Skagit River
Flood Risk Management
General Investigation

Hydraulic Effectiveness of Measures

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Objective

Determine “hydraulic effectiveness” of measures proposed for flood management in the lower Skagit River basin

Definitions

Hydraulic effectiveness is the impact of the measure on flow rates and water levels upstream and downstream from the measure location, and the impact on spill onto the floodplain.

A **measure** is a proposed project that provides stand-alone flood damage reduction benefits.

Some Limitations

- Considers “hydraulic effectiveness” only.
- No analysis of cost.
- No analysis of environmental or cultural impacts.
- List of measures analyzed is not complete. It is expected that additional measures will be considered as the study proceeds.
- Skagit River complexity makes evaluation of measures rather than alternatives difficult

Measures Considered

	Measure	
1	Increased Upper Baker Storage	
	a.	74,000 acre-ft Upper Baker flood control storage, 0 cfs minimum release
	b.	85,000 acre-ft Upper Baker flood control storage, 0 cfs minimum release
	c.	100,000 acre-ft Upper Baker flood control storage, 0 cfs minimum release
	d.	110,000 acre-ft Upper Baker flood control storage, 0 cfs minimum release
2	Increased Early Flood Control Season Storage at Upper Baker	
3	Increased Early Flood Control Season Storage at Upper Baker and Ross	
4	Mount Vernon Flood Wall	
5	Burlington Urban Levee	
6	Three Bridge Corridor Improvements	
	a.	With levee setbacks and bridge modifications (“with bridge modifications”)
	b.	With levee setbacks only (“without bridge modifications”)

Measures Considered (cont.)

	Measure	
7	Base Condition Measures (includes Mount Vernon Floodwall, Burlington Urban Levee and Three Bridge Corridor Improvements)	
8	Nookachamps Storage	
	a.	Nookachamps Low Storage option
	b.	Nookachamps High Storage option
9	North Mount Vernon (Riverbend) Levee	
10	Sterling Levee	
11	Improve Existing Levees	
12	Levee Setbacks	

Measures Considered (cont.)

	Measure	
13	Fir Island and Mount Vernon Bypasses	
	a.	Fir Island Bypass (diversion at North Fork RM 7.0)
	b.	Fir Island Bypass + Mount Vernon Bypass
14	Swinomish Bypass	
15	Improve Outlet Structures	
	a.	Joe Leary Slough Outlet Structure
16	Other Facility and Community Levees	
	a.	United General Hospital
	b.	Clear Lake
	c.	West Mount Vernon
	d.	La Conner
	e.	Sedro-Woolley and Sedro-Woolley WWTP

Methodology

Upper Baker and Ross storage measures:

- Analyzed using spreadsheet-based reservoir routing model
- Hydraulic effectiveness based on change in regulated peak discharge at USGS Concrete gage relative to existing operation.

Methodology (cont.)

Levee, Bypass, 3-Bridge Corridor & Nookachamps measures:

- Analyzed using 1-D HEC-RAS model.
- Hydraulic effectiveness based on change in Skagit River in-channel flows and water levels, spills onto the floodplain, and water levels in the Nookachamps and Riverbend storage areas.
- Floodplain flows and extent of inundation not considered other than for the Nookachamps and Riverbend areas.

Methodology (cont.)

Improve Outlet Structure measure:

- Analyzed improved outlet structure for Joe Leary Slough only to provide example for outlet structures in general.
- Analyzed using stand-alone 1-D HEC-RAS model.
- Hydraulic effectiveness based on change in draw down time of flood water stored behind sea dike.

Facility and Community Levees:

- Assessment of impacts varied by location.
- Designs will depend on impact of other larger flood management measures.

Some Assumptions

- Hydrology and existing condition hydraulic model from most recent (March/April 2011) USACE report
- Levee overtopping occurs but no breaches.
- No flood fighting.
- “Average” debris loads on BNSF and Great Northern bridges, no debris elsewhere.

Debris Loads

November 1995: Debris jam on BNSF bridge - 500 ft wide x 15-20 ft deep

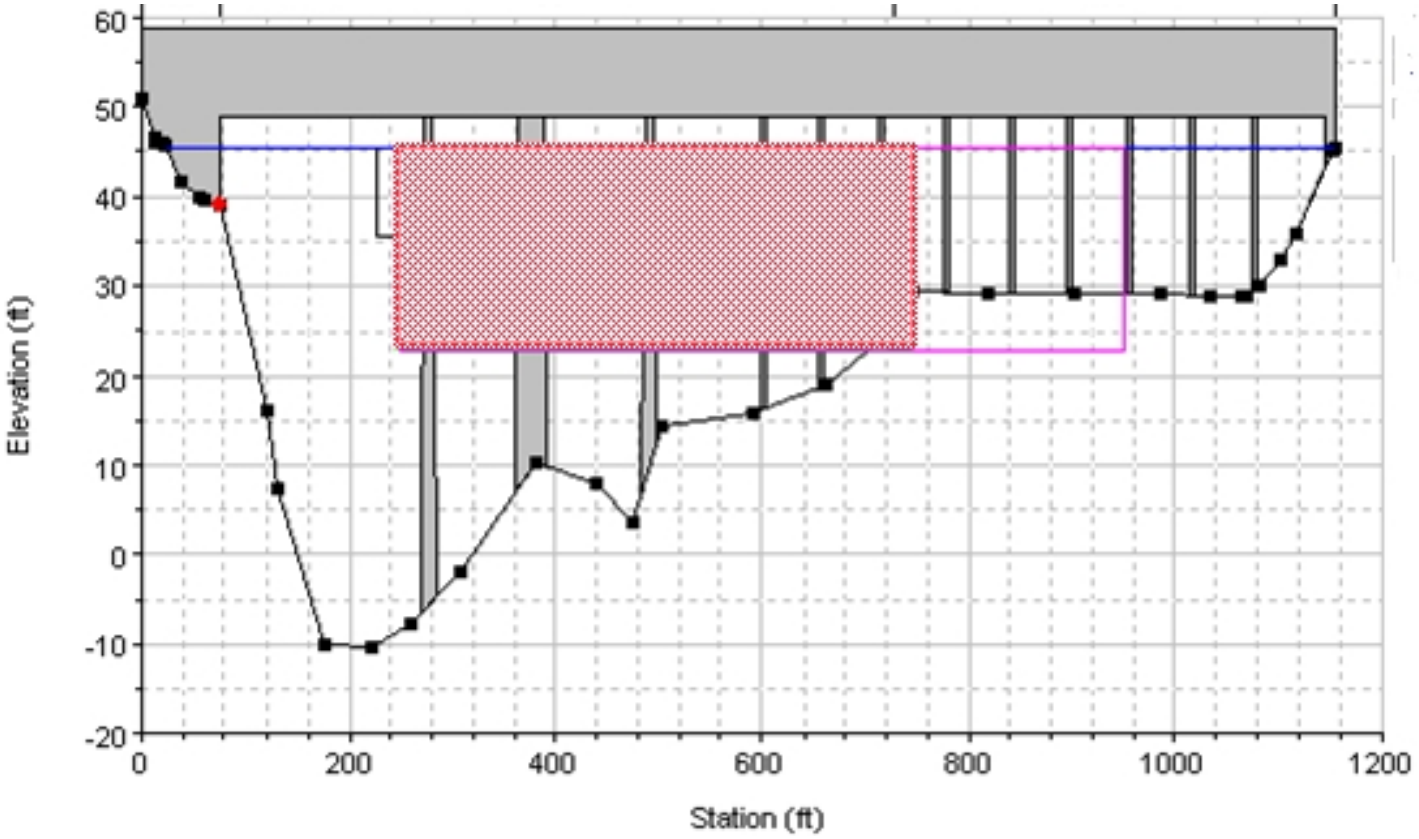
Debris Loads

Debris Jam Parameters BNSF Bridge

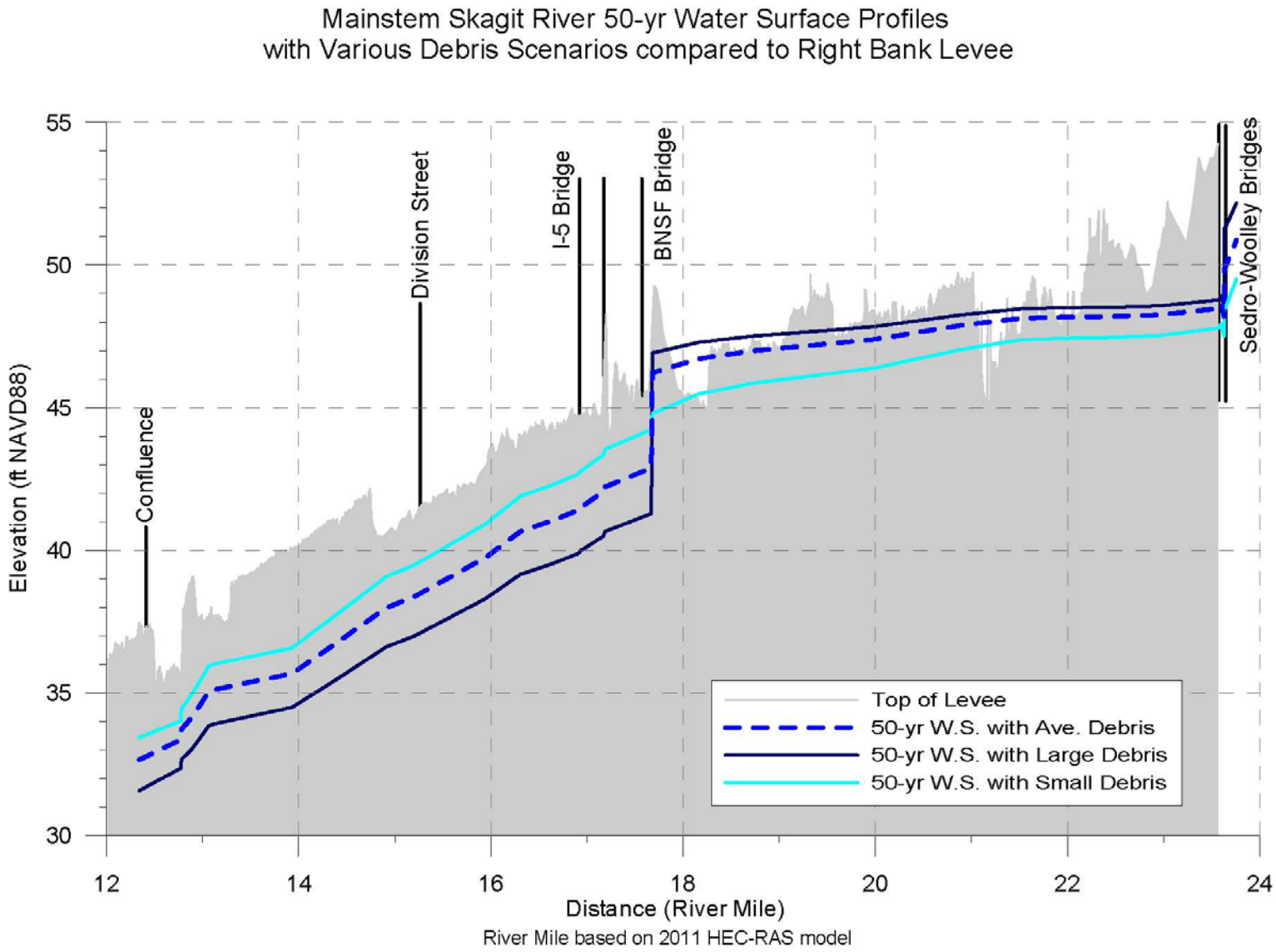
Flood Class	Debris Load	Width of Blockage (ft.)	Depth of Blockage (ft.)
Large (25-yr event and larger)	Low	300	10
	Average	500	20
	High	700	20

Debris Loads (cont.)

BNSF Bridge Average Debris Jam (500 ft x 20 ft)



Impacts of Varying Debris Load



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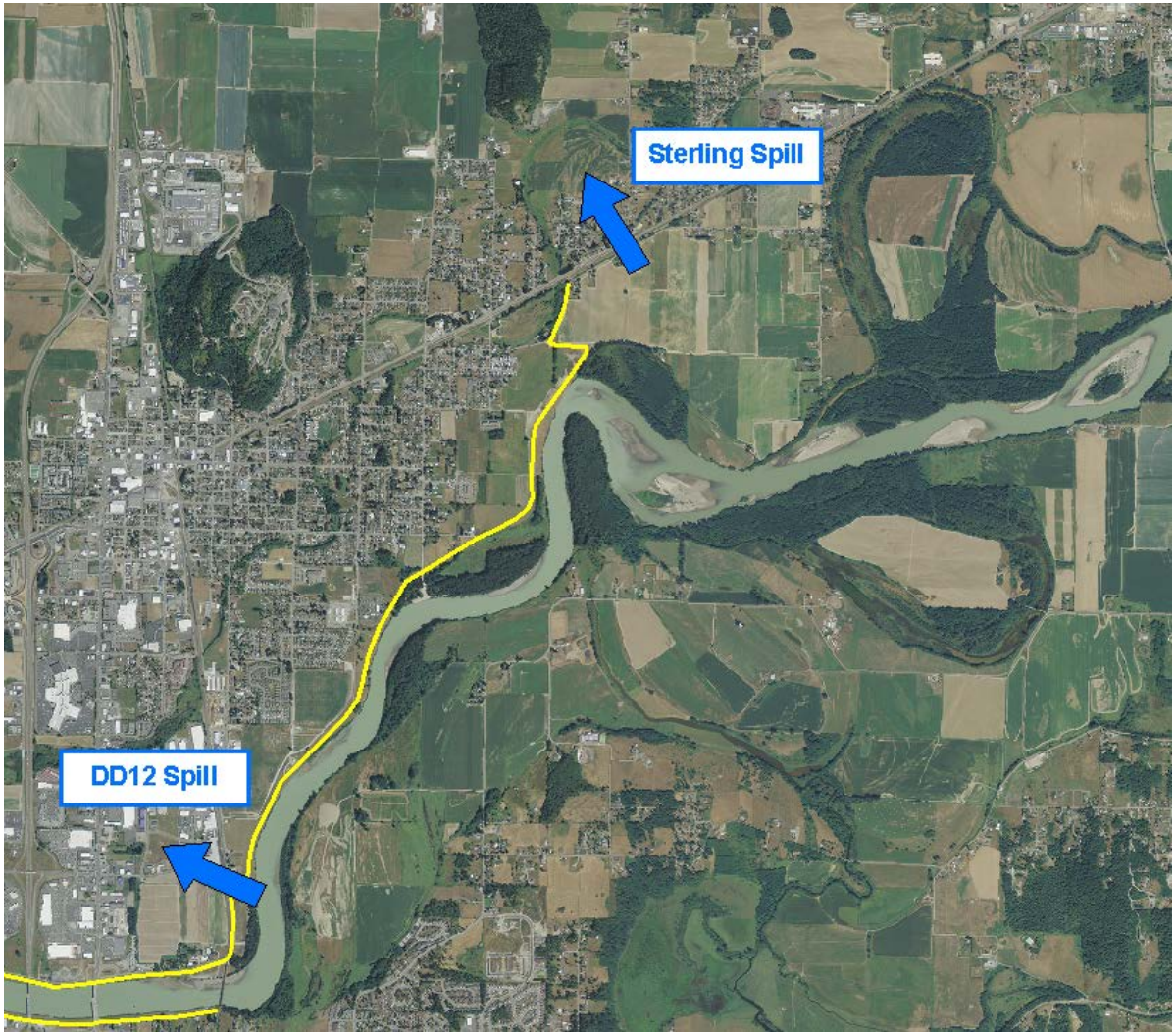
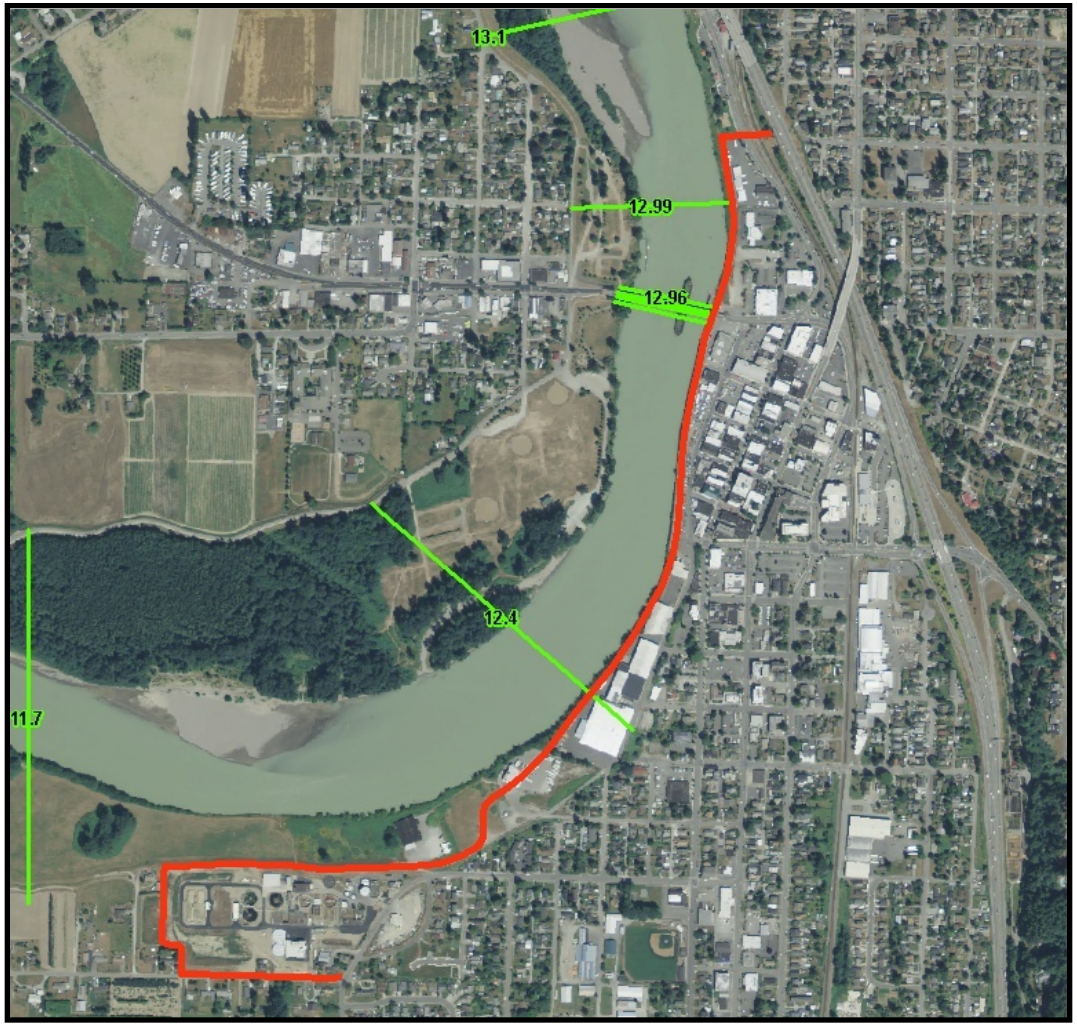
Key Spill Locations



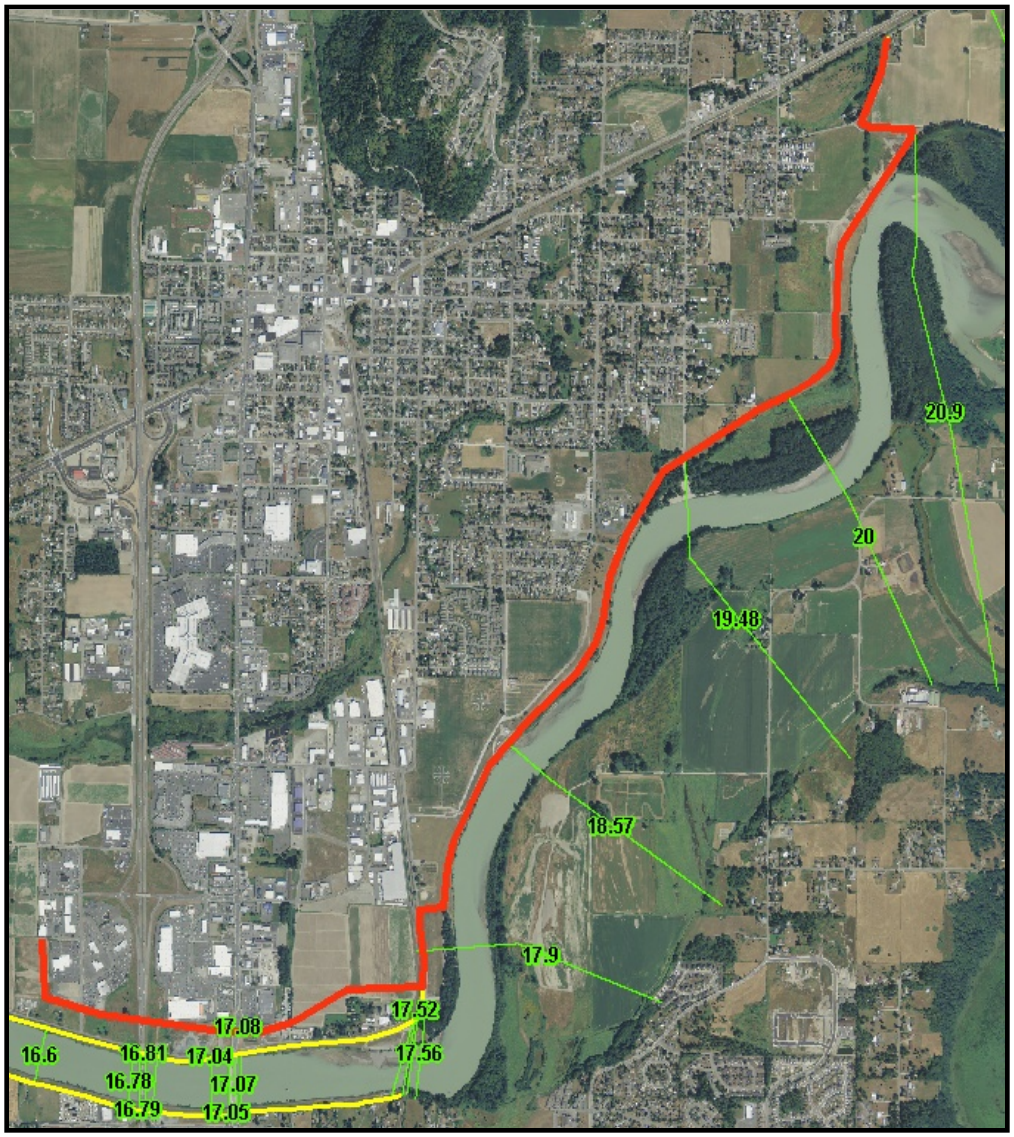
Key Spill Locations (cont.)

Mount Vernon Flood Wall



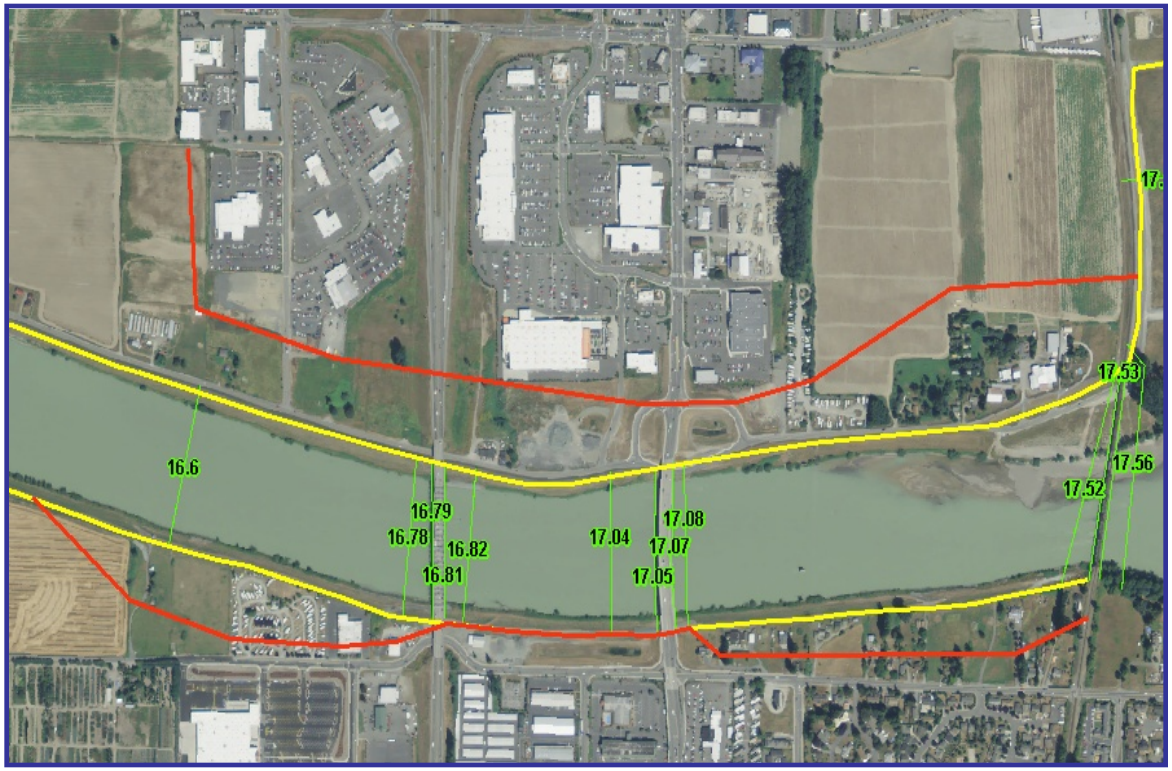
- Provide 100-year protection to urban area
- Combination of flood wall and levee per PIE design from about RM13.0 to RM 11.8
- Considered as measure rather than Existing Condition

Burlington Urban Levee



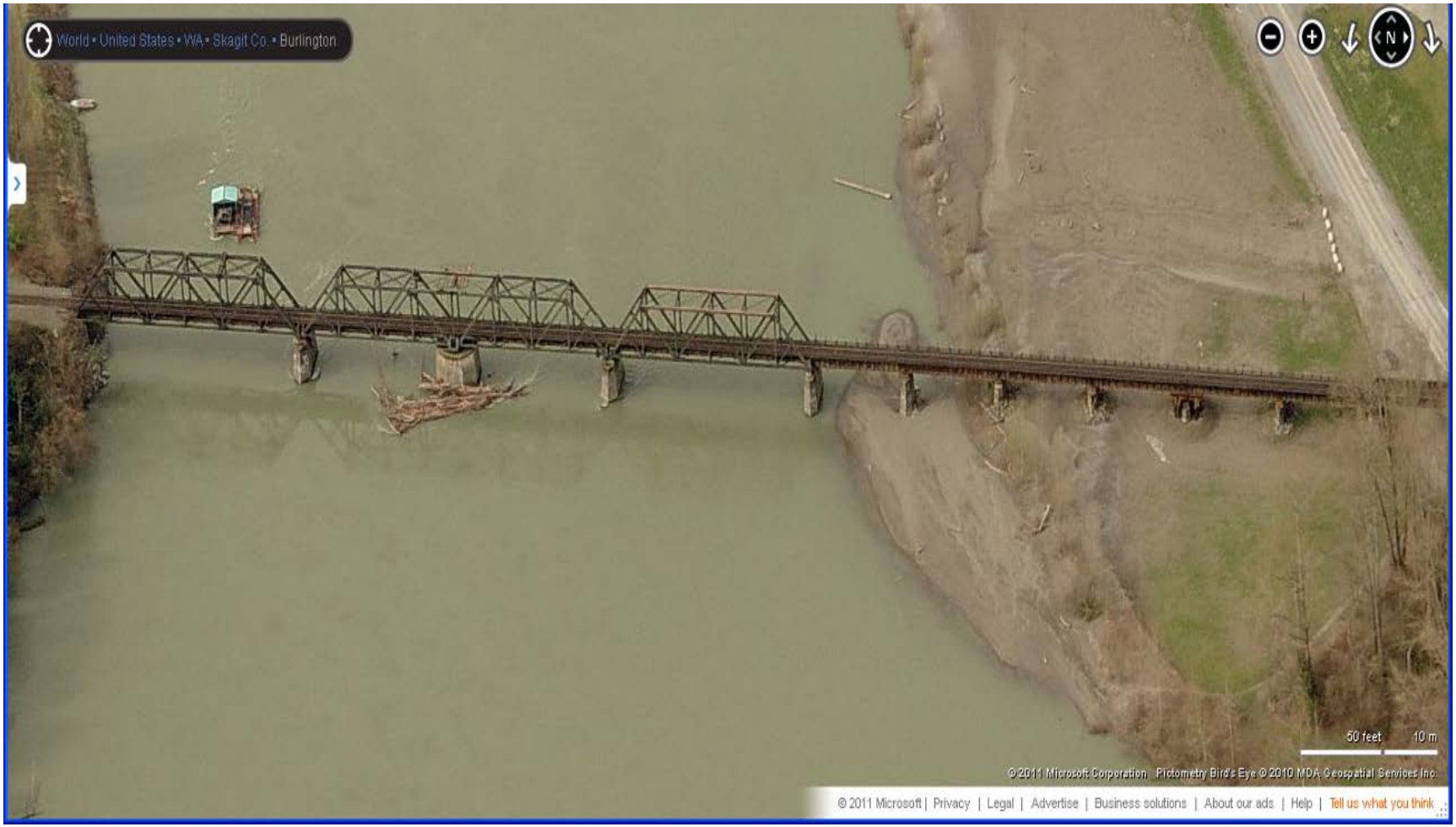
- Provide 100-year protection to urban area
- Improve existing levee SR-20 to about RM 17.9.
- Setback levee through Three Bridge Corridor.
- Tie in to high ground at u/s end to be determined.

Three Bridge Corridor



- Setback levees through Three Bridge Corridor with and without bridge improvements.
- Right bank setback levee part of Burlington Urban Levee measure.
- Bridge improvements: setback bridge abutments and replace BNSF bridge.

Existing BNSF Bridge



Hypothetical BNSF Bridge Replacement

Performance – 50-yr Event

Measure	Spill Sterling (cfs)	Spill Burl. Levee (cfs)	WL Nookachamps	Q USGS Gage (Riverside) (cfs)	WL USGS Gage (Riverside)	Q Forks (cfs)	WL Forks	Spill BNSF to Forks (cfs)	Spill N Fk + S Fk (cfs)
Existing	30,300	6,300	48.2	146,700	41.9	145,100	27.7	1,500	2,100
Mt Vernon Flood Wall	+100	+100	+0.0	-300	+0.0	+1,200	+0.1	-1,500	+1,000
Burlington Levee	+2,500	-6,300	+0.1	+2,400	+0.2	+1,900	+0.1	+500	+700
Three Bridge Corridor w/o bridge mods	-1,100	-500	+0.0	+1,300	+0.1	+1,100	+0.1	+300	+300
Three Bridge Corridor w bridge mods	-13,000	-6,300	-0.8	+13,300	+1.3	+9,800	+0.7	+3,500	+2,600
Base w/o bridge mods	+1,300	-6300	+0.1	+3,200	+0.4	+4,700	+0.3	-1,500	+1700
Base w bridge mods	-10,200	-6,300	-0.5	+10,800	+1.2	+12,200	+0.8	-1,500	+3,100

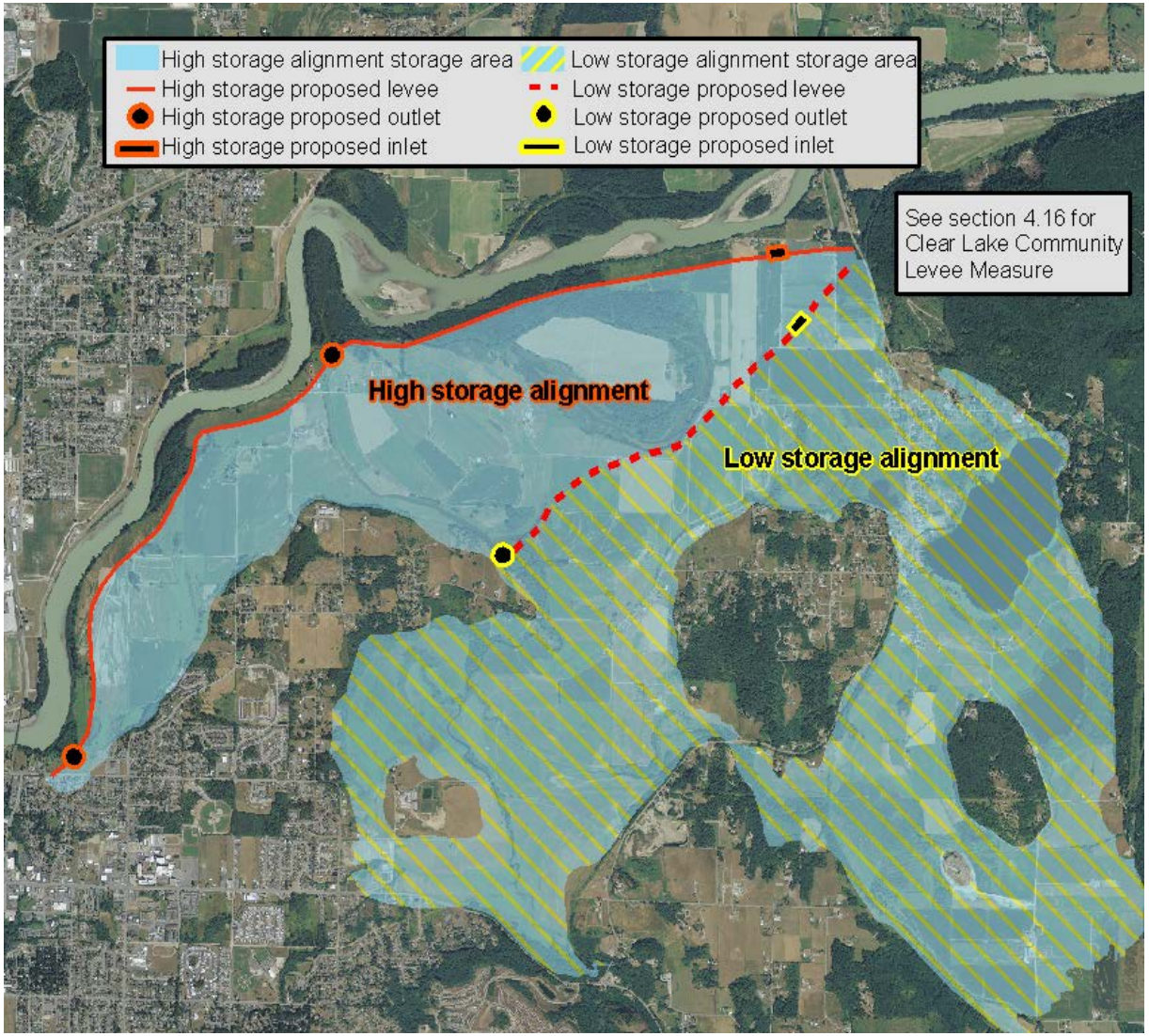
Q Sedro Woolley 187,500 cfs

Performance – 100-yr Event

Measure	Spill Sterling (cfs)	Spill Burl. Levee (cfs)	WL Nookachamps	Q USGS Gage (Riverside) (cfs)	WL USGS Gage (Riverside)	Q Forks (cfs)	WL Forks	Spill BNSF to Forks (cfs)	Spill N Fk + S Fk (cfs)
Existing	50,300	18,600	49.0	154,200	42.7	150,800	28.2	3,300	4,100
Mt Vernon Flood Wall	+200	+400	+0.0	-600	+0.0	+2,600	+0.1	-3,300	+400
Burlington Levee	+9,500	-18,600	+0.4	+6,600	+0.6	+4,500	+0.3	+2100	+800
Three Bridge Corridor w/o bridge mods	-800	-1,300	+0.0	+1,900	+0.1	+1,400	+0.1	+600	+300
Three Bridge Corridor w bridge mods	-10,400	-12,200	-0.4	+18,800	+1.7	+11,800	+0.8	+6,900	+2,700
Base w/o bridge mods	+8,400	-18,600	+0.3	+7,300	+0.8	+10,500	+0.7	-3,200	+2,300
Base w bridge mods	-3,300	-18,600	-0.1	+16,800	+1.7	+18,500	+1.1	-2,300	+5,600

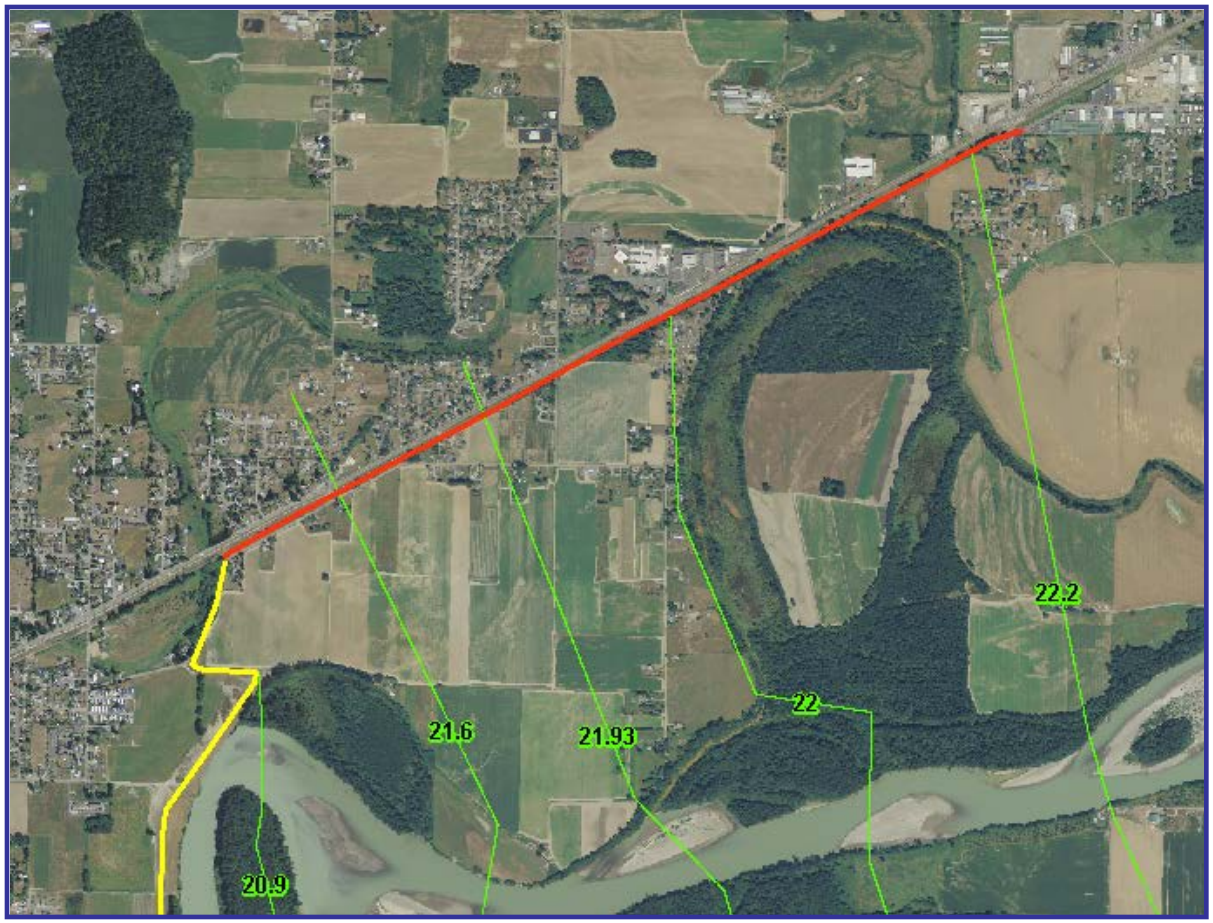
Q Sedro Woolley 222,700 cfs

Nookachamps Storage



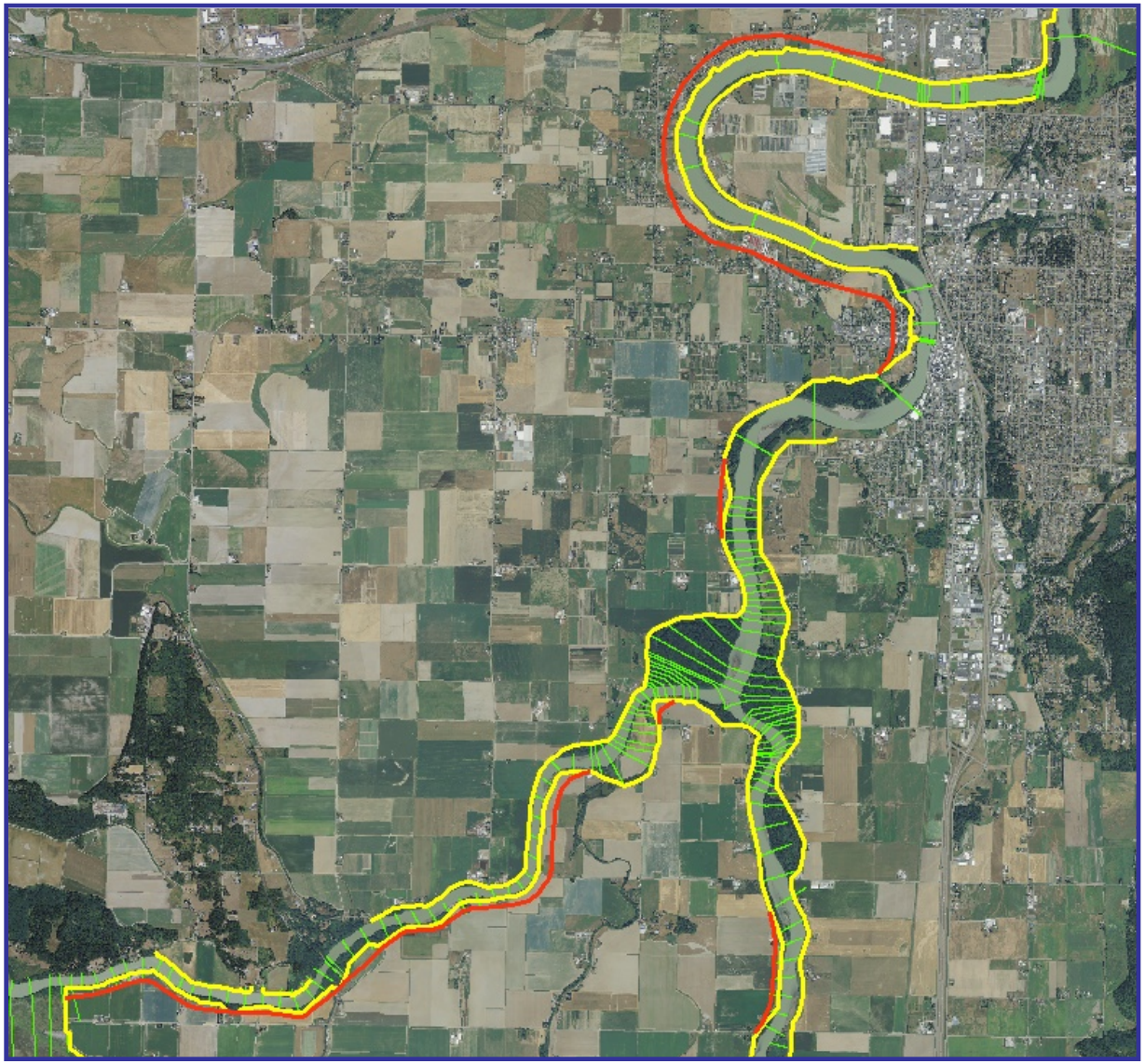
- Low storage option ~51,000 acre-ft.
- High storage option ~79,000 acre-ft.
- Inlet structure consisting of overflow weir, crest elevation 27 ft with fuse gates.
- Outlet structure, flap gates with100 ft x 20 ft total opening.

Sterling Levee



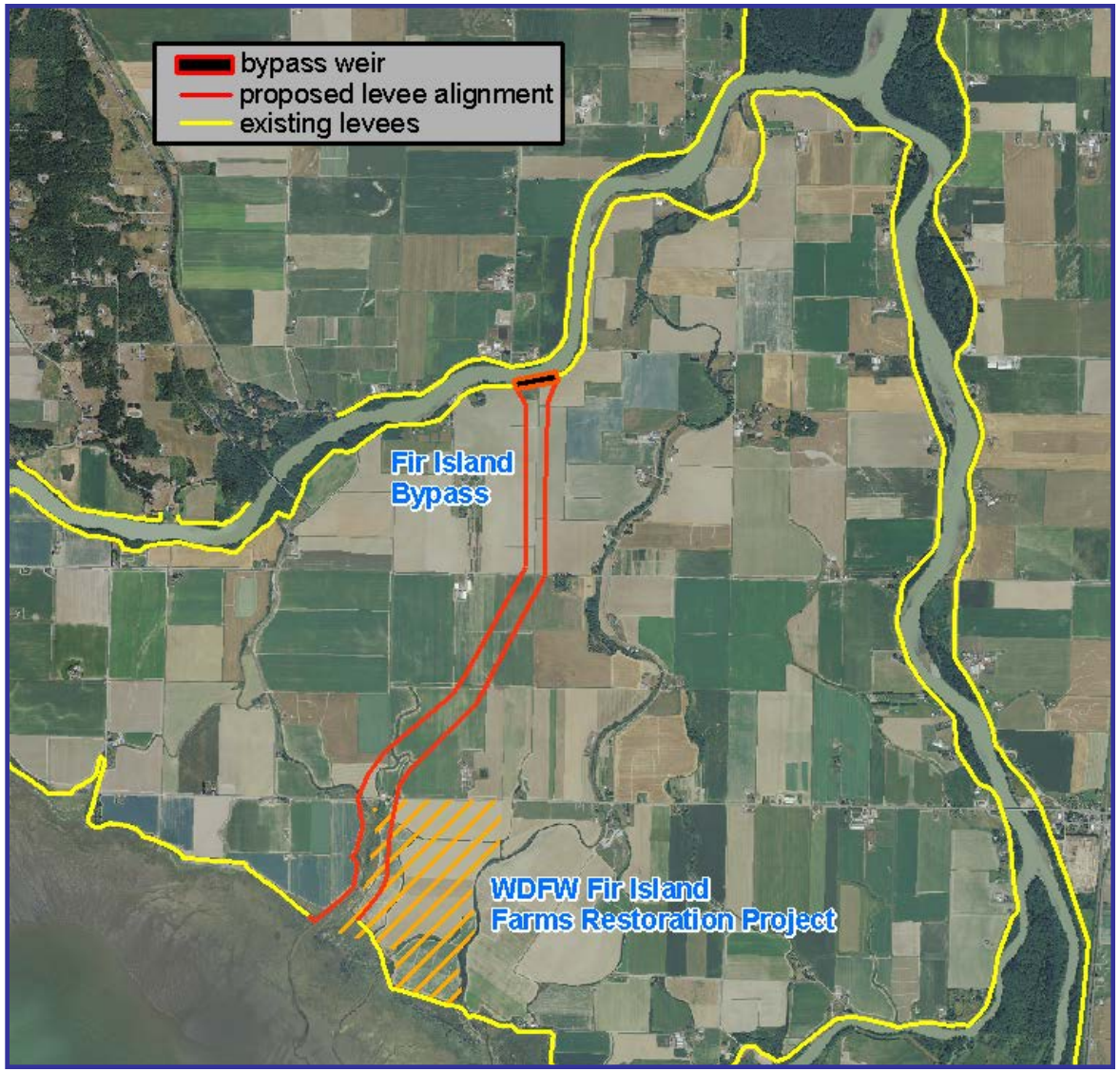
- Several possible levee alignments – alignment along SR-20 for illustration only.
- Levee crest elevation set to just prevent spill during 50-year existing condition peak discharge with average debris on BNSF bridge.

Levee Setback



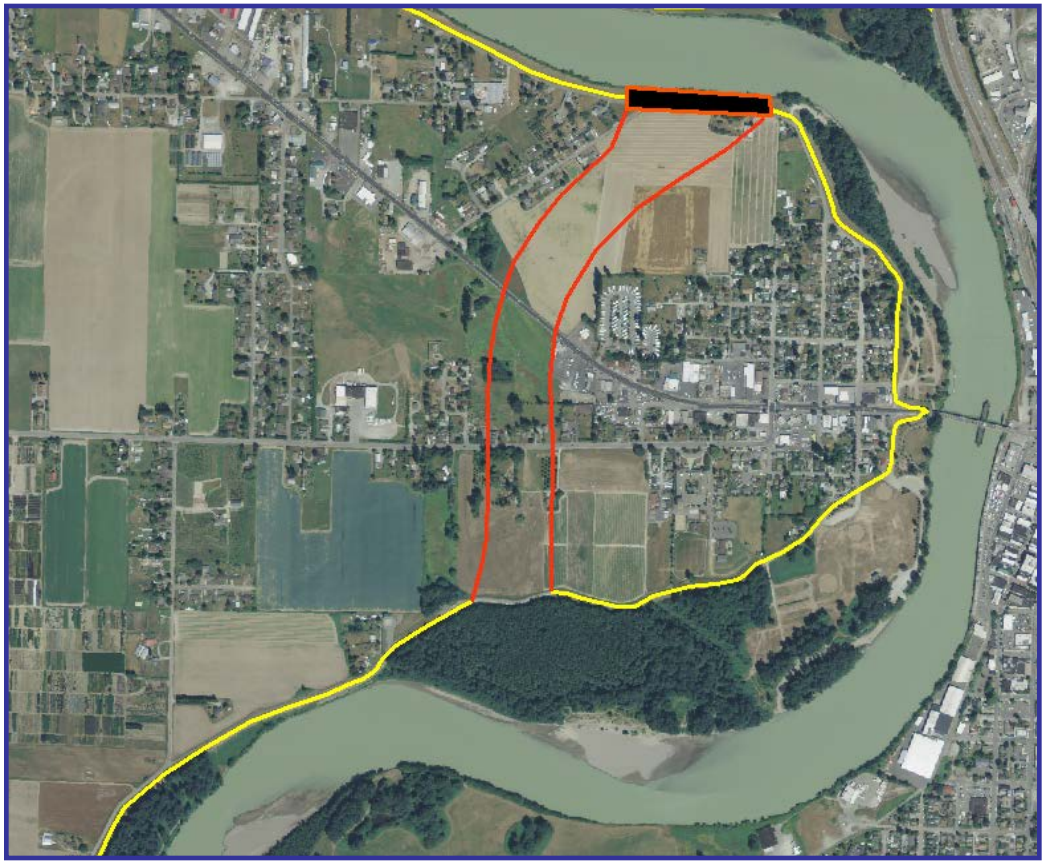
- Levee setback downstream from Three-Bridge Corridor.
- 1,500 ft minimum corridor width main stem Skagit.
- 1,000 ft minimum corridor width North and South Forks.

Fir Island Bypass



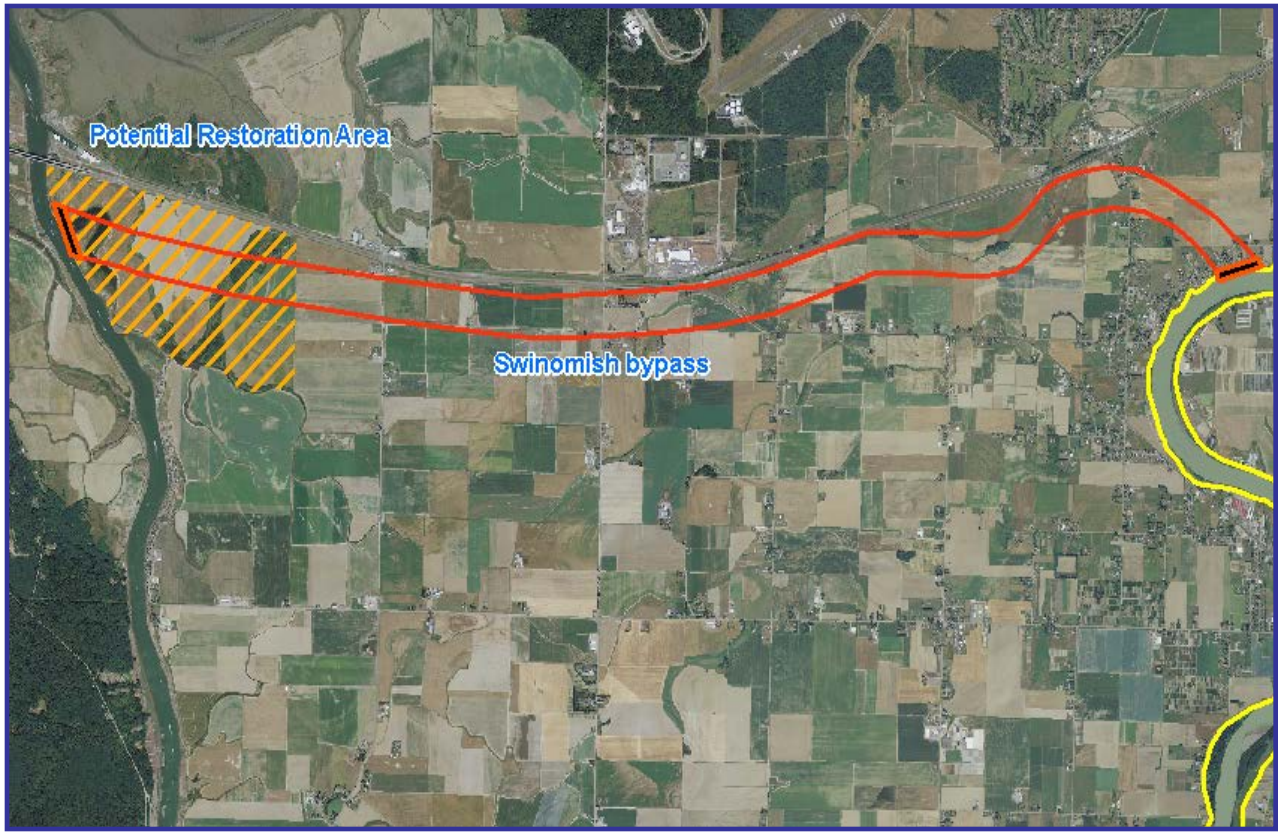
- 1,000 ft long diversion weir with crest elevation at 15.0 ft (approx. 2-yr water surface elevation).
- 500 ft wide 3 mile long leveed bypass channel at existing ground elevation.
- Tie in to existing levee at u/s end and sea dikes at d/s end.

Mount Vernon Bypass



- 1,000 ft long diversion weir with crest elevation at 29.0 ft (approx. 2-yr water surface elevation).
- 500 ft wide 0.8 mile long leveed bypass channel at existing ground elevation.
- Tie in to existing levees at either end.

Swinomish Bypass



- Diversion structure consisting of three 200-ft long fuse plug levee sections triggered at ~150,000 cfs (50-yr flow, Base w/o bridge mods)
- 1,000 ft wide leveed bypass channel extending about 7 miles to Swinomish Slough.
- 40 ft wide excavated drainage channel.
- Outlet Structure u/s of Swinomish Slough to prevent tidal flooding

Performance – 50-yr Event (cont.)

Measure	Spill Sterling (cfs)	WL Nookachamps	Q USGS Gage (Riverside) (cfs)	WL USGS Gage (Riverside)	Q Forks (cfs)	WL Forks	Spill BNSF to Forks (cfs)	Spill N Fk + S Fk (cfs)	Q Bypass(cfs)
Base w/o bridge mods	31,600	48.3	150,000	42.3	149,800	28.1	0	3,900	n/a
Nookachamps (low storage)	-6,600	-0.9	-5,000	-0.5	-5,500	-0.4	+0	-2,000	n/a
Nookachamps (high storage)	-7,100	-0.5	-18,900	-2.0	-19,200	-1.6	+0	-3,400	n/a
Sterling Levee	-26,500	+1.5	+16,500	+1.7	+16,100	+1.1	+500	+4,100	n/a
Levee Setback	-3,600	-0.2	+3,800	-0.5	+3,800	-0.2	+0	-1,200	n/a
Fir + Mt Vernon Bypass	-2,500	-0.1	+3,300	-0.4	+3,500	+0.0	+0	+100	25,500 Mt V 10,900 Fir Is
Swinomish Bypass	-9,000	-0.5	+14,000	-1.4	-14,300	-1.1	+0	-3,300	32,400

Q Sedro Woolley 187,500 cfs

Performance – 100yr Event (cont.)

Measure	Spill Sterling (cfs)	WL Nookachamps	Q USGS Gage (Riverside) (cfs)	WL USGS Gage (Riverside)	Q Forks (cfs)	WL Forks	Spill BNSF to Forks (cfs)	Spill N Fk + S Fk (cfs)	Q Bypass(cfs)
Base w/o bridge mods	58,700	49.3	161,500	43.5	161,300	28.8	0	6,400	n/a
Nookachamps (low storage)	-10,900	+0.3	-5,700	-0.5	-5,600	-0.4	+0	-1,400	n/a
Nookachamps (high storage)	-7,100	+0.4	-19,300	-1.9	-19,300	-1.3	+0	-4,800	n/a
Sterling Levee	-28,700	+1.4	+30,300	+2.2	+17,200	+0.9	+12,400	+8,900	n/a
Levee Setback	-5,400	-0.2	+5,500	-0.5	+5,400	-0.1	+100	-700	n/a
Fir + Mt Vernon Bypass	-4,000	-0.1	+4,000	-0.4	+4,300	+0.1	+0	+200	29,100 Mt V 12,100 Fir Is
Swinomish Bypass	-19,200	-0.7	+20,800	-2.3	-24,600	-1.8	+0	-5,600	48,000

Q Sedro Woolley 222,700 cfs

Questions

- Should spill be controlled at Sterling and if so how and to what degree?
- How should impacts of possible future BNSF bridge replacement be accounted for?