TECHNICAL MEMORANDUM

Date: October 11, 2024
To: Matt Dillin, Chehalis River Basin Flood Control Zone District
From: Kai Steimle and MaryLouise Keefe, PhD, Kleinschmidt Associates
Cc: Jason Kent, PE, PMP, Kleinschmidt Associates
Re: Riparian Shade Temperature Model

Chehalis Basin Strategy Proposed Flood Retention Expandable Mitigation Plan – Riparian Shade Temperature Model

Introduction

Background

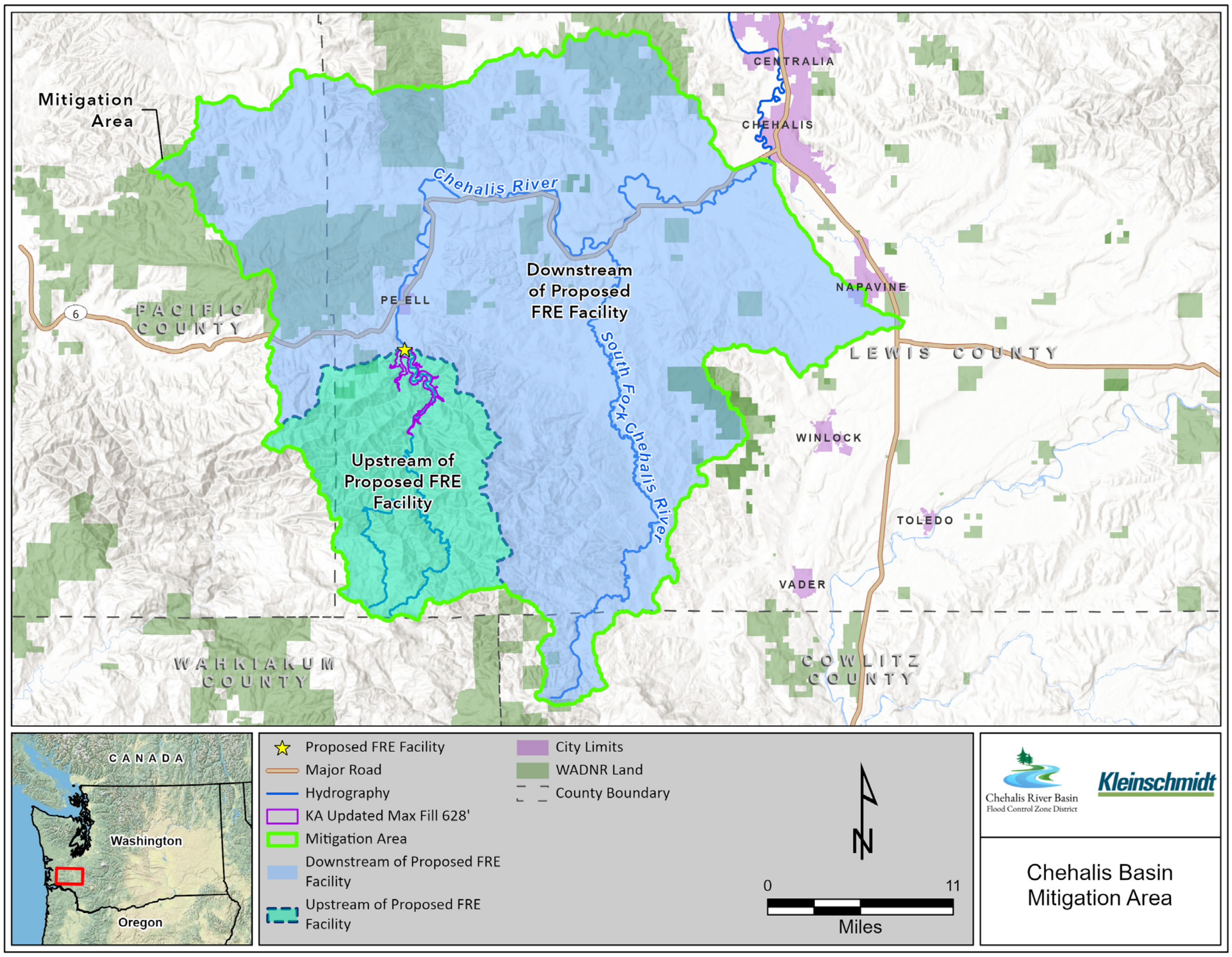
The Chehalis River Basin Flood Control Zone District (Applicant) is proposing to construct a Flood Retention Expandable (FRE) facility to reduce the risk of flood damage along the mainstem Chehalis River. The proposed FRE facility is located approximately 1.7 miles upstream from the town of Pe Ell, Washington in the upper Chehalis River watershed near river mile (RM) 108.4 (Figure 1). It also includes a temporary reservoir that is only inundated during infrequent flood operations. The temporary reservoir extends approximately 6.2 miles upstream from the FRE facility. The primary purpose of the FRE facility is to reduce flooding coming from the Willapa Hills by storing floodwaters in the temporary reservoir during major floods. In 2020, the two draft Environmental Impact Statements (DEISs) released for this project (the Washington Department of Ecology's [Ecology] under the State's Environmental Policy Act [Ecology 2020] and the United States Army Corps of Engineers' [Corps'] under the National Environmental Policy Act [Corps 2020]) projected that by temporarily storing peak flows during major flood events, the FRE facility operations would alter riparian vegetation and thereby impact riparian shade. This in turn was hypothesized to negatively impact water temperatures based on results from a water quality model documented in each of the DEISs. Due in part to the projected increases in water temperature, the DEISs subsequently determined that the proposed project will have significant impacts on aquatic resources and anadromous salmonids (Ecology 2020; Corps 2020). Impacts were generally represented as occurring upstream of the confluence of Elk Creek (around RM 100).

In addition, the upper Chehalis River basin Total Maximum Daily Load (TMDL) has been developed by Ecology for surface water temperature standard exceedances that are caused almost entirely by solar radiation (Ecology 2001). Temperature is a measure of heat, which is considered a pollutant under Section 502(6) of the Clean Water Act. Heat generated by the amount of solar radiation from sunlight reaching the stream provides energy to raise water temperatures. Contributions of heat from municipal and industrial point sources in the upper Chehalis River are small, but they have been addressed in this upper Chehalis River basin TMDL through wasteload allocations. This upper Chehalis River basin TMDL is designed to address impairments due to surface water temperature increases on nine water quality-limited streams (representing 19 segments) located in the watershed and provide goals for protection of all remaining streams. Streamside shade is used as a surrogate measure for water temperature. Use of surrogate measures is allowed by federal regulations (40 CFR 130.3) and the July 1998 Report to the Federal Advisory Committee on the TMDL Program (EPA-100-R-98-006). A decrease in shade increases incoming solar radiation and the resultant heat transfer to the stream.

The Applicant's revised mitigation plan (RMP; Kleinschmidt 2024) proposed shade rehabilitation to offset potential shade loss and associated water temperature impacts. Consistent with the upper Chehalis River basin and other regional TMDLs, shade restoration is an accepted method for mitigating water temperature effects in thermally impacted rivers (Dugdale et al. 2018; Trimmel at al. 2018) including locations throughout the Pacific Northwest (Fuller et al. 2022). The potential for effective shade cooling is related to the interception of solar input that would otherwise increase water temperatures. For rivers, shade effectiveness is limited by the relationship between maximum tree height and the river bankfull width, with effective shading requiring tree height that is at least 1.4 times the stream width (Ecology 2007). A review of bankfull width data available for the Chehalis River in the Mitigation Area indicated that this condition would be met for the mainstem as well as major tributaries. Further, a previous sensitivity analysis by the Applicant concluded that vegetation heights influenced modeled changes to water temperature and that a conceptual Vegetation Management Plan (VMP) minimized temperature increases (Chehalis River Basin Flood Control Zone District 2021).

This report summarizes an updated application of the CE-QUAL-W2 water temperature model to evaluate water temperature changes associated with the proposed FRE facility, the implementation of a VMP, and riparian reforestation mitigation actions. These versions of the CE-QUAL-W2 model applied to this analysis were obtained online from Portland State University and were developed for use in the NEPA and SEPA DEIS analyses, as well as in a temperature sensitivity analysis conducted by the Applicant (HDR 2021). Adaptations to the PSU models were made to include shade input parameters that were identified from application of the Shade-a-lator model as described below.

Figure 1
Chehalis Basin Mitigation Area.



Study Area

The study area for both shade modeling and water temperature impacts included the temporary inundation area upstream of the proposed FRE facility and downstream in the Chehalis River from the FRE facility to the confluence of the Chehalis River and the Newaukum River, near Chehalis RM 75.2.

Shade Model

The Applicant used the Shade-a-lator modeling tool (Boyd and Kasper 2003) to develop a site-specific riparian shade model and identify riparian reforestation mitigation that would offset DEIS impacts (Kleinschmidt 2024). The shade model provided more recent information about the existing vegetation within the inundation area than the previous CE-QUAL-W2 versions, so it was used to update the without-project shade condition. Updated canopy information was necessary as the previous modeling incorporated in the DEISs did not have vegetative shading data available and so vegetative shading for the entire temporary inundation area was assumed to be equivalent to the 2 kilometer (km) reach downstream of the FRE location (PSU 2017). In addition, the Shade-a-lator model used refined shade parameters for the temporary inundation area that were consistent with revised expectation for vegetation heights of future plant communities following implementation of the VMP (Appendix D in Kleinschmidt 2024). Finally, the shade benefits of mitigation actions downstream of the FRE were quantified.

Shade-a-lator is a module of the Heat Source model, a stream assessment tool used by the Oregon Department of Environmental Quality (ODEQ) (Boyd and Kasper 2003). ODEQ currently maintains the Heat Source methodology and software development, which can be accessed via the ODEQ analysis tools webpage (ODEQ 2024). TTools is an ArcGIS extension that is also used and maintained by ODEQ. TTools was used to sample geospatial data and assemble high-resolution inputs necessary to run the Heat Source model.

As described in Chapter 8 of the RMP (Kleinschmidt 2024), the Applicant used Shade-a-lator to assess shade supply available in the Upper Basin and selected 131 parcels along the upper Chehalis River and Bunker Creek for mitigation riparian shade enhancement that would prevent approximately 880,606,358 kilocalories per day (kcal/day) from reaching the water. The proposed riparian planting areas span the mainstem Chehalis River from Adna, Washington upstream to the FRE facility. Once implemented, this mitigation is predicted to provide sufficient shade to offset potential FRE facility shade impacts by a factor of approximately 2.5 to 1.

The Light Detection and Ranging (LiDAR)-based shade supply analysis identified many additional miles of degraded riparian canopy including areas along the mainstem Chehalis River downstream of Adna, as well as in the South Fork Chehalis and Newaukum rivers. These areas provide additional shade enhancement opportunities in the upper Chehalis River basin that could be used to refine mitigation during future phases of the project, for example, if needed during adaptive management.

CE-QUAL-W2 Model

Model Background

The Corps of Engineers-Quality-Width-averaged 2-dimensional (CE-QUAL-W2) model is a computer model for predicting water flow and quality in rivers, estuaries, lakes, and reservoirs (Cole and Wells 2016) that was used for both DEIS assessments (PSU 2017). The application of the CE-QUAL-W2 model to the Chehalis River was configured and run by researchers at Portland State University (PSU) and relied upon multiple data sources and other models as documented in the Chehalis Modeling Technical Memorandum (PSU 2017). Model inputs that affect the computation of water temperature include the following:

- Channel shape, orientation, and latitude as described in the bathymetry input.

- Meteorological inputs, air and dew point temperature, wind speed and direction, and cloud cover, which affect simulated heat fluxes, including short-wave solar radiation, long-wave atmospheric radiation, evaporation, and conduction.
- Flow at the starting locations for the Chehalis River, tributaries, along with distributed flow along the modeled segments representing unaccounted tributaries, groundwater, seeps, and springs.
- Water temperature associated with each river, creek, and distributed inflow where it enters the modeled system.
- Shading described by vegetation height, distance from water, density or opacity, time of year (i.e., leaf on or off for deciduous species), and topography.

Of the above list of model inputs, the only input modified from the original PSU model for this study was the input of shade parameters.

The CE-QUAL-W2 manual documents multiple waterbody applications and peer-reviewed papers that demonstrate the capabilities of the model for predicting changes to water temperature (Cole and Wells 2016). The model calculations include water surface and bottom heat exchange along with solar radiation absorption within the water column. It is important to understand the model computations because although vegetation heights influence water temperature, so do many other factors within the model as the water moves down the Chehalis River.

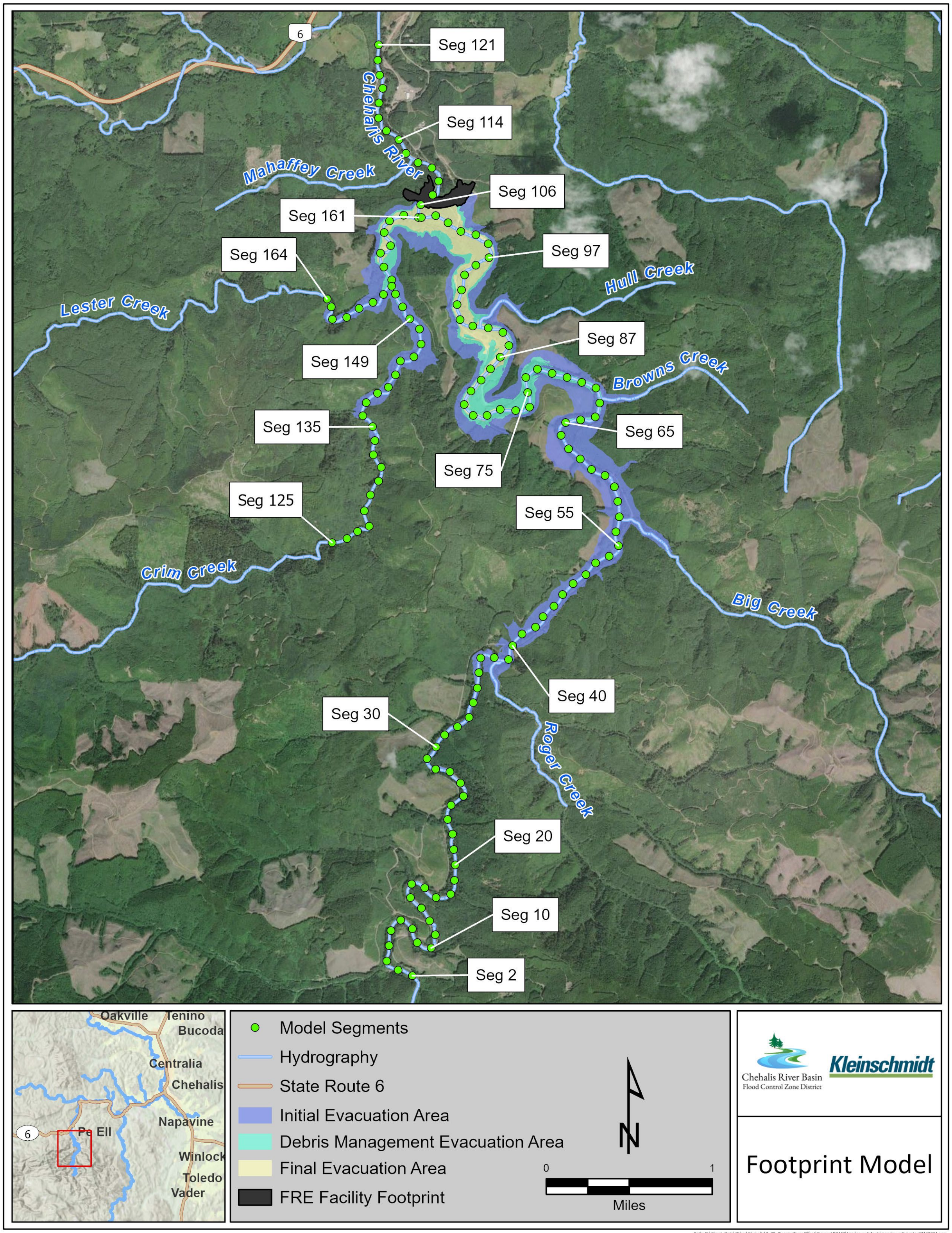
Model Frameworks

The application of the CE-QUAL-W2 model to the Chehalis River for the DEISs included two models: the Chehalis Reservoir Footprint Model (Footprint Model), the Chehalis Temporary Reservoir Model, and the Chehalis River Downstream Model (PSU 2017). The Footprint Model simulates the temporary inundation area during free-flowing conditions. The Chehalis Temporary Reservoir Model simulates the temporary inundation area during a flood event when the proposed FRE facility is retaining water. The Chehalis River Downstream Model simulates the Chehalis River downstream of the proposed FRE facility. Since the DEISs, the CE-QUAL-W2 model of the Chehalis River downstream of the proposed FRE facility was expanded and refined (Jensen 2020). Notably, temperature and flow models of four large tributaries of the Chehalis River, including the South Fork Chehalis, were created.

Footprint Model

The Footprint Model is composed of a grid overlain on portions of the Chehalis River, Crim Creek, Lester Creek, Big Creek, and Roger Creek. This grid is composed of 191 model segments, with each segment being either 150 or 152.4 meters long in the direction of water flow. Some segment numbers are inactive in the model and are of zero length. Figure 2 below provides a map of the Footprint Model segments. Shade input parameters, including vegetation height, were input into the Footprint Model using the references to the segment numbering at locations along the Chehalis River.

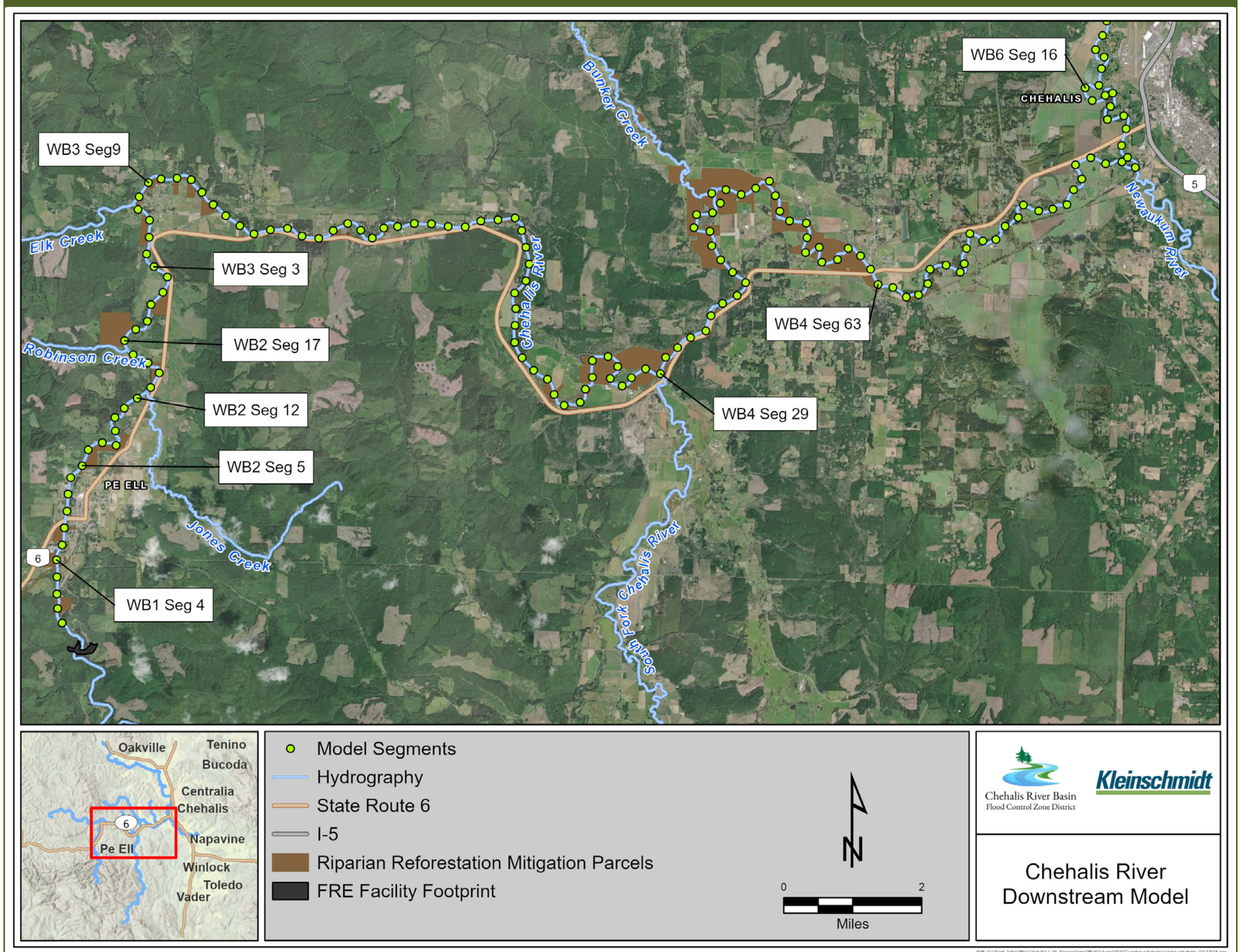
Figure 2
Locations of Footprint Model Segments.



Chehalis River Downstream Model

The Chehalis River Downstream Model grid used in the DEISs was composed of nine (9) modeled waterbodies (WBs), with 334 model segments, and with each segment being 400 meters long in the direction of water flow (PSU 2017). Model runs for this analysis were limited to the Mitigation Area (Figure 1). Some segment numbers are inactive in the model and are of zero length. Figure 3 below provides a map of the Chehalis River Downstream Model segments. Elevation data entered into the model were referenced to the North American Vertical Datum of 1988 (NAVD88). Vegetation heights were input into the Chehalis River Downstream Model using the references to the segment numbering at locations along the Chehalis River.

Figure 3
Locations of Chehalis River Downstream Model Segments.



Methods

As described above, the water temperature analysis was restricted to changing shading parameters within the previously developed CE-QUAL-W2 models. Shading is calculated in the models using inputs describing vegetation height, distance from water, density or opacity, time of year (i.e., leaf on or off for deciduous species), and topography. Methods for updating these input parameters for each model and model scenario are described in more detail below.

The primary data source for developing new shading input parameters was LiDAR data across the Mitigation Area that provided a three-dimensional representation of the landscape, including vegetation heights and bare earth elevations. These LiDAR data were collected between 2015 and 2019 by the Washington Department of Natural Resources (WA DNR), and the resulting data files were used to calculate updated digital surface models (DSMs), which ignore objects such as trees and give the elevation of the surface of the ground (Washington Geological Survey 2024a, 2024b). Digital terrain models (DTMs) represent elevation data including terrain objects such as trees and were used to describe existing vegetation as described below.

Topographic Shade

Topographic shade parameters allow the CE-QUAL-W2 model to account for shade created by landforms. The shade algorithm uses 18 topographic inclination angles surrounding each segment center-point at intervals of 20 degrees. Controlling topographic angles were computed for both models in GIS using the LiDAR-based digital surface model.

Riparian Shade

The shade generated by riparian vegetation is modeled in CE-QUAL-W2 using inputs describing vegetation height, distance from the stream centerline, and vegetation density or opacity. These parameters are developed at the model segment scale for each bank. Vegetation heights and density were all extracted from LiDAR-based DTMs and modifications of those surfaces developed to describe conditions under various model scenarios described in Section 0.

Estimating distance from the centerline required defined banklines and centerlines for each model segment. Banklines used for the NEPA DEIS analysis were used for the Chehalis River and its tributaries within the temporary inundation area, and the mainstem Chehalis River downstream to the confluence of the Newaukum River (Corps 2020). Banklines for the model segments upstream of the temporary inundation area were digitized in ArcPro at a scale of 1:2000 using MAXAR satellite imagery from July 2022.

To estimate vegetation height, the scenario-specific DTM was sampled at 10-foot intervals along a line parallel to the bank. For scenarios with mature canopy, the line was 50 feet shoreward of the bank. Within the temporary inundation area, where early-successional vegetation was anticipated for future scenarios, vegetation heights were sampled along the bankline as well. Samples of canopy height from the DTM along the CE-QUAL-W2 model segment were summarized in two metrics. First, vegetation height was calculated as the median of the sampled elevations per segment. Where vegetation was evaluated at two distances, the vegetation that provided shade at the highest sun angle was used to develop the model input. Distance to the centerline of the stream was recorded. Second, these surface sample points were used to estimate canopy density, defined in CE-QUAL-W2 as a shade reduction factor (SRF). The SRF was estimated for each bank of each segment as the percent of the sampled elevations with vegetation heights greater than 2 meters (m) multiplied by a landcover density. Landcover density was estimated to be 0.9.

The LiDAR-based DTMs used a different vertical datum than the bathymetry grid for the CE-QUAL-W2 model, which was based on Hydrologic Engineering Center's River Analysis System cross-sections (PSU 2017). To integrate the shade inputs with the model grid, the vegetation elevation estimates derived from the DTMs were adjusted to a relative height above the bankline. Without this offset in elevations, the digital surface model was lower in elevation than the bathymetric grid in some model segments.

Model Scenarios and Assumptions

Existing Riparian Vegetation

As described above, LiDAR data along the Chehalis River was collected between 2015 and 2019 by the WA DNR. This analysis calculated updated baseline scenario vegetation conditions (Washington Geological Survey 2024a, 2024b). The current land designation of the temporary reservoir and the surrounding land is Forest Reserve Land and its primary use is commercial forestry. Under active timber management, additional vegetative changes have occurred since the LiDAR data collection. These changes were digitized in ArcPro at a scale of 1:2000 using Maxar satellite imagery from July 2022 and used to update the DTM for the temporary inundation area (Maxar Technologies 2022). This scenario was named the 2022 Current Conditions scenario.

No Vegetation in Inundation Area

The SEPA DEIS analysis evaluated a reduction in riparian shade due to the removal of vegetation in the temporary inundation area. A previously developed Pre-Construction VMP (Anchor QEA 2016) informed assumptions made in the SEPA DEIS that construction activities would include the removal of all non-flood-tolerant trees within approximately 420 acres of the temporary inundation area and all other trees greater than 6 inches diameter breast height throughout the temporary inundation area (Ecology 2020). This scenario was named the No Vegetation Future Conditions scenario.

Vegetation Management Plan in Inundation Area

The Applicant has developed a revised VMP that includes expected vegetation survivability based on the depth and duration of inundation when the proposed FRE facility is operating (Appendix D in Kleinschmidt 2024). As described in the VMP, the temporary inundation area includes three zones with increasing frequency and duration of inundation: the Initial Evacuation Area, the Debris Management Evacuation Area, and the Final Reservoir Evacuation Area. For the shade analysis, expected vegetation heights in each zone were evaluated in both the first summer after operation (VMP1) and in the fifth summer after operation (VMP5). The VMP5 was modeled to have higher solar loading than VMP1, and was therefore chosen as the VMP scenario for temperature modeling.

Under all scenarios, each zone would have two potential canopy components, an upper canopy with an associated cover percentage and height, and a lower canopy with an associated cover percentage and height (Table 1). The upper canopy height under future scenarios was assumed to be 100 feet in all evacuation areas, representing a conservative estimate of mature tree height. The lower canopy height was assumed to be new regrowth after inundation and varied by zone and scenario (Table 1). These two height components were integrated into a randomized raster to simulate variable canopy elevations within each inundation area.

Under VMP5, the Initial Evacuation Area (the upstream-most area above Water Surface Elevation [WSEL] 528 feet that is flooded less frequently and would be inundated for shorter durations) would be actively managed to promote taller vegetation, and taller trees can be expected to tolerate the flooding conditions anticipated in this area. An upper canopy cover of 25 percent was assumed with a lower canopy height of 35 feet. As described for VMP1, it was assumed that vegetation could survive infrequent and short-duration inundation and no changes to existing canopy heights were assumed in the Initial Evacuation Area upstream of the inundation limit for the 2007 flood (WSEL 620 feet). The Debris Management Evacuation Area (the middle portion of the temporary reservoir between WSEL 528 to 500 feet) and the Final Reservoir Evacuation Area (the lowest part of the temporary reservoir, from WSEL 500 to 425 feet, and the area that would be inundated for the greatest duration) were modeled with the same vegetation. It was assumed that any upper canopy of standing dead trees would have fallen by post-operation year 5, so no upper canopy was assumed (reflected as 0 percent cover in Table 1) and the lower canopy was modeled at 25 feet, based on estimated tree regrowth rates in the VMP.

Table 1
Canopy Height Surfaces Modeled in VMP Future Condition Scenarios.

RESERVOIR EVACUATION AREA	FINAL	DEBRIS MANAGEMENT	INITIAL	INITIAL WSEL >620 FEET
FIFTH SUMMER SCENARIO (VMP5)				
Upper Canopy Height (feet)	100	100	100	Existing
Upper Canopy Cover (%)	0	0	25	Existing
Lower Canopy Height (feet)	25	25	35	Existing
Lower Canopy Cover (%)	100	100	75	Existing

Mitigation Plantings

The Applicant's proposed mitigation for shade impacts is reforestation of existing degraded habitats with native riparian trees and shrubs that will enhance tree canopy and shade conditions as the vegetation matures. Vegetation parameters for the mitigation conditions scenario for riparian restoration sites were based on ecologically relevant planting plans that included a high diversity of native trees and shrubs that contribute to riparian ecological function. Dominant shade-producing species included black cottonwood (*Populus trichocarpa*) and red alder (*Alnus rubra*). Tree heights of 98 feet (30 meters) were based on species characteristics and the system potential vegetation identified in previous TMDL modeling in analogous Northwest river systems (ODEQ 2006). Mitigation plantings were modeled within a 60-foot buffer along each streambank. This future condition was integrated into a modified continuous raster surface model.

CE-QUAL-W2 Model Outputs and Analysis

The CE-QUAL-W2 models can be set to output water temperature for any segment, time-step, or depth in the water column. For this analysis, water temperatures were output at select segments relevant to evaluating project effects at time steps of 2.4 hours (0.1 days). The Footprint Model was configured to output temperatures at the downstream extent of Crim Creek (Segment 161) and at the location of the FRE at the time of the DEIS (Segment 114) (Figure 2). The Chehalis River Downstream Model was configured to output temperatures downstream of the FRE (WB1 Segment 4), upstream of Jones Creek (WB2 Segment 12), near Robinson Creek (WB2 Segment 17), near Elk Creek (WB3 Segment 9), at the confluence with the South Fork Chehalis River (WB 4 Segment 29), and near Adna (WB 4 Segment 63).

Both latitude and day of the year affect the solar path and associated incoming solar radiation. When evaluating riparian revegetation effects on water temperature, it can be helpful to understand conditions both during periods of relatively high temperatures (summer) and periods when riparian shade is most effective at reducing incoming solar radiation (fall). The late summer months are when the DEISs identified water temperature increases to be greatest. The CE-QUAL-W2 model temperature outputs for the Chehalis River were summarized for the period between June 20 and September 22.

Results

The following sections describe outputs from the CE-QUAL-W2 temperature modeling for potential project effects on riparian shade in the temporary inundation area; the effectiveness of the VMP in avoiding and minimizing those effects; and the potential for riparian shade mitigation to address unavoidable impacts downstream of the FRE.

Temperature Within the Inundation Area

Temperature modeling in the temporary inundation area evaluated changes in water temperature under summer low flow conditions under three canopy scenarios (Table 2). All temperature changes are characterized as the maximum change in the 7-day average of the daily maximum water temperature (7-DADMax) in degrees Celsius. Daily estimates of 7-DADMax for the summer low flow period of June 20 to September 22 are plotted for the mouth of Crim Creek (Figure 4) and near the FRE (Figure 5). As the most recent assessment of existing conditions, the 2022 condition was used as the basis for comparison with future scenario alternatives. Under the SEPA DEIS scenario, removing all vegetation in the temporary inundation area would increase stream temperatures near the FRE above the 2022 condition by up to 1.9°C and increase stream temperatures at the mouth of Crim Creek by up to 3.6°C (Ecology 2020).

Implementing the VMP would avoid up to 2.0°C of temperature increase at the mouth of Crim Creek and up to 0.7°C of temperature increase near the FRE. Based on the VMP5 shade scenario, the residual water temperature effect (total increase to current conditions with all vegetation removed minus VMP shade reduction) is predicted to be up to 1.6°C at the mouth of Crim Creek and 1.2°C near the FRE; this value was used to represent a conservative estimate of temperature impact that would require mitigation (Ecology 2020).

Table 2
Maximum Change in Modeled 7-DADMax Water Temperature During Low-flow Summer Conditions (June 20 to September 22) at the Mouth of Crim Creek and at the FRE Under Shade Scenarios.

LOCATION	NO VEGETATION FUTURE CONDITION	VEGETATIVE MANAGEMENT PLAN VMP5	AVOID AND MINIMIZE IMPACT
	NO VEGETATION WITHIN THE TEMPORARY POOL, COMPARED TO 2022 HARVEST CONDITIONS	VMP 5 YEARS POST-OPERATION, COMPARED TO 2022 HARVEST CONDITIONS	5 YEARS POST-OPERATION, COMPARED TO NO VEGETATION WITHIN THE TEMPORARY POOL
At Mouth of Crim Creek	3.6°C	1.6°C	-2.0°C
At FRE Facility (RM 108.4)	1.9°C	1.2°C	-0.7°C

Figure 4

7-DADMax Water Temperatures at the Mouth of Crim Creek for Riparian Vegetation Scenarios.

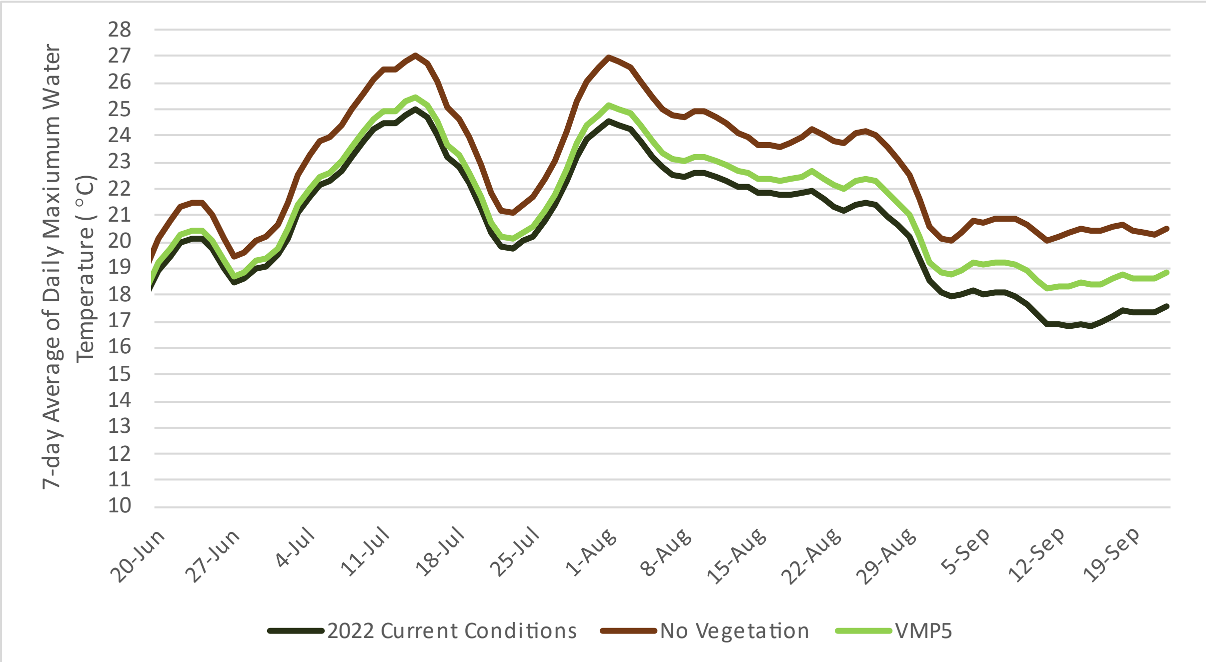
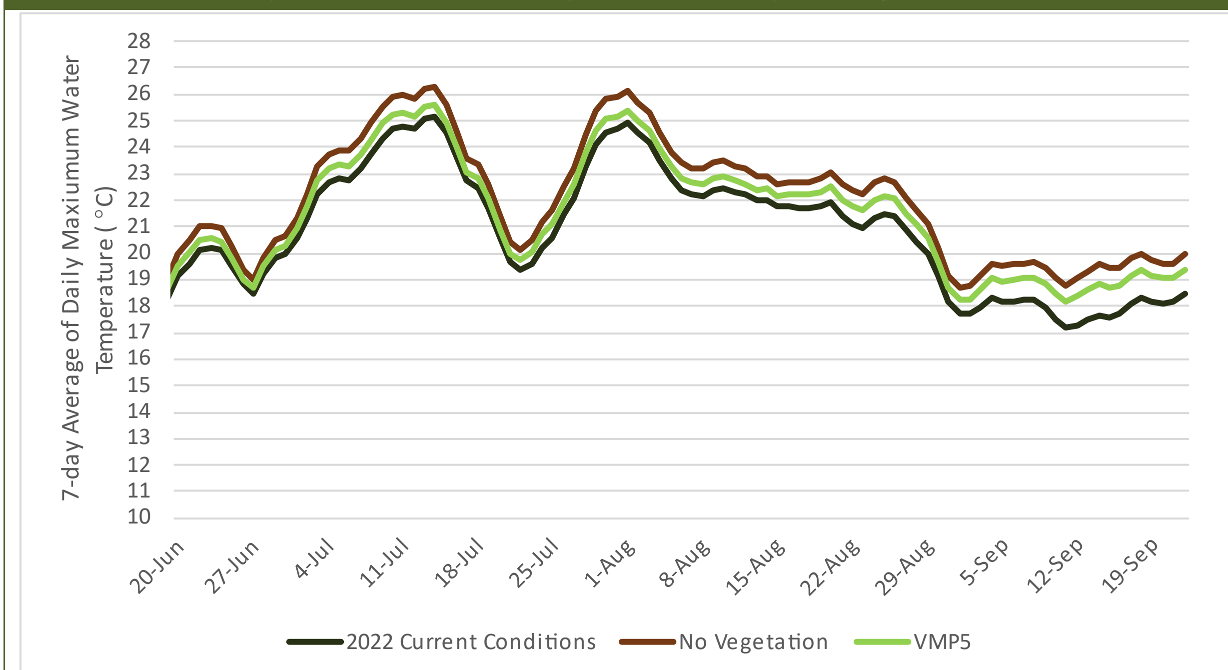


Figure 5

7-DADMax Water Temperatures at the FRE Facility (RM 108.4) for Riparian Vegetation Scenarios.



Riparian Reforestation Mitigation

Temperature modeling in the Mitigation Area downstream of the proposed FRE facility evaluated changes in summer water temperatures under four canopy scenarios: 2022 Harvest scenario, No Vegetation scenario, VMP5 scenario, and the VMP5 with Mitigation scenario (Table 3). All temperature changes are characterized as the 7-DADMax in degrees Celsius. Daily estimates of 7-DADMax for the summer low flow period of June 20 to September 22 are plotted for the Chehalis River upstream of Jones Creek (Figure 6), near Elk Creek (Figure 7), downstream of the South Fork Chehalis (Figure 8), and near Adna, Washington (Figure 9). As the most recent assessment of existing conditions, the 2022 condition was used as the basis for comparison with future scenario alternatives. As described above (Section 1.3), the Applicant selected 131 parcels along the upper Chehalis River and Bunker Creek for riparian shade enhancement mitigation. The proposed riparian planting areas span the mainstem Chehalis River from Adna, Washington to the FRE facility.

Under the No Vegetation scenario described in the SEPA DEIS (Ecology 2020), removing all vegetation in the temporary inundation area would increase stream temperatures downstream of the FRE above the 2022 condition by up to 1.2°C, increase temperatures near Elk Creek up to 0.3°C, and increase stream temperatures downstream of the South Fork Chehalis by up to 0.1°C (Table 3). Implementing the VMP would avoid up to 0.5°C of temperature increase downstream of the FRE, 0.1°C near Elk Creek, and 0.1°C downstream of the South Fork Chehalis. Model results of the VMP5 shade scenario predicted reduced effects on summer water temperature, with predicted residual effects of 0.7°C downstream of the FRE, 0.2°C near Elk Creek (RM 100.2), and 0.0°C downstream of the South Fork Chehalis (RM 88). Modeling of the shade mitigation downstream showed that stream temperatures downstream of the FRE would still be predicted to increase above the 2022 condition by up to 0.7°C, but the temperature increases decrease at locations downstream. Predicted with mitigation temperature would be reduced to 0.2°C approximately near the mouth of Jones Creek (RM 103.7), while no temperature effect was predicted at the confluence of Elk Creek and a small net cooling effect of - 0.1°C was predicted downstream of the confluence of the South Fork Chehalis River. The predicted thermal benefits of shade mitigation were greater in the fall, when sun angles are lower and trees block the solar input for a greater portion of the day (Figure 8, Figure 9).

Table 3

Maximum Change in Modeled 7-DADMax Water Temperature During Low-flow Summer Conditions (June 20 to September 22) at Locations Along the Chehalis River Downstream of the FRE Under Shade Scenarios.

LOCATION	SEGMENT	NO VEGETATION FUTURE CONDITION	VEGETATIVE MANAGEMENT PLAN VMP5	RIPARIAN REFORESTATION
		NO VEGETATION WITHIN THE TEMPORARY POOL, COMPARED TO 2022 HARVEST CONDITIONS	VMP5 YEARS POST-OPERATION, COMPARED TO 2022 HARVEST CONDITIONS	VMP5 AND RIPARIAN REFORESTATION, COMPARED TO 2022 HARVEST CONDITIONS
At Mouth of Crim Creek	161	3.6°C	1.6°C	NA
At FRE Facility (RM 108.4)	114	1.9°C	1.2°C	NA
Downstream of FRE	WB1 Segment 4	1.2°C	0.7°C	0.7°C
Upstream of Jones Creek	WB2 Segment 12	0.8°C	0.5°C	0.2°C
Near Robinson Creek	WB2 Segment 17	0.6°C	0.4°C	0.2°C
Near Elk Creek	WB 3 Segment 9	0.3°C	0.2°C	0.0°C
Near South Fork Chehalis	WB4 Segment 29	0.1°C	0.0°C	-0.1
Near Adna	WB4 Segment 63	0.1°C	0.0°C	-0.2

Figure 6
Modeled 7-DADMax Water Temperatures on the Chehalis River Upstream of Jones Creek (WB2 Segment 12).

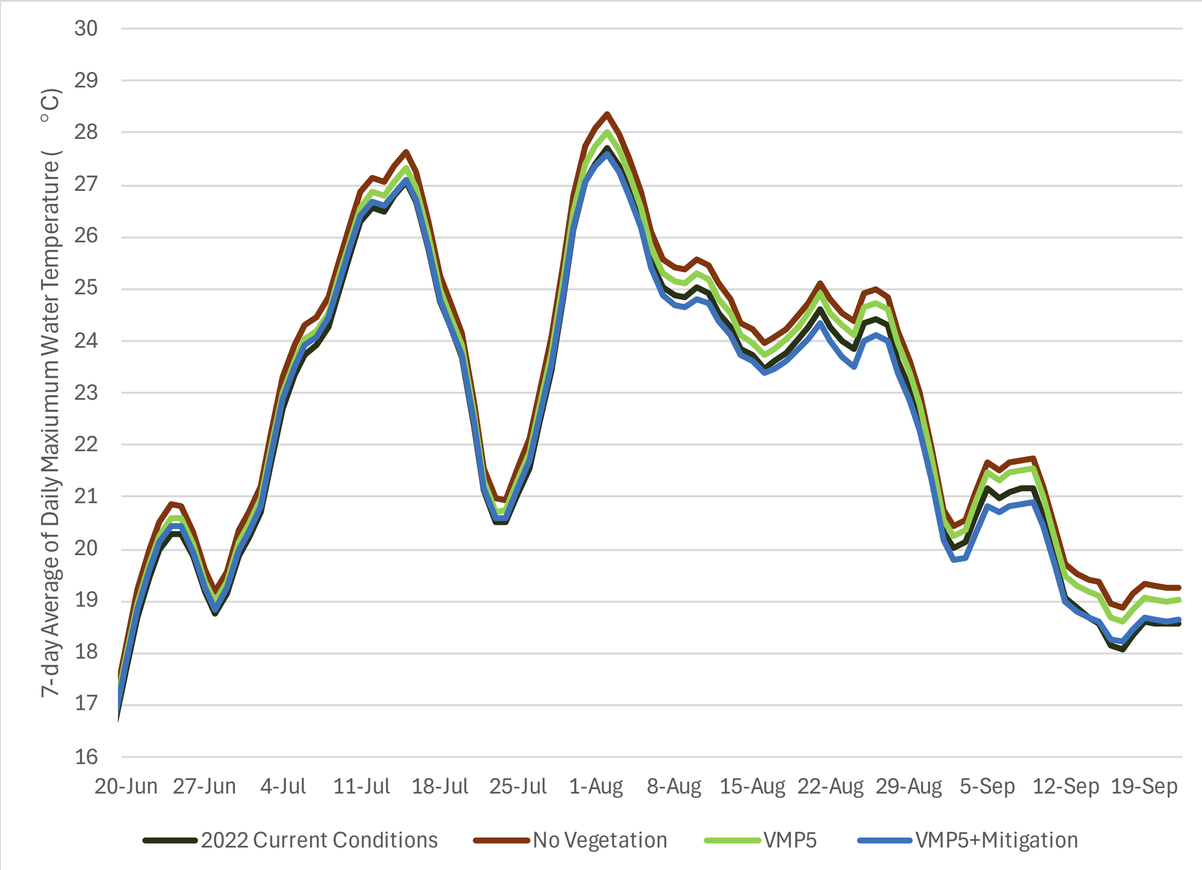


Figure 7
Modeled 7-DADMax Water Temperatures on the Chehalis River Near Elk Creek (WB 3 Segment 9).

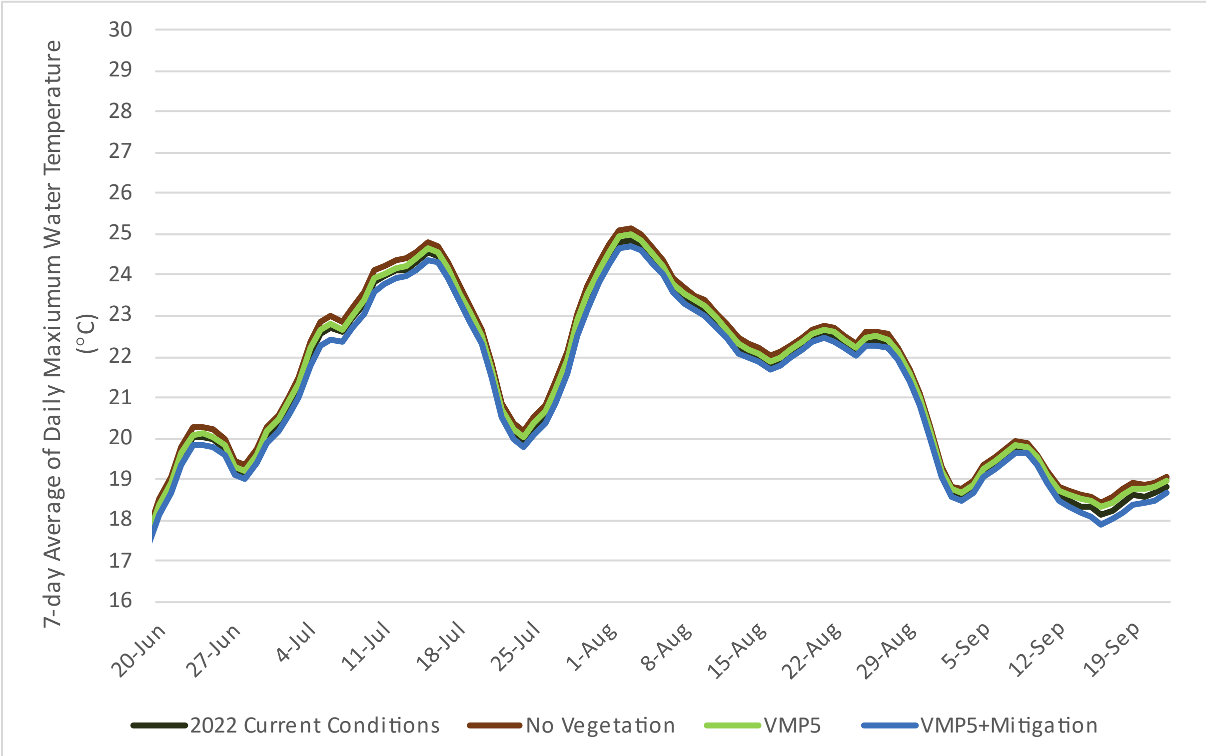


Figure 8
Modeled 7-DADMax Water Temperatures on the Chehalis River Near South Fork Chehalis (WB4 Segment 29).

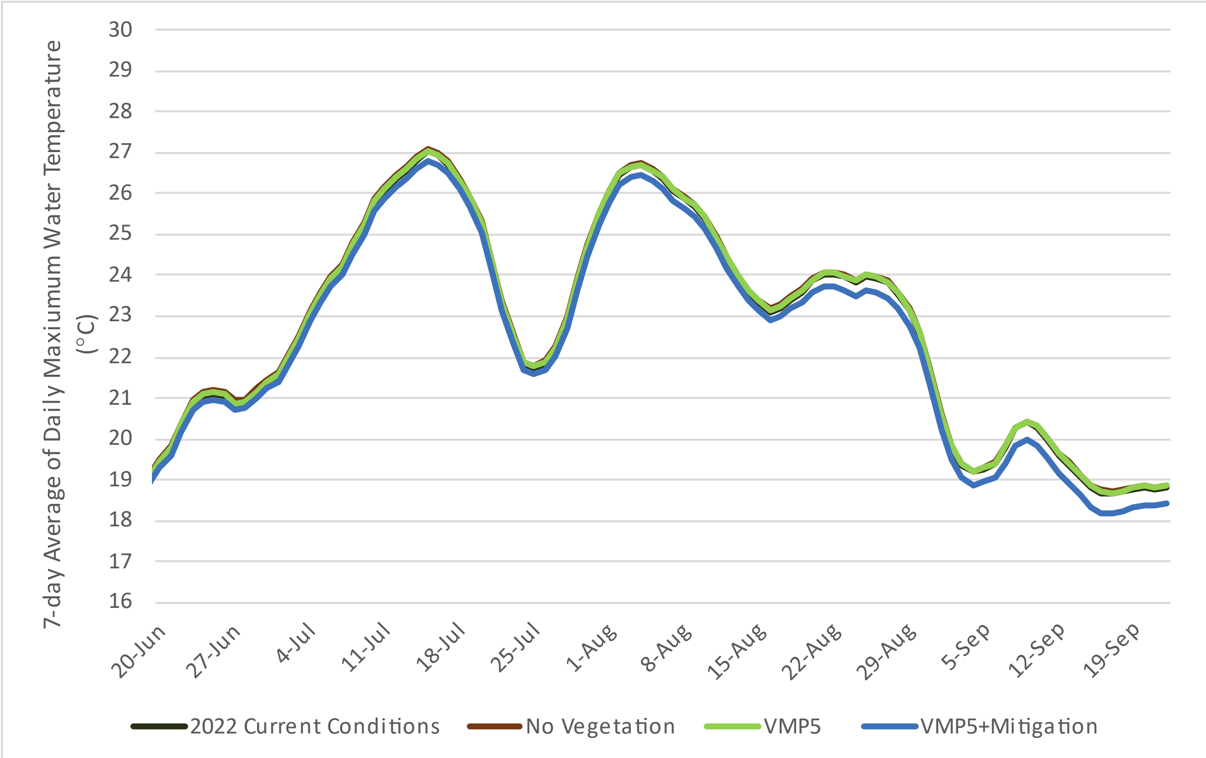
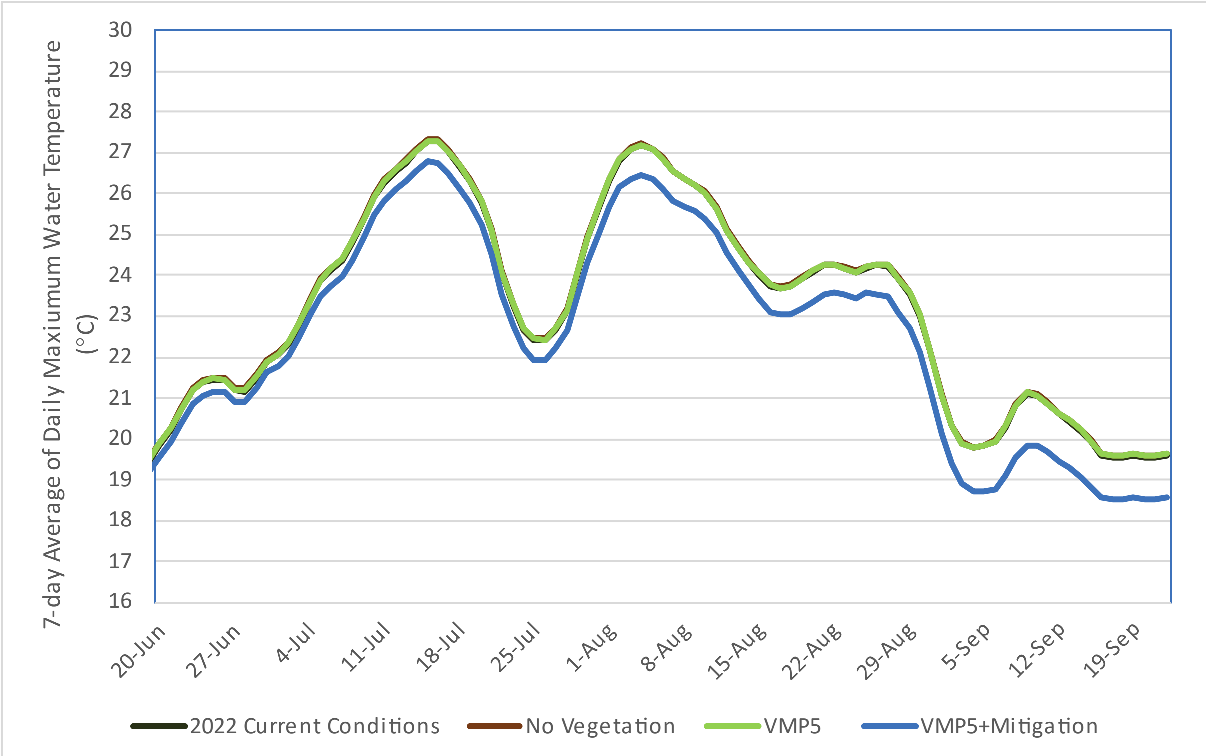


Figure 9
Modeled 7-DADMax Water Temperatures on the Chehalis River Near Adna (WB4 Segment 63).



Discussion

The NEPA and SEPA DEISs indicated that the proposed project summer water temperatures would increase as the result of tree mortality and loss of shade in the inundation area. The CE-QUAL W2 model updated the prediction of that potential effect based on 2022 conditions of the timberlands around the upper Chehalis River mainstem. The model results of the 2022 condition predicted that the construction and operation of the flow-through dam would be similar to, but slightly less than the DEIS impacts both at the FRE location and downstream. These results provide validation that the Applicant's model is depicting a similar level of contribution of existing shade and shade loss to the water temperature in the Mitigation Area.

The Applicant's model also predicted that shade restoration associated with the implementation of the VMP and operating the project as characterized by 2017 operational constraints would result in further reduced summer water temperatures as compared to the no vegetation condition. The potential for reduced temperature effects was evident from model simulations at the mouth of Crim Creek, at the FRE location and in the mainstem river downstream. The reduced impact on water temperature with the VMP was predicted from Jones Creek to Elk Creek, while the project impacted was no longer evident immediately downstream of the South Fork Chehalis River. Once mitigation was added to the VMP the modeled temperature effect at Jones Creek was further reduced to level less than Washington State criteria, while no effect was evident at Elk Creek, and a slight temperature benefit was predicted at the South Fork Chehalis River.

The model scenario with VMP and mitigation also predicted that the shade-related temperature benefit would be greater in later summer months. This result is related to the arc of the sun being lower in the sky in September as compared to July and thus, increases the extent of shade effect across width of the river. This finding is particularly important for adult Chinook salmon which are spawning in the upper Chehalis River in September.

Similar to other riverine systems throughout the Pacific Northwest, the current riparian shade conditions of the upper Chehalis River between RMs 108 and 86 are substantially degraded and offer ample opportunity for shade enhancement that can mitigate for the residual impact upstream. The results of this temperature modeling exercise in combination with the shade supply analysis presented in the RMP (Appendix G of Kleinschmidt 2024) demonstrate the feasibility of mitigation to offset temperature effects by restoring riparian shade and reducing the thermal input to the river from the sun.

Shade rehabilitation as mitigation to offset temperature impact has become an accepted practice in the Pacific Northwest. It has been successfully applied in Oregon to offset temperature impacts on the Tualatin River, the Clackamas River and the Rogue River. The Tualatin River program has been ongoing the longest and is considered the gold standard for shade mitigation (CWS 2024) The successes achieved in each of these programs exceeded expectations with benefits that extended beyond the intended temperature reduction and included improved water quality from run off, increased counts of adult salmon, increased value of wildlife habitat, and improved recreational and esthetic values. There is every reason to expect that these ancillary benefits of native riparian habitat enhancement also will occur along the upper Chehalis River as a consequence of the proposed shade mitigation.

Ecology has guidelines applicable for this type of temperature mitigation, which the Applicant relied upon to determine the quantity of shade mitigation proposed. As indicated in the RMP and detailed in the recently released mitigation contingency plans technical memorandum, there is much more shade supply available both along the mainstem river and in tributaries than that required for mitigation. As this project advances it would be possible to consider alternative configurations of shade mitigation parcels and to evaluate how to maximize the potential benefits of shade mitigation with the modeling tools developed by the Applicant.

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