide and Gorelick 2006) and degraded aquatic habitat. Channel incision due to decreased coarse sediment supply will further amplify the reduction in baseflow by reducing lateral hydrologic connectivity between the channel, floodplain water bodies, and wetlands. In addition, the downcutting of the channel drives increased rates of lateral groundwater flow, which results in earlier and more rapid drainage of groundwater into the local channel (Beechie et al. 2008; Tague et al. 2008). The resulting loss of groundwater storage leads to reduced availability for groundwater contributions to baseflow, which results in lower and warmer summer flows (Hunt et al. 2018; Loheide and Gorelick 2006).

Flood Retention, Channel Incision, and Groundwater Link to Floodplain Habitat

The Chehalis River downstream of the FRE facility has a diversity of floodplain water bodies (e.g. oxbows, side channels, ponds, abandoned sloughs) and wetlands that are critical salmonid and amphibian habitat (Hayes et al. 2018; Holgerson et al. 2019). The mosaic of floodplain habitats is generated and maintained by episodic flood disturbances and groundwater (Naiman et al. 2005; Ward and Stanford 1995).

The elimination of major flood peaks (i.e., greater than 38,800 cfs at Grand Mound, which has an annual flood recurrence interval of approximately 7 years under current climate conditions (DEIS, Table N-5) will reduce floodplain inundation, channel migration, and groundwater recharge. This in turn impairs the formation and maintenance of floodplain aquatic habitat (Figure 5). These critical aquatic habitats will be further degraded by the reduction in groundwater storage, which is driven by channel incision. Over time, these indirect impacts will result in desiccation of floodplain aquatic habitat and a terrestrialization of formerly active floodplains (Naiman et al. 2005; Richards et al. 2002; Ward and Stanford 1995), impacting the quantity and quality of aquatic habitats that are critical to fish and amphibian populations, especially during summer low flow conditions (Hayes et al. 2018; Holgerson et al. 2019).

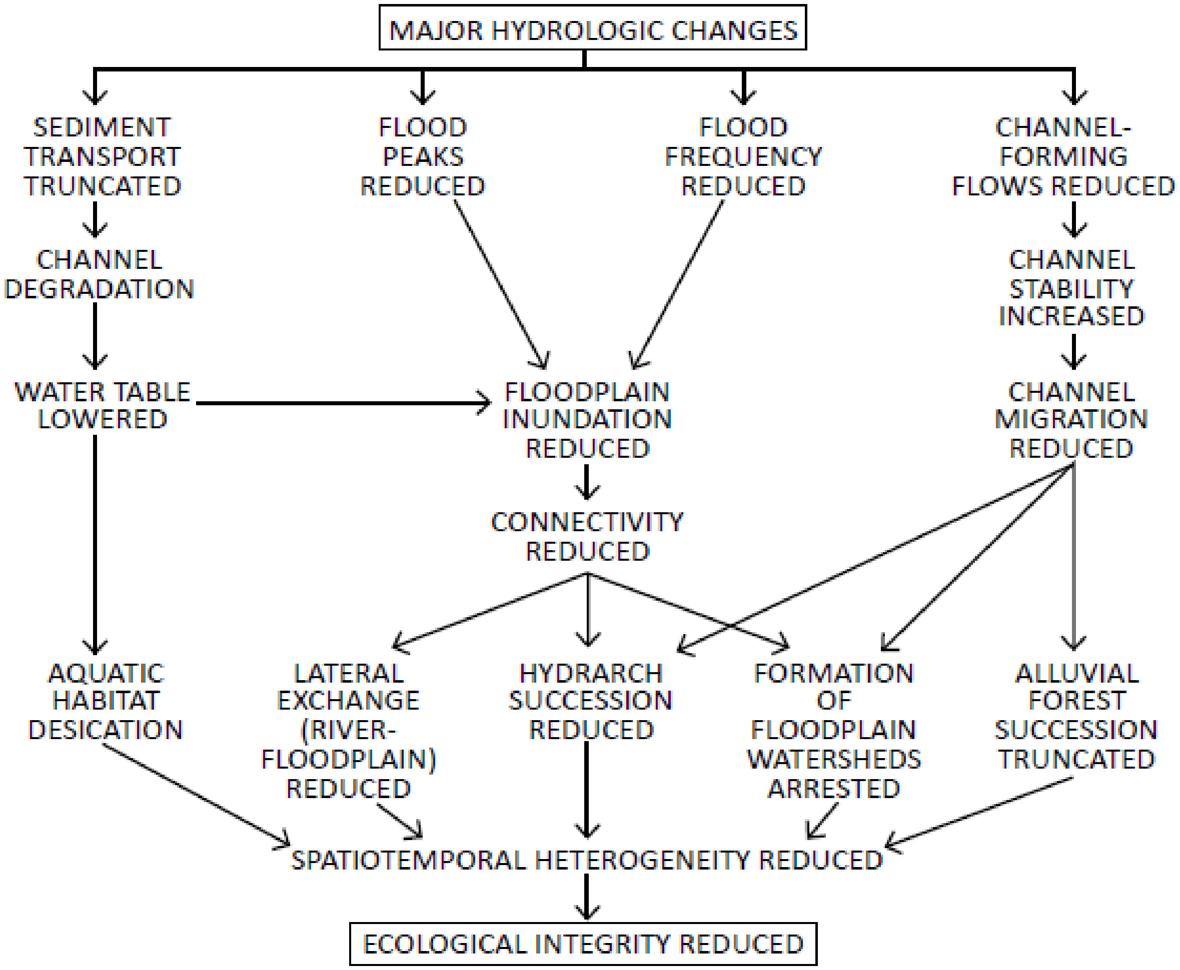


Figure 5. First, second, third and fourth-order effects of flood regulation on downstream river and floodplain ecosystems. (Naiman et al. 2005; after Ward and Stanford 1995)

DEIS Fails to Link the Cascade of Effects and Underestimates Impacts to Aquatic Habitats

The DEIS acknowledges that the reduction of peak flows (first-order impact) and associated reduction in large wood and sediment transport (second-order Impact) would “impact the creation of habitats that depend on channel forming processes” (DEIS P-66; third-order impact). In particular, these effects are characterized as a “significant adverse impact on aquatic habitat from the FRE facility to the South Fork Chehalis River confluence” (DEIS P-66), with the conclusion (emphasis added):

> *“Downstream of the FRE facility, flood control would cause a reduction in the magnitude of peak floods, which would reduce natural geomorphic processes such as channel migration and formation of side channels, bars, and wetlands, especially those that are driven by major floods. While flooding of the magnitude that would trigger flood retention would be infrequent,* ***it is the largest floods that have the greatest ability to reshape the river channel and form habitats for aquatic and semi-aquatic species and wildlife species that use the riparian areas and the floodplain*** *(Meadow Run Environmental and Anchor QEA 2019). Reduced sediment and large woody material transport through the FRE facility may also reduce the formation of in-channel habitats.” (DEIS, Appendix P, P-88)”*

Linkages between some first-, second-, and third-order impacts are also made in the impacts analysis presented in theindividual Earth, Water, and Wildlife Discipline Reports. Despite acknowledging interrelated impacts to peak flows and habitat forming processes, the DEIS analysis of downstream impacts to floodplain water bodies and wetlands concludes the impacts will be 'minor' (Table 1. Comparison of inconsistent DEIS impact assessments for floodplain off-channel water bodies and associated wetlands.; P-17 Floodplain Wetland report, and DEIS Wetland Section 5.5.2.1 P-100). This conclusion is inconsistent with the DEIS's own supporting documents, and does not account for well-established linkages between large flood events and the formation and maintenance of floodplain water bodies and wetlands (Ward and Stanford 1995).

Floodplain water bodies and wetlands are created and maintained through dynamic fluvial processes such as avulsions, abandonment of side channels, and oxbow cut offs. The 2-D hydraulic model used in the DEIS analysis (DEIS Exhibit 3-2) to quantify downstream effects of the FRE facility on flood reduction quantifies between 3,514 and 4,679 acres as no longer flooding under FRE operations (DEIS Appendix N, Table N-13). This means that the fluvial disturbance and habitat generation processes inherent to flooding would also no longer be occurring across these acres of floodplain. Consequently, the floodplain water bodies and wetland areas no longer flooded under FRE operations will over time lose much of their aquatic and riparian fish and wildlife habitat functions. In addition, first- and second-order impacts will drive a loss of future generated floodplain wetlands and off-channel water bodies by impairing the processes that form new wetlands and off-channel waters over time.

Table 1. Comparison of inconsistent DEIS impact assessments for floodplain off-channel water bodies and associated wetlands.

RESOURCE AREA	IMPACT	DEIS IMPACT FINDING
Wetlands	"This reduction in peak flows and corresponding reduction in large wood and sediment transport would impact the creation of habitats that depend on channel-forming processes. This would be a **significant adverse impact** on aquatic habitat from the FRE facility to the South Fork Chehalis River confluence." (P-66 DEIS)	Significant
Water	"Cottonwood habitat downstream of the FRE site would be **moderately** affected by the Proposed Project. Wildlife would be **moderately impacted** by decreased water quality conditions." (P-86 DEIS)	Moderate
Wildlife	"Changes to downstream habitat and reductions in the quantity and quality of aquatic habitat would be a **significant adverse impact.**	Significant
Wildlife	"Over the long term, the reduction in peak flows would decrease the occurrence of natural hydrologic processes, such as channel migration and formation of side channels, bars, and wetlands, downstream of the FRE facility. The probable adverse impact is considered **significant** because flooding above a certain magnitude has been entirely removed." (P-91 DEIS)	Significant
Wetlands	"Operation of the FRE facility would have **moderate impacts** on bank erosion and channel migration in unconfined areas from RM 105 to RM 88, by slightly reducing bank erosion and channel migration rates, and minor effects on bank erosion and channel migration in other river areas." (P-66 DEIS)	Moderate
Wetlands	**"Impacts Downstream of the FRE Facility** Under the Proposed Project, some wetlands and waterbodies downstream of the FRE facility would no longer be inundated during the major or catastrophic floods because floodwaters would be held back by the FRE facility. About 522 acres of wetlands would no longer be inundated under the late-century major flood, a 9.7% reduction. For a late-century catastrophic flood, about 506 acres of wetlands would no longer be inundated, a 9.7% reduction. These probable adverse impacts **are considered minor** because the wetlands would not lose their primary water source." (P-100 DEIS)	Minor

In addition to the impacts to floodplain aquatic habitat from the impairment of habitat-forming processes (described above), the DEIS underestimates direct and particularly indirect impacts to wetlands. In particular, the DEIS concludes from 2-D hydraulic modeling that approximately 522 acres of wetlands would no longer be inundated by late-century major flood and 506 acres would no longer be inundated by late-century catastrophic flood (a 9.7% reduction in estimated wetland acreage in each case), and that:

> “These probable adverse impacts are considered **Minor** because the wetlands would not lose their primary water source.” (P-100 DEIS)

This assessment fails to account for the first-order impacts to peak flows, sediment transport, and groundwater recharge, which are underestimated in the DEIS analysis. Furthermore, the conclusion of ‘minor’ impacts fails to account for the impairment of the fundamental processes that form and maintain wetlands and floodplain waterbodies over time, and the consequent implications for the quantity and function of aquatic and wetland fish and wildlife habitats, as discussed above and as articulated in other sections of the DEIS (Table 1. Comparison of inconsistent DEIS impact assessments for floodplain off-channel water bodies and associated wetlands.).

Flawed Analyses

In addition to underestimated alterations to first-order processes and insufficient analysis of the cascade of ecosystem effects, several analyses used to quantify first-, second- and third-order effects in the DEIS are fundamentally flawed:

- The methods used to develop the sediment transport model are flawed and result in under-estimating impacts to geomorphic processes.
- The determination and delineation of the longitudinal spatial extent of the DEIS impact analysis domain is based upon flawed hydrogeomorphic assumptions.
- The conclusions reached by the hydraulic and geomorphic impact assessments are used as the basis for evaluating impacts to all other resource areas. Because there are demonstrated flaws in the hydraulic and geomorphic modeling approaches, all analyses that depend on those models are inadequate (e.g. channel and floodplain morphology, hydrologic connectivity, ecological processes, and plants, fish, and wildlife habitats).
- The DEIS fails to define any metric for determining there are only ‘minor’ impacts to downstream wetlands and bases its conclusions of impact on ecologically unsupportable and inaccurate statements regarding the processes that create and support wetlands.
- The analysis of impacts to habitat fails to account for the ways in which climate change projections will amplify, or be amplified by, downstream impacts.

Flaws in the Sediment Transport Model and Determination of Impacts to Geomorphic Processes

The evaluation of impacts to sediment transport and geomorphic processes associated with operation of the proposed project is conducted in the DEIS using a sediment transport model (Appendix F, Earth Discipline Report). The model was developed using the 1-dimensional HEC-RAS platform and used to quantify changes in bed-elevation, sediment storage, and channel bed grain size distribution both upstream and downstream of the FRE facility. The model is fundamental to the geomorphic impact assessment and is how the DEIS quantifies impacts to the first order process of Sediment Supply. Our evaluation of the methods used to develop the sediment transport model identified several flaws which indicate that the model under-estimates impacts to sediment transport processes both upstream and downstream of the proposed FRE facility. Those flaws include:

1. The modeling approach significantly under-estimates the sediment load from the 2007 storm event by omitting ~90% of the estimated sediment load (Watershed GeoDynamics and Anchor QEA 2017). Exclusion of this sediment volume from the model is greater than the entire sediment load from non-landslide sources for the entire length of the model. The DEIS acknowledges that the persistence of this sediment will influence river morphology for decades, but does not use that conclusion to qualify the results of the sediment transport model. By omitting this major input, the model under-estimates changes to coarse and fine sediment that would occur both upstream and downstream of the FRE facility.
2. The model does not account for increases in the frequency and magnitude of landslides due to reservoir operations (Earth Discipline White Paper, NSD and SaturnaH2O 2020). By omitting this input, the model under-estimates changes to coarse and fine sediment that would occur both upstream and downstream of the FRE facility.
3. The model is not calibrated with bedload measurements and therefore the accuracy of the model is unknown. No discussion of the implications or range of possible conclusions is included in the DEIS.
4. The sediment transport function used to simulate transport within the model under-estimates bed scour compared to scour monitor observations presented in the 2017 sediment transport report. Because of this, more sediment transport would be expected to occur than what is simulated by the model. This would result in greater amounts of channel incision and less sediment storage downstream of the FRE facility than what is predicted by the model.
5. The model's assumption that bedload constitutes 10% of the total sediment load is contrary to the sensitivity analysis conducted for the model in the 2017 and 2019 sediment transport reports which assume 6% and 5% respectively (Watershed Geodynamics and Anchor QEA 2017; Watershed GeoDynamics 2019). The doubling of the bedload proportion was done without explanation in the DEIS and would act to dampen the effects of the FRE facility on channel bed elevations by increasing the simulated amount of bed-forming coarse sediment delivered to the mainstem river through tributary inputs. If the values previously reported in the 2017 and 2019 reports were used, more channel incision and less sediment storage would be expected downstream of the FRE facility.
6. The model does not account for how changes to large wood loading within the Chehalis River as a result of proposed FRE operations would impact sediment transport. The DEIS states that there would be a significant impact to large wood loading, however this change was not incorporated into the sediment transport model. Reducing large wood loads would cause decreases in channel roughness and increases in sediment transport. By omitting these changes from the model, the DEIS under-estimates decreases in sediment storage downstream of the proposed FRE facility.

The summation of these flaws and omissions result in the DEIS under-estimating the impacts to fundamental sediment transport processes. Upstream of the FRE facility, there would be a greater increase in both fine and coarse sediment. Downstream of the FRE facility, there would be a greater increase in fine sediment and a greater decrease in coarse sediment. These underestimations of impacts to sediment supply and transport cascade throughout the river ecosystem and drive consequent impacts to second- and third-order processes to also be under-estimated.

Flaws in the Determination of the Longitudinal Spatial Extent of Impacts

In addition to the flaws and omissions noted above, the sediment transport model, as well as the geomorphic impact analyses, improperly limit the longitudinal extent of impacts caused by the FRE facility. The geomorphic impact assessment presented in the Earth Discipline Report identified **significant and moderate** impacts only in areas of the main-stem Chehalis River upstream of the South Fork Chehalis confluence at river mile (RM) 85. This includes impacts to the large woody material recruitment, channel formation, sediment transport, and channel migration. However, the data and rationale presented in the DEIS ***do not support limiting the spatial extent of significant and moderate impacts to areas upstream of the South Fork Chehalis (Table 2).***

Table 2. Geomorphic impact assessments with flawed spatial extents.

IMPACT	DEIS IMPACT FINDING	ANALYSIS OF SPATIAL EXTENT AND IMPLICATIONS FOR IMPACT DETERMINATION
Decreased large woody material levels within and downstream of the FRE facility to the South Fork confluence	Significant	No data is presented in the DEIS to limit the longitudinal extent of the impact to the large wood cycle to areas upstream of the South Fork Chehalis River confluence (RM 85). Operation of the proposed FRE facility is expected to reduce large wood loading by eliminating all large wood sourced to the river from above the FRE facility, through reductions in channel migration rates (and subsequent local sources of wood), and changes to the structure of floodplain vegetation. **There is no data presented in the DEIS to indicate that changes to these processes will not occur downstream of the South Fork Chehalis confluence, and thus there is no basis for limiting the determination of significant impacts to areas upstream of this location.**
Decreased channel formation downstream of the FRE facility to the South Fork confluence from reduced flow, large woody material, and sediment	Significant	No data is presented in the DEIS to limit the longitudinal extent of the impacts to channel formation to areas upstream of the South Fork Chehalis River confluence (RM 85). The DEIS bases limiting the spatial extent of this impact with the statement that "The greatest adverse impact would occur in Reaches 2 and 3 of the upper Chehalis River mainstem from the FRE facility to the confluence with the South Fork Chehalis River and would diminish as major tributary flows enter the mainstem in Reaches 4, 5, and 6 moving downstream" [F-81]. However, no data is presented to support this claim such as changes to sediment transport, stream power, or large wood loading. Furthermore, **because impacts to flow, large woody material, and sediment (the underlying basis for assessment of this impact) have all been under-estimated in the DEIS, impacts to channel formation are also under-estimated.**
Changes to sediment transport and substrate downstream of RM 85	Minor	The sediment transport model used to support this impact assessment was truncated at the Newaukum River confluence (RM 75) and thus there is no data to support the assessment of impacts to sediment transport below this location. No justification for ending the model at the Newaukum confluence was provided in the DEIS. The model results of changes in bed elevation as a result of the proposed project (Figure F-27; pg. F-77) do not support ending the model at RM 75 given that the largest aggradation segment of the river is shortly upstream of the Newaukum River confluence and thus sediment transport was not in equilibrium at the downstream model extent. **The methods used to develop the sediment transport model also under-estimate impacts to sediment transport in general, and thus impacts below RM 85 are also under-estimated.**

IMPACT	DEIS IMPACT FINDING	ANALYSIS OF SPATIAL EXTENT AND IMPLICATIONS FOR IMPACT DETERMINATION
Changes to channel migration in Reaches 2A, 2C, 4, 5, and 6	Minor	No data is presented in the DEIS to limit the extent of impacts to channel migration to areas upstream of the South Fork Chehalis Confluence. The DEIS bases limiting the spatial extent of this impact with the statement that "LWM loading would be reduced, and sediment accumulations would decrease between the FRE facility and the confluence with the South Fork Chehalis River. Because bank erosion and channel migration is the result of a complex interaction of high flows, LWM loading, and sediment accumulation, it is anticipated that operation of the FRE facility would slightly decrease channel migration in Reaches 2B and 3 [Upstream of South Fork Chehalis] and have little noticeable effect on channel migration downstream of the South Fork," [F-79]. However, no data or modeling results are presented to support this claim. **Results from the 2-D hydraulic model indicate that reductions in depth and water-surface elevation are expected downstream of the South Fork Chehalis confluence. Because stream energy (i.e. stream power or shear stress) is dependent on discharge and stage, it is to be expected that reductions in flow would also cause reductions in stream energy. Therefore, impacts to channel migration should be expected where-ever changes to depth and stage occur.** These impacts are not evaluated in the DEIS.

The spatial limitation of impacts to geomorphic processes is contradicted by the flood reduction benefits claimed as a consequence of the proposed FRE facility. Reductions in water surface elevations as far downstream as Montesano are presented in the DEIS (Appendix N-1.1 - Hydraulic Modeling Water Surface Elevation Results – Key Locations). The reductions in water surface elevations would also result in reductions in geomorphic processes such as sediment transport, channel migration, and floodplain inundation and therefore, limiting the model domain is unfounded. Essentially, by presenting this data, the DEIS acknowledges that impacts to geomorphic processes will occur downstream of the sediment transport model domain – further calling the analyses into question.

Flaws in the Downstream Impact Assessment of Channel and Floodplain Morphology

The conclusions reached by the hydraulic and geomorphic impact assessments are used as the basis for evaluating impacts to all other resource areas. This is underscored by DEIS Exhibit 3-2 (p. 32) (Figure 6 herein) and Section 3.4 of the DEIS which states:

> “the results of these models – Hydraulic and Geomorphic – are used throughout the preparation of technical Discipline Reports and the Draft EIS chapters” as well as “for the fish population and lifecycle models for salmonid impacts.”

Because there are demonstrated flaws in the hydraulic and geomorphic modeling approaches, all analyses that depend on those models are inadequate. Just as changes in first-order hydrology, sediment supply and water quality cascade through the riverine and riparian ecosystems as second-, third-, and fourth- order effects, the results of the hydraulic and geomorphic modeling also propagate through the analysis, affecting all impact determinations. This includes the magnitude and the spatial extent of the impact assessments for all resource areas presented in Figure 6.

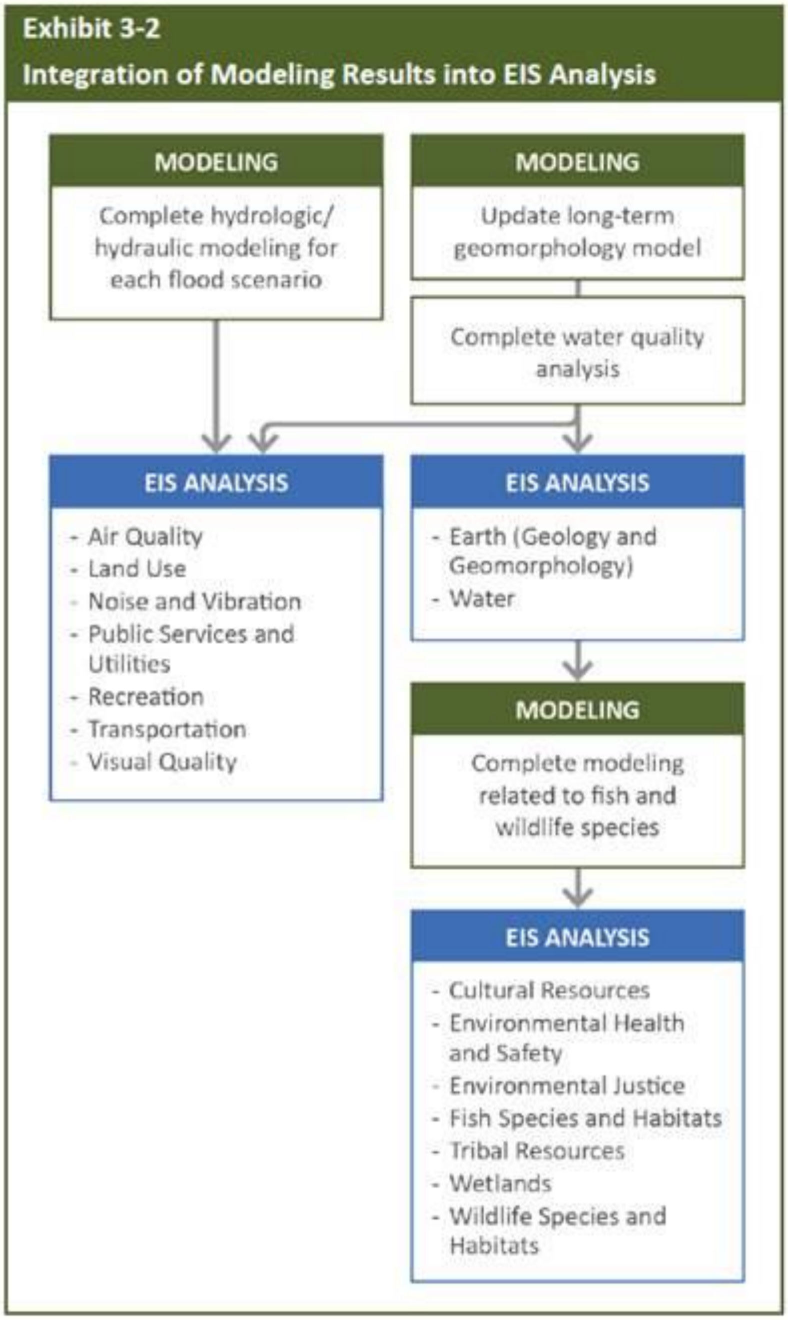


Figure 6. DEIS exhibit 3-2

As an example, we have highlighted the specific impacts to wetlands and wildlife presented in the DEIS where the spatial extent of the impact was improperly limited by unsupported claims made in the geomorphic impact analysis (Table 3).

Table 3. Impact assessments for wetland and wildlife that are dependent on flawed conclusions reached in the geomorphic impact assessment.

RESOURCE AREA	DEIS IMPACT	DEIS IMPACT FINDING
Wetlands	Impacts on mainstem Chehalis River between Pe Ell and the South Fork Chehalis River due to reduced peak flows from operation of the FRE facility. Sediment and wood transport would be reduced and similarly reduce channel formation, leading to a narrower and simpler channel over time.	**Significant**
Wetlands	Impacts on features of regulatory waterbodies downstream of the South Fork Chehalis River due to temporary changes in hydrology from operation of the FRE facility	**Minor**
Wildlife	Long-term changes to quality and quantity of downstream aquatic habitats from reduced flooding hydrology that creates side-channel, oxbow, and other aquatic habitats.	**Significant**

The errors, omissions, and unsupported conclusions of the geomorphic impact analysis represents a significant flaw in the DEIS because of how heavily it is relied upon for the impact analysis of nearly all other resource areas. This is exemplified by the ecosystem cascade framework which demonstrates how flaws in evaluating first-order processes such as sediment supply become amplified when they cascade to other resource areas. The DEIS should have acknowledged how methods and assumptions used to develop the sediment transport model influenced the model results. Furthermore, the available data presented in the DEIS and baseline supporting documents should have been relied upon and referenced in the determination of the spatial extent of impacts to geomorphic and ecological processes. When the data do not support such spatial limitations, the DEIS should have acknowledged those findings and applied them to the impact assessments. By not discussing the limitations of the underlying models, studies, and data, many of the conclusions reached by the DEIS are unsupported and unfounded.

Flaws in the Downstream Floodplain Wetland Impact Analysis

The stated purpose of the Downstream Floodplain Wetland Analysis (Anchor QEA 2019) is:

> "…to assess the potential effects of temporary flow regulation from the operation of the FRE on wetlands within the 100-year floodplain of the Chehalis River. The following specific questions are addressed by this study:
>
> 1. What is the distribution of existing wetlands by type in the 100-year floodplain?
> 2. How frequently are existing floodplain wetlands inundated by overbank flooding from the Chehalis River?
> 3. What changes could temporarily flow regulation from the proposed FRE have on floodplain wetlands from a reduction in the frequency and duration of overbank flooding in the Chehalis River 100-year floodplain?" (P-6 Downstream Floodplain Wetland Analysis)

The DEIS analysis used Washington State Department of Ecology Modeled Wetland Inventory for the Chehalis River 100-year floodplain, and WDFW's (2019) mapped off-channel water bodies (ponds, oxbows, sloughs, side channels). The DEIS used a RiverFlow 2-D hydraulic model and LiDAR terrain models to map the area and depth of flood inundation for the 2, 10, 100-year events. The 10-year event was used as a conservative proxy for the 7-

year FRE facility operational event. The wetland impact assessment methodology compared the floodplain wetland and off-channel water bodies areas inundated under the 10-year event proxy with the extent of the 100-year flood.

The DEIS fails to indicate how wetland "impacts" were measured, other than to say that areas no longer inundated with FRE operations were impacted, and those still inundated were not (DEIS P-41;). The Downstream Floodplain Wetland Study analysis results are then reported as area no longer inundated and as percentage change (Tables 10, 11 Anchor 2019). **The metric of wetland impact determination (I.e. minor, moderate or significant) and the implications of impacts for wetland function are not stated in the Anchor (2019) or DEIS documents, an error of omission.**

The Anchor (2019) Downstream Floodplain Wetland Study analysis is also inadequate because it is not process-based, uses static inundation modeling as the impact metric, and does not integrate a surface water-groundwater interaction analysis. State of the science of fluvial geomorphology and riparian ecology states that riverine and riparian ecosystems are dynamic in nature and that flood pulses are critical disturbance processes which form channel, floodplain and floodplain off-channel water bodies and wetlands (Ward and Stanford 1995; Hauer et al. 2016; Naiman et al. 2000). Floodplain wetlands and water bodies are generated and maintained by fluvial dynamics including channel migration and avulsions.

Furthermore, in interpreting the results of the static modeling of wetland and water body inundation, the DEIS incorrectly concludes that most of the wetlands no longer inundated under FRE operations have groundwater and precipitation as their primary water sources and that therefore impacts downstream of the FRE facility would be 'minor'. The logic of this argument completely misses reach-scale second- and third-order impacts to channel and floodplain water body and wetland forming processes. Loss of these flood pulse disturbances associated with floods that would trigger FRE operation will result in a reach and landscape-scale cumulative impact to floodplain area, floodplain water bodies and floodplain wetlands. As noted above, the result will be a terrestrialization of those floodplains no longer inundated with the loss of floodplain wetland functions over time (Richards et al. 2002).

Despite the fact that the DEIS acknowledges that FRE facility hydroregulation will result in significant impacts to channel forming processes (DEIS P-66) and that the loss of channel processes (second-order Impact) that generate and maintain these wetlands is a significant impact, the DEIS incorrectly maintains the conclusion that downstream floodplain wetland impacts are 'minor'. The ecological logic of this analysis is flawed. **If there are significant impacts to the processes that generate floodplain water bodies and wetlands, there would be significant impacts to floodplain wetlands and associated fish and wildlife habitats.** The DEIS itself makes this very point:

> "Over the long term, the reduction in peak flows would decrease the occurrence of natural hydrologic processes, such as channel migration and formation of side channels, bars, and wetlands, downstream of the FRE facility. The probable adverse impact is considered **significant** because flooding above a certain magnitude has been entirely removed." (DEIS P-91)
>
> "Operation of the FRE facility would reduce flood peaks downstream and this would eliminate channel-forming avulsions. Large woody material would be removed from the temporary reservoir during the reservoir drawdown and would no longer move downstream. Operation would affect channel-forming processes because the input of water, wood, and sediment within the FRE footprint and downstream of the FRE facility would change. When flows are reduced due to water backing up at the entrance to the outlets or water is held in the temporary reservoir during flood events, the stream power needed for most channel-forming processes would be reduced or eliminated. This reduction in peak flows and corresponding reduction in large wood and sediment transport would impact the creation of habitats

> that depend on channel-forming processes. This would be a **significant adverse impact** on aquatic habitat from the FRE facility to the South Fork Chehalis confluence.” (DEIS P-66)
>
> “Downstream of the FRE facility, the magnitude of large peak floods would be reduced, which would reduce natural processes such as channel migration and formation of side channels, bars, and wetlands, especially those that form during large floods. These large floods have the greatest ability to reshape the river channel and form habitats for aquatic species and those that use riparian areas and floodplain.” (DEIS P-65)

Flaws in the Inclusion of Climate Change Projections

Although the DEIS included climate change projections for peak flows, low flows, and stream temperature, the analysis failed to consider two key ways in which climate change projections will amplify, or by amplified by, downstream impacts.

Summer low flows are projected to decline by 16% by late century and these values were included in the Ecosystem Diagnosis & Treatment (EDT) modeling related to fish habitat (Hill and Karpack, 2019). The magnitude and temperature of summer streamflow will simultaneously be affected by reduced floodplain inundation and reduced groundwater recharge, both of which are underestimated in the DEIS analysis. The DEIS fails to consider that these downstream impacts to streamflow will exacerbate the projected low flows, resulting in underestimated impacts to fish habitat in the EDT model and related impacts to amphibian habitats.

Peak flows are projected to increase in magnitude and frequency (Hill and Karpack, 2019), which includes increases across a range of flood recurrence intervals (Karpack and Butler 2019). Increased frequency of peaks flows that are higher than the threshold for transporting sediment, but lower than the threshold for triggering FRE operation, will result in increased channel incision. This relationship is well-established as “regime” theory in geomorphology, which quantifies the relationship between peak flows and channel depth and width (Leopold and Maddock 1953). Thus, channel incision due to increased peak flows will occur independently of the channel incision driven by reduced sediment transport due to the FRE facility. The DEIS fails to consider that increased peak flows due to climate change will amplify channel incision due to the FRE facility, and will therefore amplify the third- and forth-order impacts to ecosystems, species, and habitats.

CONCLUSIONS

Based on our understanding of the Proposed Project, it is our conclusion that the impacts to the fundamental processes which create and sustain aquatic ecosystems are insufficiently and inaccurately analyzed, and are underrepresented in the DEIS, as are the consequent impacts to fish and wildlife resources. Specifically, we conclude that:

- Impacts related to upstream reservoir ecosystems are underestimated for the following reasons:
  - The following first-order impacts related to upstream reservoir ecosystem hydrology and sediment supply are individually underestimated in the DEIS.
    - The frequency and duration of reservoir impoundment are underestimated for both current and future climate conditions.
    - The frequency and duration of backwatering events and their associated impacts are not considered or analyzed.
    - Increases in the frequency and magnitude of landslides and hillslope erosion, and therefore sediment delivery, are drastically underestimated.
  - Underestimating impacts to individual first-order processes leads to underestimation of impacts to channel morphology, sediment transport, vegetation, and aquatic habitat within the reservoir area.
  - Compounding impacts that result from the interactions and feedback between processes (both those underestimated and those sufficiently characterized) are not considered and will amplify ecosystem impacts relative to assessments of individual impacts.
- The same first-order impacts that drive the cascade of local ecosystem impacts in the upstream reservoir are also applicable to downstream ecosystem impacts, including underestimation in the frequency and duration of reservoir impoundment, the frequency and magnitude of landslides and therefore sediment supply, and reductions in large wood recruitment.

Additional downstream impacts that are in error or underestimated include:

- Reductions to groundwater recharge are underestimated based on underestimated frequency of peak flow events that would trigger FRE operation and underestimated recharge rates.
- The hydrologic connection between groundwater and surface water are inadequately analyzed, resulting in underestimated impacts to floodplain water bodies, wetlands, and baseflow.
- Reductions to downstream sediment transport and coarse sediment supply are underestimated due to flawed modeling assumptions.
- An underestimation of impacts to individual first-order processes leads to underestimation of impacts to channel morphology, sediment transport, vegetation, and aquatic habitat. The compounding impacts that result from the interactions and feedback between processes was not considered and will amplify ecosystem impacts relative to assessments of individual impacts.

In addition to underestimated alterations to first-order processes, and insufficient analysis of the cascade of ecosystem effects, several analyses used to quantify second- and third-order effects in the DEIS are flawed:

- The determination and delineation of the longitudinal spatial extent of the DEIS impact analysis domain is based upon flawed hydrogeomorphic assumptions regarding the longitudinal extent of the FRE operations impacts. Modeling results and data presented in the DEIS do not support limiting the spatial extent of moderate to significant impacts on geomorphic processes to areas upstream of the South Fork Chehalis and Newaukum River confluences.

- The downstream impact assessment to channel and floodplain morphology and hydrologic connectivity (second-order effects) is based upon a flawed hydrogeomorphic modelling analysis.
- The impact analysis of downstream ecological processes, and plant, fish and wildlife community habitats (third-order effects) is based upon an inadequate modeling approach.
- The analysis of downstream impacts to floodplain water bodies and wetlands does not account for well-established linkages between large flood events and the formation and maintenance of floodplain water bodies and wetlands.
- The analysis of direct and indirect impacts to fish and amphibian habitat, in light of altered channel morphology, are inadequate.

Because there are demonstrated flaws in the hydraulic and geomorphic modeling approaches, all analyses that depend on those models are inadequate. ***Therefore, all impacts to geomorphic processes and those dependent on the conclusions of the geomorphic analyses are under-estimated in the DEIS.***

Overall, the DEIS fails to consider, analyze or characterize the physical and ecologic process linkages inherent in riverine ecosystems and thus **fails to consider the consequent indirect impacts of the cascade of ecosystem effects and the amplification of those effects over time that will result from the proposed project.** The proposed project will result in a cascade of impacts to both existing floodplain/off-channel water bodies and wetlands, as well as a loss of the physical processes that create and sustain the future formation of floodplain wetlands and floodplain/off-channel water bodies, resulting in a significant, unmitigable amplification of impacts over time.

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