



INFORMATIONAL MEMORANDUM

TO: Community Development and Neighborhoods Committee
FROM: Henry Hash, Public Works Director
BY: Ryan Larson, Senior Program Manager
CC: Mayor Ekberg
DATE: January 25, 2019
SUBJECT: Surface Water Fund – Tukwila 205 Levee Certification
Project No. 91341203, Contract No. 14-164
Phase II - Draft Report

ISSUE

Provide an update on the Tukwila 205 Levee Certification effort and the Phase 2 draft report.

BACKGROUND

The Tukwila 205 Levee is located on the left bank of the Green River between S 196th St and I-405 and provides flood protection to the Tukwila Urban Center. The Corps of Engineers (Corps) notified the City that due to a change in their policy, they would no longer provide levee certification for this or any federal levee. Levee certification expired in August 2013.

The City hired NHC to perform the first phase of the levee certification effort that included an engineering analysis in accordance with FEMA requirements. This analysis looked at the entire levee system to determine which segments did not meet FEMA requirements. The results of the Phase I study revealed that the levee does not meet minimum free board requirements in 14 segments and that embankment, foundation, and stability issues are present. Phase II of this certification effort is near completion and looked at each of the deficient areas identified in Phase 1, collected additional site information, developed alternatives for correcting the deficiencies, and developed costs estimates.

DISCUSSION

The Phase 2 report identified ten separate segments totaling 17,900 feet of levee or approximately 75% of the total length that do not meet federal requirements for levee safety. These segments have been identified as needing large scale improvements to primarily address steep slopes and foundation issues. To address steep slopes, levee setbacks that require additional levee easements or the use of floodwalls are required. NHC has provided conceptual designs for levee repairs. All proposed designs are only to bring the levee to a 100-year level of protection to allow the levee to be certified. It is recommended that all future levee projects be constructed to the 500-year level of protection given the nature of the area being protected.

FISCAL IMPACT

Final cost estimates are still being developed, but the total cost to correct all deficiencies are anticipated to exceed \$100M. Staff is working with the Flood District to add these projects to the Flood District's Capital Improvement list so that they can be prioritized with the other needed projects throughout King County.

RECOMMENDATION

Informational item only.

ATTACHMENTS

- Tukwila Levee Accreditation, Phase 2 Levee Segment Assessment

**TUKWILA LEVEE ACCREDITATION
PHASE 2 – LEVEE SEGMENT ASSESSMENT AND PROPOSED
SEQUENCING FOR LARGE SCALE IMPROVEMENTS**

INTERIM REPORT

Prepared for:

City of Tukwila Public Works
Tukwila, WA

Prepared by:

Northwest Hydraulic Consultants Inc.
Tukwila, WA

October 17, 2018

NHC Ref. No. 2000098

DISCLAIMER

This document has been prepared by Northwest Hydraulic Consultants Inc. in accordance with generally accepted engineering practices and is intended for the exclusive use and benefit of City of Tukwila and their authorized representatives for specific application to the Tukwila 205-Green River Levee Accreditation in Tukwila, WA, USA. The contents of this document are not to be relied upon or used, in whole or in part, by or for the benefit of others without specific written authorization from Northwest Hydraulic Consultants Inc. No other warranty, expressed or implied, is made.

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EXECUTIVE SUMMARY

Northwest Hydraulic Consultants Inc., and their subconsultants Wood (formerly Amec Foster Wheeler Environment & Infrastructure, Inc.) and KPG, are providing professional engineering services to evaluate and certify the Tukwila 205 Levee in accordance with Federal Emergency Management Agency (FEMA) requirements. The 4.5-mile long levee is located on the left bank of the Green River between Interstate-405 and South 196th Street. This report documents Phase 2, the Alternatives Analysis for Large Scale Improvements of the project.

The purpose of the prior Phase 1 was to evaluate the levee condition relative to Code of Federal Regulations Title 44, Chapter I, Subchapter B, Part 65, Section 10 criteria on a project reach scale, determine if the levee could be certified in the existing condition and, when not, identify the deficiencies in meeting the criteria. Tabulated below are the findings for each criteria evaluated.

Criteria	Phase 1 Evaluation Results
Freeboard	Less than 2000 feet total of levee are below minimum elevation, but typically only on the order of inches.
Closures	No flood closures in the system to certify.
Embankment Protection	Existing rock and vegetated banks are sufficient to certify that there will be no appreciable anticipated erosion of the levee banks during the 100-year flood.
Embankment and Foundation Stability	Steep slopes significantly limit levee certification and the addition of predicted scour increases failure risk.
Settling	No significant levee settlement issues that will negatively impact freeboard.
Interior Drainage	Little significant interior flooding landward of the levee for the simulated 100-year condition.

The Phase 1 general reach analysis found that steep levee side slopes result in significant lengths of levee failing to meet the required factor of safety for several geotechnical criteria. Including estimated river channel scour further decreases the factors of safety. A review of historic records shows the levee was purposely constructed at these steep slopes; however, those designs do not now pass the required design criteria. FEMA requires that levees be certified in their entirety – no segmentation of a contiguous levee system is allowed - so the levee cannot be accredited in its current condition.

The Phase 2 approach has taken a more detailed look at site specific information, including additional geotechnical work, to investigate if more accurate data and refined methods may result in segments of levee meeting certification criteria. Work has included dividing the levee reach into segments that can and can't be accredited. Detailed work during Phase 2 of the project has shown that roughly 20% of the levee can be certified in its existing condition. For those segments of the levee that could not be certified in the current state, Phase 2 has considered large scale improvement options for certifying

levee segments, developed conceptual level plans and initial cost estimates, and proposed a prioritization for constructing large scale improvements. Once Phase 2 is finalized, the construction repair for each deficient segment of the levee will then move into final design, permitting, and construction in Phase 3. Phase 4 will provide the documentation necessary to certify the Tukwila 205 Levee. Tabulated below are a description of the levee segments, which of these segments are anticipated to be certified in their existing condition, and for the remaining levee segments, proposed sequencing for large scale improvements to obtain levee accreditation.

Levee Segment Stationing (feet)		Description of Land Features Approximately Paralleling Segment	Length of Anticipated Certifiable Levee Segment (feet)	Construction Improvements for Certification	
Beginning	Ending			Proposed Sequencing	Total Length (feet)
0	600	66 th Avenue S. approach road, I-405, and tie in to high topographic ground.	600	N/A	0
600	1600	68 th Avenue S./Christensen Road.	300	Low	700
1600	2100	Wide left (south side of river) overbank downstream of the pedestrian/bicycle bridge.	500	N/A	0
2100	3200	Riverview Plaza Business Park.	0	Medium	1100
3200	3500	Bicentennial Park.	300	N/A	0
3500	5300	Business parks and related parking from upstream of Strander Boulevard to just beyond railroad bridge crossing.	1800	N/A	0
5300	6500	Business parks and related parking along Christensen Road capital project in the Green River SWIF.	0	High	1200
6500	7700	Tukwila Pump Station.	1200	N/A	0
7700	10150	Sperry Drive and parking lots near Costco and Home Depot.	0	Medium	2450
10150	10250	S 180 th Street crossing.	100	N/A	0
10250	12200	From S 180 th bridge crossing upstream including Lily Point and the Ratolo Levee Green River SWIF project area.	0	High	1950
12200	13200	Outside of bend along S 180 th .	0	Medium	1000

Levee Segment Stationing (feet)		Description of Land Features Approximately Paralleling Segment	Length of Anticipated Certifiable Levee Segment (feet)	Construction Improvements for Certification	
Beginning	Ending			Proposed Sequencing	Total Length (feet)
13200	14300	Business parks and associated parking upstream of S 180 th . Area of 2008 Corps levee repair.	1100	N/A	0
14300	15900	Business parks and associated parking upstream of 2008 Corps levee repair.	0	Medium	1600
15900	18500	Corps' Gaco-Mitchell Levee being designed.	0	High	2600
18500	22750	Segale property.	0	Very High	4250
22750	23800	Cross-levee.	0	Low	1050
Total Length:			5900		17900

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1 INTRODUCTION

The City of Tukwila (City) Department of Public Works has selected an engineering consultant team led by Northwest Hydraulic Consultants Inc. (NHC) to evaluate the Tukwila 205 Levee in accordance with the Federal Emergency Management Agency (FEMA) levee accreditation requirements described in Code of Federal Regulations Title 44, Chapter I, Subchapter B, Part 65, Section 10 (44 CFR Section 65.10).

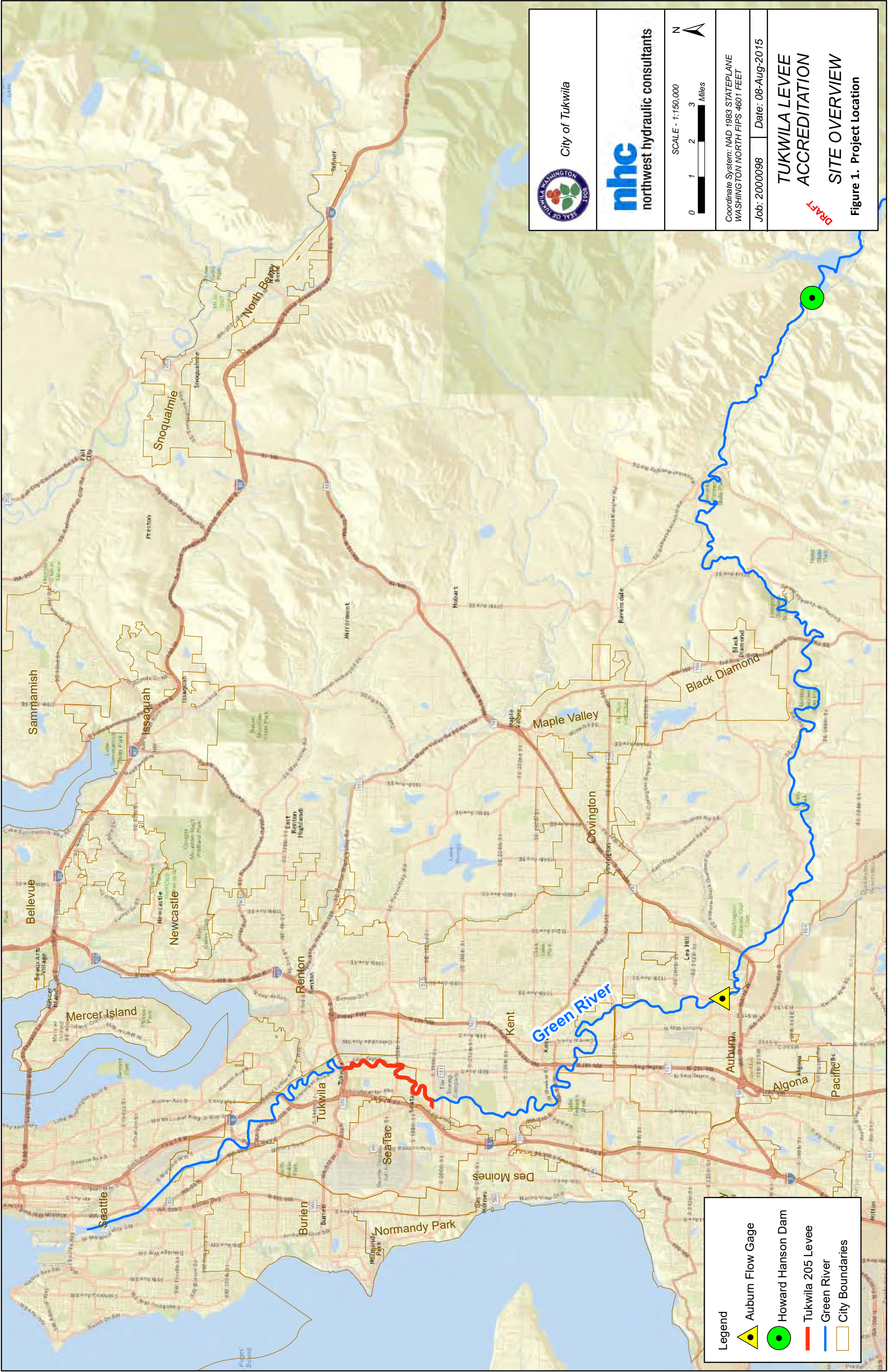
NHC is the prime consultant for this project and is responsible for analyzing hydraulic aspects of the project including freeboard, embankment protection, scour potential, and interior drainage, as well as project management. The team subconsultants are Wood Group (Wood) responsible for geotechnical analyses of the levee, and KPG, responsible for general civil including surveying services. Wood staff on the first phase of this project were then working under the company name of Amec Foster Wheeler Environment & Infrastructure, Inc. (Amec).




2 BACKGROUND

The Green River flows from the Cascade Mountains generally westward until the city of Auburn, and then northward to Elliott Bay in Seattle, WA, passing through the cities of Kent, Tukwila, and then Seattle. The Tukwila 205 Levee is located on the left bank (looking downstream) of the Green River within the City of Tukwila, WA. The 4.5-mile long levee extends from I-405 upstream past bridge crossings at Strander Boulevard and South 180th Street to a cut-off segment that extends to the west valley wall just downstream of the South 200th Street bridge. Figure 1 shows an overview of the overall Green River system downstream of Howard Hanson Dam, operated by the U.S. Army Corps of Engineers (USACE), and the Tukwila 205 Levee project area.

Portions of the Tukwila Levee were first constructed to limit Green River flooding of agricultural farmlands (a general chronology of levee construction and repairs can be found in Amec, 2015). After construction of the Howard Hanson Dam in the 1960s, the USACE controlled releases above the 2-year level (50% annual exceedance probability, approximately 9,200 cfs) by detaining flood waters within the Howard Hanson reservoir and releasing them over a period of days to weeks (NHC, 2007). The United States Geological Survey (USGS) stream gage at Auburn is used by the USACE for its regulation targeting. The dam initiated a development boom in the Green River valley, with extensive levee and revetment improvements constructed during the 1960s.

Tukwila 205 Levee was initially certified by USACE as providing protection up to the 100-year event. The USACE has since generally discontinued their levee certification services, so levees must be re-certified by others to remain recognized by FEMA as providing flood protection. The City was notified by FEMA of the need for re-certification on July 10, 2012.



 <p>City of Tukwila</p>	 <p>northwest hydraulic consultants</p>	 <p>SCALE - 1:150,000</p> <p>0 1 2 3 Miles</p>	<p>Coordinate System: NAD 1983 STATEPLANE WASHINGTON NORTH FIPS 4601 FEET</p>	<p>Job: 2000098 Date: 08-Aug-2015</p>	<p>TUKWILA LEVEE ACCREDITATION</p> <p>SITE OVERVIEW</p> <p>Figure 1. Project Location</p>

Legend	
	Auburn Flow Gage
	Howard Hanson Dam
	Tukwila 205 Levee
	Green River
	City Boundaries

3 PURPOSE

The ultimate purpose of the project is to certify the Tukwila 205 Levee to FEMA standards. As work was started on the project, it became clear that much of the levee system could not be certified under current design standards. Due to the costs and complexity of reconstructing thousands of feet of levee in an urban area, the project was broken into phases.

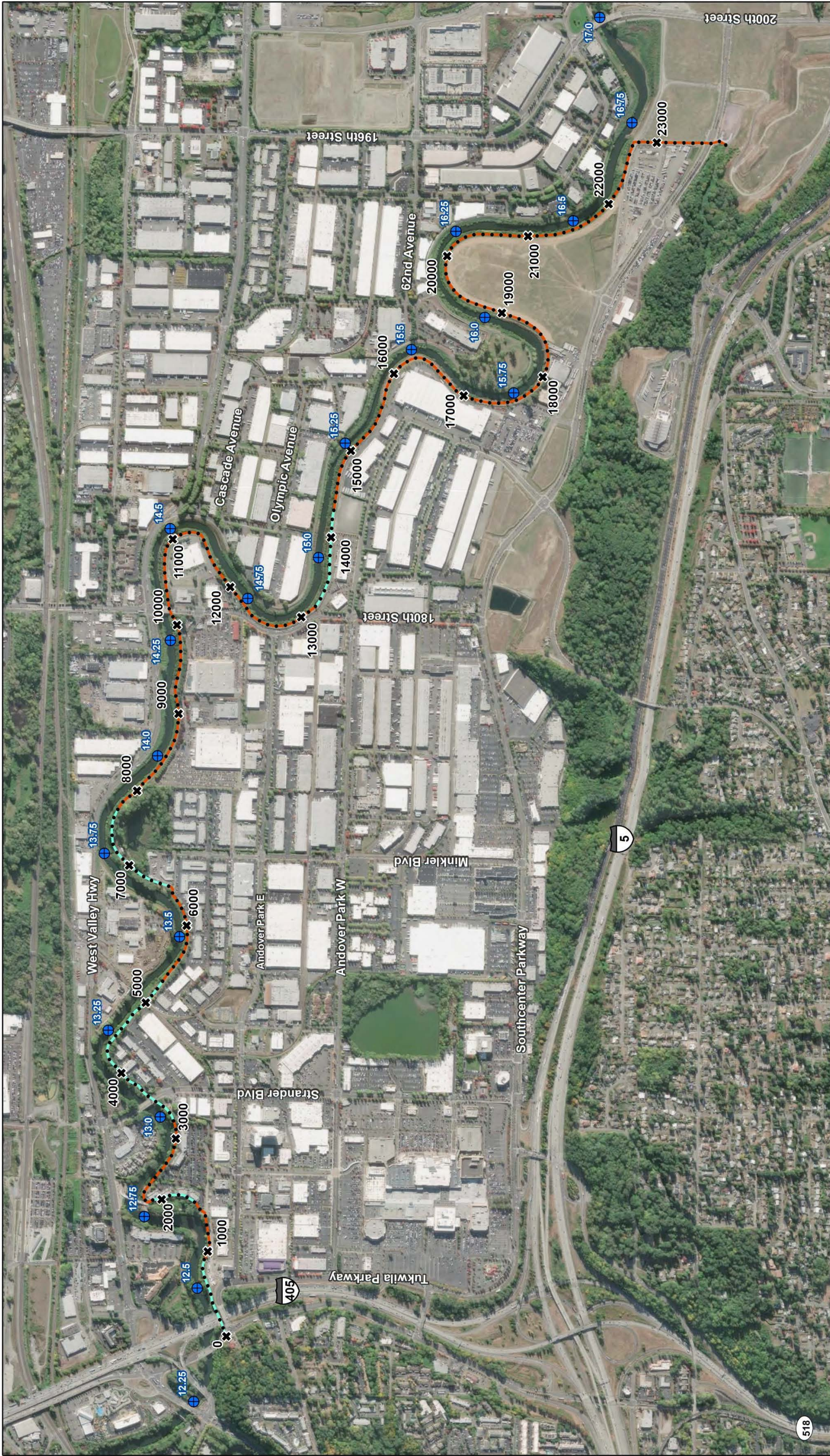
Phase 1, “Engineering Analyses and Improvement Identification” (NHC, 2015), work included data collection, performing engineering analyses required under 44 CFR 65.10, and identifying levee deficiencies that must be addressed for accreditation. That work documented the hydrologic, hydraulic, and geotechnical engineering conducted to evaluate whether the existing levee satisfies FEMA’s accreditation requirements, and where and what deficiencies were found. One of the most significant findings from that work was that steep bank slopes throughout the reach prevent the ability to certify the levee as-is.

As such, Phase 2 work, “Alternatives Analysis for Large Scale Improvements”, documented in this report, had two main tasks. The first was to perform more detailed, site specific assessments at locations where the existing levee might be certified. This included discretizing the project reach based on common characteristics. This initial Phase 2 task looks at a finer scale with more site specific analyses, versus the generalized reach wide Phase 1 approach. The second task of Phase 2 evaluates alternative options, develops conceptual level construction plans, and proposes a prioritization for those segments of the Tukwila Levee that must be modified to meet certification standards.

Phase 3 will take concepts through final design for the Phase 2 construction improvements, including providing permitting and construction support. Phase 4, once all deficiencies have been addressed, would then provide the documentation necessary to certify the Tukwila Levee, including developing an Operations and Maintenance Manual, of which the basis will be the existing USACE approved manual, but also will adopt other recent policies and procedures, if appropriate, such as those from King County’s ongoing System-Wide Improvement Framework (SWIF) assessment for the Green River. Once Phase 2 is completed, the specific tasks to be completed in Phases 3 through 4 can be refined and a cost estimate prepared to complete the work.

4 SITE SPECIFIC ENGINEERING ANALYSES

The project reach was discretized based on common physical characteristics and relative complexity of levee reconstruction alternatives needed to achieve certification (Figure 2) and then detailed analysis conducted to determine if existing levee conditions for each segment could be certified to provide flood protection. Table 1 provides a brief description of the individual segments. To try and provide more detailed site information and maximize the levee lengths that could be certified, Wood collected additional soil characteristics through cone penetration test (CPT) probes (Wood, 2018) and additional bathymetric data were surveyed for the entire study reach.



<p>TUKWILA LEVEE ACCREDITATION</p> <p style="color: red; font-weight: bold;">DRAFT</p>		<p>Figure 2. Levee Condition</p>	
<p>SCALE - 1:12,000</p> <p>0 500 1,000 2,000 Feet</p>		<p>Coordinate System: NAD 1983 HARN STATEPLANE WASHINGTON NORTH FIPS 4601 FEET</p>	
<p>DATA SOURCES: ESRI Basemap Imagery 2017</p>		<p>Job: 2000098 Date: 10-Oct-2018</p>	
<p>Legend</p> <ul style="list-style-type: none"> ● River Mile ✕ Levee Stationing - 1000ft ● Levee Stationing - 100ft 		<p>Levee Condition</p> <ul style="list-style-type: none"> — Improvement Needed — Certifiable 	
<p>northwest hydraulic consultants</p>			

Table 1. Tukwila 205 Levee Segments.

Beginning Station (feet)	Ending Station (feet)	Description of Land Features Approximately Paralleling Segment
0	600	High topographic section north of I-405, I-405, and 66 th Avenue S. approach road.
600	1600	68 th Avenue S./Christensen Road.
1600	2100	Section of undeveloped wide left (south side of river) overbank downstream of the pedestrian/bicycle bridge.
2100	3200	Riverview Plaza Business Park including a 200' long parking lot section.
3200	3500	Bicentennial Park.
3500	3600	Strander Boulevard
3600	5300	Business parks and related parking from upstream of Strander Boulevard to just beyond railroad bridge crossing.
5300	6500	Business parks and related parking along outside river bend. Referred to as Christensen Road capital project in the Green River SWIF.
6500	7700	Tukwila Pump Station.
7700	10150	Sperry Drive including Costco and Home Depot parking lots.
10150	10250	S 180 th Street crossing.
10250	12200	From S 180 th bridge crossing upstream. Includes Lily Point and the Ratolo Levee CIP project area discussed in the Green River SWIF.
12200	13200	Outside of bend along S 180 th .
13200	14300	Business parks and associated parking upstream of S 180 th and through the area of the 2008 Corps levee repair.
14300	15900	Business parks and associated parking upstream of the 2008 Corps levee repair
15900	18500	Corps Gaco-Mitchell Levee Design Site including outside bend. Referred to as the Segale-Green and Gaco-Western project area in the Green River SWIF.
18500	22750	Segale property.
22750	23800	Cross-levee.

4.1 Levee Accreditation

There are several components to accredit a levee following the Code of Federal Regulations Title 44, Chapter I, Subchapter B, Part 65, Section 10 criteria. Phase 1 of this project evaluated the levee on a reach scale and of these criteria (Table 2), embankment and foundation stability were found to be the most limiting factor, with much of the levee failing to meet these criteria.

Table 2. Code of Federal Regulations levee certification criteria and Phase 1 assessment.

Criteria	Phase 1 Evaluation Results
Freeboard	Less than 2000 feet total of levee are below minimum elevation, but typically only on the order of inches.
Closures	No flood closures in the system to certify.
Embankment Protection	Existing rock and vegetated banks are sufficient to certify that there will be no appreciable anticipated erosion of the levee banks during the 100-year flood.
Embankment and Foundation Stability	Steep slopes significantly limit levee certification and the addition of predicted scour increases failure risk.
Settling	No significant levee settlement issues that will negatively impact freeboard.
Interior Drainage	Little significant interior flooding landward of the levee for the simulated 100-year condition.

Work as part of Phase 2 took a more detailed look at site specific information to determine if more accurate data collected and refined methods could result in segments of levee meeting certification criteria. Based on this work, of the 4.5 miles of levee, it's anticipated that approximately 20% of the levee can be certified in its existing condition. This includes segments that have stable slopes when accounting for potential scour, segments that fail levee stability criteria, but that when under the most likely failed scenario have at least 11 feet of remaining levee width at or above the Base Flood Elevation (BFE), as well as the three bridge crossings where as-built drawings and other documentation is assumed to be sufficient to support certification.

- Levee stationing 0 to 600. This segment includes the 66th Avenue S approach road to the bridge crossing I-405, I-405, and ground to the north of I-405 (Figure 3). For this segment, should the levee fail, there is sufficient width of ground landward, that is at or above the BFE (27'), to provide flood protection.
- Levee stationing 600 to 900. 68th Avenue S./Christensen Road (Figure 4). Approximately 300 feet of this segment could be certified. Simulated geotechnical failures would leave 11' or more of existing ground (at 30') at or above the BFE (27').
- Levee stationing 1600 to 2100. The levee is approximately 100 feet or more away from the channel edge behind a forested floodplain bench (Figure 4), and further than any potential point of slope failure.

- Levee stationing 3200 to 3500. Bicentennial Park (Figure 6). Slope failure may reach landward of the levee; however, the ground elevation (28') is still greater than the BFE (27.7').
- Levee stationing 3500 to 5300. Strander Boulevard and upstream section through the business parks and related parking have stable slopes (Figure 7).
- Levee stationing 6500 to 7700. Portions of the levee along the Tukwila Pump Station and a portion of the business park downstream of the pump station (Figure 8) have stable slopes.
- Levee stationing 10150 to 10250. It's assumed sufficient documentation exists to certify this approximate 100' long existing S 180th Street bridge crossing section.
- Levee stationing 13200 to 14300. Business parks and associated parking (Figure 9) along the Corps 2008 levee repair have stable bank slopes.

Results of the geotechnical slope stability analysis for additional cross-sections evaluated in Phase 2 are presented in Table 3. In order to be certified on the embankment and foundation criteria, the representative cross-section for the levee segment must have a computed factor of safety greater than a USACE minimum value for all cases (e.g. evaluations at river miles 13.055, 13.11 and 13.219 define stable slopes for levee segment 3600 to 5300, evaluations at river miles 13.624 and 13.892 define stable slopes for levee segment 6500 to 7700, and the evaluation at river mile 14.934 defines stable slopes for levee segment 13200 to 14300).

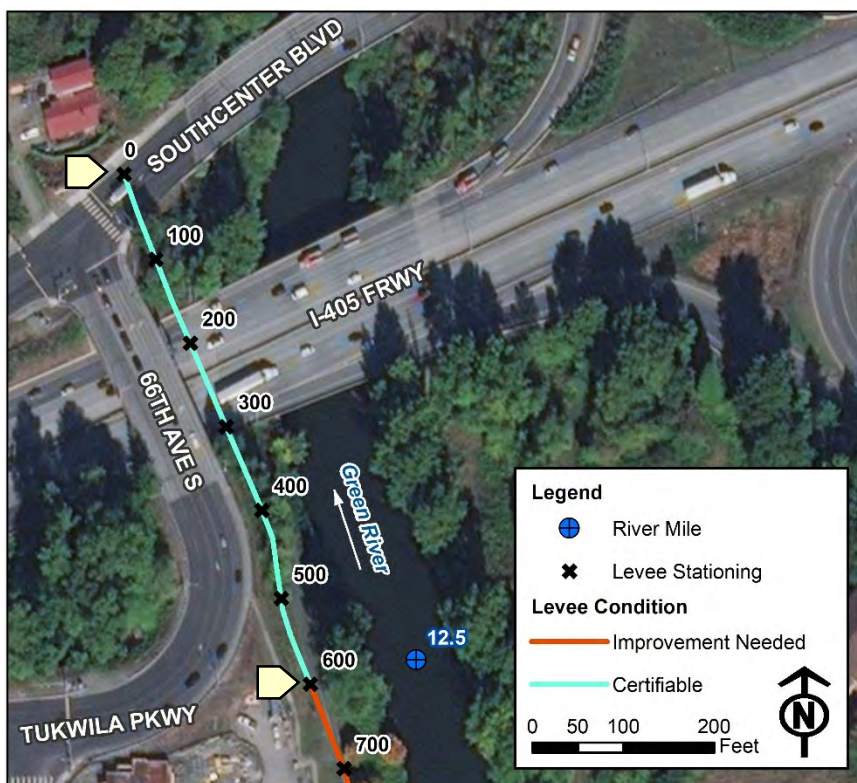


Figure 3. Tukwila Levee segment where stationing 0 to 600 can be certified as is.

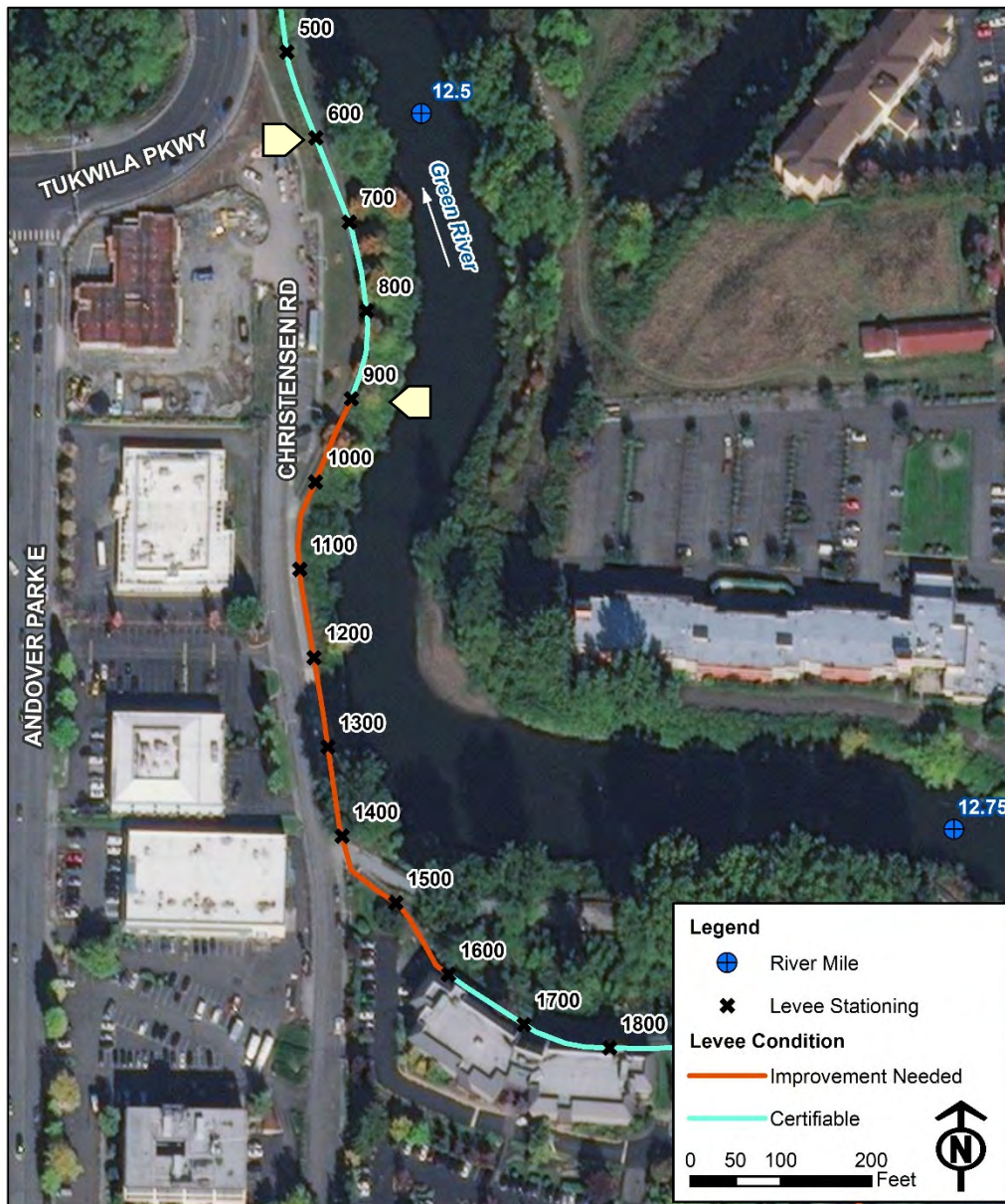


Figure 4. Tukwila Levee segment 600 through 1600 where existing portion 600 through 900 can be certified.

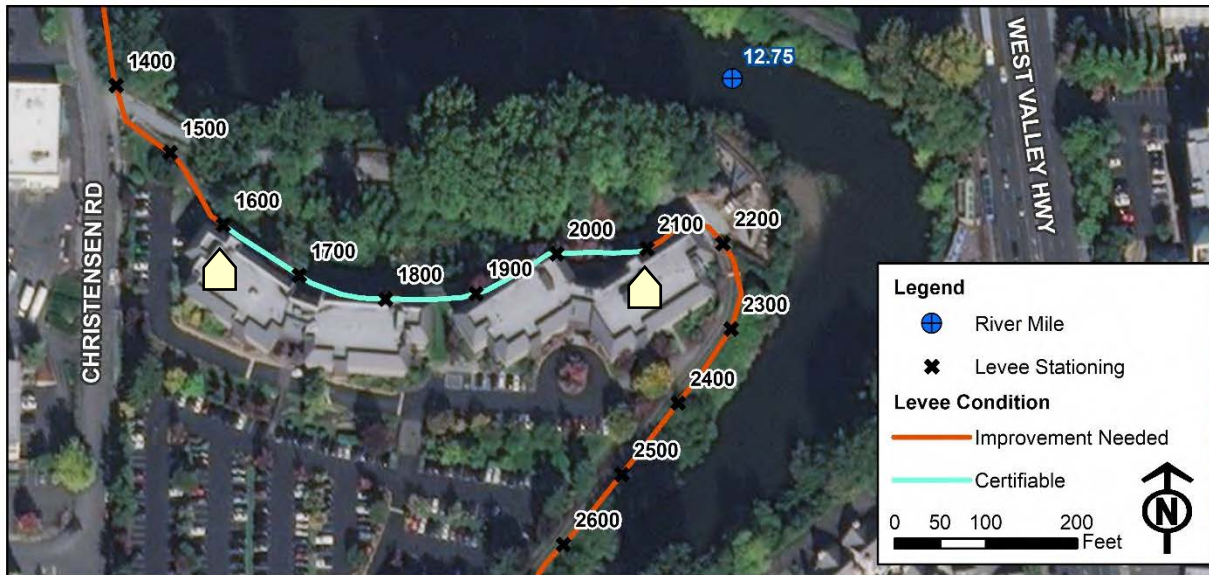


Figure 5. Tukwila Levee segment where stationing 1600 through 2100 can be certified.



Figure 6. Tukwila Levee segment where stationing 3200 through 3500 can be certified.

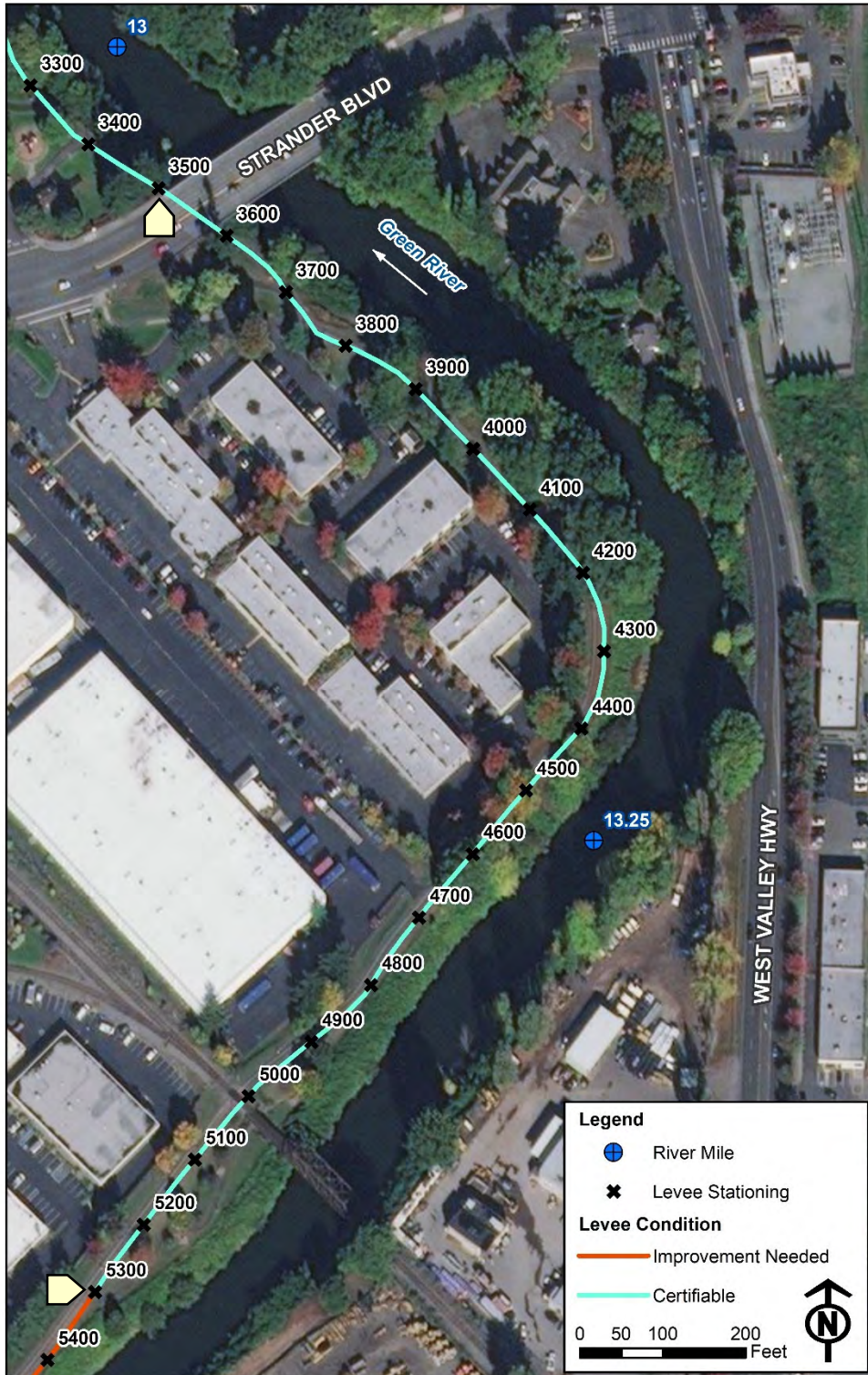


Figure 7. Tukwila Levee segment where existing section 3500 to 5300 can be certified.



Figure 8. Tukwila Levee segment where existing section 6500 to 7700 can be certified.

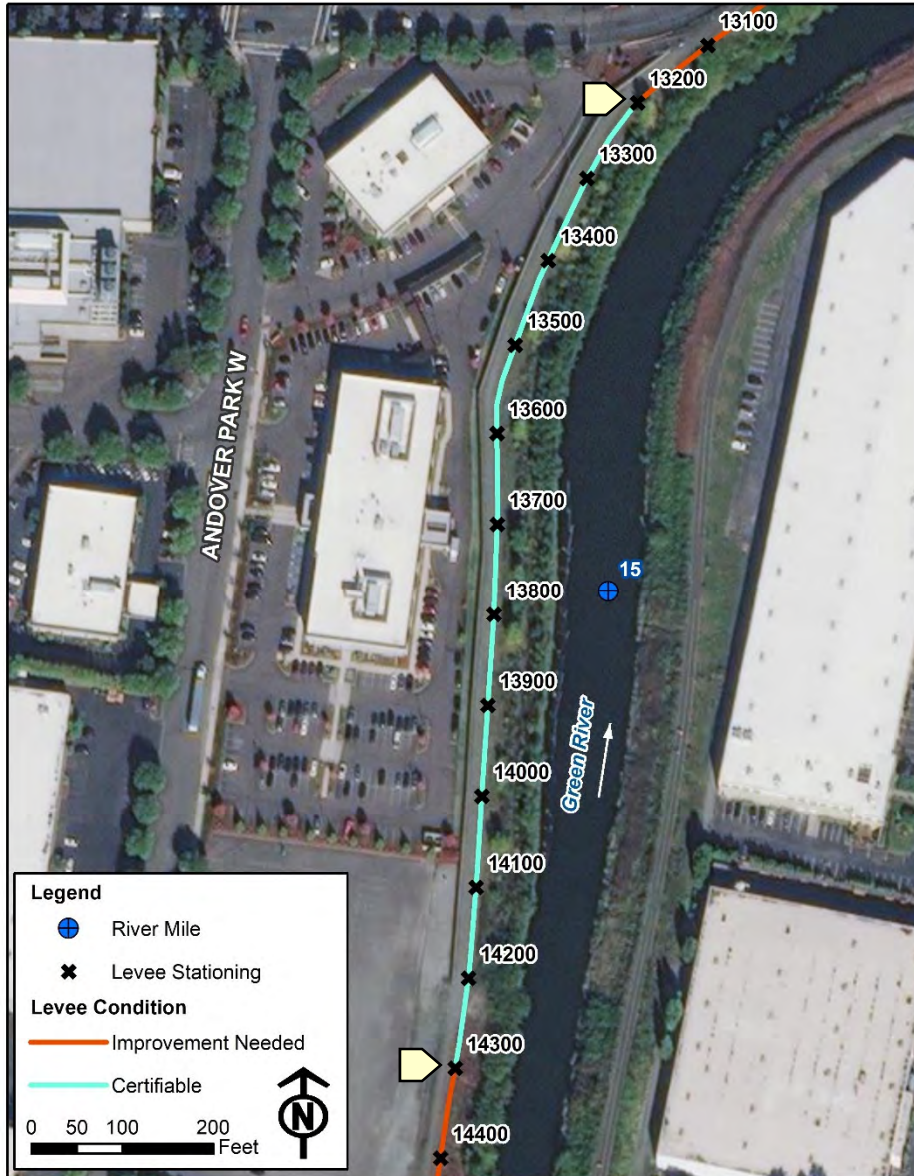


Figure 9. Tukwila Levee segment where existing section 13200 to 14300 can be certified.

Table 3. Summary by cross-section of additional Phase 2 geotechnical slope stability assessments.

Location Evaluated (River Mile)	Case I - End of Construction (Existing Conditions)	Case II - Rapid Drawdown	Case III - Steady State Seepage	Case IV - Earthquake Post EQ kh=0 liquefied	Case IV - Earthquake kh = 0.10g non-liquefied	Case IV - Earthquake kh @ k yield	Case IV Earthquake - Approximate deformation
12.412	1.5	1.05	1.27		1.1	0.14	< 1 inch
13.055	1.71	1.3	1.74	0.57	1.29	0.19	< 1 inch
13.11	1.56	1.22	1.56	0.84	1.2	0.18	< 1 inch
13.219	1.3	1.02	1.43	0.5	1.06	0.11	~1 inch
13.6243	1.63	1.09	1.68	0.73	1.27	0.2	< 1 inch
13.8235	1.81	1.31	2	0.72	1.38	0.24	< 1 inch
13.892	1.08	0.53	0.9				
14.2042	1.35	1	1.21	0.38	1.02	0.11	~1 inch
14.534	1.91	0.98	1.39	0.5	1.34	0.2	< 1 inch
14.934	1.98	1.29	2.2	0.56	1.39	0.24	< 1 inch
15.1	1.35	0.93	1.29	0.38	1.04	0.11	~1 inch
15.2993	1.3	1.23	1.77	1.37	1.12	0.15	< 1 inch

USACE minimum Factor of Safety:	1.3	1	1.4	1.2	1
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Legend

	Meets USACE Levee Design Manual minimum factor of safety (FS)
0.93	Does not meet USACE minimum FS in current configuration.
1.23	Meets USACE minimum FS but does not meet King County minimum FS (=1.4)
	Does not meet minimum USACE minimum FS, but predicted deformation is minor, therefore acceptable.

kh = lateral earthquake design load (0.10g was considered the 100-year earthquake)

kyield = lateral earthquake load that produces a non-liquefied FS = 1.0

5 ALTERNATIVES ANALYSIS – LARGE SCALE PROJECTS

Potential alternative construction fixes that will lead to the levee being certified were identified for each levee segment that could not currently be certified. For each levee section characterized, alternatives were evaluated and were discussed with the City during an in-person meeting on September 6, 2018.

5.1 Construction Fixes

Alternative construction fixes were considered for the segments that were deemed non-certifiable in their existing condition. One or more of three alternatives were considered; re-grading and flattening the levee, raising and widening the levee, and installing a floodwall. Concept designs for three alternatives are provided in Appendix A. Cost estimates to design and construct the alternatives are provided in Table 4. These are initial, planning level estimates that were determined in conjunction with KPG and are based on implementing typical sections over a 1,000-foot stream reach to develop a construction cost per linear foot. This approach assumes consistent grading quantities throughout the reach; however, this could vary significantly along any reach and should be refined as design details evolve for specific levee segments. Costs assume right of way is purchased for the levee setback and widening alternatives, but not for floodwalls. Design, permitting, and construction management were estimated at 40% of the construction cost in anticipation of a fairly extensive permit process.

Table 5 shows the results of the various geotechnical slope stability assessments from the initial Phase 1 reach assessment. These evaluations were made at various river cross-sections along the Tukwila 205 Levee, and a representative location was chosen when assessing each levee segment. Yellow shading in this table indicates where USACE factors of safety are not met (and therefore the levee segment is not certifiable).

For consistency with the Green River SWIF (King County, 2016), conceptual future levee fixes were assumed to provide a 500-year level of protection (i.e. 500-year water surface elevation plus three feet). This is a peak Green River flow of 18,800 cfs based on a 2012 Corps report that downgraded the level of protection provided by the upstream Howard Hanson Dam to a 140-year event. This is a much higher level than historically the lower Green River Valley has been developed for, as it has generally been assumed that the upstream Howard Hanson Dam provided protection for a 500-year event.

Table 4. Planning level cost estimate for final design and construction of levee certification improvements.

Levee Segment Stationing (feet)		Subsection Length (LF)	Description	Re-Grade/Flatten Levee	Raised/Widened Levee	Retaining Wall/Floodwall
Beginning	Ending					
600	1600	1000	68 th Avenue S./Christensen Road.	\$5,100,000	\$3,200,000	\$4,100,000
2100	3200	1100	Riverview Plaza Business Park.	N/A	N/A	\$4,500,000
5300	6500	1200	Business parks and related parking along Christensen Road capitol project in the Green River SWIF.	\$6,200,000	\$3,800,000	\$4,900,000
7700	10150	2450	Sperry Drive and parking lots near Costco and Home Depot.	\$12,600,000	\$7,800,000	\$10,000,000
10250	12200	1950	From S 180th bridge crossing upstream including Lily Point and the Ratolo Levee Green River SWIF project area.	\$10,000,000	\$6,200,000	\$7,900,000
12200	13200	1000	Outside of bend along S 180th.	N/A	N/A	\$4,100,000
14300	15900	1600	Business parks and associated parking upstream of 2008 Corps levee repair.	\$8,200,000	\$5,100,000	\$6,500,000
18500	22750	4250	Segale property.	\$22,000,000	\$10,000,000	\$17,000,000
22750	24000	1250	Cross-levee.	N/A	\$4,000,000	N/A

Table 5. Summary by cross-section of Phase 1 geotechnical slope stability assessments.

Location Evaluated (River Mile)	Case I - End of Construction (Existing Conditions)	Case II - Rapid Drawdown	Case III - Steady State Seepage	Case IV - Earthquake kh = 0.10g non-liquefied	Case IV Earthquake - Approximate deformation
12.61	1.35	0.79	1.27	0.82	10-16 inches
12.98	1.33	0.91	1.23	0.73	3-4 feet
13.11	1.7	1.01	1.34	1.17	< 1-2 inches
13.53	1.1	0.72	1.12	0.87	8-12 inches
14.02	1.03	0.82	0.91	0.81	5-6 feet
14.72	1.3	0.69	1.05	0.94	2-4 inches
14.82	1.08	0.89	1.19	0.86	1.5-2 feet
15.49	1.47	1.12	1.41	1.08	< 1-2 inches
15.86	1.13	0.74	0.88	0.98	1-3 inches
16.07	1.43	0.81	1.14	1.06	< 1-2 inches
16.47	1.06	0.73	0.92	0.82	3-4 feet

USACE minimum Factor of Safety	1.3	1	1.4	1
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The following text describes the alternatives considered for each segment as well as approximate costs to develop final design and build the project.

Segment stationing 600 through 1600 parallels 68th Avenue South/Christensen Road (Figure 10). Here steep slopes exacerbated by anticipated river channel scour could lead to a levee bank failure (as evaluated at cross-section 12.61 in Table 5) that includes portions of the roadway and the Green River trail. As discussed in prior Section 4.1, the segment of this levee from stationing 600 to 900 can be certified as is, as there is sufficient existing ground remaining after the predicted failure, that is at or above the BFE, to prohibit floodwaters from reaching landward infrastructure. Similarly, from station 900 to 1600, a slope failure would not flood landward of the levee (the ground elevation at the point of extent of failure is very close to, but above, the 27' BFE); however, a portion of Christensen Road, as well as nearby parking and potentially the closest buildings, would be lost. Slope stability in this reach is relatively less of a concern at this segment compared to other portions of the levee, based on the computed factor of safety from the geotechnical analysis of this segment (Table 5).

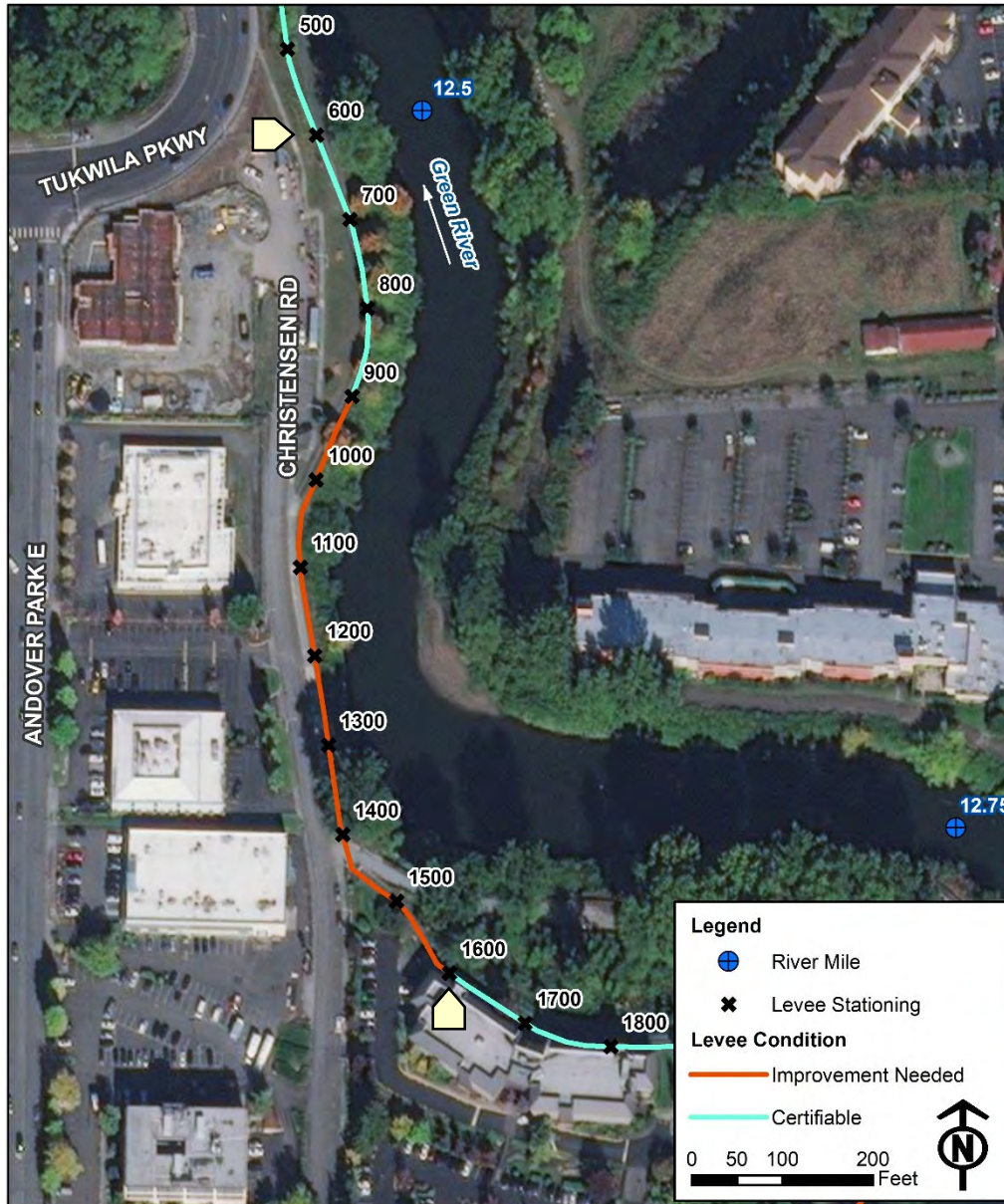


Figure 10. Tukwila Levee segment 600 through 1600 where existing portion 900 through 1600 can't be certified.

A construction fix here to protect the roadway, trail, and buildings up to the 500-year level of protection includes either a levee setback, raising the levee, or a floodwall. Table 4 provides a planning level cost estimate for these alternatives. For all concepts, the construction fix was assumed to occur for the entire length of the segment, so that the same level of protection would be continuously provided from stationing 600 through 1600. For the levee setback and raising options, a retaining wall would likely be placed on the landward side of the levee, where existing buildings would limit ability to construct a 2:1 backslope. This alternative would require relocation of any utilities and raising of Christensen Road to provide access to the Holiday Inn constructed in 2018.

Segment 2100 through 3200 parallels the Riverview Plaza business park, which is built up to the levee edge (Figure 11). Estimated scour depths here and the short distance between river edge and the business park, preclude any realistic fix other than sheet pile walls. Table 4 provides a cost estimate for a construction fix at this segment. There is a short reach from approximately 2400 to 2700 that has an open parking lot, where the levee potentially could be set back or a design other than a sheet wall could be considered as part of the final design. Slope stability in this reach is relatively moderate compared to other segments, based on the computed factor of safety from the geotechnical analysis of this segment (as evaluated at river mile 12.98 in Table 5).

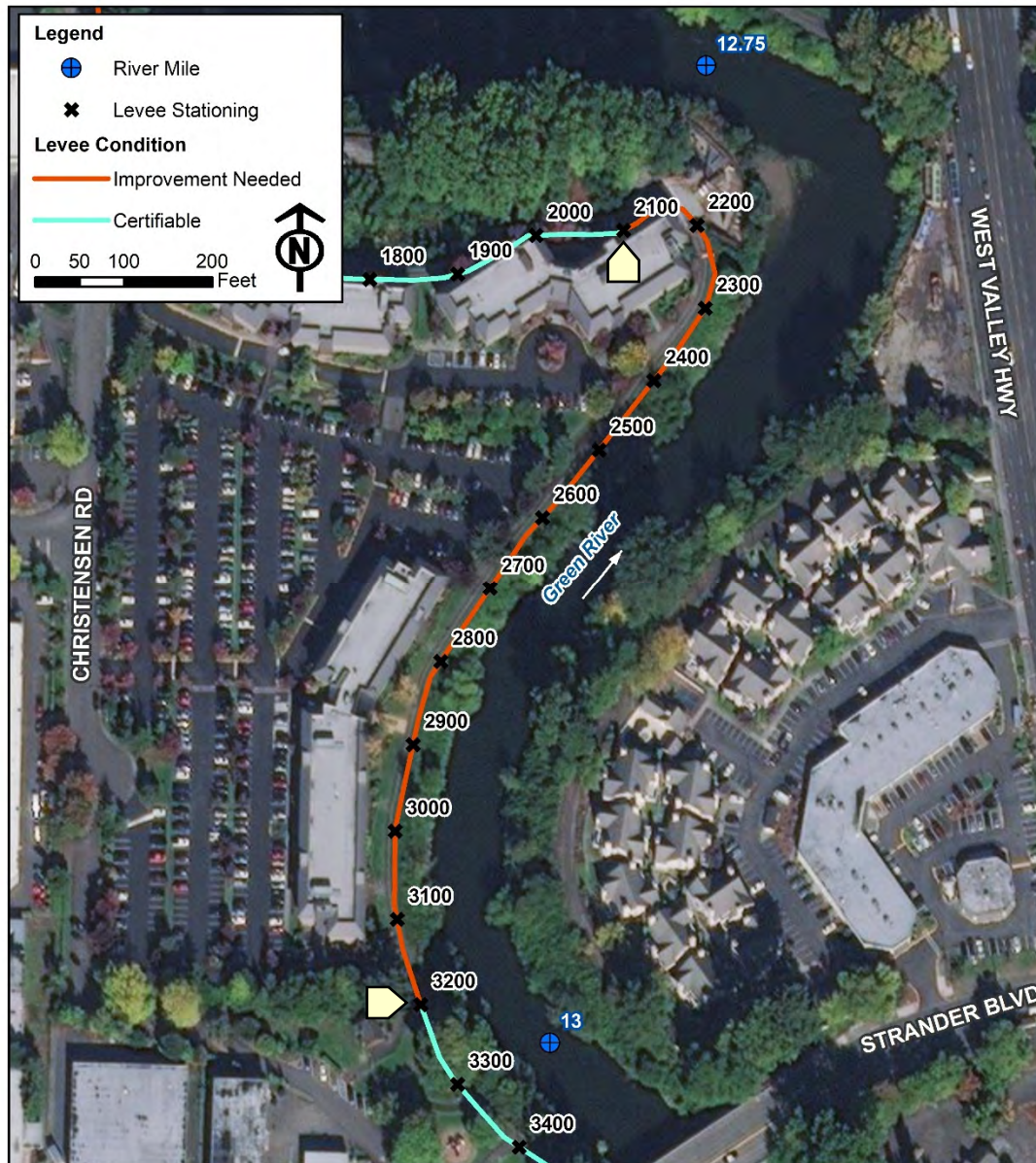


Figure 11. Tukwila Levee segment 2100 through 3200 that can't be certified in its existing condition.

Segment 5300 through 6500 (Figure 12) is in the outside of a river bend and includes the Green River SWIF Christensen Road capital project. Similar to other levee segments, unstable channel slopes under anticipated potential channel scour create conditions that can't be certified (as evaluated at river mile 13.53 in Table 5). Failure risk here, where scour is greater in the outside of a channel bend, is some of the greatest in the system. Levee setback, levee raising, and floodwall alternatives were considered for this site (cost estimates provided in Table 4). The levee setback and raising would take land currently used for business parking.

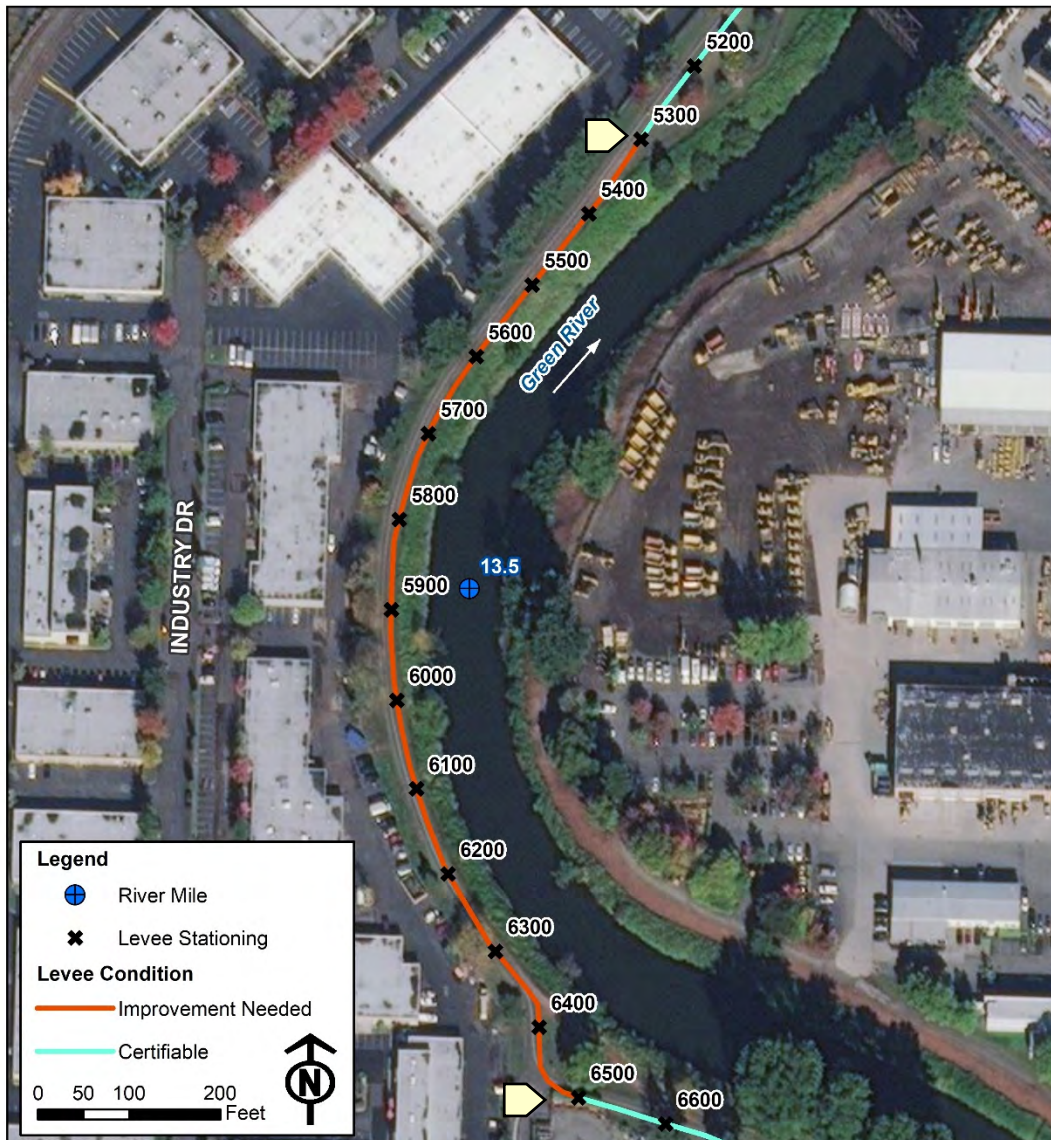


Figure 12. Tukwila Levee segment 5300 through 6500 that can't be certified in its existing condition.

Segment 7700 through 10150 parallels Sperry Drive and parking for large box stores (Figure 13). Slope stability in this reach is relatively moderate compared to other segments, based on the computed factor of safety from the geotechnical analysis of this segment (as evaluated at river mile 14.02 in Table 5). Cost estimates to design and construct both a levee setback and a floodwall for the entire segment are

provided in Table 4. Note that the levee setback and levee raising concepts would modify land currently used for business parking, though parking lots through this segment are relatively wide. A simple site specific concept through just the non-certifiable section of the Tukwila Pump Station Pond, stationing 7700 through 8200, was also considered. The cost of bringing in additional levee material to provide protection to the 500-year water surface plus three feet, for this short 500-foot section, is estimated to be approximately \$2.3 million.

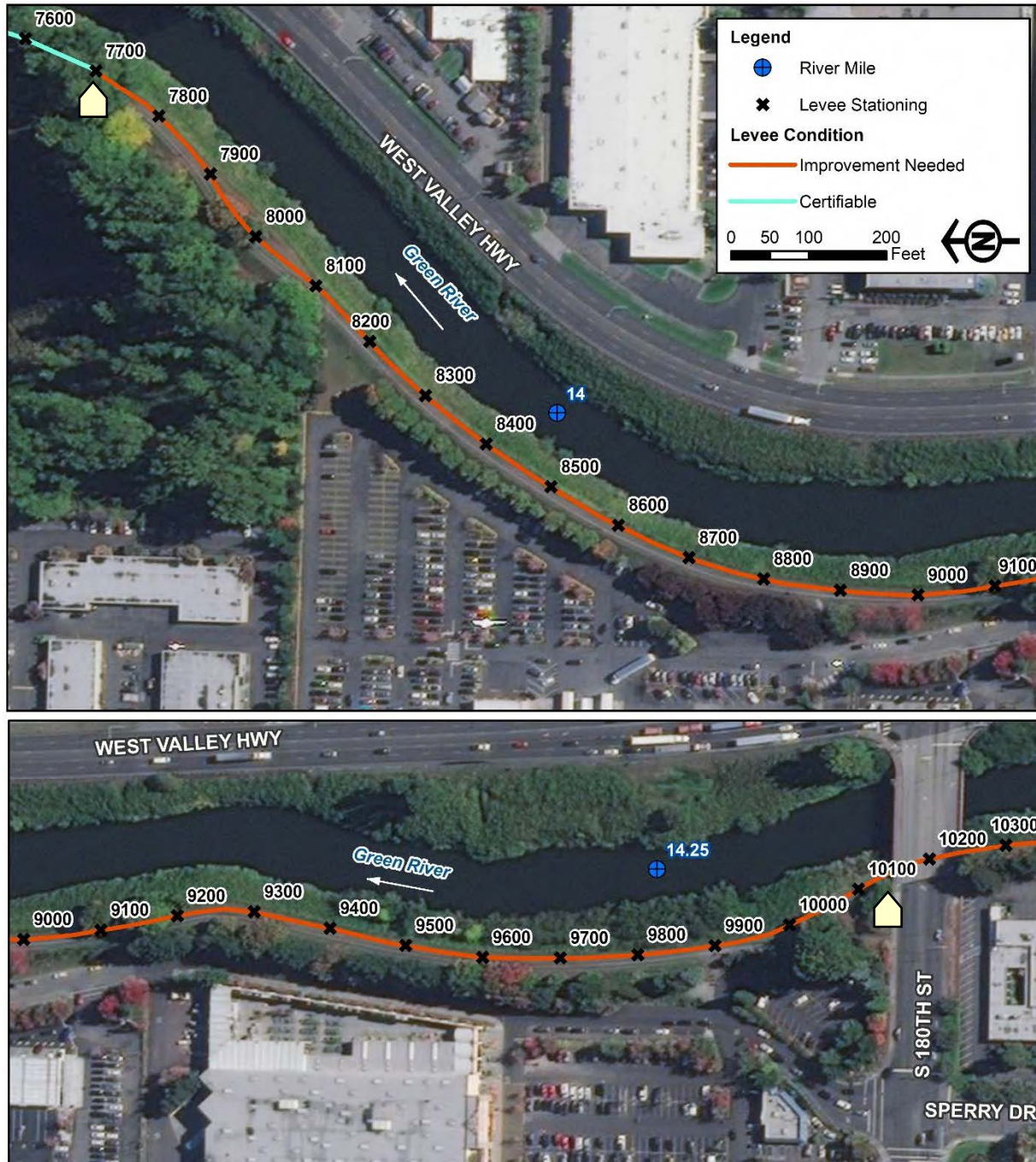


Figure 13. Tukwila Levee segment 7700 through 10150 that can't be certified in its existing condition.

Segment 10250 through 12200 (Figure 14) has a history of slope instability and was repaired most recently in 2008 (Amec, 2015). Slope stability in this reach is relatively moderate to high, depending on location within the segment, compared to other segments (as evaluated at river mile 14.534 in Table 3 and at river mile 14.72 in Table 5). Both a levee setback, levee raising, and floodwall were evaluated as potential construction fixes at this segment (Table 4 provides the estimated costs).

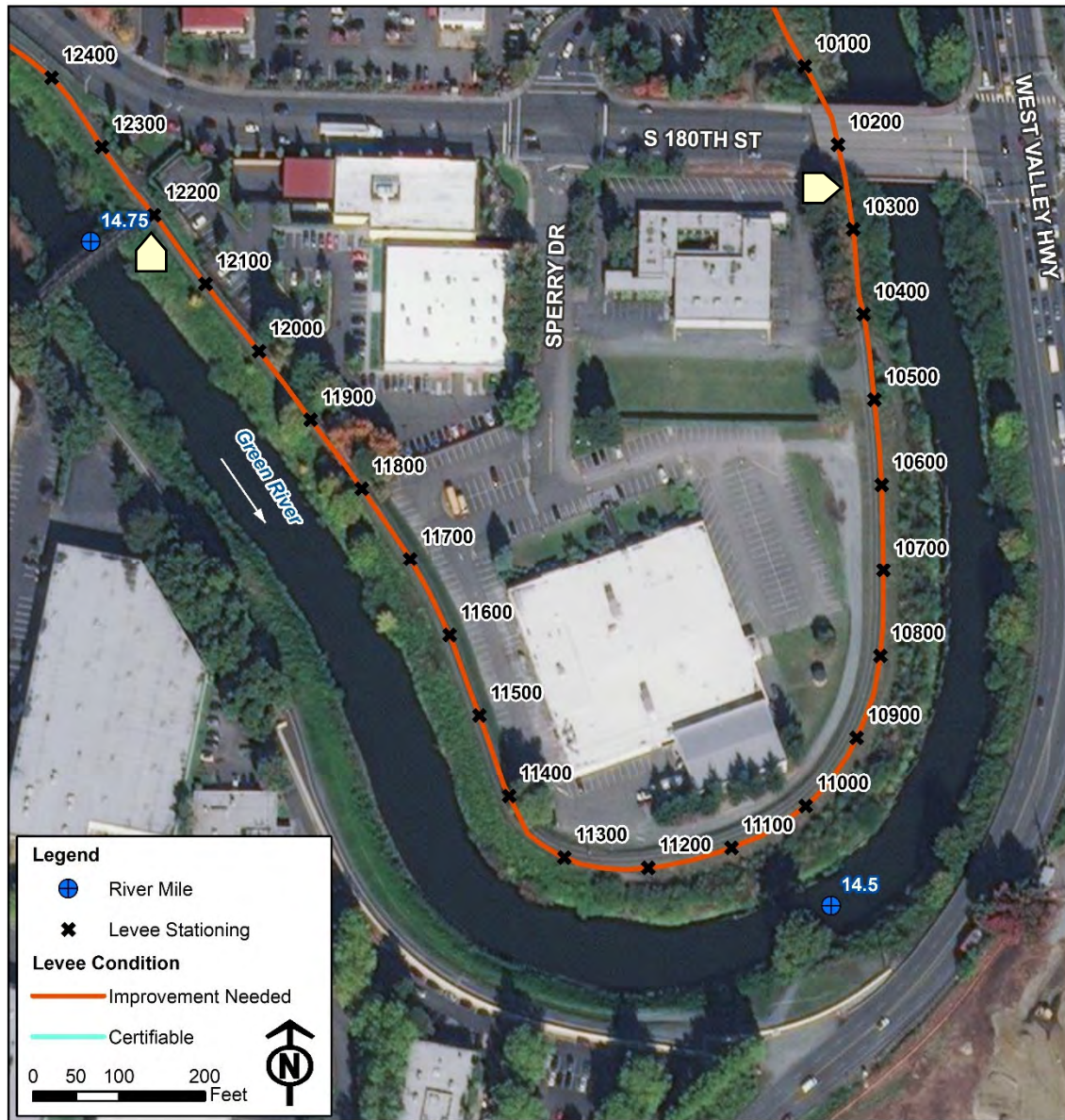


Figure 14. Tukwila Levee segment 10250 through 12200 that can't be certified in its existing condition.

For segment 12200 through 13200, the proximity of S 180th Street severely limits construction options given how close the roadway is to the existing levee (Figure 15). In addition, the levee being in the outside of the river bend has relatively more scour compared to straight river sections, leading to less stable slopes (as evaluated at river mile 14.82 in Table 5). Only sheet pile floodwalls were considered for this site. Table 4 provides a cost estimate to design and construct this project.



Figure 15. Tukwila Levee segment 12200 through 13200 that can't be certified in its existing condition.

Segment 14300 through 15900 (Figure 16) is the site of an existing repair, like the downstream levee segment; however, unlike the downstream section, steep slopes and soil conditions for this segment indicate that this section can't be certified in its existing condition (e.g. as evaluated at river mile 15.1 in Table 3). This is one section that may warrant additional soil testing (e.g. CPT) to further classify soils and thus potentially be able to certify the levee segment. A levee setback, levee raising, and a floodwall were considered for this site (cost estimate provided in Table 4).

USACE is managing the design and construction of the Gaco-Mitchell Levee repair from station 15900 to 18500 (approximate river mile 15.4 to 15.9) (Figure 17). This has some of the greatest failure risk within the entire levee reach (as evaluated at river mile 15.86 in Table 5). The new levee along the Green River left bank will provide 500-year level of protection plus 3 feet of freeboard per the SWIF. There is a detailed analysis and design being completed for that project, so therefore no additional conceptual level designs and planning level cost estimates were conducted for this Phase 2 work.

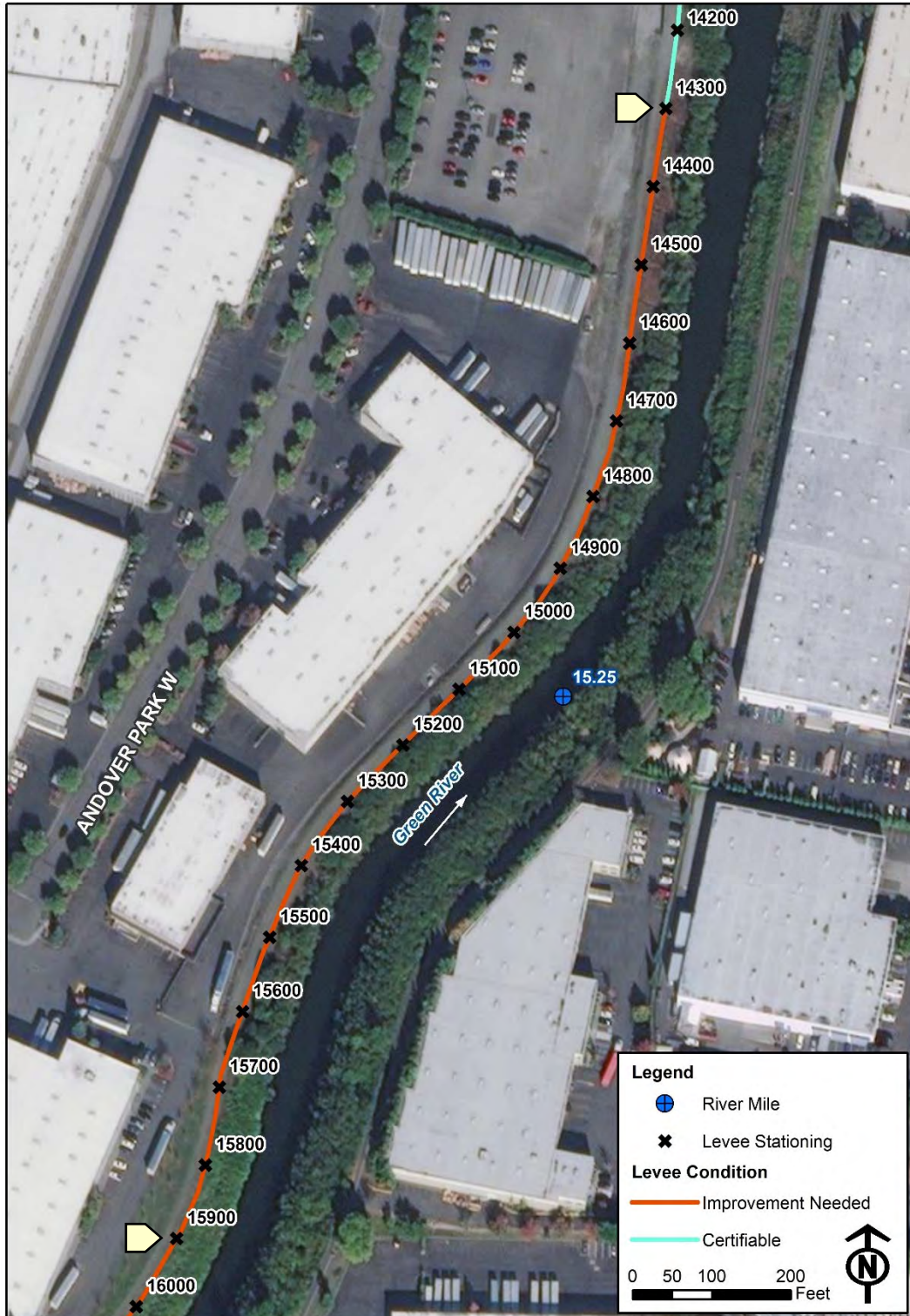


Figure 16. Tukwila Levee segment 14300 through 15900 that can't be certified in its existing condition.



Figure 17. Tukwila Levee segment 15900 through 18500 that can't be certified in its existing condition.

The geotechnical analyses (evaluated at river mile 16.07 and 16.47 in Table 5) indicate that a potential slope failure could occur along the Segale property from station 18500 to 22750 (Figure 18 and Figure 19). However, with the grade landward of any slope stability failure at or above BFE, the section could be certified as is no infrastructure is threatened by a slope failure. This is the only segment of the Tukwila 205 Levee reach, and one of the few remaining in the Lower Green River, where there is currently no development, though site grading has occurred in preparation for construction. As future development plans are uncertain, alternatives were developed for this segment including developing setback levees, raising the levees and constructing sheet pile walls for 500-year protection. Cost estimates for these fixes are provided in Table 4. For the fill option, a site specific cost estimate was made based on actual ground elevations (from 2014) versus computing by linear foot. In addition, a cost was estimated for filling the entire undeveloped area paralleling levee segment 18500 to 22000 (a majority of which is shown in Figure 18) to a uniform elevation at the 500-year level of protection. This is estimated to be approximately \$23 million assuming a fill quality suitable for construction (e.g. free from contamination, compacted and prepared for foundation, etc.) and does not include the cost for purchasing land. Assuming a purchase price of \$10 per square foot for undeveloped property, and approximately 1.7 million square feet of area, land costs are estimated to be another \$17 million. In this segment, work could be completed in phases, with the first phase acquiring land (before development occurs) and then constructing levee improvements (e.g. levee setback) later.

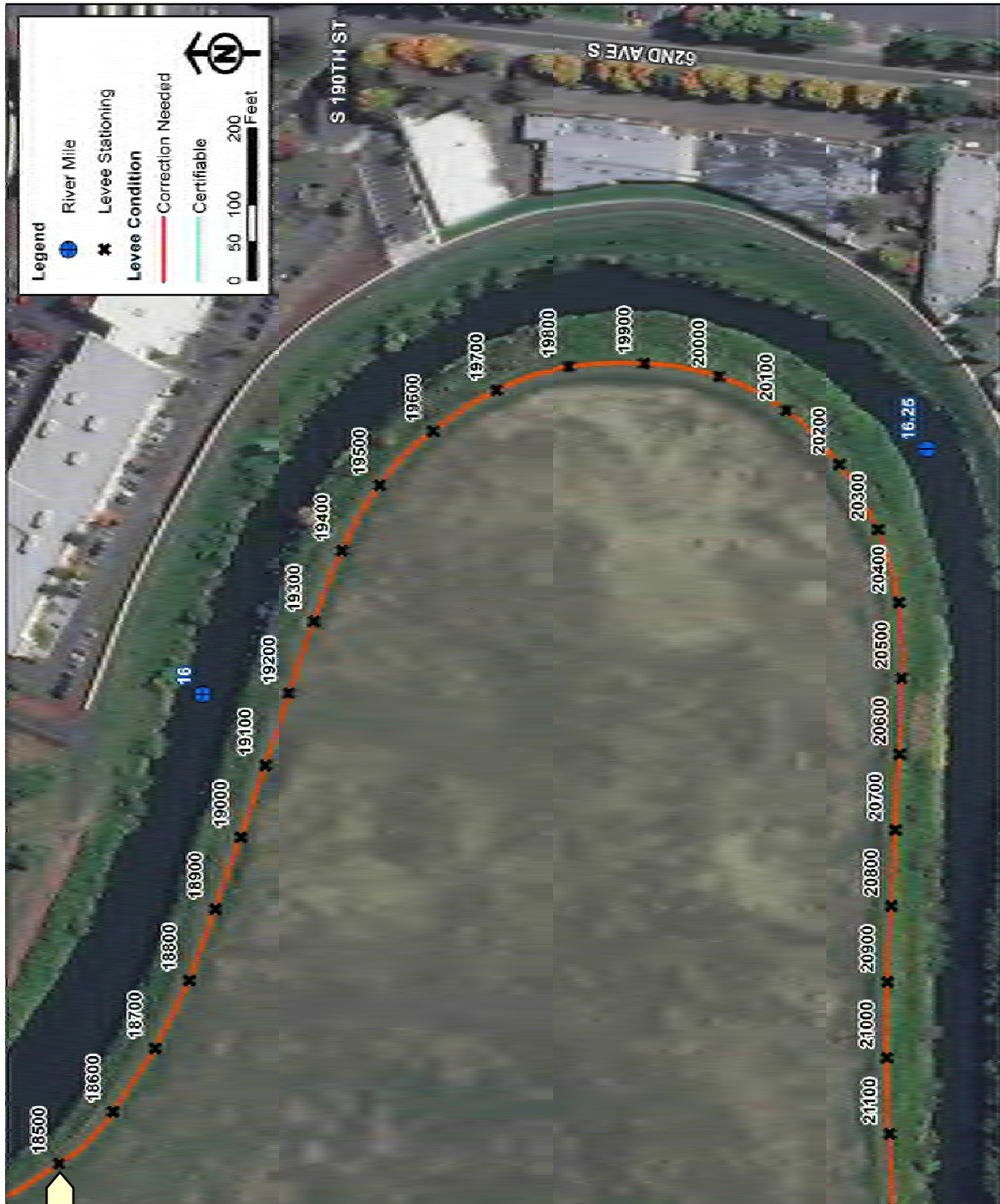


Figure 18. Tukwila Levee segment 18500 through 22750 (downstream portion) that can't be certified in its existing condition.



Figure 19. Tukwila Levee segment 18500 through 22750 (upstream portion) that can't be certified in its existing condition.

Levee segment 22750 through 23800 is a cross-levee section that spans from the Green River to high ground on the east side of the valley (Figure 20). The BFE here is approximately 35.6 feet and the levee low point is approximately 38.1; therefore, the levee elevation needs to be raised a few inches to be certified. The 500-year elevation plus 3 feet of freeboard is 38.7 feet; therefore, the recommended fix would be to bring this levee up to the 500-year level of protection. Table 4 provides a cost estimate for a construction fix at this segment.



Figure 20. Tukwila Levee segment 22750 through 23800 that can't be certified in its existing condition.

6 PROPOSED PRIORITIZATION

Of those levee segments that could not be certified, the proposed construction sequencing based on risk and apparent opportunity is tabulated in Table 6.

Table 6. Proposed improvement prioritization based on risk and opportunity.

Levee Segment Stationing (feet)		Basis for Sequencing	Construction Improvements for Certification	
Beginning	Ending		Proposed Sequencing	Total Length (feet)
600	1600	68 th Avenue S./Christensen Road. Has a lower risk of slope failure and 300 feet of this could be certified in its current condition.	Low	1000
2100	3200	Riverview Plaza Business Park. Has a moderate risk of slope failure.	Medium	1100
5300	6500	Business parks and related parking along Christensen Road capital project in the Green River SWIF. Has some of the highest deviation from slope stability factors of safety.	High	1200
7700	10150	Sperry Drive and parking lots near large box stores. Has a moderate risk of slope failure.	Medium	2450
10250	12200	From S 180 th bridge crossing upstream including the Ratolo Levee Green River SWIF project area. One of highest scour areas and potential opportunity to work with landowner.	High	1950
12200	13200	Outside of bend along S 180 th . Has a moderate to high risk of slope failure.	Medium	1000
14300	15900	Business parks and associated parking upstream of 2008 Corps levee repair. Has a moderate risk of slope failure.	Medium	1600
15900	18500	Corps' Gaco-Mitchell Levee being designed. One of the greatest levee failure risks in the levee reach based on comparison with computed factors of safety.	High	2600
18500	22750	Segale property. This is one of the last undeveloped overbank areas in the lower Green River. At a minimum land acquisition should occur as soon as possible.	Very High	4250
22750	23800	Cross-levee likely will be in contact with floods during the highest of events.	Low	1250

7 PHASE 3 PREVIEW

Phase 1 conducted a reach wide assessment of the levees using generalized information and identified deficiencies for levee certification. In Phase 2, the project reach was discretized based on common characteristics and the deficiencies in each of these segments addressed in one of two ways. First, each segment was evaluated to determine if a more site specific analysis, versus the generalized reach wide Phase 1 approach, could potentially show that the current condition is certifiable. For each of the segments identified as such, a site specific analysis was conducted including collecting additional data and conducting additional or refining existing analyses to determine if that portion of the levee could be certified as is. For those segments of the levee that couldn't be certified in their current condition, costs were estimated for one or more construction alternatives that would lead to the levee being certified.

Phase 3 will provide civil design and construction support of the preferred design determined in Phase 2 for large-scale, complex physical deficiencies. Meetings will be held as needed. The scope of work for Phase 3 will be refined at the completion of Phase 2, and a cost estimate prepared.

Once all deficiencies have been identified and corrected, the Tukwila Levee Certification report will be prepared for submittal. The Phase 4 scope of work will be refined at the completion of Phase 3, and a cost estimate prepared.

8 REFERENCES

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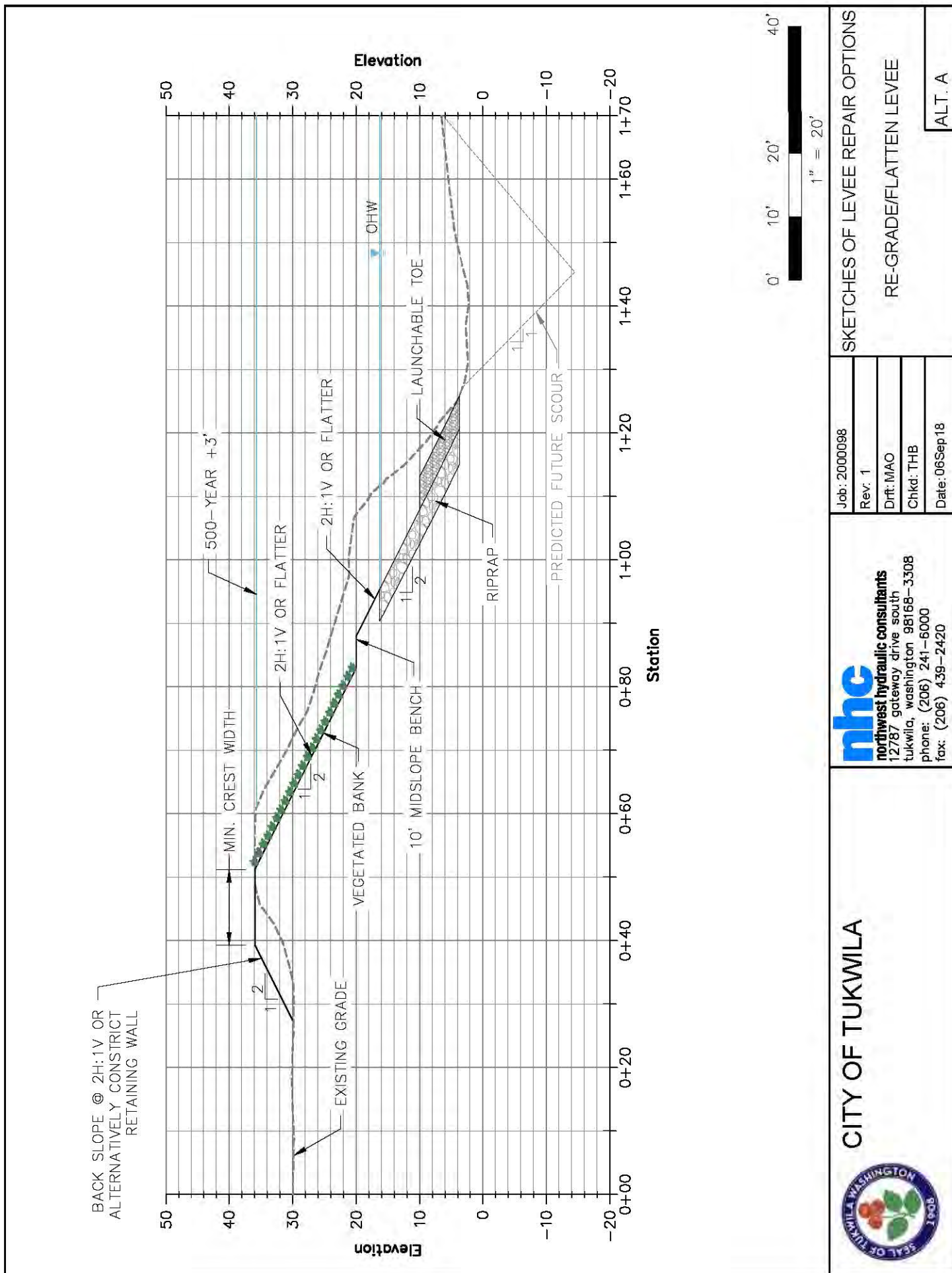
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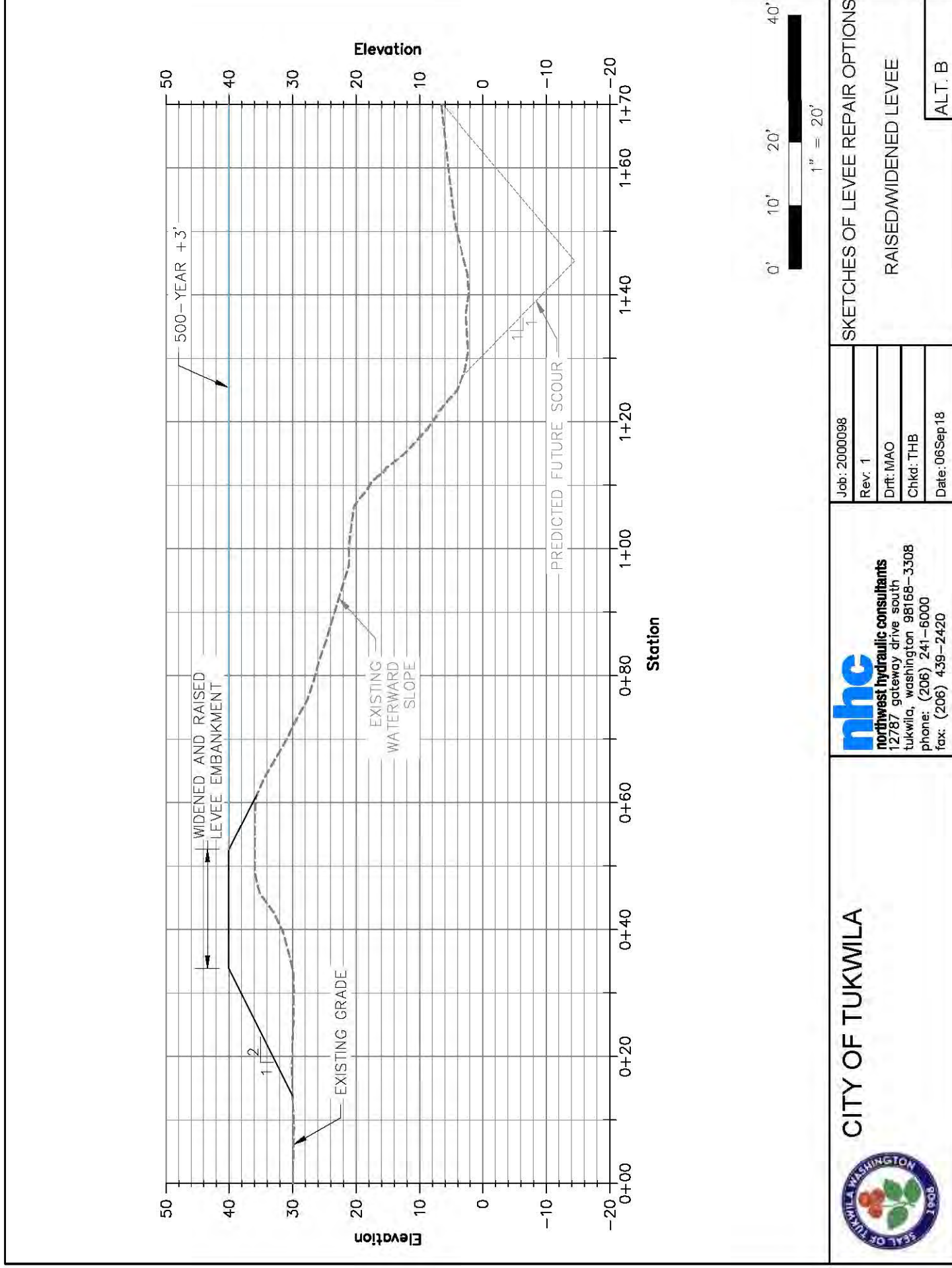
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Appendix A

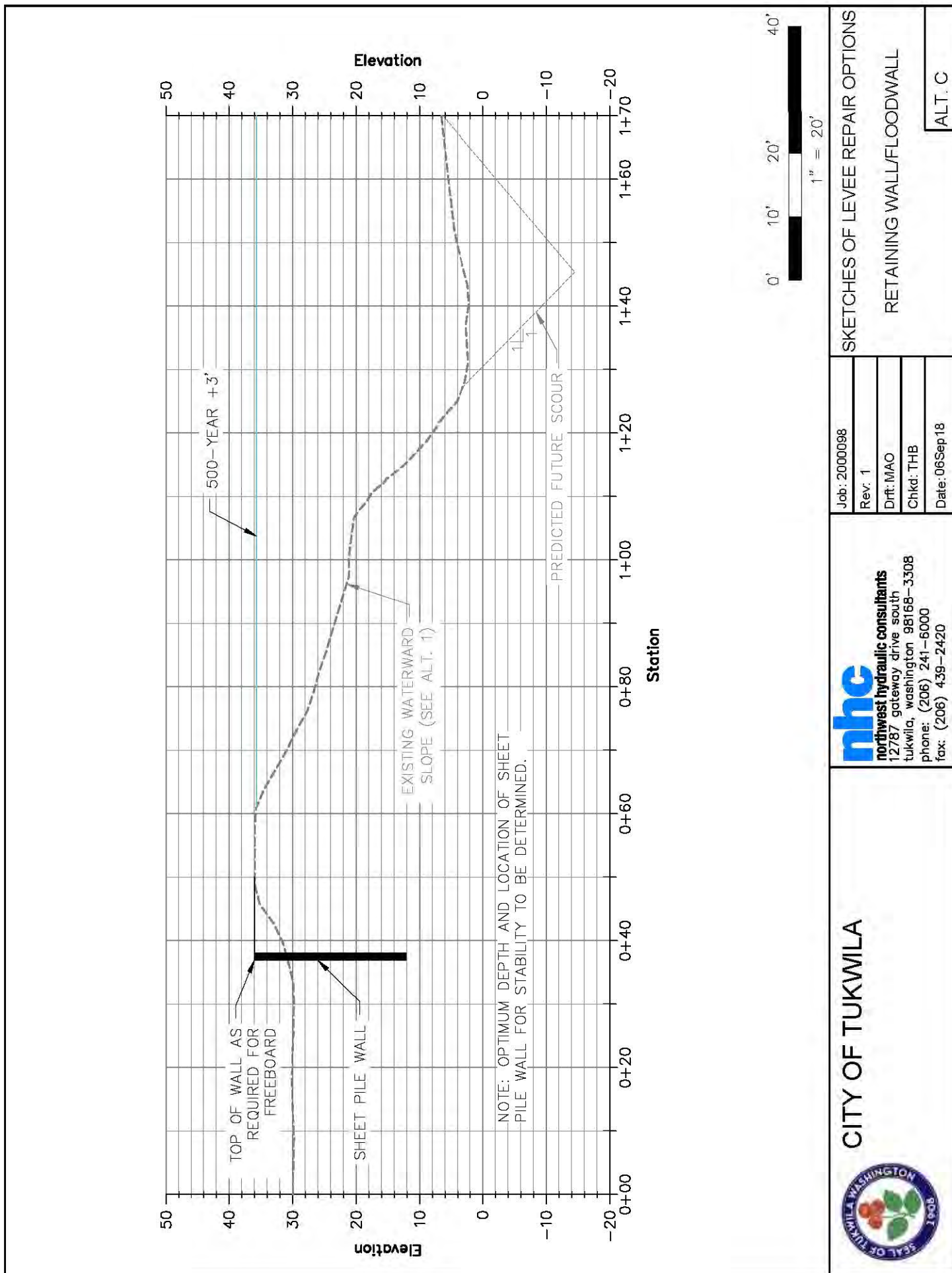
Concept Designs



 CITY OF TUKWILA	 northwest hydraulic consultants 12787 gateway drive south tukwila, washington 98168-3308 phone: (206) 241-6000 fax: (206) 439-2420	Job: 2000098	SKETCHES OF LEVEE REPAIR OPTIONS
		Rev: 1	RE-GRADE/FLATTEN LEVEE
		Drft: MAO	
		Chkd: THB	
		Date: 06Sep18	
			ALT. A



 CITY OF TUKWILA	 northwest hydraulic consultants 12787 gateway drive south tukwila, washington 98168-3308 phone: (206) 241-6000 fax: (206) 439-2420	Job: 2000098	SKETCHES OF LEVEE REPAIR OPTIONS
		Rev: 1	RAISED/WIDENED LEVEE
		Drft: MAO	
		Chkd: THB	
		Date: 06Sep18	
			ALT. B



<p>CITY OF TUKWILA</p>	<p>northwest hydraulic consultants 12787 gateway drive south tukwila, washington 98168-3308 phone: (206) 241-6000 fax: (206) 439-2420</p>	Job: 2000098 Rev: 1 Dwf: MAO Chkd: THB Date: 06Sep18	SKETCHES OF LEVEE REPAIR OPTIONS RETAINING WALL/FLOODWALL
		ALT. C	