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**Re: Chehalis Basin LAND Alternatives Analysis  
Hydraulic Modeling Technical Memorandum**

## 1 INTRODUCTION

Northwest Hydraulic Consultants Inc. (NHC) was contracted by Moffatt & Nichol (M&N) to perform hydraulic modeling services in support of developing and refining design alternatives as part of the ongoing Local Action Non-Dam (LAND) Alternatives assessment. The objectives of the LAND Alternative are to provide flood damage reduction while considering impacts on local wildlife, residents and businesses, and cost. This phase of the LAND alternatives analysis includes detailed hydraulic modeling to evaluate changes in water surface elevations, velocities, inundated area, and flood duration for proposed conceptual design alternatives. Conceptual design alternative components that will be incorporated into the hydraulic modeling include levee footprints, geometry, and heights; specific locations of levee features; extent and location of conveyance features; and other design characteristics that affect channel or overbank hydraulics. This technical memorandum describes the development and calibration of the base hydraulic models and the adaptation and incorporation of proposed design features into both models.

## 2 HYDRAULIC ANALYSIS

The analysis utilized two existing base hydraulic models: a one-dimensional (1D) Hydraulic Engineering Center-River Analysis System (HEC-RAS) model developed by WEST Consultants, Inc. (WEST) (WEST, 2014); and a two-dimensional (2D) RiverFlow2D model developed by Watershed Science and Engineering (WSE) (WSE, 2019). Due to faster simulation times and efficiency of incorporating proposed design features, the HEC-RAS model was used during the preliminary phases of the project to analyze different combinations of proposed design elements. Once the type, location, and extent of proposed project features were selected, the

final modeling and analysis was performed using RiverFlow2D. The full 2D capabilities of RiverFlow2D provide improved accuracy and resolution of overbank flows in critical design areas and has been calibrated.

Both models were adapted to incorporate the proposed conceptual design features as described in Section 0, to ensure accurate representation of hydraulic conditions within the project area. However, following inclusion of the proposed design features, the prior calibration for both hydraulic models was not subsequently checked. Brief descriptions of model development and calibration are provided in Section 2.1 for each model, while additional design and development details can be found in their respective design reports.

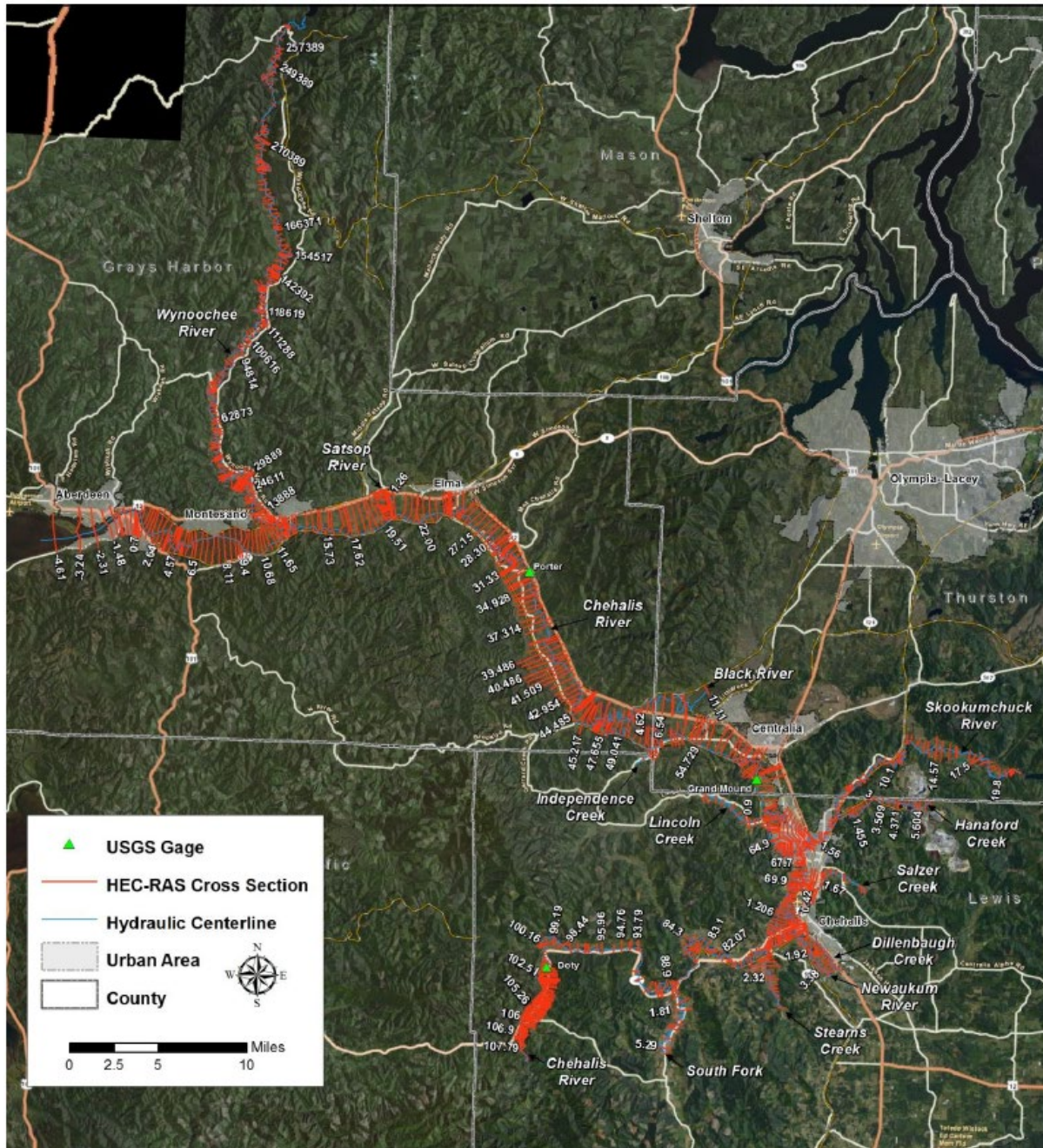
## **2.1-Base Model Development**

### **2.1.1-HEC-RAS 1-D Model**

WEST developed a combined 1D HEC-RAS model of the Chehalis River Basin in 2014 (WEST, 2014), by updating and expanding an existing 2003 U.S. Corps of Engineers (USACE) HEC-RAS model. The extents of the updated model are shown in Figure 2.1.

The HEC-RAS model was calibrated by comparing simulated water surface elevations (WSEL) to observed values at several United States Geological Survey (USGS) gages for both low and high flow conditions, as well as to a series of high-water marks. Low flow periods analyzed were between August and October, and high flow events in 1996 and 2009 were used for calibration. An additional high flow event in 2007 was used for model validation. The target for calibration was to be within 0.5 feet at USGS gages and within 1.5 feet at ungauged locations (such as high-water marks).

Calibration of the model was achieved by adjusting Manning's  $n$  values for the channel and overbank areas; modifying weir coefficients for lateral structures; and adding ineffective flow areas. Additional information on model development, including the source and resolution of the base terrain; type location and source of inflow and outflow boundary conditions; roughness coefficients; and model run parameters, is provided in WEST, 2014.



**Figure 2.1 1D HEC-RAS model extents (from WEST, 2014)**

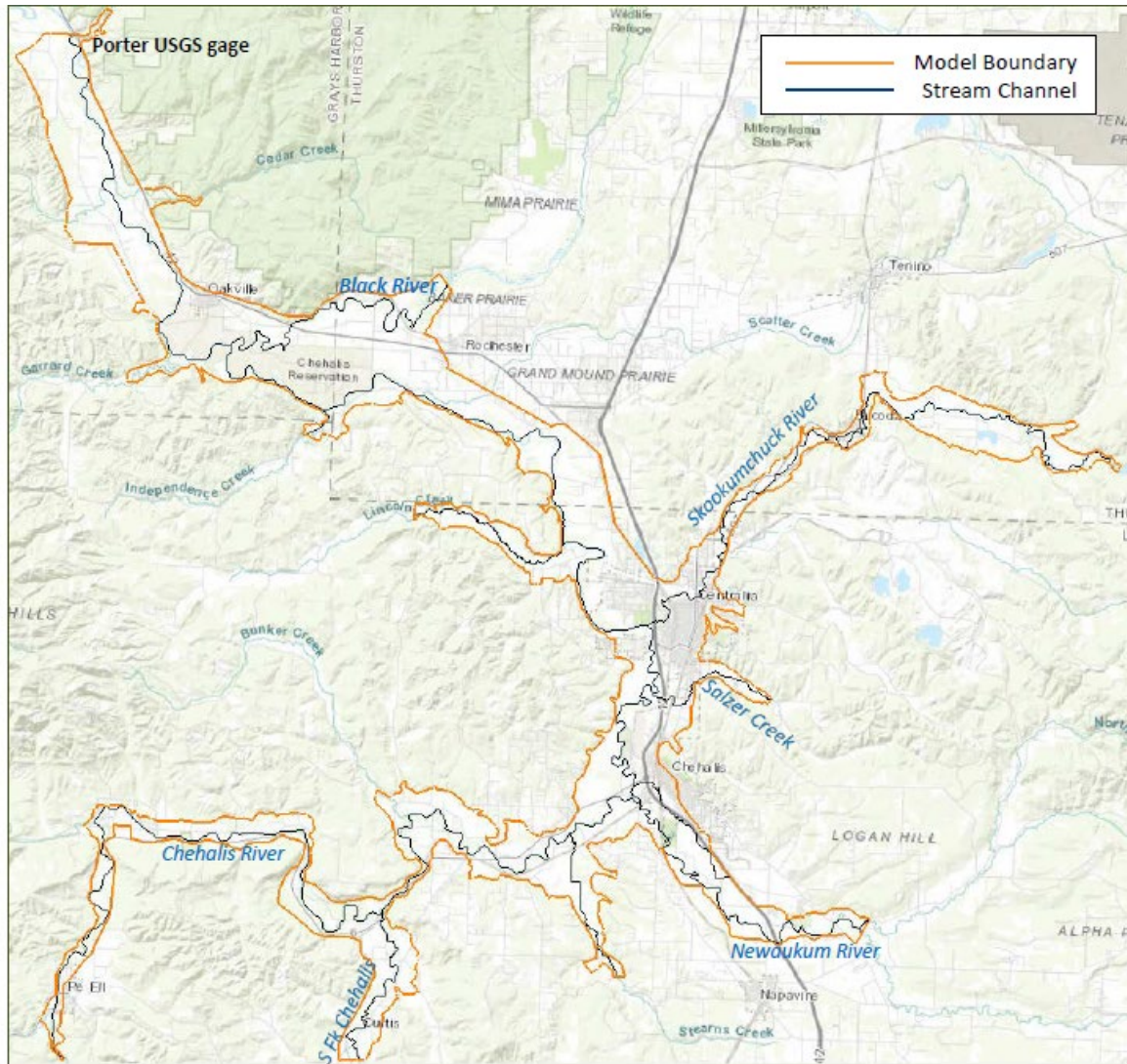
### 2.1.2-RiverFlow2D Model

WSE developed and calibrated a fully 2D model of the Chehalis River and floodplain within Riverflow2D in 2019 (WSE, 2019). The 2D model generally covers the same modeling extents as the 1D HEC-RAS model, except for the Wynoochee River, but because it is fully 2D, it is assumed to more accurately represent overbank and floodplain hydraulics, which are critical in evaluating



and quantifying flood risks. The model was developed primarily using ArcGIS and the pre- and post-processing software Surface-water Modeling System (SMS). The RiverFlow2D model extents are shown in Figure 2.2.

The RiverFlow2D model was calibrated and verified by comparing simulated results against high water marks obtained following flood events in 1996, 2007, 2009 and 2022, along with measured stage and discharge hydrographs at several USGS gage locations. The target for calibration was for simulated values to have an average absolute error within 1 foot of observed values and that any model bias, as measured by the average error, was less than 0.5 feet. Additional information on model development, including the source and resolution of the terrain; type location and source of inflow and outflow boundary conditions; roughness coefficients; and model run parameters, is provided in WSE, 2019.



**Figure 2.2 RiverFlow2D model extents (from WSE, 2019)**

## 2.2-Model Adaptation and Application

Both the 1D HEC-RAS and RiverFlow2D models were adapted for use within this analysis to represent the proposed conceptual design features, and identify potential changes in hydraulic conditions, such as depth, inundation extent, flow distribution, etc., due to these proposed features. A description of the proposed design features, along with the adaptation of each model, are provided in the following sections.

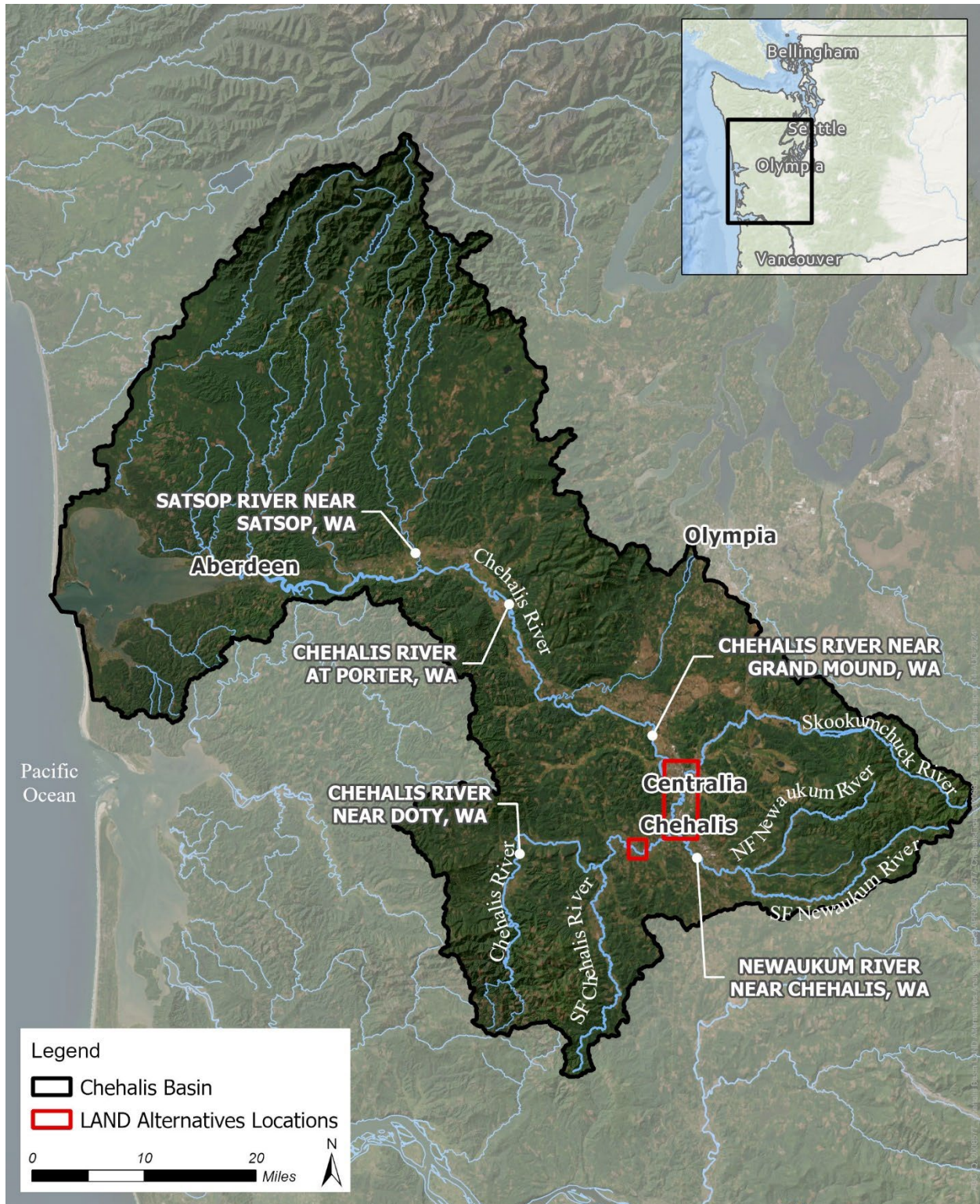
### 2.2.1 Proposed Conceptual Design Features

A majority of the LAND alternatives conceptual design features are located near the Chehalis and Centralia City areas, and the confluences of the Newaukum and Skookumchuck Rivers with

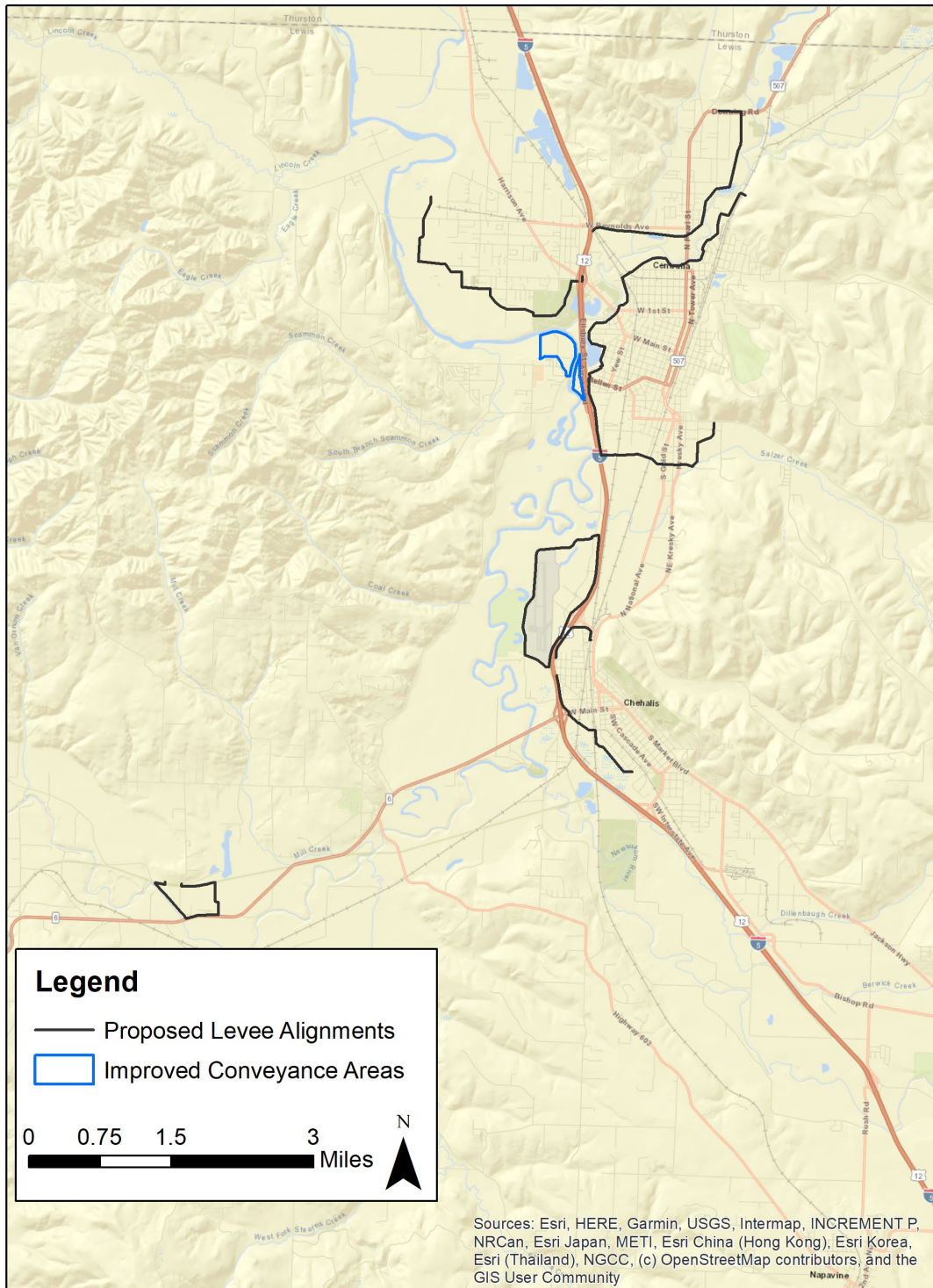
the Chehalis River. Figure 2.3 shows the Chehalis Basin watershed and LAND alternatives project implementation areas.

To support the primary LAND Alternatives objective of flood damage reduction, the proposed conceptual design features were designed to minimize the inundation extents, duration and magnitude of the 100-year plus 26% flood. This was primarily accomplished through implementation of high ground features (levees, floodwalls, gates, or raising existing roads), and measures to improve channel and floodplain conveyance (structure removal and excavation). The methods of incorporating these features into the geometries of the two models is described in the following subsections.

The final hydraulic model geometries incorporated nine (9) distinct high ground features (i.e. levees & floodwalls) and one conveyance area, which includes the removal of the Mellen Street bridge. Figure 2.4 shows the general location of the proposed project elements. A more detailed description of their location, extent, purpose, and design can be found in the main LAND report.



**Figure 2.3 Chehalis Basin Watershed and locations of proposed LAND Alternatives project implementation areas**



**Figure 2.4 Location of proposed conceptual project features (levees, floodwalls, road raises & conveyance improvements)**

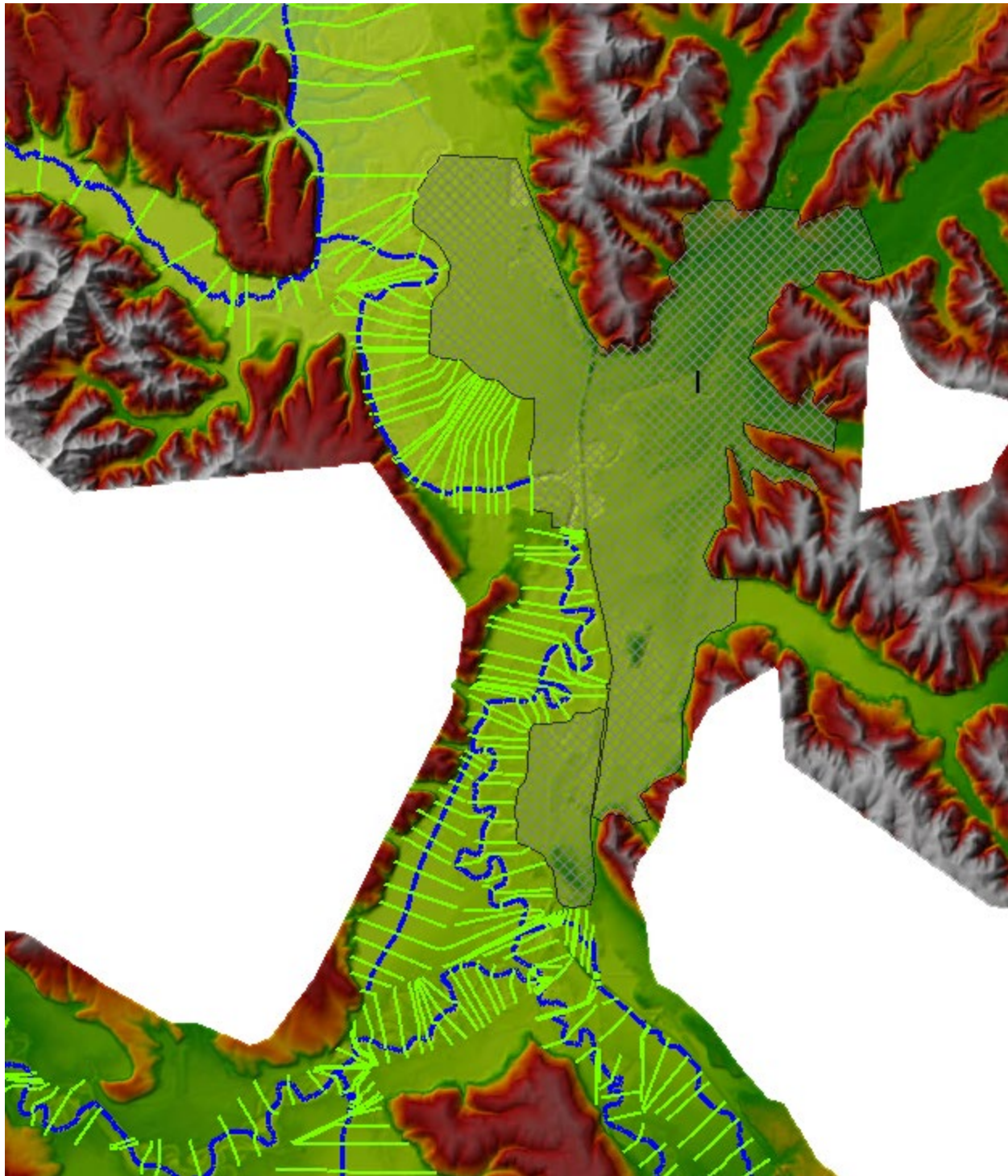
### 2.2.2-HEC-RAS 1-D Model Updates

NHC updated the base 1D HEC-RAS model to include several 2D flow areas and adapted the model to version 6.2 to take advantage of newer design and analysis tools within HEC-RAS. Two-dimensional flow areas were added to improve the accuracy and resolution of channel and overbank flows in areas with the highest concentration of proposed design elements. These are generally located near the Chehalis and Centralia City areas as shown in Figure 2.5.

Proposed project elements were incorporated into the model using built in design and modeling tools. In 1D areas, levees were added using the geometric data editor by indicating the station and elevation of the proposed feature at each cross-section, or by modifying existing lateral structures. In 2D areas, the levees were modeled as weirs within SA/2D connection lines, with widths and top elevations delineated for each levee segment.

Improved conveyance areas, achieved through excavation of the left and right overbank areas up and downstream of the Mellen Street bridge, were incorporated using built-in terrain modification tools within HEC-RAS. The conveyance areas were designed to be inundated at approximately the 2-year recurrence interval flood. The Mellen Street bridge was also removed by deleting the bridge geometry in the Geometric Data editor.

No changes were made to Manning's n roughness values, inflow or outflow boundary conditions, or other model parameters, except for the computation interval. The addition of 2D flow areas required a significant reduction the computation interval from over a minute to 10 seconds in order to maintain computational stability.



**Figure 2.5 2D flow areas (shown with cross-hatching) added to HEC-RAS model (1D cross-sections shown with green lines)**

### 2.2.3-RiverFlow2D Model Updates

NHC ran the model using RiverFlow2D version 7.45 and performed pre- and post processing within SMS version 13.1. These are updated versions compared to what was available when WSE originally developed the model and were used to take advantage of updated computational and analysis tools within these programs. The RiverFlow2D model was modified by updating the terrain and computational mesh in areas of proposed design elements, removing the Mellen Street bridge from the project geometry, and relocating tributary inflows that were impacted by the proposed levee alignments.

Updated terrain for proposed design elements, including high ground features (levees, floodwalls, gates, and raising existing roads) and improved conveyance areas (overbank excavation), were developed within AutoCAD and were consistent with design information, such as feature heights, widths, depths and side slopes, provided by M&N. Terrain surfaces were exported from AutoCAD as either Digital Elevation Models (DEM) or LandXML files to be used within the pre-processing software SMS.

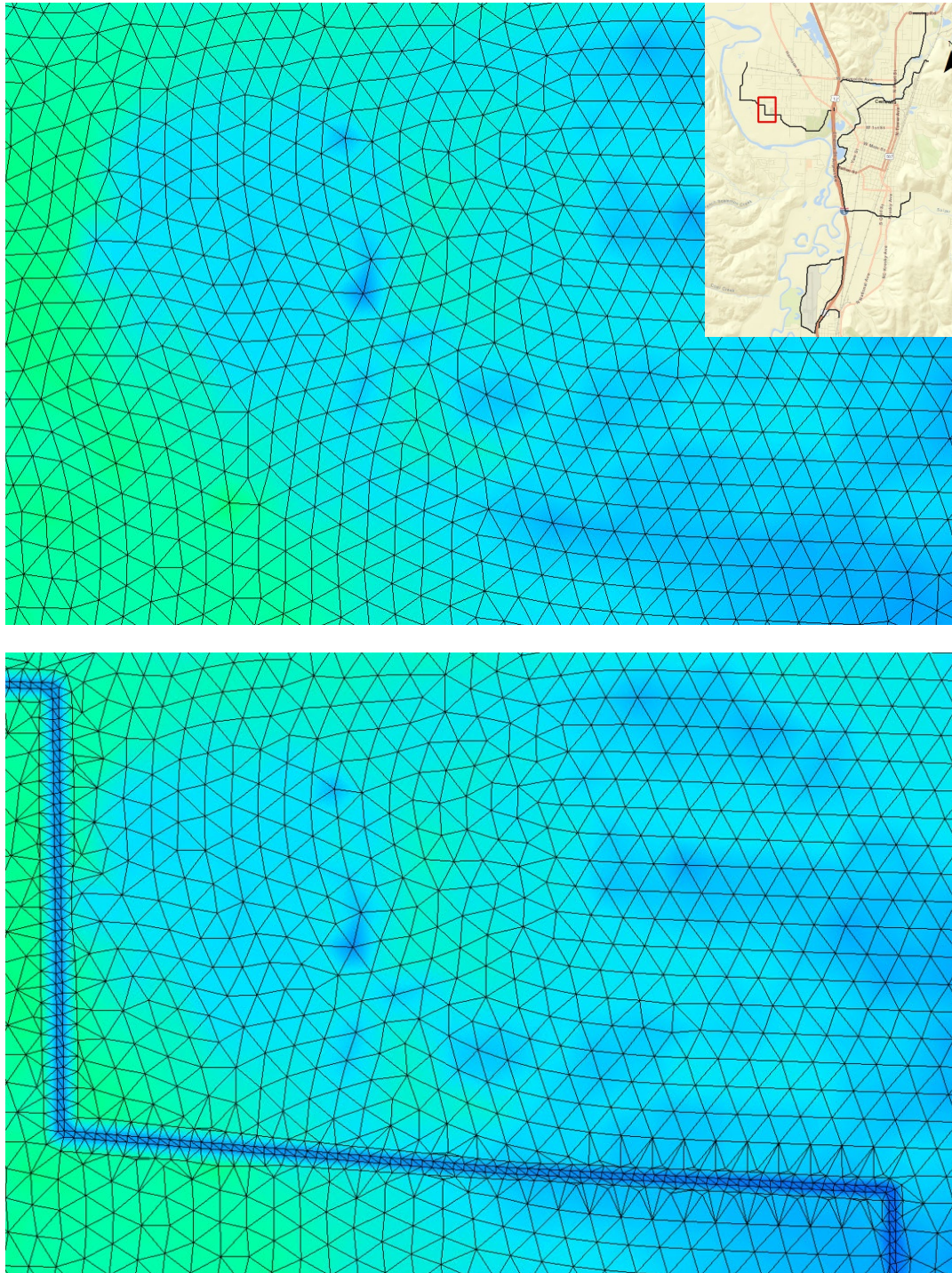
Individual meshes were created within SMS for each proposed design element using breaklines representing significant slope changes or critical design features (e.g. top of bank, toe of slope, levee centerline, etc.). Individual project element meshes were then merged with the overall base mesh, forming a "With Project" mesh that incorporated all of the proposed design elements. This allowed higher mesh resolution in the areas of proposed project features and ensured that the model more accurately represented the hydraulics in these areas. Figure 2.6 provides an example of mesh refinements between Existing and With Project conditions along a section of the Fort Borst levee.

The Mellen Street bridge was removed from the project geometry by deleting internal boundary conditions within the model representing the bridge deck and piers.

Tributary inflows for China and Coffee Creeks were relocated to be outside the limits of the proposed levee system. For China Creek, the inflow boundary conditions were moved downstream of the proposed levee at Lakeshore Drive, approximately 1,400 feet upstream from the confluence with the Chehalis River. For Coffee Creek, the internal inflow boundary condition was relocated downstream of the proposed levee near Reynolds Avenue, approximately 1,700 feet upstream from its confluence with the Skookumchuck River. Relocation of these inflows was necessary to ensure that the final results accounted for all hydrologic inputs, and to prevent internal flooding within levee protected areas.

A 3-foot culvert under Interstate 5 (I-5), located between the West and Main Street intersections with I-5 in Chehalis, was removed due to impacts with the proposed levee alignment. Based on invert data, the culvert drains from west to east, away from the Chehalis River. Additional analyses may need to be performed to confirm flow direction and ensure conveyance and management of flood flows within this area.

No changes were made to Manning’s n roughness values, inflow or outflow boundary conditions, or other model parameters, beyond those described above.



**Figure 2.6 Mesh comparison of existing base mesh (top) and With Project mesh (bottom) for a section of the Fort Borst levee**

### 3 Closure

This report documents the original hydraulic model sources and how these models were modified for the LAND project. Complete model details for the base hydraulic models are provided in their respective design reports. Development of the hydraulic models used within this assessment, including incorporation of proposed design features, followed industry standard best practices. For a more comprehensive discussion on the design and development of the proposed conceptual design features, including an analysis of results, see additional sections of Appendix D.

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