moffatt & nichol
600 University Street
Suite 610
Seattle, WA 98101
www.moffattnichol.com

Chehalis Basin LAND Basis of Analysis

To: Office of Chehalis Basin (OCB)

From: Moffatt & Nichol (MN)

Date: 5/1/2025

Subject: Chehalis Basin LAND Basis of Analysis

M&N Job No.: 232215

1 Background

The Office of Chehalis Basin (OCB) has contracted Moffatt & Nichol (MN) to complete an alternatives analysis focused on refining the major infrastructure elements of the Local Actions Non-Dam (LAND) Alternatives developed in a previous phase of the project. The MN work is intended to further support the OCB's decision-making process on the long-term flood risk reduction strategy within the basin. This document is the basis of analysis for refining the previously developed LAND project components. The document will be updated throughout the project as the analysis methodology is refined.

2 Objective & Approach

The objective of this document is to define the design flood conditions, analysis criteria, unit cost assumptions, and other considerations that will be used to refine the LAND project features shown in Figure 1.

The levee, diversion, and conveyance improvement alignments selected in the previous phase were highly conceptual. Therefore, the alignment of the project components will be refined during this phase of the study will be conducted using the following stepwise approach:

- **Step 1** – Screening Analysis**:** MN will conduct a high-level screening analysis to refine the previously developed LAND alternatives using existing information, including previous phase model results. The refined alternatives will be assessed at a screening level for cost, hydraulics, and environmental impacts. MN will incorporate OCB and stakeholder feedback into the refined alternatives prior to conducting Step 2.
- **Step 2 – Conceptual Design:** After the screening process is conducted and a preferred alternative alignment is selected, more detailed analysis, including hydraulic modeling,

environmental & cultural resources, and geotechnical analysis will be conducted to further refine the alternatives and develop conceptual designs.

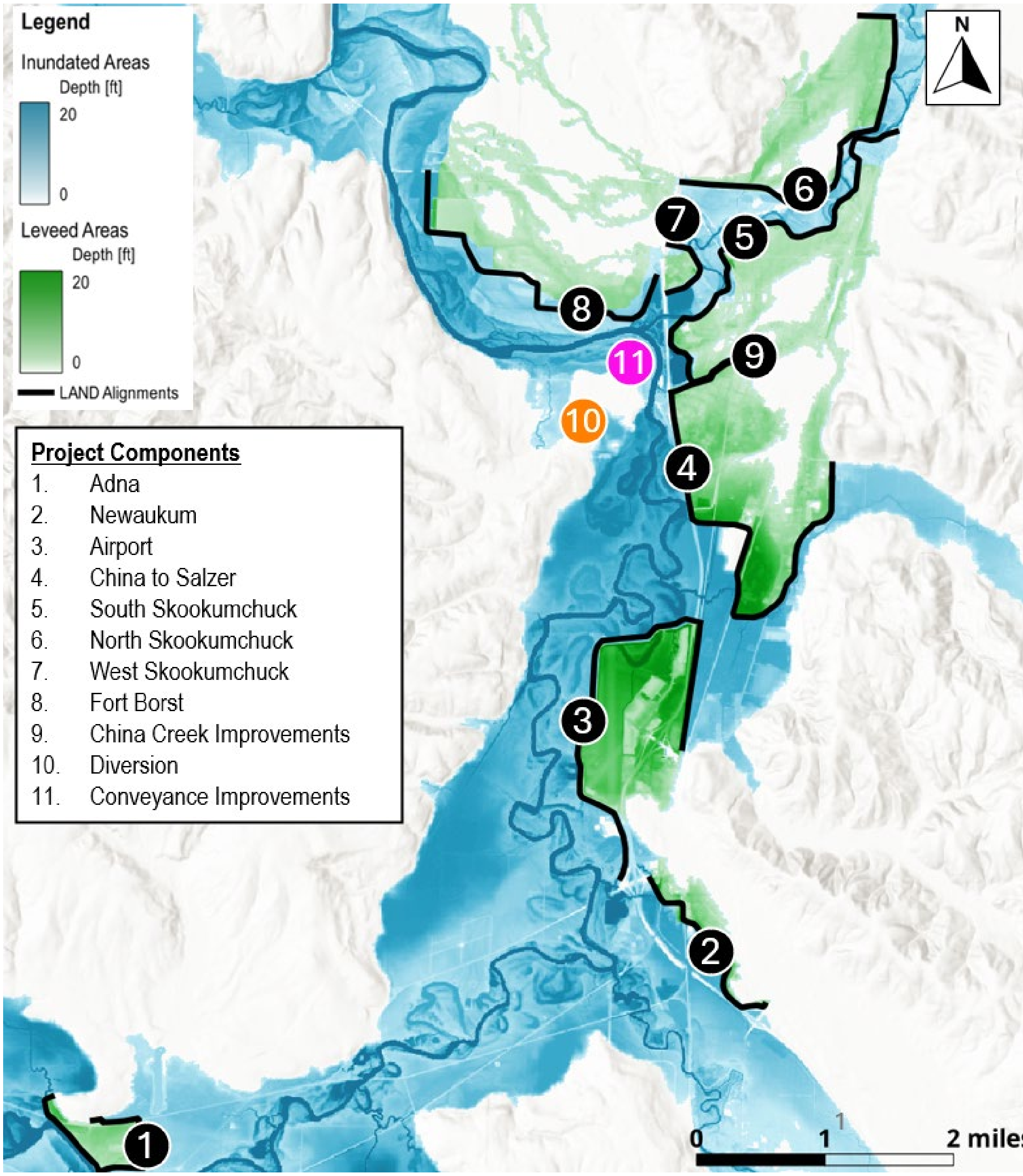

Figure 1. LAND project components. LAND alignments shown as developed in previous phase of work. Note that the bridges included as part of the diversion & conveyance improvements are not shown. These alignments will be refined using the methodology described in this memorandum.

3 Alignment Refinement Methodology

The previously developed LAND levee and floodwall alignments (Project Components 1-9) shown in Figure 1 will be refined by MN using the following approach:

1. **Categorize inundation of existing structures:** Using the previously developed structure inventory (Anchor, 2024) and design storm flood depths (OCB, 2024), MN will categorize inundation above the finished floor levels for all structures. This will allow targeted refinement to the previously developed levee & floodwall alignments.

2. **Review Community Lifelines:** Using Lewis County public facilities data (Lewis County, 2024a), MN will refine the alignments to protect community lifelines (hospitals, schools, transportation systems, etc.).

3. **Review Land Use:** Assess land use of areas around previously developed LAND levee and floodwall alignments. In general, the alignments will try to utilize public right of way (government owned areas, roads, utility corridors, etc.) instead of private land.

4. **Qualitative Assessment of Hydraulics, Geomorphology, Environmental Impacts:** During screening (Step 1), hydraulic impacts will be assessed qualitatively using model results from the previous phase. Note that numerical modeling of the revised alternative alignments will be conducted in Step 2- Conceptual Design. Geomorphological and environmental impacts will be qualitatively assessed using publicly available databases such as WDFWs priority habitats, the National Wetland Inventory, etc.

5. **Develop Refined Alignments:** Using the results of the analysis in steps 1-4, MN will develop refined alignment(s) for each flood protection features.

6. **Categorize Alignments:** Each alignment will be broken into levee and floodwall sections. Generally, levees will be placed in open, unconfined areas. In more urban and/or restricted areas, floodwall sections will be selected. Along each alignment, the need for pump stations, closure structures, and real estate acquisitions will be assessed.

7. **Develop Screening Level Costs:** Screening level costs will be developed for each alignment refinement considered. See Section 6 for additional information on the development of screening level costs.

A similar approach will be taken to refine the diversion and conveyance improvement features. MN will investigate potential refinements to the spatial extents, elevations, and alignments of the diversion, conveyance improvements, and associated infrastructure including bridges & fords.

4 Guiding Principles

Guiding principles were developed in coordination with OCB to help provide direction for refining the previously developed LAND alternatives. These guiding principles will be considered when developing alternative alignments to ensure the alternatives are meeting project goals. The following guiding principles will be considered when refining the alternatives.

- Minimize any impact on downstream water levels,
- Minimize any impact on downstream geomorphic processes
- Minimize any impact to Interstate 5 (I-5),
- Ability to implement fully or incrementally over time,
- Maintain community lifelines: protect critical facilities & emergency route access,
- Preserve cultural resources & habitat.

The guiding principles serve as broad, foundational concepts that will shape the development of refined alternative designs. One essential component of the alternative refinement is the "Room for the River" concept (Rijke, J et al., 2012), which focuses on creating additional space for rivers to accommodate high water flows while reducing downstream impacts. Whenever feasible, levee alignments will be positioned further from the river floodplain to maximize the river's natural capacity, while improving the level of protection for existing infrastructure.

5 Analysis Criteria

The following design criteria apply to all project components:

- **Design Event:** Per discussions with OCB, MN is using the 100-yr + 26% model results (Design Flood Level) from the previous phase of the LAND Study.
- **Numerical Model:** the RiverFlow2D model developed in the previous phase of the LAND project will be used as the base for analysis to maintain consistency with other studies and previous phases of LAND. Proposed levee and floodwall alignments will be built into the numerical model to assess the project conditions. Input flow conditions will remain unchanged from the previous phase of the LAND study, and will represent the 100-yr + 26% design event. Updated modeling should be conducted in future phases to incorporate any refinements, and coordination with other projects in the basin to refine the LAND alternative.

- **Interstate 5 (I-5):** Assume no alterations to I-5 are included as part of the project.

- **Seismic:** A key consideration in the seismic stability of levees is the proximity to the riverbank, as levees near the river can have taller slopes and saturated soils at the toe of the levee. While wide crests and flat slopes on flat land are generally more seismically stable, future seismic vulnerability assessments should consider levee height, soil profiles, and levee's distance from the riverbank. This can help categorize levee segments into zones based on the likelihood of seismic effects: those far enough to avoid concern, middle zones requiring further study, and areas near the riverbank that almost certainly necessitate seismic considerations and additional investment. A geotechnical risk assessment is included in the main report and associated geotechnical appendices; however detailed seismic vulnerability assessment and design criteria evaluation are not included in this phase of work and should be assessed during detailed design in future phases.

5.1 Levees

The levee analysis criteria were developed considering internal databases and industry standard guidelines including USACE, 2000 & California DWR, 2012. The following assumptions will be applied to the levee analysis:

- **Freeboard:** Assumed three (3) feet above the design event (100-yr + 26%).

- **Crest Width:** Assumed twelve (12) foot levee crest.

- **Sideslope:** Assumed 3H:1V. When the available footprint is constrained by adjacent features, layouts will consider steeper slopes up to 2H:1V.

- **Fill:** Assumed imported fill from offsite for cost analysis. Reuse of excavated material from the diversion and/or conveyance excavations will be considered and should be investigated further in future phases. Future phases should also conduct a detailed investigation of adjacent borrow sites, including development of new borrow areas.

- **Right of Way Distance:** Assumed fifteen (15) feet on either side of the levee.

- **Parks & Recreation Opportunities:** Levees will be assessed for opportunities to integrate trail (on top of) or parks and recreation features (adjacent to).

5.2 Floodwalls

The floodwall analysis criteria were developed considering internal databases, industry standard, and local guidelines including USACE, 2011, USACE, 2022, and California DWR, 2012. The following assumptions will be applied to the floodwall analysis:

- **Freeboard:** Assumed three (3) feet above the design event (100-yr + 26%).
- **Floodwall Type:** Floodwall type will vary by location. Concrete T-Walls and sheetpile walls (I-walls) will be considered.
    - I-walls: Assumed when vertical structure is less than twelve (12) feet above grade.
    - T-Walls: Assumed when vertical structure is greater than twelve 12) feet above grade. Further assessment is needed in future phases, where geotechnical properties may require T-walls for stability.
    - The 12-foot maximum sheetpile floodwall height is based on USACE, 2011 guidance, which recommends a maximum water height of 9 feet for sheetpile walls in sandy soils. With the 3 feet of freeboard assumed in this study, the maximum water depth at a 12-foot wall is therefore 9 feet. This assumption is based on general guidance and should be validated with a deformation analysis once additional subsurface data becomes available.
    - Floodwalls in areas with poor geotechnical characteristics, i.e., soft soils, may require pile supported concrete T-walls or similar structures even at floodwall heights less than 12 feet. Additionally, 12 feet represents a general practical maximum for sheetpile floodwall heights (USACE, 2011). In future phases, floodwalls less than 12 feet in height may require concrete t-walls depending on site specific geotechnical characteristics. Specific selection of either concrete t-walls or sheetpile structures should be assessed further in future phases of the project once additional geotechnical data is collected and surface constraints are better understood .
- **Floodwall Embedment:** Assumed I-walls are 1/3 above ground, 2/3 below ground (i.e. a 3-foot floodwall would be embedded 6 feet).
- **Right of Way Distance:** Assumed fifteen (15) feet on either side of the floodwall.

5.3 Road Raise

The road raise criteria were developed considering internal databases, industry standards, and local guidelines including WSDOT, 2024 and Lewis County, 2024c. The following assumptions will be applied to the road raise analysis:

- **Freeboard:** Assumed three (3) feet above the design event (100-yr + 26%).
- **Assumed Width:** Assumed thirty-two (32) foot road width. Assumed twelve (12) foot lane width four (4) foot shoulder. Road raises are in rural areas, no sidewalk assumed.

- **Sideslope:** Assumed 3H:1V. When the available footprint is constrained, preliminary layouts will consider steeper slopes up to 2H:1V.
- **Material:** Assumed asphalt road with top course, base course, and subgrade fill.

5.4 Interior Drainage (Pump Stations)

The following assumptions will be applied to the pump station designs:

- **Siting:** A screening level interior drainage analysis will be conducted to determine the potential need for pump stations. The interior drainage analysis will use LiDAR (USGS, 2012 & NV5 Geospatial, 2024) to preliminarily delineate interior drainage basins and determine pump station capacities. A full interior drainage modeling analysis is required in future phases.
    - **China Creek & China Creek:** the levee and floodwall alignments cross Coffee Creek and China Creek. It is assumed that a gate structure will allow flow to pass through the structure. During flood events, the gate will close, and the pump station will be activated. The pump station will have fish passage features, similar to the recently designed Black River pump stations (Jacobs, 2020).
- **Rainfall Event:** Assumed 100-yr 24-hr rainfall storm for screening analysis (NOAA, 1973). The design rainfall event may be revised during the conceptual design phase to align with the criteria used for similar pump station projects in the region, provided additional relevant information becomes available.
- **Pump Sizing:** Using the rainfall event stated above, peak flows will be calculated for each pump station using the TR-55 analytical methodology (USDA, 1986). The pump sizing will be conducted using the approximate peak flow within each interior drainage analysis area (i.e. within each levee or floodwall system).
- **Additional Considerations:** internal drainage improvements, such as weirs, detention ponds, and other drainage improvements should be investigated in future phases to reduce internal flooding, particularly at the Coffee Creek and China Creek pump stations. Routing of flows, existing interior drainage, and final pump station siting should be conducted in future phases.

5.5 China Creek Improvements

The following assumptions will be applied to the China Creek Improvements:

- **Floodwall/Levee Alignment:** The alignment of the previous phase levees were located on the north and south sides of China Creek approximately from I-5 to the existing railroad tracks. This alignment would require over 10 closure structure across roadways, and acquisition of many homes. Instead, a pump station and gate structure was included in the design to eliminate the need for the China Creek levees.

- **Daylighting:** The previous phase investigated daylighted the current underground culvert to expand flood capacity of the creek and add a community amenity. Potential options for daylighting will be included as part of the final report Appendices. Alternatives considered should Alternatives consider projects identified in the Centralia Parks Recreation and Open Spaces Plan to identify possible connections to existing and proposed recreation in the vicinity of China Creek Future studies, coordinated with the City of Centralia, should be conducted to refine the conceptual level improvements shown in the final report.

5.6 Closure Structures

The closure structure analysis criteria were developed considering internal databases, industry standards, and local guidelines including USACE, 2000, California DWR, 2012, and Lewis County, 2024c. The following assumptions will be applied to the closure structure analysis:

- **Freeboard:** Assumed three (3) feet above the design event (100-yr + 26%).
- **Closure Locations:**
    - Closure structures assumed at all railroad grade crossings.
    - Where levees intersect roadways, closure structures will be assumed.
        - Per Lewis County Code, maximum road grade is 12% (Lewis County, 2024c). In future phases, the use of road crossings over the levees to facilitate access should be investigated and coordinated with emergency evacuation and bypass routes in accordance with this criteria. In general, road crossings in urban areas adjacent to homes would assume closure structures rather than road raises, to reduce impacts on adjacent properties, driveways, and parking lots.
- **Closure Structure Type:** Closure structure type will vary by location. For this analysis swing gates are assumed at road crossings and rolling gates will be assumed at railroad crossings.

5.7 Bridges & Fords

The bridge & ford analysis criteria were developed considering internal databases, industry standards, and local guidelines including WSDOT, 2022, Lewis County 2024a, and USDA, 2006. The following assumptions will be applied to the bridge & ford analysis:

- **Width:** All bridges assumed to be 45 feet wide. This includes the following assumptions:
    - Lane Width: 12 feet each, two lanes.
    - Shoulder: 6 feet (one side)
    - Shared Use Path: 12 feet (one side)
    - Buffer Strip: 3 feet.
- **Length:** Varies based on crossing distance & adjacent roadways.
- **Conveyance Bridge Siting:**
    - New Mellen Street Bridge (Across Chehalis River)
- **Diversion Bridge Siting:**
    - Military Avenue (Across Diversion)
    - Cooks Hill Avenue (Across Diversion)
    - South Schuber Road (Across Diversion)
- Structure Type: The new Mellen Street Bridge is assumed to be a concrete girder bridge. The Military Avenue, Cooks Hill Avenue, and South Schuber Road sites will be assessed for concrete girder bridges, and/or “fords”. A ford is a lower cost, concrete structure that allows traffic to cross when water levels are low but may become impassable during high water or flood events.
- **Ford Criteria:**
    - Maximum roadway slope not to exceed 12% (Lewis County, 2024c).
    - Depth markers will be required to indicate the depth of flow over the structure.
    - Material Type: Assumed at grade concrete slab ford with 2-4% minimum downstream cross slope. Riprap and/or gabion basket scour protection will be added around the roadway as required per USDA, 2006 requirements.
- **Existing Bridge Demolition:** The existing bridge is assumed to be demolished in place and materials disposed of at a landfill or similar disposal site. During demolition, future phases of the study should consider potential for lead paint, etc. that could be present

and would need to be remediated. East & westbound traffic will be rerouted to the new Mellen Street Bridge location.

5.8 Diversion & Conveyance

The following assumptions will be applied to the diversion analysis:

- **Bottom Width:** The bottom width of the diversion in the previous phase was 700'. Preliminary numerical modeling will be conducted to investigate the effectiveness of smaller diversions.

- **Sideslope:** Assumed 6H:1V.

- **Location:** The approximate diversion location developed in the previous phase of the LAND study is shown in Figure 1. Based on preliminary examination of existing LiDAR (USGS, 2012, NV5 Geospatial, 2024) and structure databases (Anchor QEA, 2024), this general location appears to minimize excavation while impacting the least number of homes. Small variations in diversion alignment will be investigated as part of the updated analysis.

- **Elevation Profile:** Longitudinal slope to prevent fish stranding. The slope will tie into existing adjacent grades. The bottom elevation of the diversion will be set such that it is dry during day-to-day conditions and only flooded during higher water events (approximate 1- or 2-year flood elevation based on the no-action numerical modeling results from the previous phase of the study).

- **Material Disposal:** Use of the excavated material to construct the levees will be investigated from a feasibility level using available geotechnical and geological data. Alternatively, material can be trucked to a landfill or sold for other uses in construction or agricultural augmentation. Future studies will be required to assess the suitability of the excavated material for these purposes.

- **Effectiveness:** the relative effectiveness of the diversion (i.e. reduction in water levels upstream) will be assessed via preliminary level numerical modeling. The diversions effectiveness will be assessed via cost metrics, and by coordinating with stakeholders.

The following assumptions will be applied to the conveyance analysis:

- **Location:** The approximate conveyance improvement location developed in the previous phase of the LAND study is shown in Figure 1. Alternative footprints will be investigated in this phase of work; however, the general area is anticipated to remain the same.

- **Excavation Depth:** Excavation depth as defined in the previous phase varies from approximately 0 to 10 feet depending on the existing topography. Alternative excavation designs for the conveyance features will be investigated in this phase of work; however, the general approach of matching the elevations selected in the previous phase of work is anticipated to remain the same.

- **Material Disposal:** Use of material in levee construction will be investigated from a feasibility level using available geotechnical and geological data. Alternatively, material can be trucked to a landfill or sold for other uses in construction or agricultural augmentation. Future studies will be required to assess the suitability of the excavated material for these purposes.

- **Effectiveness:** the relative effectiveness of the conveyance (i.e. reduction in water levels upstream) will be assessed via preliminary level numerical modeling. The conveyance effectiveness will be assessed via cost metrics, and by coordinating with stakeholders.

5.9 Structure Raises & Floodproofing

The following assumptions will be applied to the structural raise and floodproofing analysis:

- **Freeboard:** Assumed finish flow set to one (1) feet above the design event (100-yr + 26%)

- **Location:** The structures database (Anchor QEA, 2024) has structures along the Chehalis River basin, extending from the project area to the Chehalis River confluence with Grays Harbor. Outside of the levee boundaries, any residential or commercial property that is deemed valuable in the Anchor 2024 database and is adversely affected by the alternative (i.e. water level is raised at the property due to the LAND alternative) will be assessed for structural raises & floodproofing. The LAND project cost analysis assumes that the difference in cost between the without project, and with project conditions, will be included in the overall project cost estimates for these structures. Additionally, structures in close proximity (assumed to be approximately 0.5 miles from the levee or floodwall for this study) to the levee and floodwall alignments, but not within the protected area, will be included in the structural raise costs. It is assumed that structures outside of these two categories will be addressed by other projects and/or initiatives within the basin.

- **Raises vs Floodproofing:** Floodproofing will be assumed for commercial structures outside of the proposed levee footprints that meet the above requirements. Residential structures meeting the requirements stated above will be assessed under the following assumptions, consistent with the previous phase of LAND (OCB, 2024):

- 0 to 1 feet of Inundation: Floodproof the structure
- 1 to 5 feet of inundation: Raise the structure.
- >5 feet of inundation: Assume relocation of the structure.

6 Planning Level Cost Estimate

The following unit cost assumptions will be applied to each project component analyzed . Costs were developed from a combination of data sources including WSDOT construction database, National Levee Safety Program Data, USACE Planning Level Cost Estimates, OCB local project data, and internal databases. All project costs were escalated to 2025 dollars using the USACE Civil Works Construction Cost Index System (USACE, 2021)

Given the preliminary nature of the conceptual (10%) cost analysis, project costs will be assessed using a range of unit cost assumptions. Low (L), medium (M), and high (H) values will be used where data is available to bound the cost estimate. Note that all costs shown are in 2025 dollars. Costs derived from older references were escalated to 2025 dollars using USACE Civil Works Construction Cost Index System (USACE, 2021).

- **Mobilization:** Assumed 10% of the project cost (NLSP, 2023)
- **Environmental:** Assumed 6% of the project cost (NLSP, 2023). Assumed to include mitigation projects, however a full mitigation assessment should be conducted in future phases. Assumed to include permitting costs.
- **Planning, Design, Construction Management:** Assumed 20% of the project cost (NLSP, 2023).
- **Utility Relocates:** Assumed 2% (L), 4% (M), and 5% (H) of total project cost (NLSP, 2023). Full utility relocation analysis recommended in future phases.
- **Project Contingency:** Assumed 55% of total project cost (NLSP, 2023)
- **Levees (L, M, H):** $40, 50, $90 per CY (Internal Database)
- **Floodwalls:** Costs per NLSP, 2023 and Internal Database.
  - 0–3 foot tall (L, M, H): $600, 800, $900 per LF. Assumed sheetpile I-wall.
  - 3–6 foot tall (L, M, H): $1,100, $1,500, $1,800 per LF. Assumed sheetpile I-wall.

- 6–9 foot tall (L, M, H): $1,700, $2,200, $2,700 per LF. Assumed sheetpile I-wall.
- 9+ foot tall (L, M, H): $2,200, $2,900, $3,600 per LF. Assumed sheetpile I-wall.
- 12+ foot tall (L, M, H): $11,500, $15,800, $20,100 per LF.Assumed concrete T-wall.

- **Closure Structures:** Costs per NLSP, 2023 and Internal Database.
  - Stoplog (L, M, H): $1,550, $3,150, $4,750 per SF
  - Swing Gate (L, M, H): $890, $4,300, $7,700 per SF
  - Rolling Gate (L, M, H): $1,000, $6,900, $12,700 per SF
- **Road Raises:** Costs per WSDOT, 2025 and Internal Database
  - 0-5 foot tall (L, M, H): $600, $800, $1,100 per LF
  - 5-8 foot tall (L, M, H): $800, $1,000, $1,400 per LF
  - 8+ foot tall (L, M, H): $1,000, $1,300, $2,000 per LF
- **Pump Stations (L, M, H):** $15,000, $18,500, $22,000 per CFS. (Internal Database, WA Department of Commerce, 2021)
- **Structural Floodproofing:** Costs per Chehalis Basin Strategy, 2014. Applied to valuable commercial structures and residential structures with less than 1 foot of inundation.
  - Perimeter Floodproofing (L, M, H): $340, $380, $420 per LF
  - Door Floodproofing (L, M, H): $200, $220, $240 per SF
    - Note, this assumes 10% of walls are doors.
  - Incidentals (L, M, H): $10,000, $12,900, $20,000 additional costs
- **Structural Raises (L, M, H):** $90, $140, $190 per SF (OCB local project data). Applied to valuable residential structures.
- **Structure Relocation Costs:** For costing purposes, structures that need to be relocated, either due to conflicts with the levee, floodwall, diversion, or conveyance improvement construction or due to exceeding the inundation values described in Section 5.9, will be assessed at the parcel’s total assessed value plus 5% (L),10% (M), and 15% (H).

- **Real Estate (ROW):** For costing purposes, it is assumed that property owners will be compensated for the land value that is in the right of way (ROW). Real Estate ROW compensation are based on the average cost per acre (land only) for each property in the levee, floodwall, or road raise ROW, assessed on an individual property basis using the assessed parcel values. (Lewis County, 2024b). The final costs are calculated using the parcel's assessed land value, without improvements, plus 5% (L),10% (M), and 15% (H). Structures within the levee or alignments ROW will be assessed separately on a case-by-case basis, as described in the "Structure Relocation Cost" item.

- **Diversion/Conveyance Excavation (L, M, H):** $25, $35, $45 per CY (Internal Database)

- **New Bridges (L, M, H):** $400, $500, $600 per SF (Internal Database, WSDOT, 2024a)

- **Existing Bridge Demolition (L, M, H):** $4M, $6M, $8M per bridge demolished.

- **Fords (L, M, H):** $15, $20, $25 per SF (WSDOT & Internal Database)

- **Operations & Maintenance (O&M):** Concept level O&M estimates were developed for the different project components. All costs assumed in 2025 dollars, with no discounting future value to present values performed as part of the cost assumptions. A summary of the assumed O&M costs is provided below:

    - **General:** Assumed general O&M costs are not specific to any flood protection feature and include staffing, overhead, building, maintenance yard equipment, etc. The rolled up yearly O&M cost for general activities is assumed to be 0.2% of the capital construction costs of the levees, floodwalls, and closure structures.

    - **Levees:** Assumed O&M costs include mowing, tree removal, levee inspection, and trail sweeping. Assumed frequency of maintenance at 8 times per year. Assumed 2 trees removed each maintenance event. The rolled-up yearly O&M cost is assumed to be 1.20% of the capital construction cost of the levees.

    - **Floodwalls:** Assumed floodwall O&M includes floodwall inspection at a one-year interval, and maintenance and repairs at an assumed fifteen (15) year interval. The rolled-up yearly O&M cost is assumed to be 0.05% of the capital construction cost of the floodwalls.

    - **Closure Structures:** Closure structure maintenance included the cost of training crews to operate the gate structures, and for testing, inspecting, and exercising each gate system. Assumed frequency of once per year. The rolled-up O&M cost is assumed to be 0.2% of the capital construction cost of the closure structures.

- **Pump Stations:** Pump station maintenance includes periodic operations and inspections, general maintenance of engine, motor, fuel/energy costs, etc. Assumed frequency of once per year. The rolled-up O&M cost is assumed to be 0.75% of the capital construction cost of the pump stations.

- **Bridges:** Bridge maintenance includes periodic inspections, striping, concrete repairs, etc. The rolled-up O&M cost is assumed to be 0.80% of the capital construction cost of the bridge based on AASHTO, 2020.

- **Environmental:** Assumed 0.70% of the capital environmental construction costs per year for habitat monitoring and maintenance costs for mitigation areas. Assumed cost based on internal databases. Scale of mitigation and therefore any O&M costs to be determined in future phases based on permitting requirements.

7 Cost Model

The unit costs documented in the previous section will be applied to a screening level cost model to aid in refining the alternatives. The cost model uses the No-Action 100-yr + 26% flood depth results modeled in the previous phase of the study to develop preliminary estimates of levee and/or floodwall height, considering the freeboard requirements stated in Section 5. This allows quick estimates of overall project cost, as well as identifying sections of the alignments that are higher cost and can be optimized further. An example of the cost model for a conceptual alignment at the Fort Borst Levee location is shown below in Figure 2. During the conceptual design analysis, the cost model will be updated using new model results that include the levee alignments.

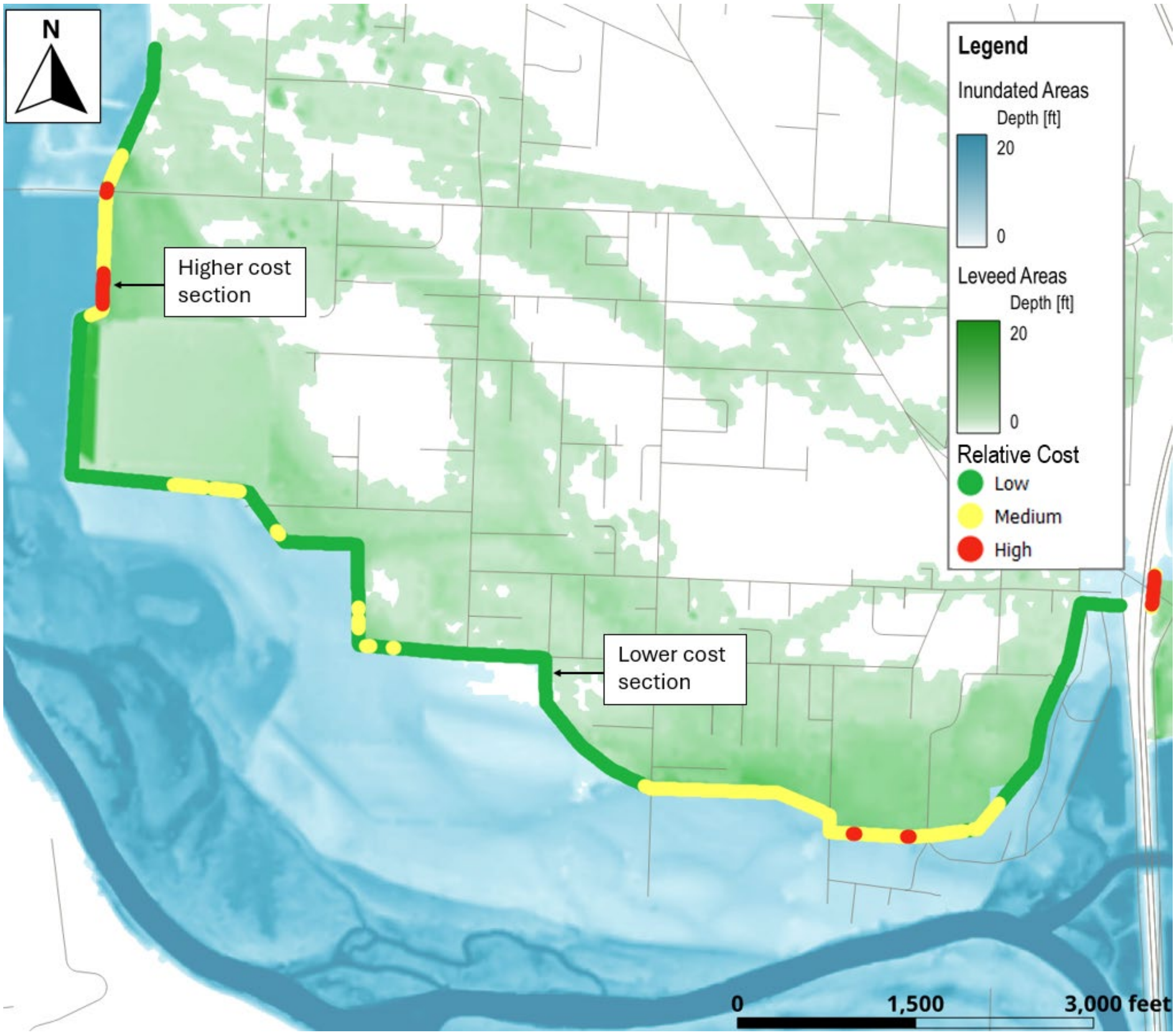

Figure 2. Spatial variation in relative levee cost (low, medium, high) along a conceptual levee alignment. Note that the alignment shown is under development and subject to change throughout the project.

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