Revised Draft

ENGINEERING ANALYSIS OF LEVEE ALTERNATIVES

Skagit River Bridge Modification and Interstate Highway Protection Project

September 2008

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Prepared for

Skagit County Department of Public Works

September 2008

Prepared by

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Engineering Analysis of Levee Alternatives

DRAFT

Skagit River Bridge Modification and Interstate Highway Protection Project

Engineering Analysis of Levee Alternatives

1.0 INTRODUCTION

The Skagit River is subject to extensive property and highway damage during major flood events. Although major floods are generally infrequent, three major events have occurred in the past 18 years. Studies (1) have shown that a 100-year flood event would cause nearly $1 billion in damage to the basin and would shut down Interstate 5 for approximately 15 miles.

As the lower Skagit River Basin developed, low levees were constructed to protect the very productive farm lands in the lower basin. Over the years, these levees were increased in size to provide a greater degree of protection to the farm lands and to the rapidly growing urban areas around Mount Vernon and Burlington. Today, levees on the north side of the river extend from upstream of Burlington to the mouth of the Skagit River near La Conner. On the south side of the river, the levees extend from the Burlington Northern Santa Fe railroad bridge in Mount Vernon to the mouth. Figure 1 shows the lower Skagit River Basin and the location of these levees in the vicinity of the study area.

The flood risk to the lower Skagit River Basin has been widely recognized and efforts have been underway for many years to develop a cost effective plan for preventing flood damages. The U. S. Army Corps of Engineers (Corps) and Skagit County have been deeply involved in the preparation of a flood control plan for the past 10 years and a draft plan is expected to be available within the next few years. Although a number of alternatives are still on the table and being investigated, virtually all alternatives include plans for improving the levees that are located in the corridor between Mount Vernon and Burlington. This area, historically called the "Three Bridge Corridor", is a significant pinch point in the levee system as shown in Figure 1. The three bridges in this reach of the river are the Interstate 5 Bridge, the Riverside Bridge, and the Burlington Northern Santa Fe (BNSF) railroad bridge.

The levee reach being studied in this project is from just upstream of the BNSF railroad bridge to just downstream of the Mount Vernon and Burlington city boundaries, a distance of about 1.2 miles. The scope of the project is to look at ways to improve the system of levees in this reach but does not include modification of the three bridges or the approaches to the bridges. It is assumed that the bridge related improvements, if needed, will be included in the much larger General Investigation of the Skagit River now being undertaken by the Corps and Skagit County.

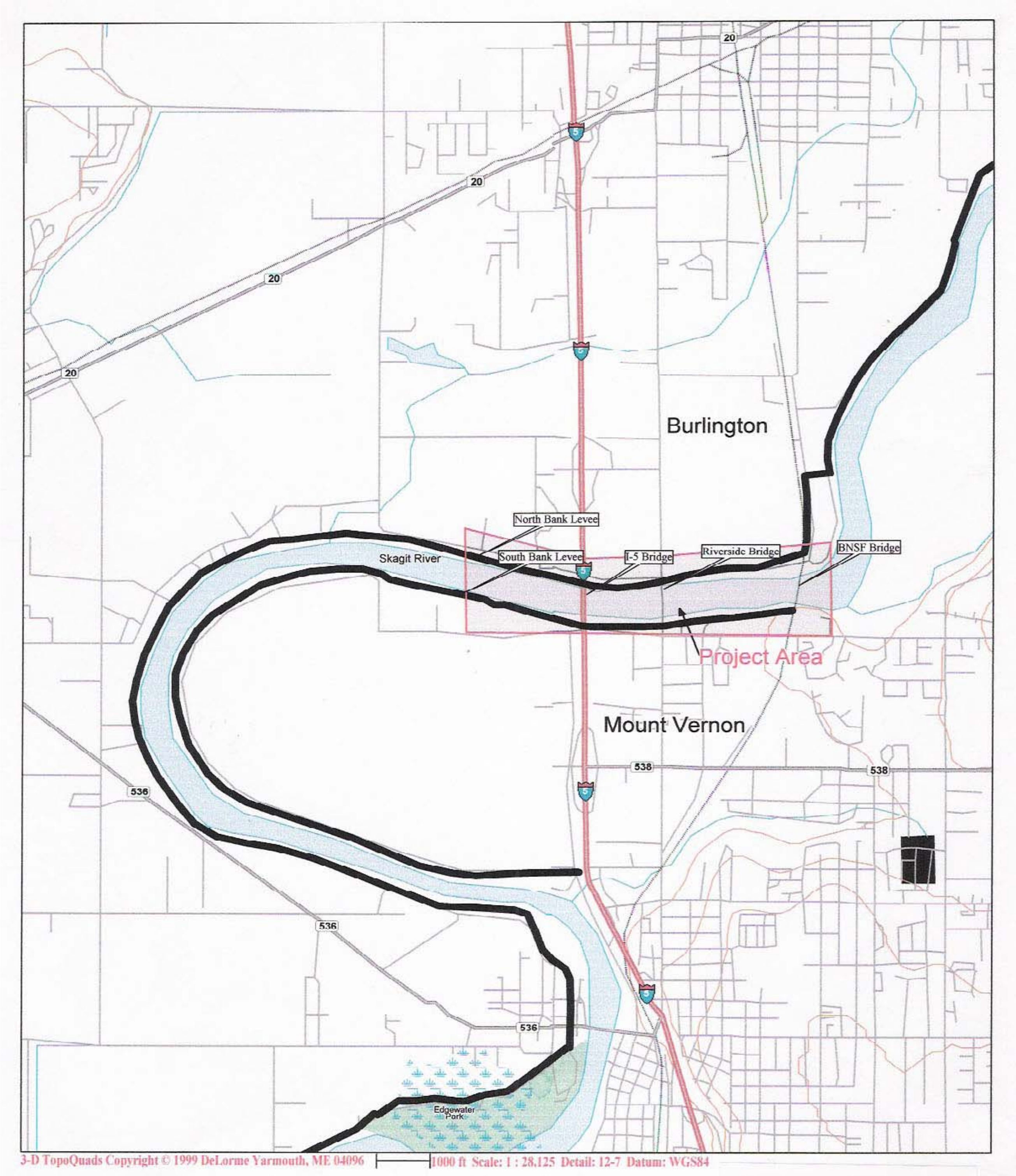

Figure 1 Vicinity Map

Three general alternatives will be described and evaluated in this report:

- The No-Action Alternative – This alternative assumes that the levees will be maintained in their present configuration and that only maintenance activities will occur in the future.

- An Improved Existing Levee Alternative – In this alternative, it is assumed that the levees will be raised modestly, improved structurally, but will remain in their current location.

- The Setback Levee Alternative – This alternative envisions new levees that will be set back from the river and raised to the maximum extent practicable. Two variations in design height will be evaluated.

2.0 NO ACTION ALTERNATIVE

2.1 Description

As inferred from the title, this alternative assumes that the existing levees will remain in their current configuration and that no significant improvements will occur in the future. The locations of the levees are presented in Figure 2. The River Mile designations are taken from the most recent Corps of Engineers Hydrology and Hydraulics reports (2, 3).

2.1.1 Left Bank Levee

The existing south bank (left) levee begins at the high ground at the BNSF railroad bridge and ties into the abutment of the bridge. Although some erosion of the south bank of the river has occurred upstream of the BNSF bridge, the abutment is founded on very hard material and no erosion has occurred at the bridge abutment. Downstream of the bridge, the levee is located fairly close to the edge of the river and there is only a very small overbank area between the levee and edge of the river at low flows. A typical cross section of the levee in this location is shown in Figure 3a. Also shown is the normal high water surface elevation that corresponds to the 2-year flood event, about 80,000 cfs. The levee crests have not been surveyed recently so the elevations are approximate but are assumed to be within about a foot of the actual elevations. All elevations are based upon the 1929 NAVD datum.

At the Riverside Bridge, the left bank levee ties into the abutment of the bridge and the areas underneath of the bridge are fully rip-rapped. The existing levee is approximately 2 feet lower than the low chord of the bridge as it meets the abutment. A cross section of the levee at the bridge abutment is shown in Figure 3b.

West of the Riverside Bridge, the left bank levee parallels a stormwater drainage pond that was constructed to handle runoff from the bridge when it was constructed in 2004. As shown in Figure 3c, the stormwater pond embankment ties into the existing left bank levee. The levee parallels the pond for a distance of approximately 900 feet.

West of the pond, the levee passes underneath of the I-5 Bridge and continues westward. Although two of the piers from the bridge are located within the levee prism, as shown in Figure 3d, the bridge clears the levee crest by approximately 10 to 12 feet. Stewart Road lies just south of the levee in this location and also passes under the I-5 Bridge approach span.

Throughout much of the length of the left bank levee within the project reach, the toe of the bank has been rip-rapped. In most cases, the rip rap is not part of the levee itself but protects the bank riverward of the levee from erosion. Except under the three bridges, there does not appear to be rip rap on the levees themselves.

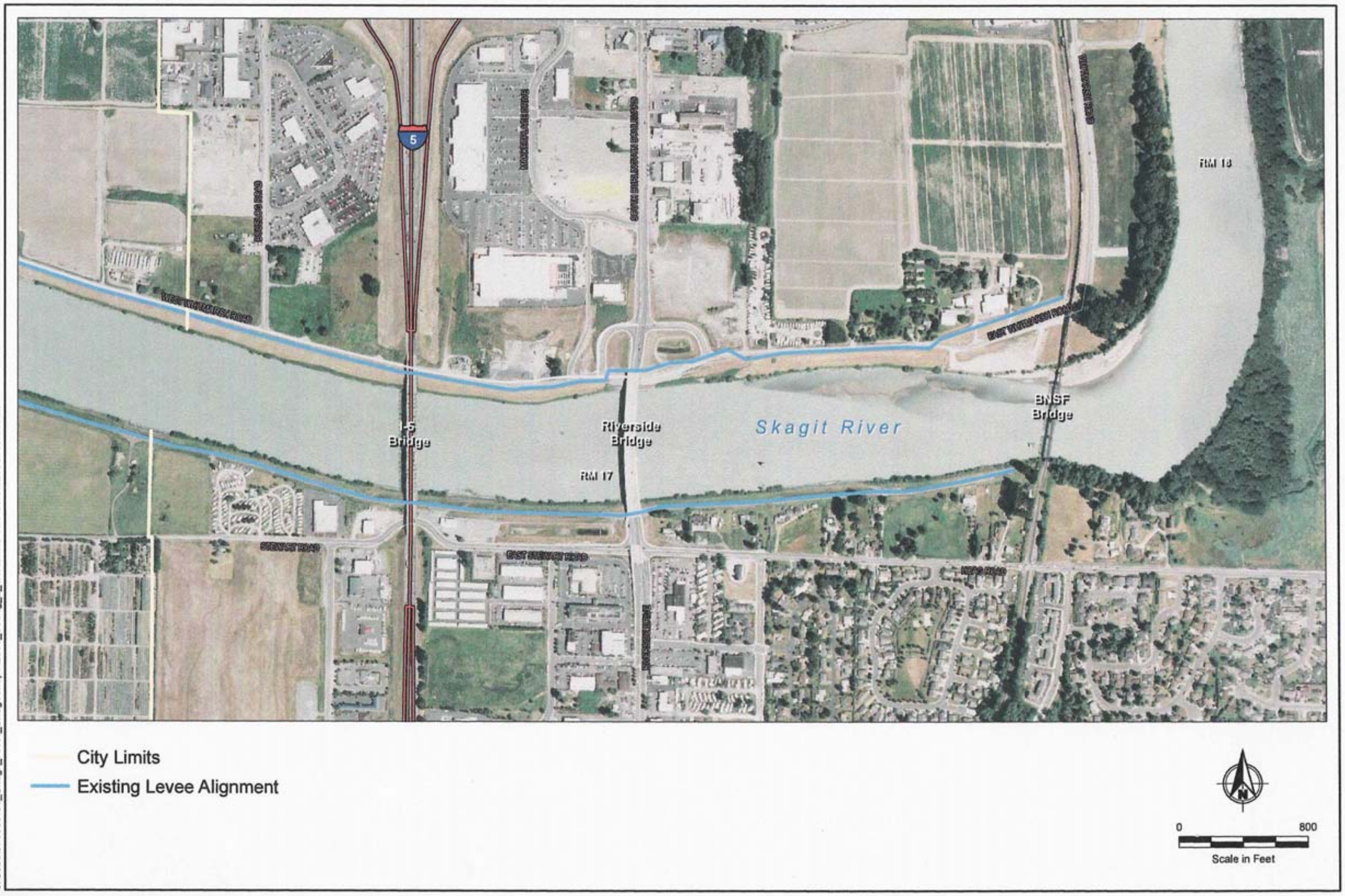

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Figure 2
No Action Alternative
Skagit River Bridge Modification and
Interstate Highway Protection Project

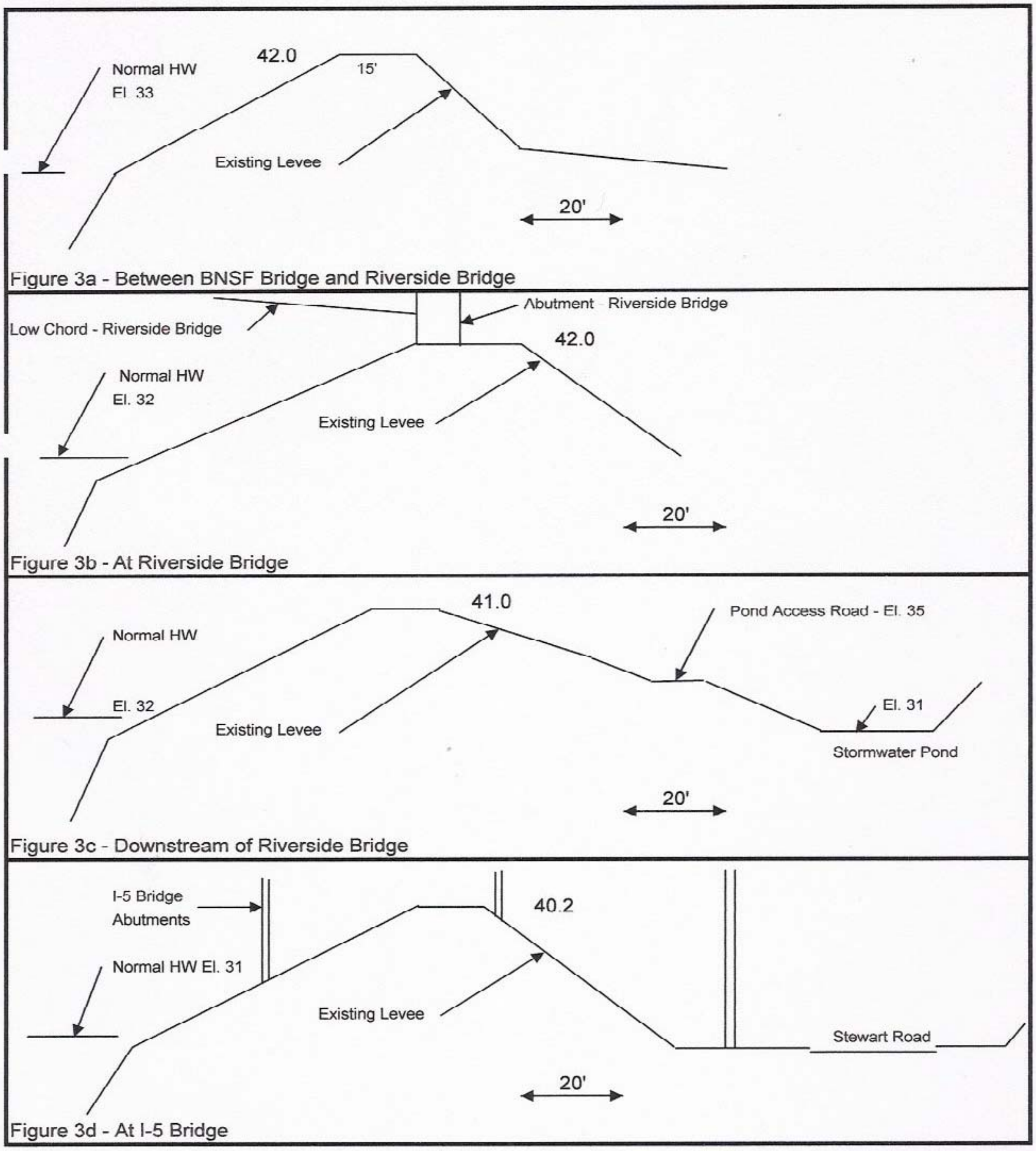

Figure 3a - Between BNSF Bridge and Riverside Bridge

Figure 3b - At Riverside Bridge

Figure 3c - Downstream of Riverside Bridge

Figure 3d - At I-5 Bridge

Figure 3 - Left Bank Levee Sections - No Action Alternative

2.1.2 Right Bank Levee

The existing north bank, right, levee is quite similar to the south bank levee except that it is paralleled throughout the reach by Whitmarsh Road. Upstream of the BNSF railroad bridge, the levee is contiguous to the railroad embankment and serves as a levee for a distance of approximately 1,600 feet.

Just upstream of the BNSF Bridge, a small levee exists adjacent to the waters edge. This levee is not maintained, covered with vegetation, and has a height of only 4 or 5 feet. Except at very low flows, it does not appear to impact flow conveyance. However, it may direct flows away from the overbank area adjacent to the bridge at nearly all flow levels.

The north end of the BNSF Bridge is a trestle section with 7 piers within the overbank area. These piers impair flows during flood events and during the 1995 flood event scour caused one of the piers to settle several feet, forcing closure of the rail line for several days.

Between the railroad bridge and the Riverside Bridge, the levee is integral with East Whitmarsh Road in many locations and crosses over the levee approximately 900 feet west of the railroad bridge and again just upstream of the Riverside Bridge. Consequently, Whitmarsh Road is closed to traffic during moderate to extreme flood events. Figure 4a shows typical levee cross sections in this area.

Whitmarsh Road passes under the Riverside Bridge adjacent to the river and a stormwater pond that handles runoff from the north end of Riverside Bridge. Although the crest elevation of the levee is maintained in this area, it is somewhat discontinuous as it traverses around the road, the pond, and the bridge abutment. Figure 4b shows a cross section of the levee at the pond/bridge interface.

The USGS stream gauging station *Skagit River at Mount Vernon* is located just downstream of the Riverside Bridge. Its cableway for flow measurements is a few hundred feet further downstream.

West of the Riverside Bridge, Whitmarsh Road is immediately north of the levee and tends to constrain the extent of the levee, forcing steep side slopes and limiting levee improvements in this area. See Figure 4c for a typical levee section in this area.

Whitmarsh Road and the levee both pass under the I-5 Bridge approach section. Road clearance is greater than 16 feet and the levee crest is approximately 10 feet lower than the low chord of the bridge. West of the I-5 Bridge, the levee and Whitmarsh Road parallel each other and the cross section is similar to the section shown in Figure 4c.

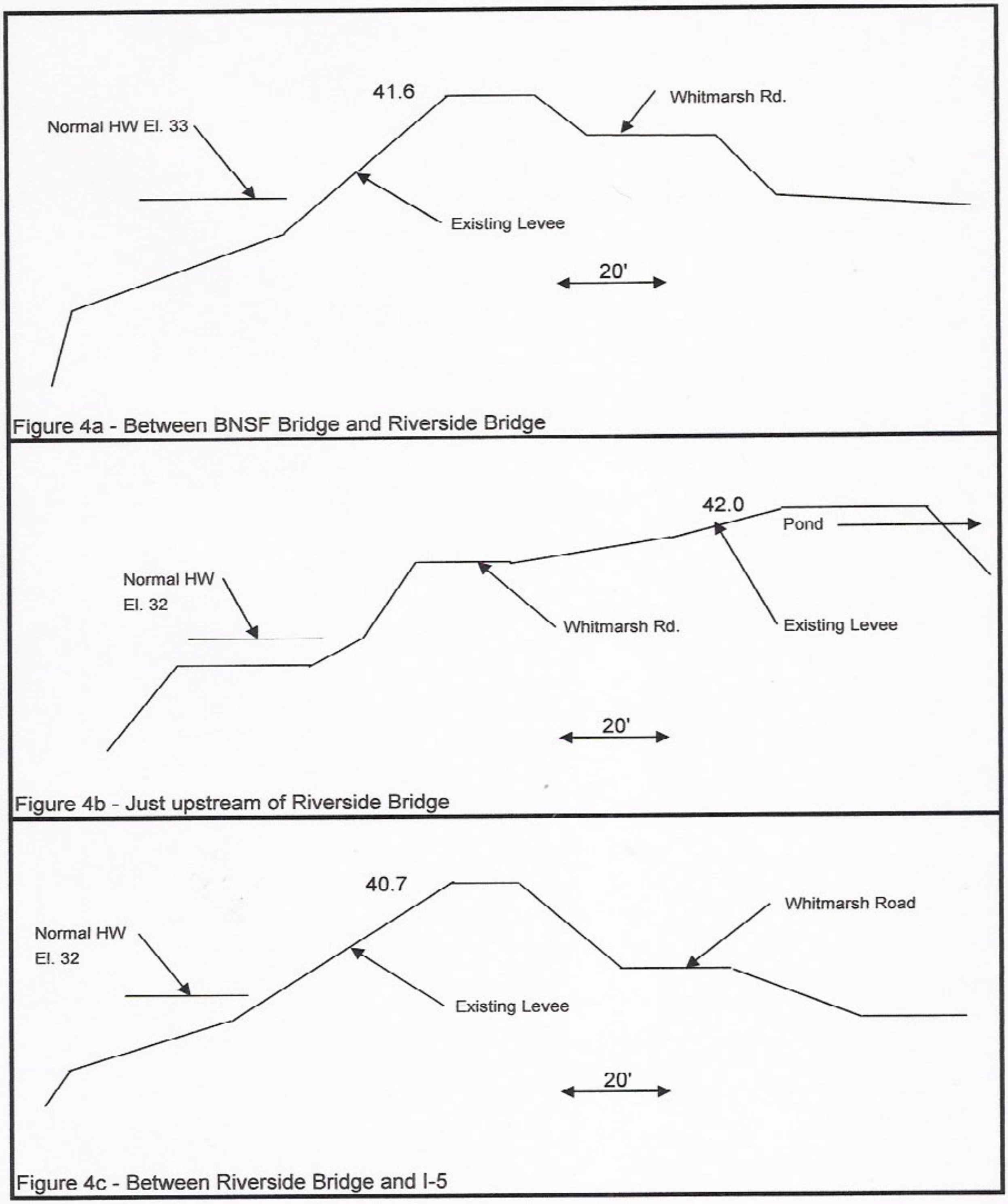

Figure 4 - Right Bank Levee Sections - No Action Alternative

Similar to the left bank levee, rip rap has been placed within the toe of the river bank. The rip rap reduces the erosion potential of the river bank but is seldom actually part of the levee section except at the bridge crossings.

2.2 Hydraulic Analysis

The section of Skagit River levees covered in this project are currently being studied by the Corps of Engineers as part of its General Investigation (GI) currently expected to be completed in about two more years. It has been anticipated that the preliminary results from the hydrologic investigations as part of the GI study would be used in this project analysis. Each alternative being considered here, for instance, would be modeled hydraulically to determine each ones impact on river flows. However, due to a number of factors, the hydrologic analyses that have been completed to date are now being revised and can not be relied upon at this time. Consequently, the analyses that will be presented in this report are based upon an analysis of hydrology and hydraulics reports (2, 3) that are currently available. These reports, for example, deal only with current conditions and do not reflect an analysis of proposed alternatives. The analysis presented in the current report reflects a cursory assessment of the existing reports and data and should be considered preliminary. It is expected that a more detailed analysis will be prepared and will supplement the analysis presented in this report.

It should also be noted that floods up to and including the 100-year flood will be analyzed in this report. Larger floods, such as the 250- and 500-year floods, are analyzed in the Corps reports (2, 3) but because of their magnitude and extent of flooding it is virtually impossible to analyze without the use of detailed computer models. And even those models rely heavily on input that predicts exactly where levees may fail, a highly speculative endeavor at best.

In the No-Action Alternative, there will be no change in flows in the Skagit River if this alternative is selected. Consequently, flows will remain as they are at the present and the Corps of Engineers Hydrology and Hydraulics Reports (2, 3) are utilized to determine the frequency of flooding in this reach of the river.

For purposes of this analysis, it will be assumed that the flow capacity of the river will be based upon the flow level that provides 3 feet of freeboard at the lowest crest of the levees. Figure 5 shows the crest elevation of each levee as taken from the Corps reports as well as the flood elevations for the 2-, 10-, 25-, 50-, and 100-year floods. In addition, the elevations corresponding to the lowest levee crest minus three feet of freeboard is also shown. The figure shows that the 25-year flood is the largest flood that can pass through the reach without encroaching upon the 3-feet of freeboard on the levees.

It should be noted that the Corps has estimated, in the *Hydrology* Report (2), that the 25-year flood at the USGS Mount Vernon gage is 146,000 cfs. However, when flows reach this quantity, flows begin to leave the river upstream of the existing levee system or may overtop some levees unless flood fighting is used to restrain flows to the river.

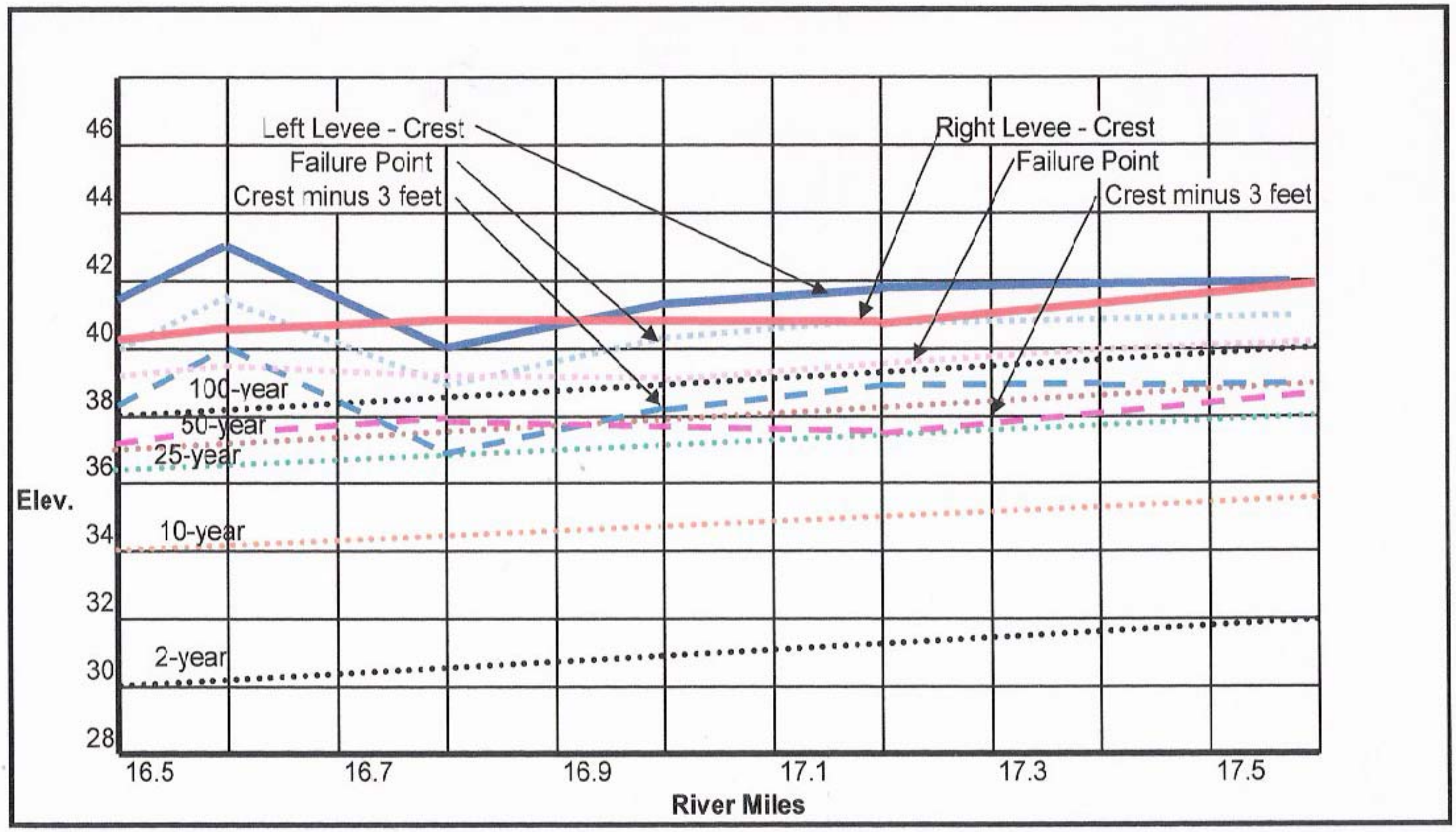

Figure 5 - Levee Crest Elevations and Flood Profiles - Existing Conditions

Consequently, the modeled flows in the Corps *Hydraulics* report (3) for the 25-year flood event are approximately 133,000 cfs as measured at the USGS gage.

As part of the Corps of Engineers hydraulics analysis (3), it makes estimates about when various existing levees may fail when the water level approaches the tops of the levees. It should be noted that none of the levees in this reach are “likely” to fail at flows up to and including the 100-year flood. In other words, there is less than a 50 percent probability that levees in the study reach would fail at floods smaller than the 100-year event.

2.3 Cost Estimate

Since no improvements are required for the No Action Alternative, there are no capital or maintenance costs.

2.4 Rights of Way

Again, since there will be no changes to the existing levee system, there will be no additional rights of way required.

3.0 IMPROVED EXISTING LEVEE ALTERNATIVE

3.1 Description

The Improved Existing Levee Alternative is designed to provide a higher degree of flood protection but without moving the existing levees or making significant changes to the levees. This can be done by raising the existing levees in their existing locations, the maximum increase in height limited by existing bridges, roadways, and other structures. The analysis that led to the determination of the probable crest elevations for this alternative *Technical Memorandum, Alternative Levee Designs,* is included as Appendix A.

As described in the Technical Memorandum, the most southerly girder of the newly constructed Riverside Bridge is the controlling elevation for raising the levees in this reach of the river. Assuming that three feet of freeboard is desired, the maximum water surface elevation at the Riverside Bridge will be 41.0 feet and the maximum levee crest elevation will be 44.0 feet. Using Corps of Engineers model runs (3), the slope of the river in this reach during major floods is estimated to be 0.00032 and the design crest elevations of the improved existing levees will be as shown in Table 1.

Table 1
Design Water Surface Elevations and Levee Crests

Location	Design Water Surface Elevation (NAVD)	Design Levee Crest Elevation (NAVD)
River Mile 16.50 (City Limits)	39.9	42.9
River Mile 16.80 (Interstate 5 Bridge)	40.5	43.5
River Mile 17.07 (Riverside Bridge)	41.0	44.0
River Mile 17.56 (BNSF Bridge)	41.8	44.8

It should be noted that the BNSF Bridge is actually the more constraining bridge in this reach if adequate freeboard is desired. In addition, the number and size of the piers cause considerable backwater. Even if the bridge were to be replaced as studied by Skagit County (4), the low chord elevations cannot be corrected unless the railroad grades are raised and this would require that the track elevations be raised for a considerable distance north and south of the bridge. This could be difficult and/or very expensive.

The existing levees have been constructed over many years, beginning with very simple farm levees in the late 1800’s. The composition of the levees is not completely known or documented and the side slope of the levees varies throughout the reach. For levees of the height planned for this project, side slopes could vary between 2:1 and about 5:1. A detailed geotechnical investigation will be necessary during the final design of the project to select the materials to be used in the levees and the final side slopes.

For purposes of this project, it is assumed that the levee will have a top width of 15 feet and normal side slopes of 3:1. This will allow steeper side slopes of 2:1 and 4:1 where one side of the levee may be limited by existing structures, roads, or the river bank. Potential limitations and side slopes at various locations will be described in the following paragraphs. In general, the crest of the levees will be increased approximately 2 feet above their existing elevations. Also, it may be desirable to keep all improvements to the levees above the normal high water levels of the Skagit River. According to the hydraulics reports (3) prepared by the Corps of Engineers, this elevation, the 2-year flood, is approximately 30 to 33 feet NAVD within this reach. In addition, where possible, a distance of 20 feet will be maintained on the landward side of the levee for maintenance purposes.

The Improve Existing Levee Plan is shown on Figure 6.

3.1.1 Improved Left Bank Levee

The existing levee between the BNSF Bridge and the Riverside Bridge is fairly consistent in that the levee is located fairly close to the rivers edge and side slopes are generally similar throughout. As shown on Figure 7a, the levee can be improved and raised to the design height without encroaching on the normal high water elevation (approximately 33). However, in much of this reach it may be necessary to purchase some additional rights of way in order to obtain the 3:1 side slopes desired. Dike District 17 does own some of the needed properties or has obtained options to purchase others.

Just downstream of the Riverside Bridge, the levee is adjacent to an existing stormwater pond that will remain intact as part of this alternative. However, as shown in Figure 7b, the levee can be raised to the desired height without encroaching upon the stormwater pond or the normal high water elevation.

West of the stormwater pond to the I-5 Bridge, the levee returns to a more normal configuration as shown on Figure 7c. The toe of the landward side levee will be close to the existing Dike District 17 maintenance building but there appears to be adequate clearance to allow approximately 20 feet for maintenance of the levee. Underneath of the I-5 Bridge, clearance between the bridge and the levee crest will be reduced by about 2 feet. However, there still should be sufficient clearance for small maintenance vehicles to pass under the bridge as shown in Figure 7c.

West of the I-5 Bridge, there should sufficient area to allow the improved levee to be constructed above normal high water although it will require that some additional rights of way be obtained on the landward side of the levee. A typical cross section of the levee is shown on Figure 7d. At the west end of the improved levee, an existing drainage pump station is located on the levee and may need to be relocated or modified. This will be researched further.

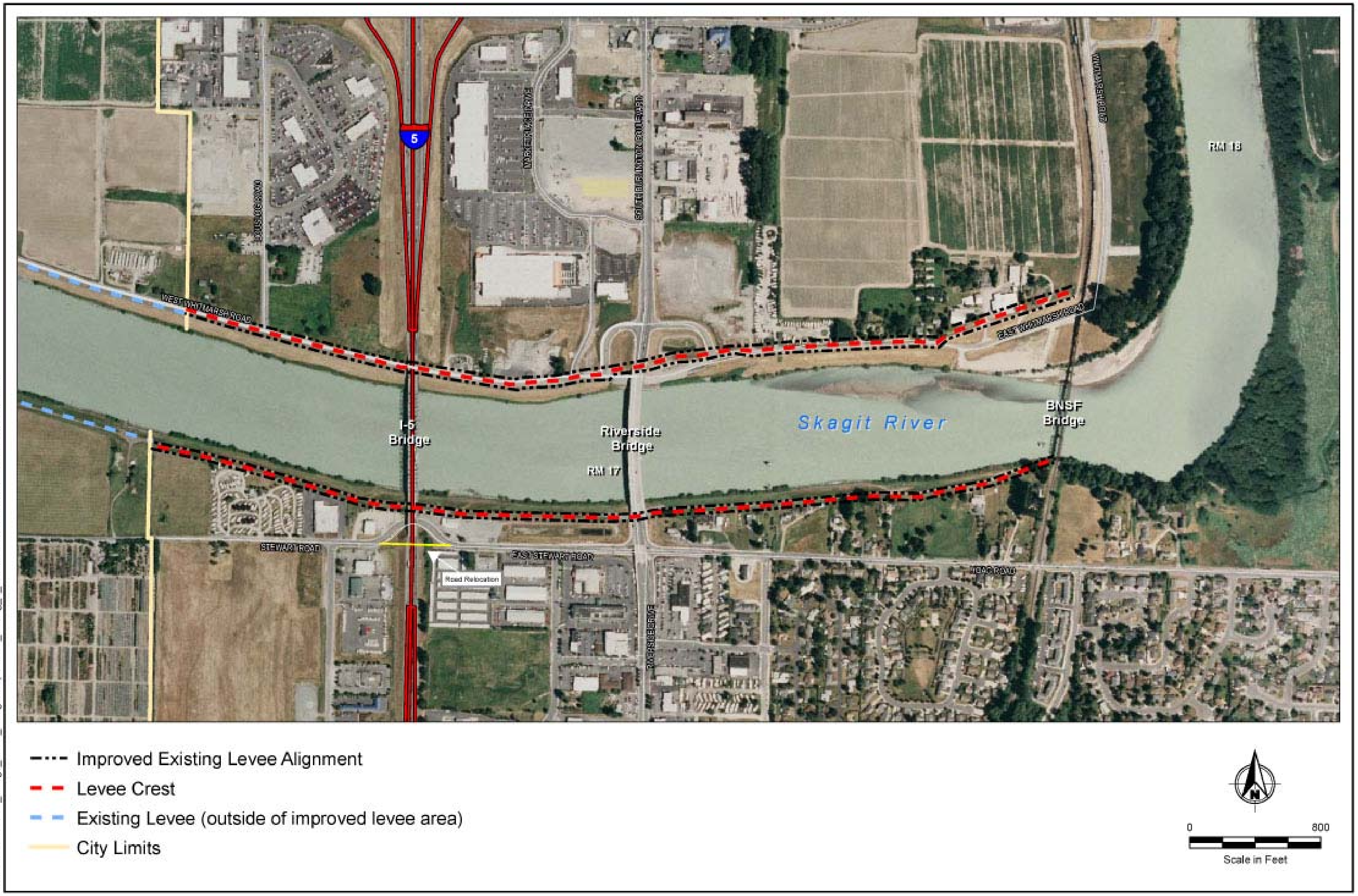

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Figure 6
Improved Existing Levee Alignment Alternative
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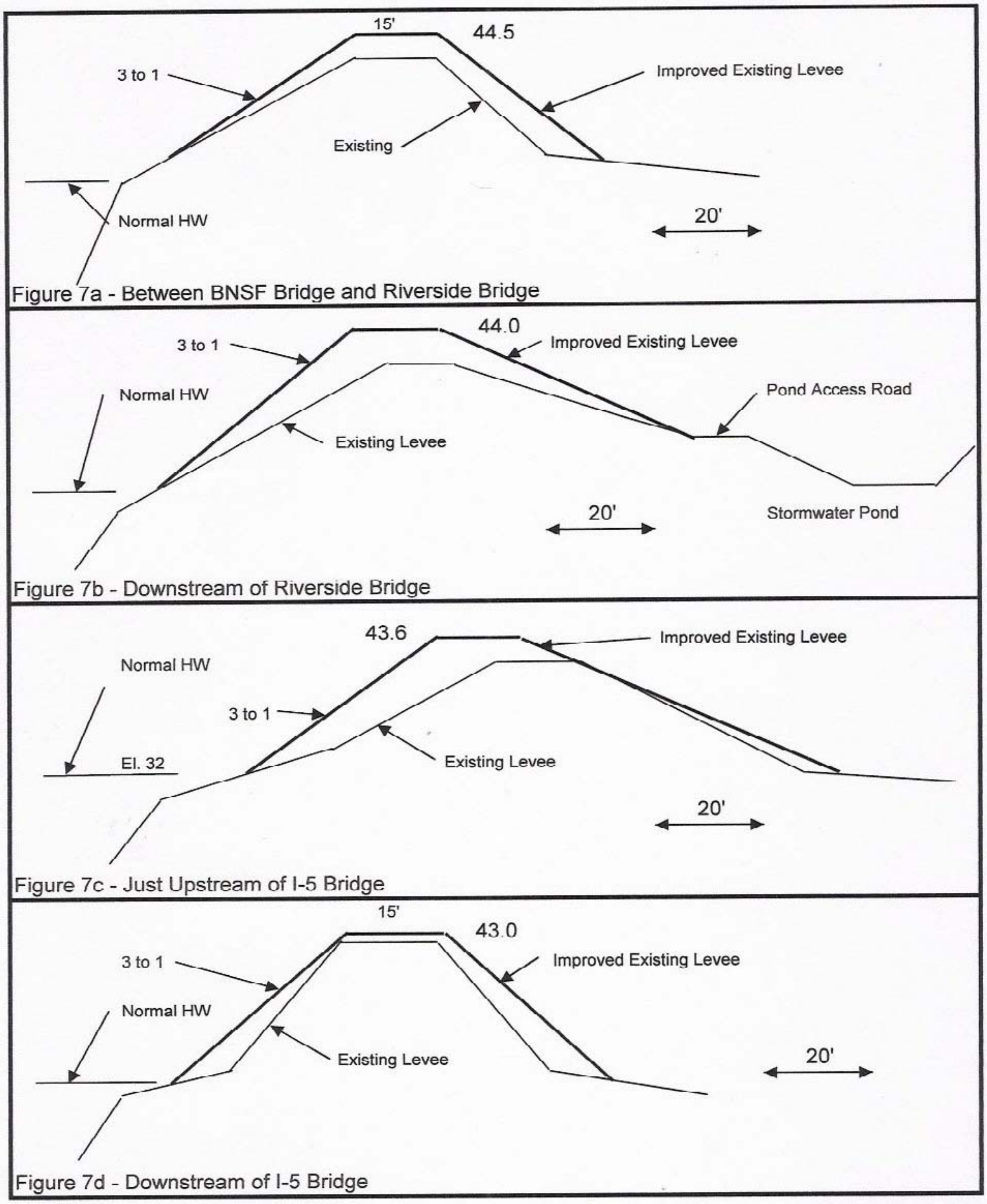

Figure 7a - Between BNSF Bridge and Riverside Bridge

Figure 7b - Downstream of Riverside Bridge

Figure 7c - Just Upstream of I-5 Bridge

Figure 7d - Downstream of I-5 Bridge

Figure 7 - Left Bank Levee Sections - Improved Existing Levee Alternative

3.1.2 Improved Right Bank Levee

Improving the Right Bank Levee in the area between the BNSF Bridge and the Riverside Bridge will require a close integration with East Whitmarsh Road. As shown on Figure 8a, the levee just west of the BNSF Bridge can be modified without any change to the road or the need to obtain additional rights of way.

Approximately half way between the bridges, Whitmarsh Road crosses over the existing levee. If the levee is increased in height, about 2 feet, the road grade will have to be raised for about 150 feet on each side of the levee. Since the existing levee is currently set back about 50 feet from the edge of the river bank, the levee can be modified on the river side without encroaching on the river as shown in Figure 8b. However, some construction within the normal high water limits may be necessary unless the alignment of West Whitmarsh is modified.

In the vicinity of the Riverside Bridge, the roadway passes through the levee prism twice. In each case, it is relatively simple to increase the road and levee profiles to allow the levee to be raised. Figure 8c shows the improved configuration of the levee and road in this area. However, construction within the normal high water limits does not seem to be necessary at this location.

West of the Riverside Bridge, the modifications to the levee to allow it to be raised are limited by the location of Whitmarsh Road that is located at the landward toe of the levee. Fortunately, the existing levee is setback slightly from the rivers edge such that the levee can be modified as shown in Figure 8d without encroaching upon the normal high water limits. Maintenance vehicles will still be able to traverse the top of the levee under I-5 though the clearance will be slightly less than at current.

3.2 Hydraulic Analysis

The Corps of Engineers Hydrology and Hydraulics Reports (2, 3)have been used to estimate the flow and frequency for the river under this alternative. Figure 9 shows the levee profiles under this alternative as well as the 2-, 10-, 25-, 50-, and 100-year flood levels as taken from the Corps reports. Also shown is the levee crest profile minus the 3-feet of freeboard. The figure shows that the improved levee system can not only pass the 100-year flood but also all flows up to the 500-year flood (not shown). This occurs because as flow levels increase, upstream levees are overtopped and breached and water flows leave the river upstream of the existing levees.

To understand the amount of flows leaving the system, Table 2 has been prepared to show the flows at the level of the Mount Vernon gage, as taken from the Corps *Hydrology Report* (2), and the actual in-channel flows passing the gage as taken from the Corps *Hydraulics Report* (3).

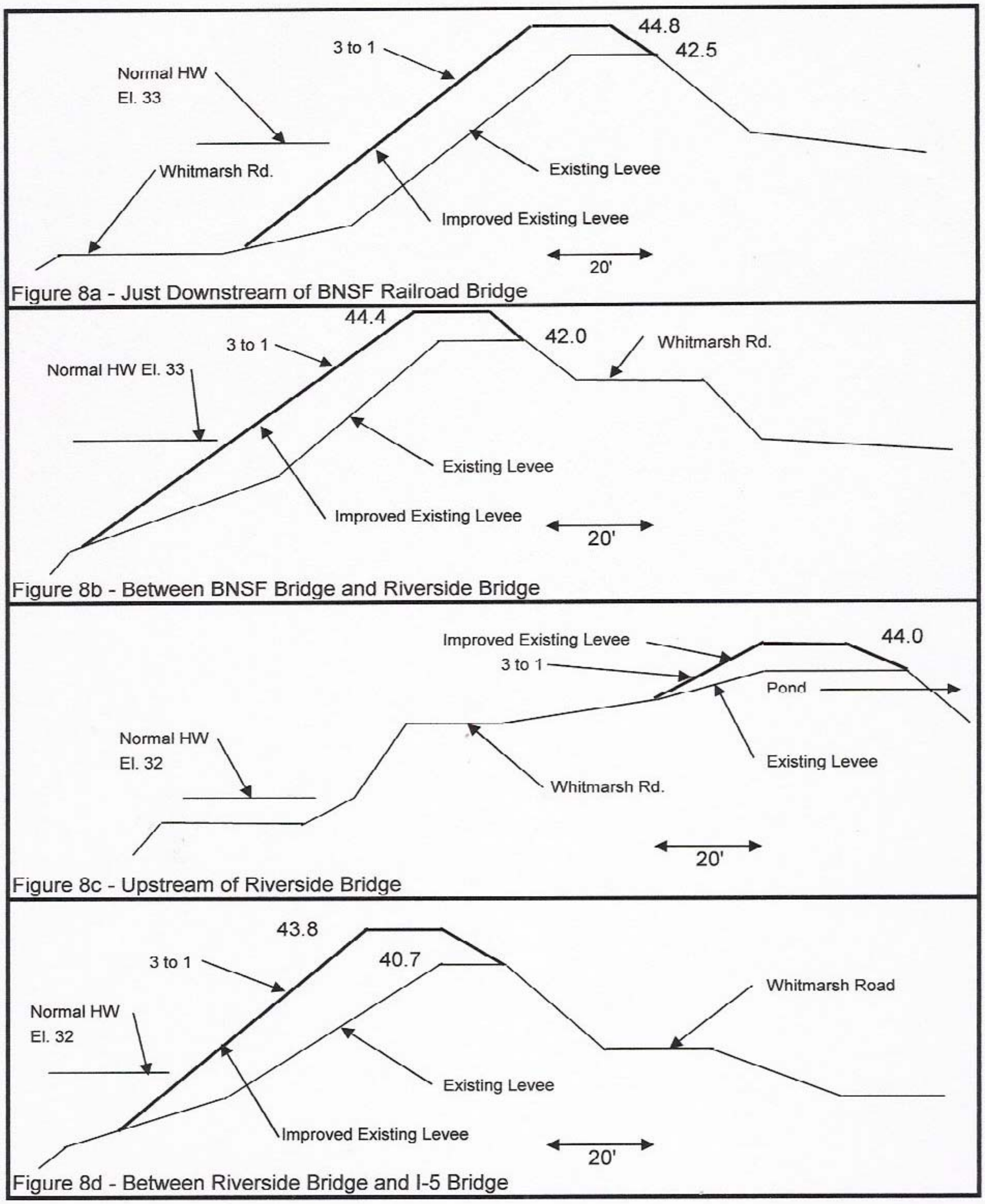

Figure 8 - Right Bank Levee Sections - Improved Existing Levee Alternative

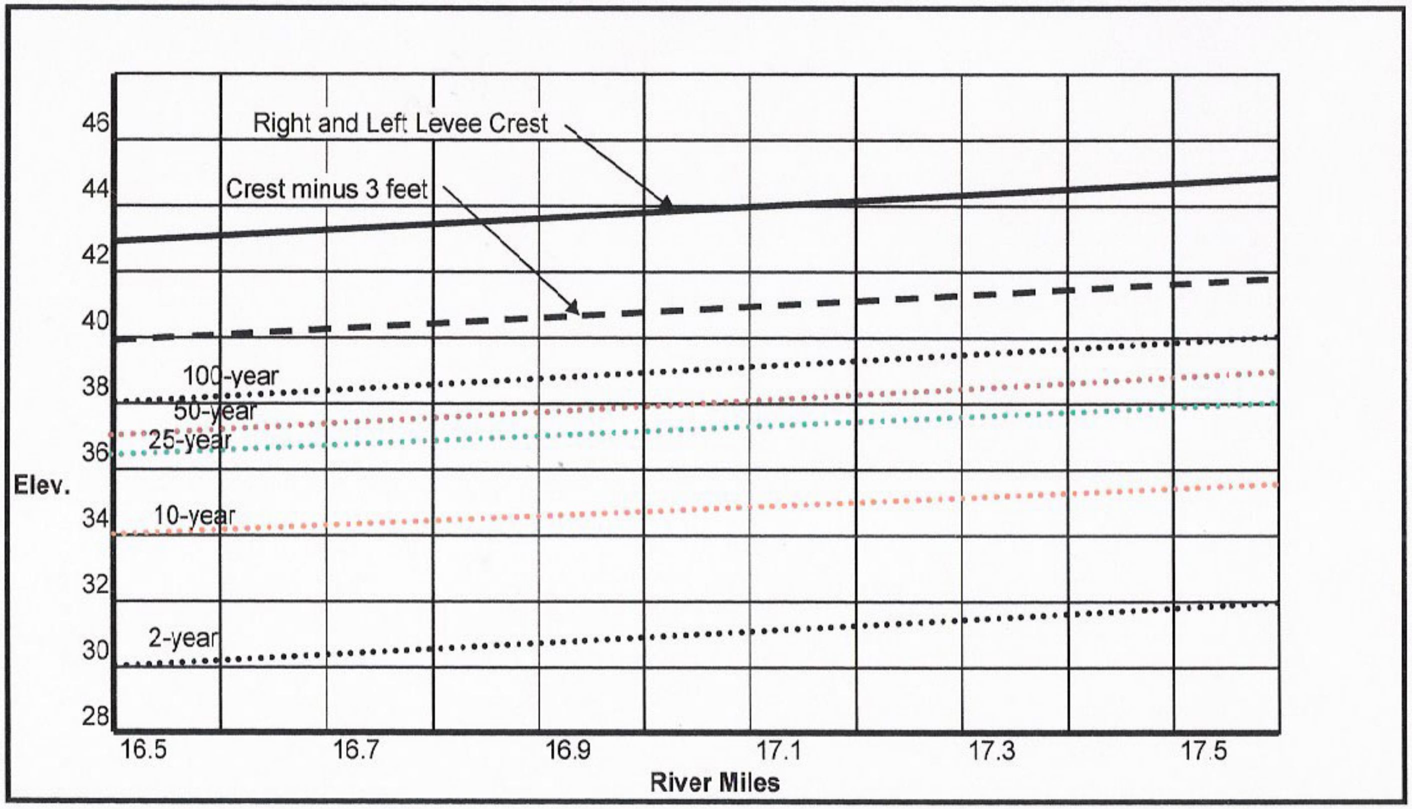

Figure 9 - Levee Crest Elevations and Flood Profiles - Improved Existing Levee Alternative

Table 2 **Flows at the USGS Mount Vernon Gage**		
Flow Frequency	**Flows at Level of Gage (1)**	**In Channel Flows at Gage (2)**
2-year	75,700 cfs	
5-year	97,300 cfs	97,300 cfs
10-year	117,000 cfs	117,000 cfs
25-year	146,000 cfs	133,000 cfs
50-year	191,000 cfs	145,000 cfs
75-year	212,000 cfs	153,000 cfs
100-year	230,000 cfs	159,000 cfs

(1) Taken from Table 22 of the 2004 Corps of Engineers Hydrology Report for the Skagit River (2)
(2) Taken from Table 12 of the 2004 Corps of Engineers Hydraulics Report for the Skagit River (3)

The existing analysis appears to lead to the conclusion that if the existing levees are improved and raised to the elevations shown, then they will be capable of passing the 100-year flood event, about 160,000 cfs, with at least 3 feet of freeboard. However, this assumes that the levees upstream of the BNSF Bridge are not raised or extended beyond their existing terminus.

Although the existing levees are not certified at the present time and it may be unlikely that they can be, this alternative assumes that they will be improved and raised such that they could be certified in the future. This assumption is based upon the premise that if this alternative were to be selected for construction, a detailed geotechnical investigation would be conducted during the design phase and the levees would be improved such that they could be certified if desired. The cost estimate presented below reflects these assumptions and includes provisions for making reasonable degrees of improvements to the existing levees.

3.3 Cost Estimate

A detailed cost estimate for this alternative is presented in Appendix B. Costs for the project include direct construction costs, sales tax, rights of way, a 30 percent contingency, and an 18 percent allowance for engineering and administrative costs. The total estimated cost for this alternative is $4,300,000.

3.4 Rights of Way

The cost estimate presented above includes the costs of purchasing rights of way for this alternative as outlined in Appendix B. The only rights of way necessary are on the left bank and have a total estimated cost of $824,000.

4.0 SETBACK LEVEE ALTERNATIVE

There are two potential configurations for this alternative as well as a few optional variations. The main difference between the two configurations is the height of the levee. The first configuration is based upon the low chord elevations of the existing bridges and the hydraulic analysis assumes that flows into the study reach continue to be impacted by upstream overflows due to either the lack of levees or by overtopping levees. These limitations result in an increase in height over the existing levees of approximately 2 feet. The second configuration is based upon levee crest elevations that are independent of the low chord elevations of existing bridges and assume that upstream levee developments allow the full flow of the Skagit River to enter into the study reach. This configuration results in an increase in height of approximately 6 feet over existing levees.

The analysis that led to the adoption of the 2-foot height increase is included in this report as Appendix A. Note that the final alignment of the setback levees is slightly different than presented in Appendix A. However, this has no appreciable change to the analysis.

4.1 Description

The Setback Levee Alternative envisions the construction of mostly new levees that are setback from the existing levees. Although it might be possible to set back the levees almost an infinite distance on each side of the river, the practical limit is set by the level of existing development, existing roads and bridges, and existing development regulations. On the south side of the river, there is extensive development south of Hoag and Stewart Roads. Therefore, these developments tend to limit the areas that can be considered. On the north side, the City of Burlington has a long-standing regulation that has prohibited development within about 600 feet of the river and current developments tend to stop at that point. Consequently, this is a limitation to levee setbacks on the north side of the river that will be honored.

As with the previous alternative, the low chord elevation of the south end of the Riverside Bridge is a potential limitation as to how high levees can be constructed. Consequently, the elevations shown in Table 1 earlier are the same elevations used in the lower elevation option in this alternative. The higher levees being considered are four feet higher than the low option.

In the absence of a detailed geotechnical investigation of levee foundations and the materials to be used in the construction, it will be assumed that levees with side slopes of 3:1 will be used in identifying the construction footprint of the levees. This is the same footprint that would be necessary if the levees were constructed with a 2:1 slope on the water side of the levees and a 4:1 slope on the landward side. All levees are assumed to have a 15-foot wide access road on the crest of the levees and a 20-foot strip of land at the toe of the landward side of the levee for maintenance activities.

The purchase of rights of way for the set back levees is an important financial consideration for this alternative and will be presented later in this chapter.

The location of the proposed setback levees are presented in Figure 10.

4.1.1 Left Bank Setback Levee

The setback levee on the left bank begins approximately 300 feet south of the intersection of the existing levee and the BNSF railroad embankment and angles southwestward towards Hoag Road. It parallels Hoag Road until it is approximately 400 feet east of Riverside Drive at which point it angles back to the intersection of the existing levee and the Riverside Bridge. A typical cross section of the levee in this reach is shown on Figure 11a. Both of the potential levee heights are shown.

At the upstream face of the Riverside Bridge, the limiting elevation is the low chord of the bridge. Consequently, it is necessary to tie the levee into the abutment and it is not possible to move the levee further to the south. In addition, since the bridge will not be modified during this project, a smooth transition between the setback levee and the levee under the bridge is necessary to reduce the potential for scour and erosion. Also, given the geometry and grades of the bridge and adjacent streets, it is likely that it will not be possible to extend the bridge beyond its current abutment location. However, for the higher levee crest option, it will be necessary to build a retaining wall around the abutment to prevent flood waters from reaching the abutment and low chord.

West of the Riverside Bridge, the existing levee adjacent to the existing stormwater pond will be maintained and raised. Since it does not appear possible to extend the Riverside Bridge on the south side of the river, there does not appear to be any significant reason why the stormwater pond should be relocated. The cross section shown previously on Figure 7b is also applicable to this alternative.

Between the west end of the stormwater pond and the I-5 Bridge, the levee will be setback approximately 50 feet and Stewart Road will be realigned to pass under I-5. This realignment allows Stewart Road to pass under a different span of the I-5 approach but does not require any work on I-5 or the bridge. However, new retaining walls will be required on both sides of I-5 adjacent to Stewart Road. Figure 11b shows a cross section of the relocated road and the setback levee.

West of I-5 the levee parallels Stewart Road for approximately 800 feet and once the setback levee reaches a distance of approximately 350 feet from the river, it then parallels the river. The setback levee follows this alignment until it reaches the western city limits of Mount Vernon. At this point, the levee diagonals back towards the river and ties into the existing levee approximately 600 feet downstream. A typical cross section is shown on Figure 11c.

Riprap will be required where the levee passes under each of the bridges. However, virtually all of this riprap will be on new levee that is above the normal high water mark. In addition, the existing levees will be removed down to natural grade but no lower than the normal high water elevation, about 30 feet. It is assumed that all existing riprap will remain in place and be maintained as is currently being done.

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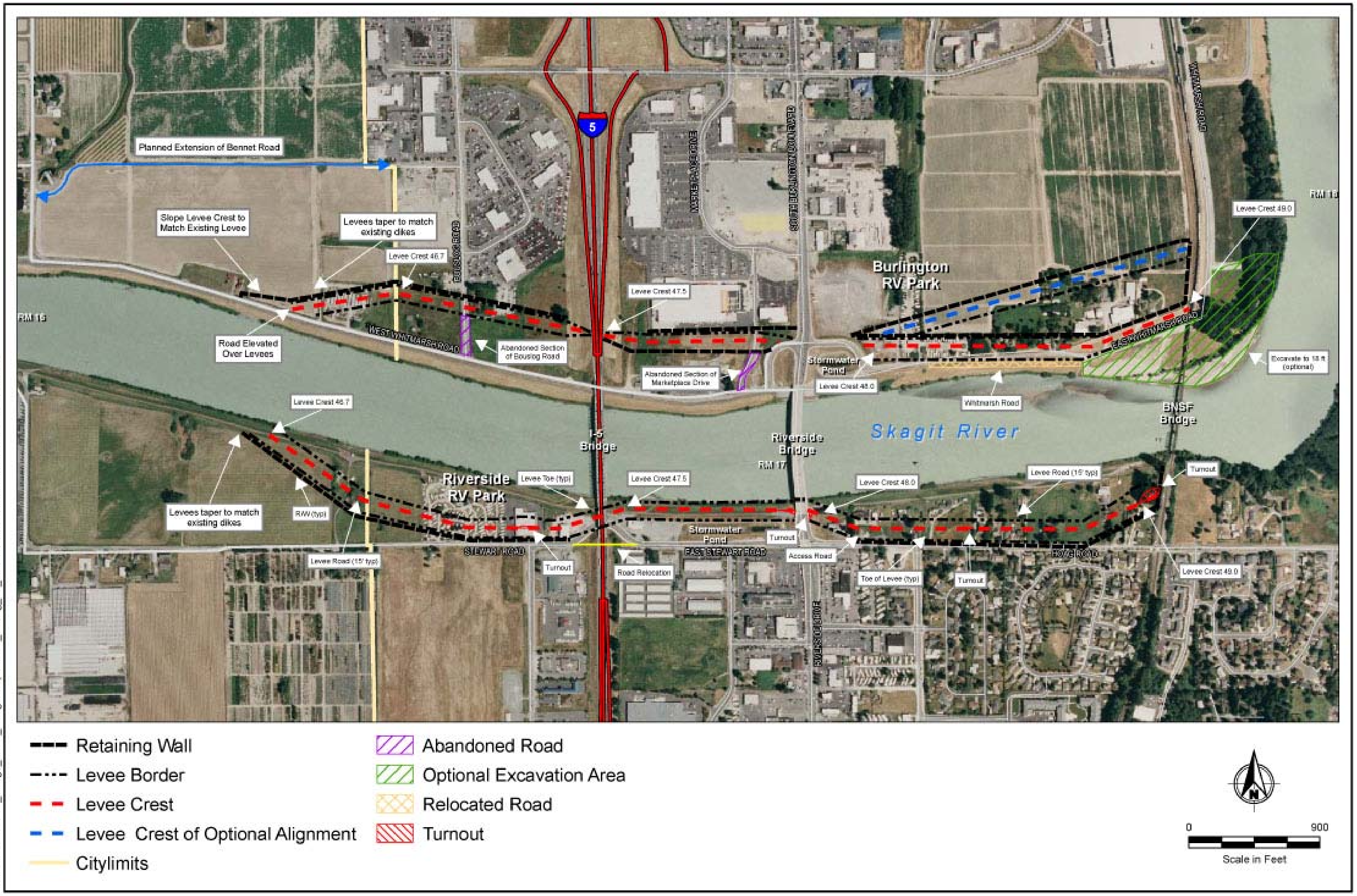


ANCHOR ENVIRONMENTAL, L.L.C.

Figure 10
Levee Setback Alignment Alternative
Skagit River Bridge Modification and
Interstate Highway Protection Project

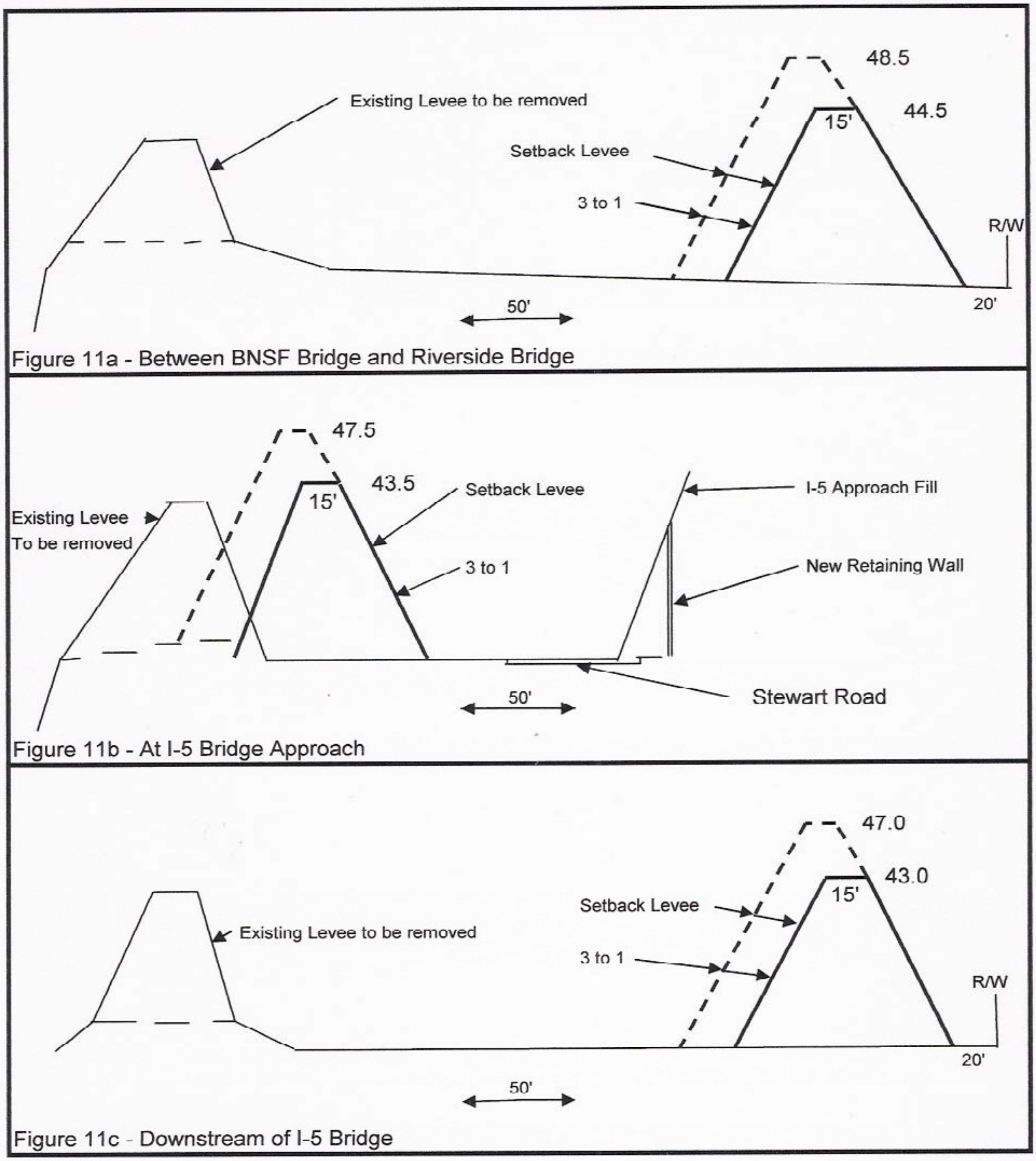


Figure 11a - Between BNSF Bridge and Riverside Bridge

Figure 11b - At I-5 Bridge Approach

Figure 11c - Downstream of I-5 Bridge

Figure 11 - Left Bank Levee Sections - Setback Levee Alternative

Right Bank Setback Levee

The BNSF Bridge and approaches are acknowledged to be a major constriction to the Skagit River in this reach. Unfortunately, the company has shown a great reluctance to even consider improvements to the bridge that might reduce the constriction. In addition, due to the size of the bridge piers and the amount of rip rap that has been placed to minimize scour, dead trees and other debris frequently backs up behind the bridge and causes additional backwater.

Although previous planning has envisioned setting back the levees just downstream of the BNSF bridge several hundred feet, this may do little good if BNSF is unwilling to consider modifying the bridge and its abutment. Consequently, it appears to be more effective to leave the existing levees just downstream of the railroad where they are at the present time and improve the conveyance on the north side of the river. Figure 10 shows a possible plan for grading to improve flow characteristics of this area. Note that this plan assumes that the piles under existing BNSF trestle sections can be lengthened to prevent scour as more water passes through this area.

Beginning about 600 feet downstream of the bridge, the levee can be setback as shown on Figure 10. The setback levee will allow East Whitmarsh Road to be relocated off of the top of the existing levee and located on the water side of the levee. Figure 12a shows a cross section of the new levee and relocated road. Much of the existing levee in this area will be removed.

Since the Riverside Bridge will not be lengthened as part of this project, there is also no particular reason to relocate the existing stormwater pond now. Consequently, the levee will tie into the existing roadway embankment, leaving the stormwater pond intact. Figure 12b shows a cross section of the levee, Whitmarsh Road, and the stormwater pond. West of the Riverside Bridge, the levee will be setback as shown in Figure 10. West Whitmarsh Road will maintain its existing alignment although the current roadway from the shopping center will be abandoned. Figure 12c shows a cross section of this realignment just downstream of the Riverside Bridge. If the higher levee elevation crest is selected, the roadway approaches on both sides of Riverside Bridge will have to be raised up to elevation 48.0.

West of the Riverside Bridge, the setback levee will tie into the existing embankment of I-5. To prevent erosion of the I-5 embankment, it will be reinforced with riprap. Downstream of I-5, the levee will be setback as shown and West Whitmarsh Road will be maintained in its current alignment. Bouslog Road south of the levee will be abandoned. In the future, it is expected that Bennett Road will be extended to Bouslog Road but this is not part of this project. In addition, West Whitmarsh Road will be ramped to cross over the levee at the downstream end of the project. The levee will be tapered downward to match the elevation of the existing levee.

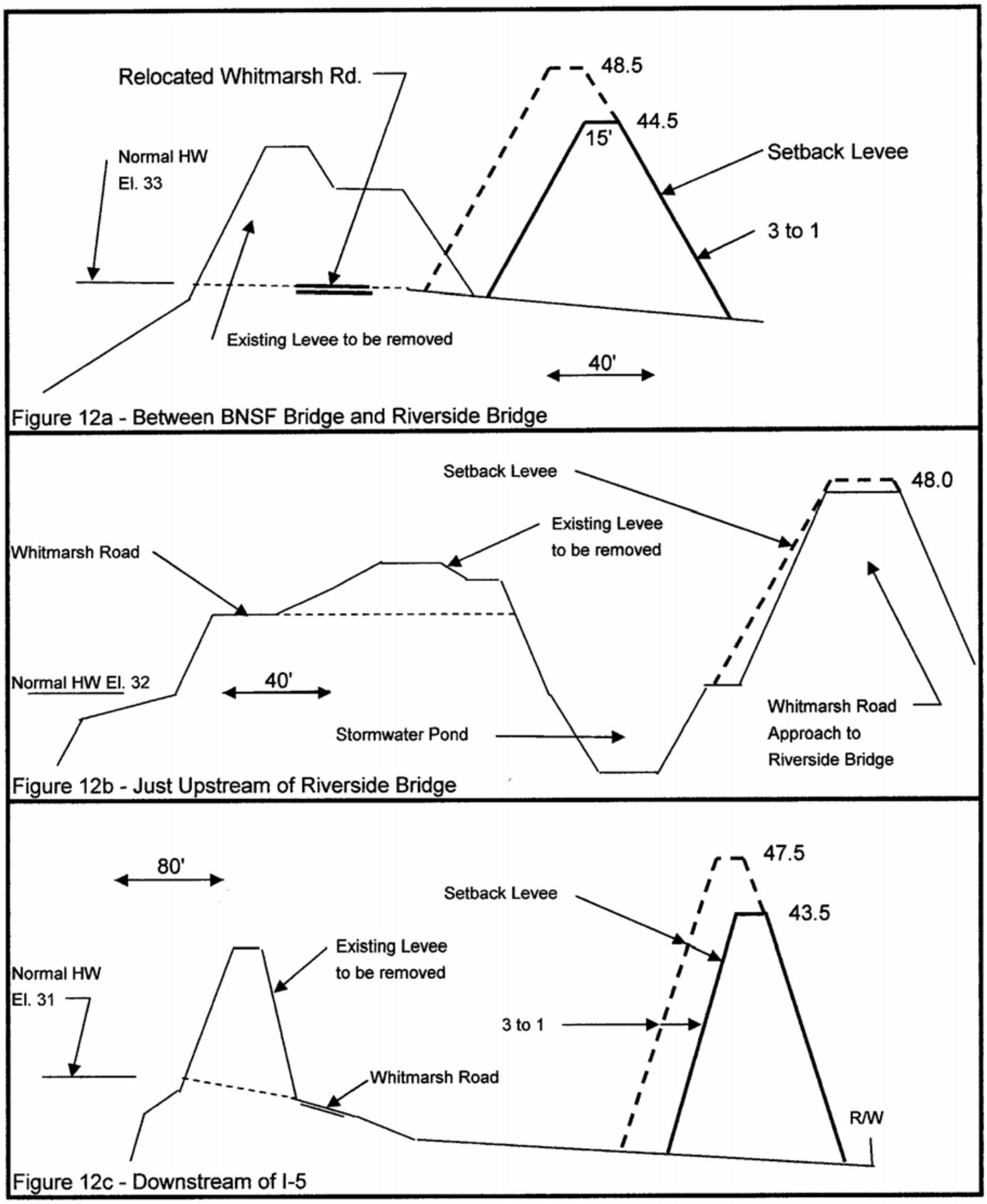


Figure 12 - Right Bank Levee Sections - Setback Levee Alternative

4.2 Hydraulic Analysis

The following analysis needs to be prefaced by noting that it has been prepared using approximate methods that estimate flows and water surface elevations but that do not purport to eliminate the need to use detailed computer models as are available from the Corps of Engineers. The report will and must be revised when this information becomes available.

Figure 13 presents the levee and flood profiles for the 2-, 10-, 25-, 50-, and 100-year flood events for this alternative. The cursory analysis shows that water surface levels in the study reach are only about 0.2 to 0.4 feet lower than currently exist. This occurs for several reasons, including (1) the existing bridges and bridge approaches are not modified in this scenario, (2) the overbank areas are relatively shallow resulting in only moderate increases in flow at fairly low velocities, (3) this is a fairly short river reach and backwater from downstream reach tends to limit the potential for significant lowering of the water surface in this reach, and (4) it is assumed that vegetative growth in the overbank area will be allowed to increase riparian habitat and this will somewhat limit the potential to lower the water surface.

As described above, the water surface elevation will be reduced slightly if the setback levee alternative is constructed. This reduction will allow slightly more water to pass downstream. It is estimated that during the occurrence of a 100-year flood, the channel capacity will increase to approximately 170,000 cfs and more than 3 feet of freeboard will be maintained. Since this alternative envisions all new levees, they will be constructed in a manner such that they can be certified if necessary.

Currently, upstream conditions limit the 100-year flood to approximately 160,000 cfs and the levee setback alternative may increase this to approximately 170,000 as discussed above. This will increase further only if upstream levees are raised or improved and new levees are constructed upstream of the existing terminus of the right bank levee.

It should be noted that the major benefit of this alternative is that improved conveyance will reduce the water surface elevation upstream of the study reach. This will reduce the potential for levee failure and will reduce the amount of water that will bypass the levee system completely by flowing around the upstream terminus of the levees near river mile 21. These benefits will be discussed in Chapter 5. It should also be noted that the upstream reduction in flows leaving the system will also result in additional water being maintained in the river and passing downstream to the lower reaches of the river. Since this will increase the potential for levee overtopping and failure downstream, this will also be discussed in Chapter 5.

It should be noted that under <u>current conditions</u>, the higher levee elevation option does not improve hydraulics in the study area over the lower elevation option. This is because the lower option provides 3 feet of freeboard over the 100 year flood elevation and raising the levee higher only provides additional freeboard.

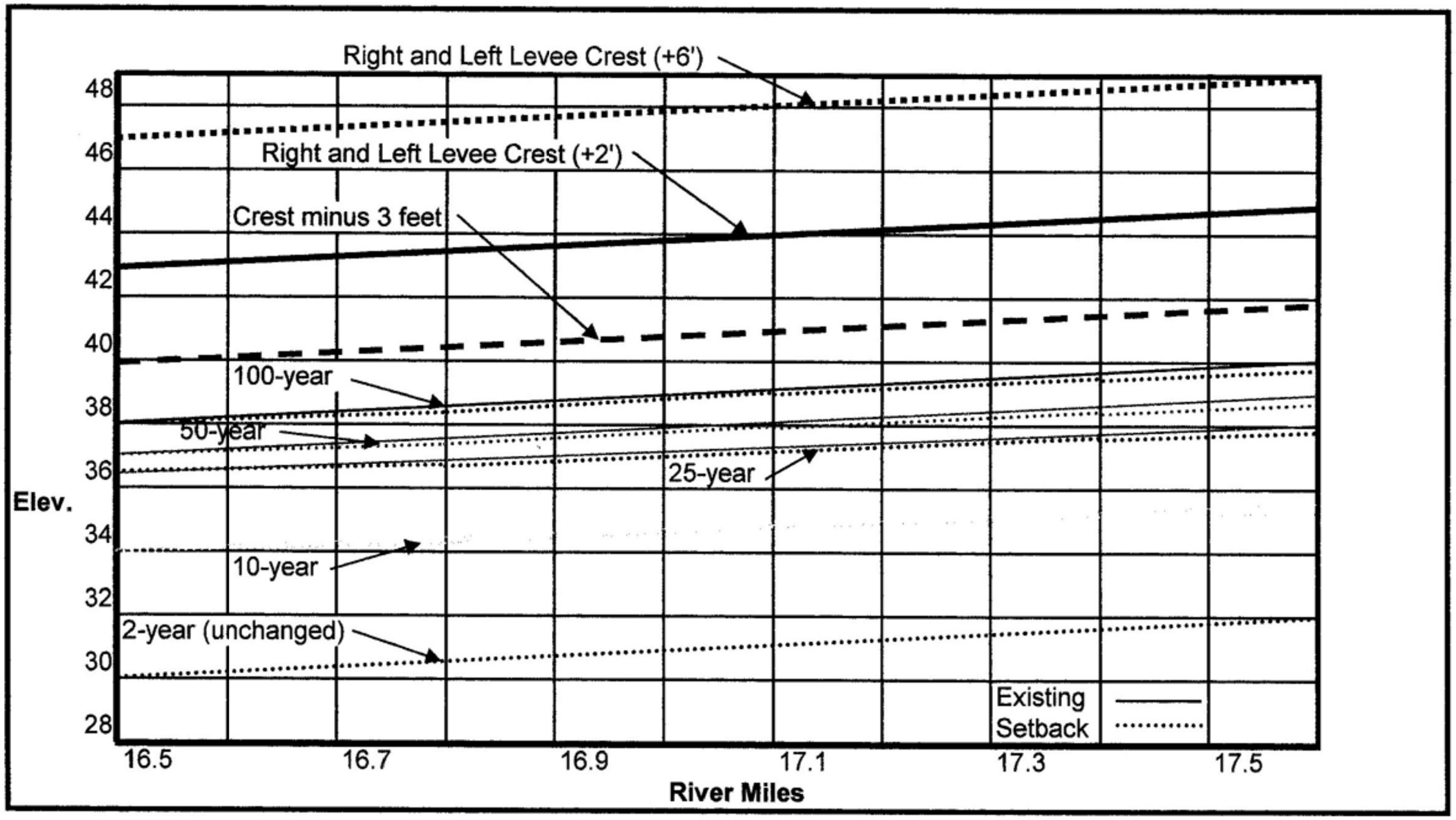


Figure 13 - Levee Crest Elevations and Flood Profiles - Setback Alternative

4.5 Cost Estimate

The estimated cost of constructing the setback levee alternative with the 2 foot increase in height, including all construction costs, contingencies, rights of way, and engineering and administration is estimated to be $30,000,000. The details of this estimate are presented in Appendix B.

The estimated cost of constructing the setback levee alternative with the 6 foot increase in height, including all construction costs, contingencies, rights of way, and engineering and administration is estimated to be $35,000,000. The details of this estimate are presented in Appendix B.

4.6 Rights of Way

The costs of obtaining rights of way for either the 2-foot or 6-foot alternatives for this project are shown in Appendix B and are estimated at $12,500,000. This includes costs for land purchases on both the right and left bank of the river. These costs are included in the total estimated project costs shown in the previous paragraphs.

4.7 Optional Features

There are four possible modifications to the setback levee alternatives described earlier in this chapter that have been evaluated. These are:

- Widen the crest width of all levees from 15 to 30 feet. This will make it easier for maintenance or emergency vehicles to pass during inspection, maintenance and flood fighting activities.

  The most common method of providing passage for vehicles on the top of levees is to construct turnouts and turnarounds at intervals of approximately 2500 feet (Corps Levee Design Manual) (5). Turnouts and turnarounds meeting this criterion have been incorporated in the preliminary designs described above.

  However, if it is desired to widen the levee crest to 30 feet, there will be an increase in the cost of the levees and a slight loss of flow capacity. The estimated total project cost to increase the top width of all levees in the setback levee alternative is $2,700,000.

- Install rip rap at the toe of all new setback levees and no longer maintain existing rip rap that exists at the toe of many existing levees.

  There are a number of factors that would go into the design of riprap for this project and a detailed design is beyond the scope of this investigation. For cost estimating purposes, it is assumed that the thickness will be 2 feet, the rip rap will extend from 1 foot below normal low water (about elevation 16) to 1 foot above the design high water elevation (average of 46 feet), and that all new levees will include riprap. These assumptions are probably conservative but are reasonably consistent with the Corps of Engineers manual on riprap design (6).

If new riprap is provided following the criteria described above, the total project cost for this feature is $3,300,000 million.

- On the right bank of the river, just downstream of the BNSF railroad, setback the levee approximately 400 feet and taper it to meet the approach to the Riverside Bridge. The location of this option is shown on Figure 10.

  Until the BNSF railroad bridge approach is modified, not part of this project, then there are no hydraulic benefits to constructing this option because the conveyance area provided will simply be a dead zone with no flow passing through it. The cost of converting the existing bridge approach fill to a bridge section is unknown but if it is done to improve flood control, then the cost would have to be born by the project. It is likely that this cost could be $20 to 30 million.

  The cost of setting back the levee at the optional location shown is approximately $3.3 million greater than the cost of constructing the levee at the location described above. This cost is in addition to the cost of constructing the 2-foot-higher-than-current levee and includes the cost of purchasing the necessary right of way. In comparison to the 6-foot-higher-than-current levee, the additional cost is $4.3 million.

- In the trestle section of the BNSF railroad bridge, extend and reinforce the bridge pilings and excavate the overbank area to elevation 18. Note that this feature has been included in the setback levee alternatives presented earlier but could be deleted.

  If excavating the overbank area and reinforcing the bridge trestle is eliminated from the setback levee alternative, two things will occur. First, and most important, the improvement in flood flow conveyance due to the setback will be reduced by about 50%, meaning that benefits will also be reduced by about 50%. Second, the cost of the setback levee alternatives will be reduced by $1,000,000.

5.0 UPSTREAM AND DOWNSTREAM IMPACTS OF ALTERNATIVES

As noted earlier, this analysis is being completed without the use of the Corps of Engineers hydraulic models and is based upon previously published hydrology and hydraulics reports that may be revised in the near future. However, it is felt that the results presented below for upstream and downstream are representative of the results that will be obtained when the models are modified to reflect the alternatives presented here.

5.1 Upstream Impacts

5.1.1 No Action Alternative

In this Alternative, there are no physical changes to the existing levees within the study reach. Consequently, there will be no change to the area upstream of the BNSF Bridge. The Corps of Engineers Hydraulics Report (3) indicates that at all flows greater than the 1-in-25-year flood the existing levee at River Mile 17.8, right bank, has a 50 percent probability of failing and that overflows will leave the river channel upstream of the end of the present levee system. At flows greater than the 1-in-50-year flood, the levee at River Mile 17.8 will overtop. Consequently, flows will leave the river and flood extensive areas between Burlington and La Conner. Appendix B to the Corps Hydraulics Report is a series of maps that depict the limits and depth of flooding due to different frequencies of flooding.

However, since this report makes no changes to the existing situation, flooding will continue as it does currently if the No Action Alternative is selected.

5.1.2 Improved Existing Levee Alternative

In this alternative, raising and improving the existing levees increased the levee freeboard in the study reach but the Corps of Engineers analysis showed that there was no significant potential for levee failure at the level of the 100-year flood. Consequently, since there was no change in flows within the study reach, there is no change in flows or stage upstream and flooding conditions are the same as at the present. The impacts are as described above for the No Action Alternative.

5.1.3 Setback Levee Alternatives

With the Setback Levee Alternative, all flows up to the 100-year flood event will be contained within the levees and the only impact within the study reach is a decrease in stage of approximately 0.4 feet at the upstream end of the reach at River Mile 17.56. Upstream of this point, a stage decrease of 0.4 feet will impact the frequency of levee failures and overtopping on the right bank at River Mile 17.8 and overflows around the upstream end of the existing levee at approximately River Mile 21.6.

The impact of a decrease in stage of approximately 0.4 feet upstream of the BNSF Bridge is difficult to assess without the use of a computer model. The primary impact of this decrease is a proportional decrease in the amount of water that would leave the right bank of the river via levee failures, overtopping, and overflows around the levee system. There would also be a slight decrease in the depth of flooding in the Nookachamps area on the right bank. An analysis of the Corps Hydrology and Hydraulics Reports (2, 3) and a UNET Modeling Report (7) prepared for Skagit County in 2003 gives an indication of the overflows and the change in overflows as shown in Table 3.

Table 3
Right Bank Overflows Upstream of River Mile 17.56

Flow Frequency	Overflows, Levee Failures, and Overtopping flows under current conditions	Reduction in Overflows, Levee Failures, and Overtopping due to 0.4 decrease in stage
25 years	Negligible	0 cfs
50 years	30,000 cfs	10,000 cfs
100 years	50,000 cfs	15,000 cfs

The table indicates that the change in overflows is significant and that there is a benefit to the Setback Levee Alternative. However, as will be described in 5.2.3, there is a potential negative downstream benefit and the Corps computer models will be necessary to quantify the changes in flows and flood damages.

5.2 Downstream Impacts

5.2.1 No Action Alternative

Under current conditions, the levees downstream of the study reach have inadequate freeboard and are subject to potential levee failures and overtopping. In general, the levees have inadequate freeboard at very frequently flood events and by the 10-year flood event (about 116,000 cfs), there are significant reaches of the levees on both banks of the main channel downstream of the study reach as well as both banks of the levees on the North and South Forks of the Skagit River that have inadequate freeboard. The potential for levee failure or overtopping are similarly widespread and by the 25-year flood (about 133,000 cfs) numerous sections of levee are at risk.

Under the No Action Alternative, the impact of flooding due to levee failure or overtopping does not change from the existing condition.

5.2.2 Improved Existing Levee Alternative

Since there is no increase in flow or stage in the river with implementation of this alternative, there is no additional impact on downstream flood conditions.

5.2.3 Setback Levee Alternative

The analysis presented above has shown that the Setback Alternative has the potential to reduce depths of flow in the study reach which in turn potentially reduces the depth of flooding upstream of the BNSF Bridge by approximately 0.4 feet at flows up to the 100-year flood. At flows above the 25-year flood event, this causes a reduction in levee failure or overtopping potential and a reduction in overflows from the river into the north bank area around Burlington.

A reduction in upstream overflows will result in more flow staying in the river and an increase in flow in the downstream reaches of the Skagit River. This increase in flow, up to approximately 10,000 cfs in the 100-year event, will have a negative impact on downstream levees and will increase levee failures and levee overtopping at flood events greater than the 1-in-25 year event. Although there would already be widespread flooding (without flood fighting efforts) under current conditions, this increase in flow will increase the frequency of flooding above current levels. As will be discussed later, in order to mitigate for the downstream impact due to the Setback Levee Alternative, it may be desirable to improve the downstream levees to pass a flood flow of about 145,000 cfs.

One reason for the setback levee alternative that would raise levee elevations by approximately 6 feet over existing levee heights is to provide flow conveyance capacity if upstream levees are raised and/or extended in the future. It should be noted that unless downstream levees are also raised significantly, the potential for levee failure or overtopping in the downstream levees will also increase.

6.0 PRELIMINARY BENEFIT COST ANALYSIS

A preliminary benefit versus cost comparison has been prepared for the two alternatives that include modifications to the existing conditions. Flood control benefits will be displayed in terms of annual benefits for each alternative. Capital construction costs and annual maintenance cost will be converted to annual costs based upon a 5 percent discount rate and a 50-year period of analysis.

At this time, the only costs included in the analysis are for levee construction and related road relocation costs and the costs of procuring the necessary rights of way. If the project is formulated to include riverine and terrestrial habitat improvements, these costs will be included at a later date. Likewise, benefits currently included are for flood control and potential benefits due to habitat improvements are not currently included.

6.1 Improved Existing Levee Alternative

As shown in Chapter 4, the cost of improving the levees in this alternative is approximately $4.3 million. Converting this to an annual cost will result in an annual cost of $240,000, assuming that maintenance costs are essentially the same as current.

Although the hydraulic analysis has indicated that improving the existing levees will increase the flow capacity in this reach of the river, the analysis also appears to indicate that the potential for levee failure or overtopping is non-existent under current conditions in the study reach. Consequently, there are no measurable flood control benefits for this alternative and the benefit to cost ratio is negligible.

6.2 Setback Levee Alternative

Chapter 4 showed that the capital costs for constructing the setback levee alternative is $30 million for the 2 foot levee height increase and $35 million for the 6 foot increase. If it assumed that operations and maintenance costs remain the same as the existing levees, then the average annual cost will be $1.64 million and $1.92 million, respectively, for the two levee height options.

The hydraulic analysis indicates that setting back the levees in the study reach will produce a <u>reductio</u>n of flood damages in the area upstream of the project reach (between the BNSF Bridge and the Highway 9 Bridge near Sedro Woolley due to a potential reduction in the water surface elevation of 0.4 feet during major flood events. However, the analysis also indicates that downstream of the study reach flows will increase for most major floods and this produces an <u>increase</u> in flood damages downstream of the study reach.

Appendix C contains a Technical Memorandum with a detailed analysis of the flood control benefit analysis for this alternative. Table 4 summarizes the results of the analysis and displays the existing flood control damages for the upstream and downstream areas and the resultant flood control damages if the setback levee alternative is constructed.

Table 4 Flood Control Benefits Levee Setback Alternative			
	Upstream	Downstream	Total
Existing Annual Flood Damages	$44.8 million	$25.6 million	$70.4 million
Post Project Annual Flood Damages	$43.4 million	$26.9 million	$70.3 million
Project Annual Flood Benefits	+ $1.4 million	- $1.3 million	+ $0.1 million

Table 5 summaries the annual costs of each option, the average annual flood benefits, and the benefit to cost ratio.

Table 5 Benefit to Cost Ratio Setback Levee Alternative			
Levee Height Options	**Average Annual Costs - $Millions**	**Average Annual Benefits - $Million**	**Benefit to Cost Ratio**
2 foot Increase	1.64	0.1	0.06
6 foot Increase	1.92	0.1	0.05

The analysis summarized in Tables 4 and 5 show that the levee setback alternative does not produce sufficient flood control benefits to cover the estimated costs of construction. The major issue is that even though the project will produce upstream benefits, the increase in flow downstream increases annual downstream damages by approximately the same amount. This does not indicate that the project is not worthwhile but only that as currently configured it can not stand alone. It may be necessary to combine this project with other features if a positive benefit to cost ratio is to be obtained.

7.0 DISCUSSION OF BRIDGE AND ADDITIONAL FLOOD PREVENTION IMPROVEMENTS

7.01 Introduction

Chapters 3 and 4 discussed the alternative levee improvements that could be made to improve conveyance through the study reach. However, Chapters 5 and 6 pointed out that these improvements have impacts on both the upstream and downstream reaches of the Skagit River and that by themselves, there may be minimal overall benefits to demonstrate the economic viability of the project. In this chapter, we will discuss other additional flood prevention projects and how they need to be integrated with the proposed alternatives into an overall flood control plan for the basin. In addition, since the proposed setback alternative could increase downstream flows, methods of minimizing these impacts will be discussed.

7.02 Hydrology, Hydraulics, and the Reduction of the Risks from Flooding

The reality of the existing flood control situation in the lower Skagit Basin is that all floods greater than about the 1-in-25-year flood event will cause significant damage to the lower Basin (below Sedro Woolley). Lesser flows, say the 10 year flood, may also cause potentially large amounts of damage but local flood fighting efforts have been effective in ameliorating the damage that might occur.

The primary goal of Skagit County, Mount Vernon, Burlington, and Sedro Woolley is to provide flood protection against the 100-year flood event and to insure that the levees that protect the urban areas can be certified. Although the currently published 100-year flood entering the levee system is approximately 230,000 cfs, there are three issues that may reduce this value to approximately 200,000 cfs. First, the methodology used in the FEMA flood insurance process allows this value to be reduces by approximately 10,000 cfs because the concept of “expected probability” is not normally used in its analysis. Next, the USGS has recently modified its opinion on the historical flood of 1921 as defined by the Stewart Report and this may reduce the 100-year flood by another 10,000 to 15,000 cfs. Thirdly, upstream storage modifications at the Baker and Skagit Hydroelectric Projects may provide another 5,000 to 10,000 cfs flow reduction in the future. Together, these three adjustments can realistically reduce the 100-year flood to approximately 200,000 cfs and this becomes the upstream flow that we may need to deal with in examining the current situation.

Next, if we skip downstream to the levee system that exists below the urban areas of Mount Vernon and Burlington, we see that these levees currently have a safe capacity of approximately 115,000 to 135,000 cfs. These levees are primarily designed to protect rural and agricultural lands and although it may be possible to upgrade most of these levees to pass about 145,000 cfs, additional upgrades to pass higher flows would be very expensive and probably would not be economically justified. This flow level represent about a 1-in-25-year-flood according to Corps of Engineers hydrology.

The issue, then, is how to manage flood risks given that the desired design flood level (about 200,000 cfs upstream) is greater than the maximum downstream flood channel capacity (about 145,000 cfs). Another consideration is that with setback levee alternative discussed earlier, the maximum capacity of the river in that reach is in the range of approximately 170,000 cfs under existing conditions.

The remainder of this chapter is devoted to looking how these limitations affect the selection of an overall flood control plan for the lower Skagit River Basin. None of the concepts discussed here have been evaluated in detail and they are presented merely to encourage discussion.

7.1 Bridge Improvements

The levee improvements presented in the previous chapters assumed that no specific improvements are made to the existing bridges, abutments, and approaches. However, it is assumed that at some time in the future, these improvements will be made and the flow capacity of the river will increase. At this point, it is not possible to specifically evaluate these flow improvements but they can be estimated using the Corps of Engineers flow models in the future.

7.1.1 I-5 Bridge

The existing I-5 Bridge provides little impediment to flows in the Skagit River. However, if the levees are set back as anticipated in the third alternative, it will be necessary to either extend the bridge and modify the approaches, or to construct a new bridge. Current planning anticipates that a new, wider bridge to accommodate more lanes of traffic may be constructed in the next 30 years. Regardless of which type of improvement is selected, they can be accommodated with the setback levee alternative with little change to the bridge elevations or approaches. Note that only the north end of the I-5 bridge and approach will need to be modified.

7.1.2 Riverside Bridge

Although the low chord elevations of this bridge somewhat limit water surface elevations in this reach, the studies have indicated that other factors control the volume of flow through the study reach. Consequently, there does not appear to be any reason why the south abutment, the lowest elevations, needs to be raised or extended. Therefore, the only significant change to the bridge to accommodate the setback levee alternative is to extend the right (north) bridge span and modify the approach. The existing grades of the roadway and bridge are adequate and only slight modifications may be necessary when the bridge is extended.

7.1.3 BNSF Bridge

As described earlier, this bridge is the lowest of the three bridges in the study reach and probably provides the most constriction to flow. Even though studies have been completed and suggested replacing the structure, BNSF has shown no inclination to consider replacing the bridge in the near future. In addition, the bridge appears to be a major impediment to the movement of large trees and other debris down the river.

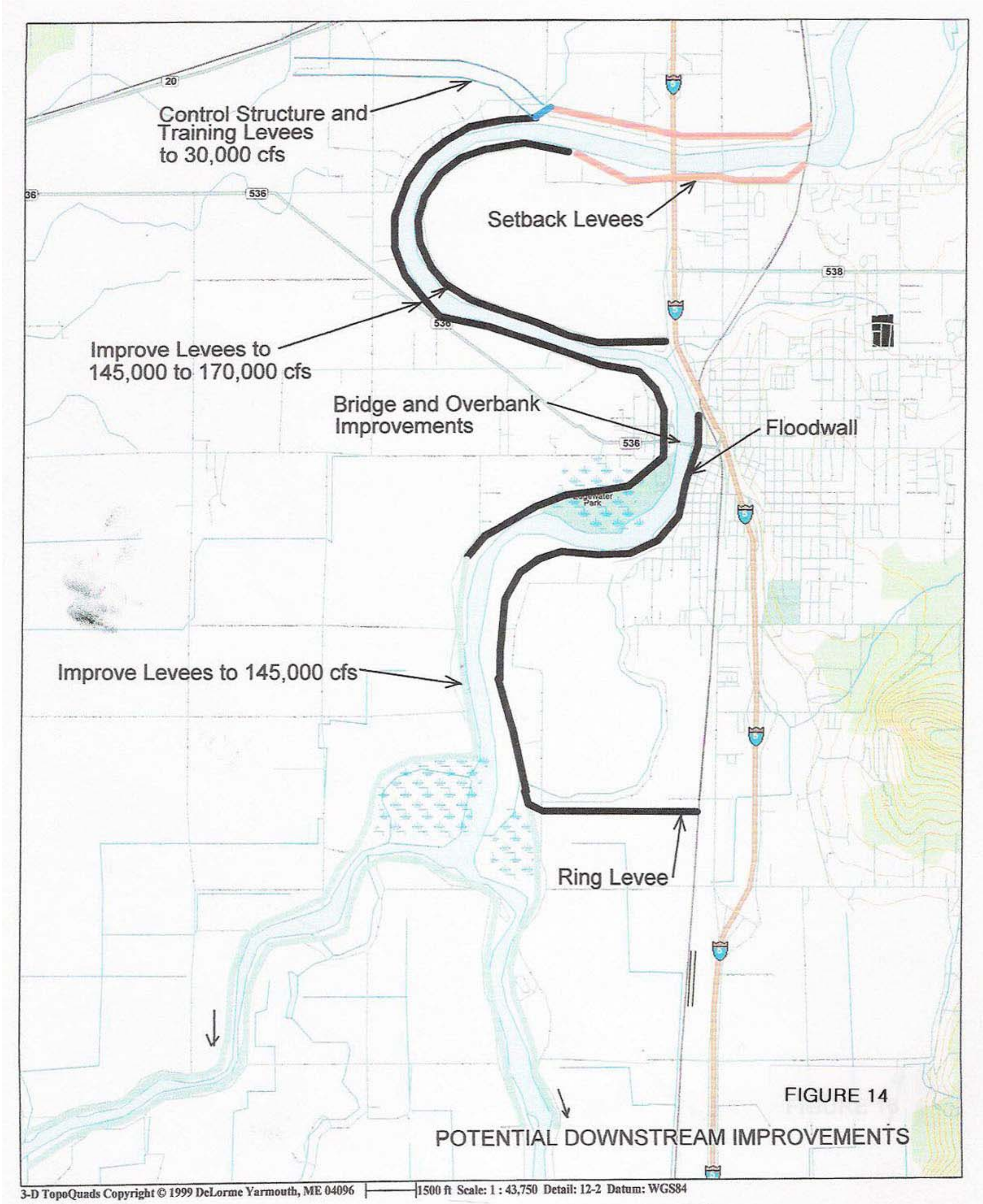
A major issue in modifying the BNSF Bridge is the need to increase the elevation of the railroad grade. To be consistent with the other bridges and the design of the levees, raising the bridge approximately 3 to 4 feet would appear to be warranted. However, raising the grade of the rail bed by even a couple feet would be very difficult, particularly to the south of the bridge in Mount Vernon. Because of the flat grades required for railroads, raising the bridge grade would necessitate raising the elevation of the railroad where it crosses Hoag Road, College Way, and Riverside Drive by several feet. We see that as a very questionable option.

Consequently, it is believed that (1) improving the conveyance through the trestled section of the bridge by improving the piers, (2) lowering the water surface during major floods by the construction of overflow structures, and (3) excavating a portion of the overbank area in the vicinity of the north abutment of the bridge will increase conveyance through this area and may negate the need to replace this bridge. Reducing the buildup of debris upstream of the bridge could be a partial solution to the conveyance problems, possibly by dredging just upstream of the bridge or perhaps by improving the existing piers to reduce scour potential. This issue needs more attention.

7.2 Downstream Improvements

If the setback levee alternative is selected, it will increase the downstream flows during all flow events greater than the 25-year flood. As mentioned above, modest levee improvements will be necessary just to improve these levees to the 25-year flood level, 145,000 cfs. Consequently, it is highly unlikely and probably uneconomical to attempt to increase the flow conveyance in the levee system downstream of Mount Vernon beyond 145,000 cfs. With these considerations in mind, the following improvements seem to be realistic:

1. Approximately 25,000 to 30,000 cfs need to be removed from the river in the reach below the study area. A diversion structure located in the Avon area has the benefit of reducing the amount of downstream levees that need to be improved and will improved flow conveyance capacity upstream as far as Sedro Woolley. Both of these situations dictate that the diversion structure be placed as far upstream as feasible and a location near the intersection of Plover and Whitmarsh Road appears a likely choice. This was the location shown in the most recent Pacific International Engineering report on alternatives (8). Figure 14 shows the proposed location of this structure. Although levees could be constructed all the way to the Swinomish Channel, the minimum required are training levees that ensure that overflows do not backup into Burlington west of I-5 and protect utility features near Highway 20 and the Avon-Allen Road.


Control Structure and Training Levees to 30,000 cfs
Setback Levees
Improve Levees to 145,000 to 170,000 cfs
Bridge and Overbank Improvements
Floodwall
Improve Levees to 145,000 cfs
Ring Levee
20
536
538
FIGURE 14
POTENTIAL DOWNSTREAM IMPROVEMENTS
3-D TopoQuads Copyright © 1999 DeLorme Yarmouth, ME 04096
1500 ft Scale: 1 : 43,750 Detail: 12-2 Datum: WGS84

2. The Corps of Engineers hydraulic study (3) shows that the area surrounding the Division Street Bridge, State Route 536, is a pinch point that needs to be improved, even to increase the conveyance capacity to 145,000 cfs. It appears that constructing a flood wall to protect the downtown area of Mount Vernon, lengthening the west end of the Division Street Bridge and removing the existing roadway fill, and perhaps excavating the overbank areas on the north and south sides of the bridge approach may improve the channel capacity up to approximately 170,000 cfs. Modifying the wooden structure that currently protects the center pier of the bridge may also be warranted.

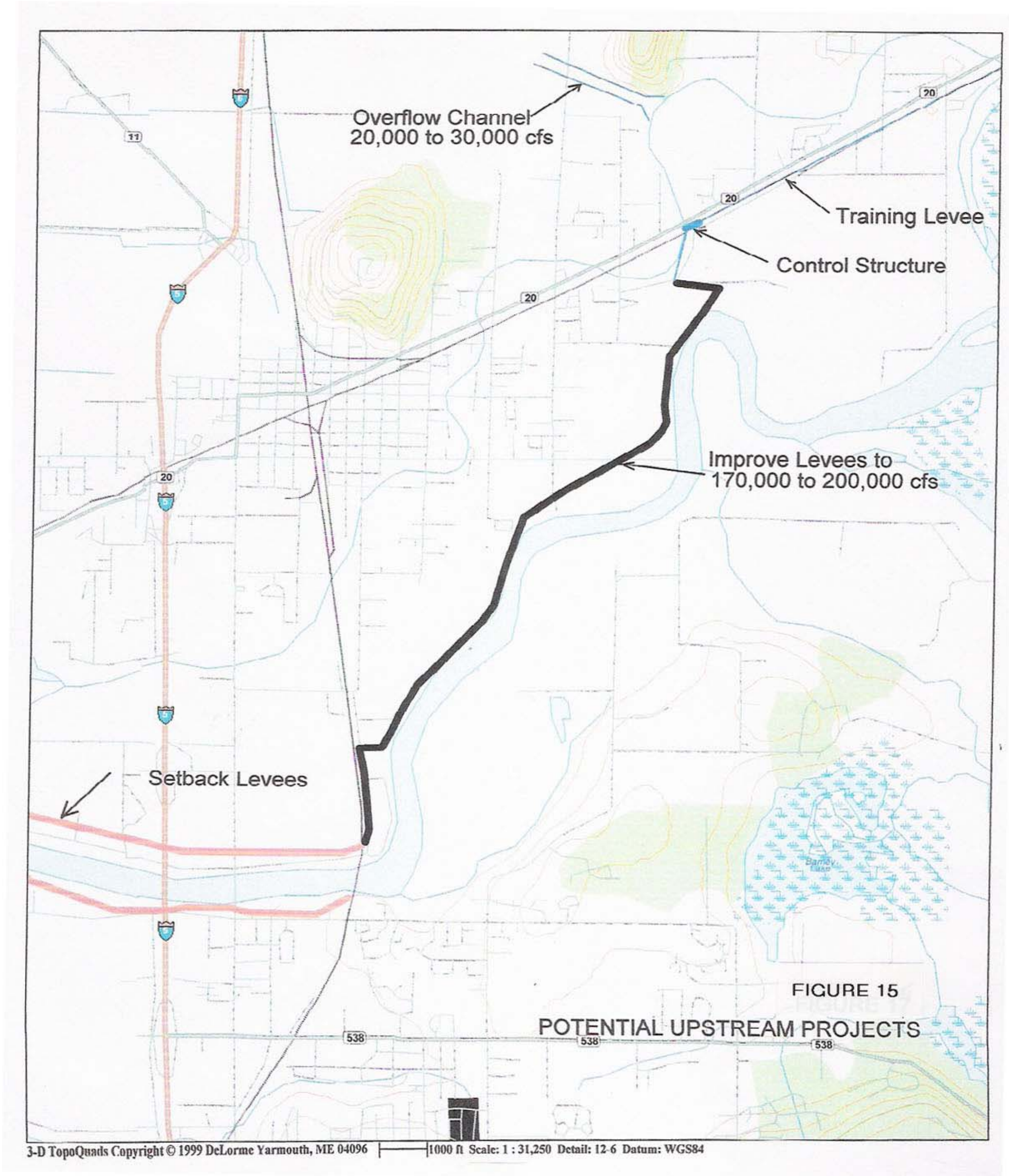
3. Depending upon whether a bypass is constructed or not, it may be necessary to set back the levees between the downstream end of the study reach and the Division Street Bridge.

4. The above improvements have the capability of increasing the levee capacity upstream of Mount Vernon to 170,000 cfs and the level of flood protection to Mount Vernon to the 100-year level. However, it may be necessary to construct a ring levee around the south edge of Mount Vernon to prevent potential levee overtopping flows from Dike District 3 backing into the city. Each of the facilities discussed are shown on Figure 14.

7.3 Upstream Improvements

Since the only impact due to either alternative is a potential lowering of the water surface upstream of the BNSF Bridge, no improvements are specifically needed to offset the construction of levee improvements in the study reach. However, if improvements in the study reach and downstream are instituted with the goal of providing 100-year protection, then significant upstream improvements are needed. If the maximum flow through the study reach is limited to about 170,000 cfs (slightly higher if the overflow structure near Avon is constructed) and the 100-year flood is in excess of 200,000 cfs, then facilities to reduce instream flows are needed and portions of the existing right bank levee will need to be improved. Specific ideas are described below:

1. An overflow structure needs to be provided and a logical location appears to be near the end of the existing system of right bank levees as shown in Figure 15. At this location, the existing railroad grade could be used to prevent uncontrolled overflows that would flood Highway 20 and provide a training levee for a control structure that would be located near where Gages Slough goes under the railroad grade. This structure would have the capacity to remove between 20,000 and 30,000 cfs from the river and discharge it into rural lands west of Sterling Hill and eventually into the Samish River. The specific ground elevations and flow paths have not been studied in detail and the impact of overflows on I-5 and the BNSF rail line would need to be investigated.


Overflow Channel
20,000 to 30,000 cfs
Training Levee
Control Structure
Improve Levees to
170,000 to 200,000 cfs
Setback Levees
FIGURE 15
POTENTIAL UPSTREAM PROJECTS
3-D TopoQuads Copyright © 1999 DeLorme Yarmouth, ME 04096
1000 ft Scale: 1 : 31,250 Detail: 12-6 Datum: WGS84

2. Downstream of the overflow structure, the existing Dike District 12 levees would have to be raised slightly to meet the 100-year design flow, or a greater flow if desired. Based upon Corps of Engineers hydraulics models, most of the improvements would be needed just upstream of the BNSF Bridge. However, construction of the two overflow structures will minimize the amount of improvements that may be necessary to these levees.

It should be noted that ongoing studies have investigated off-stream flood storage in the Nookachamps and Hart Island areas as a method of reducing peak flood flows in this area. A cursory review of these concepts concludes that they will be very expensive and would not provide the flexibility that would be provided by the overflow structure discussed above. However, on-going studies by the Corps and Skagit County will further investigate this concept.

7.4 Summary and Conclusions – Upstream and Downstream Improvements

The resolution of flooding problems in the Skagit River Basin will be a difficult undertaking and although construction of either of the alternatives presented will fit with most solutions, there are still a variety of potential issues that need to be evaluated. However, there are two concepts that need to be considered:

1. Although a major goal of flood protection facilities is to protect against the so-called 100-year flood event, the facilities should be able to handle even larger floods and to insure that highly developed urban areas are protected. In other words, when larger floods do occur, we need to know that flows in excess of the design capacity will be diverted away from the highly developed urban areas.

2. The design of a flood protection plan must start by resolving the future design capacity of the levees below Mount Vernon. Since the existing levees protect predominately rural and agricultural lands, is 100 year protection desired and economically justified or is a lower level of protection (say 1-in-25-years) acceptable?

In light of the above and the information presented in the previous chapters, the following conclusions are apparent:

1. It will be infeasible to construct levees along the Skagit River that can contain the 100-year flood, much less even larger events.

2. Although it may be feasible to construct a series of levees to protect the urban areas, it will be necessary to bypass some flood waters out of the main river channel. As a minimum, it will be necessary to provide a bypass feature either at the upper end of the existing levees near Burlington or in the riverbend area downstream of Interstate 5.

3. A combination of new levees, modified existing levees, bypasses, and setback levees are the most promising method of providing economical, feasible, and practical flood protection to the lower Skagit River basin.

7.0 References

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11. Draft NEPA Project Description, Anchor Environmental LLC, August 2008

APPENDICES

A. Technical Memorandum – Alternative Levee Designs

B. Technical Memorandum – Alternative Levee Cost Estimates

C. Technical Memorandum – Flood Damage Reduction Analysis

Appendix A
Alternative Levee Design

TECHNICAL MEMORANDUM

Skagit River Bridge Modification and Interstate Highway Protection Project

Alternative Levee Designs

1.0 INTRODUCTION

The purpose of this memorandum is to describe the alternative levee designs and configurations that will be analyzed in the Skagit River Bridge Modification and Interstate Highway Protection Project. The three general designs are:

- The No Action Project
- The Improved Existing Levee Alignment Alternative
- The Setback Levee Alignment Alternative

These will become the basic alternatives to be analyzed in the environmental documents although there may be some slight variations of one or more of these alternatives. Each alternative will have its own set of criteria, including height, location, and conveyance capacity. It should be emphasized early on that this project does not have an identified desired or goal level of protection. However, an acceptable alternative needs to have the capability to integrate, with appropriate modification, into the Skagit County Comprehensive Flood Hazard Management Plan (CFHMP) once it is defined for the 100-year protection for urban areas. Current physical limitations will govern the volume of water that can be passed through this reach of the river for this project. Consequently, each alternative will be able to pass a given flow volume which can then be assigned a level of protection.

This is a levee modification project and focuses on improvements to the levees along both banks of the Skagit River in the reach of the river adjacent to Mount Vernon and Burlington. As such, the project may be constrained by the location and elevation of the three existing bridges in the reach (the I-5 Bridge, the Riverside Bridge, and the BNSF railroad bridge). Although the analysis may evaluate the hydraulic capacity of the river with and without bridge improvements, the proposed project should be considered Phase 1 of improvements to this reach to meet the ultimate project purpose, Skagit River Bridge Modification and Interstate Highway Protection Project, and will deal only with improvements to the levees. Subsequent studies within the CFHMP development will define the Phase 2 improvements needed for the 100-year conveyance through this corridor.

The hydraulic analysis will identify both the upstream and downstream impacts of the proposed project alternatives. It is of the intent of this project to minimize hydraulic impacts to other areas within the basin, particularly downstream of the project. Since this project will increase flow conveyance through this reach of the river, it is likely that construction may not occur until improvements are made to the levee system downstream of the project.

As noted above, this project is a part of a much larger flood control project on the Skagit River. The larger project will investigate upstream storage, diversions, and levee improvements throughout the basin. This ongoing General Investigation is a joint effort of the Army Corps of Engineers and Skagit County and with sufficient funding is expected to be completed in 2010. Since the river reach covered in this memorandum is also covered in the General Investigation, information available in that study will be utilized to the maximum extent possible. Hydrology and hydraulics analysis, specifically, will rely upon information from that study.

2.0 DESIGN ASSUMPTIONS

The following sections outline the assumptions and criteria that will be used to design the two alternatives that will be analyzed in this project as well as to analyze the existing conditions (No Project) alternative.

2.1 Maximum Water Surface Elevations

Since the scope of this project is to modify the existing levees and not the existing bridges and roadways, the low chord elevations of the existing bridges are the primary limitation as to the maximum water surface elevation that can be obtained. The elevations of each of the three bridges are different and are discussed below. All elevations presented in this study utilize the 1929 NGVD datum.

2.1.1 I-5 Bridge

The I-5 Bridge is a steel girder bridge with concrete approaches approximately 1050 feet long. The bridge has a slight camber with low chord elevations at the abutments of approximately 49 feet. If the levees are setback as anticipated, the low chord elevation of an extended bridge would be lower but still might be greater than 45 feet. However, conversations with WSDOT indicate that this bridge may be replaced or modified within the next 20 years or so. Consequently, the levee heights probably should not be selected based upon the elevations of this bridge.

2.1.2 Riverside Bridge

The Riverside Bridge is a concrete girder bridge with both camber and curvature. It was constructed in 2004 and was designed with this setback project in mind. As such, the bridge was constructed so that it could be extended in the future to accommodate setback levees. The bridge plans indicate that the left (south) abutment was contemplated to be relocated or extended. However, it is considerably lower in elevation than the right (north) abutment and the bridge gradient on the left abutment will make it impractical to extend the bridge on that side. The current low chord elevations are 44.0 feet on the left abutment and 48.68 feet on the right abutment. If the levee is setback on the right abutment and the bridge extended, then the low chord elevation would be approximately 47.1 feet. Consequently, the left abutment elevation at 44.0 will continue to be the controlling elevation.

2.1.3 Burlington Northern/Santa Fe (BNSF) Railroad Bridge

The BNSF Bridge is a steel girder bridge that is straight and with relatively little camber and a trestle section on the right bank. The low chord elevation is approximately the same on both ends of the bridge at 43 feet. Although there have been several studies by Skagit County of replacing this bridge, there are no current plans to replace it. Further study is needed to determine to what degree it impedes flows in the river.

2.2 Levee Design Section

The design of a levee cross section is usually dictated by the type of soils available and maintenance considerations. A detailed geotechnical investigation will be conducted during the design of the levees and this will determine the source of the materials to be used in either modifying the existing levees or constructing the setback levees, the need for a keyway or similar facility to reduce seepage, the top width, and the slopes of the levees. For purposes of this phase of the project, guidance from the Corps of Engineers manual on levee design will be used. The manual specifies that the maximum side slopes shall be 2 to 1 with a 12 foot top width. However, for maintenance purposes, a slope of 3 to 1 is frequently used to allow for ease of mowing. In addition, a 15 foot top width gives a little more room for heavy equipment that may be used for maintenance.

However, until additional geotechnical work is completed, it will be assumed that the footprint will be based upon a cross section of 3 to 1 side slopes on the water side, 3 to 1 side slopes on the land side, and a 15 foot top width. This gives the maximum likely area to be disturbed by the alternatives being considered. This may be conservative assumption for new levees that may be built but given the lack of structural stability information on the existing levees, it is a reasonable assumption at this time.

Although these levees may be designed with a keyway or similar cutoff facility to control seepage, the need for a keyway does not impact the initial configuration of the levees. This will be given further consideration as the project progresses.

Several sections of the existing levees include riprap at the toes of the levees to prevent erosion of the levee during high flow events. For purposes of this study, it is assumed that the existing levees have adequate riprap protection and that the setback levees will be located far enough back from the main channel and high velocity areas such that additional riprap will not be needed. This will also be evaluated further in the future.

2.3 Alignment

For the No Action and Improved Existing Levee Alignment alternatives, the current alignment of the levees will be maintained. The modifications to the existing levee for the improved alternative are assumed to occur on the outsides of the levees or if the improvements are on the riverside, they will be constructed above normal high water.

For the Levee Setback alternative, tentative alignments have been agreed upon in the past and were shown in the 30% Design Report. These alignments generally are restricted by the location of Stewart and Hoag Roads on the south bank and by a 600 foot moratorium setback restriction on the north bank that was adopted by the City of Burlington.

It appears that there are at least two locations where the currently agreed upon levee alignments need to be investigated further and perhaps modified. On the south bank, in the vicinity of the south abutment of the Riverside Bridge, it may not be possible to set the levee back to Hoag/Stewart Road because of the elevation of the ramp to the bridge. On the north bank, in the area just downstream of the BNSF railroad bridge, the alignment may need to be modified as its currently proposed alignment would require that the trestle section of the bridge be lengthen by approximately 200 to 300 feet. Since this project does not contemplate constructing a new bridge section, it may be necessary to revise the levee alignment in this area.

In the vicinity of the Riverside Bridge, storm water ponds have been constructed on both sides of the river to control runoff from the bridge. These may have to be relocated or perhaps protected if the levees are setback in these areas.

At the downstream end of the project, the setback levees in that alternative will need to tie into the existing levees. A simple transition section of levee will be utilized in this plan; the actual final location of the levees in this reach will probably be based upon the results of the on-going General Investigation study by the Corps of Engineers and Skagit County.

2.4 Freeboard

Levee freeboard is used in the design of levees to provide a measure of protection against unknowns in the hydraulic design of the levees, wave action, and other factors. Although there is no adopted value for this factor, FEMA generally prescribes a 3 foot value and this is probably the most common value used for levees everywhere. Consequently, 3 feet will be used for all levees in this project. Additional study may prescribe a lesser or perhaps greater value for this freeboard.

Another consideration is the potential allowance for debris passage under these three bridges. A five-foot clearance has been used as the design criteria for some locations and this issue should be considered in the future.

2.5 Overbank Excavation

Past studies of setback levee schemes have considered excavating materials in the new overbank areas, inside the levees, as a method of increasing the conveyance capacity of the river. Although excavation does have the potential for increasing conveyance, it also has the potential to cause significant impacts to riparian habitat along the river. Consequently, in this project, overbank excavation will only be considered as part of any plans for environmental restoration that may be proposed.

2.6 River Gradient

Hydraulic studies by the Corps of Engineers show that during a major flood event, in the vicinity of say the 50-year flood, that the gradient of the river will be approximately 0.00032. This slope gives a difference in water surface between the downstream termini of the project, approximately 1800 feet downstream of the I-5 Bridge, and the upstream terminus of the project, at the downstream side of the BNSF railroad bridge, of 1.9 feet. Consequently, the differences in water surface throughout the project reach are as follows:

Downstream end of project	0.0 feet
I-5 Bridge	+0.6 feet
Riverside Bridge	+1.1 feet
BNSF RR Bridge	+1.9 feet

3.0 DESCRIPTIONS OF THE PROPOSED ALTERNATIVE LEVEES

The three proposed levee alternatives (no action, modified existing levees, and setback levees) are described in the following sections. The levee proposals are subject to revision as the project proceeds and are intended primarily at this time as the baseline for initiating the environmental evaluation process.

3.1 The No Action Alternative

In this alternative, the levees will remain as they currently exist and other than periodic maintenance and minor modifications due to erosion that may occur during flood events, they are assumed to remain unchanged. The height and elevations of the existing levees have been taken from cross sections used in the General Investigation and presented in the Hydrology and Hydraulics reports by the Corps of Engineers.

The results of computer model runs by the Corps of Engineers show that a flow of approximately 133,000 cfs would pass through the levees with a freeboard of 3 feet. This is derived from runs that produced flows of 117,400 cfs and 146,000 cfs at the USGS gage at Mount Vernon, located just downstream of the Riverside Bridge. The Corps of Engineers will furnish model runs to verify the estimated flow for this alternative.

3.2 The Improved Existing Levee Alternative

In this alternative, the existing levees will be raised to meet the design elevation. Where appropriate, the levees may be modified to meet the side slope and top width criteria. However, if the existing slopes are reasonably close to the criteria, they will not be modified. No new seepage control cutoffs will be constructed. It is assumed that all new construction will be placed on the outside of the current levees. New property will be purchased for this alternative, if needed.

As described earlier, the controlling elevations for raising the levees is the low chord elevation of the three bridges. The low chord elevations for the three bridges are as follows:

I-5 Bridge	49.0 feet
Riverside Bridge	44.0 feet
BNSF RR Bridge	43.0 feet

It is readily apparent that the BNSF Bridge is the limiting bridge in being able to pass more water through this reach by raising the existing levees. Not only is it the lowest bridge but it also is the most upstream bridge. In addition, the low chord of this bridge is essentially at the same elevation as the existing levees. Consequently, this bridge could effectively eliminate this alternative if it is used to limit the maximum water surface elevation.

If the BNSF Bridge is not considered, then the Riverside Bridge becomes the limitation to flow conveyance. With a low chord elevation of 44.0 feet and a freeboard of 3 feet, the maximum water surface elevation is 41.0 feet at the upstream face of the bridge. Using the Corps of Engineers 2004 Hydrology and Hydraulics Reports, the maximum conveyance at that elevation is estimated to be 167,000 cfs. The Corps will utilize the assumed levee configuration in this alternative to produce new model runs that will verify the flow conveyance.

Based upon the above analysis and elevations, the levee elevations at four locations in the study reach would be as follows:

Downstream end of project	44.0 – 1.1 = 42.9 feet
I-5 Bridge	44.0 – 0.5 = 43.5 feet
Riverside Bridge	44.0 – 0.0 = 44.0 feet
BNSF RR Bridge	44.0 + 0.8 = 44.8 feet

Note that if the height of the levees at the BNSF railroad bridge is 44.8 (a water surface of 41.8) and the low chord is 43.0, then there is only 1.2 feet of clearance during a design flood. Additional study of this issue will be required if this alternative is selected.

Figure 1 shows the location and extent of the improvements that would be necessary to increase the flow capacity throughout this reach to 160,000 cfs.

3.3 Levee Setback Alternative

The water surface and levee elevations presented in the previous alternative, Improved Existing Levees, are also applicable to this alternative. The only significant difference is that there will be additional flow that can be carried in the overbank areas on both sides of the river inside of the new levees. Computer modeling will be necessary to specifically estimate this additional volume of flow. However, as a first approximation, this flow can be estimated using typical roughness values, the slope of the river, the depth of flow, and the additional width available. Using the 30% design as a guide, this additional flow is estimated to be 10,000 cfs. When added to the flow computed for the previous alternative, the total flow is estimated to be 170,000 cfs. This value will be verified by the Corps of Engineers based upon the configuration shown for this alternative. (Note: This is a revision from the original draft of this memorandum and reflects more detailed analysis and recognition that the downstream water surface will minimize the increase inflow.)

The alignment for the setback levees will generally follow the footprint shown in the 30% design document. This alignment allows for a 20 foot setback from property lines and roadways. It appears that the I-5 Bridge can be extended through the addition of one bridge section on the south side of the river and perhaps 2 sections on the north side. There appears to be sufficient clearance such that these additions can be made without a change to the main bridge section and perhaps only minor changes to the approaches. Actual changes to the bridge, or perhaps construction of a new bridge, would be considered in Phase 2.

As mentioned earlier, it appears likely that the south side of the Riverside Bridge is a limitation to levee construction and that it may be impractical to extend the bridge on this side. Consequently, it may be prudent to modify the levee alignment in this area to make a smooth transition with the bridge abutment. On the north side of this bridge, it appears likely that the bridge can be extended sufficiently to clear the proposed levee height. One new bridge section would probably be needed. The existing stormwater pond on the north side of the river can be left in place, inside of the proposed setback levee location. On the south side, however, it may be necessary to leave the existing stormwater pond in place and continue to utilize the existing levee in this area and raise it to meet the desired levee crest elevation. Downstream of the pond, the levee will be setback to the vicinity of Stewart Road. Any changes to the bridge or abutments would occur in Phase 2.

The location of the proposed setback of the right bank levee downstream of the BNSF Bridge as shown in the 30% design document could only be constructed if 400 feet of new railroad bridge is constructed. If the bridge is left in place as is, an ineffective backwater area would exist so that there would be no practical reason to set the levee back to the location shown. Consequently, it is proposed that the existing right bank setback levee terminate at the same location as the existing levee and that the channel be excavated both downstream and upstream of the bridge to improve conveyance through this area. It would be necessary to modify the existing trestle section by constructing new pilings and integrating them with the existing bridge structure. If the levee is setback to the original location, it would be done in Phase 2 of the project.

Figure 2 shows the location of the proposed setback levees and other features of this plan.

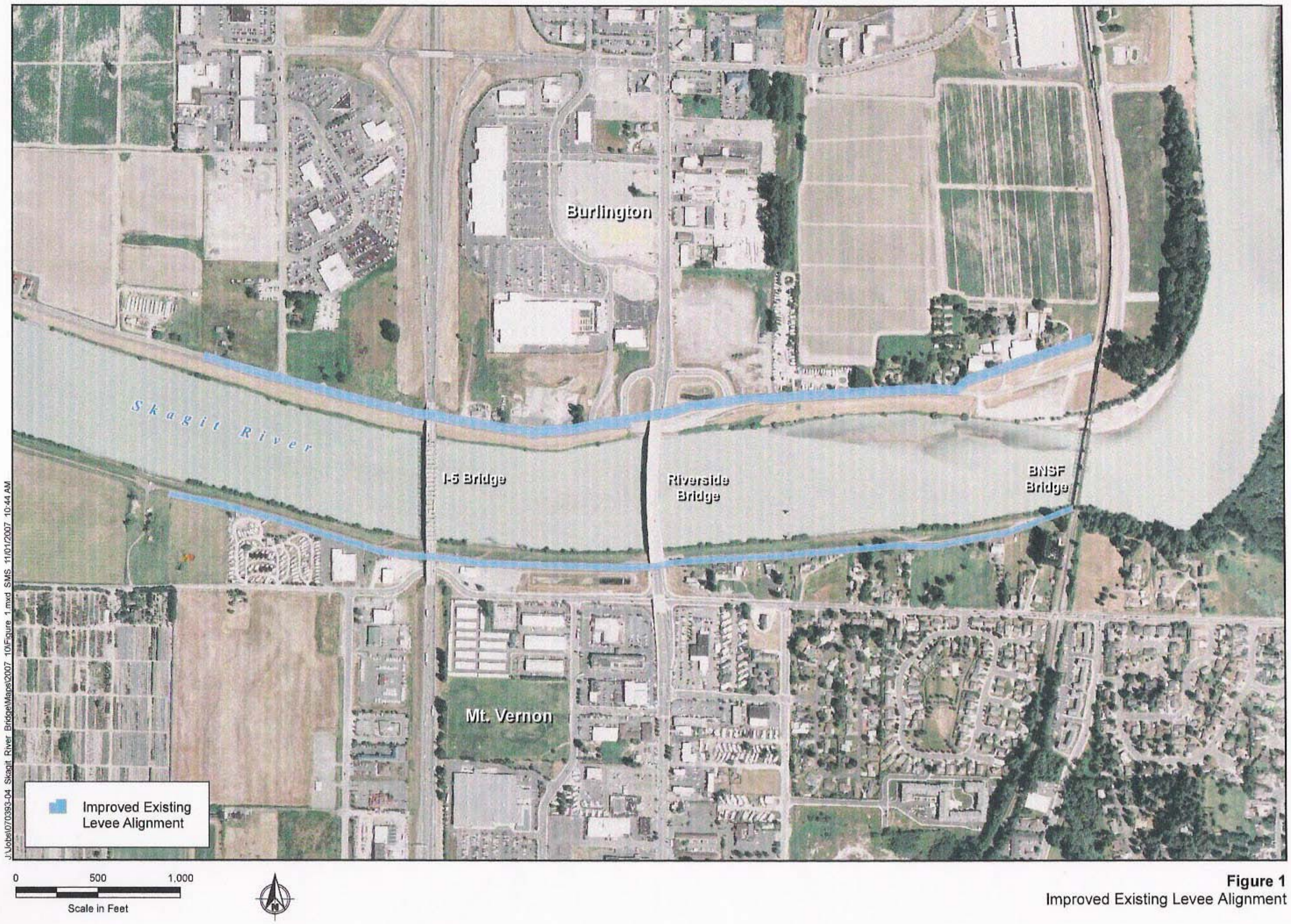
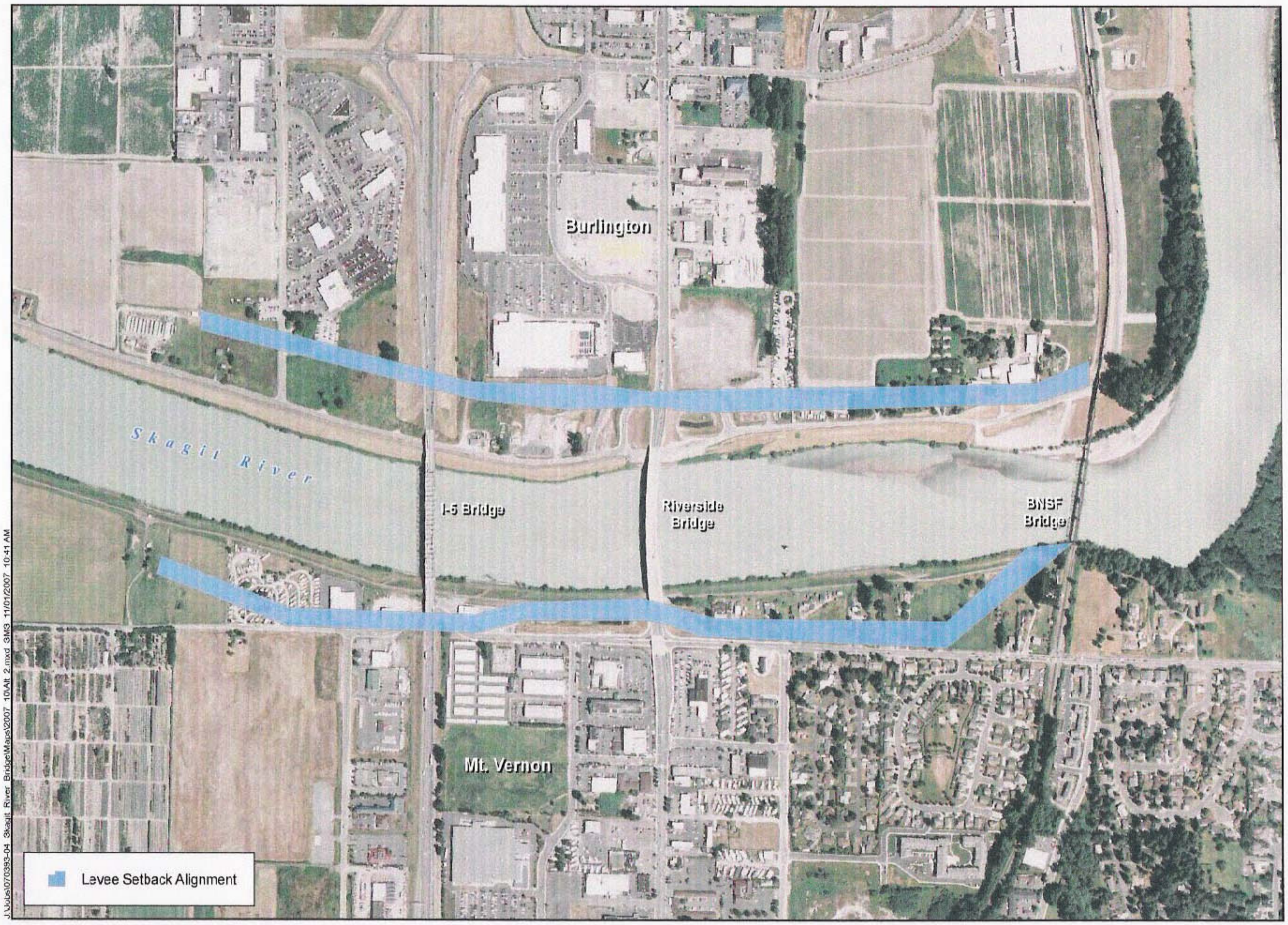


Figure 1
Improved Existing Levee Alignment



0 500 1,000
Scale in Feet

Figure 2
Levee Setback Alignment

Appendix B
Alternative Levee Cost Estimates

DRAFT TECHNICAL MEMORANDUM

Skagit River Bridge Modification and Interstate Highway Protection Project

Alternative Levee Cost Estimates

Introduction

This memorandum presents cost estimates for each of the Alternatives that have been discussed in the report to which this Appendix is attached. Since there are no costs for the No Action Alternative, this memorandum covers the (1) Improved Existing Levee Alternative, and (2) Setback Levee Alternative. Separate sections of this memorandum cover the costs of purchasing rights of way and construction costs for the levees.

Rights of Way

The costs of purchasing rights of way for each alternative have been estimated based upon the current market values for the properties that will be needed. The estimates are based upon a number of assumptions, including:

1. The estimated market values used in the analysis are derived directly from current Skagit County Assessors records.

2. Where only land must be purchased, only the land market values are used. If a percentage of the land in each parcel is needed, the estimated cost is calculated on a percentage-of-use basis. If a structure is on land that must be purchased, its full market value is added to the land value.

3. If the amount of land needed for the project substantially degrades the value of the property, it is assumed that the entire parcel will be purchased.

4. In the Modified Existing Levee Alternative, no property will be needed if the new landward toe of the levee is located on Dike District or public property. However, if the toe extends beyond Dike District or public property, then it is assumed that an additional 20 feet of land will be purchased to provide sufficient land for maintenance.

5. In the Setback Levee Alternative, the land to be purchased includes 20 feet of land that can be used for maintenance activities.

6. The acquisition values determined will be increased by 10 percent to allow for inflation and for the fact that a percentage of the usable land will be obtained from the property owner. In addition, an additional 10 percent will be added to cover the costs of appraisals and acquisition activities. These will be added on as part of the cost estimates later in this memorandum.

Table 1 summarizes the rights of way costs for the Modified Existing Levee Alternative and the Setback Levee Alternative for the left bank properties that have been developed using the rationale discussed above. Figures 1 is an index of the figures that will be used to show the limits of the properties to be purchased. Figures 1a to 1l show the left bank properties.

Table 2 summarizes the rights of way costs for the Modified Existing Levee Alternative and the Setback Levee Alternative for the right bank properties that have been developed using the same rationale. Figures 2a to 2m show the location of each property identified in Table 2.

It should be noted that if this project proceeds on it present course, funding may be provided through the Washington Department of Transportation and their procedures will be used to purchase the identified properties. In addition, the two dike districts are actively pursuing the purchase of several of the identified properties. The estimates provided here do not deal with either of these activities and are intended to merely provide basic market value information for inclusion in the preliminary cost estimates for the alternatives.

Table 1
Left Bank Rights of Way Acquisition Costs
Modified Existing and Setback Levee Alternatives

ID	Parcel #	Owner	Modified Existing		Setback Levee	
			Acreage	Market Value	Acreage	Market Value
1	23938	Fohn			1.23	$7,640
2	23933	PUD			1.70	0
3	23932	DD 17	0.18	0	2.85	0
4	24028	Rivercrest	0.135	$43,600	1.98	$640,000
5	24026	Rivercrest	0.146	$77,000	1.76	$929,000
6	24029	Rivercrest	0.106	$34,300	1.23	$398,000
7	24027	Calicorp	0.115	$175,000	1.10	$1,681,000
8	24021	Calicorp	0.08	$29,700	0.6	$222,000
9	24022	HQ Partnership	0.06	$28,300	0.34	$152,000
10	24020	HQ Partnership	0.13	$64,300	0.91	$452,000
11	24025	DD 17	0.10	0		0
12	24024	DD 17			0.21	0
13	24023	DD 17	0.05	0	0.97	0
14	24018	Mount Vernon				0
15	24206	Mount Vernon			0.18	0
16	24201?	Roald	0.05	$15,900	0.67e	$281,000?
17	24226	Mount Vernon			0.54	0
18	24219	Curry	0.41	$51,400	1.01	$401,000
19	24213	Van Duzen	0.05	$5,600	0.76	$271,000
20	24208	DD 17	0.05	0	0.82	0
21 22 23	112779 121427 121425	Hocking	0.65	$92,600	3.23	$461,000
24	24213	Steiner	0.07	$7,600	0.77	$199,000
25	24215	Bridges	0.08	$8,800	0.77	$203,000
26 27	24217 24216	Wolf	0.10	$13,200	1.41	$379,000
28	24193 24218	DD 17			0.97	0
29	24196	Ross			0.83	$207,000
30 31 32	111922 111652 111653	DD 17			2.4	0
33	111654	Lund			0.93	$243,000
34	24210	Pimentel	0.09	$8,800	0.68	$132,000
35	24209	Armendarez	0.07	$10,600	0.45	$70,000
36	24224	Stolpe	0.09	$19,400	0.78	$169,000
36a	24225	Salt			0.83	$192,000
Total Left Bank Properties			**2.81**	**$686,000**	**32.91**	**$7,700,000**

Table 2 Right Bank Rights of Way Acquisition Costs Modified Existing and Setback Levee Alternatives						
ID	Parcel #	Owner	Modified Existing		Setback Levee	
			Acreage	Market Value	Acreage	Market Value
37	23923	Hanson			0.69	$18,000
38	23921	Larson			4.90	$130,000
39	23922	Rock Island Partner			2.39	$506,000
40	23917	Tapley Investments			1.58	$514,000
41	23963	Covarrubias			0.15	$30,400
42	23943	Covarrubias			0.09	$13,200
43	23942	Covarrubias			0.76	$138,000
44	23927	DD 12			4.0	0
45	23941 23939 116918	DD 12			4.33	0
46	24144	DD 12			3.83	0
47 48 49	24138 24142 24141	Burlington RV			1.72	$1,070,000
50	24137	Nagatani			0.47	$25,500
51	24156	Leonovich			0.71	$43,500
52	24162	Cleave			0.34	$121,000
53	24163	Trevino			0.66	$157,000
54	24152	Satsuma			0.17	$7,400
Total Right Bank Properties					**26.79**	**$2,800,000**

Cost Estimates

The costs of constructing the levee improvements for the two alternatives have been estimated and are included below. A number of assumptions have been made and are discussed below:

1. The levee will be constructed as outlined in the earlier sections of this report, i.e. crest elevation as shown, top width of 12 feet, and 3 to 1 side slopes. The volume needed is increased by 5% to account for compaction.

2. The material for the levee will be obtained locally at a cost of $ 4 /yard. Based upon the NRCS soils report for Skagit County, there are materials suitable for embankments within a reasonable distance although mixing may be necessary to obtain homogenous soils.

3. The cost of transporting the material to the site and placing it is estimated to be approximately $11 per yard, making the total cost of the embankment approximately $15 per yard in place.

4. The estimate assumes that two feet of top soil will be excavated from the ground surface under the footprint of the setback levee prior to construction and that one foot of this topsoil will be placed on the top 1 foot of the levee and seeded. The cost is estimated at $10 per yard for excavating and placing the material and $50,000 to hydro seed the new setback levee.

5. It is assumed that 6 inches of gravel will be placed on top of all levees as a road surfacing at a cost of $30 per yard, in place.

6. It is assumed that all lands needed for the project will be purchased and that the cost will be based upon the market values described earlier. The computed market values for each parcel has been increased by 10 percent to account for inflation and the size of the parcels being purchases and an additional 10 percent to cover appraisal and purchase expenses.

Modified Existing Levee Cost Estimate

Table 3 presents an estimate of cost for construction of the Modified Existing Levee Alternative. The costs are based upon the assumptions listed above and current cost levels for similar construction in Skagit County. The rights of way cost are taken from earlier sections of this memorandum. Note that a contingency of 30 percent has been added to the estimate to cover changes in bidding conditions and minor items that have not be detailed at this point.

Table 3 Cost Estimate – Modified Existing Levee Alternative			
Item	**Quantity**	**Unit Cost**	**Cost**
Mobilization	1	$200,000	$200,000
Levee Embankment-Left Bank	50,000 cubic yds	$15 per yard	750,000
-Right Bank	65,000 cubic yds	$15 per yard	875,000
Hydro seed	1 job	$50,000	50,000
Levee road gravel-Left Bank	1,200 cubic yards	$30 per yard	36,000
-Right Bank	1,200 cubic yards	$30 per yard	36,000
Road Improvements	200 lf	$500 per lf	100,000
Sub Total Construction			$2,050,000
Contingency – 30 percent			600,000
Sales Tax - 8.3 percent			170,000
Total Construction			$2,820,000
Rights of Way- Left Bank			$686,000
- Right Bank			0
10% Contingency			69,000
Appraisals and Purchases			69,000
Total Rights of Way Costs			$824,000
Total Direct Project Costs			**$3,644,000**
Engineering, Construction Observation, and Agency Administration – 18 percent			$656,000
Total Project Costs			**$4,300,000**

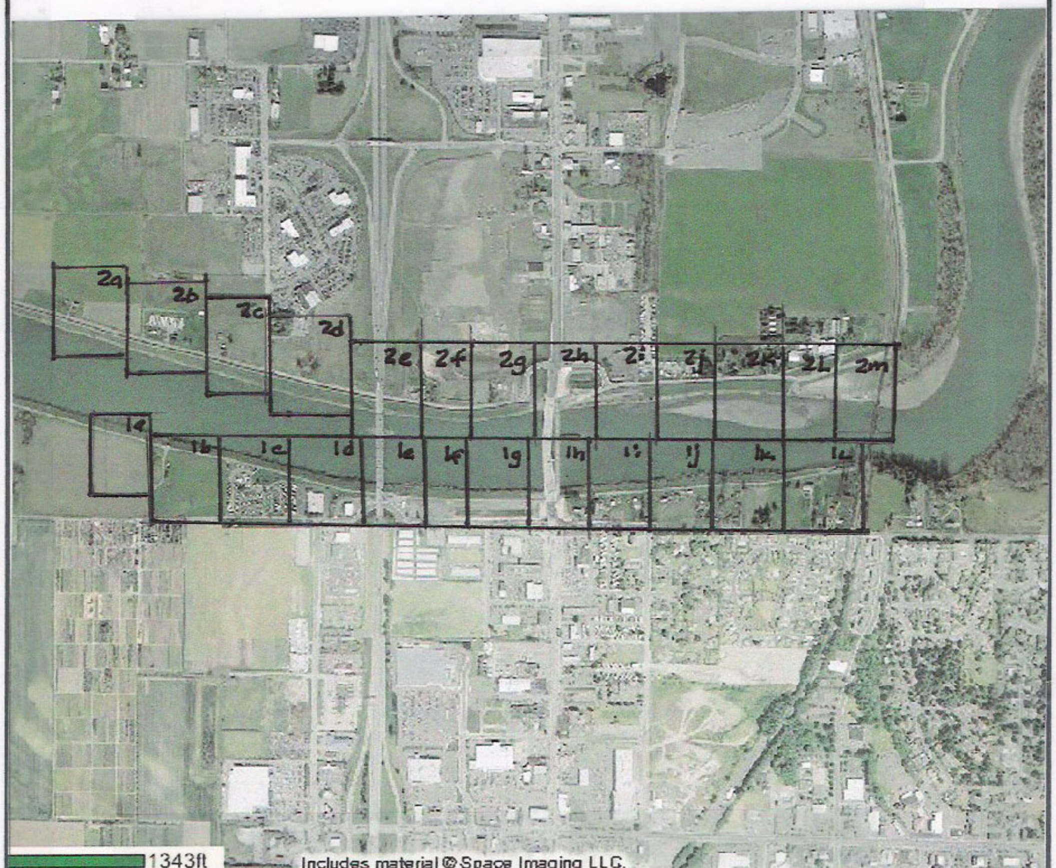
Setback Levee Cost Estimate

Table 4 presents the cost estimate for construction of the Setback Levee Alternative, the plus 2 foot option. Table 5 presents the cost estimate for construction of the Setback Levee Alternative, the plus 6 foot option. The costs are presented on the same basis as described above.

Table 4
Cost Estimate – Setback Levee Alternative, 2 foot Option

Item	**Quantity**	**Unit Cost**	**Cost**
Mobilization	1	$300,000	$300,000
Levee Embankment-Left Bank	153,000 cubic yds	$15 per yard	2,300,000
-Right Bank	216,000 cubic yds	$15 per yard	3,240,000
Foundation Preparation	84,000 cubic yds	$10 per yard	840,000
Right Bank Excavation @ RM 17.5	89,000 cubic yds	$5 per yard	445,000
Levee Removal	170,000	$5 per yard	850,000
Hydro seed	1 job	$50,000	50,000
Levee road gravel-Left Bank	1,200 cubic yards	$30 per yard	36,000
-Right Bank	1,200 cubic yards	$30 per yard	36,000
Road Improvements	2,200 lf	$500 per lf	1,100,000
Railroad Trestle Pilings	6 each	$28,000	148,000
Sub Total Construction			$9,345,000
Contingency – 30 percent			2,805,000
Sales Tax - 8.3 percent			780,000
Total Construction			$12,930,000
Rights of Way- Left Bank			$7,700,000
- Right Bank			2,800,000
10% Contingency			1,000,000
Appraisals and Purchases			1,000,000
Total Rights of Way Costs			$12,500,000
Total Direct Project Costs			**$25,430,000**
Engineering, Construction Observation, and Agency Administration – 18 percent			$4,570,000
Total Project Costs			**$30,000,000**

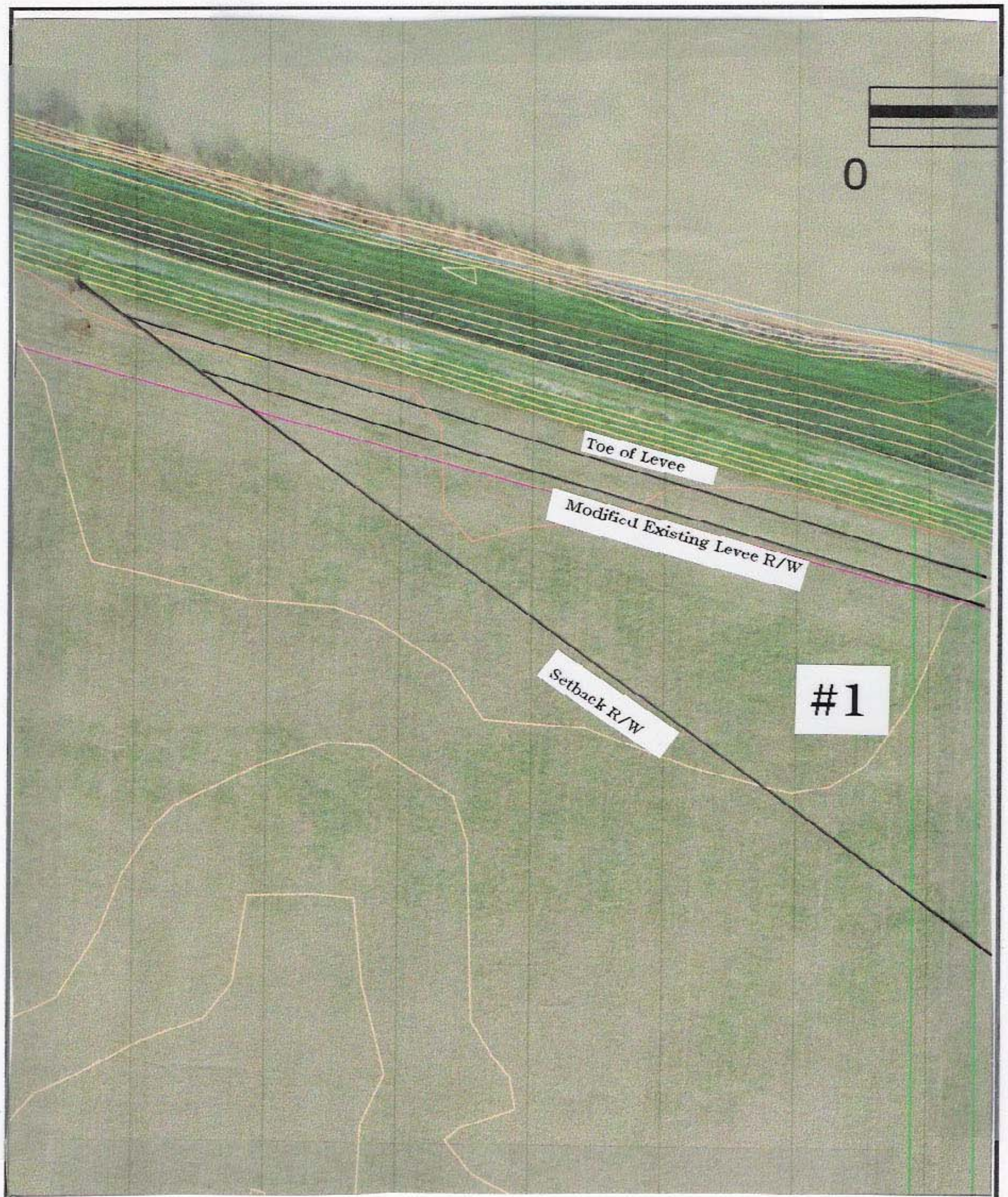
Table 5 Cost Estimate – Setback Levee Alternative, 6 foot Option			
Item	**Quantity**	**Unit Cost**	**Cost**
Mobilization	1	$300,000	$300,000
Levee Embankment-Left Bank	248,000 cubic yds	$15 per yard	3,720,000
-Right Bank	316,000 cubic yds	$15 per yard	4,740,000
Foundation Preparation	84,000 cubic yds	$10 per yard	840,000
Right Bank Excavation @ RM 17.5	89,000 cubic yds	$5 per yard	445,000
Levee Removal	170,000	$5 per yard	850,000
Hydro seed	1 job	$50,000	50,000
Levee road gravel-Left Bank	1,200 cubic yards	$30 per yard	36,000
-Right Bank	1,200 cubic yards	$30 per yard	36,000
Road Improvements	2,200 lf	$500 per lf	1,100,000
Railroad Trestle Pilings	6 each	$28,000	148,000
Sub Total Construction			$12,365,000
Contingency – 30 percent			3,710,000
Sales Tax - 8.3 percent			1,025,000
Total Construction			$17,100,000
Rights of Way- Left Bank			$7,700,000
- Right Bank			2,800,000
10% Contingency			1,000,000
Appraisals and Purchases			1,000,000
Total Rights of Way Costs			$12,500,000
Total Direct Project Costs			**$29,600,000**
Engineering, Construction Observation, and Agency Administration – 18 percent			$5,400,000
Total Project Costs			**$35,000,000**



Scale 1" = 0.3 miles

Figure 1

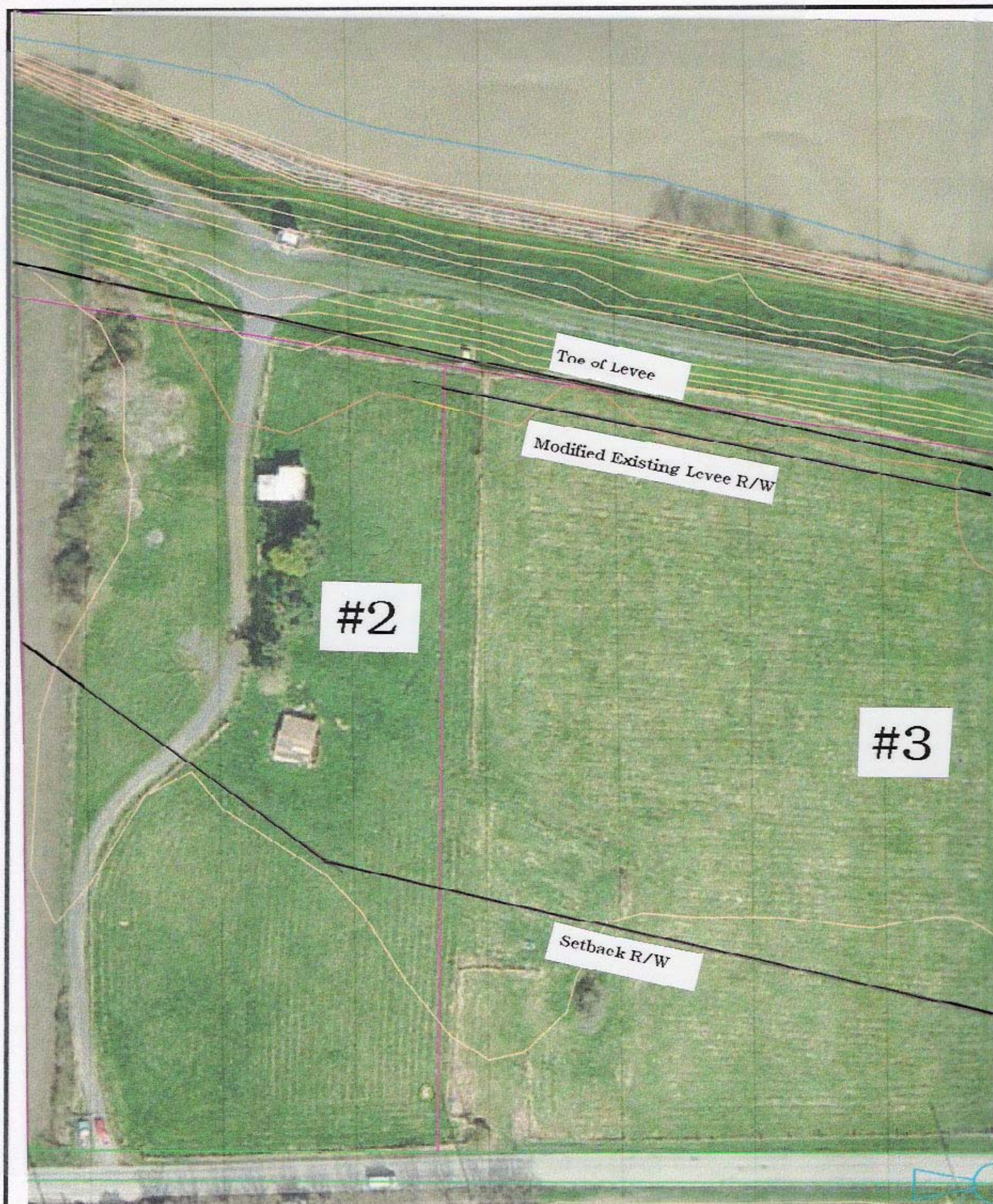
Parcel Index Sheet



Scale 1" = 100'

Figure 1a

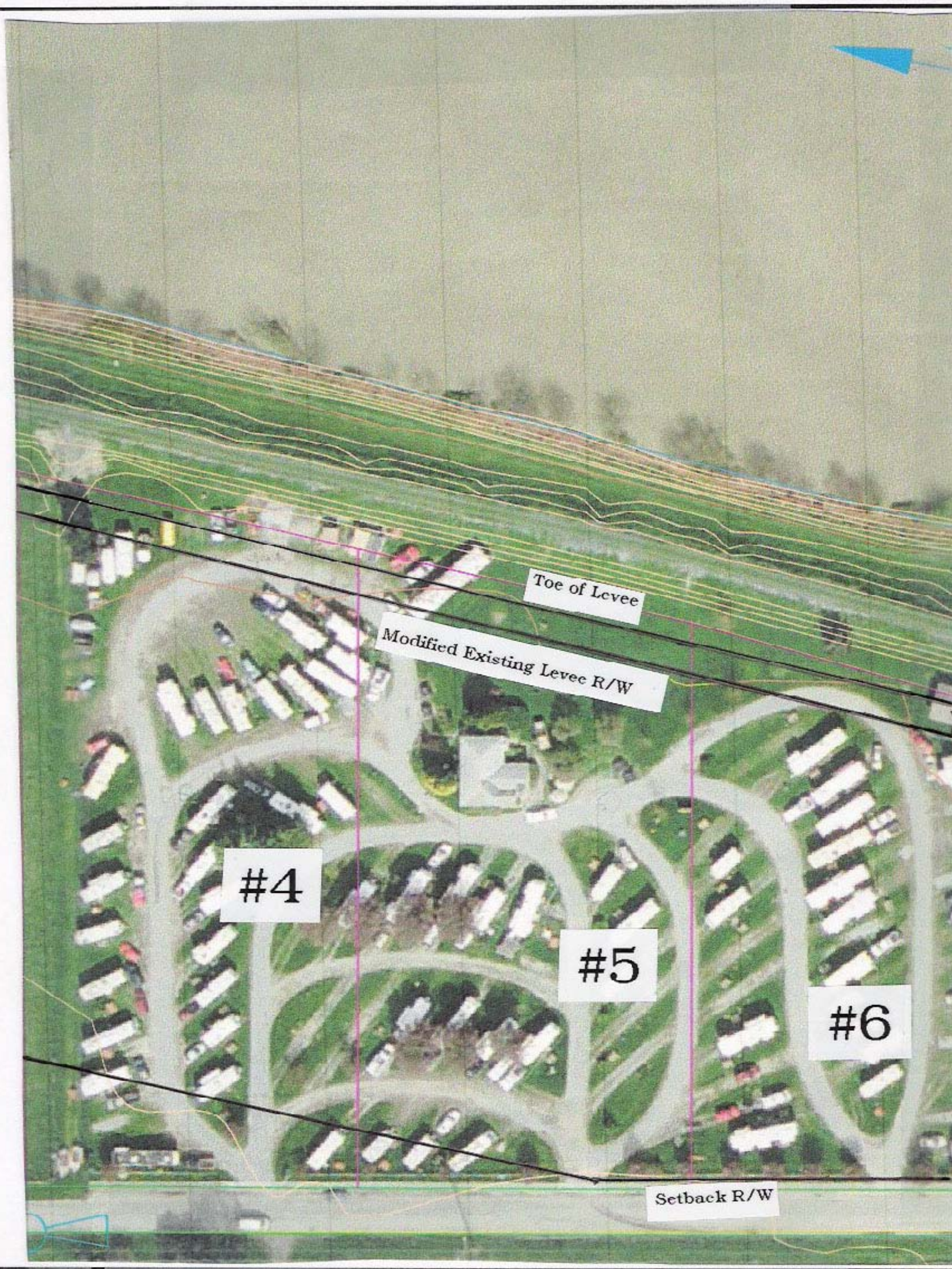
Left Bank Parcels



Scale 1" = 100'

Figure 1b

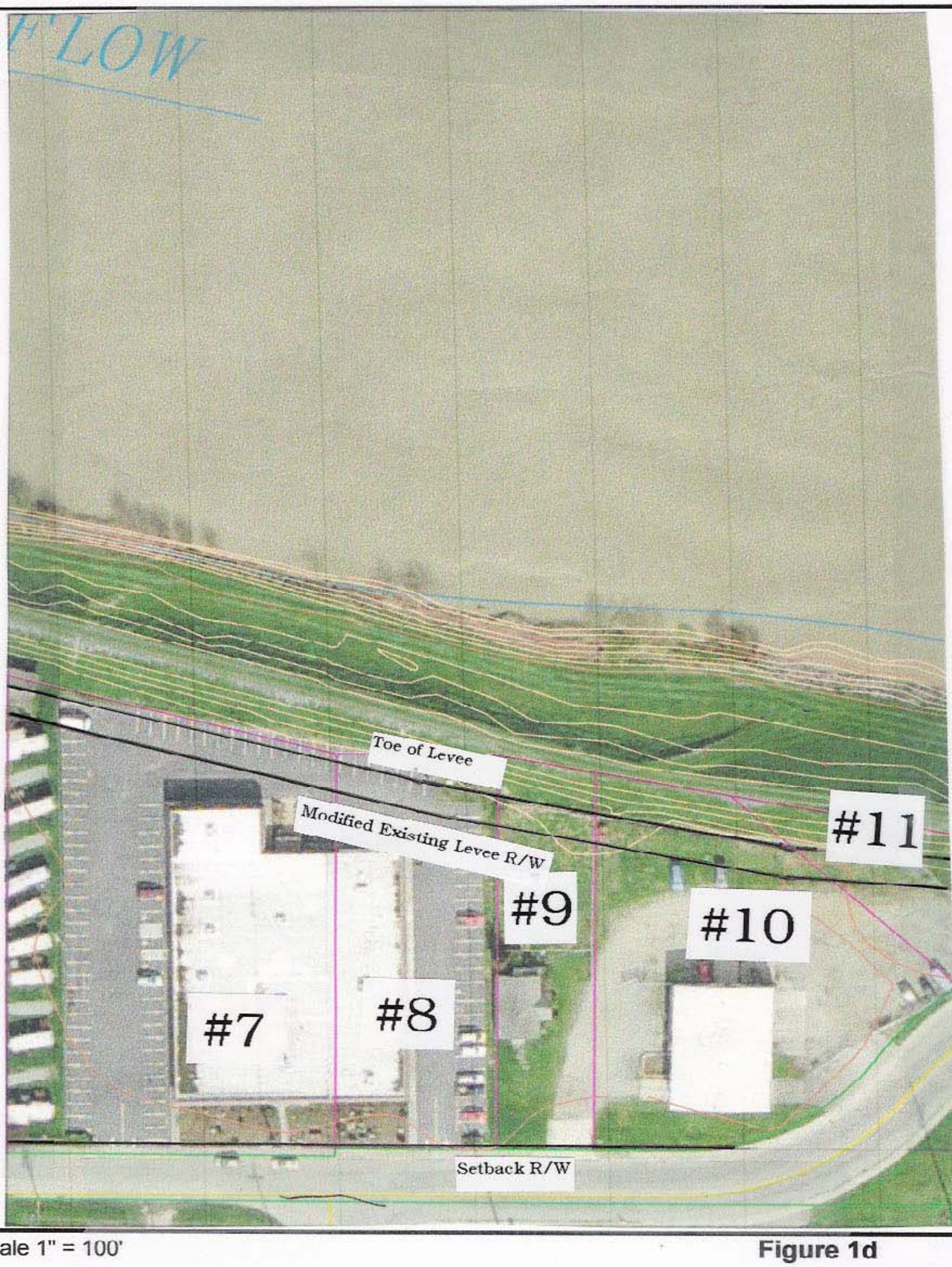
Left Bank Parcels



Scale 1" = 100'

Figure 1c

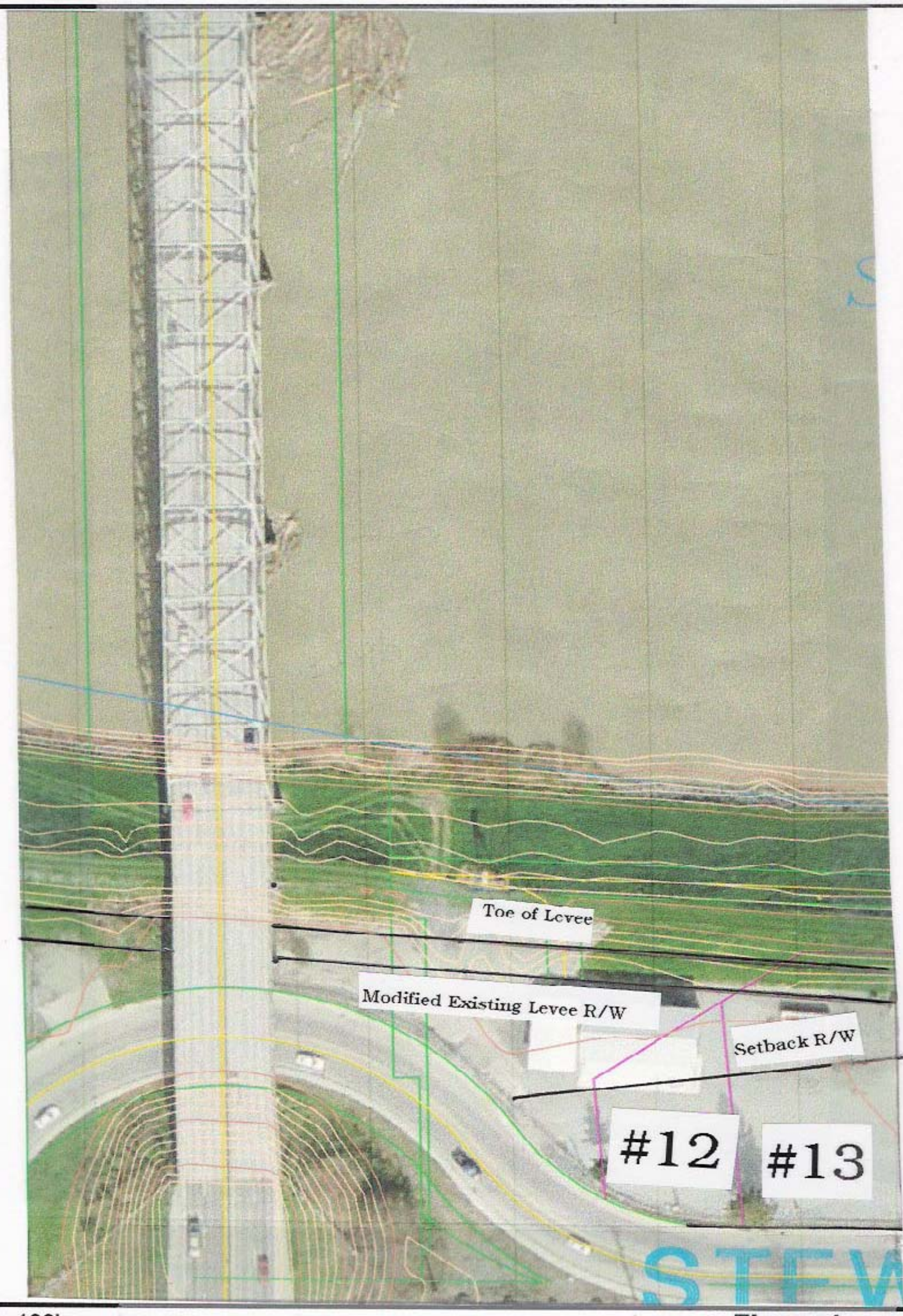
Left Bank Parcels



Scale 1" = 100'

Figure 1d

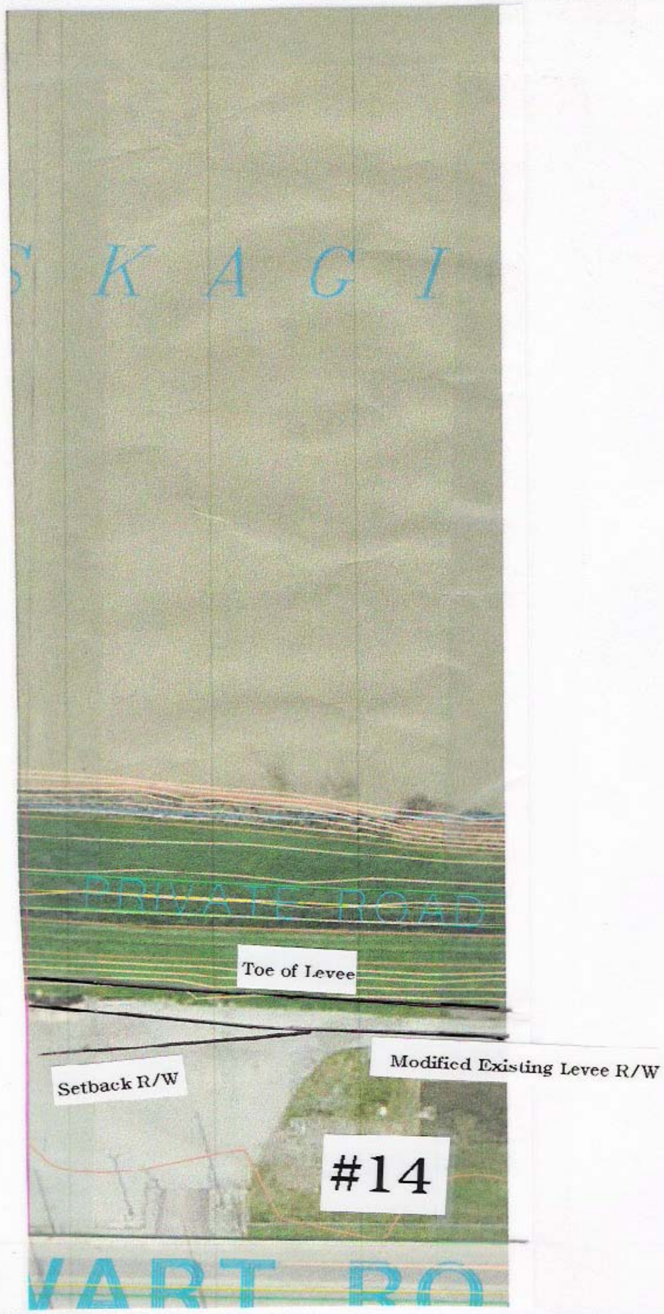
Left Bank Parcels



Scale 1" = 100'

Figure 1e

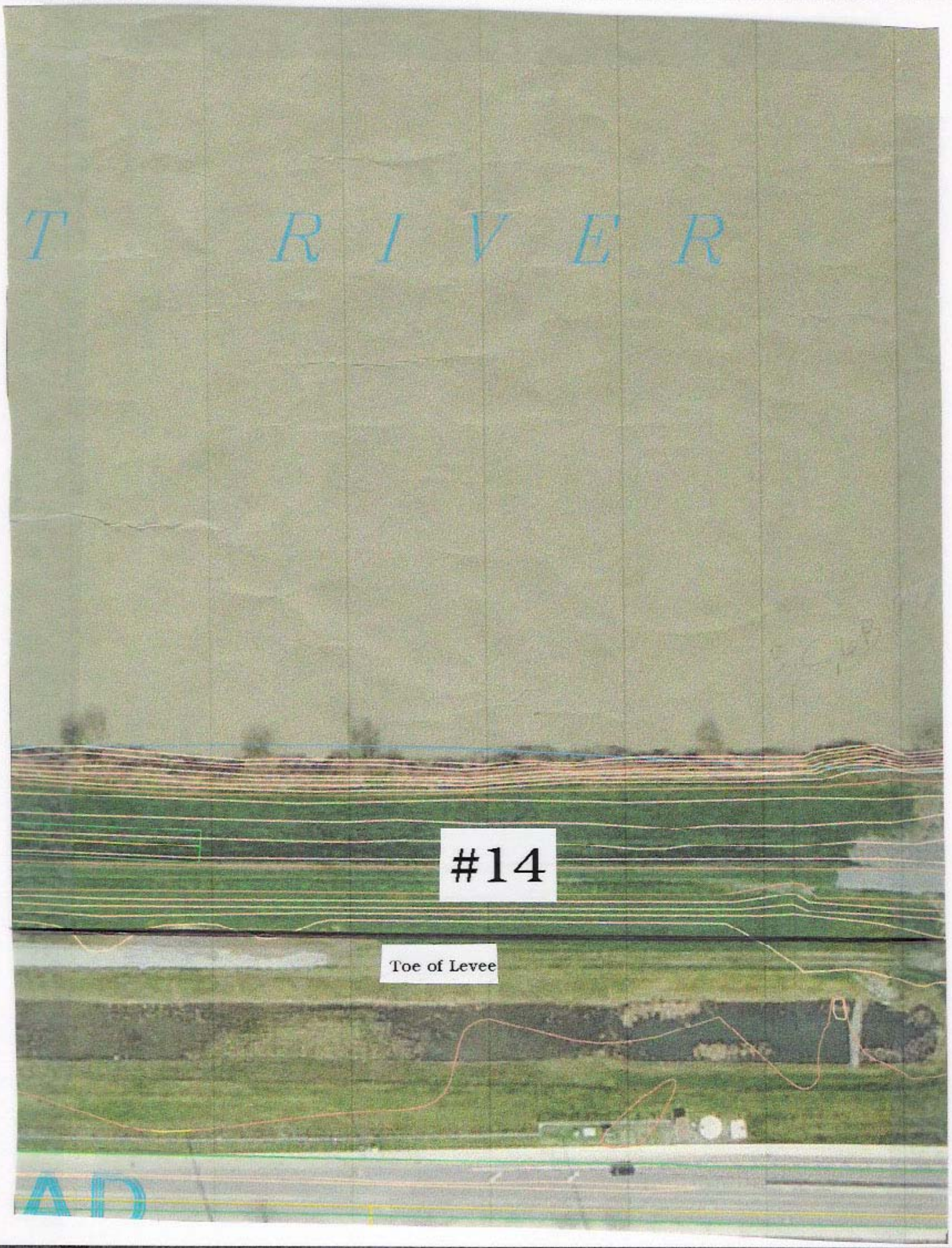
Left Bank Parcels



Scale 1" = 100'

Figure 1f

Left Bank Parcels



Scale 1" = 100'

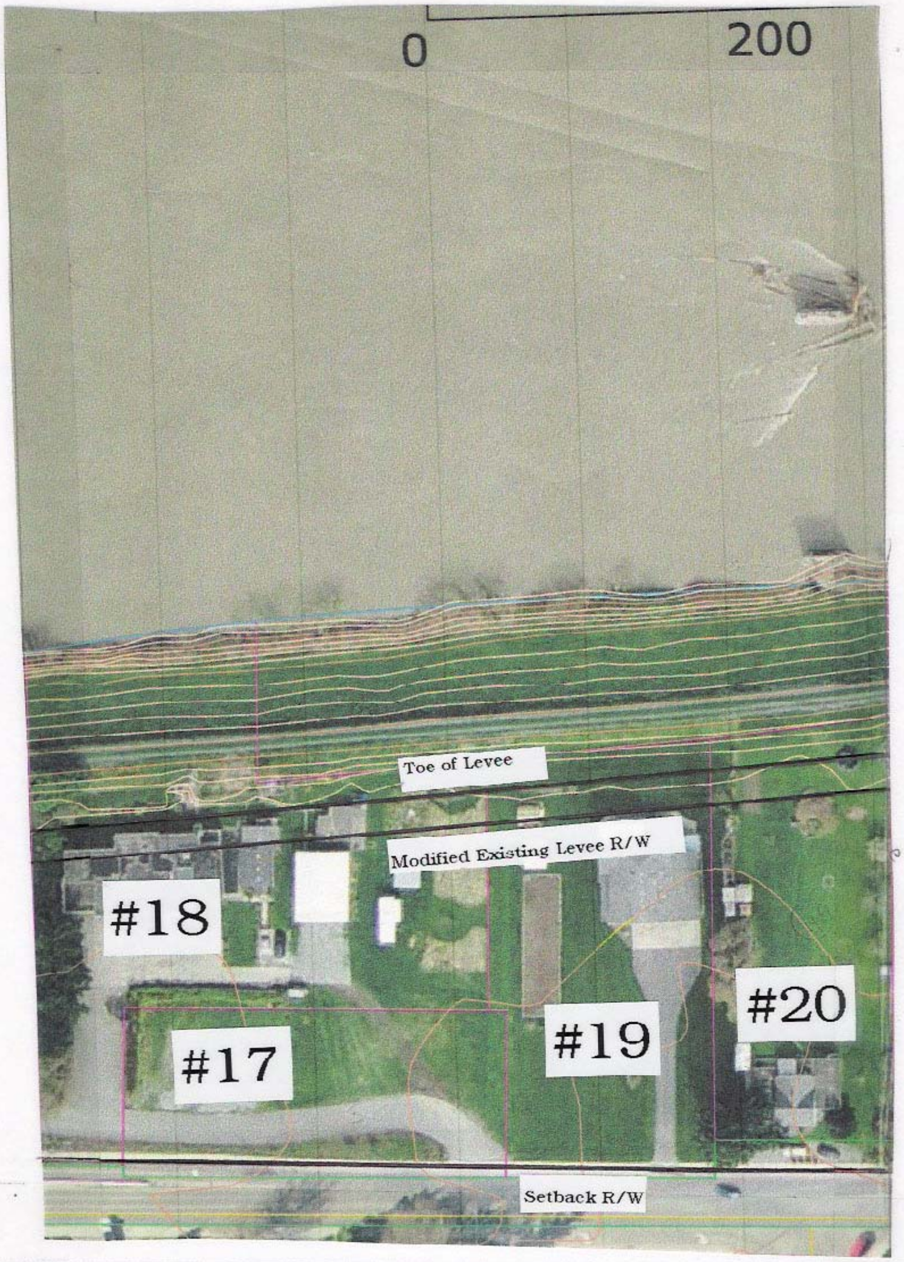
Figure 1g

Left Bank Parcels

Scale 1" = 100'

Figure 1h

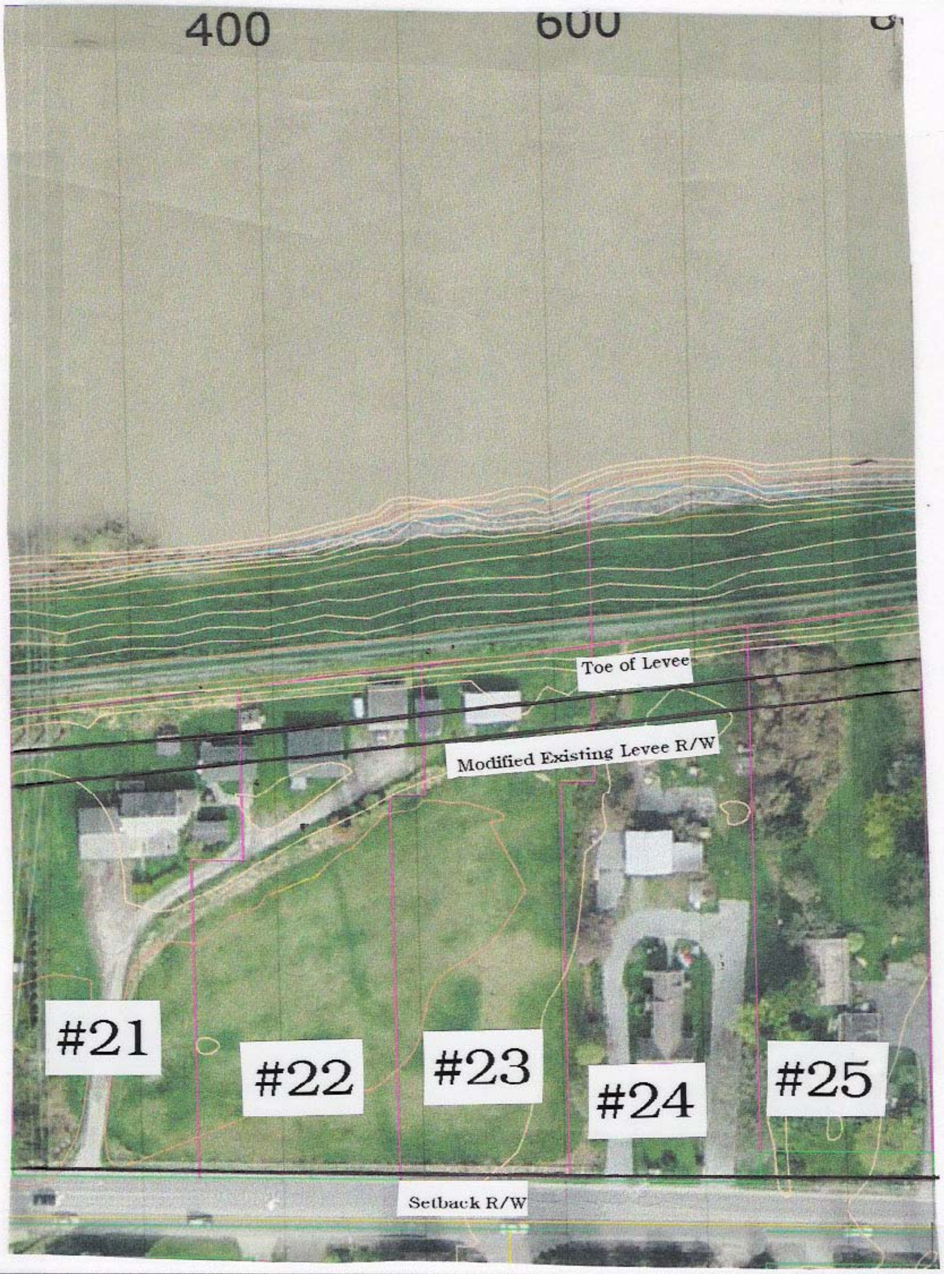
Left Bank Parcels



Scale 1" = 100'

Figure 1i

Left Bank Parcels



Scale 1" = 100'

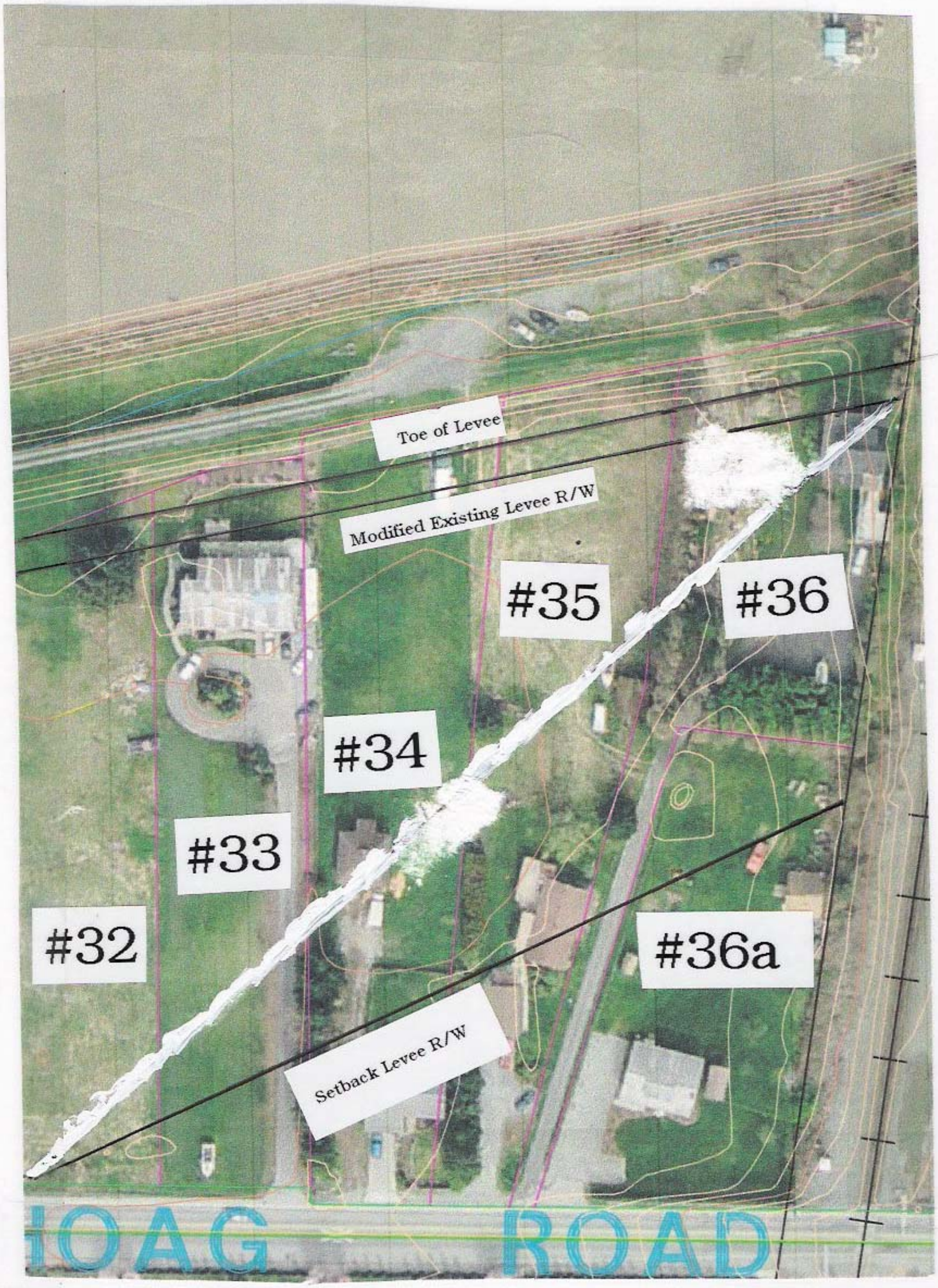
Figure 1j

Left Bank Parcels

Scale 1" = 100'

Figure 1k

Left Bank Parcels



Scale 1" = 100'

Figure 1I

Left Bank Parcels

Scale 1" = 100'

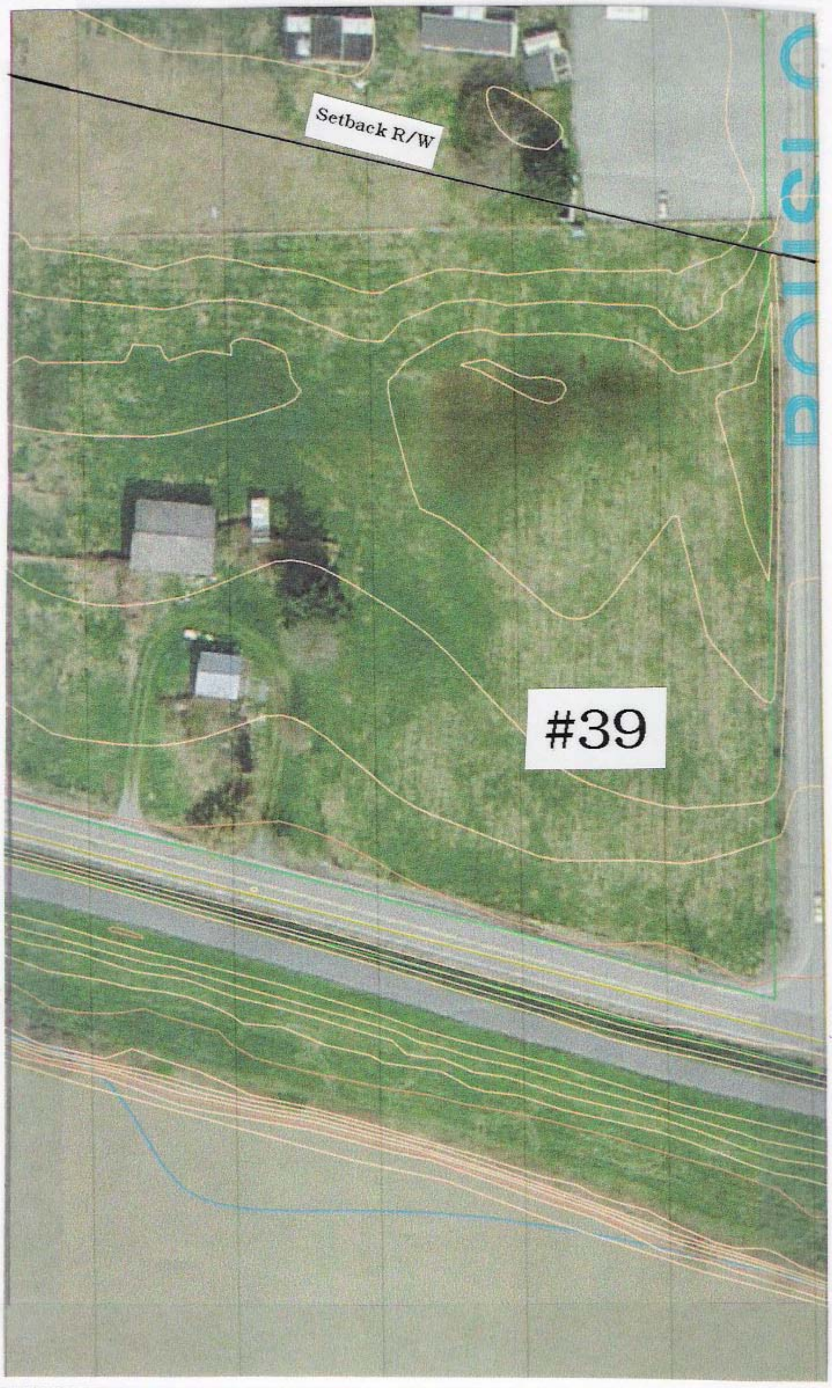
Figure 2a

Right Bank Parcels

Scale 1" = 100'

Figure 2b

Right Bank Parcels



Scale 1" = 100'

Figure 2c

Right Bank Parcels

Scale 1" = 100'

Figure 2d

Right Bank Parcels

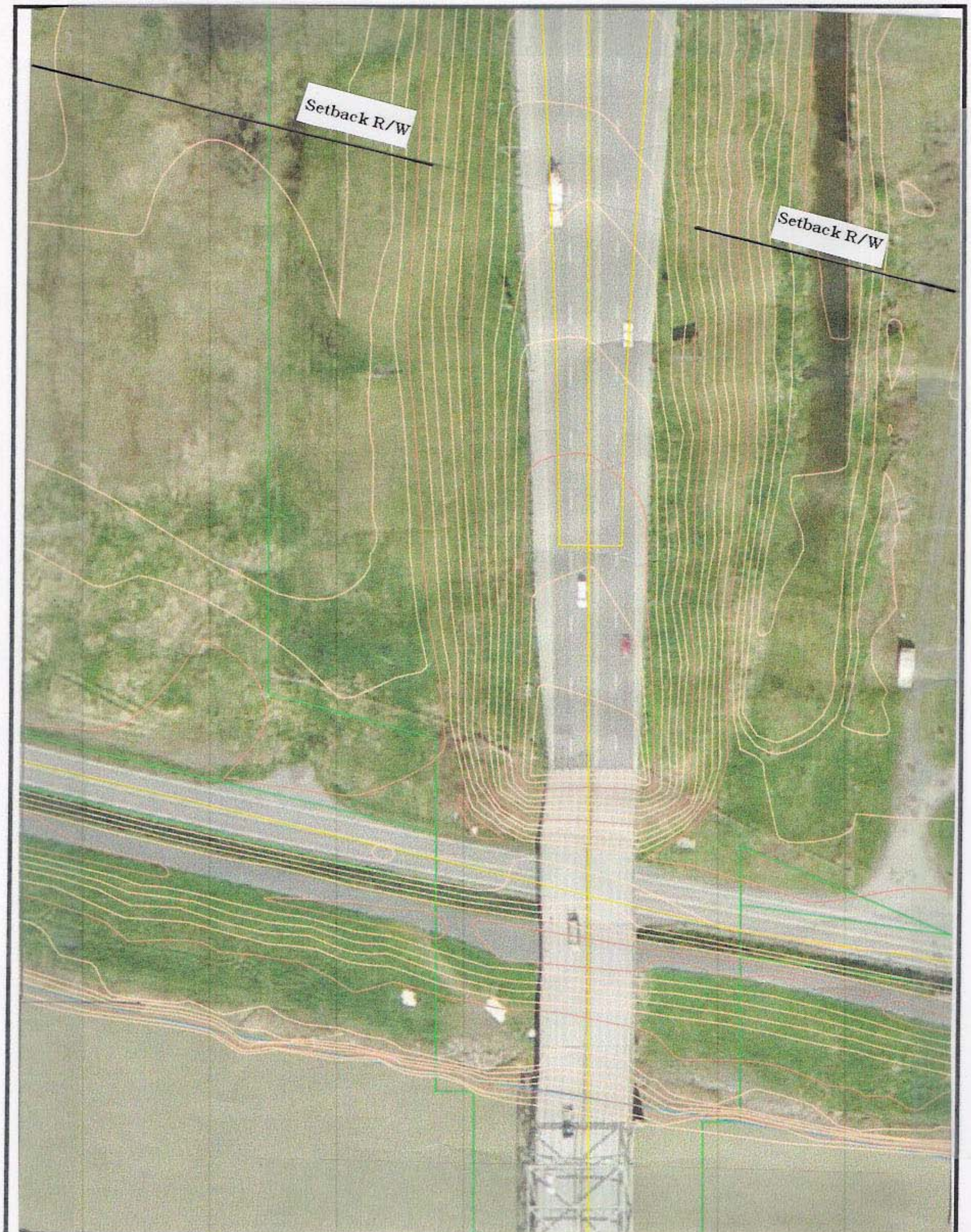


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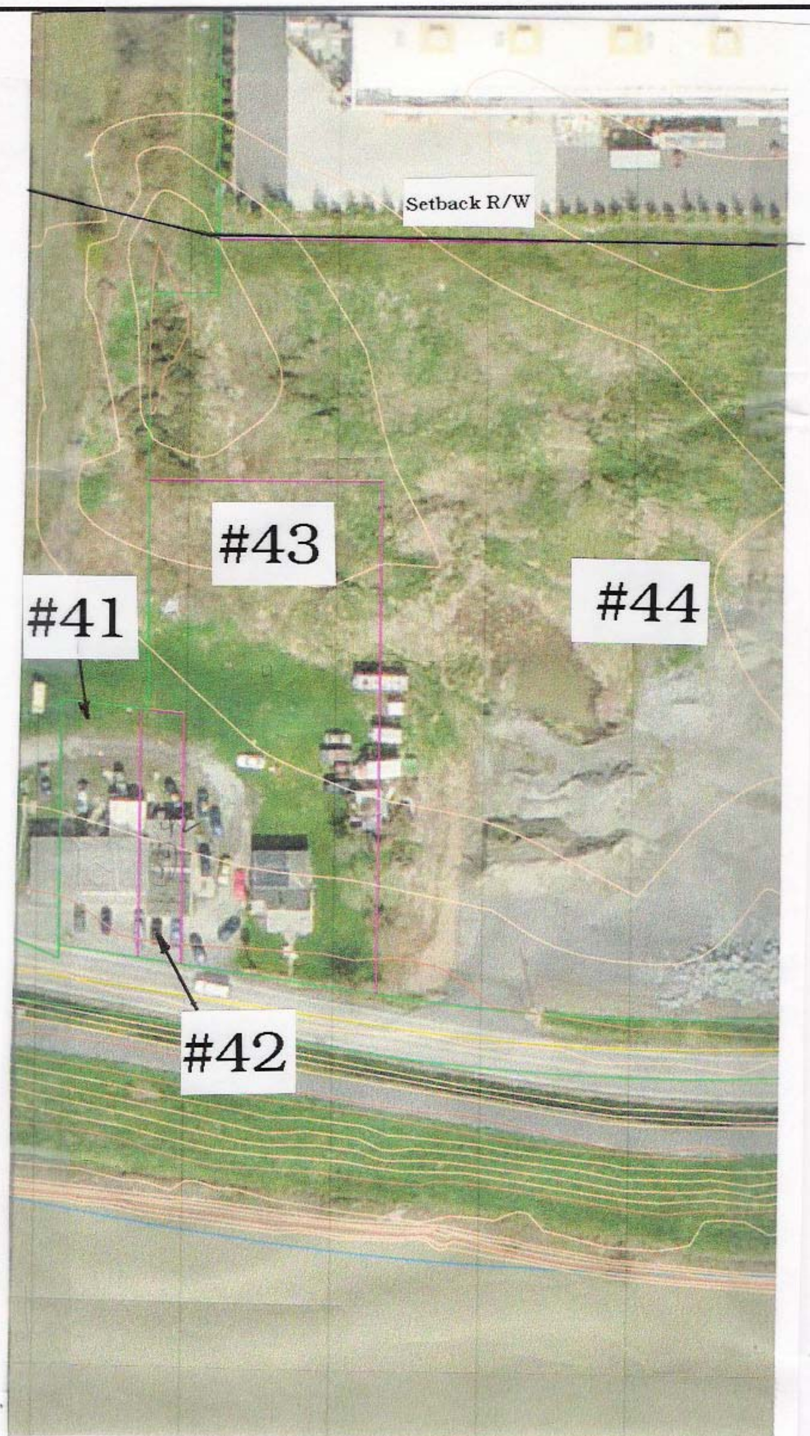
Figure 2e

Right Bank Parcels



Scale 1" = 100'

Figure 2f

Right Bank Parcels

Scale 1" = 100'

Figure 2g

Right Bank Parcels

Scale 1" = 100'

Figure 2h

Right Bank Parcels

Scale 1" = 100'

Figure 2i

Right Bank Parcels

Scale 1" = 100'

Figure 2j

Right Bank Parcels

Scale 1" = 100'

Figure 2k

Right Bank Parcels

Scale 1" = 100'

Figure 2I

Right Bank Parcels

Scale 1" = 100'

Figure 2m

Right Bank Parcels

Appendix C
Flood Damage Reduction Analysis

DRAFT TECHNICAL MEMORANDUM

Skagit River Bridge Modification and Interstate Highway Protection Project

Flood Damage Reduction Analysis

Introduction

The hydraulic analysis of the three project alternatives under consideration (No Action, Modified Existing Levees, and Setback Levees), has shown that the No Action and Modified Existing Levees alternatives have no significant impact on the hydraulics of the lower Skagit River. The Setback Levee alternative has been shown to reduce the water surface elevation of the river by approximately 0.4 feet for flows between the 25 year and 100 year flood events. Additional detailed computer modeling by the Corps of Engineers will be necessary to verify this conclusion.

The analysis presented in this memorandum is based upon the estimated stage reduction of 0.4 feet and utilizes a June 2005 report "*Economic Flood Damage Assessment of Without Project Conditions, Skagit County, Washington*" (1) as the basis of the relationship between flood flows and flood damages.

Overflow Estimates

At all flows above approximately the 25-year flood event, overflows from the river will occur on the right bank upstream of the end of the existing right bank levee system. In addition, at some of the higher flows, the existing levees may be overtopped. The amount of overflow has been estimated using the Corps of Engineers Hydraulics Report (2) as well as a 2003 report prepared by Tetra Tech for Skagit County (7). Table 1 shows the estimated amount of the overflows from the two sources as well as an estimate of the amount of overflows that will be reduced if the water surface upstream of the BNSF Bridge is reduced by 0.4 feet.

Table 1
Estimated Overflows and Overflow Reductions (cfs)

Flow	Estimated Overflows from Corps Hydraulics	Estimated Overflows from Tetra Tech Report	Estimated Reduction in Flows with Setback Levees Upstream	Downstream
25-year	0	8,000	5,000	4,000
50-year	24,000	36,000	10,000	7,000
75-year	40,000	-	12,500	9,000
100-year	53,000	48,000	15,000	10,000

Figure 1 depicts the changes that would occur to the flood frequency curves used in the Economics Report due to the flow changes that would occur due to the Setback Levees.

Flood Damages Under Existing Conditions

The Corps of Engineers Economics Report (1) presents flood damages at different flood events for ten assumed damage reaches from Concrete down to the mouth of the Skagit River. Reaches 8, 9, and 10 are upstream of Sedro Woolley and are assumed not to be impacted by the setback levees. Figure 2, from the Corps Economics Report, shows the area covered by each of the seven remaining reaches.

Flood Damages are broken into a number of categories and summarized by flood frequencies between 10-year and 500-year events. Tables 2 through 8 summarize food damages by frequency for each of the seven reaches.

For purposes of this analysis, it is assumed that flood potential in Reach 1 and Reach 6 will be reduced by a reduction in the flood stage and that flood potential will be increased in Reaches 2 to 5 and Reach 7. The rationale here is that if the levee setback project is implemented, for a given frequency of flood, the upstream level of flooding will be reduced. Likewise, since for a given stage of the river in the levee setback reach, flows will be increased and this will result in higher flows downstream of the study area. Therefore, flood damages have been summarized for the upstream areas that will be subject to less flooding (Reaches 1 and 6) and for the downstream areas that will be subject to greater flooding (Reaches 2 to 5 and 7). The summaries are included on Table 9.

The flood damage versus flood frequency data are plotted for existing conditions in Figure 3 for the upstream and downstream reaches. The area underneath each curve is the average annual flood damage and Table 10 shows the calculation of this value for the upstream and downstream areas. As shown in the table, the two upstream reaches are subject to $44.8 million in annual flood damages while the five downstream reaches are currently subject to $25.6 million in flood damages.

Flood Damages with the Setback Levee Alternative

The flood damage versus flood frequency curves from Figure 3 can be modified to reflect the flood frequency curves from Figure 1 that results from construction of the setback levees. The revised curve is shown in Figure 4. The area underneath the curve is the resultant damages once the project is constructed. The calculation of these damages is presented in Table 11 and show that the resultant upstream damages are decreased to $43.4 million annually while the downstream damages with the project are increased to $26.9 million.

Flood Control Benefits due to Setback Levee Alternative

A comparison of the flood damages from Tables 10 and 11 shows that flood damages upstream of the project decrease from $44.8 million annually under pre-project conditions to $43.4 million when the project is constructed. This results in a benefit of

$1.4 million annually. However, downstream flood damages increase from $25.6 million pre-project to $26.9 million annually, an increase of $1.3 million.

Therefore, the net flood control benefit for the levee setback alternative is approximately $0.1 million annually ($1.4 minus $1.3). Other project features may produce other benefits that should be considered. Also, these are very preliminary numbers and Corps of Engineers hydraulic and economic models need to be re-run to obtain more reliable values for this project.

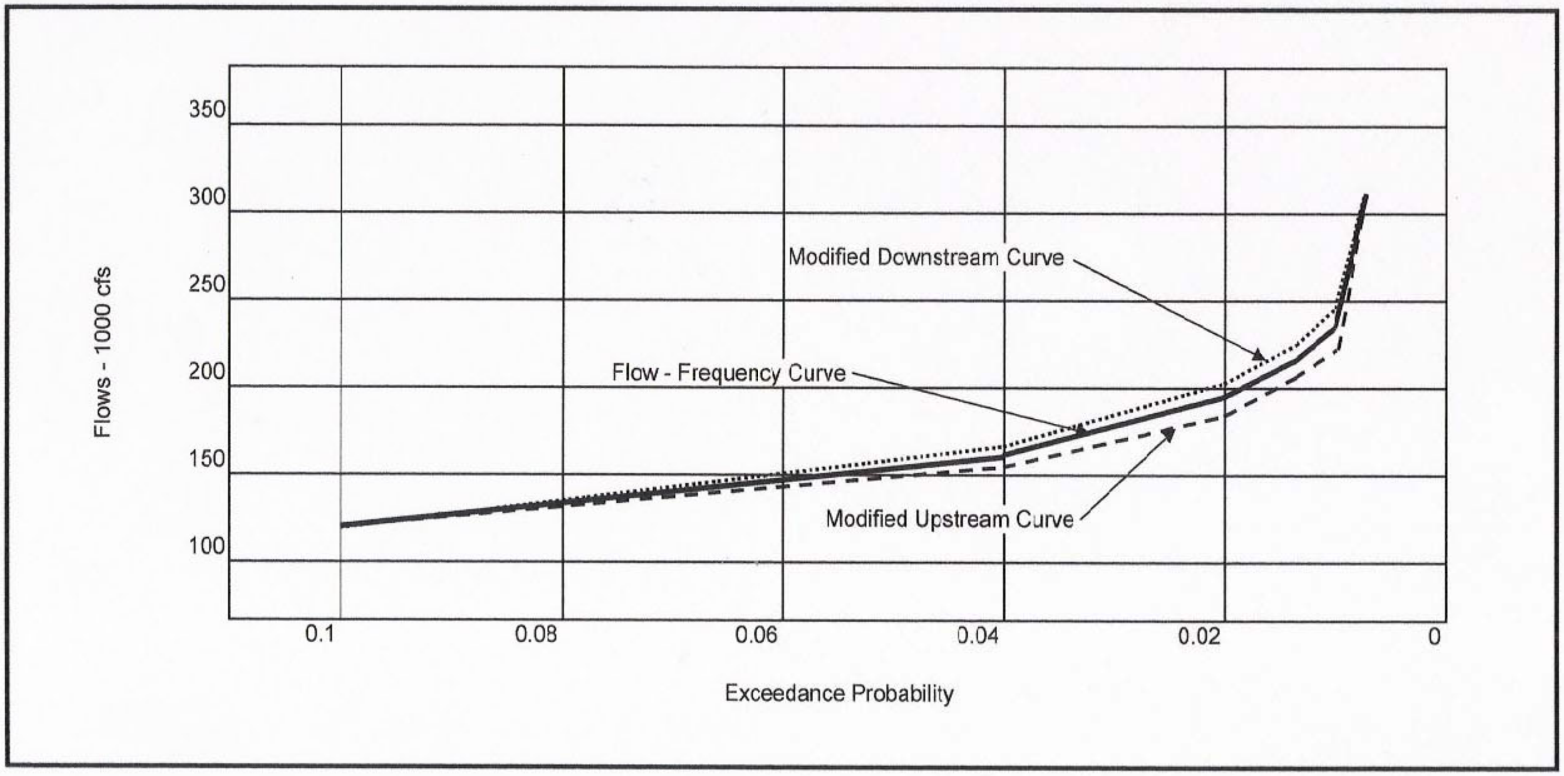
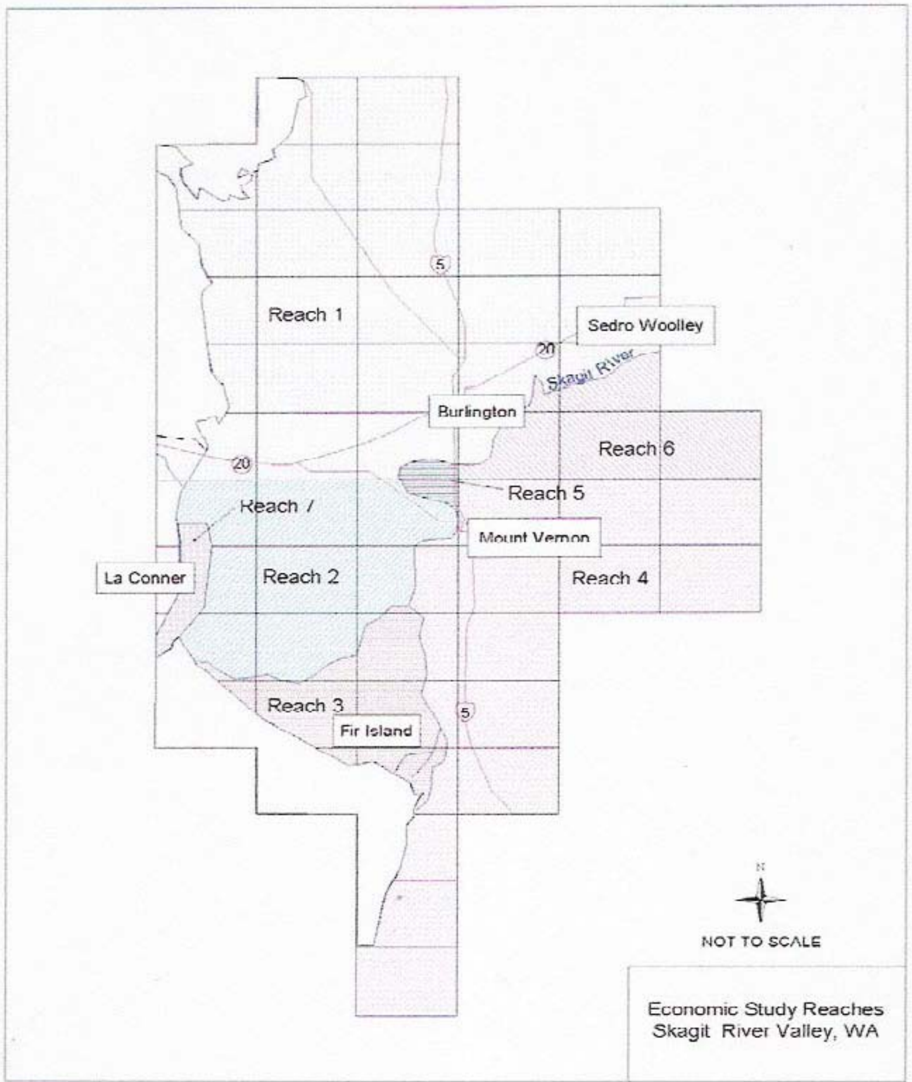


Figure 1
Flow - Frequency Curves
Seback Levee Alternative

Figure 2 - Downstream Study Reaches



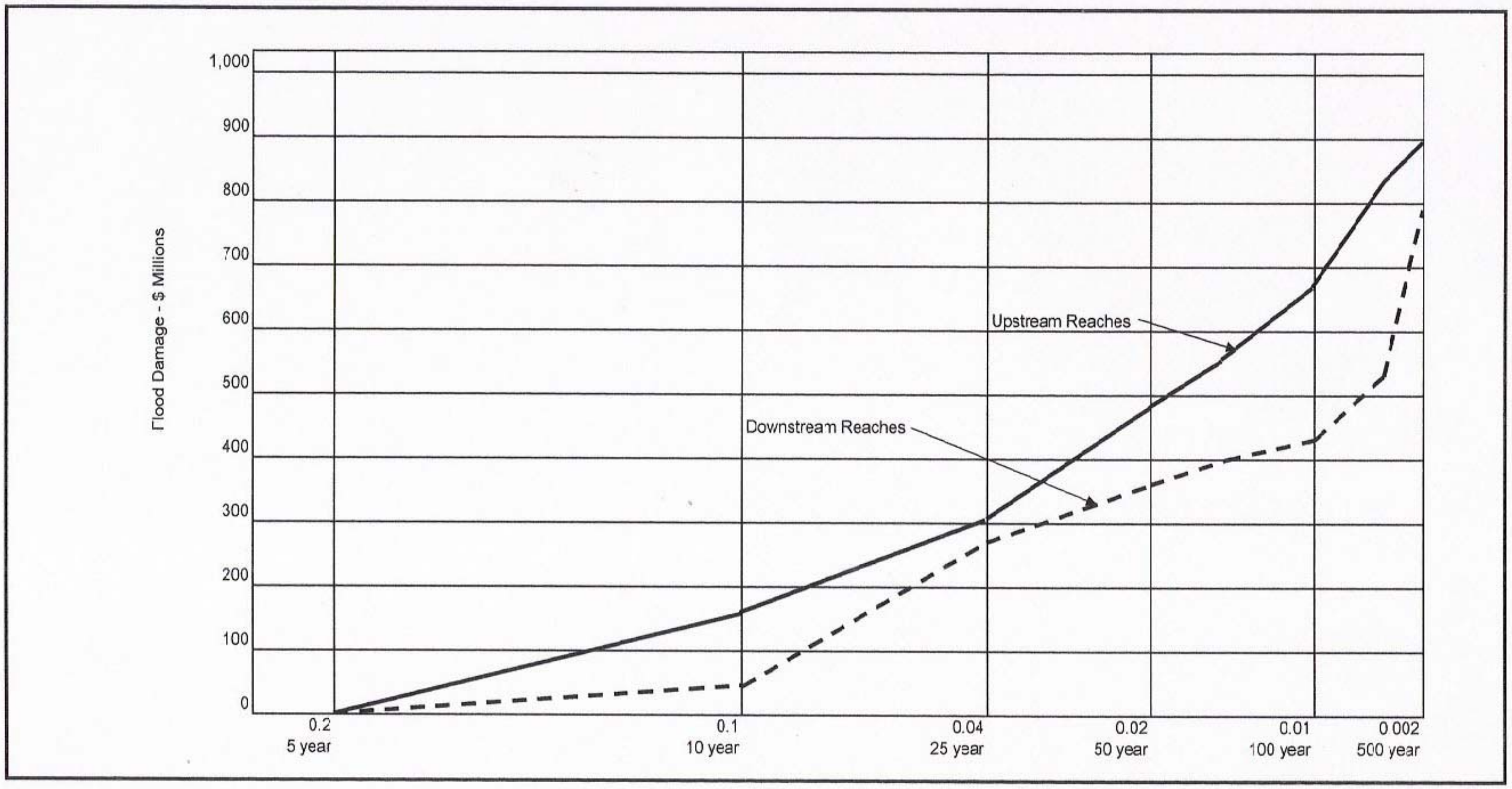


Figure 3
Damage Frequency Curves

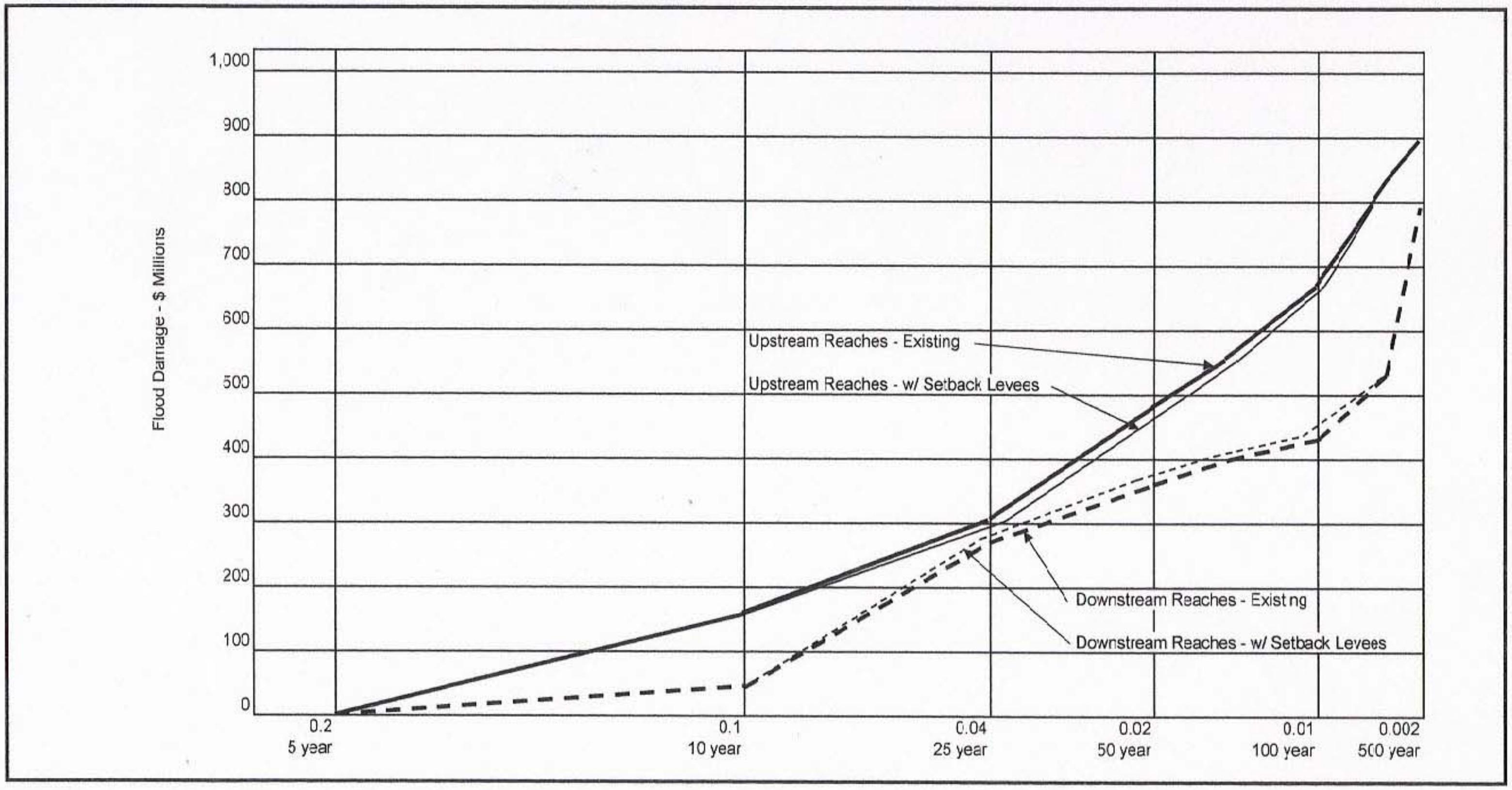


Figure 4
Damage Frequency Curves
With Setback Levees

Flood Damages **Reach 1** Damages in Millions

	Residential					Non Residential					
	Structures	Contents	Clean Up	Public Assist.	Temp. Reloc.	Structures	Contents	Clean Up	Agriculture	Traffic	Total
10-year	23	13	7	6	2	45	38	7	3	0	144
25-year	72	41	16	15	4	60	55	9	7	0	279
50-year	120	67	23	21	6	77	75	13	11	37	450
75-year	148	82	24	22	6	83	85	13	12	46	521
100-year	187	103	27	25	7	96	101	14	13	55	628
250-year	241	131	28	26	7	117	132	14	13	64	773
500-year	269	145	28	26	7	125	145	14	13	73	845

Table 2

Flood Damages **Reach 2** Damages in Millions

	Residential Structures	Residential Contents	Clean Up	Public Assist.	Temp. Reloc.	Non Residential Structures	Non Residential Contents	Non Residential Clean Up	Agriculture	Traffic	Total
10-year	13	7	3	3	1				3		30
25-year	25	14	4	4	1				4		52
50-year	31	17	5	4	1				30		88
75-year	35	19	5	4	1				30		94
100-year	40	22	5	5	1				30		103
250-year	76	41	10	9	3	6	5	1	31		182
500-year	99	53	12	10	3	8	6	1	32		224

Table 3

Flood Damages **Reach 3** Damages in Millions

	Residential			Public	Temp.	Non Residential			Agriculture	Traffic	Total
	Structures	Contents	Clean Up	Assist.	Reloc.	Structures	Contents	Clean Up			
10-year	0	0	0	0	0	0	0	0	0	0	0
25-year	0	0	0	0	0	0	0	0	0	0	0
50-year	0	0	0	0	0	0	0	0	0	0	0
75-year	1	1	0	0	0	0	0	0	1	0	3
100-year	2	1	0	0	0	0	0	0	1	0	4
250-year	2	1	0	0	0	0	0	0	1	0	4
500-year	2	1	0	0	0	0	0	0	1	0	4

Table 4

Flood Damages **Reach 4** Damages in Millions

	Residential			Public	Temp.	Non Residential			Agriculture	Traffic	Total
	Structures	Contents	Clean Up	Assist.	Reloc.	Structures	Contents	Clean Up			
10-year	0	0	0	0	0	0	0	0	0	0	0
25-year	49	27	9	9	2	41	43	12	2	0	194
50-year	65	36	11	10	3	50	54	14	2	0	245
75-year	76	42	12	11	3	55	60	15	2	0	276
100-year	81	45	12	11	3	56	63	15	2	0	288
250-year	86	47	13	12	3	59	66	15	2	0	303
500-year	155	83	16	14	4	86	105	16	3	0	482

Table 5

Flood Damages **Reach 5** Damages in Millions

	Residential Structures	Residential Contents	Residential Clean Up	Public Assist.	Temp. Reloc.	Non Residential Structures	Non Residential Contents	Non Residential Clean Up	Agriculture	Traffic	Total
10-year	0	0	0	0	0	0	0	0	0	0	0
25-year	0	0	0	0	0	0	0	0	0	0	0
50-year	0	0	0	0	0	0	0	0	0	0	0
75-year	0	0	0	0	0	0	0	0	0	0	0
100-year	0	0	0	0	0	0	0	0	0	0	0
250-year	0	0	0	0	0	0	0	0	0	0	0
500-year	7	3	1	0	0	8	9	1	0	0	29

Table 6

Flood Damages **Reach 6** Damages in Millions

	Residential			Public	Temp.	Non Residential			Agriculture	Traffic	Total
	Structures	Contents	Clean Up	Assist.	Reloc.	Structures	Contents	Clean Up			
10-year	6	3	1	1	0	0	0	0	2	0	13
25-year	10	6	2	1	0	1	1	0	3	0	24
50-year	13	7	2	2	1	1	1	0	3	0	30
75-year	15	8	2	2	1	1	1	0	3	0	33
100-year	16	9	2	2	1	1	2	0	3	0	36
250-year	20	11	3	2	1	2	2	0	3	0	44
500-year	22	12	3	3	1	2	2	0	3	0	48

Table 7

Flood Damages **Reach 7** Damages in Millions

	Residential			Public	Temp.	Non Residential			Agriculture	Traffic	Total
	Structures	Contents	Clean Up	Assist.	Reloc.	Structures	Contents	Clean Up			
10-year	1	1	1	1	0	3	2	1	0	0	10
25-year	5	3	2	2	0	5	4	1	0	0	22
50-year	7	4	2	2	0	5	4	1	0	0	25
75-year	7	4	2	2	0	6	4	1	0	0	26
100-year	8	5	2	2	0	6	5	1	0	0	29
250-year	12	7	2	2	1	7	7	1	0	0	39
500-year	15	8	2	2	1	9	9	1	0	0	47

Table 8

Total Flood Damages, Damages in Millions

Upstream		Reach 1	Reach 6	Total
10-year		144	13	157
25-year		279	24	303
50-year		450	30	480
75-year		521	33	554
100-year		628	36	664
250-year		773	44	817
500-year		845	48	893

Downstream		Reach 2	Reach 3	Reach 4	Reach 5	Reach 7	Totals
10-year		30	0	0	0	10	40
25-year		52	0	194	0	22	268
50-year		88	0	245	0	25	358
75-year		94	3	276	0	26	399
100-year		103	4	288	0	29	424
250-year		182	4	303	0	39	528
500-year		224	4	482	29	47	786

Table 9

Computation of Annual Flood Damages

Existing Conditions

Reaches 1 and 6

Flood Event	Exceedance Probability	Incremental Probability	Average Damage $ Million	Annual Damage $ Million
5 year	0.2			
		0.1	115	11.5
10 year	0.1			
		0.06	230	13.8
25 year	0.04			
		0.02	391	7.8
50 year	0.02			
		0.0067	517	3.5
75 year	0.0133			
		0.0033	609	2.0
100 year	0.01			
		0.006	740	4.4
250 year	0.004			
		0.002	905	1.8
500 year	0.002			
			Total	$44.8 million

Reaches 2, 3, 4, 5, 7

Flood Event	Exceedance Probability	Incremental Probability	Average Damage $ Million	Annual Damage $ Million
5 year	0.2			
		0.1	20	2.0
10 year	0.1			
		0.06	154	9.2
25 year	0.04			
		0.02	313	6.3
50 year	0.02			
		0.0067	378	2.5
75 year	0.0133			
		0.0033	412	1.4
100 year	0.01			
		0.006	476	2.9
250 year	0.004			
		0.002	659	1.3
500 year	0.002			
			Total	$25.6 million

Table 10

Computation of Annual Flood Damages

With Setback Levees Conditions

Reaches 1 and 6

Flood Event	Exceedance Probability	Incremental Probability	Average Damage $ Million	Annual Damage $ Million
5 year	0.2			
		0.1	115	11.5
10 year	0.1			
		0.064	230	14.7
27.7 year	0.036			
		0.019	391	7.4
58.8 year	0.017			
		0.006	517	3.1
90.9 year	0.011			
		0.002	609	1.2
111 year	0.009			
		0.005	740	3.7
250 year	0.004			
		0.002	905	1.8
500 year	0.002			
			Total	$43.4 million

Reaches 2, 3, 4, 5, 7

Flood Event	Exceedance Probability	Incremental Probability	Average Damage $ Million	Annual Damage $ Million
5 year	0.2			
		0.1	20	2.0
10 year	0.1			
		0.053	154	8.1
21.3 year	0.047			
		0.024	313	7.5
43.5 year	0.023			
		0.007	378	2.6
62.5 year	0.016			
		0.004	412	1.6
83.3 year	0.012			
		0.008	476	3.8
250 year	0.004			
		0.002	659	1.3
500 year	0.002			
			Total	$26.9 million

Table 11