Technical Memorandum

Date:	February 22, 2022
Project:	Chehalis River Basin Flood Damage Reduction Project
To:	Chehalis Basin Flood Control Zone District
From:	HDR
Subject:	Airport Levee Wetland Avoidance

1.0 Introduction and Purpose

As part of the proposed Chehalis-Centralia Airport Levee (Airport Levee) improvement project (Airport Levee Project), the Chehalis River Flood Control Zone District (District) proposes to improve and raise the existing Airport Levee approximately 5 feet and raise the elevation of a section of connected road embankment (NW Airport Road) as part of the Chehalis River Basin Flood Damage Reduction Project, which also includes construction of a flood control retention facility (Flood Retention Expandable [FRE]) on the Chehalis River near Pe Ell, Washington. The current FRE facility proposal would permit run-of-the-river conditions with no impoundment except when large flood events are predicted. The Airport Levee Project improvements would protect the airport and area inside the levee from flooding up to the 100-year flood with the FRE facility in operation.

As part of the proposed Flood Damage Reduction Project, the District proposes to increase the height of the flood protection levee on the west side of the Chehalis-Centralia Airport (Airport) airfield. The Draft Environmental Impact Statements (DEISs) prepared by the Washington Department of Ecology (Ecology; pursuant to the State Environmental Policy Act) and the U.S. Army Corps of Engineers (USACE; pursuant to the National Environmental Policy Act) assumed that to raise the airport levee to increase flood protection for the airport, the levee footprint would need to be widened leading to a potential impact to adjacent regulated wetlands.

This memorandum provides additional information regarding the ability to use standard levee design/construction methods to avoid affecting regulated wetlands and update assumptions used in the development of the DEISs regarding effects on wetlands.

2.0 Summary of Findings

Based on more detailed information regarding careful design and construction management, the proposed Airport Levee improvements can be constructed within the existing Airport Levee footprint eliminating the need to extend any construction activity or permanent facilities into the jurisdictional wetland. Given the limited height of the proposed (Phase 2) levee raise and the available space within the footprint of the existing levee, there are multiple options for achieving the required levee height within the existing levee footprint without affecting the wetlands. Based on the existing levee top-width and required raise, preliminary plans and cross sections were developed for each of the representative segments identified. With careful design and construction management including best management practices to protect the wetland, a concept could be implemented that would avoid impacts to jurisdictional wetlands.

3.0 Background

The Airport Levee was originally constructed in 1943 by the USACE Seattle District for the U.S. Department of the Navy under *Development of Landing Areas for National Defense* authority. Lewis County is the sponsor of record for the levee system, but maintenance is primarily performed by Chehalis-Centralia Airport staff. The levee is periodically inspected by the USACE as part of the Rehabilitation & Inspection Program under Public Law 84-99, which provides reimbursement for specific damages to levees that result from high-water events. The Airport Levee was most recently inspected by USACE in February 2019 and found to be in acceptable condition (USACE 2019).

The levee starts at a tie into high ground near NW Airport Road at the southeast corner of the airport property (Figure 1; all figures located in Attachment A). The levee follows a northwest direction and parallels the airport runway, before turning east/northeast toward the Interstate 5 road embankment at the far end. The levee embankment is set back approximately 500 yards from the right bank of the Chehalis River. The Airport Levee protects about 464 acres, most of which is comprised of the Chehalis-Centralia Airport property.

The existing Airport Levee provides protection from smaller (less than 100-year) flood events and was most recently improved in 2014 during Phase 1 (levee base improvement) of the Airport Levee Project. Phase 1 expanded the top width of the existing levee while restoring the top to the original intended design elevation. A vicinity map for the current Airport Levee configuration is provided in Figure 1. The existing 100-year flood inundation zone is shown affecting the inside of the levee area under the current levee elevation (Figure 2). The Washington State Office of Financial Management grant for Phase 1 anticipated a possible future levee raise to provide 100-year flood protection. Phase 2 of the Airport Levee Project would build on the work completed during Phase 1.

In order to provide future flood protection for the airport, businesses, and transportation corridors enclosed by the levee, Phase 2 of the Airport Levee Project proposes to raise the existing levee from 1.3 to 5.3 feet depending on the location along the existing levee. The Phase 2 height raise and final elevation was determined using hydrologic modeling of future scenarios for the Chehalis Basin.

The hydrologic modeling effort was initiated by Watershed Sciences and Engineering (WSE) who developed the Chehalis River Basin hydrologic model and RiverFlow2D model (WSE 2019a and 2019b, respectively) and used them to study future conditions, including the District's proposed Flood Damage Reduction Project (which includes both a temporary flood flow storage reservoir upstream and the increased levee height at the Airport) and climate change. WSE considered Airport Levee Project conditions to include the proposed Flood Retention Only -

Expandable (FRE) facility, and an estimated 4-foot height raise to the existing Airport Levee. An Anchor QEA memorandum documents the preparation of streamflow and flooding estimates under future climate change conditions (Anchor QEA 2019a):

> *"The streamflow estimates use the information contained in the Chehalis River Basin Hydrologic Modeling (WSE 2019a) technical memorandum combined with U.S. Geological Survey (USGS) flow records to develop flows under future climate change conditions. The flows were input to the 2D model developed for the Chehalis River Basin Existing Conditions RiverFlow2D Model Development and Calibration (WSE 2019b) technical memorandum to estimate flooding conditions under future climate change conditions."*

Figure 3 provides a vicinity map for the Airport Levee Project that shows the 100-year flood inundation zone includes the forecasted effects of climate change and with project conditions. This figure demonstrates protection of the airport property with an initially assumed 4-foot levee height raise. The results of these analyses were used to determine the actual required raise of the Airport Levee to protect against a 100-year flood event including climate change and implementation of the FRE facility. Using model results received from WSE and the existing levee elevations based on Lewis County Public Works' cross sections for the Phase 1 design elevation, HDR determined the necessary design levee elevation at each station along the length of the levee by determining the difference in elevation between the existing levee and the modeled 100-year flood event (Attachment B). The design levee top elevation includes a 3-foot freeboard allowance to accommodate FEMA certification guidelines.

Certification refers to the FEMA National Flood Insurance Program process for establishing that a levee has been designed in accordance with established federal standards. These standards include geotechnical investigations at intervals along the levee as well as seepage and stability analyses to provide documentation and adequate level of protection for a 100-year flood. Additionally, construction, maintenance, and operation standards will need to be met by the Phase 2 design. The USACE is authorized to inspect and evaluate levees to determine whether they meet the National Flood Insurance Program certification eligibility requirements for operations and maintenance.

4.0 Phase 2 Levee Raise

Phase 2 of the Airport Levee Project proposes to raise the existing levee between 1.3 and 5.3 feet depending on the location along the levee with most of the levee raise between 3 and 4 feet. The function of the levee is to provide a stable structure that will resist flow through the levee body and foundation. When designing a levee raise, the existing levee material and foundation needs to be investigated to determine if there is sufficient strength in the existing levee and its foundation to support the raised levee height and increased water pressure during a flood. Standard levee design requires a levee crest width of 10 to 12 feet, depending on local and emergency vehicle access requirements.

To evaluate the Phase 2 concept, HDR reviewed design cross sections from Phase 1 of the Airport Levee Improvement Project provided by the Lewis County Department of Public Works. Where possible, Phase 1 widened the levee crest between 19 and 30 feet, with most of the finished crest widths between 26 and 28 feet. The proposed Phase 2 design side slopes proposed were typically 2H:1V (Horizontal:Vertical) except where restricted by wetlands or right-of-way constraints. Where space allows, a 4-foot levee raise can be achieved with 2H:1V side slopes by reducing the new crest width to 10 feet and regrading side slopes to the recommended 2H:1V. Construction of the levee raise in this manner can be completed within the existing levee footprint and achieve standard levee design criteria.

A total of 17 cross sections representing the levee existing cross sectional geometry at 50-foot intervals were reviewed to identify which segments within the existing levee could be raised with a 2H:1V fill slope and those that would require an alternate approach. The proposed levee raise for each cross section was assessed to determine if adequate levee crest width would remain on top of the existing levee. Although a 10-foot crest would meet standard design practice, for this analysis, a more conservative 12-foot minimum width criteria was used. Representative cross sections were identified based on the required levee raise and the existing crest width. A summary of the results is provided in Table 1.

Table 1. Potential Levee Raise Configuration by Levee Segment

Segment	Stations		Required Raise (ft)[1]	Reduction in Top-Width (ft)[2]	Existing Top-Width (ft)[3]	Remaining Top-Width (ft)	Levee Toe Setback (Ditch)[3]	Levee Toe Setback (Road)[4]
1	0+00	1+00	5	20	30	10	5-10	n/a
2	1+50	15+00	4	16	28-30	12-14		
3	15+50	15+50	4	16	23	7	2-3	20
4	16+00	28+50	3.5	14	21-24	7-10	0	20+
5	29+00	34+00	3.5	14	28	14		
6	34+50	35+50	3.5	14	22-24	8-10	2-5	40
7	36+00	36+50	4	16	25-26	9-10	5-7	30
8	37+00	45+00	4	16	27	11	2-5	30
9	45+50	58+50	4	16	29	13		
10	59+00	64+50	3	12	29	17		
11	65+00	78+00	3	12	27	15		
12	78+50	85+50	3	12	32	20		
13	86+00	91+40	3	12	21-22	9-10	0	10-30
14	92+00	92+50	n/a	n/a	n/a	n/a	n/a	n/a

Segment	Stations		Required Raise (ft)[1]	Reduction in Top-Width (ft)[2]	Existing Top-Width (ft)[3]	Remaining Top-Width (ft)	Levee Toe Setback (Ditch)[3]	Levee Toe Setback (Road)[4]
15	93+00	94+50	2	8	20-22	12-14		
16	95+00	95+50	3	12	21	9	10	
17	96+00	96+80	2	8	19-20	11-12		

At least 12 feet (6,000 feet)
Between 10 and 12 feet (1,000 feet)
Less than 10 feet (2,100 feet)

[1] Per 'Airport Levee station and height' table
[2] Assuming 2:1 slope on both sides of levee
[3] Per 'Levee Cross Sections' document
[4] Per Airport Levee Phase 1B Environmental Quantities

As provided in Table 1, two-thirds of the levee would meet the minimum crest width after the proposed raise. The remaining one-third, however, would require an alternate approach to accomplish the levee raise without expanding the existing levee footprint. Table 1 also includes approximate setback distances from the existing levee toe to the edge of the jurisdictional wetland on the airport side of the levee, as well as to the roadway right-of-way on the river side of the levee. Although the levee footprint could be widened on either side without encroaching into either of these limits, widening the levee footprint could result in unintended impacts to the wetland and/or the floodplain. As such, the focus of this analysis is on alternatives that maintain the existing footprint.

5.0 Phase 2 Levee Raise Alternatives

For the segments of the levee what would not meet the 12-foot minimum crest width (highlighted in yellow and red in Table 1), alternative approaches were considered, including: Type I levee fill (including fill within the existing floodplain), mechanically stabilized backfill, and concrete floodwalls.

Alternative 1 – Type I Levee Fill

Type I levee fill is proposed for all segments where the levee can be raised within the existing footprint while maintaining the 12-foot minimum crest width. Type I Levee Fill refers to select fine grained low permeable fill that meets USACE guidance for levee fill. Where widening the levee crest 1 to 2 feet is required, the Type I levee fill would still be used by allowing some fill on the floodplain side of the levee. Although placing extensive fill in the existing floodplain could result in an increase in the river water surface, minimal fill as required for the 1- to 2-foot widening would likely have little to no adverse impact on the water surface elevations. The proposed fill would have to be modeled to confirm the impacts, which is outside the scope of this analysis; however, this alternative was included for cost comparison purposes. This method of construction could be completed within the existing levee footprint without impact to the wetlands.

Alternative 2 – Mechanically Stabilized Backfill

In areas where the footprint is restricted by wetlands or right-of-way constraints, a mechanically stabilized backfill may be used to raise the levee while remaining within the existing levee footprint (Figure 4). This type of construction would allow steeper slopes (e.g., 1.5H:1V) for segments where a 2H:1V cross section would not meet the minimum 12-foot crest width within the existing levee footprint. The stabilized backfill method utilizes one or more layers of flat reinforcing material (geogrids or welded wire fabric) placed between the layers of engineered fill (Type I Levee Fill) to improve the strength and stability of the combined soil and reinforcing that allows steeper (potentially even vertical) construction. An impervious cutoff, such as a sheet pile wall, may be required to be installed through the existing levee below the mechanically stabilized backfill cross section to cut off seepage flow through potential permeable layers in the foundation and/or levee to maintain USACE minimum standard seepage gradients for the raised water level. The requirement for such additional structures would be determined during final design. This method of construction could be completed within the existing levee footprint without impact to the wetlands.

Alternative 3 – Concrete Flood Wall

A concrete flood wall could be a potential levee raise option constructed within the existing levee footprint (Figure 5); however this would restrict access to the top of the levee and into the airport for segments where such construction was implemented if access was required. This type of wall has a small footprint and could easily be constructed on top of the existing Phase 1 levee. An impervious cutoff, such as a sheet pile wall may be required below the flood wall to provide a flow gradient sufficient for the raised water level. The requirement for such additional structures would be determined during final design. This method of construction could be completed within the existing levee footprint without impact to the wetlands.

6.0 Opinion of Probable Construction Cost Analysis

A representative cross section was selected for each of the segments to estimate quantities and unit costs. For the yellow and red segments in Table 1, nine representative cross sections were selected based on the existing levee crest width and required raise. For the green segments in Table 1, an average levee raise of 4 feet was assumed. A summary of the representative cross section(s) for each segment is provided in Table 2.

Table 2. Summary of Representative Cross Sections

Segment	Stations		Representative Cross-Section
1	0+00	1+00	1+00
2	1+50	15+00	n/a
3	15+50	15+50	15+50
4	16+00	28+50	21+00, 27+00
5	29+00	34+00	n/a
6	34+50	35+50	35+00
7	36+00	36+50	37+00

Segment	Stations		Representative Cross-Section
8	37+00	45+00	44+00
9	45+50	58+50	n/a
10	59+00	64+50	n/a
11	65+00	78+00	n/a
12	78+50	85+50	n/a
13	86+00	91+40	88+00
14	92+00	92+50	n/a
15	93+00	94+50	n/a
16	95+00	95+50	95+50
17	96+00	96+80	n/a

Unit costs for the three alternatives, along with the standard levee raise approach for the green segments, were developed for the range of levee raises and crest widths and a representative (i.e., average) cost was identified. A summary of these costs is provided in Table 3.

Table 3. Summary of Alternative Unit Costs

Alternative	Unit Cost
1	$520/LF
2	$505/LF
3	$600/LF

The unit costs provided in Table 3 have been developed to provide a preliminary high level (AACE Class 5 Opinion of Probable Construction Cost) cost comparison between the alternatives and are not intended to be used to estimate total project costs. The unit costs are not all-inclusive of all required work to deliver the project, as the level of design definition is not detailed enough to inform these costs. The following costs have not been included in the development of the unit costs above: mobilization, project indirect costs, contractor margin, non-construction contract costs (i.e., construction management services, testing, permitting), escalation, market conditions, market volatility, and contingencies.

The work breakdown structure for each alternative is as follows:

- Alternative 1 - erosion and sediment control, topsoil stripping, borrow, place, compact, hydroseeding, and crest roadway.
- Alternative 2 - erosion and sediment control, topsoil stripping, borrow, place, compact, geogrid, hydroseeding, and crest roadway.
- Alternative 3 - erosion and sediment control, topsoil stripping, footing excavation, borrow, place, compact, reinforced concrete, hydroseeding, and crest roadway.

The unit costs used to develop the alternative's comparison were obtained from RSMeans and professional estimating judgement based on similar scopes of work from previous projects.

The unit costs in Table 3 are similar and could vary within their differences depending on multiple factors. The size of the project, as well as contractor interest in the project may have a considerable effect on the project cost. For example, contractors that are aware of the project well in advance of the bid, can be more competitive and schedule their workload/workforce (A-B team players) to be more cost effective. Solicitation of contractors whose primary work is aligned with the project will likely provide better costs, as well. Obtaining three or more bids will help make the project more competitive.

7.0 Comparison of Alternatives

All of the alternatives meet the project purpose of constructing the requisite levee raise within the existing Airport Levee footprint to avoid wetlands and cultural resource impacts, so the comparison of alternatives is based on the following elements:

- Access – deals with impact to levee access for inspection, maintenance, and flood fighting
- Constructability – deals with ease of construction within existing levee footprint
- Cost – compares unit costs as provided in Table 3
- Risk – deals with potential risk of design and performance based on known and unknown geotechnical information

The Pros and Cons of each alternative are summarized in Table 4.

Table 4. Summary of Comparison of Alternatives

Alternative	Pros	Cons
1 – Type I Fill	• Results in the least impact to access by maintaining the existing slopes • Standard construction from top of existing levee • Within 3% of least expensive alternative	• Fill could extend into the floodplain on the river side of the levee (impact would have to be confirmed) • Potential conflicts with adjacent utilities, etc. on the river side of the levee
2 - Mechanically Stabilized Backfill	• Least expensive alternative • Little to no impact to access • Provides more stable fill which could offset geotechnical uncertainty	• Ability to construct from the top of levee could be somewhat complicated by placement of geogrid
3 - Concrete Flood Wall	• Least impact to floodplain or adjacent infrastructure	• Most expensive of the three alternatives, but within reasonable degree of tolerance • Construction requirements could have greater impact on existing levee (e.g., forms) • Would likely be used for the entire project to avoid change of construction methods and transition between levee types issues

Based on the above comparison, defaulting to Alternative 1 wherever possible is recommended. If fill in the floodplain or utility conflicts are an issue, then incorporating the steeper slope of Alternative 2 may be preferable. The use of a floodwall (Alternative 3) could be considered for the entire project, as long as access to and along the levee crest could be maintained.

8.0 Restrictions, Limitations, and Additional Studies

This alternatives analysis is appropriate for use in the environmental review stage of the project, but is based on limited information. Further investigations are required to advance the design of the Phase 2 levee raise to better understand existing conditions, including as-built conditions and if the foundation soil needs to be improved to accommodate the raised levee and potential higher water levels. FEMA certification requires levee improvements be designed in accordance with established federal standards. These standards include geotechnical investigations at intervals along the levee as well as seepage and stability analyses to provide documentation and adequate level of protection for a 100-year flood. These investigations would be required to progress the selected alternative to final design. Additionally, construction, maintenance, and operation standards will need to be met by the Phase 2 design. The USACE is authorized to inspect and evaluate levees to determine whether they meet the FEMA certification eligibility requirements for operations and maintenance.

Specialized construction limitations are also needed to avoid temporary impacts to the wetlands during construction. Exclusion zones and best management practices will be identified that restrict any construction activities (including staging areas) within or affecting the existing wetlands. All access points to the levee will be identified and limited to the river-side of the levee (i.e., no direct access from the airport).

Additional consideration is also needed for the segment of levee north of the existing airport runway (approximate levee stations 60+00 to 65+00). The existing Airport Levee extends into the protected airspace for the main runway (Runway 16), indicating an existing obstruction. The proposed Airport Levee Project would further extend into the protected airspace and may intrude into the protected airspace over the length of the Runway Protection Zone. Consultation with the Federal Aviation Administration (FAA), subsequent aeronautical studies to determine the extent of the intrusion into the Runway 16 approach, and consideration of feasible mitigation actions would be required before moving forward with the proposed Airport Levee Project. There are no foreseen conflicts on Runway 34; however, the airport sponsor (City of Chehalis) is still required to submit the proposed Airport Levee elevation changes to the FAA for approval.

To meet FAA regulations discussed above and avoid intrusion into protected airspace, previous conceptual layouts for the Phase 2 Airport Levee Project included a potential alignment of the Airport Levee that extended outside of its current footprint in the northwest corner (also referred to as the bump out) which is not being considered as part of this memo. Methods to avoid intruding into the protected airspace for Runway 16 could include temporary flood barrier options. The Airport Sponsor in consultation with the FAA may consider measures to satisfy FAA regulations without needing to extend the footprint of the Airport Levee. Temporary flood barrier options that may satisfy FAA are discussed in Attachment C.

9.0 Conclusions

The DEIS assumptions regarding footprint can be updated based on the more detailed review of the existing facility and consideration of three different standard, proven, feasible construction methods that will provide for increased levee height without extending temporary or permanent construction impacts into delineated, regulated wetlands. Given the limited height of the proposed Phase 2 levee raise and the available space within the footprint of the existing levee, options for achieving the Phase 2 levee height within the existing levee footprint without impacts to the wetlands were evaluated. Based on the existing levee top-width and required raise, preliminary plans and cross sections were developed for each of the representative segments identified in Table 1 and Table 2, based on the Alternative 1 and 2 concepts previously identified (Attachment D). With careful design and construction management, including best management practices to protect the wetland, a concept can be implemented that would avoid impacts to jurisdictional wetlands.

10.0 Literature Cited

Anchor QEA

2019a Memorandum to: Andrea McNamara Doyle and Chrissy Bailey, Office of Chehalis Basin. Regarding: Chehalis River Basin Climate Change Flows and Flooding Results. May 6, 2019.

2019b Chehalis-Centralia Airport Levee Wetland Delineation Report. Chehalis River Basin Flood Damage Reduction Proposed Project. Prepared for Washington Department of Ecology and U.S. Army Corps of Engineers. Prepared by Anchor QEA, LLC. May 2019.

GeoEngineers

2010 Geotechnical Report. Preliminary Geotechnical Report, Chehalis-Centralia Airport Dike Improvements Chehalis, Washington. For: Chehalis-Centralia Airport. October 15, 2010.

U.S. Army Corps of Engineers (USACE)

2019 Levee Inspection Report. Chehalis-Centralia Airport Levee. Routine Inspection. March 8, 2019.

Watershed Sciences and Engineering (WSE)

2019a Memorandum to: Bob Montgomery, Anchor QEA, LLC. Regarding: Chehalis River Basin Hydrologic Modeling. February 28, 2019.

2019b Memorandum to: Bob Montgomery, Anchor QEA, LLC. Regarding: Chehalis River Existing Conditions RiverFlow2D Model Development and Calibration. February 28, 2019.

Attachment A. Figures

Figure 1. Chehalis Airport Levee Configuration and Wetland Map

Figure 2. Chehalis Airport Levee 100-Year Floodplain (No Action)

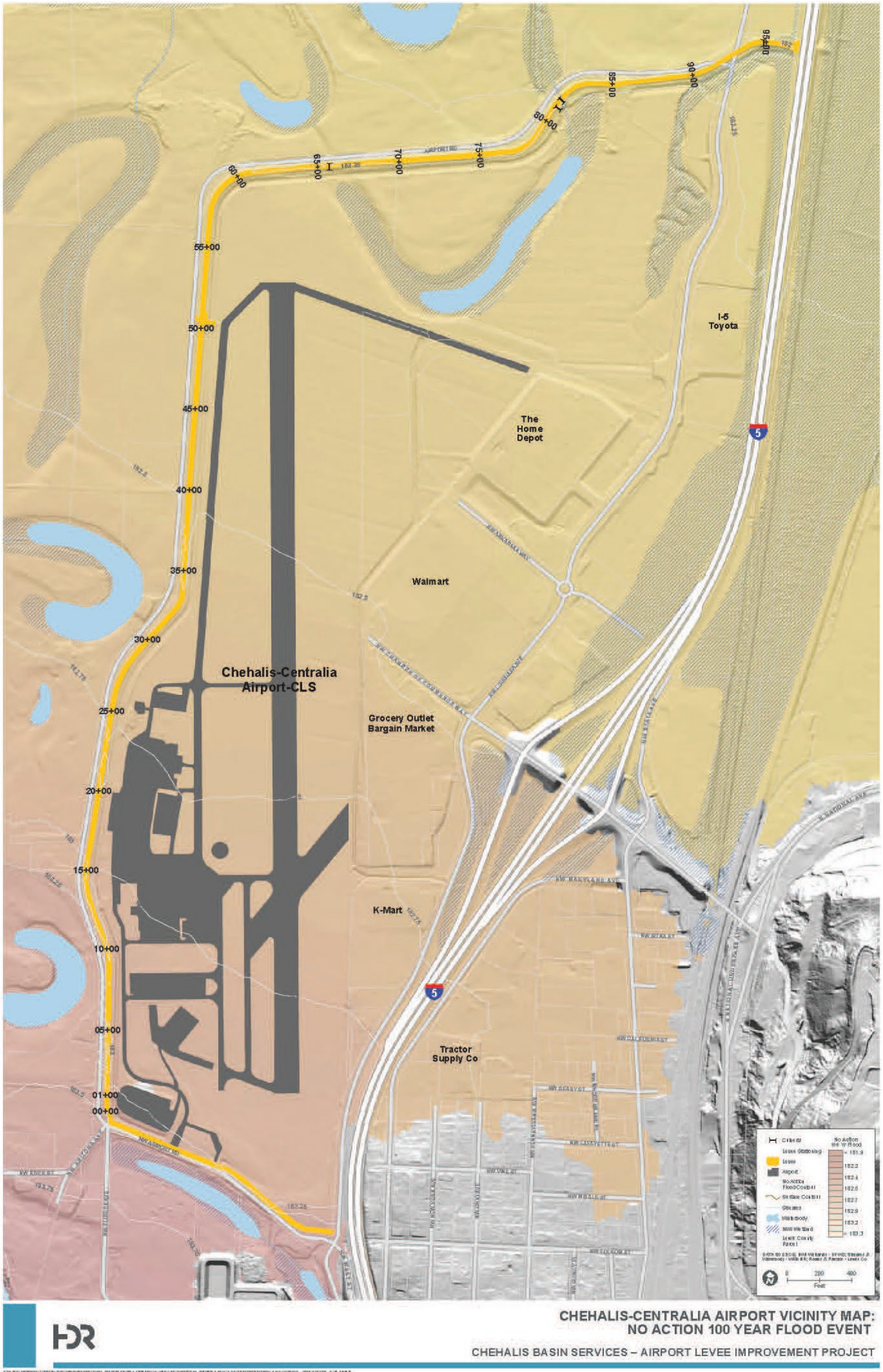


Figure 3. Chehalis Airport Levee 100-Year Floodplain (Proposed Action)

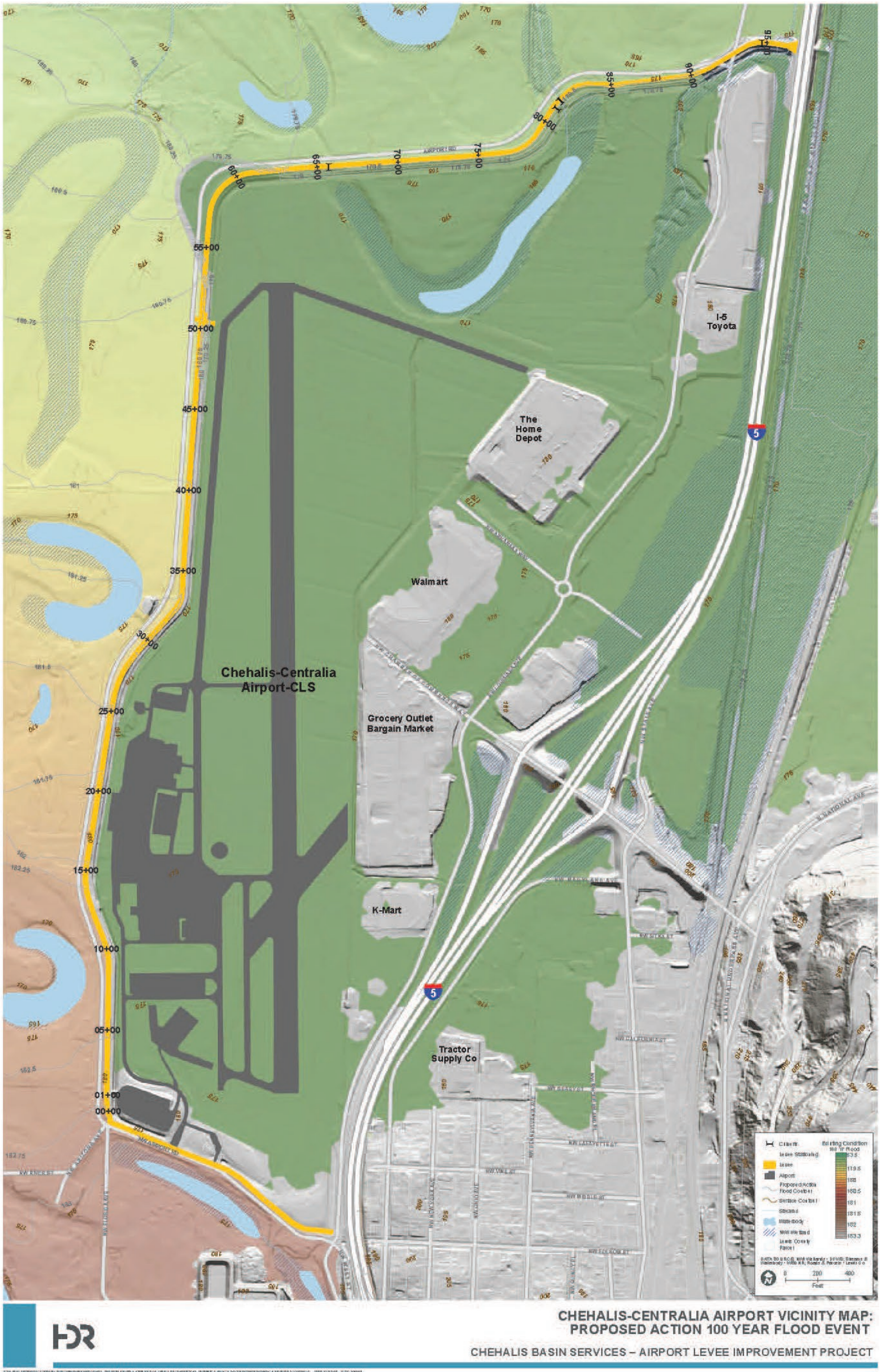
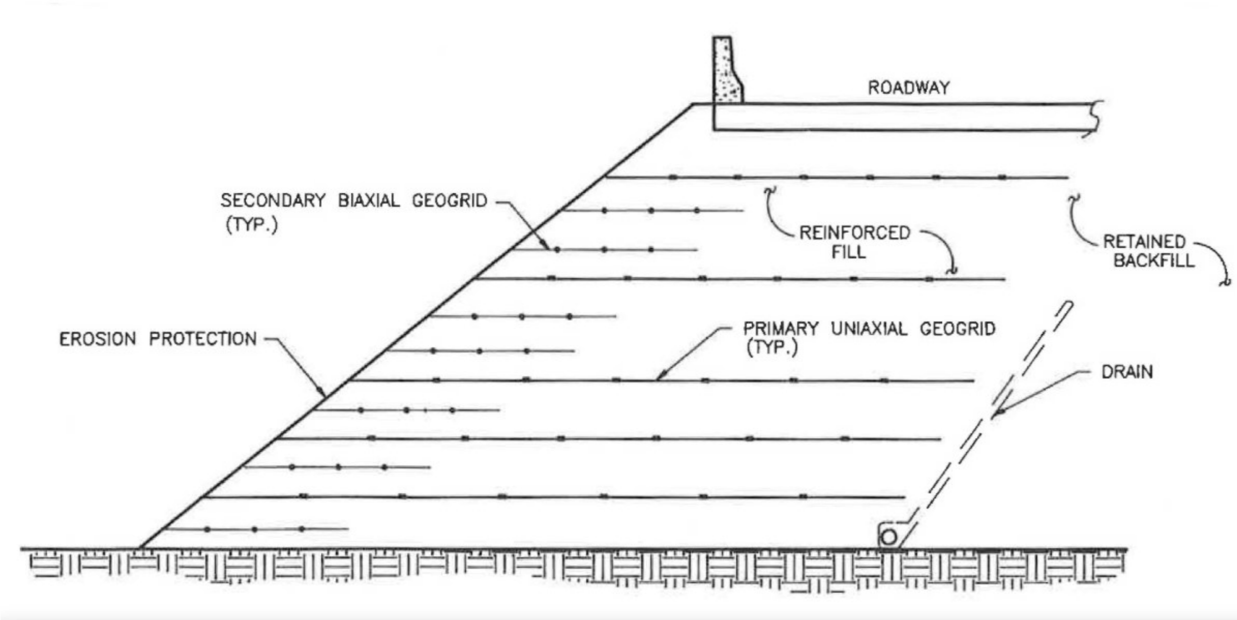
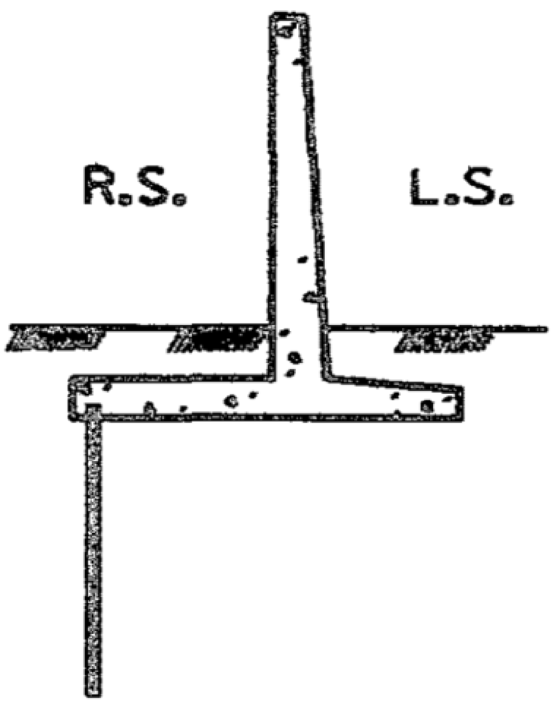


Figure 4. Mechanically Stabilized Earth Levee Raise Concept



Source: Reinforced Soil Highway Slopes, R. Berg, Ronald P Anderson, Robert J Race, V. Chouery-Curtis (1990)



Source: USACE EM 1110-2-2502
R.S – River Side
L.S. – Land Side

Attachment B. Airport Levee Project Design Elevation and Levee Height Raise Data

Airport Levee Project Design Elevation and Levee Height Raise Data

Station	No Action 100 Year Flood Height Elevation	With Project and Climate Change 100 Year Flood Height Elevation	Phase 1 Levee Design Elevation	Approximate Final Elev. w/ project	Estimated Levee Height Raise
00+00.00	183.49	182.80	180.5	185.8	5.3
00+50.00	183.39	182.70	180.75	185.75	5
01+00.00	183.34	182.68	181	185.7	4.7
01+50.00	183.20	182.64	181.25	185.65	4.4
02+00.00	183.07	182.57	181.5	185.6	4.1
02+50.00	182.97	182.51	181.5	185.5	4
03+00.00	182.90	182.51	181.5	185.5	4
03+50.00	182.91	182.51	181.5	185.5	4
04+00.00	182.91	182.51	181.5	185.5	4
04+50.00	182.92	182.50	181.5	185.5	4
05+00.00	182.93	182.49	181.5	185.5	4
05+50.00	183.07	182.47	181.5	185.5	4
06+00.00	183.07	182.47	181.5	185.5	4
06+50.00	183.09	182.47	181.5	185.5	4
07+00.00	183.08	182.48	181.5	185.5	4
07+50.00	183.06	182.48	181.5	185.5	4
08+00.00	183.03	182.48	181.5	185.5	4
08+50.00	183.04	182.47	181.5	185.5	4
09+00.00	183.02	182.47	181.5	185.5	4
09+50.00	182.99	182.47	181.5	185.5	4
10+00.00	182.98	182.46	181.5	185.5	4
10+50.00	182.96	182.47	181.5	185.5	4
11+00.00	182.89	182.47	181.5	185.5	4
11+50.00	182.87	182.47	181.5	185.5	4
12+00.00	182.92	182.46	181.5	185.5	4
12+50.00	182.92	182.45	181.5	185.4	3.9
13+00.00	182.85	182.43	181.5	185.4	3.9
13+50.00	182.80	182.36	181.5	185.4	3.9
14+00.00	182.88	182.24	181.5	185.2	3.7
14+50.00	182.97	182.14	181.5	185.1	3.6
15+00.00	182.99	182.07	181.5	185.1	3.6
15+50.00	182.99	182.00	181.5	185	3.5
16+00.00	182.96	181.95	181.5	184.9	3.4
16+50.00	182.93	181.92	181.5	184.9	3.4
17+00.00	182.91	181.91	181.5	184.9	3.4
17+50.00	182.90	181.81	181.5	184.8	3.3
18+00.00	182.92	181.86	181.5	184.9	3.4
18+50.00	182.92	181.80	181.5	184.8	3.3

Station	No Action 100 Year Flood Height Elevation	With Project and Climate Change 100 Year Flood Height Elevation	Phase 1 Levee Design Elevation	Approximate Final Elev. w/ project	Estimated Levee Height Raise
19+00.00	182.90	181.80	181.5	184.8	3.3
19+50.00	182.87	181.80	181.5	184.8	3.3
20+00.00	182.83	181.79	181.5	184.8	3.3
20+50.00	182.72	181.78	181.5	184.8	3.3
21+00.00	182.65	181.76	181.5	184.8	3.3
21+50.00	182.60	181.73	181.38	184.68	3.3
22+00.00	182.71	181.67	181.25	184.65	3.4
22+50.00	182.76	181.62	181.13	184.63	3.5
23+00.00	182.76	181.60	181	184.6	3.6
23+50.00	182.74	181.59	181	184.6	3.6
24+00.00	182.73	181.56	181	184.6	3.6
24+50.00	182.71	181.53	181	184.5	3.5
25+00.00	182.69	181.51	181	184.5	3.5
25+50.00	182.68	181.49	181	184.5	3.5
26+00.00	182.67	181.46	181	184.5	3.5
26+50.00	182.68	181.42	181	184.4	3.4
27+00.00	182.69	181.37	181	184.4	3.4
27+50.00	182.69	181.34	181	184.3	3.3
28+00.00	182.68	181.31	181	184.3	3.3
28+50.00	182.67	181.29	181	184.3	3.3
29+00.00	182.66	181.28	181	184.3	3.3
29+50.00	182.66	181.23	181	184.2	3.2
30+00.00	182.65	181.28	181	184.3	3.3
30+50.00	182.65	181.27	181	184.3	3.3
31+00.00	182.64	181.29	181	184.3	3.3
31+50.00	182.62	181.27	181	184.3	3.3
32+00.00	182.61	181.26	181	184.3	3.3
32+50.00	182.60	181.21	181	184.2	3.2
33+00.00	182.57	181.26	181	184.3	3.3
33+50.00	182.53	181.25	181	184.3	3.3
34+00.00	182.51	181.24	181	184.2	3.2
34+50.00	182.46	181.22	181	184.2	3.2
35+00.00	182.49	181.21	181	184.2	3.2
35+50.00	182.46	181.20	180.75	184.15	3.4
36+00.00	182.47	181.17	180.5	184.2	3.7
36+50.00	182.50	181.15	180.25	184.15	3.9
37+00.00	182.49	181.14	180	184.1	4.1
37+50.00	182.48	181.13	180	184.1	4.1
38+00.00	182.43	181.11	180	184.1	4.1
38+50.00	182.44	181.10	180	184.1	4.1

Station	No Action 100 Year Flood Height Elevation	With Project and Climate Change 100 Year Flood Height Elevation	Phase 1 Levee Design Elevation	Approximate Final Elev. w/ project	Estimated Levee Height Raise
39+00.00	182.41	181.07	180	184.1	4.1
39+50.00	182.43	181.04	180	184	4
40+00.00	182.45	181.01	180	184	4
40+50.00	182.46	181.00	180	184	4
41+00.00	182.46	180.99	180	184	4
41+50.00	182.45	180.98	180	184	4
42+00.00	182.44	180.97	180	184	4
42+50.00	182.43	180.95	180	184	4
43+00.00	182.41	180.93	180	183.9	3.9
43+50.00	182.42	180.92	180	183.9	3.9
44+00.00	182.41	180.91	180	183.9	3.9
44+50.00	182.40	180.90	179.87	183.87	4
45+00.00	182.41	180.89	179.75	183.85	4.1
45+50.00	182.41	180.88	179.62	183.92	4.3
46+00.00	182.40	180.88	179.5	183.9	4.4
46+50.00	182.38	180.87	179.5	183.9	4.4
47+00.00	182.37	180.87	179.5	183.9	4.4
47+50.00	182.37	180.85	179.5	183.9	4.4
48+00.00	182.39	180.83	179.5	183.8	4.3
48+50.00	182.40	180.82	179.5	183.8	4.3
49+00.00	182.39	180.81	179.5	183.8	4.3
49+50.00	182.37	180.80	179.5	183.8	4.3
50+00.00	182.37	180.79	179.5	183.8	4.3
50+50.00	182.36	180.79	179.5	183.8	4.3
51+00.00	182.36	180.79	179.5	183.8	4.3
51+50.00	182.37	180.78	179.5	183.8	4.3
52+00.00	182.37	180.77	179.5	183.8	4.3
52+50.00	182.37	180.77	179.5	183.8	4.3
53+00.00	182.37	180.53	179.5	183.5	4
53+50.00	182.36	180.74	179.5	183.7	4.2
54+00.00	182.36	180.71	179.5	183.7	4.2
54+50.00	182.35	180.68	179.5	183.7	4.2
55+00.00	182.34	180.64	179.5	183.6	4.1
55+50.00	182.33	180.60	179.5	183.6	4.1
56+00.00	182.33	180.56	179.5	183.6	4.1
56+50.00	182.35	180.53	179.5	183.5	4
57+00.00	182.36	180.50	179.5	183.5	4
57+50.00	182.36	180.43	179.5	183.4	3.9
58+00.00	182.36	180.29	179.5	183.3	3.8
58+50.00	182.36	180.09	179.5	183.1	3.6

Station	No Action 100 Year Flood Height Elevation	With Project and Climate Change 100 Year Flood Height Elevation	Phase 1 Levee Design Elevation	Approximate Final Elev. w/ project	Estimated Levee Height Raise
59+00.00	182.35	179.82	179.5	182.8	3.3
59+50.00	182.34	179.76	179.5	182.8	3.3
60+00.00	182.31	179.75	179.5	182.8	3.3
60+50.00	182.29	179.75	179.5	182.8	3.3
61+00.00	182.27	179.75	179.5	182.8	3.3
61+50.00	182.27	179.75	179.5	182.8	3.3
62+00.00	182.25	179.75	179.5	182.8	3.3
62+50.00	182.27	179.75	179.5	182.8	3.3
63+00.00	182.28	179.37	179.5	182.4	2.9
63+50.00	182.27	179.61	179.5	182.6	3.1
64+00.00	182.27	179.67	179.5	182.7	3.2
64+50.00	182.27	179.67	179.5	182.7	3.2
65+00.00	182.29	179.67	179.5	182.7	3.2
65+50.00	182.29	179.65	179.5	182.7	3.2
66+00.00	182.27	179.63	179.5	182.6	3.1
66+50.00	182.28	179.62	179.5	182.6	3.1
67+00.00	182.29	179.62	179.5	182.6	3.1
67+50.00	182.28	179.63	179.5	182.6	3.1
68+00.00	182.28	179.62	179.5	182.6	3.1
68+50.00	182.28	179.63	179.5	182.6	3.1
69+00.00	182.26	179.63	179.5	182.6	3.1
69+50.00	182.25	179.62	179.5	182.6	3.1
70+00.00	182.22	179.62	179.5	182.6	3.1
70+50.00	182.19	179.61	179.5	182.6	3.1
71+00.00	182.20	179.60	179.5	182.6	3.1
71+50.00	182.21	179.60	179.5	182.6	3.1
72+00.00	182.19	179.61	179.5	182.6	3.1
72+50.00	182.20	179.64	179.5	182.6	3.1
73+00.00	182.21	179.65	179.5	182.7	3.2
73+50.00	182.20	179.65	179.5	182.6	3.1
74+00.00	182.20	179.65	179.5	182.6	3.1
74+50.00	182.21	179.64	179.5	182.6	3.1
75+00.00	182.22	179.64	179.5	182.6	3.1
75+50.00	182.23	179.63	179.5	182.6	3.1
76+00.00	182.24	179.62	179.5	182.6	3.1
76+50.00	182.23	179.60	179.5	182.6	3.1
77+00.00	182.23	179.59	179.5	182.6	3.1
77+50.00	182.23	179.61	179.5	182.6	3.1
78+00.00	182.24	179.62	179.5	182.6	3.1
78+50.00	182.25	179.61	179.5	182.6	3.1

Station	No Action 100 Year Flood Height Elevation	With Project and Climate Change 100 Year Flood Height Elevation	Phase 1 Levee Design Elevation	Approximate Final Elev. w/ project	Estimated Levee Height Raise
79+00.00	182.25	179.63	179.5	182.6	3.1
79+50.00	182.26	179.65	179.5	182.6	3.1
80+00.00	182.26	179.63	179.5	182.6	3.1
80+50.00	182.26	179.62	179.5	182.6	3.1
81+00.00	182.25	179.64	179.5	182.6	3.1
81+50.00	182.24	179.61	179.5	182.6	3.1
82+00.00	182.23	179.59	179.5	182.6	3.1
82+50.00	182.20	179.57	179.5	182.6	3.1
83+00.00	182.17	179.50	179.5	182.5	3
83+50.00	182.17	179.43	179.5	182.4	2.9
84+00.00	182.16	179.46	179.5	182.5	3
84+50.00	182.18	179.46	179.5	182.5	3
85+00.00	182.18	179.45	179.5	182.4	2.9
85+50.00	182.17	179.41	179.5	182.4	2.9
86+00.00	182.17	179.38	179.5	182.4	2.9
86+50.00	182.16	179.38	179.5	182.4	2.9
87+00.00	182.18	179.38	179.5	182.4	2.9
87+50.00	182.17	179.41	179.5	182.4	2.9
88+00.00	182.16	179.38	179.5	182.4	2.9
88+50.00	182.17	179.38	179.5	182.4	2.9
89+00.00	182.20	179.36	179.5	182.4	2.9
89+50.00	182.21	179.32	179.5	182.3	2.8
90+00.00	182.21	179.35	179.5	182.3	2.8
90+50.00	182.19	179.37	179.5	182.4	2.9
91+00.00	182.18	179.53	179.5	182.5	3
91+50.00	182.18	179.53	179.9	182.5	2.6
92+00.00	182.18	179.53	No Stationing - Road	NA	NA
92+50.00	182.21	179.53	No Stationing - Road	NA	NA
93+00.00	182.19	179.53	180.5	182.5	2
93+50.00	182.18	179.53	180.5	182.5	2
94+00.00	182.16	179.52	180.5	182.5	2
94+50.00	182.16	179.53	180.23	182.53	2.3
95+00.00	182.17	179.53	179.77	182.57	2.8
95+50.00	182.17	179.53	179.72	182.52	2.8
96+00.00	182.12	179.53	180.27	182.57	2.3
96+50.00	181.99	179.53	180.82	182.52	1.7
96+80.36	182.04	179.53	181.16	182.56	1.4

Attachment C. Temporary Flood Barrier Options

Appendix C – Temporary Flood Barrier Options

Sandbags have traditionally been selected method for temporarily raising the height of levees to protect against rising flood waters. However, even if sandbags are readily available, filling and placing them are labor intensive and time consuming. Moreover, a significant clean-up effort is needed to remove the sandbags when the flood event is over and store them for the next event. More recently, the industry has developed several other temporary flood protection products that have proven effective and, in many cases, more efficient to install than sandbag systems. The following factors should be taken into account to select the most suitable solution for the specific situation:

- Stability – related to sliding/overturning, seepage, and soil loading
- Constructability – including access, manpower, equipment, on-site preparation, storage, and flexibility
- Cost – including materials, labor (installation and removal), maintenance, and storage
- Durability –related to short-term and long-term use/reuse
- Environmental Impact – both temporary and long-term impacts
- Previous Experiences/Applications – in terms of both testing/certifications, as well as real applications

Temporary flood protection products typically fall into three main categories:

- Cellular Barrier Systems
- Flood Walls/Barriers
- Air/Water Filled Tubes

Each category is briefly described below.

Cellular Barrier Systems

Cellular Barrier Systems are prefabricated cellular structures (e.g., wire-mesh cages) filled with rock, soil, or water. Essentially, these are collapsible multi-cellular structures, made of panels of wire mesh reinforced with vertical steel bars. Flexibility of the metal cage and hinged structural connections enable good adaptation to local terrain. Impermeability of the structure is achieved by geotextile lines and fill material. Examples of these products are shown below.


Flood Walls/Barriers

Temporary flood walls are made of free-standing and/or interlocking heavy duty sections. The wall material is impermeable and can be either rigid or flexible. The stability of these barriers depends on either the weight of the water acting on a long skirt on the water side of the wall resisting the water loading on the barrier or by vertical supports that may be permanently or temporarily placed along the levee.

Air/Water Filled Tubes

These flood protection products are typically pre-fabricated geomembrane tubes filled with air or water to restrain flood waters. The tubes can be portable or left in place and inflated as needed using pumps. If filled with water, the tubes act as gravity dams, which use the weight of water to provide stability. To prevent rolling, these systems typically require some form of anchoring. Air-filled tubes can also be used in conjunction with gates to allow raising and lowering the wall height as needed.

There are many advantages and disadvantages to each of these products which should be considered before making a final selection for a specific application.

Attachment D. Conceptual Plans

OVERALL LEVEE SITE PLAN

Culverts
Levee Stationing
Levee
Airport
Proposed Action Flood Contour
Surface Contour
Streams
Waterbody
NWI Wetland
Lewis County Parcel

Existing Condition 100 Yr Flood
53.5
179.5
180
180.5
181
181.5
182
183.3

DATA SOURCE: NWI Wetlands - DFWS; Streams & Waterbody - WSDNR; Roads & Parcels - Lewis Co

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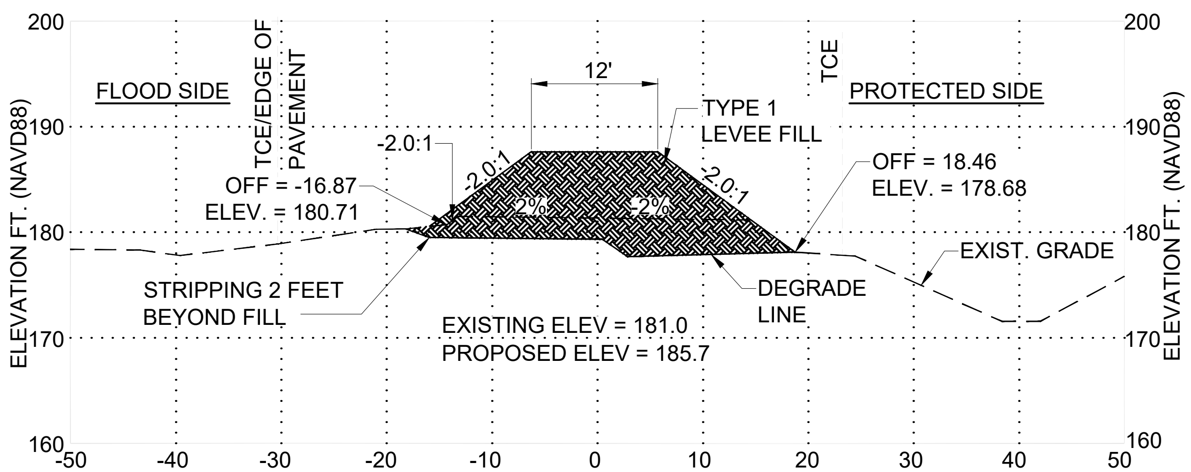
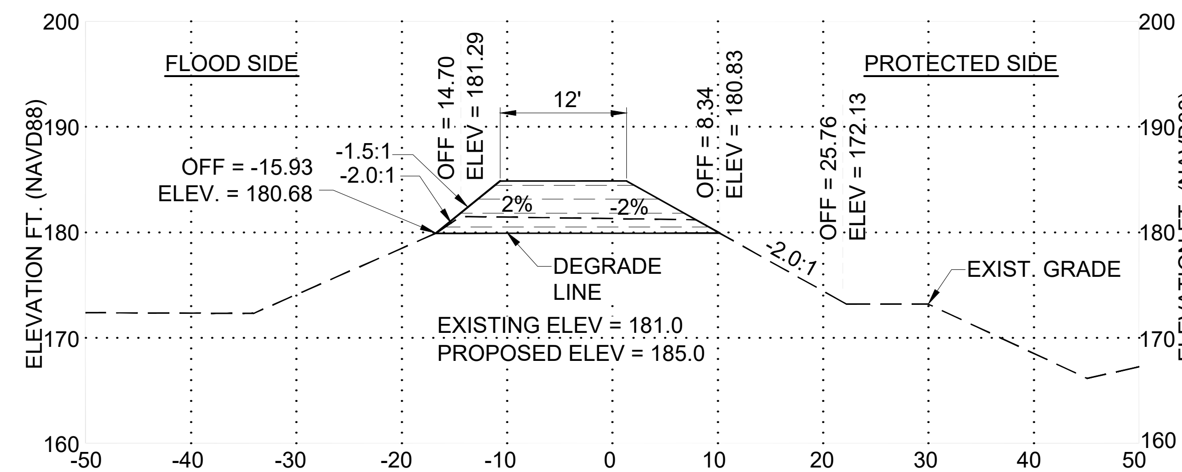
OVERALL LEVEE SITE PLAN

DATE
2/2022

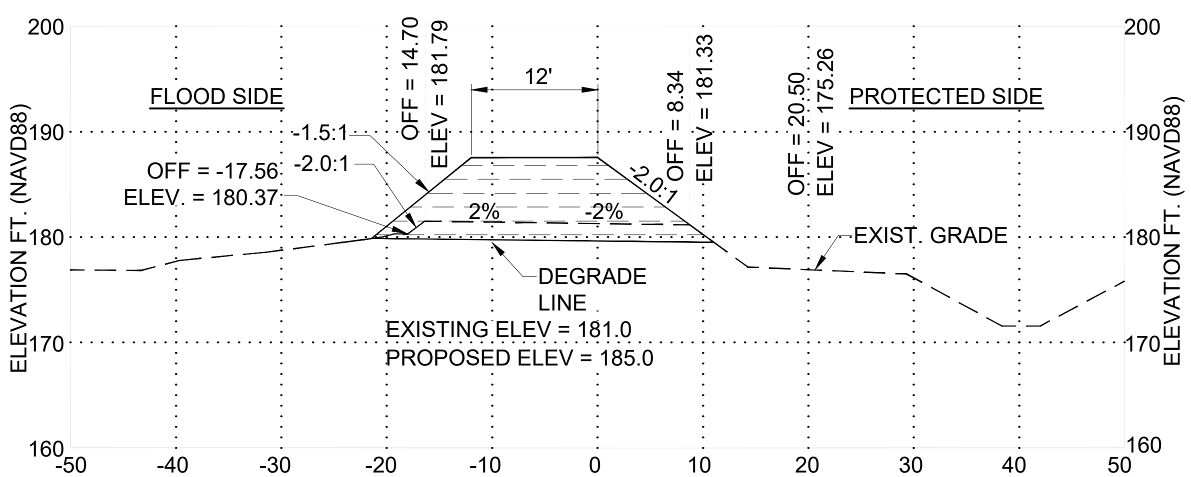
FIGURE
PLAN-01



STA. 0+00 - 1+00



STA. 19+50 - 22+50



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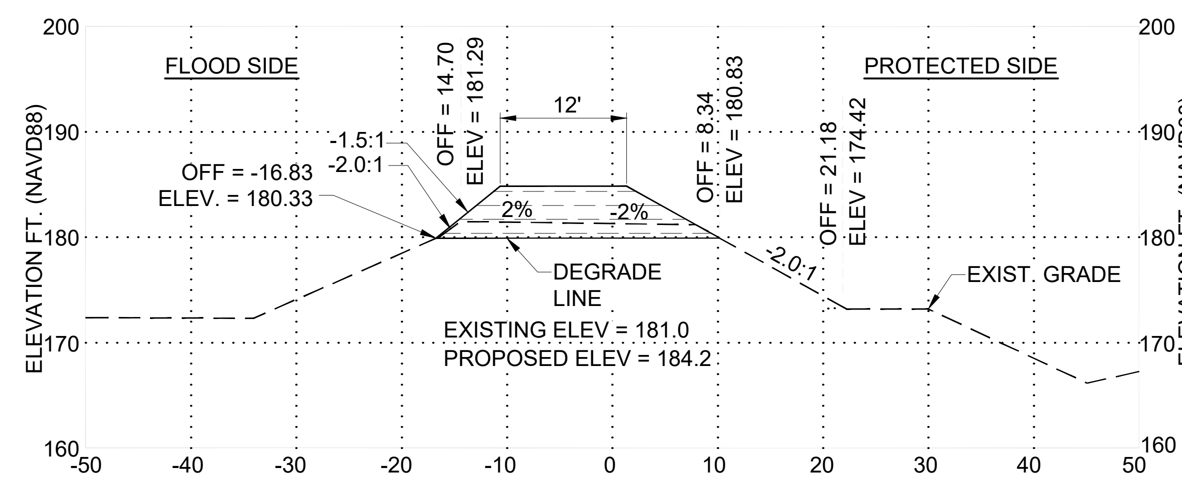

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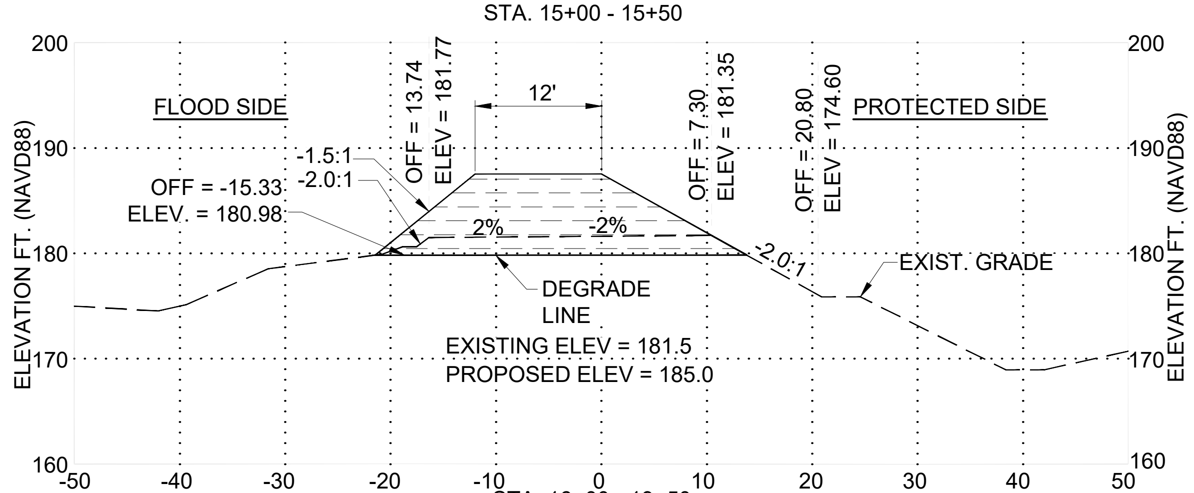

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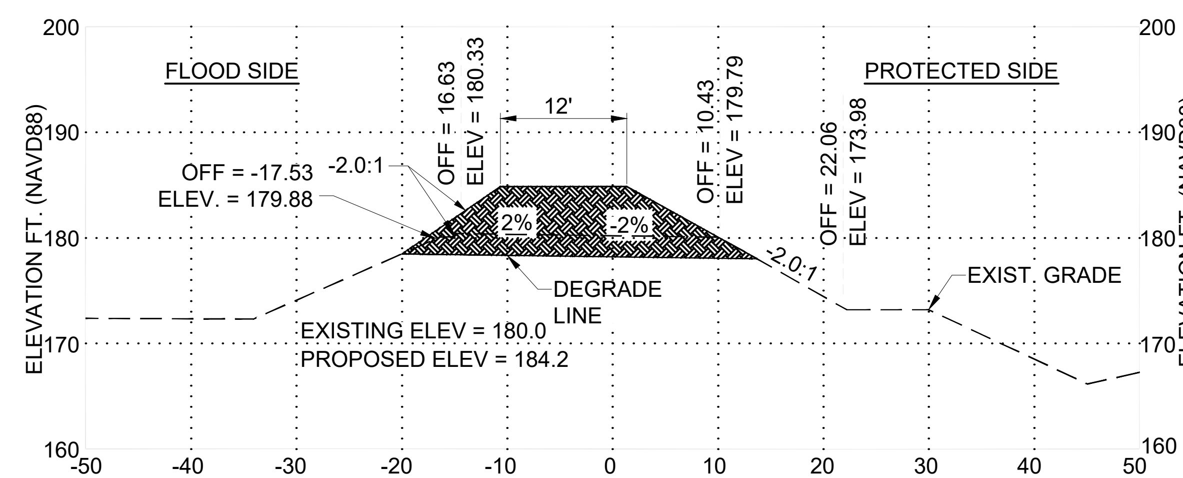

STA. 36+00 - 37+00

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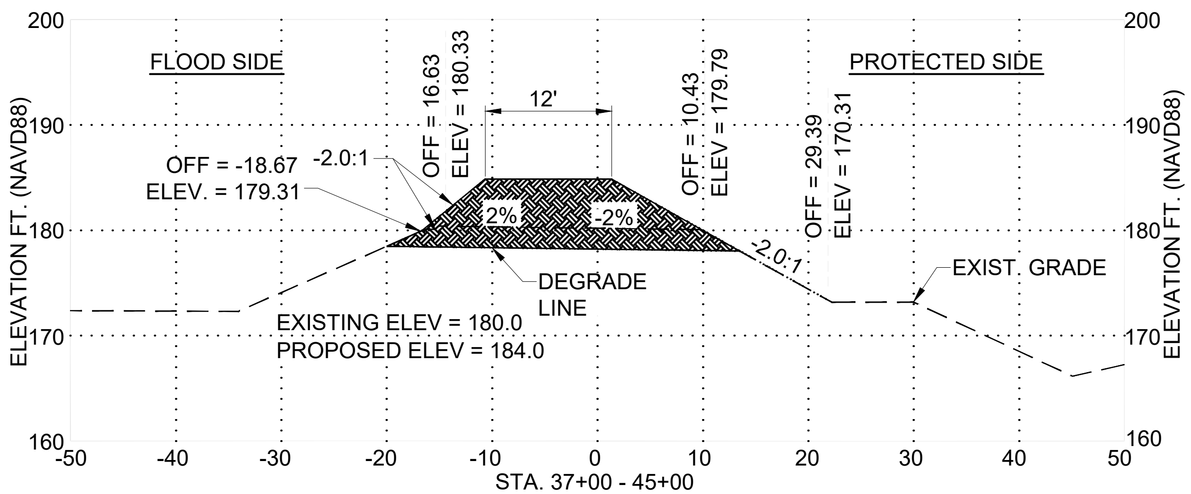
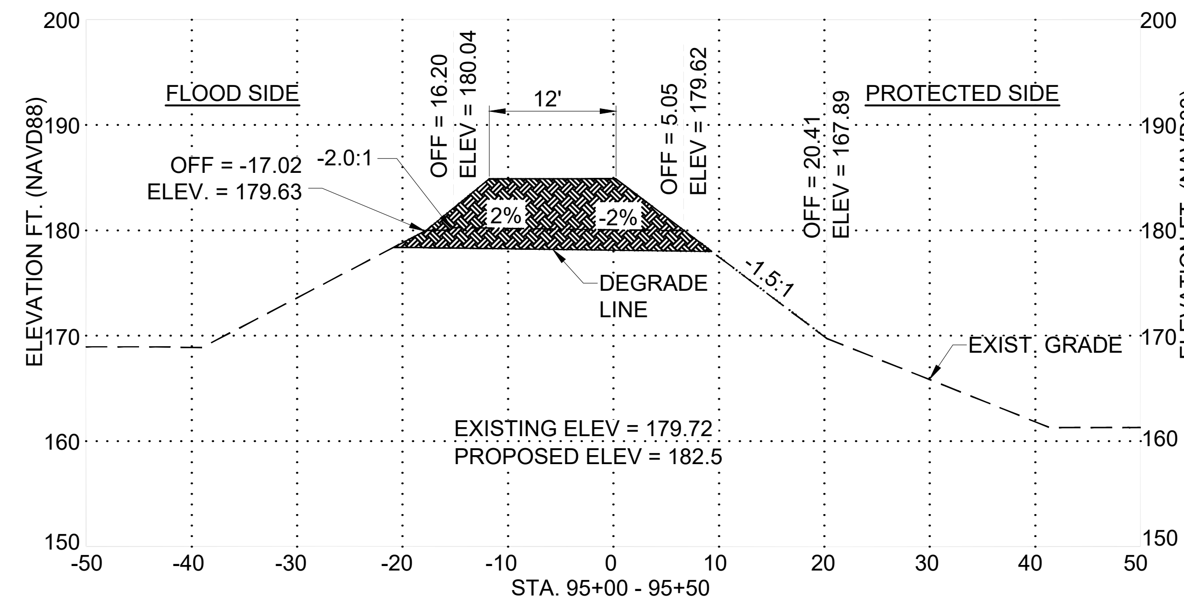
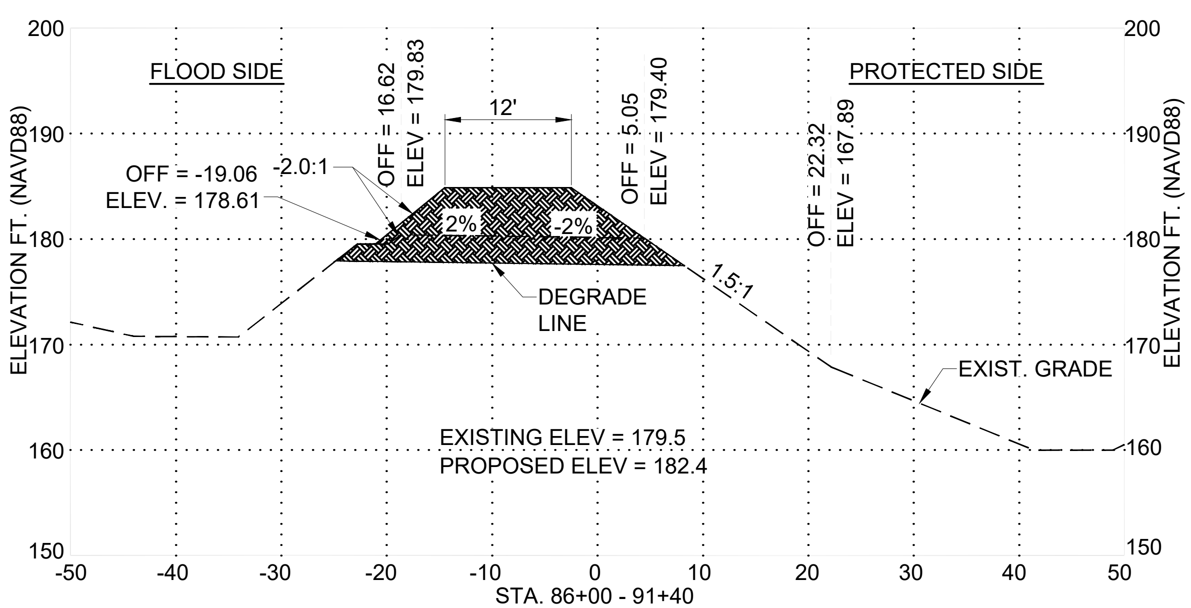
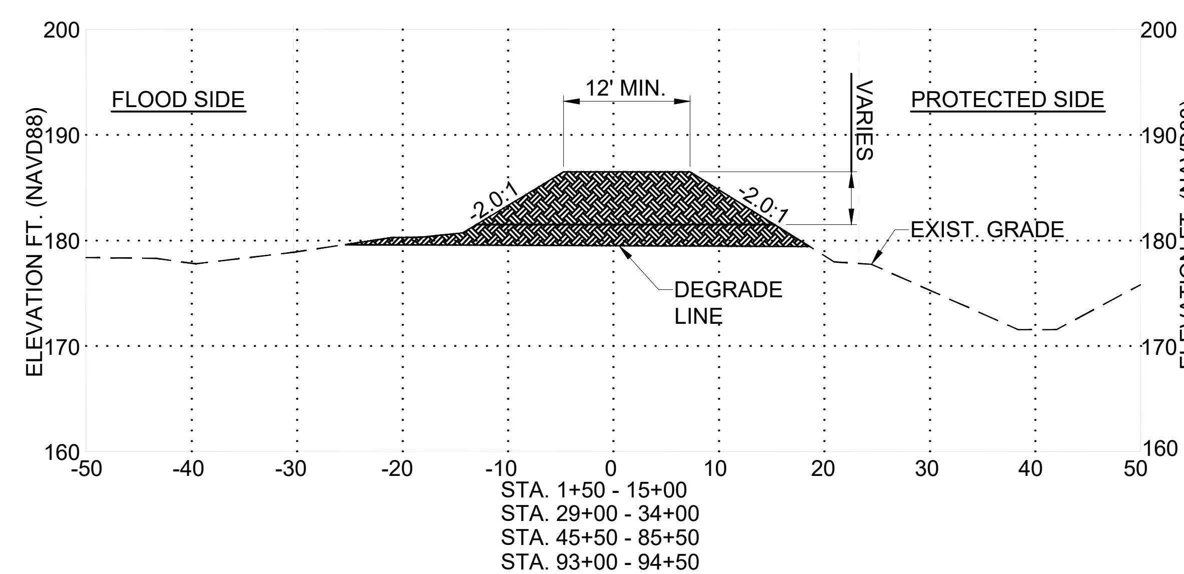
FIGURE CP-01









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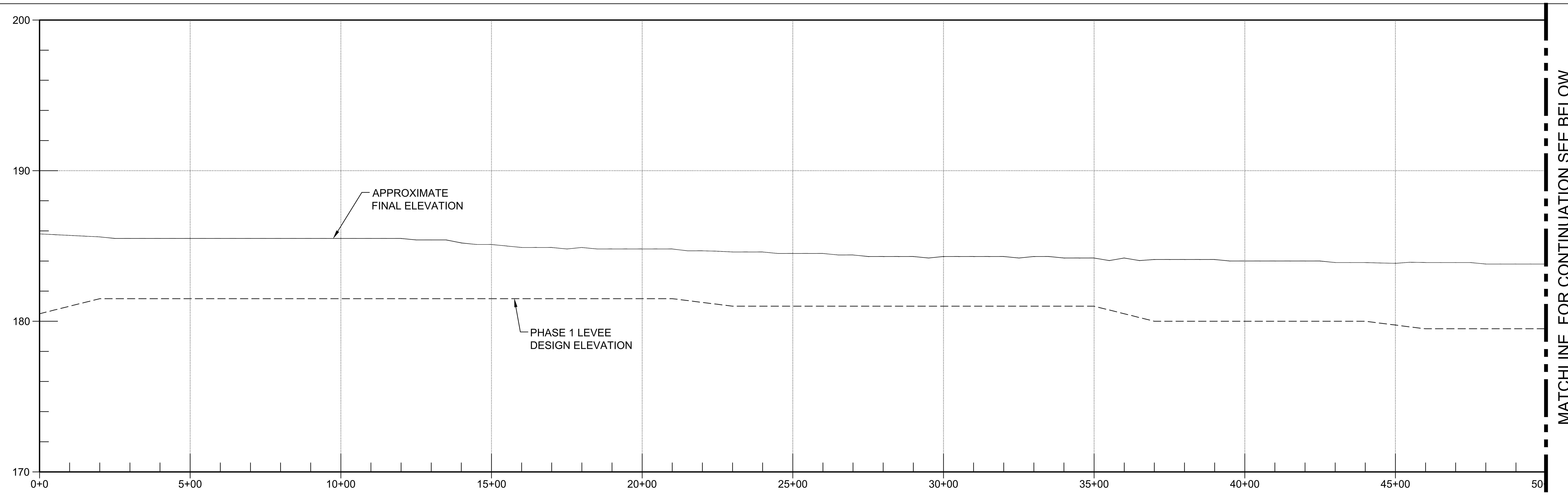
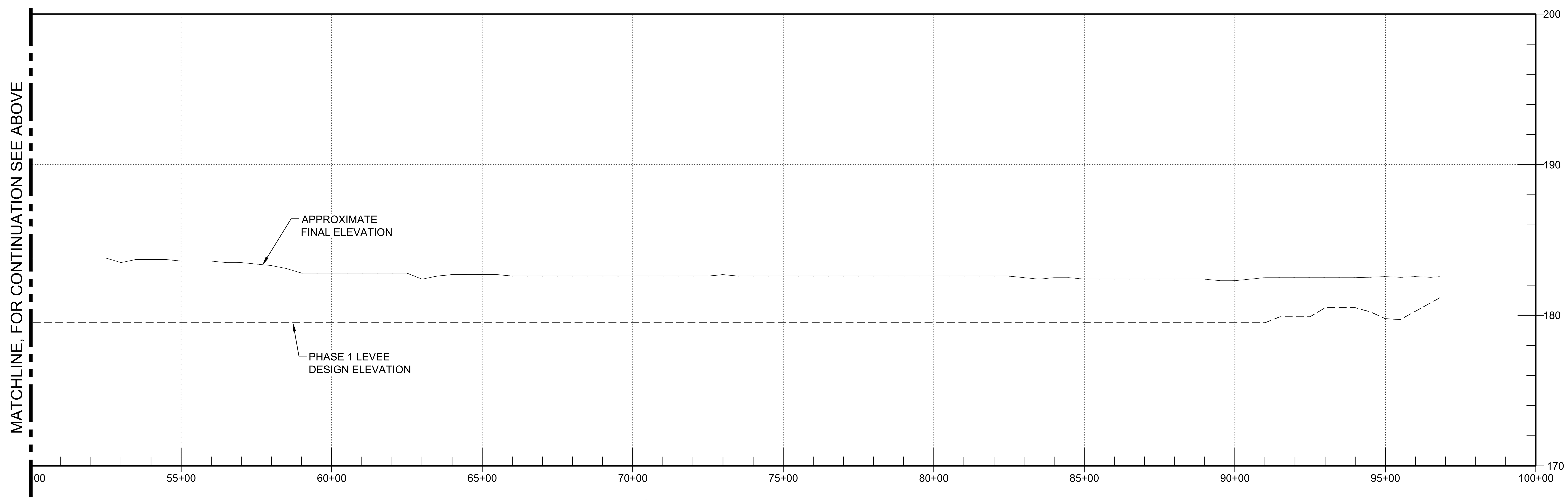
PROFILES

DATE
2/2022

FIGURE
CP-01B



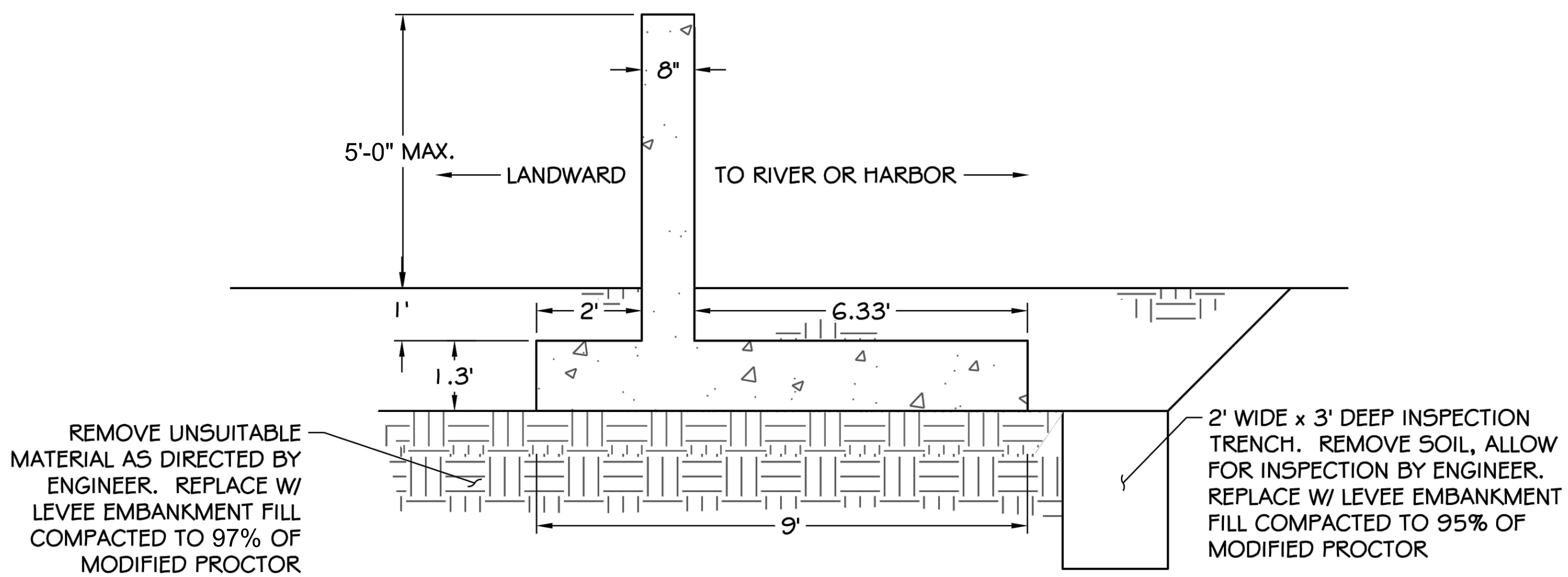
PROFILE
SCALE: ½"=1'-0"



PROFILE
SCALE: ½"=1'-0"

0 1' 2' 4'

HDR	**OFFICE OF CHEHALIS BASIN** **AIRPORT LEVEE 10% CONCEPTUAL DESIGN** **PROFILE**	DATE 2/2022 FIGURE CP-02



TYPICAL CONCRETE FLOOD WALL SECTION

SCALE: 1" = 3'

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DETAILS

DATE 2/2022

FIGURE FW-01