

Chapter 8 – Flood Hazard Management Strategies

8.0 Introduction

Skagit County has many flood control options to choose from to mitigate the impacts of flooding. Due to the complex nature of the flooding, several methods of flood control are understandably necessary to accomplish a desirable measure of protection. The County has used several different flood control methods throughout its history and has been successful in controlling flood damages. This chapter discusses the flood control management options, both structural and non-structural, available to the County. (Skagit County, 1989)

8.1 The Original Fifteen

In 2007, the U.S. Army Corps of Engineers (USACE) established fifteen measures for the Skagit River General Investigation (GI) that specifically focused on storage, setback levees, ring dikes, diversions, and emergency structures.

Table 8.1 Original Measures (2007)

Measure	Description	Type
1a	Sedro-Woolley Water Treatment Plant Ring Dike	Ring Dike
2ab	Sterling and SR-9 to BNSF (Right Bank) Levees	Ring Dike
3ac	Multi-bridge (3-bridge) corridor (Right Bank)	Setback Levees
3bd	Multi-bridge (3-bridge) corridor (Left Bank) Levees	Setback Levees
4	Anacortes Waste Water Treatment Plant Ring Dike	Ring Dike
5abc	Mount Vernon Floodwall and Setback Levees	Setback Levees
6a	Big Bend Cut-off Levee	Diversion
7abc	Nookachamps Left Bank Storage Levees	Storage
8a	Clear Lake Levee	Ring Dike
9	River Mile 16 Water Control Structure	Diversion
9af	West Side Floodplain Conveyance Areas	Diversion
10ab	Setback Levees below Mount Vernon	Setback Levees
11a	North Fork (Right Bank) Setback Levee	Setback Levees
12a	South fork (Left Bank) Setback Levee	Setback Levees
13	Mount Vernon Diversion Channel	Diversion
14	Cross Island Connector Diversion Channel	Diversion
15	LaConner Ring Dike	Ring Dike

Appendix F provides a site map for reference.

Emergency structures are typically outlet structures that release water into the floodplain. The water would most likely evacuate through the bay area. Locations to be determined.

8.2 Preliminary Measures Presentation

On August 18, 2008, the USACE presented thirty-seven measures that were elaborations of the original fifteen. Two measures were previously screened out: 1.) a dam on the Sauk River due to the river's national designation as a Wild and Scenic River, and 2.) dredging because of its high cost, continual upkeep, and negative impacts to endangered species. The presentation was widely attended by members from various areas of the community, including dike and drainage districts, municipalities, and environmental entities.

All the measures fell under the same types of functions as the Original Fifteen.

- Hold back flood water (storage),
- Get floodwater out of river – bypass (diversion),
- Enlarge channel – dredging, natural valley storage and setbacks (levee setbacks),
- Keep river in bounds – levees (ring dikes), and
- Let river flood, remove damages – relocations, flood proofing and evacuation plans (emergency structures).

8.3 Modifications to Existing Dams

Flood water storage is the most direct means of flood water control. It is also the most versatile as the approach reduces the flood flow rate and peak rate, reduces the area inundated, and controls the duration of the flood. The degree of protection is dependent on the type of flood storage *device* and the storage capacity. Flood control storage can be attained with dams and reservoirs, holding ponds or sedimentation basins, or property acquisition of inundated lands. (Skagit County, 1989)

8.3.1 Measure 1 – Upper Baker Dam

The Upper Baker Dam is located at River Mile (RM) 9.3 on the Baker River tributary to the Skagit River, which comes into the Skagit River (RM 56.5) just upstream of the Concrete Gage. The drainage area above Upper Baker Dam is 215 square miles, which is roughly 7% of the drainage area for the Skagit River near Mount Vernon, and typically contributes 12% of the peak flow seen on the Skagit River. The USACE currently has the authorization for flood control space that maximizes at 74,000 acre-feet on November 15 of the flood season. With the existing flood control space, Upper Baker Dam outflow's current contribution to the 100-year flow is 9,000 cfs, which represents 4% of the total flow. These measures are designed to reduce the flow contribution coming from Upper Baker Dam with additional storage, timing, and minimum outflow adjustments.

The major potential advantage of Measure 1 is the reduction in flood flows during more frequent, smaller flood events. Potential disadvantages include increased flood flows during large events, impacts to endangered species, and hydropower losses. In addition, design must meet new Corps HQ structure and design requirements. Resolution of designation of FERC

Probable Maximum Flood would be required for the HQ to approve this measure. Finally, the measure only reduces flows from 15% of total inflow to mainstem.



Upper Baker River Dam
(Courtesy of U.S. Army Corps of Engineers)

The preliminary construction cost is zero. However, it does not account for any structural changes that may be necessary or maintenance or mitigation costs. Any additional dam maintenance would be a 100% local sponsor cost, and compensation for hydropower losses are also a local sponsor responsibility. The benefit-to-cost ratio will be developed when the Federal Energy Regulatory Commission (FERC) issues are resolved.

Sub-Measure 1A – Upper Baker Dam (74K Storage – 0 cfs Outflow)

This measure reduces the minimum flow released from Upper Baker Dam from 5,000 cfs to 0 cfs. The flood storage remains the same at 74,000 acre-feet and the flood control follows what is set in the Water Control Manual. This measure reduces the outflow at the dam for flood events up through a 25- year event but fills up the storage quicker and causes more flow to be released at larger flood events such as the 100-year. The benefits are seen because of the higher frequency of the lower events. Damages prevented by 1A would amount to about \$6 million annually. The Benefit-to-cost ratio is not available.

Considerations for further study:

- A more detailed analysis of possible structural modifications at the dam (necessary to meet Corps safety requirements) will be developed based on HQ guidance.
- This measure reduces flood flows for more frequent events (less than a 50-year event) but causes the storage to fill up prematurely in larger flood events, which causes increases in flows. Areas that normally do not see flooding until the larger flood events such as Sedro-Woolley have negative benefits because of this while most of the other areas see a benefit.
- These estimates of benefits and costs should be considered preliminary and are provided for the purpose of initial screening of management measures.
- Corps Headquarters will need to determine whether the dam meets current Corps operation and design requirements. If the dam does not meet criteria, Headquarters will need to identify what dam modifications are required and these costs will be attributed to the measure. This effort cannot be initiated until FERC determines what modifications may be required to the dam for Puget Sound Energy (PSE) to meet FERC requirements.
- This measure has the potential to increase flooding for Sedro-Wooley in major events. This would need to be mitigated.
- Costs to structurally modify the dam have not been determined or included in this evaluation. Dam maintenance and operation costs attributed to additional flood storage would be a 100% local cost.
- Costs of measure are based strictly on hydropower loss from change in operations of the dam. Power loss compensation would be a 100% local cost.
- Potential environmental impacts have not been evaluated. Need to assure that this measure would not impact critical in-stream flows (i.e. spawning beds and fish stranding).

Sub-Measure 1B – Upper Baker Dam (85K Storage – 0 cfs Outflow)

This measure reduces the minimum flow released from Upper Baker Dam from 5,000 cfs to 0 cfs and increases the flood storage from 74,000 acre-feet to 85,000 acre-feet. The flood control follows what is set in the Water Control Manual. This measure reduces the outflow at the dam for all flood events up to a 75-year event and then is similar to existing conditions. Damages prevented by 1B would amount to about \$8 million annually. The benefit-to-cost ratio is 49:3.

Considerations for further study:

- This measure reduces flood flows for more frequent events (less than a 100-year event) but causes the storage to fill up prematurely in larger flood events, which causes increases in flows. Areas that normally do not see flooding until the larger

flood events such as Sedro-Woolley have negative benefits because of this while most of the other areas see a benefit.

- These estimates of benefits and costs should be considered preliminary and are provided for the purpose of initial screening of management measures.
- Need determination of whether dam meets Probable Maximum Flood criteria and, if not, what would be necessary to meet the criteria.
- Corps Headquarters will need to determine whether the dam meets current Corps operation and design requirements. If the dam does not meet criteria, Headquarters will need to identify what dam modifications are required and these costs will be attributed to the measure. This effort cannot be initiated until FERC determines what modifications may be required to the dam for Puget Sound Energy (PSE) to meet FERC requirements.
- Measure has the potential to increase flooding for Sedro-Wooley in major events. This would need to be mitigated.
- Costs to structurally modify the dam have not been determined or included in this evaluation. Dam maintenance and operation costs attributed to additional flood storage would be a 100% local cost.
- Costs of measure are based strictly on hydropower loss from change in operations of the dam. Power loss compensation would be a 100% local cost.
- Potential environmental impacts have not been evaluated. Need to assure that this measure would not impact critical in-stream flows (i.e. spawning beds and fish stranding).

Sub-Measure 1C – Upper Baker Dam (100K Storage – 0 cfs Outflow)

This measure reduces the minimum flow released from Upper Baker Dam from 5,000 cfs to 0 cfs and increases the flood storage from 74,000 acre-feet to 100,000 acre-feet. The flood control follows what is set in the Water Control Manual. This measure reduces the outflow at the dam for all flood events. Damages prevented by 1C would amount to about \$9 million annually. The benefit-to-cost ratio is 21:1.

Considerations for further study:

- This measure reduces flows for all events greater than a 2-year flood at all locations.
- These estimates of benefits and costs should be considered preliminary and are provided for the purpose of initial screening of management measures.
- Corps Headquarters will need to determine whether the dam meets current Corps operation and design requirements. If the dam does not meet criteria, Headquarters will need to identify what dam modifications are required and these costs will be attributed to the measure. This effort cannot be initiated until FERC determines what modifications may be required to the dam for Puget Sound Energy (PSE) to meet FERC requirements.

- Costs to structurally modify the dam have not been determined or included in this evaluation. Dam maintenance and operation costs attributed to additional flood storage would be a 100% local cost.
- Costs of measure are based strictly on hydropower loss from change in operations of the dam. Power loss compensation would be a 100% local cost.
- Potential environmental impacts have not been evaluated. Need to assure that this measure would not impact critical in-stream flows (i.e. spawning beds and fish stranding).

Sub-Measure 1D – Upper Baker Dam (110K Storage – 0 cfs Outflow)

This measure reduces the minimum flow released from Upper Baker Dam from 5,000 cfs to 0 cfs and increases the flood storage from 74,000 acre-feet to 110,000 acre-feet. The flood control follows what is set in the Water Control manual. This measure reduces the outflow at the dam for all flood events but is only marginally better than 100K storage even in large events. Damages prevented by 1D would amount to about \$9 million annually. The benefit-to-cost ratio is 15:3.

Considerations for further study:

- This measure reduces flows for all events greater than a 2-year event at all locations.
- These estimates of benefits and costs should be considered preliminary and are provided for the purpose of initial screening of management measures.
- Corps Headquarters will need to determine whether the dam meets current Corps operation and design requirements. If the dam does not meet criteria, Headquarters will need to identify what dam modifications are required and these costs will be attributed to the measure. This effort cannot be initiated until FERC determines what modifications may be required to the dam for Puget Sound Energy (PSE) to meet FERC requirements.
- Costs to structurally modify the dam have not been determined or included in this evaluation.

8.3.2 Measure 2 – Lower Baker Dam

The Lower Baker Dam is located at River Mile (RM) 1.2 on the Baker River tributary to the Skagit River, which comes into the Skagit River (RM 56.5) just upstream of the Concrete Gage. The drainage area above Lower Baker Dam is 297 square miles, of which, 82 square miles is between Upper and Lower Baker Dams which is an additional 3% of the drainage area and 15% combined for the Skagit River near Mount Vernon. With the existing flood control space and flow releases at Upper Baker Dam, Lower Baker Dam's combined existing outflow contribution to the 100-year flow is 16,500 cfs which represents 7.3% of the total flow (7,500 cfs is the runoff between Upper and Lower Baker Dam and 9,000 cfs is the release from Upper Baker). These measures are designed to reduce the flow contribution coming from Lower Baker Dam with storage and outflow adjustments.

The major advantage of this measure is that implementation can be carried out on an informal basis by Puget Sound Energy in appropriate flood events (case-by-case basis). Potential disadvantages include limited storage capacity, limited outflow capacity, and hydropower losses. In addition, new Corps HQ structure and design requirements must be met. Finally, the flood forecasting technology currently available does not allow for the sufficiently precise prediction of storm timing and magnitude that would be required for this project to be federally authorized.



Lower Baker River Dam
(Courtesy of U.S. Army Corps of Engineers)

Sub-Measure 2A 1&2 – Lower Baker Dam (15K Storage – 0 cfs Outflow)

This measure would initiate flood control at Lower Baker Dam. This measure would set aside 15,000 acre-feet of storage for floods. In this evaluation, there is no way to maintain any storage by the time the peak flow occurs at Concrete using any conventional methods of flood control even for smaller events such as the 5-year and 10-year. This result is caused by two limitations. There is limited outflow capacity to maintain the storage (can only release 4000 cfs below the spillway crest), and the limited storage fills up with the excess inflow.

To define what is conventional, it is generally recognized that a set plan and storage needs to be in place before any flood occurs because, otherwise, the plan requires a very good understanding of the weather and its hydrologic response to act appropriately.

An example of a set plan is what the Corps has with Upper Baker and that is that the Corps shuts flows down to minimum flows 3 hours before the unregulated (natural (without dam flow)) Skagit River near Concrete flow reaches 90,000 cfs and then reduces flows to 0 cfs until the flood peak passes and then begin to evacuate pool.

Considerations for further Study:

- Corps Headquarters will need to determine whether the dam meets current Corps operation and design requirements. If the dam does not meet criteria, Headquarters will need to identify what dam modifications are required and these costs will be attributed to the measure. This effort cannot be initiated until FERC determines what modifications may be required to the dam for Puget Sound Energy (PSE) to meet FERC requirements.
- Operation, as described, would require that the National Weather Service (NWS) could, with 90%+ certainty, forecast upcoming flood events' time, magnitude and duration to be sufficiently reliable for Corps authorization. Based on discussions with NWS, this is impossible.
- Costs to structurally modify the dam have not been determined or included in this evaluation. Dam maintenance and operation costs attributed to additional flood storage would be a 100% local cost.
- Costs of implementation of this measure are based strictly on hydropower loss from change in operations of the dam. Power loss compensation would be a 100% local cost.
- Potential environmental impacts have not been evaluated. Assurance that this measure would not impact critical in-stream flows (i.e. spawning beds and fish stranding) is needed.

Measure 2B 1&2 – Lower Baker Dam (29K Storage – 0 cfs Outflow)

This measure would initiate flood control at Lower Baker Dam. This measure would set aside 29,000 acre-feet of storage for floods. In this evaluation, there is noway to maintain any storage by the time the peak flow occurs at Concrete using any conventional methods of flood control even for smaller events such as the 5-year and 10-year. This result is caused by two limitations. There is limited outflow capacity to maintain the storage (can only release 4000 cfs below the spillway crest), and the limited storage fills up with the excess inflow.

To define what is conventional, it is generally recognized that a set plan and storage needs to be in place before any flood occurs because, otherwise, the plan requires a very good understanding of the weather and its hydrologic response to act appropriately. An example of a set plan is what we have with Upper Baker and that is that we shut flows down to minimum flows 3 hours before the unregulated (natural (without dam flow)) Skagit River near Concrete flow reaches 90,000 cfs and then reduce flows to 0 cfs until the flood peak passes and then begin to evacuate pool.

Considerations for further Study:

- Corps Headquarters will need to determine whether the dam meets current Corps operation and design requirements. If the dam does not meet criteria, Headquarters will need to identify what dam modifications are required and these costs will be attributed to the measure. This effort cannot be initiated until FERC determines what modifications may be required to the dam for Puget Sound Energy (PSE) to meet FERC requirements.
- Operation, as described, would require that the National Weather Service (NWS) could, with 90%+ certainty, forecast upcoming flood events' time, magnitude and duration to be sufficiently reliable for Corps authorization. Based on discussions with NWS, this is impossible.
- Costs to structurally modify the dam have not been determined or included in this evaluation. Dam maintenance and operation costs attributed to additional flood storage would be a 100% local cost.
- Power loss compensation would be a 100% local cost.
- Potential environmental impacts have not been evaluated. Assurance is needed that this measure would not impact critical in-stream flows (i.e. spawning beds and fish stranding).

Sub-Measure 2C 1&2 – Lower Baker Dam (45K Storage – 0 cfs Outflow)

This measure would initiate flood control at Lower Baker Dam. This measure would set aside 45,000 acre-feet of storage for floods. In this evaluation, there is no way to maintain any storage by the time the peak flow occurs at Concrete using any conventional methods of flood control even for smaller events such as the 5-year and 10-year. This result is caused by two limitations. There is limited outflow capacity to maintain the storage (can only release 4000 cfs below the spillway crest), and the limited storage fills up with the excess inflow.

To define what is conventional, it is generally recognized that a set plan and storage needs to be in place before any flood occurs because, otherwise, the plan requires a very good understanding of the weather and its hydrologic response to act appropriately. An example of a set plan is what we have with Upper Baker and that is that we shut flows down to minimum flows 3 hours before the unregulated (natural (without dam flow)) Skagit River near Concrete flow reaches 90,000 cfs and then reduce flows to 0 cfs until the flood peak passes and then begin to evacuate pool.

Considerations for further study:

- Corps Headquarters will need to determine whether the dam meets current Corps operation and design requirements. If the dam does not meet criteria, Headquarters will need to identify what dam modifications are required and these costs will be attributed to the measure. This effort cannot be initiated until FERC

determines what modifications may be required to the dam for Puget Sound Energy (PSE) to meet FERC requirements.

- Operation, as described, would require that the National Weather Service (NWS) could, with 90%+ certainty, forecast upcoming flood events' time, magnitude and duration to be sufficiently reliable for Corps authorization. Based on discussions with NWS, this is impossible.
- Costs to structurally modify the dam have not been determined or included in this evaluation. Dam maintenance and operation costs attributed to additional flood storage would be a 100% local cost.
- Power loss compensation would be a 100% local cost.
- Potential environmental impacts have not been evaluated. Assurance is needed that this measure would not impact critical in-stream flows (i.e. spawning beds and fish stranding)

8.3.3 Measure 3 – Ross Dam

Ross Dam is located at River Mile (RM) 105.20 on the Skagit River, which is just upstream of Newhalem. The drainage area above Ross Dam is 999 square miles which is roughly 32% of the drainage area for the Skagit River near Mount Vernon and would typically contribute roughly 18% of the peak flow seen on the Skagit River if there was no flood control. The Corps of Engineers currently has the authorization for flood control space that maximizes at 120,000 acre-feet on December 1st of the flood season. With the existing flood control space, Ross Dam outflow's current contribution to the 100-year flow is 10,500 cfs which represents 4.7% of the total flow. These measures are designed to reduce the flow.

The potential advantage of this measure is the reduction of flows for events greater than the 10-year event. Potential disadvantages include impacts to endangered species, hydropower losses, and impacts to Seattle City Light facilities. In addition, the measure would require re-opening of the FERC license, and might require negotiations with Canada.

The preliminary construction cost is zero. However, this does not account for any structural changes that may be necessary or maintenance or mitigation costs. Any additional dam maintenance would be a 100% local sponsor cost, and compensation for hydropower losses are a local sponsor responsibility.



Ross Dam
(Courtesy of U.S. Army Corps of Engineers)

Sub-Measure 3A – Ross Dam (150K Storage – 0 cfs Outflow)

This measure increases the flood storage set aside from 120,000 acre-feet to 150,000 acre-feet and sets the minimum flow released from Ross Dam to 0 cfs. The flood control follows what is set in the Water Control manual. This measure reduces the outflow at the dam for flood events greater than or equal to a 25-year event. This measure reduces flows for all events greater than a 10-year event at all locations. Damages prevented by 3A would amount to about \$2 million annually. The benefit-to-cost ratio is not available.

Considerations for further study:

- Seattle Public Utilities (SPU) is not supportive of modifying the operation or structure of their dams. Modifications could require a reopening of their FERC license and could impact their launch and other facilities. Increases in pool elevation would require international negotiations with Canada.
- Cost attributable to any changes in operation or maintenance, or hydropower losses would be funded 100% by the local sponsor.

- The estimate of benefits should be considered preliminary and are provided for the purpose of initial screening of management measures.
- Environmental impacts of modifications have not been identified.

Sub-Measure 3B – Ross Dam (180K Storage – 0 cfs Outflow)

This measure increases the flood storage set aside from 120,000 acre-feet to 180,000 acre-feet and sets the minimum flow released from Ross Dam to 0 cfs. The flood control follows what is set in the Water Control manual. This measure reduces the outflow at the dam for flood events greater than or equal to a 25-year event. This measure reduces flows for all events greater than a 10-year event at all locations. Damages prevented by 3B would amount to about \$3 million annually. The benefit-to-cost ratio is not available.

Considerations for further study:

- Seattle Public Utilities (SPU) is not supportive of modifying the operation or structure of their dams. Modifications could require a reopening of their FERC license and could impact their launch and other facilities. Increases in pool elevation would require international negotiations with Canada.
- Cost attributable to any changes in operation or maintenance, or hydropower losses would be funded 100% by the local sponsor.
- Benefit estimates should be considered preliminary and are provided for the purpose of initial screening of management measures.
- Environmental impacts of modifications have not been identified.

8.4 Additional Storage – Small Scale

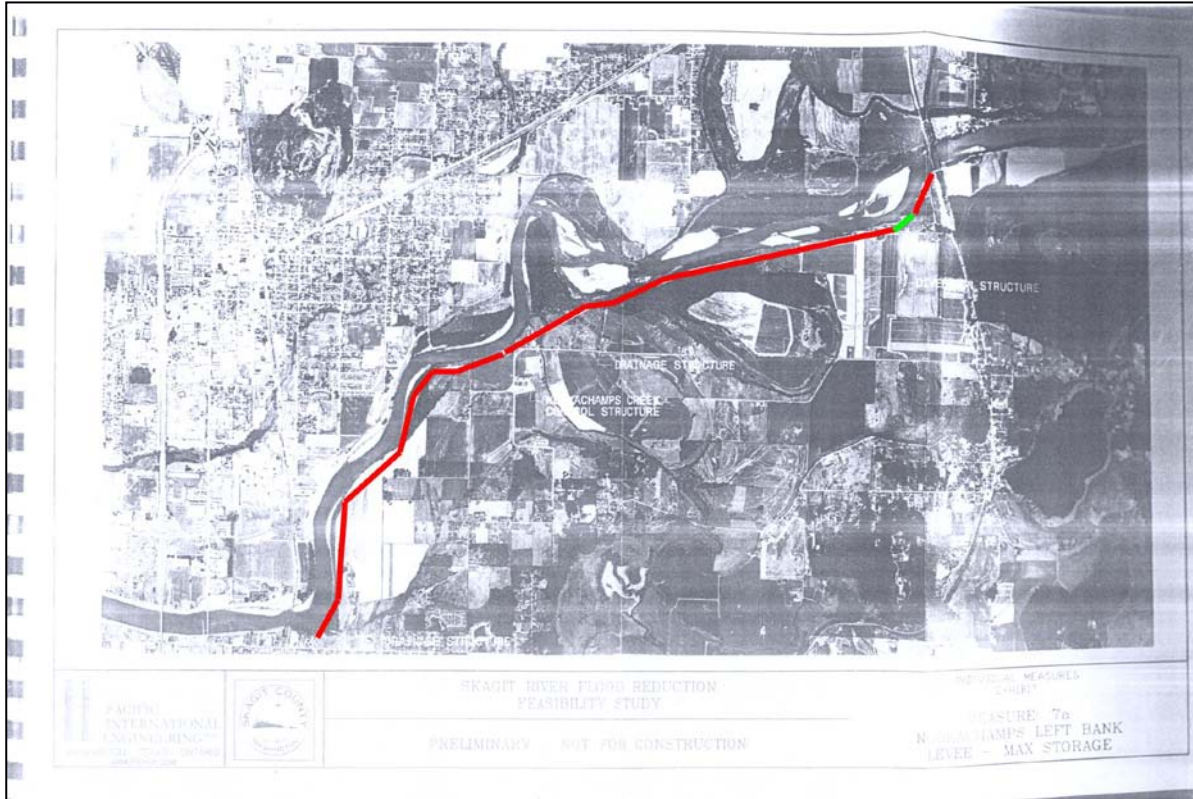
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8.4.1 Measure 4 Nookachamps Storage

This measure attempted to follow the design and modeling provided by PIE in 2006. This design is a levee structure on the left bank from the Highway 9 bridge just downstream of Sedro-Woolley (River Mile (RM) 22.7) to the BNSF Bridge at the beginning of the three bridge corridor (RM 17.56). There is a gate at the upstream end that would control when the water entered into the storage area. The design of this measure has a gate that is 15 feet high and 300 feet wide and has an invert of 35 feet NGVD 29. The gate opens when the flow through the 3 bridge corridor approaches 140,000 cfs.

The potential advantage of this project is that it reduces peak flow for large flood events. Its potential disadvantages is that it does not meet Corps requirements (i.e. high O&M costs, risks in operating properly), requires perfect ability to predict timing and magnitude of storm events to be federally authorized, induces flooding upstream and downstream of project and increases duration of small, frequent flood events on nearby levees, has significant impacts to fish and wetlands, may significantly impact local residents (relocations), has environmental and flooding

impacts would need to be mitigated and costs attributed to overall project cost, and may require significant construction costs to entire levee system.



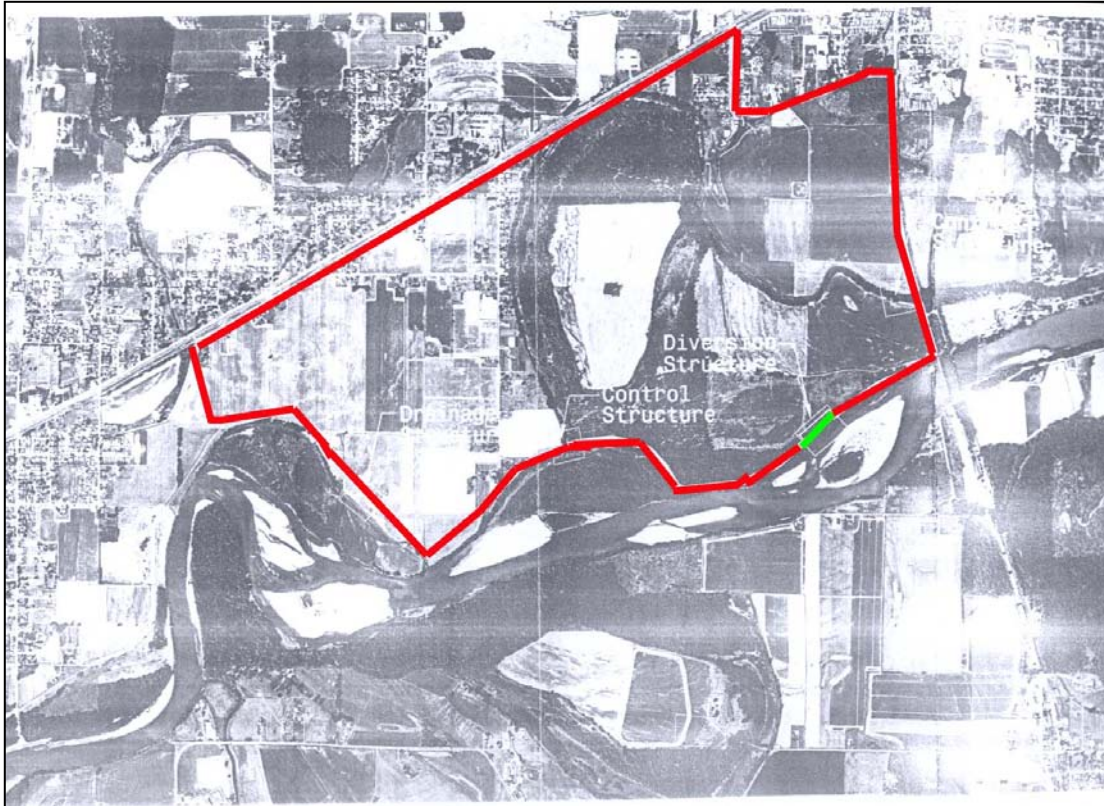
Nookachamps Storage
(Courtesy of U.S. Army Corps of Engineers)

The preliminary construction cost is approximately \$90 million as derived from Pacific International Engineering's (PIE's) *Interim Evaluation of Measures Report* (April 2006). The costs do not include operation and maintenance (O&M), access to structures, flowage easements and relocations, environmental mitigation or flood mitigation. The benefit-to-cost ratio is 6:6.

8.4.2 Measure 5 – Hart's Slough Storage

This measure attempted to follow the design and modeling provided by PIE's *Interim Evaluation of Measures Report* (April 2006). This design is a levee structure on the left bank from the Highway 9 bridge just downstream of Sedro-Woolley (River Mile (RM) 22.7) to the start of the levee system at RM 21.6. There is a gate at the upstream end that would control when the water entered into the storage area. The design of this measure has a gate that is 15 feet high and 170 feet wide and has an invert of 35 feet NGVD 29. The gate opens when the flow through the 3 bridge corridor approaches 140,000 cfs.

The potential advantage of this project is that it reduces peak flow for large flood events. Its potential disadvantages is that it does not meet Corps requirements (i.e. high O&M costs, high operation failure risk), measure requires perfect ability to predict timing and magnitude of storm events to be federally authorized, it induces flooding upstream and downstream, it has significant environmental impacts (i.e. loss of wetlands), may require relocations, and would require significant mitigation for induced flooding and environmental impacts.



Hart's Slough Storage
(Courtesy of U.S. Army Corps of Engineers)

The preliminary construction cost is approximately \$52 million as derived from PIE's *Interim Evaluation of Measures Report* (April 2006). Costs do not include O&M, access to structures, flowage easements and relocations, environmental mitigation, or flood mitigation. The benefit-to-cost ratio is not available.

8.5 Levees – Modifications, Setbacks, and Flood Walls

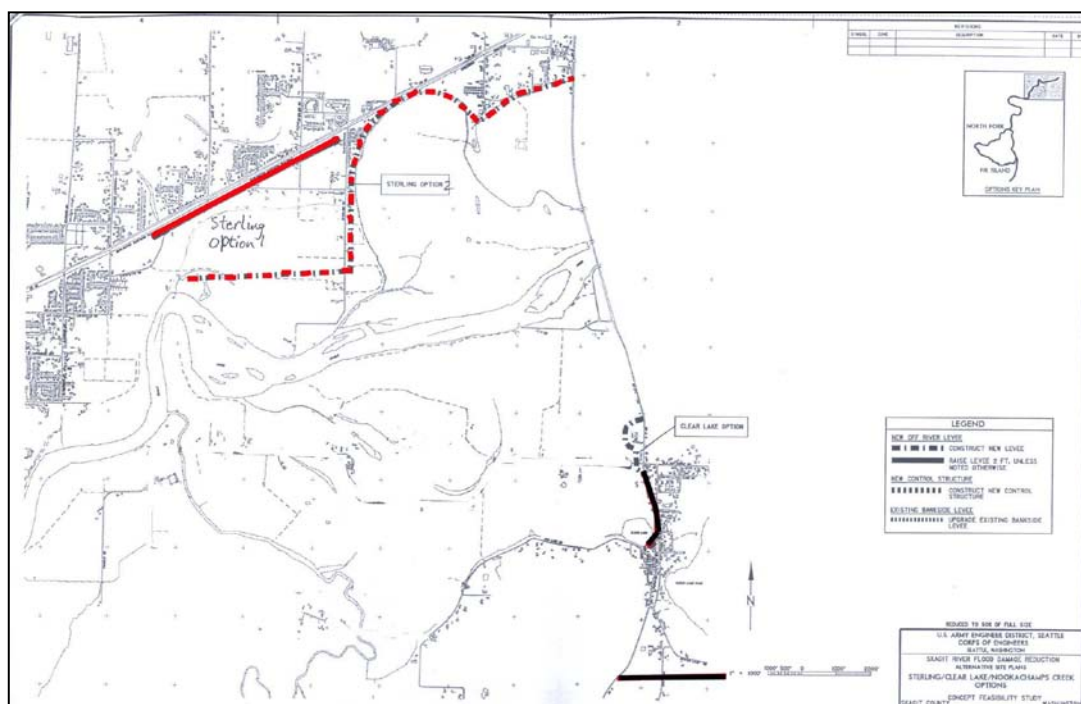
A variation of the standard levee, which is usually located as close as possible to the river channel is the "setback levee" in which the riverside toe of the levee is "setback" from the river banks at a minimum distance determined by the regulated FEMA floodway. Of course, the setback may be wider. An optimum setback distance should satisfy other criteria: 1) exceed the meander belt of the river, 2) allow for recreation use of the area contained within the levees, either in a natural condition or augmented by play fields, bike paths or picnic areas, 3) would not

interfere with existing standards of vegetation, and 4) avoid interference with particular wildlife habitat.

Floodwalls perform much like levees except that they are vertical sided structures, which require much less surface area. (Ecology, 1991)

8.5.1 Measure 6 – Sterling Levee

This levee is designed to plug up the low spot in the Highway 20 and railroad that is found on the right bank at roughly RM 21.9 where the ground elevation dips to 39.9 feet NGVD 29. This elevation corresponds to roughly a 10-year flood elevation so any floods larger than a 10-year flood (125,000 cfs) allows water to overflow in this area and eventually makes its way into Burlington. This area has been flood fought in the past but this measure would make the structure more permanent.



Sterling Levee
(Courtesy of U.S. Army Corps of Engineers)

There were two designs for this levee developed in 2001. One of them ties in the levee at the upstream side at Sedro-Woolley and the downstream side at the existing levee system. It also encompasses most of the houses that are found in this area. The other design raises the ground elevation for the low spot only to match what is upstream and downstream.

Major potential advantages for this measure are that it will be considered in conjunction with a large levee system during alternatives analysis, and that the addition of an optional setback would have less environmental impacts. Potential disadvantages include a lack of significant

flood protection as a standalone project, lack of completed environmental impacts analysis, possibility of relocation requirements with the setback option, and that sub-measure 6B is limited to protection between 10- and 20-year events.

There are two versions of the design for this area:

- 6A – Ties in the levee at the upstream side at Sedro-Woolley and the downstream side at the existing levee system. It also encompasses most of the houses that are found in this area.
- 6B – Raises the ground elevation for the low spot only to match what is upstream and downstream.
- Project does not “stand alone”- needs to be combined with other measures

The preliminary construction cost will be developed in alternatives analysis. The benefit-to-cost ratio is not available.

Considerations for further study:

- This measure will be considered in conjunction with a larger levee system during alternatives analysis. It does not provide significant flood protection as a stand-alone project.
- This measure does not represent protection by itself, but is tied to the protection downstream. There is some benefit to filling in the low spot (not yet quantified). However, in the analysis, the results would only appear for events above a 10-year, and below a 20-year probability. In the levee failure analysis that has been completed, additional levees fail beyond a 20-year event, making it difficult to distinguish between the flooding caused by overtopping, and the flooding caused by other levee failures that contribute water to this same area. A detailed analysis of only this levee is possible, but may not be pragmatic. Unless the Sterling Levee is the only other chosen measure, the analysis may not be warranted. It is best at this time to tie this levee to Measure 15 - Improve Levee System – Right Bank.
- The environmental impacts of this measure have not been evaluated.

8.5.2 Measure 7 – Levee Setback Downstream of 3-Bridge Corridor

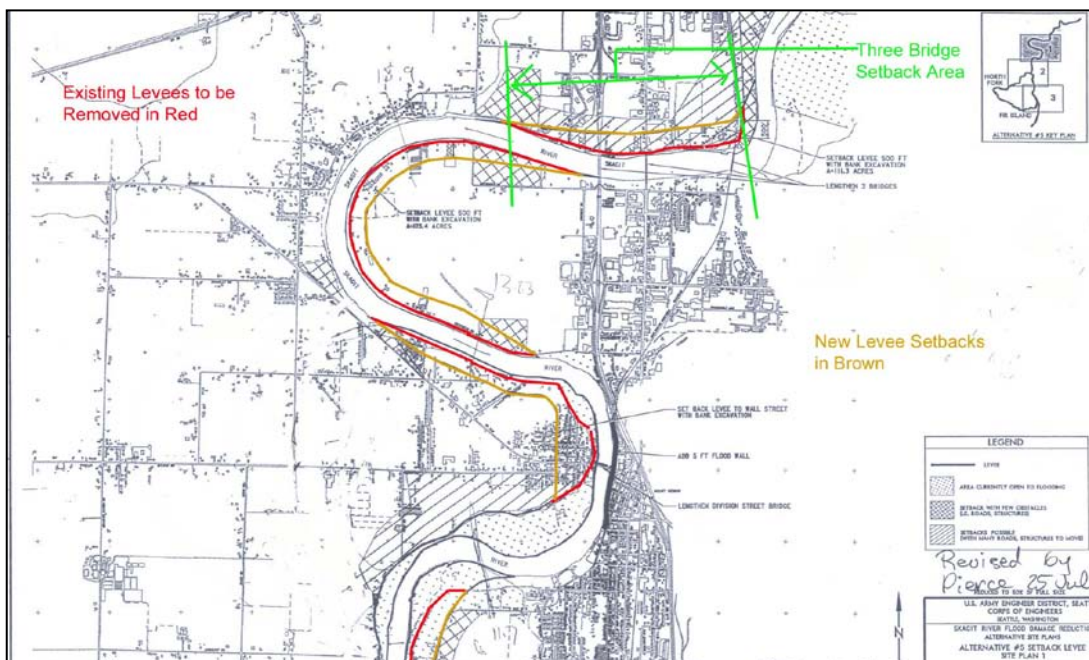
This setback is designed to improve the levee system's ability to move more water downstream by giving the river more area to move downstream. This setback starts just downstream of the I-5 bridge (RM 16.8) and extends out both the North and South Forks. The setback starts below the three-bridge area to see what the benefit is without having to expensively rebuild the three bridges. The Mount Vernon Bridge would still need to be set back as well as the North Fork and South Fork bridges. The picture shows the existing cross section with the black dots and the revised setback cross section in pink. The next three pictures show the plan view with the setback including everywhere but the area in green.

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This measure is a 500 foot setback on the Mainstem from RM 16.8 to the Forks, the North Fork from the Mainstem to its mouth, and the South Fork from the Mainstem to its mouth. The setback starts at the top of bank elevation and the levee is moved back 500 feet from where it currently is. The setback alternates which side of the bank it is on based on a preliminary look at where the real estate would be cheaper to obtain.

The layout is as follows:

- Mainstem
 - Left Bank – RM 16.8 to 13.8 Right Bank – RM 13.8 to 11.7 Left Bank – RM 11.7 to Forks North Fork Left Bank – RM 9.25 to mouth
- South Fork
 - Left Bank – RM 9.25 to 7.8
 - Right Bank – RM 7.8 to mouth



Levee Setback Downstream of 3-Bridge Corridor
(Courtesy of U.S. Army Corps of Engineers)

Potential advantages of this measure include the reduction of induced flooding and required levee height, as well as the minimization of environmental impact and the provision of riparian improvement opportunities. Potential disadvantages include the necessary modifications to bridges (Mount Vernon, North Fork, and South Fork), the difficulty of raising a levee on only one side of the river (induced flooding), increased sediment transport, increased localized flooding, impacts to agricultural land, and potential toxic contamination. Also, the measure will require purchasing of property (relocation) and replacement of existing infrastructure (i.e. West Mount Vernon).

The preliminary construct cost is approximately \$424 million, which includes real estate, costs to modify North and South Forks and Mount Vernon bridges. It does not include mitigation or O&M costs. The benefit-to-cost ration is 1:0.

Considerations for further study:

- At this time, this measure has only been run with the levee setback elevations being the same as the existing levee elevations. This is partly because the improvement alternates from one side of the river to the other. It would be difficult to raise one side and not the other, particularly when it is not connected all the way from upstream to downstream. Running a setback levee all on the same side will alter the costs of the measure.
- Environmental impacts have not been evaluated. However, setting back levees generally minimizes environmental impact.

8.5.3 Measure 8 – Levee Setback 3-Bridge Corridor Only

This setback is designed to improve the levee system's ability to move more water downstream past the three bridge corridor by giving the river more area to move in this area. This setback starts at the BNSF RR bridge (RM 17.56) and ends just downstream of the I-5 bridge (RM 16.8). This setback is designed to determine the benefit of the setback just at the three bridge area. This involves the replacement of the BNSF RR bridge, the Riverside bridge, and the I-5 Bridge. The picture below shows the existing cross section with the black dots and the revised setback cross section in pink. The next picture below shows the plan view of the setback in the green area.

This measure is a 500 foot setback on the Mainstem right bank from RM17.56 to 16.8. The setback starts at the top of bank elevation and the levee is moved back 500 feet from where it currently is. The setback alternates which side of the bank it is on based on a preliminary look at where the real estate would be cheaper to obtain.

This layout is as follows:

- Mainstem
 - Right Bank – RM 17.56 to 16.8

Potential advantages of this measure include the reduction of flooding upstream of the 3-Bridge Corridor, minimization of environmental impact, opportunities for riparian improvements, and indirect reduction of debris management issues through bridge modifications. Potential disadvantages include the necessity of bridge modifications, Hwy 99 abutments replacements, the possibility of worsening downstream flooding, and the real estate purchasing requirements for setbacks (relocations, road/infrastructure replacement). In addition, bridge modifications would be the responsibility of WSDOT and BNRR, but a Corps project must “stand on its own”. It would be invalid to assume that bridges would be modified in time for the Corps project.

Preliminary construction cost is to be determined. The USACE requested a cost estimate from the Washington Department of Transportation to replace I-5 bridge. Some modifications to approaches to Highway 99 bridge would be needed. The railroad bridge cost as of 2003 was \$32 million. This also require 500-foot setback of levees. The benefit-to-cost ratio is not available.

Considerations for further study:

- Elimination of river constriction will require significant modifications to the three bridges.
- At this time, this measure has only been run with the levee setback elevations being the same as the existing levee elevations. This is partly because the improvement alternates from one side of the river to the other. It would be difficult to raise one side and not the other, particularly when it is not connected all the way from upstream to downstream. Running one side only will alter the costs of the measure.
- Environmental impacts have not been evaluated. However, setting back levees generally minimizes environmental impact

8.5.4 Measure 9 – Overtopping Levees

The purpose of this project is to selectively allow flow to overflow the levees by creating low spots where water can start leaving the system. Five locations would allow selective overtopping: 1.) Sterling at RM 21.9 – 1,000 feet – Right Bank, 2.) Avon at RM 15.9 – 3,000 feet – Right Bank, 3.) Forks at RM 10.5 – 2,000 feet – Right Bank, 4.) Forks at RM 10.5 – 1,000 feet – Left Bank, and 5.) Dry Slough at North Fork RM 8.85 – 1,000 feet - Left Bank.

Potential advantages of this project are that it attempts to ensure areas share flood waters equally, and reduces flows in high flow events. Potential disadvantages are that rlowage easements would be required, the measure requires additional levees and/or improvements to existing levees, overtopping elevations would be set at a 5- to 10-year event, overtopping areas will flood more frequently, and significant environmental impacts, including the stranding of fish when levees overtop.

The preliminary construction cost is approximately \$101 million, which includes real estate costs for new levees only. It does not include mitigation or O&M costs. The benefit-to-cost ratio is 0:4.

8.5.5 Measure 10 – Levee Setback Mainstem and North Fork Only

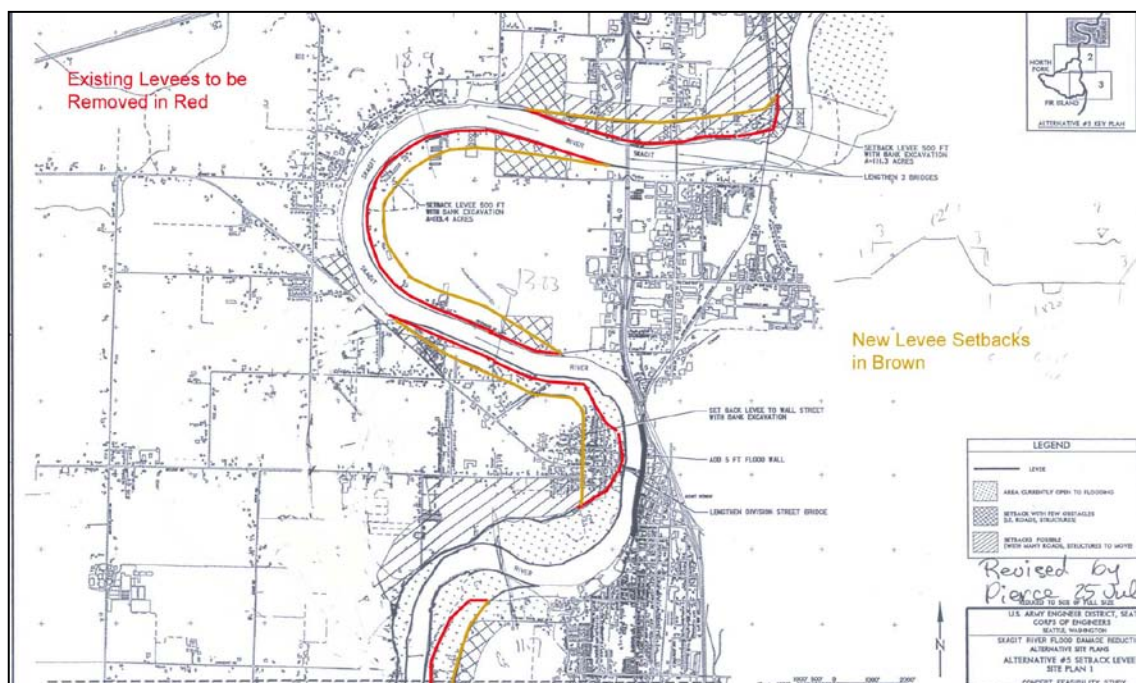
This setback is designed to improve the levee system's ability to move more water downstream by giving the river more area to move downstream. This setback starts at the beginning of the three bridge corridor at the BNSF Bridge (RM 17.56) to where the mainstem splits into the North and South Forks and then extends out the North Fork. The setback only extends down the North Fork to see whether the North Fork is the main downstream constriction of the two forks. This requires setting back 5 bridges.

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This measure is a 500 foot setback on the Mainstem from RM 17.56 to the Forks and the North Fork from the mainstem to its mouth. The setback starts at the top of bank elevation and the levee is moved back 500 feet from where it currently is. The setback alternates which side of the bank it is on based on a preliminary look at where the real estate would be cheaper to obtain.

This layout is as follows:

- Mainstem
 - Left Bank – RM 17.56 to 13.8
 - Right Bank – RM 13.8 to 11.7
 - Left Bank – RM 11.7 to Forks
- North Fork
 - Left Bank – RM 9.25 to mouth



Levee Setback Mainstem and North Fork Only
(Courtesy of U.S. Army Corps of Engineers)

Potential advantages of this measure include the reduction of induced flooding, the minimization of environmental impacts, and the opportunity for riparian improvements. Potential disadvantages include the required setback of five bridges, increased sediment transport, localized erosion, relocation requirement, and the difficulty in raising a levee on only one side of the river. In addition, Corps policy does not support projects that encourage development in rural areas. Lastly, large property purchases and infrastructure replacement would be necessary.

The preliminary construction cost is approximately \$395 million, which includes real estate costs. It does not include mitigation or O&M costs. The benefit-to-cost ratio is 0:2.

Considerations for further study:

- At this time, this measure has just been run with the levee setback elevations as the same as the existing levee elevations. This is partly because the improvement alternates from one side of the river to the other. It would be difficult to raise one side and not the other, particularly when it is not connected all the way from upstream to downstream. Running it with a levee only on one side will alter the costs of the measure.
- Environmental impacts have not been evaluated. However, setting back levees generally minimizes environmental impact.

8.5.6 Measure 11 – Improve Existing Levees

This measure raises the entire existing levee system and adds a levee on the right bank from Highway 9 to the start of the existing levee system.

The preliminary construction cost is approximately \$97 million as derived from PIE's *Interim Evaluation of Measures* Report (April 2006). It includes real estate costs, but does not include infrastructure modifications, mitigation, O&M or contingency costs. The final measure will consider optimum level of protection. The benefit-to-cost ratio is 11:5.

8.5.7 Measure 12 – Setback Levees with Excavation

This project is a 500-foot setback levee with excavation in the overbank of the mainstem from RM 17.56 to the Forks, the North Fork from the mainstem to its mouth, and the South Fork from the mainstem to its mouth of 20 feet.

The potential advantage of this measure is that in 2001 it was considered to maximize channel capacity and minimize environmental impact. The potential disadvantages are that it has high construction costs, due to massive removal of material, the measure does not have flood protection advantages beyond setback with no excavation, and costs are higher, it destabilizes channel, increasing sedimentation and erosion, it has high maintenance costs – would need constant dredging of eroded sediments. (100% Local Sponsor cost), it would require setback of five bridges, it will necessitate purchasing a great deal of improved property and replacing a large portion of existing infrastructure, it would require relocations of structures riverward of levee, and there is a potential for environmental impacts through disturbance of riverbank and dredging.

The preliminary construction cost was not developed, as the measure is not feasible. The benefit-to-cost ratio is not available.

8.5.8 Measure 13 – Setback Levees – Entire System

This setback is designed to improve the levee system's ability to move more water downstream by giving the river more area to move downstream. This setback starts at the beginning of the three bridge corridor at the BNSF Bridge (RM 17.56) to where the mainstem splits into the North and South Forks and then extends out both the North Fork and South Fork Skagit River. This requires setting back 5 bridges. The picture below shows the existing cross section with the black dots and the revised setback cross section in pink. The next 3 pictures below show the plan view of the setback.

This measure is a 500 foot setback on the Mainstem from RM 17.56 to the Forks, the North Fork from the mainstem to its mouth, and the South Fork from the mainstem to its mouth. The setback starts at the top of bank elevation and the levee is moved back 500 feet from where it currently is. The setback alternates which side of the bank it is on based on a preliminary look at where the real estate would be cheaper to obtain.

This layout is as follows:

- Mainstem
 - Left Bank – RM 17.56 to 13.8
 - Right Bank – RM 13.8 to 11.7
 - Left Bank – RM 11.7 to Forks
- North Fork
 - Left Bank – RM 9.25 to mouth
- South Fork
 - Left Bank – RM 9.25 to 7.8
 - Right Bank – RM 7.8 to mouth

Potential advantages of this measure include the reduction of induced flooding, the minimization of environmental impacts, and the opportunity for riparian improvements. Potential disadvantages include Corps policy on not supporting encouragement of rural development, setback of 5 bridges, increased sediment transport, increased localized erosion, and the difficulty in raising a levee on only one side of the river. In addition, the measure would require property purchased for a wider levee footprint and replacing large portion of existing infrastructure.

The preliminary construction cost is approximately \$406 million, which includes real estate costs. It does not include mitigation, O&M, infrastructure modifications or relocations. The benefit-to-cost ratio is 0:2.

Considerations for further study:

- At this time, this measure has only been run with the levee setback elevations at the same elevation as the existing levee elevations. This is partly because the improvement alternates from one side of the river to the other. It would be difficult to raise one side

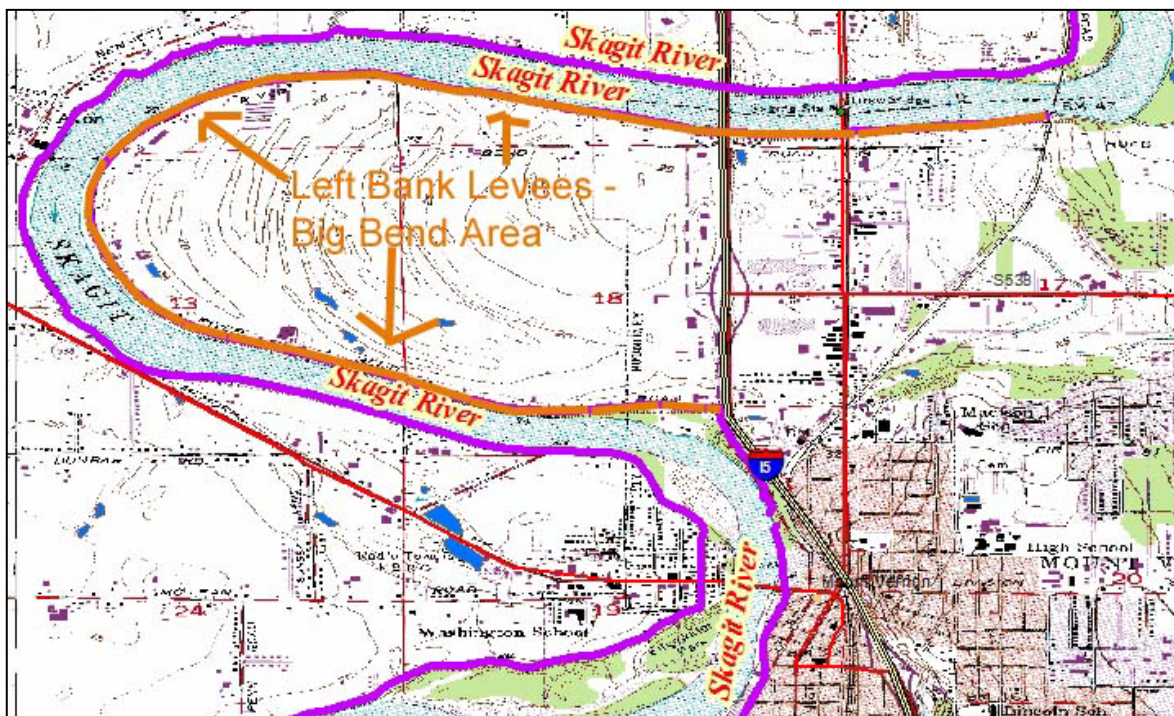
and not the other, particularly when it is not connected all the way from upstream to downstream. Running a setback levee with it all on one same side will alter the costs of the measure.

- Environmental impacts have not been evaluated. However, setting back levees generally minimizes environmental impact.

8.5.9 Measure 14 – Improve Levee System – Left Bank

This improvement of existing levee measure is evaluating the benefits of raising the left bank levee system that protects the North Mount Vernon area (RM 17.56 to RM 13.1) as well as from East Mount Vernon south to Stanwood (RM 13.1 to the mouth of the South Fork).

The major potential advantage of this measure is the minimal change in footprint versus a setback levee. Potential disadvantages include violation of Corps policy and Executive Order 11988, requirement to improve entire system, mitigation requirement for environmental impacts, increased sedimentation and localized erosion, and the difficulty in raising a levee on only one side of the river.



Improve Levee System – Left Bank
(Courtesy of U.S. Army Corps of Engineers)

The preliminary construction cost is approximately \$23 million as derived from PIE's *Interim Evaluation of Measures Report* (April 2006). It includes real estate costs, but does not include infrastructure modifications, mitigation, O&M or contingency costs. The benefit-to-cost ratio is 12:1.

Sub-Measure 14A– Improve Existing Levees – Left Bank – Remove All Damages

This measure looks at removing all damages from the North Mount Vernon area (RM 17.56 to RM 13.1) and East Mount Vernon south to Stanwood (RM 13.1 to the mouth of the South Fork). This encompasses reaches 4, 4A, 5, and 5A.

Considerations for further study:

- This is a hypothetical measure which assumes all damaged can be prevented. It is used as a baseline comparison in determining damages prevented among the various measures.

Sub-Measure 14B – Improve Existing Levees – Left Bank - Remove Damages Seen from a 90% Assurance of Containing the 100-year Flood Levee

This measure looks at removing damages from areas behind levees when the stage in the river does not exceed the one that is derived to have a 90% assurance of containing the 100-year flood in the North Mount Vernon area (RM 17.56 to RM 13.1) and East Mount Vernon south to Stanwood (RM 13.1 to the mouth of the South Fork). This encompasses reaches 4, 4A, 5 and 5A.

Considerations for further study:

- Environmental impacts have not been evaluated. This measure could have impacts on riverine habitat.

Sub-Measure 14C– Improve Existing Levees– Left Bank– Big Bend Area Only- Remove All Damages

This measure looks at removing all damages from the North Mount Vernon area (RM 17.56 to RM 13.1). This encompasses reaches 5 and 5A. No analysis of damages prevented has been completed. No project cost estimate has been completed.

Considerations for further study:

- This is a hypothetical measure which assumes all damaged can be prevented. It is used as a baseline comparison in determining damages prevented among the various measures.

Sub-Measure 14D – Improve Existing Levees – Left Bank – Big Bend Area Only - Remove Damages Seen from a 90% Assurance of Containing the 100-year Flood Levee

This measure looks at removing damages from areas behind levees when the stage in the river does not exceed the one that is derived to have a 90% assurance of containing the 100-year flood in the North Mount Vernon area (RM 17.56 to RM 13.1). This encompasses reaches 5 and 5A. No analysis of damages prevented has been completed. No project cost estimate has been completed.

Considerations for further study:

- This measure protects a largely undeveloped area within the bend. Corps regulations prohibit constructing projects that encourage development. Therefore, the preferred alignment for a levee in this area is adjacent to the highway. This would also retain an area for natural valley storage.
- Environmental impacts have not been evaluated. This measure could have impacts on riverine habitat.

Sub-Measure 14E – Improve Existing Levees – Left Bank – East Mount Vernon and South Only - Remove All Damages

This measure looks at removing all damages from the East Mount Vernon south to Stanwood (RM 13.1 to the mouth of the South Fork). This encompasses reaches 4 and 4A. No analysis of damages prevented has been completed. No project cost estimate has been completed.

Considerations for further study:

- This is a hypothetical measure which assumes all damaged can be prevented. It is used as a baseline comparison in determining damages prevented among the various measures.

Measure 14F – Improve Existing Levees – Left Bank – East Mount Vernon and South Only - Remove Damages Seen from a 90% Assurance of Containing the 100-year Flood Levee

This measure looks at removing damages from areas behind levees when the stage in the river does not exceed the one that is derived to have a 90% assurance of containing the 100-year flood in the East Mount Vernon south to Stanwood (RM 13.1 to the mouth of the South Fork). This encompasses reaches 4 and 4A. No analysis of damages prevented has been completed. No project cost estimate has been completed.

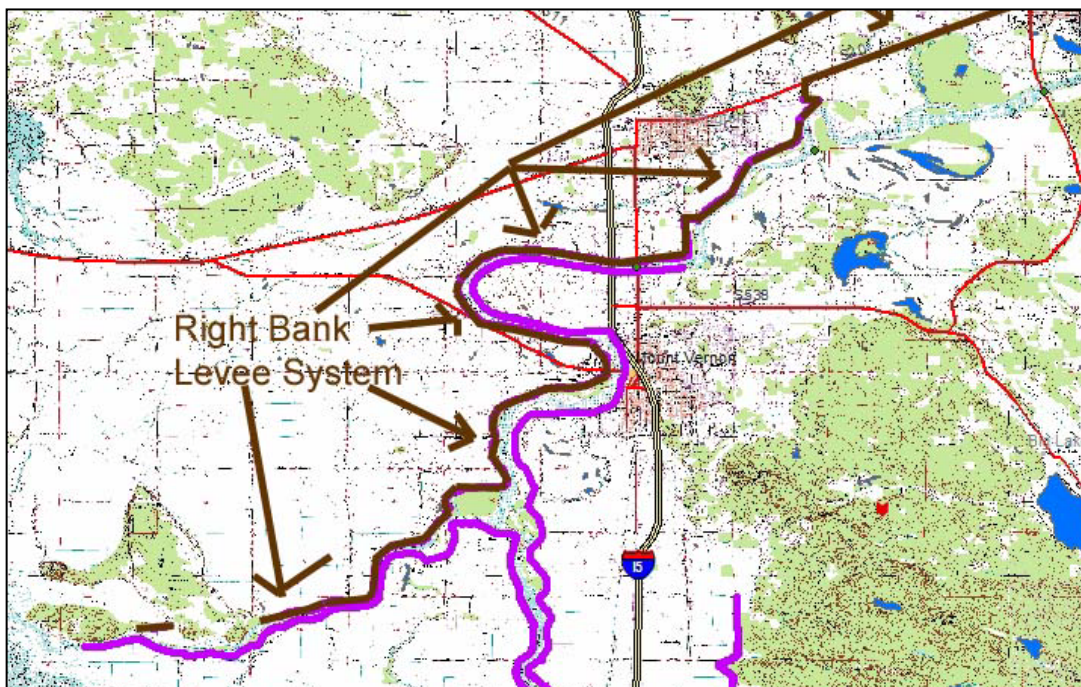
Considerations for further study:

- Environmental impacts have not been evaluated. This measure could have impacts on riverine habitat.

8.5.10 Measure 15 – Improve Levee System – Right Bank

This right bank existing levee measure is evaluating the benefits of raising the levee system that protects the right bank of the Skagit River from Highway 9 (RM 22.7) to the mouth of the North Fork Skagit River. The right bank existing levee system on the Mainstem starts at RM 20.9 and is continuous through the North Fork right bank except for minor sections on the right bank of the North Fork where there are parts that are tied to high ground. The costs for this design are derived from PIE's Interim Evaluation of Measures Report (April 2006) by combining elements Sterling Levee, Right bank Levee Highway 9 (Rhodes Road) to BNSF Bridge, 3a – DD12 Right

Bank River Bend Setback Levee, 3b - River Bend Setback Levee, 5b - Mount Vernon Right Bank Levee, 5c - Mount Vernon Right Bank Levee, 10b – DD1– Right Bank Levee RM 12 to Fork, and North Fork Right Bank Levee.



Improve Levee System – Right Bank
(Courtesy of U.S. Army Corps of Engineers)

The potential advantages of this project are that it will be considered in conjunction with a larger levee system during alternatives analysis, and it causes minimal change in levee footprint versus levee setbacks. Potential disadvantages are that Corps policy does not support projects that encourage development in rural areas, it would require improvements to the entire existing system, it would require significant maintenance, it would have significant mitigation for environmental impacts, it would increase in sedimentation and localized erosion, it is difficult to raise a levee on one side and not on the other, impacts to left bank, and it induces flooding.

The preliminary construction cost is approximately \$95 million as derived from PIE's *Interim Evaluation of Measures Report* (April 2006). It includes real estate costs, but does not include infrastructure modifications, mitigation, O&M or contingency costs. The benefit-to-cost ratio is 8:3.

Sub-Measure 15A – Improve Existing Levees – Right Bank - Remove All Damage

This measure looks at removing all damages from right bank of the Skagit River from Highway 9 (RM 22.7) to the mouth of the North Fork Skagit River. This encompasses reaches 1, 1A, 2, 2A, and 7.

Potential advantages of this measure include minimal changes in levee footprint versus a setback levee, and that the measure will be considered in conjunction with a large levee system during alternatives analysis. Potential disadvantages include Corps policy to not encourage development in rural areas, requirement to improve entire levee system, significant maintenance requirements, significant mitigation for environmental impacts, increased sedimentation and localized erosion, induced flooding, and the difficulty in raising a levee on only one side of the river.

Consideration for further study:

- This is a hypothetical measure which assumes all damaged can be prevented. It is used as a baseline comparison in determining damages prevented among the various measures.

Sub-Measure 15B – Improve Existing Levees – Right Bank - Remove Damages Seen from a 90% Assurance of Containing the 100-year Flood Levee

This measure looks at removing damages from areas behind levees when the stage in the river does not exceed the one that is derived to have a 90% assurance of containing the 100-year flood on the right bank of the Skagit River from Highway 9 (RM 22.7) to the mouth of the North Fork Skagit River. This encompasses reaches 1, 1A, 2, 2A, and 7.

Considerations for further study:

- Environmental impacts have not been evaluated. This measure could have impacts on riverine habitat

8.5.11 Measure 16 – Mount Vernon Floodwall

The Mount Vernon Floodwall is a design to reduce damages to downtown East Mount Vernon by building a floodwall to eliminate the low spot that is currently sandbagged during floods. This evaluation has similar challenges as the Sterling Levee in that it is difficult to quantify damages. The Mount Vernon Floodwall is designed to plug up the low spot on the left bank at East Mount Vernon (RM 12.96) to RM 12.4. This area is currently sandbagged during floods and has a rough ground elevation of 28 to 29 feet NGVD 29 which corresponds to roughly a 10-year water surface (120,000 cfs). Floods larger than a 10-year flood, therefore, could allow water to overflow into downtown East Mount Vernon if the area was not sandbagged. This measure would make the structure more permanent.

The design for this floodwall developed in 2001 is shown in the picture above. The design raises the ground elevation for the low spot only to match what is upstream and downstream.

Potential advantages of this measure include a permanent feature to reduce damages in East Mount Vernon (replace annual flood fighting), and the minimization of impacts to structures adjacent to the river, compared to a levee. Potential disadvantages include lack of significant

flood protection as a stand-alone project, impacts to commercial structures (i.e. parking), restriction of public access to the river, and the need to assess impacts on historic buildings.

The preliminary construction cost will be developed during alternative analysis, as this will be evaluated as part of a regional system. The benefit-to-cost ratio is not available.

Considerations for further study:

- This measure could impact Mount Vernon commercial structures near the river. Possible induced flooding will need to be evaluated and mitigated.
- The challenge with this measure is that it does not represent protection by itself, but is tied to the protection upstream and downstream. There is a benefit to filling in the low spot but, in the analysis, the results would only appear between a 10-year event and a 25-year event. In the levee failure analysis that was completed, some additional levees fail beyond a 25-year event and so it becomes difficult to distinguish the flooding being caused by this overtopping and the flooding caused by levees failing that contribute water to this same area. This analysis can be done but would take some extensive analysis that may not be worth it unless we plan to only do the Mount Vernon Floodwall at a minimal protection level and not do anything else. It is best at this time to extend this floodwall and make it a ring dike as is done in Measure 35 – East Mount Vernon Ring Dike

8.5.12 Measure 38 – 3-Bridge Corridor Modifications

This measure will consider modifying the BNRR, I-5, and Burlington Boulevard bridges and setting back levees. Other measures/alternatives will likely be considered with and without this measure to ensure that the analysis is capturing all possible benefits from reduced damages to Burlington.

Potential advantages of this measure include increased width of the channel in the 3-bridge corridor, leading to increased hydraulic capacity that can sustain larger flows.

The high expense of bridge modifications may not be justified in the alternatives analysis, but including it as a possibility will ensure that no opportunity for maximizing benefits is overlooked. In addition, running each of the identified alternatives with and without these modifications will provide information about what projects will be affordable. In reality, while bridge modifications are a measure under consideration for Federal authorization, bridge modification may need to be completed outside of the Federal authority.

This measure is currently under evaluation for hydraulic effect, costs, and potential benefits.

8.6 Bypass Systems – Bypasses to Remove Floodwaters from Mainstem

This alternative can be described as diverting stream flow during times of high volume to a parallel bed or restoring an abandoned channel for the purpose of increasing river conveyance. However, this concept may require a flow control structure at its confluence with the main channel and/or a section of man-made channel where a natural channel is not available. (Ecology, 1991)

8.6.1 Measure 17 – Swinomish Bypass

The Swinomish Bypass is a design to divert water out to the Swinomish Channel to Padilla Bay through a fusegate “designed fail” system where the levee would fail at a specific elevation and location and then this levee in down to the Swinomish Channel. The Bypass would be 6.7 miles long. This also requires a setback of the levee in the three-bridge corridor to get the flow through to the bypass.

The Swinomish Bypass design diverts water at the end of the first river bend past the three bridge corridor (RM 15.9). The fuseplugs would be designed to start failing at a water surface of 34.5 feet NGVD 29. They fail in 200 foot increments with the second failing at 34.7 feet NGVD 29 and the third at 34.9 feet NGVD 29. This measure maxes out at 600 feet wide. The 34.5 feet elevation is the elevation of the 25-year existing condition water surface in the average levee failure condition. The water that spills out is contained in a 2000 foot wide corridor with levees on both sides and expanding to 5000 feet for the last 1.5 miles down by the Swinomish Channel. No excavation is done in this measure on the route to the Swinomish Channel. The design currently is for the area to be maintained during the winter in a way that keeps the roughness of the channel down. The setback of the levee in the three-bridge corridor is 500 feet.

Potential advantages of this measure include the lack of catastrophic failure risk, and the added potential for recreation and/or environmental features. Potential disadvantages include sediment deposition into Padilla Bay (a marine sanctuary), localized erosion, impacts to Swinomish Slough, impacts to agricultural land, and required evaluation of setting weir elevation to a 5 to 10-year event. In addition, benefits will not be fully realized until 3 bridges are replaced.

The preliminary construction cost is approximately \$328 million, which includes real estate. It does not include infrastructure modifications, mitigation, O&M costs or costs for bridge modifications. The benefit-to-cost ratio is 0:4.

Considerations for further study:

- This measure does not realize its full benefit because the bypass does not become effective until water is already high enough on the levees that it can cause failures. The economic analysis sees these river stages and equates the damages that can be seen when failures occur. It is also unlikely that necessary freeboard (to make the levee system certifiable) will be available if we wait this late to have the levee fail into the

diversion. We probably want to look at allowing this diversion to become effective several feet lower.

- Environmental impacts have not been evaluated. Potential concerns include impacts to the Swinomish Channel and Padilla Bay.

8.6.2 Measure 18 – Fir Island Bypass

The Fir Island Bypass is a design to divert water from the North Fork Skagit River out to Skagit Bay. This is an excavated channel from a location on the North Fork Skagit River to Skagit Bay. This design is to help with overcoming the limited capacity of the North Fork Skagit River to convey flow to Skagit Bay. The location chosen is done to minimize movement of known residences, creation of new bridges, and length of the bypass. The bypass is 2.7 miles long and would require new bridges on Moore Road and Fir Island Road.

Potential advantages of this measure include a lack of catastrophic failure risk, the potential for environmental or recreational features, added environmental complexity to delta, no induced flooding, reduced flooding in Mount Vernon, and has a wider channel with levees as an option. Potential disadvantages of this measure include diversion of sediment to the central portion of the Skagit Bay shoreline, impacts to agricultural land, infrastructure improvement requirements, lack of economic justification as a stand-alone project, relocation requirements, and potential impacts to eelgrass beds.

Sub-Measure 18A – Fir Island Bypass – 500 feet

The Fir Island Bypass is a design to divert water from the North Fork Skagit River out to Skagit Bay at RM 7.2 of the North Fork. The bypass channel starts with a thalweg elevation that mimics RM 7.2 of the North Fork (-10 feet NGVD 29) and exits into Skagit Bay with a thalweg elevation of 20 feet NGVD 29. This measure's bypass is 500 feet wide. The design currently is for the area to be maintained during the winter in a way that keeps the roughness of the channel down.

The preliminary construction cost is approximately \$77 million, and includes real estate and construction of two county bridges. It does not include any additional infrastructure modifications, mitigation or O&M costs. The benefit-to-cost ratio is 0:1.

Considerations for further study:

- There is a potential concern to the loss of farmland.
- Design would require replacement of bridge(s).
- There is a potential benefit from creating fresh water flow to the Skagit Estuary.

Sub-Measure 18B – Fir Island Bypass –1500 feet

The Fir Island Bypass is a design to divert water from the North Fork Skagit River out to Skagit Bay at RM 7.2 of the North Fork. The bypass channel starts with a thalweg elevation that mimics RM 7.2 of the North Fork (-10 feet NGVD 29) and exits into Skagit

Bay with a thalweg elevation of -20 feet NGVD 29. This measure's bypass is 1500 feet wide. The design currently is for the area to be maintained during the winter in a way that keeps the roughness of the channel down.

Considerations for further study:

- There is a potential concern to the loss of farmland.
- Design would require replacement of bridge(s).
- There is a potential benefit from creating fresh water flow to the Skagit Estuary.

8.6.3 Measure 19 – Samish Bypass

The Samish Bypass is a design to divert water out of the system before the river reaches the three bridge corridor. This bypass takes water out of the system at the northernmost point of Hart's Slough at RM 22.0. The bypass goes north of the city of Burlington and follows the Samish River out to Samish Bay. This route is roughly 11 miles long and would require 9 bridges (Collins Road, District Line Road, Sheen Road, Burlington Alder Road, I-5, BNRR, Chuckanut Drive, Thomas Road, Farm to Market Road).

The Samish Bypass design diverts water at the northernmost point of Hart's Slough at RM 22.0 into a 1500 foot wide corridor with levees on both sides. No excavation is done in this measure on the route to Samish Bay. The entrance to the corridor is at 40.5 feet NGVD 29 which would start taking in water at floods slightly larger than a 10-year flood. The design currently is for the area to be maintained during the winter in a way that keeps the roughness of the channel down.

Potential Advantages of this measure include lack of catastrophic failure risk, potential for added recreation and/or environmental features, and removal of water upstream of the 3-bridge corridor. Potential disadvantages of this measure include the required construction (9 bridges, levees, excavation), weir height evaluation requirement, Samish basin impact analysis requirement, environmental impact analysis requirement, impacts from cross-basin fish mixing, impacts to agricultural land, and diversion of fine sediments to Samish Bay during flood events.

The preliminary construction cost is approximately \$363 million, and includes real estate. It does not include mitigation, O&M, infrastructure modifications and additions, levees, excavation. The benefit-to-cost ratio is 0.

Considerations for future study:

- This is the only measure that removes flow from the Skagit upstream of the Three Bridge Corridor. This measure will need to evaluate induced flooding to the Samish River system.
- This measure has challenges in showing major benefits because the bypass does not become effective until water is already high enough on the levees that it can cause failures. The economic analysis sees these river stages and equates the damages that can be seen when failures occur. The initial bypass grade is not very favorable to move

a lot of flow. To make it more effective, a lot of excavation in this upper reach is probably necessary.

- Environmental impacts have not been evaluated. A potential issue is the cross basin mixing of the Skagit and Samish Rivers and resulting impacts on fish.

8.6.4 Measure 20 – Mount Vernon Bypass

The Mount Vernon Bypass is a design to overcome the constriction of the Skagit River at the Division Street Bridge. This increases conveyance in this area by creating an additional channel from upstream of West Mount Vernon at RM 14.0 to downstream at RM 11.2 (see picture below). This bypass is 1 mile long and requires two bridges at Highway 536 (Memorial Highway) and McLean Road.

Potential advantages of this measure include reduction of flood elevations near Mount Vernon, elimination of catastrophic failure risk, potential for added recreation and/or environmental features, minimization of environmental impact, and opportunity for riparian improvements. Potential disadvantages include infrastructure modification requirements, relocation requirements, loss of urban land, downstream sediment deposition, erosion, and possible levee improvements downstream of outlet. In addition, the measure may need to be combined with another to minimize the impacts to Fir Island.

Sub-Measure 20A – Mount Vernon Bypass (500 feet)

The Mount Vernon Bypass is an excavated channel that has a thalweg that is in between the thalwegs seen on the Skagit River at RM 14.0 and that of the Skagit River at RM 11.2 downstream (-5 feet NGVD 29). This measure's bypass is 500 feet wide.

The preliminary construction cost for 20A is approximately \$73 million, and includes real estate and construction of two county bridges. It does not include any additional infrastructure modifications, mitigation, O&M costs or relocations. The benefit-to-cost ratio is 6:7.

Considerations for future study:

- These benefits should be considered preliminary and are provided for the purpose of initial screening of management measures.
- Environmental impacts have not been evaluated.
- Costs have not been evaluated.

Sub-Measure 20B – Mount Vernon Bypass (1,500 feet)

The Mount Vernon Bypass is an excavated channel that has a thalweg that is in between the thalwegs seen on the Skagit River at RM 14.0 and that of the Skagit River at RM 11.2 downstream (-5 feet NGVD 29). This measure's bypass is 1500 feet wide.

Considerations for future study:

- These estimates of benefits and costs should be considered preliminary and are provided for the purpose of initial screening of management measures.
- Environmental impacts have not been evaluated.
- Costs have not been evaluated.

8.7 Ring Dikes – Levees Surrounding Urban Areas

The term “dikes” generally is used to denote linear structures along saltwater shorelines, while a levee is a structural embankment along a river. In many instances, it may be more feasible to confine waters to the stream channel by raising its banks than it would be to control the streamflow rate with impoundments.

The materials used for the construction of a dike system will dictate the cost of the project and land area requirements for such construction. This material may be rock and earth fill, concrete, or combinations thereof. In many cases, particularly in urban areas, aesthetics play an important role in the design of levees. Water ecology should be considered here also. A rubble mound or earth levee often requires that excavated material be brought to the construction site. This material may have a deleterious effect on water quality, particularly during periods immediately after construction. Such an influence may actually change natural water ecology which in turn would affect resident aquatic life. (Ecology, 1991)

8.7.1 Measure 28 – Sedro-Woolley Ring Dike

In this measure a levee would be constructed to protect Sedro-Woolley from flooding. It needs further study to determine flooding risk.

The preliminary construction cost will be developed as part of alternatives analysis. The benefit-to-cost ratio is not available.

Sub-Measure 28A – Sedro-Woolley Ring Dike – Remove All Damages

This measure looks at removing all damages from the Sedro-Woolley area. The reach that this ring dike protects is 8.

Sub-Measure 28B – Sedro-Woolley Ring Dike – Remove Damages Seen from a 90% Assurance of Containing the 100-year Flood Levee

This measure looks at removing damages from the Sedro-Woolley area when the stage in the river does not exceed the one that is derived to have a 90% assurance of containing the 100-year flood. The reach that this ring dike protects is 8.

8.7.2 Measure 29 – Sedro-Woolley Water Treatment Plant Ring Dike

These measures look at improving the levee around the Sedro-Woolley Sewage Treatment Plant to reduce damages. The outline of the levee is in light green below. This schematic and costs are partially derived from page 91 of PIE’s *Interim Evaluation of Measures* Report (April 2006).

Potential advantages of this measure include increased protection of the sewage treatment plant, and the reduction of contamination risk. Potential disadvantages include a lack of certainty as to whether flooding is significant enough to justify improvement to the dike, and the requirement of an extensive pumping system.

The preliminary construction cost has not been developed. The benefit-to-cost ratio is not available.

Sub-Measure 29A – Sedro-Woolley Sewage Treatment Plant Ring Dike – Remove All Damages

This measure will look at removing all damages from the Sedro-Woolley Sewage Treatment Plant. The measure will be evaluated during future analysis.

Sub-Measure 29B – Sedro-Woolley Sewage Treatment Plant Ring Dike – Remove Damages Seen from a 90% Assurance of Containing the 100-year Flood Levee

This measure will look at removing damages from the Sedro-Woolley Sewage Treatment Plant when the stage in the river does not exceed the one that is derived to have a 90% assurance of containing the 100-year flood. The measure will be evaluated during future analysis.

8.7.3 Measure 30 – Sedro-Woolley Hospital Ring Dike

These measures look at building a ring dike around the Sedro-Woolley Hospital to reduce damages. This levee would protect the area in the blue hatched lines below. Potential advantages of this measure include added protection of the hospital building, and the improved life safety of hospital patients. Potential disadvantages include the necessity of barricades at the entrances/exits to maintain egress and ingress, dangers associated with temporary loss of access to a hospital, and the required extensive pumping system.

The preliminary construction cost is approximately \$7.5 million. It does not include infrastructure modifications, real estate costs. The benefit-to-cost ratio is not available.

Sub-Measure 30A – Sedro-Woolley Hospital Ring Dike – Remove All Damages

This measure will look at removing all damages from Sedro-Woolley Hospital. The measure will be evaluated during future analysis. Design of the measure will need to ensure access to the hospital in a flood event. Future evaluation will need to ensure that measure does not protect undeveloped land unless absolutely necessary as defined by Executive Order 11988.

Sub-Measure 30B – Sedro-Woolley Hospital Ring Dike – Remove Damages Seen from a 90% Assurance of Containing the 100-year Flood Levee

This measure will look at removing damages from Sedro-Woolley Hospital when the stage in the river does not exceed the one that is derived to have a 90% assurance of containing the 100-year flood. The measure will be evaluated during future analysis. Design of the measure will need to ensure access to the hospital in a flood event. Future evaluation will need to ensure that measure does not protect undeveloped land unless absolutely necessary as defined by Executive Order 11988. A preliminary cost analysis estimates total project costs are \$7,854,003, equivalent to an annual cost of \$421,935. No benefit calculation has been completed. Estimate of costs should be considered preliminary and is provided for initial screening of management measures.

8.7.4 Measure 31 – Burlington Ring Dike

These measures look at surrounding the city of Burlington with a levee to reduce damages. The outline of the levee is in red below. The levee follows the existing right bank levee of the Skagit River starting at RM 20.9 to RM 16.6, then heads north to McCorquadale Road and then goes west on that road, then heads North on Pulser Road to Josh Wilson Road where it heads east to high ground just past the Burlington Northern Railroad. On the other side of the high ground it heads Northeast to another area of high ground before it heads south to connect to the Skagit River levee at RM 20.9. This design path is done to limit the length and cost of the levee while also following Executive Order 11988 which requires the Federal government “to avoid direct or indirect support of floodplain development wherever there is a practicable alternative”. This means that the levee can not target protecting undeveloped areas.

The preliminary construction cost is approximately \$10.9 million. It does not include infrastructure modifications, pumping, real estate, mitigation or O&M. The benefit-to-cost ratio is 46:9.

Sub-Measure 31A – Burlington Ring Dike – Remove All Damages

This measure looks at removing all damages from the Burlington area. The reach that this ring dike protects is 1A. This measure is a hypothetical measure used to establish a baseline for evaluation of other measures.

Sub-Measure 31B – Burlington Ring Dike – Remove Damages Seen from a 90% Assurance of Containing the 100-year Flood Levee

This measure looks at removing damages from the Burlington area when the stage in the river does not exceed the one that is derived to have a 90% assurance of containing the 100-year flood. The reach that this ring dike protects is 1A.

Ring dikes isolate communities and can have catastrophic effects if they are exceeded. This measure will require an ensured escape route and an effective warning system. Additionally, the Corps will need to evaluate potential induced flooding of other areas

8.7.5 Measure 32 – North Mount Vernon Ring Dike

These measures look at surrounding the northern part of the city of Mount Vernon with a levee to reduce damages. The outline of the levee is in red below. The levee follows the existing left bank levee of the Skagit River starting at RM 17.56 to RM 16.6, then heads directly south until it ties back into the levee system at RM 13.1 and then ties into the high ground of I-5 just north of East Mount Vernon. This design path is done to limit the length and cost of the levee while also following Executive Order 11988 which requires the Federal government “to avoid direct or indirect support of floodplain development wherever there is a practicable alternative”. This means that the levee can not target protecting undeveloped areas. The costs for this design are derived from PIE’s *Interim Evaluation of Measures* Report (April 2006) by combining elements 3c – DD17 Left Bank Levee – BNSF to I-5 (PIE Report page 131), and 6a – Big Bend Cutoff Levee (PIE Report page 185).

The preliminary construction cost is approximately \$9.6 million. It does not include infrastructure modifications, pumping, real estate, mitigation or O&M. The benefit-to-cost ratio is 0:5.

Measure 32A – North Mount Vernon Ring Dike – Remove All Damages

This measure looks at removing all damages from the North Mount Vernon area. This measure is a hypothetical measure used to establish a baseline for evaluation of other measures. The reach that this ring dike protects is 5A.

Measure 32B – North Mount Vernon Ring Dike – Remove Damages Seen from a 90% Assurance of Containing the 100-year Flood Levee

This measure looks at removing damages from the North Mount Vernon area when the stage in the river does not exceed the one that is derived to have a 90% assurance of containing the 100-year flood. The reach that this ring dike protects is 5A.

Ring dikes isolate communities and can have catastrophic effects if they are exceeded. This measure will require an ensured escape route and an effective warning system. Additionally, the Corps will need to evaluate potential induced flooding of other areas.

8.7.6 Measure 33 – West Mount Vernon Ring Dike

These measures look at surrounding the western part of the city of Mount Vernon with a levee to reduce damages. The outline of the levee is in red below. The levee follows the existing right bank levee of the Skagit River starting at RM 13.83 to RM 11.7, and then completes the ring by connecting the levee at RM 13.83 and RM 11.7 roughly 4000 feet west of the Division Street Bridge. This design path is done to limit the length and cost of the levee while also following Executive Order 11988 which requires the Federal government “to avoid direct or indirect support of floodplain development wherever there is a practicable alternative”. This means that the levee can not target protecting undeveloped areas.

The preliminary construction cost is approximately \$3.5 million. It does not include infrastructure modifications, pumping, real estate, mitigation or O&M. The benefit-to-cost ratio is 1:3.

Sub-Measure 33A – West Mount Vernon Ring Dike – Remove All Damages

This measure looks at removing all damages from the West Mount Vernon area. The reach that this ring dike protects is 2A. This measure is a hypothetical measure used to establish a baseline for evaluation of other measures.

Sub-Measure 33B – West Mount Vernon Ring Dike – Remove Damages Seen from a 90% Assurance of Containing the 100-year Flood Levee

This measure looks at removing damages from the West Mount Vernon area when the stage in the river does not exceed the one that is derived to have a 90% assurance of containing the 100-year flood. The reach that this ring dike protects is 2A.

Ring dikes isolate communities and can have catastrophic effects if they are exceeded. This measure will require an ensured escape route and an effective warning system. Additionally, the Corps will need to evaluate potential induced flooding of other areas.

8.7.7 Measure 34 – East Mount Vernon Ring Dike

These measures look at surrounding the northern part of the city of Mount Vernon with a levee to reduce damages. The outline of the levee is in red below. The levee follows the existing left bank levee of the Skagit River starting at RM 13.1, which ties into the high ground of 5' just north of East Mount Vernon, and goes to RM 11.7. At RM 11.7, it then follows the outline of the housing developments on the south side of East Mount Vernon until it reaches high ground which is at I-5 just south of the Anderson Road exit. This design path is done to limit the length and cost of the levee while also following Executive Order 11988 which requires the Federal government “to avoid direct or indirect support of floodplain development wherever there is a practicable alternative”. This means that the levee can not target protecting undeveloped areas.

The preliminary construction cost is approximately \$4 million. It does not include infrastructure modifications, pumping, real estate, mitigation or O&M. The benefit-to-cost ratio is 14:4.

Sub-Measure 34A – East Mount Vernon Ring Dike – Remove All Damages

This measure looks at removing all damages from the East Mount Vernon area. The reach that this ring dike protects is 4A. This measure is a hypothetical measure used to establish a baseline for evaluation of other measures.

Sub-Measure 34B – East Mount Vernon Ring Dike – Remove Damages Seen from a 90% Assurance of Containing the 100-year Flood Levee

This measure looks at removing damages from the East Mount Vernon area when the stage in the river does not exceed the one that is derived to have a 90% assurance of containing the 100-year flood. The reach that this ring dike protects is 4A.

Ring dikes isolate communities and can have catastrophic effects if they are exceeded. This measure will require an ensured escape route and an effective warning system. Additionally, the Corps will need to evaluate potential induced flooding of other areas.

8.7.8 Measure 35 – LaConner Ring Dike

The picture below comes from a design that was displayed in the city of La Conner's Emergency Response Plan put together by Northwest Hydraulic Consultants Inc. in February 2003. The ring dike may need to be greatly expanded as the proposed alignments tie into other levees that may not be built to appropriate standards. More study is necessary to better define the alignment and costs. The City of LaConner has requested the Corps initiate a Section 205 flood study to address this potential project.

The preliminary construction cost is approximately \$4.5 million based on 2008 Flood Control Assistance Account Program's (FCAAP) Flood Protection Feasibility Study Project for La Conner. It includes infrastructure modifications and real estate. The benefit-to-cost ratio is 10:2.

Sub-Measure 35A – La Conner Ring Dike – Remove All Damages

This measure looks at removing all damages from the La Conner area. The reach that this ring dike protects is 7. This measure is a hypothetical measure used to establish a baseline for evaluation of other measures.

Sub-Measure 35B – La Conner Ring Dike – Remove Damages Seen from a 90% Assurance of Containing the 100-year Flood Levee

This measure looks at removing damages from the La Conner area when the stage in the river does not exceed the one that is derived to have a 90% assurance of containing the 100-year flood. The reach that this ring dike protects is 7. Ring dikes isolate communities and can have catastrophic effects if they are exceeded. This measure will require an ensured escape route and an effective warning system. Additionally, the Corps will need to evaluate potential induced flooding of other areas.

8.7.9 Measure 36 – Clear Lake Ring Dike

This measure addresses flood damages in the Clear Lake area. The picture below shows a preliminary design alignment for a ring dike of the Clear Lake area developed in 2001.

The preliminary construction cost has not been developed. The benefit-to-cost ratio is not available.

Sub-Measure 36A – Clear Lake Ring Dike – Remove All Damages

This measure looks at removing all damages from the Clear Lake area. The reach that this ring dike protects is 6A. This measure is a hypothetical measure used to establish a baseline for evaluation of other measures.

Sub-Measure 36B – Clear Lake Ring Dike – Remove Damages Seen from a 90% Assurance of Containing the 100-year Flood Levee

This measure looks at removing damages from the Clear Lake area when the stage in the river does not exceed the one that is derived to have a 90% assurance of containing the 100-year flood. The reach that this ring dike protects is 6A.

Ring dikes isolate communities and can have catastrophic effects if they are exceeded. This measure will require an ensured escape route and an effective warning system. Additionally, the Corps will need to evaluate potential induced flooding of other areas.

8.7.10 Measure 37 – Anacortes Waste Water Treatment Plant Ring Dike

These measures will look at building a ring dike around the Anacortes Water Treatment Plant to reduce damages. The ring dike is displayed below in green. These measures will be evaluated during future studies.

Potential advantages of this measure include increased protection of the water treatment plant, and protection of water quality. The major potential disadvantage of this measure is the requirement of an extensive pumping system.

The preliminary construction cost is approximately \$2 million as derived from 2006 Pacific International Engineering report. It does not include real estate, infrastructure modifications, mitigation, Operations & Maintenance or contingency costs. The benefit-to-cost ratio is not available.

Sub-Measure 37A – Anacortes Water Treatment Plant Ring Dike – Remove All Damages

This measure will look at removing all damages from seen from the Anacortes Water Treatment Plant. This measure is a hypothetical measure used to establish a baseline for evaluation of other measures and will be evaluated during future studies. Project costs have been estimated at \$1,906,327. This is equivalent to an annual cost of \$102,412. No benefit calculations have been completed. Estimate of costs should be considered preliminary and are provided for initial screening of management measures.

Sub-Measure 37B – Anacortes Water Treatment Plant Ring Dike – Remove Damages Seen from a 90% Assurance of Containing the 100-year Flood Levee

This measure will look at removing damages from the Anacortes Water Treatment Plant when the stage in the river does not exceed the one that is derived to have a 90% assurance of containing the 100-year flood. This measure will be evaluated during future studies.

8.8 Nonstructural and Restoration Measures – Relocations, Natural Valley Storage, Levee Setbacks/Removals, Flood proofing, Habitat Restoration

Non-structural flood control measures attempt to modify the effect of flooding, rather than modifying the flooding itself. The primary focus of non-structural measures is to modify human actions and behaviors, which will reduce flood damages. Non-structural measures include modification of development policies and land use regulations, risk management in flood prone areas, enhancing flood plain management, and improving emergency response systems. These measures can be used alone, or in conjunction with the structural measures. (Skagit County, 1989)

Flood proofing might be defined, generally, as the construction or remodeling of physical structures such that during floods they can either be closed or their occupancy can be modified so that inundation, siltation, or velocity damage can be minimized. (Ecology, 1991)

8.8.1 Measure 22 – Cockreham Island

This is a levee removal of 8,100 feet of bank on the right bank of the Skagit River just downstream of the town of Hamilton starting roughly at River Mile 39. This reconnects 1,334 acres of floodplain. This measure can also be found on page 133 of the Skagit Chinook Recovery Plan 2005.

Potential advantages of this measure include restoration of habitat, and creation of natural valley storage. Potential disadvantages include impacts to agriculture/local residents, relocation requirements, and limited storage capacity.

The preliminary construction costs will be developed when restoration projects are evaluated. The benefit-to-cost ratio is not available.

Considerations for future study:

- This measure has very limited storage capacity.
- Benefits have not been evaluated.
- Costs have not been evaluated.
- Environmental impacts have not been evaluated.
- This measure will be further evaluated as a restoration feature.

8.8.2 Measure 23 – Estuarine Restoration

The Skagit Chinook Recovery Plan's measures Theins Farm, Sullivans Hacienda, Wiley Slough, Milltown Island, Deepwater Slough, and Fisher Slough are all estuarine restoration projects that expand the conveyance areas near Skagit Bay. These measures will be further evaluated as restoration features.

The major potential advantage of this measure is the restoration of estuarine habitat. Potential disadvantages include impacts to agriculture/local residents, and the possibility that flood reduction benefits may be minimal.

Preliminary construction costs will be developed when restoration projects are evaluated. The benefit-to-cost ratio is not available.

8.8.3 Measure 24 – Riparian Restoration

These riparian restoration measures are either levee removals or levee setback. The major potential advantage of this measure is the restoration of riparian habitat. Potential disadvantages include minimal flood reduction benefits, impacts to agriculture, impacts to local residents, impacts to infrastructure, and potential increases in floodplain deposition.

The preliminary construction cost will be developed when restoration projects are evaluated. The benefit-to-cost ratio is not available.

Sub-Measure 24A – Gilligan Floodplain Restoration

This measure removes 560 feet of a flood control dike along the Skagit River just downstream of Gilligan Creek. The levee is on the left bank just before a bend at RM 28. This reconnects 170 acres of floodplain. This measure can also be found on page 131 of the Skagit Chinook Recovery Plan 2005. This measure will be further evaluated as a restoration feature.

Sub-Measure 24B – River Bend

This measure removes the levee on the left bank of the Skagit River from RM 16.6 to RM 13.1 and builds a River Bend cutoff levee that would be 7600 feet long and extend from River Bend Road at RM 16.6 directly south to River Bend Road at RM 13.1. This design is detailed in PIE's *Interim Evaluation of Measures* Report (April 2006) on pages 185-7. A similar measure is also found on page 123-4 of the Skagit Chinook Recovery Plan 2005 with the main exception being that the floodplain is controlled by gates in the recovery plan. The gates are removed in this evaluation as this reduces the complexity of operation. It also allows water to shortcut the river from RM 16.6 to 13.1 which can help to reduce flood levels. This levee location would meet Corps requirements to not encourage development in rural areas.

Sub-Measure 24C – Setback Levees North Fork Only

This setback is designed to improve the levee system's ability to move more water downstream by giving the river more area to move downstream. This setback starts at the beginning of the split into the North Fork (RM NF9.25) to where the North Fork starts widening towards the bay (RM NF 3.90) and is entirely on the left bank. This requires setting back the North Fork bridge.

This measure is primarily an 800-1000 foot setback. The setback starts at the top of bank elevation and the levee is moved back from where it currently is. Environmental impacts have not been evaluated. However, setting back levees generally minimizes environmental impact.

Sub-Measure 24D - Britt Slough Restoration

This measure sets back the left bank levee roughly 500 feet just downstream of Mount Vernon from RM 11.7 to RM 8.75 of the South Fork. The setback location is highlighted in red in the picture below. This measure can also be found on page 127 of the Skagit Chinook Recovery Plan 2005. This measure will be further evaluated as a restoration feature.

Sub-Measure 24E – Cottonwood Island

This measure sets back the right bank levee just upstream from where the mainstem splits into the two forks. This setback starts 1000 feet upstream of the start of Cottonwood Island and goes back 1000 feet at the island to restore the hydraulic connectivity of the slough to the river. The setback location is highlighted in red in the picture below. This measure can also be found on page 128 of the Skagit Chinook Recovery Plan 2005. This measure will be further evaluated as a restoration feature.

8.8.4 Measure 25 – Nonstructural Measures

Non-structural measures will be further evaluated in future analysis. Prerequisites to the evaluation of non-structural measures are as follows. The new hydraulic analysis must be completed, including the new levee failure analysis, followed by generation of alternatives. These prerequisites will better define the areas where non-structural measures might be practicable. Examples of non-structural measures that may be evaluated include: flood proofing, relocations, landscape features, and flood warning evacuation systems.

Potential advantages of these measures include minimal environmental impacts, and increased public safety and awareness. The major potential disadvantage is that these measures allow residual damages.

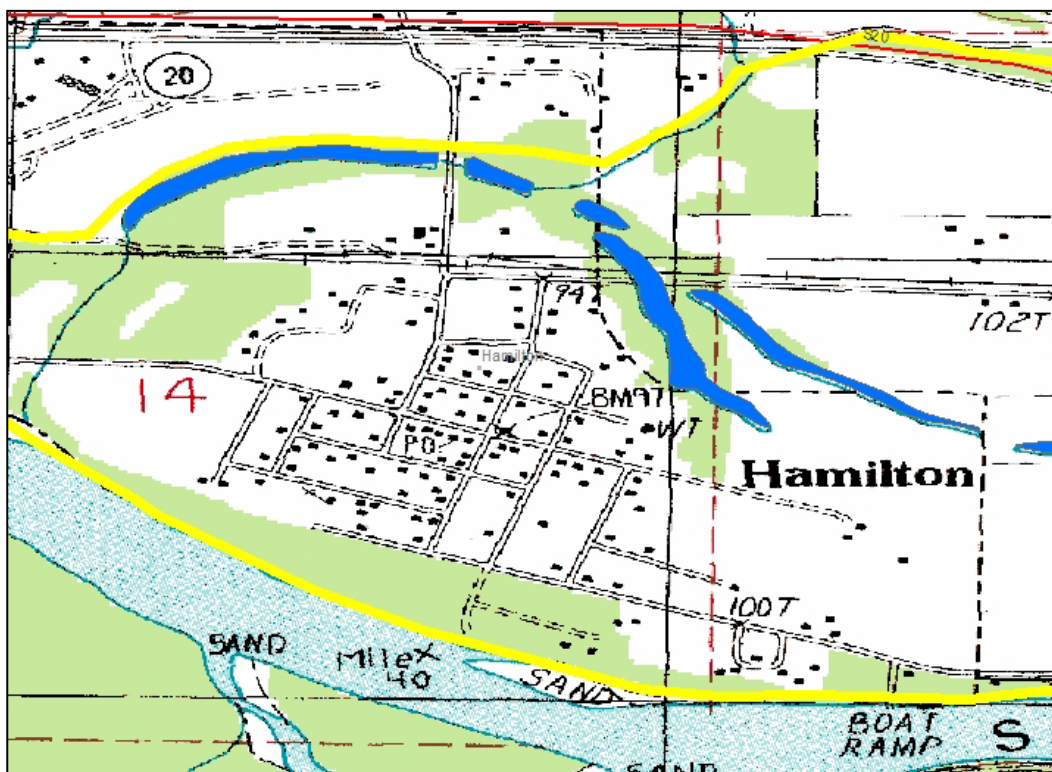
The preliminary construction cost has not been developed. The benefit-to-cost ratio is not available.

8.8.5 Measure 26 – Hamilton Relocation

Hamilton is being considered for nonstructural flood damage reduction and relocation. A Section 205 study completed by the Corps in the 1980's indicated that a structural solution for Hamilton is not feasible. This evaluation will take place following the non-structural measures' prerequisites identified in Section 6.5.1.49. Analysis will likely involve a benefit-cost analysis that evaluates multiple project alternatives such as: prioritizing the lowest lying properties, the properties with the lowest relocation cost, or the highest value properties. A flood model would

be used to compare the average annual damages to a property with the cost of moving that property.

The Corps previously completed an evaluation of protecting Hamilton from flooding. No alternative was economically justified under this evaluation. The Corps, at the request of the State, will consider relocating Hamilton based on potential increased environmental benefits. The Corps will coordinate this with ongoing local efforts.



Hamilton Relocation
(Courtesy of U.S. Army Corps of Engineers)

Potential advantages of this measure include the possible justification of the project on environmental grounds, the removal of structures and infrastructure from the floodway, increased public safety, and coordination with state, local, and private entities. Potential disadvantages include the possibility that environmental benefits may not be economically justified, and that relocation costs are high.

The preliminary construction cost is not available because the project is found to be infeasible based on a 1980's Section 205 study. Regarding benefit-to-cost ratio, the project was not economically justified for flood control. This measure will focus on environmental benefits of relocations.

8.8.6 Measure 27 – Debris Management

This measure looks at different ways woody debris can be handled to avoid blockages and other situations that jeopardize the flood protection system. The existing condition assumes that in larger floods that the BNSF Bridge will collect debris in a way similar to the way it did in 1995. This condition can be seen below

Potential advantages of this measure include the reduction of flow constriction at bridges, reduced pressure on bridges, and reduction of the risk associated with debris removal during flood events (including life safety). Potential disadvantages include loss of large woody debris that is valuable as fish habitat, and that current environmental regulation do not allow for the permanent removal of debris.

The preliminary construction cost has not been developed. The benefit-to-cost ratio is not available.

Considerations for further study:

- For this measure, it is assumed that the blockage at the BNSF Bridge could be prevented by some measure. Currently, we do not have a feasible plan to implement this measure and to determine what the costs are.
- No evaluation of environmental impacts has been conducted to date.
- There are potential issues in the permitting required for debris removal.

8.9 References:

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