Prepared for:

Skagit County

Carpenter Creek, Hill Ditch and Fisher Slough Watersheds Initial Flood and Sediment Study

Skagit County, WA

Final Report
March 2007

Prepared by:

TETRA TECH

In association with

Perkins Geosciences
Miller Consulting

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Initial Flood and Sediment Study

Skagit County, Washington

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Prepared by:
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1.0 INTRODUCTION AND OVERVIEW

The Fisher Slough Restoration Project and Fisher Slough Watersheds Flood and Sediment Study are a collaborative effort being undertaken by Skagit County Public Works, The Nature Conservancy Washington Branch, Diking District #3 and Drainage District #17. The project involves development of two project elements including a site assessment and restoration plan for Fisher Slough, and an assessment and development of flood and sedimentation assessment, conceptual plans and strategies for the contributing upstream watershed areas within the Carpenter Creek and Fisher Slough watersheds. This report addresses Project Element 2, the Carpenter Creek/Hill Ditch and Fisher Slough Watersheds Flood and Sediment Study. Details regarding Project Element 1, the Fisher Slough Restoration Plan, are located in an accompanying report (Tetra Tech, 2006a).

The Fisher Slough Watersheds are a 23 square mile area south of the City of Mount Vernon that drain the western edge of the Cascade foothills through natural resource, agricultural and rural developed areas, downstream to the tidally influenced marsh and wetland areas of Fisher Slough, and to the South Fork of the Skagit River (**Figure 1**). The watershed has six sub-basins (listed north to south below) that are located mainly within Skagit County with portions of the southern sub-basins (Big Fisher and Little Fisher Creek) originating in Snohomish County. The manipulation of landscape hydrologic functions through levee construction, drainage project development and changes in land use characteristics have and will continue to contribute to flooding and sedimentation problems throughout the watershed. In addition, there are a myriad of water resource related problems and issues within these sub-basins, for which this report focuses on flooding and sedimentation. Site assessments, engineering analyses and conceptual project recommendations were developed for each of the six sub-basins for this report.

- Carpenter Creek
- Sandy Creek
- Johnson Creek
- Bulson Creek
- Big Fisher Creek
- Little Fisher Creek

1.1 PROJECT MISSION STATEMENT AND OBJECTIVES

The Skagit County Public Works Department, Dike District #3 and The Nature Conservancy, Skagit Office are project partners developed the following mission statement and guiding principles for the Carpenter Creek, Hill Ditch, and Fisher Slough Watershed project.

> *Maximize the area influenced by natural stream and tidal processes, allow for a broad range of ecosystem variability, restore estuarine rearing habitat for juvenile salmon to the maximum extent possible, and improve flood protection and storage capacity for Carpenter Creek and Fisher Slough.*

The Fisher Slough Watersheds Flood and Sediment Investigation project evaluates flooding and sediment transport conditions within watersheds tributary to Fisher Slough. The primary objectives for Project Element 2 are:

- Identify and prioritize flood and sediment transport risks in the Carpenter Creek watershed
- Delineate opportunities to address ongoing sediment transport and flooding issues
- Identify linkages and opportunities for flood protection and sediment transport with Dike and Drainage District goals and initiatives in the Carpenter Creek and Fisher Slough basins
- Improve habitat for cold water native fish

1.2 PROJECT APPROACH AND REPORT CONTENTS

The organization and contents of the report present a general overview of watershed geology, geomorphology, hydrology and sediment transport processes and characteristics. The report discusses findings from the field site investigations and hydrologic modeling analysis for each of the six sub-basins. In final, development of concept design alternatives and management strategies are presented and prioritized in a summary list for planning and implementation of future projects.

1.2.1 Field Site Assessments and Interviews

Field site assessments and interviews were performed to document, survey and characterize existing geologic, geomorphologic and hydrologic conditions as they relate to flooding and sedimentation characteristics within each of the sub-basins. Initial investigations involved review of existing reports and interviewing Skagit County Public Works Department, Skagit County Conservation District, Dike District #3 personnel and local landowners regarding flood and sedimentation problems in the sub-basin (Appendix A). Information obtained from report reviews and interviews was used to focus on key flooding and sedimentation problem areas to visit and assess as part of the field investigations. The field investigations included windshield surveys, stream walks, photo documentation, cursory culvert and bridge inspections, sediment sampling and source assessments, and hydrologic data collection to support hydrologic and geomorphologic analysis of flood and sedimentation conditions throughout the watershed. Sub-basin geology and geomorphology is presented within the context of the field site assessments (Appendix B).

1.2.2 Hydrologic and Hydraulic Modeling and Analysis

Hydrologic runoff estimates were developed for each of the sub-basins by developing a HEC-HMS model. The model estimates peak runoff for 24-hour precipitation events based on the unique loss characteristics for each sub-basin. An unsteady flow, hydraulic model (HEC-RAS) was developed along the Carpenter (Hill Ditch) to the confluence with Fisher Slough to estimate losses and hydrograph attenuation. Hydrologic modeling results for existing and future conditions show the potential to increase flooding and sedimentation in each of the sub-basins. The modeling output was also used separately to model flood conditions and project alternatives for the downstream Fisher Slough Restoration project. (Appendix C).

1.2.3 Concept Design Alternatives and Management Strategies

Flood reduction and protection measures, as well as sedimentation measures and management strategies are presented for each of the sub-basins based on the findings and results of the field site assessments, and hydrologic runoff modeling. To facilitate discussion of concept design alternatives and management strategies, a general framework of typical non-structural and structural features and measures that can address the specific flooding and sedimentation problems in each of the sub-basins are presented. The framework is used to identify specific project and management opportunities, and develop preliminary life-cycle project costs which include the following elements:

- project construction
- engineering analysis and design
- project administration, management and coordination
- permitting
- future operations and maintenance

The project opportunity list is then summarized and prioritized with input and feedback from Skagit County and their technical committee for planning and implementation of future projects.

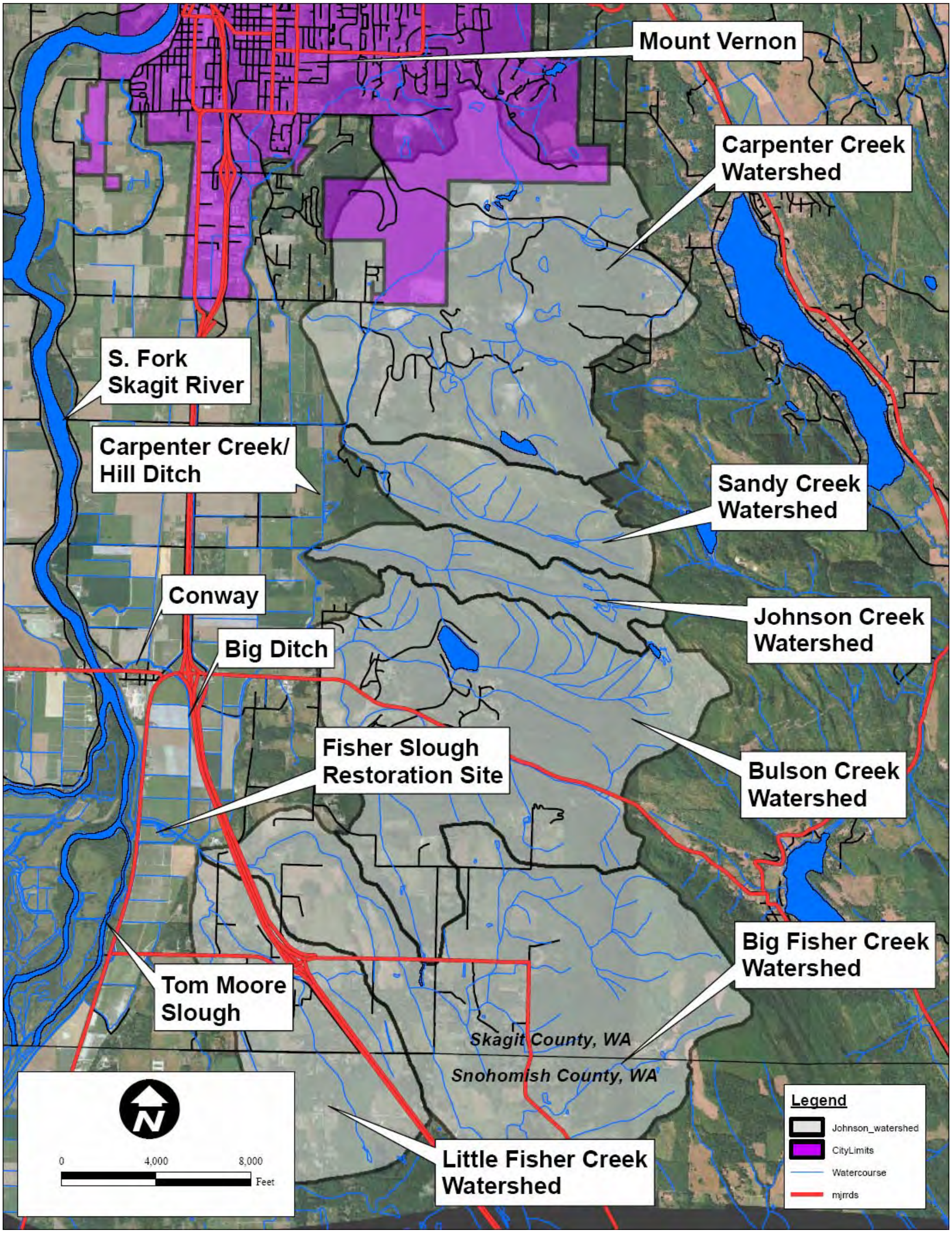

Figure 1. Fisher Slough Watersheds

2.0 WATERSHED OVERVIEW

The Fisher/Carpenter Creek watershed encompasses more than 23 square miles and is made up of six tributary sub-basins (**Table 1**). The watershed extends from the south side of Mount Vernon on the north to slightly south of the Skagit-Snohomish County line. The headwaters of the six sub-basins that make up the Fisher Slough watershed originate in the terraces and foothills within the western slopes of the North Cascades Mountains on the east and drain westerly to the Puget Lowlands.

The headwaters of the creeks are relatively narrow and steep in the northern sub-basins and have a terrace and rolling topography for the southern sub-basins. The northern tributary sub-basins (Carpenter, Sandy, and Johnson) border the western edge of the Devil's and Cultus Mountains ranging between 800 and 1000 feet in elevation. The southern sub-basins (Bulson, Big and Little Fisher) are in an area greatly influenced by glacial actions that created terrace and plateau features that trend north-northwest and range in elevations from 40 to 340 feet. The soils are moderately deep and moderately well-drained and are formed in volcanic ash and glacial till.

The creek channels generally form deeper ravines before entering the valley floodplain, where the larger creeks develop alluvial fan features as they transition from steeper gradient foothills to the relatively flat Skagit River floodplain. Underlying geology of the Skagit River delta is comprised of glacial deposits and alluvium. Soils of the delta are very deep and naturally poorly drained.

Several of the tributaries entering along the eastern edge of the Skagit Valley margin have alluvial fan features. Alluvial fans are depositional floodplain features where tributary streams transport debris and sediment from steep sections of the stream, and deposit material along the edge of the valley resulting from expansion of flow and loss of energy. Sandy and Johnson Creek have distinct alluvial fan features at the end of their ravines. Alluvial fans pose unique flood hazards in that significant deposition leads to frequent avulsions and channel switching.

Another unique process occurring within the watershed is the instances of debris dam-break floods and potential for debris flows. Debris dam-break floods found within the study watershed are primarily a result of landslide activity. Landslides can create debris dams, which may break loose causing debris dam-break floods.

Dam-break or debris floods should not be confused with debris flows. Typically debris dam-break floods have sediment concentrations less than 35% with debris flows having concentrations up to 75%. The increased concentrations of debris flows provides unique soil-water plasticity characteristics that can significantly increase the size and forces of the flow compared to clear-water flow events.

Debris flows are referred to as mudslides, mudflows, or debris avalanches. Debris flows typically occur as a result of rainfall saturation or rapid snowmelt runoff. The composition of flow is mainly of soils, rock and colluvium and other organic debris such as trees. The potential for debris flows exist within these sub-basins. Debris flows can travel rapidly at speeds up to 35mph and are extremely destructive due to the immense forces. Pacific Northwest debris flows occur in small watersheds less than 2 mi^2, with average gradients greater than 18 percent. Flows in along areas less than 18% gradient typically deposit materials and convert to debris floods with lower sediment concentrations.

The Carpenter, Sandy, Johnson and Bulson Creeks flow into the channelized Hill Ditch along the eastern valley margin. Hill Ditch and the remaining Big Fisher and Little Fisher creeks ultimately converge at Fisher Slough and outlet at the South Fork Skagit River and Tom Moore Slough.

Table 1. Fisher Drainage Areas

Basin Name	Drainage Area (Sq. Miles)	Drainage Area (Acres)
Carpenter Creek	5.5	3,550
Sandy Creek	1.5	950
Johnson Creek	1.1	730
Bulson Creek	5.8	3,680
Big Fisher Creek	6.3	4,030
Little Fisher Creek	2.8	1,760
Total Watershed Area	23.0	14,720

Historical maps of the area show the sub-basin tributaries flowing into large wetland areas on the Skagit floodplain along the valley margins and base of the Devil's and Cultus mountains. These historical wetlands extended north from Fisher Slough up valley beyond Johnson and Sandy Creeks towards the Carpenter Creek foothill outlet. Collins (2002) reconstructed potential vegetation composition maps using T-Sheet (original section surveys and descriptions) GLO (Government Land Office) information and digital elevation models showing the approximate locations of the Skagit River historical wetlands (**Figure 2**). The historical GLO maps show areas of agriculture occurring on the Skagit delta and floodplain by the 1870s. For natural and undisturbed areas along the valley bottom between Carpenter Creek and Fisher Slough the vegetation was identified as shrub scrub tidal marsh wetlands and mixed riparian forest.

Wetlands are low lying areas frequently saturated or inundated by water with soils and vegetation suited for hydric conditions. Wetlands provide many valuable floodplain functions including flood storage and attenuation, water filtering and cleansing, groundwater recharge and baseflow contribution, fish and wildlife habitat, and have aesthetic value.

Logging of streamside forests on the Skagit River Delta began in the 1870s and was generally complete by 1902 (Collins, 1998). By the early 1900s, many tidal wetlands had been diked and drained to enable farming. Sometime between 1910 and 1937, Carpenter Creek was channelized and routed south in Hill Ditch from the Carpenter Creek foothill outlet to Fisher Slough. In addition, the Big Ditch drain and flood control levees had also been constructed prior to the 1937 aerial photos.

Historically, several lumber mills were located in the vicinity of Fisher Slough; hence the "Milltown" designation located a mile south along Pioneer Highway just south of the project site. These mills took advantage of the Skagit River for transport and close proximity to forested hillsides and remnants of the historical logging rail road grade that connected to Arlington and Clear Lake run along the center of the Fisher Slough fan to Tom Moore Slough.

Historically, the cleared, low-lying delta lands were converted to agricultural row crop activities while the higher terraces and plateaus in the southern sub-basins were mostly used for pasture lands. Over the past 30 years however, the terrace and plateau areas have been slowly converted to rural residential uses of various densities. Currently, the mountainous and hill areas and the delta floodplain areas are zoned as natural resource and agricultural lands. Hill areas are zoned for forestry and timber use, and delta floodplain areas are zoned for agricultural use (**Figure 3**).

Development is generally confined to rural residential uses with densities that range from 2.5 – 10 acres per dwelling unit (DU) (**Table 2**). The exception to this is the area within the Upper Carpenter Creek basin within the City of Mount Vernon and its Urban Growth Area (UGA) where densities are 4 dwelling units per acre. Given current zoning designations, increases in dwelling units and impervious areas are expected in several of the sub-basin watersheds, and have the potential to affect water quantity and quality conditions, habitat values and fish use in the Fisher/Carpenter system. Examples of these effects include

- Increases in runoff and flooding
- Increases in erosion and sedimentation related to increases in flood volumes and reductions in flood and sediment storage through human structural encroachment
- Degradation of water quality
  - Increases in temperature from loss of forest, riparian canopy and reduction of wetland areas
  - Increases in nutrient and pesticide pollution from agricultural land uses
  - Increases in other pollutant loading from residential, commercial and highway construction

Historical channelization of the sub-basin tributaries, loss of flood storage wetlands areas and alluvial fan sedimentation zones, and changes in land uses including forestry, agriculture, residential and commercial development have cumulatively contributed to additional stormwater runoff and sedimentation problems within the six sub-basins. These conditions and problems are expected to increase in the future as development and land use conversion continue throughout the sub-basins. Specific flood and sedimentation problem areas are characterized as the following:

- Channelization of Hill Ditch along valley margin has decreased natural floodplain storage and attenuation through loss of wetland and floodplain connectivity
- Alignment and position of Hill Ditch along alluvial fan structures requires frequent sediment removal maintenance to retain flood conveyance capacity
- Channelization and ditching tributaries along valley walls have created flood storage and sedimentation problems
- Sedimentation and flooding is occurring at undersized and poorly maintained culverts and crossings throughout the watershed
- Channel and bank erosion and incision are occurring resulting from land use changes and increases in stormwater runoff
- Natural habitat areas and features for cold water fish species have been lost

The following sections of the report present findings from the field site assessments and identify flood and sedimentation problems, and recommendations for each of the sub-basins. The report then presents conceptual designs, preliminary costs and prioritization recommendations for future work.

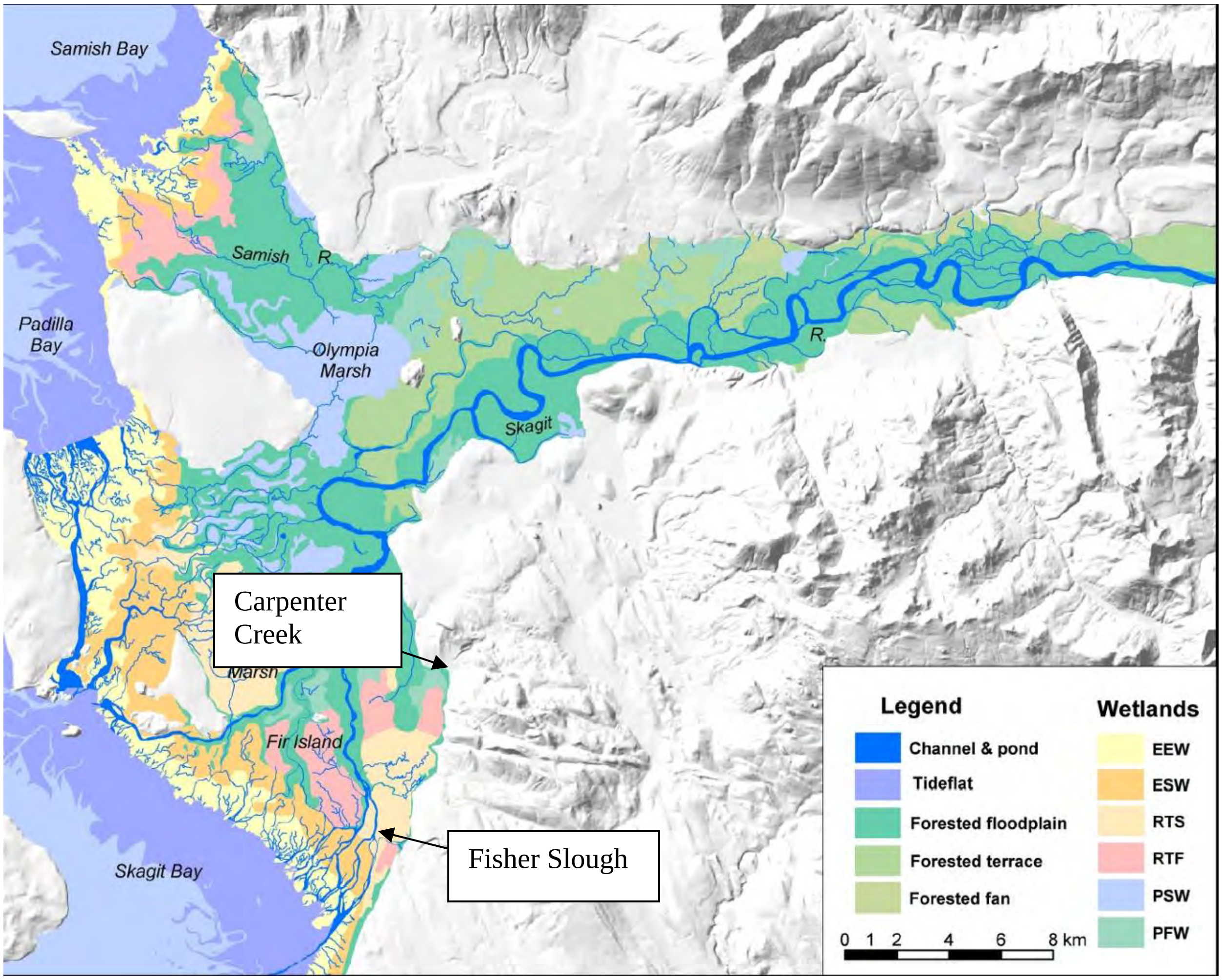

Figure 2. Collins Historical Reconstruction of Skagit River (Collins, 2002)

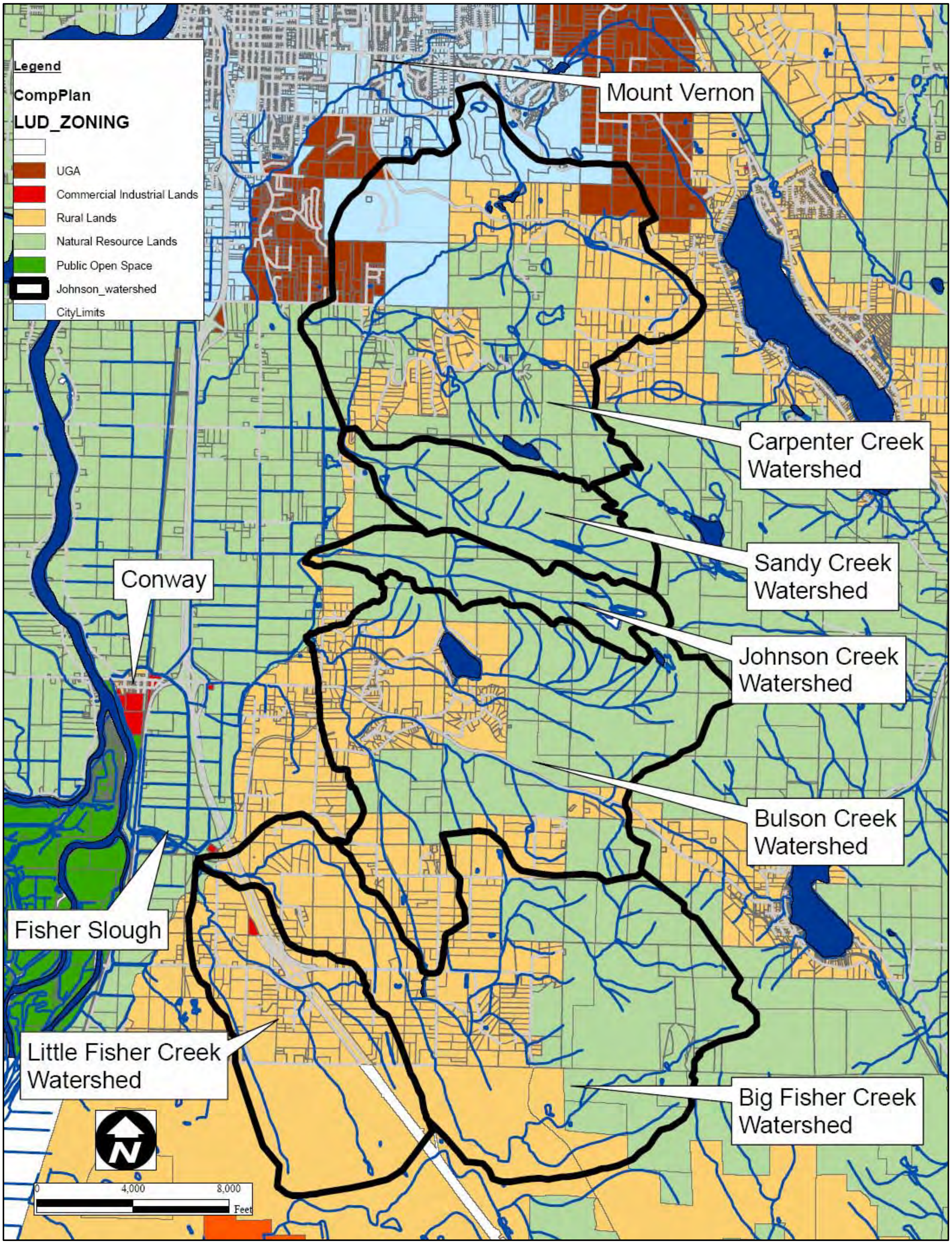

Figure 3. Skagit and Snohomish County Comprehensive Land Use Plans

Table 2. Future Increases in Impervious and Semi-Impervious Surfaces

Watershed Sub-basins	COMP. PLAN DESIGNATION	LU ZONING	Max. DU/ac allowed	Area (sq.ft)	Area (ac)	Maximun DU Allowed*	Approx. DU Existing	Future Additional Impervious Surface (acres)**	Future Additional Semi-impervious Surface (acres)***
Carpenter Creek Watershed									
City	SF - MED		4DU/ac##	11660646.0	267.7	1071.0	100.0	111.5	0
	Park	CP	0	22346280.0	513.0	NA	NA	0	0
Urban Growth Area	UGA (City)	URR (SF - MED)	(4DU/ac)##	10531143.0	241.8	967.0	40.0	106.4	0
Rural Lands	Rural Reserve	RRv	1DU/5ac or 10ac#	55074614.2	1264.3	169.0	125.0	7.1	9.1
Natural Resource Lands	Industrial Forest	IF-NRL	1DU/ 80ac	12408358.7	284.9	4.0	0.0	0.6	0.8
	Rural Resource	RRc-NRL	1DU/10ac	6647297.2	152.6	15.0	11.0	0.6	0.8
	Secondary Forest	SF-NRL	1DU/20ac	38980850.1	894.9	45.0	10.0	5.6	7.2
	Agriculture	Ag-NRL	1DU/40ac	8140999.1	186.9	5.0	10.0	0	0
Water	WAT		NA	648892.8	14.9	NA		0	0
					3820.9				
Total					**6.0 sq.mi.**	**2276.0**	**296.0**	**231.8**	**17.9**
Change from existing watershed								**6.1%**	**0.5%**
Sandy Creek Watershed									
Natural Resource Lands	Agriculture	Ag-NRL	1DU/40ac	120042.6	2.8	0.0	0.0	0.0	0
	Secondary Forest	SF-NRL	1DU/20ac	6080149.2	139.6	7.0	0.0	1.1	1.4
	Industrial Forest	IF-NRL	1DU/80ac	34189063.6	784.9	10.0	0.0	1.6	2.1
Rural Lands	Rural Reserve	RRv	1DU/5ac or 10ac#	486550.6	11.2	2.0	1.0	0.2	0.2
Water	WAT		NA	240690.4	5.5	NA		0.0	0
					943.9				
Total					**1.5 sq.mi.**	**19.0**	**1.0**	**2.9**	**3.1**
Change from existing watershed								**0.3%**	**0.3%**
Johnson Creek Watershed									
Natural Resource Lands	Agriculture	Ag-NRL	1DU/40ac	320569.9	7.4	0.0	0.0	0	0
	Secondary Forest	SF-NRL	1DU/20ac	5070367.9	116.4	6.0	0.0	1	1.2
	Industrial Forest	IF-NRL	1DU/80ac	25014041.6	574.2	7.0	0.0	1.1	1.4
Rural Lands	Rural Reserve	RRv	1DU/5ac or 10ac#	607472.7	13.9	2.0	0.0	0.3	0.4
Water	WAT		NA	635649.1	14.6	NA		0	0
					726.5				
Total					**1.1 sq.mi.**	**15**	**0**	**2.4**	**3**
Change from existing watershed								**0.3%**	**0.4%**
Bulson Creek Watershed									
Natural Resource Lands	Agriculture	Ag-NRL	1DU/40ac	211896.2	4.9	0.0	0.0	0	0
	Secondary Forest	SF-NRL	1DU/20ac	36507209.9	838.1	42.0	0.0	6.7	8.7
	Industrial Forest	IF-NRL	1DU/80ac	37366863.5	857.8	11.0	0.0	1.8	2.3
	Rural Resource	RRc-NRL	1DU/10ac	13363580.3	306.8	31.0	1.0	4.8	6.2
Rural Lands	Rural Reserve	RRv	1DU/5ac or 10ac#	51357631.7	1179.0	157.0	70.0	14	18
	Rural Intermediate	RI	1DU/2.5ac	19287776.4	442.8	177.0	130.0	10.8	0
Water	WAT		NA	2072927.4	47.6	NA		0	0
					3676.9				
Total					**5.7 sq.mi.**	**418.0**	**201.0**	**38.1**	**35.2**
Change from existing watershed								**1.0%**	**1.0%**
Big Fisher Watershed									
Natural Resource Lands	Agriculture	Ag-NRL	1DU/40ac	418168.9	9.6	0.0	0.0	0	0
	Secondary Forest	SF-NRL	1DU/20ac	24940328.3	572.6	29.0	0.0	4.7	6
	Industrial Forest	IF-NRL	1DU/80ac	37294944.0	856.2	11.0	0.0	1.8	2.3
	Rural Resource	RRc-NRL	1DU/10ac	580416.5	13.3	1.0	0.0	0.2	0.2
	Commercial Forest	CF-(Sno. Co)	1DU/80ac	14699609.0	337.5	4.0	0.0	0.6	0.8
Rural Lands	Rural Reserve	RRv	1DU/5ac or 10ac#	69190116.3	1588.4	212.0	90.0	19.6	25.2
	Rural Residential	RR/5 (Sno. Co)	1DU/5ac	21651362.1	497.0	99.0	45.0	12.4	0
	R. Res. - Transition	RR/10RT (Sno. Co.)	1DU/10ac	3533246.7	81.1	8.0	4.0	0.8	0.8
	R. Res. - Lo Density	RLDR/20 (Sno. Co.)	1DU/20ac	3331883.3	76.5	4.0	2.0	0.3	0.4
					4032.1				
Total					**6.3 sq.mi.**	**368.0**	**141.0**	**40.2**	**35.7**
Change from existing watershed								**1.0%**	**0.9%**
Little Fisher Watershed									
Natural Resource Lands	Agriculture	Ag-NRL	1DU/40ac	738664.7	17.0	0.0	0.0	0	0
Rural Lands	Rural Reserve	RRv	1DU/5ac or 10ac#	41498078.2	952.7	127.0	80.0	7.6	9.7
	Rural Business	RB	<50% area	231509.4	5.3	1.0	1.0	1.3	0
	Rural Residential	RR/5 (Sno. Co.)	1DU/5ac	32634997.8	749.2	150.0	75.0	17.2	0
Right of Way		ROW (Sno. Co.)		1775004.2	40.7	NA		0	0
					1764.9				
		Total			**2.8 sq.mi.**	**278.0**	**156.0**	**26.1**	**9.7**
Change from existing watershed								**1.5%**	**0.5%**

3.0 SUB-BASIN FLOODING AND SEDIMENTATION ASSESSMENTS

3.1 CARPENTER CREEK

Flooding and Sedimentation Site Assessment

Carpenter Creek, above Sandy Creek, has several small tributaries and a watershed area of 6 square miles. The upper watershed headwaters originate within the urban growth areas and the Mt. Vernon city limits, between the Eaglemont golf course development area to the north, and the western topographical divide with Big Lake. The remaining areas of the watershed are mostly natural resource and rural residential land use areas (**Figure 4)**.

Existing land uses in the Carpenter Creek watershed vary, with residential and rural residential uses dominating. Housing densities are higher within Mount Vernon and its Urban Growth Area UGA than in surrounding county lands. Approximately 26% of the watershed is within the City and UGA. Half (or 13%) is found within Little Mountain Park and the other 13% has a zoning designation of residential - medium density (4 dwelling units per acre). Only about 10% of this area is currently developed at this density, indicating potential for a great deal of additional residential development. Approximately 38% of the upper watershed has a county zoning designation of Rural Reserve or Rural Resource which allows 1 dwelling unit per 5 or 10 acres. Over 70% of this area has been developed for rural residential use. The remainder of the sub-basin is in Secondary or Industrial Forest (31%) encompassing the slope of Devil's Mountain or Agriculture (5%) which is located to the west of Hill Ditch.

The mainstem creek headwaters flow westerly through a broad upper valley and then turn southwest through a narrow ravine. The creek flows through recessional outwash deposits that are overlain by fine-grained, glaciomarine drift in the broad upper valley (Dethier and Whetten 1981). The outwash gravels have been mined, with an active gravel pit at the mouth of the Carpenter Creek ravine and three abandoned gravel pits in the upper valley that were mined prior to 1961 (at the Lang Pony Farm). Upon reaching the western foot of the mountains, Carpenter Creek crosses a short, sloping transitional zone before entering the flat Skagit Valley. Downstream from the ravine, near the quarry, Carpenter Creek passes under Hickox Road through a 10-foot culvert that was recently replaced after the previous culvert failed. The creek continues south along the east side of the Skagit valley margin in Hill Ditch.

Three tributaries enter the broad, upper valley. The largest tributary originates near 10 Lake and flows north through a bedrock watershed. Its deposits have formed an alluvial fan that stops short of Carpenter Creek. Two smaller, seasonally-dry tributaries flow south through glacial till watersheds that originate in the suburbs of Mount Vernon, including part of the Eaglemont development. Nearly all of their coarse sediment load drops out on the valley floor before reaching Carpenter Creek.

The northwestern tributary originates along the southern edge of Eaglemont and drains to the Lang Pony Farm through three historical sand and gravel pit ponds (**Figures 5-6)**. The upstream pond of the Pony Farm is currently a beaver pond/wetland area with a very low gradient channel that acts as a sink for coarser sediment. The upper pond may have been historically modified or constructed or could be an original beaver pond. There is evidence of logging and stumps in the upper pond. Either way the upper dam or beaver pond areas are left in a somewhat natural state with little maintenance needs and active signs of current beaver activity. The middle dam was constructed for sand and gravel mining and has an outlet structure discharging to the historical channel, and a concrete emergency spillway, along the southeastern corner. Roadway fill is excavated from the spillway to allow for flow during flood events. The Lang Dams are inspected by the Washington Department of Ecology, Dam Safety Office; Lang Dam No. 1 was repaired under this program as an inadequate spillway in 2001-2002 (WDOE, 2002).The third pond, which is downstream near Little Mountain Road, has no surface water connection and had algae scum on the surface during inspection. During the site visit to the property on September 7, 2006, Lorna Lang indicated that there has been an increase in the amount of dam overtopping and flooding since the development of Eaglemont. Her description was that the upper pond overtops and flows into the historical stream channel. The historical tributary location runs adjacent to the ponds and acts as an overflow channel from the upper beaver pond. The middle dam overtopping is less infrequent and they manage the spill by removing roadway fill over the concrete spillway. The middle pond outlet works connect with the channel downstream from the emergency overflow spillway. These dams have been identified in the (SCD 2006a) Conservation District report as having potential outlet works modifications to improve temperature conditions within the stream by allowing more consistent releases from the dam during summertime months. In order to accomplish this, the outlet works would need to be modified to release cooler water from the deeper areas of the pond.

Downstream from the Pony Farm the northern tributary passes beneath Little Mountain road and has been reported as a problematic culvert causing local flooding (**Figure 7**) (SCD, 2006a and 2006b). During the site visit, it appeared that the culvert is located in a position along the road that is higher than the drainage low point and that the culvert was partially blocked, thereby providing reduced conveyance capacity. Water was ponded on both sides of the structure indicating possible beaver activity in the area.

The next major feature is the State Haul road crossing where a railroad car bridge has been installed with a series of notched log weirs in the channel (**Figure 8**). Currently the bridge decking has several large holes, is in disrepair and could be a safety hazard. During inspection the upstream notch log weir was a fish passage barrier with drop heights greater than 1 foot. The area between the State Haul road railroad bridge and the Carpenter Creek ravine is primarily rural reserve, horse pasturelands. The pasture areas have potential for floodplain enhancement and riparian restoration along streamside grazing and horse access areas.

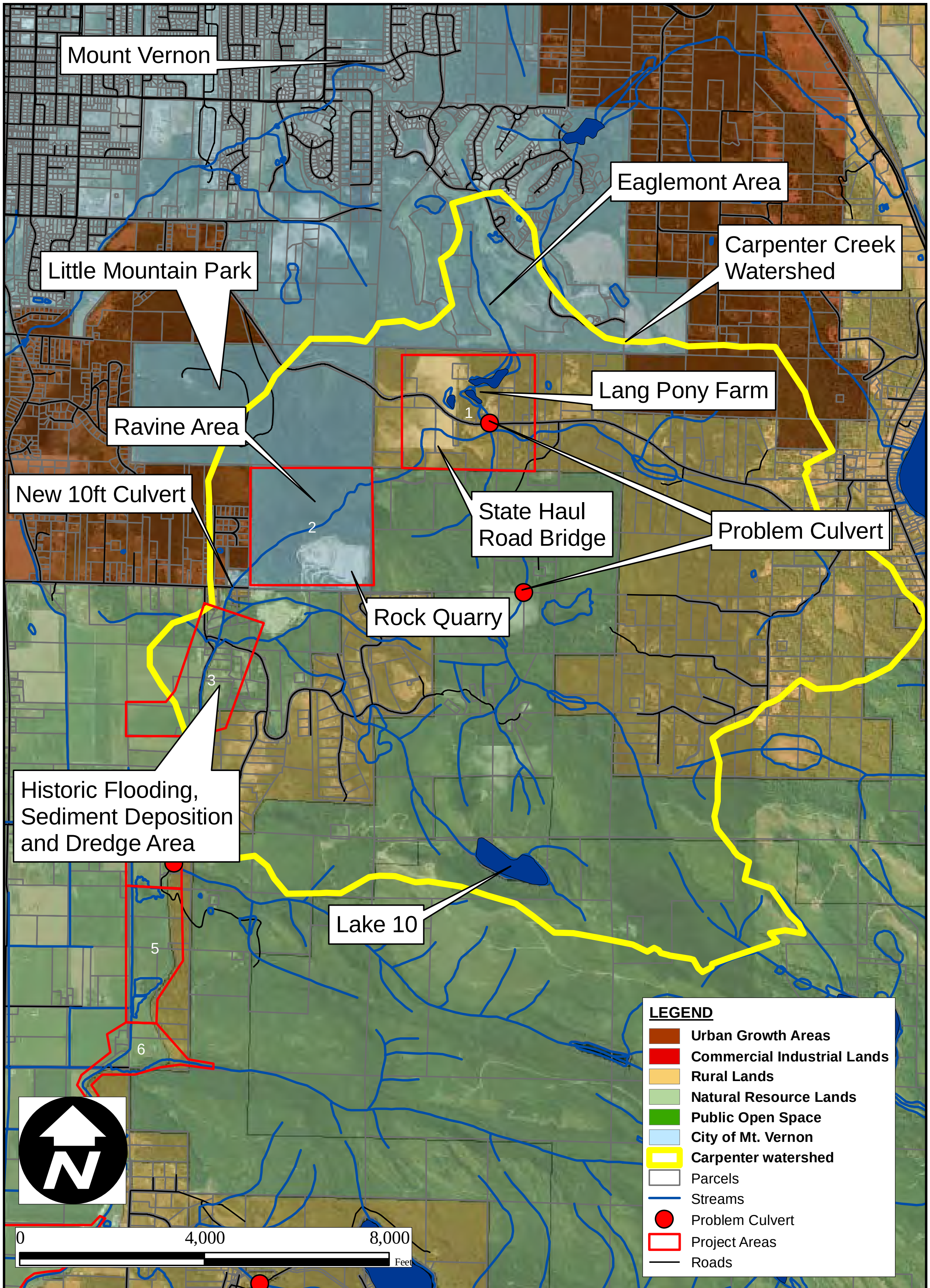

FIGURE 4. CARPENTER CREEK WATERSHED MAP

SKAGIT COUNTY, WASHINGTON

Figure 5. Lang Pony Farm Middle Pond

Figure 6. Lang Pony Farm Upper Pond

Figure 7. Little Mountain Road looking towards problem culvert area near Lang Pony Farm driveway

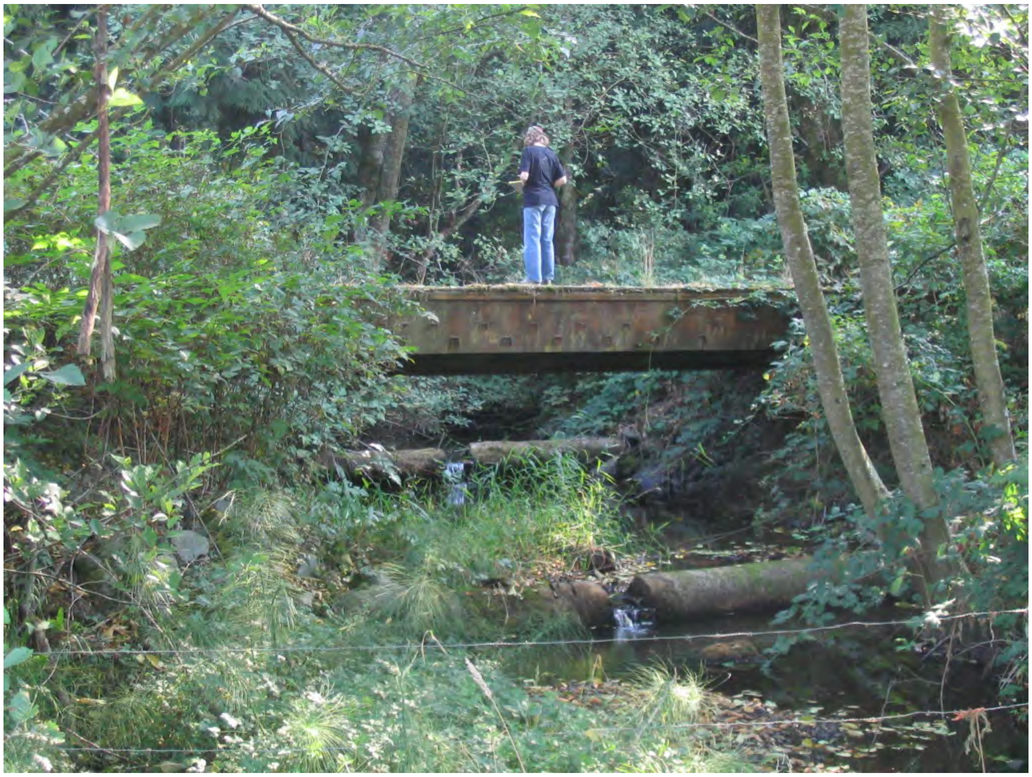

Figure 8. State Haul Road Bridge

Downstream from the horse pasture area, Carpenter Creek flows through a steeper ravine (**Figure 9**). The bed and banks of the ravine are the primary source of coarse sediment to Carpenter Creek. The ravine has an average gradient of five percent and maximum gradient of 11 percent. The ravine walls are 100 feet high and landslides probably occur in infrequent, high-intensity storm events. The creek is currently stable except for one large cut bank in the southeast quarter of Section 33 (SCD, 2006b). At its downstream end, the ravine reach has abundant large cobbles and scattered small boulders, with moderate to slight bank erosion and no instream channel structure. Most of the ravine is within Little Mountain Park and has mature riparian forest and a stable, pool-riffle channel (SCD 2006), and presumably some channel structure from LWD.

After exiting the ravine, Carpenter Creek flows down a gentle, unconfined, alluvial reach with an average gradient of four percent. This reach of Carpenter Creek had severe, localized bank erosion following the sudden failure of a three-foot diameter culvert at the quarry in 1990 (SCD 2006a). The undersized culvert was replaced with a 10 foot diameter culvert and banks have reportedly stabilized with no known current erosion sources except localized bank erosion associated with bank armoring between Hickox Road and Cascade Ridge Road. Carpenter Creek is joined on the east by 10 Lake Creek, a steep but stable bedrock channel, and on the west by Stackpole Creek, a low gradient rock-lined roadside ditch (SCD 2006a). The final reach of Carpenter Creek is a very low gradient ditch, starting a short distance below Cascade Ridge Road and paralleling Stackpole Road (**Figure 10**). This area was identified during interviews as being a flood overflow area, where Carpenter floods and overtops Stackpole Road and flows into the farm fields on the adjacent properties to the west.

The declining gradient and lack of valley confinement reduce Carpenter Creek's sediment transport capacity downstream from the ravine. The maximum size of sediment declines from 15-inch boulders just above the gravel pit to gravel, sand, and finally silt in Hill Ditch (**Figure 11**). Although this is clearly the depositional zone for the creek's coarse sediment load, the amount of sediment appears low. 800 cubic yards of gravel were reportedly dredged from this section of Hill Ditch in the 1990s. The ditch has apparently not needed recent dredging. Much of the dredged sediment may have resulted from the 1990 culvert blowout. The low sediment load is attributed to the low level of hydrologic changes from development, the broad valley and wetlands that trap sediments and attenuate flood flows in the upper half of the watershed, the relatively gentle relief and undisturbed riparian corridor (with the exception of the Stackpole Road area just downstream from the 10 Lake and Stackpole Creek confluence). However, future land use plans show significant potential development in the upper watershed within the City of Mount Vernon and Skagit County urban growth areas, which could increase flooding and sedimentation problems.

Figure 9. Carpenter Creek in ravine near quarry

Figure 10. End of Carpenter Creek and start of Hill Ditch along Stackpole Road

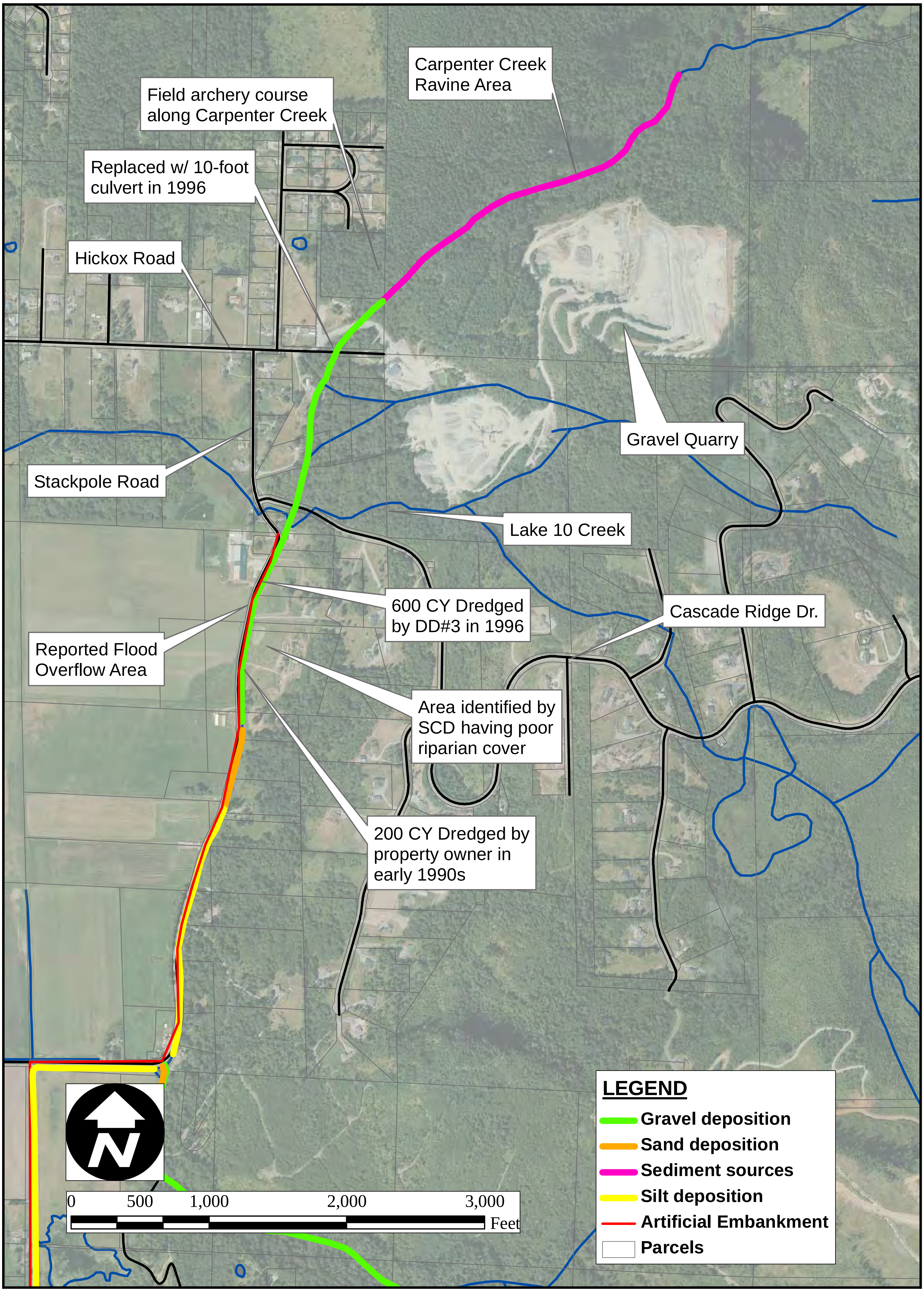

FIGURE 11. CARPENTER CREEK SEDIMENT SOURCES AND DEPOSITION ZONES

Hydrologic Modeling Flood Runoff Estimates

Hydrologic modeling using HEC-HMS was performed to assess existing and future flood runoff conditions. A detailed summary of the methods for performing the analysis is included in Appendix C. In summary, both the existing and future land use areas of the watershed were modeled and compared to evaluate the potential changes in flood runoff due to changes in the landscape based on the existing Skagit County Comprehensive Plan. For Carpenter Creek, the potential growth and build out in the upper watershed City of Mount Vernon and Skagit County Urban Growth Areas show increases of impervious and semi-impervious areas of 250 acres in total for full build out (**Figure 12**). This translates to potential increases in flood runoff of 20 cfs, for the 2-year/24-hour event and by 90cfs for the 100-year/24-hour event, if no direct actions are taken to control stormwater runoff (**Table 3 and Figure 13**).

The HEC-RAS model used in the study extends only up to the Stackpole and Cascade Road intersection, downstream along Hill Ditch to Fisher Slough, coinciding with LIDAR imagery and data provided by The Nature Conservancy. Evaluation of the hydrologic runoff conditions in HEC-RAS show that overflows occur along low lying areas of Stackpole Road and begin overtopping between the 10-year and 25-year event. There appear to be two problematic areas, immediately downstream from the 10 Lake and Stackpole Creek confluence, and an area 1,500-feet downstream where there is a sag in the roadway. Poor conveyance, sediment deposition, vegetation and high channel roughness, and the constriction by Kanako Bridge influence the hydraulics and flooding along the Stackpole road reach.

Table 3. Carpenter Creek Existing and Future Flood Runoff Conditions

Event	Precip (in/24hr)	Existing Conditions	Future Conditions	Potential Flood Increase	Percent Increase
		cfs	cfs	cfs	%
2 YR, 24HR	2.25	90	110	20	22%
5 YR, 24HR	2.60	140	180	40	29%
10 YR, 24HR	2.75	180	220	40	22%
25 YR, 24HR	3.25	300	350	50	17%
50 YR, 24HR	3.75	440	510	70	16%
100 YR, 24HR	4.50	680	770	90	13%

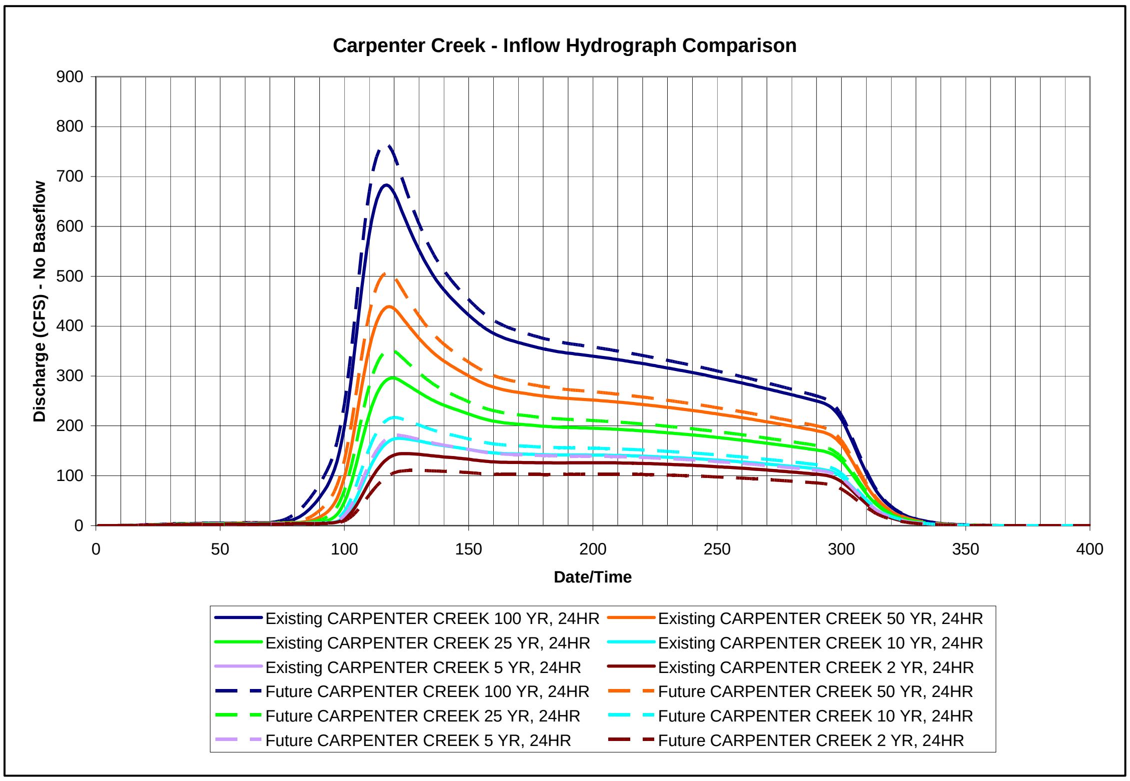

Figure 13. Carpenter Creek existing and future flood runoff estimates

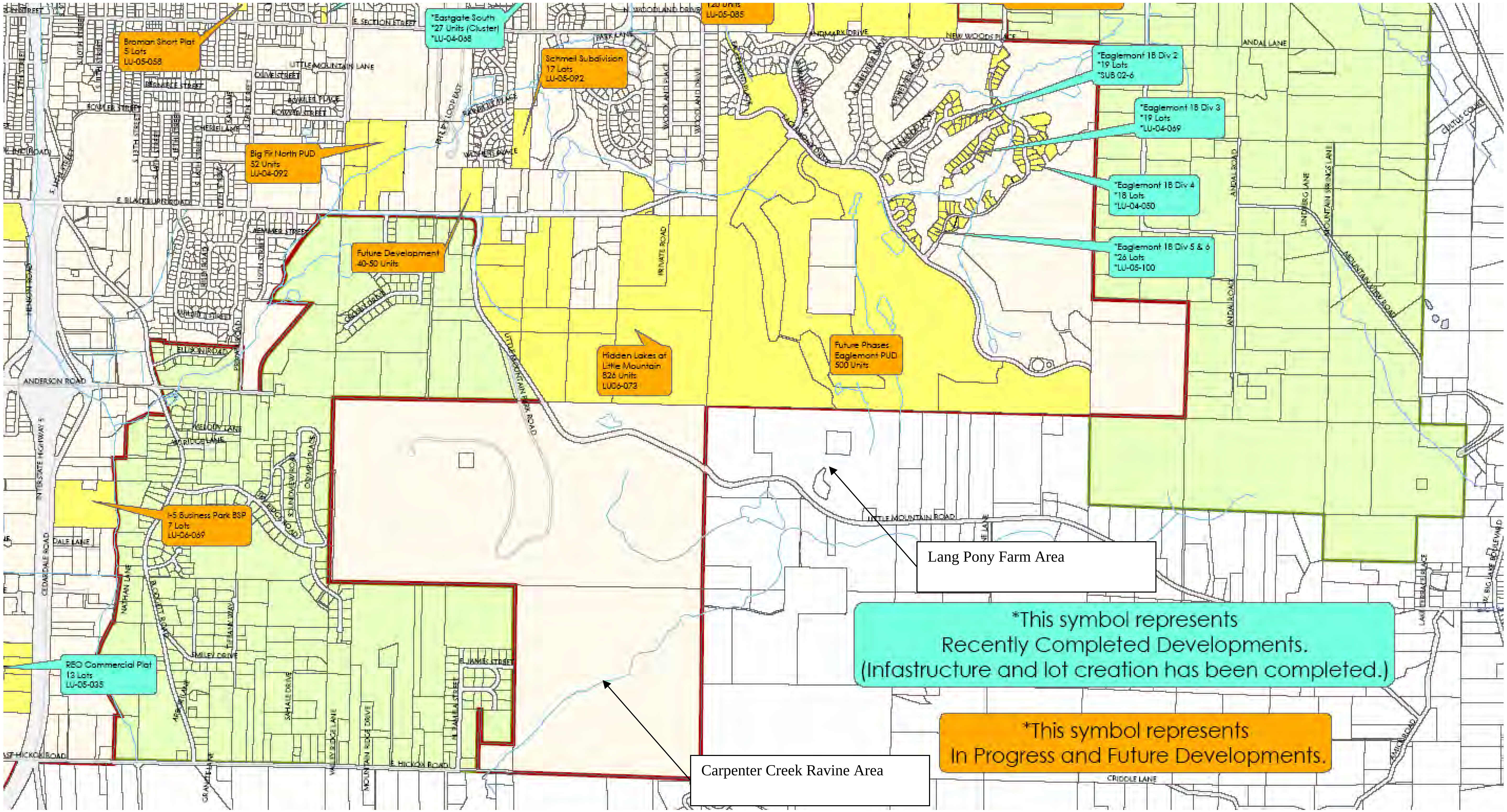

Figure 12. City of Mount Vernon Planning and Development Map (provided by the City of Mt. Vernon Planning Department, Oct. 2006)

Recommendations

Several key issues and recommendations are identified from the site assessment and hydrologic modeling effort of the Carpenter Creek sub-basin. Specific concept design alternatives and management strategies are discussed further in Section 4. The following is a summary of flood and sedimentation reduction recommendations:

- Perform ongoing Carpenter Creek Sub-basin Planning and Coordination activities focusing on coordinating stormwater runoff permitting, regulation and identification of potential regional stormwater facilities and flood and sediment control projects with the City of Mount Vernon and developers in the upper watershed.

- The Lang Pony Farm ponds are currently providing flood and sediment storage benefits downstream from Eaglemont development. Evaluate the Pony Farm ponds and downstream areas for potential dam, culvert, and stream channel improvements and protection of natural flood and sedimentation features (wetlands, floodplains, fans) to improve flood control and sediment detention benefits, and plan for future increases in runoff.

- Protect the ravine area from future development due to the fact that this area is a major sediment source and increased localized drainage and runoff would have adverse effects on flooding and sedimentation in current deposition zone problem areas at the downstream end of Carpenter Creek. The City may already have a conservation easement for the area, but follow on work should check that this is the case.

- Evaluate a flood control and sediment enhancement project between Hickox Road and Kanako Road near current dredging and flood overflow areas. Project would include evaluating widening flood and sediment storage areas, possible stream channel realignment and enhancement, and a designated overflow structure other than the dip in the road.

3.2 SANDY CREEK

Flooding and Sedimentation Assessment

Sandy Creek has a drainage area of 1.48 square miles and lies between Carpenter and Johnson watersheds. Land use within the Sandy Creek drainage is classified and used as Natural Resource Lands, Industrial and Secondary Forest areas, with a minor amount of Rural Reserve development area located at the mouth of the canyon and alluvial fan area (**Figure 14**).

The creek drains the low mountains that flank the east side of the Skagit Valley. The Sandy Creek ravine has an average gradient of 12 percent and maximum gradient of 22 percent. The creek has two forks with the south fork being flatter. The ravine walls are 160 to 220 feet high and form a steep, narrow, inner gorge. The ravine walls are underlain by glacial Vashon till and (mostly) Chuckanut sandstone along the mainstem, rhyolite on the south fork, and a mixture of rock types on the north fork (**Figure 15**). Although not shown on the geologic map, dense glacial till is commonly exposed in the creek bottom below the forks (**Figure 16**). The creek flows down a splay fault within the Devil's Mountain Fault Zone, a strike-slip fault zone that may still be active (Dragovich et al. 2002). Although Sandy Creek's watershed is larger than Johnson Creek to the south, its alluvial fan is smaller because the sediment supply is lower. The hillslopes and channel appear far more stable, suggesting that the splay fault has been far less active than the main fault that Johnson Creek follows. The historic alluvial fan at the base of the hill is about 600 feet long (east-west) and 1200 feet wide (north-south).

By 1937, the date of the earliest aerial photographs, Hill Ditch was already present and Sandy Creek was channelized to the north flowing (up valley) towards Kanako Lane and the valley wall (**Figure 17**). The Sandy Creek, Hill Ditch confluence is directly beneath the Kanako Lane bridge (**Figure 18**). Sediment deposits have accumulated in the 10 years or so since the last dredging and now nearly block the bridge opening. The current bridge was constructed in 1983. Dredging the bridge and Hill Ditch has typically been done every 5 or 6 years. According to interviews with Skagit County Public Works and Dike District #3, the dredging frequency has decreased due to difficulties in obtaining permits. Sediment deposits are located underneath the bridge and force flow towards the west abutment, which is experiencing scour and exposing the bridge abutment foundation. Hill Ditch has two 90 degree bends in its alignment that increase backwater resistance. The first bend is at Kanako Lane Bridge and the second is at the Dike District #3 levee and access road.

Figure 15. Photo of eroding glacial till streambank in ravine

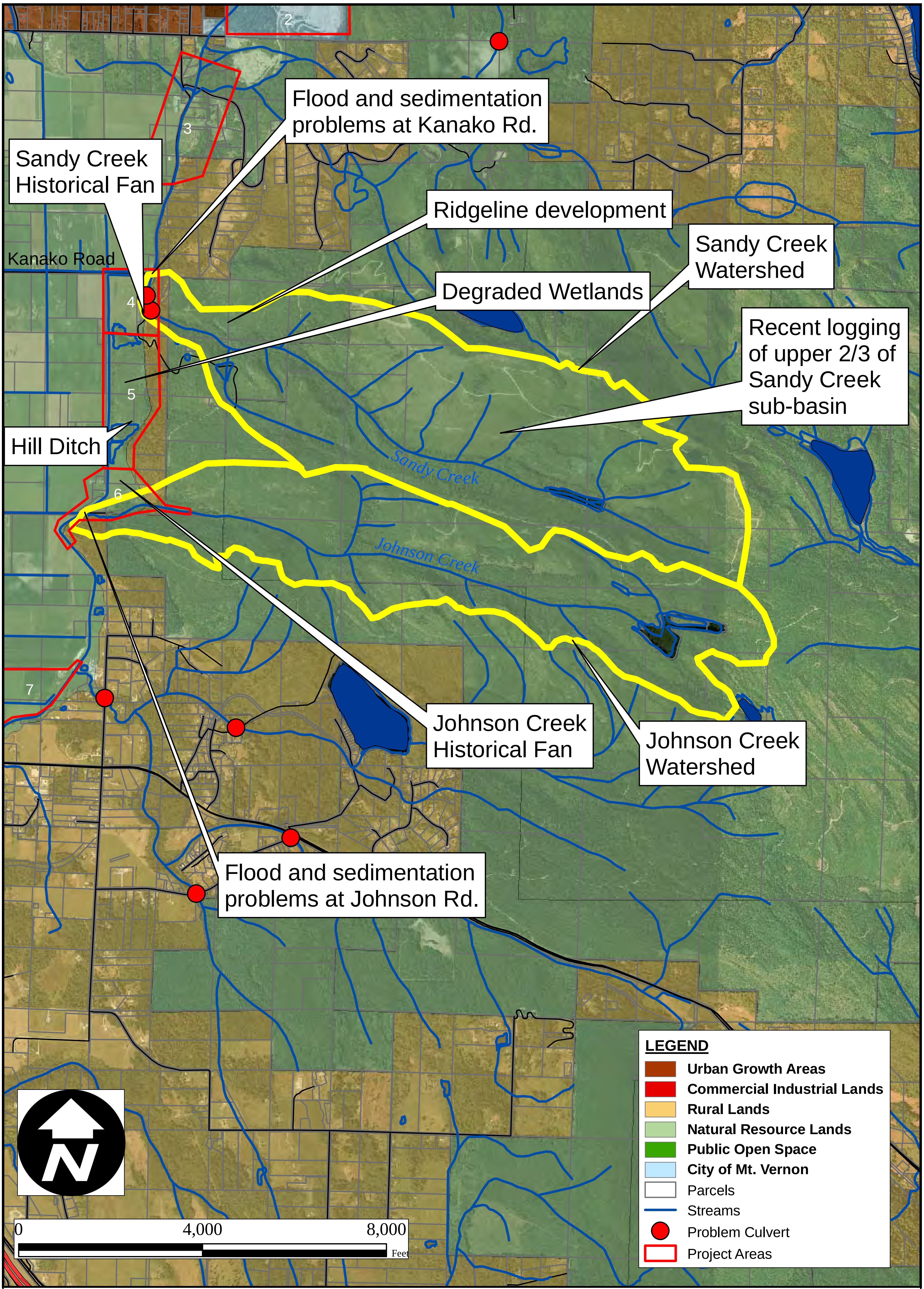

FIGURE 14. SANDY AND JOHNSON CREEKS WATERSHED MAP

SKAGIT COUNTY, WASHINGTON

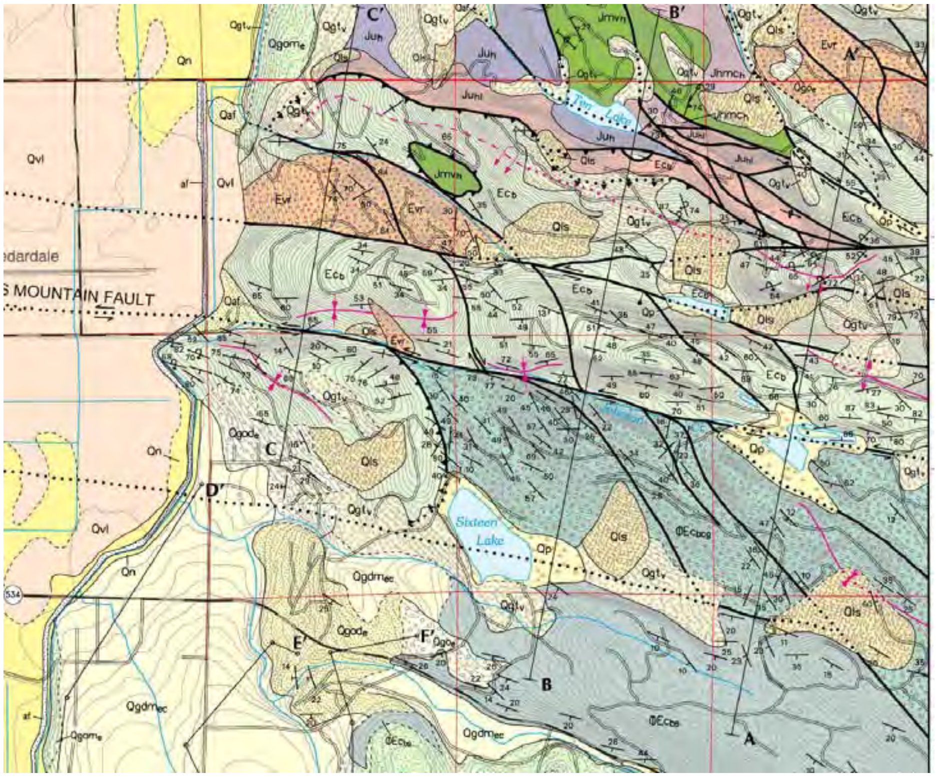

Figure 16. Geologic Map showing (from top to bottom) Sandy, Johnson and Bulson Creeks. From Dragovich et al. (2002).

Figure 17. Looking at Sandy Creek/Hill Ditch confluence at Kanako Road Bridge

Figure 18. Looking at Sandy Creek/Hill Ditch confluence at Kanako Road Bridge

The first half mile of the Sandy Creek ravine was walked to observe erosion sources and sediment transport processes. The first 500 feet upstream from the fan is a slightly entrenched, plane bed channel without gravel bars. The next 500 feet upstream the channel steepens and has a step-pool channel that is incised 3-5 feet deep. The channel then further steepens to a cascade with some bedrock falls. Revegetated landslide scars were observed at 1600 and 2300 feet upstream from the alluvial fan. The only active erosion sources were local areas of eroding streambanks, mostly composed of very dense glacial till that appears to erode slowly but some alluvium as well further downstream. The bed and banks were generally erosion-resistant materials. Overall, the creek appeared to be transporting very little sediment. The inner gorge was densely forested, and many boulders and cobbles were covered with moss, indicating minimal sediment transport (**Figure 19**), and abundant sandstone boulders form stable steps within the channel.

Figure 19. Photo of moss-covered boulders in ravine

A landslide inventory was performed using nine sets of historical aerial photographs dating from 1937 to 2004. Photos were viewed at the NRCS and WDNR offices and the Skagit County i-map website. The 1937 aerial photograph showed that the ravine walls and creek bottom had recently been clear-cut as far upstream as the bend. No landslides or channel response were visible in 1937 but the photo resolution was quite poor. Definite landslides were visible only in the 1956 and 1983 air photos. The 1956 photos showed two recent narrow landslides about one mile upstream of the forks, with a long reach of open-canopy channel immediately upstream (**Figure 20**). In addition, there was a large forested landslide scar on the south valley wall near the mouth of the ravine. In 1983, two narrow landslides occurred within the same large landslide scar. The slides were located directly beneath a new house that had been built on the ridge crest. There was a possible narrow landslide far upstream in the 1998 photos, but it may have been a bedrock chute. Overall, the Sandy Creek watershed has had long periods of low sediment supply punctuated by occasional, mostly small, landslides. The average rate of landslide delivery to Sandy Creek is between 250 and 550 cy/decade.

Although we found no evidence of historic dam-break floods or debris flows, they are possible given the confinement and gradient of the canyon and could destabilize what is currently a fairly stable ravine with a low sediment load. Sandy Creek does have a sizeable alluvial fan, indicating that periods with higher sediment loads have likely occurred in the past and could potentially occur again.

Sediment supply rates to the Sandy Creek alluvial fan were estimated based on calculated volumes of dredge spoils, information on dredging rates provided by Diking District #3 and Skagit County staff, and estimated rates of landsliding and bank erosion (Appendix A). Over the decades since Sandy Creek was diverted, thousands of cubic yards of sediment have been dredged from the creek. Most of the dredge spoils have been placed west of the creek along a narrow spoils berm next to the creek. The creek has been repeatedly dredged deeply enough that it has not become perched above the alluvial fan. The dredge spoils form a barrier preventing the creek from flowing onto the fan, and maintaining its alignment towards the Kanako Lane Bridge (Figure 10). There is also a depositional zone above the upstream culvert and the spoils levee is fairly low, so that is likely where problems tend to occur. The gradient in the culvert zone is 0.46%.

Since Kanako Lane is a private road, there are no records kept about dredging or flooding problems on the fan. No emergency operations have been performed there (Tom Sheehan, Skagit County Emergency Management). The volume of dredge spoils along Sandy Creek was estimated using the end-area method from LiDAR-generated cross sections of the spoils (Appendix B). There were nearly 5,000 cubic yards of dredge spoils, yielding a rate of 500 to 650 cy/decade depending on when the spoils were removed during the 70 to 100 year ditch timeframe. Total sediment supply is estimated between 300 and 1,100 cy/decade for all size fractions.

The decline in gradient and channel confinement from the fan apex to the mouth causes the size of sediment to decrease rapidly. The maximum sediment diameter in the channel declines from large cobbles at the fan apex (190 to 280 mm; 7 to 11 inches) and upper fan to small cobbles in the lower ditched channel reach. The median diameter of sediment was fairly constant throughout the length of the fan with median diameters in the coarse gravel class, at about 29 mm or 1.1 inches.

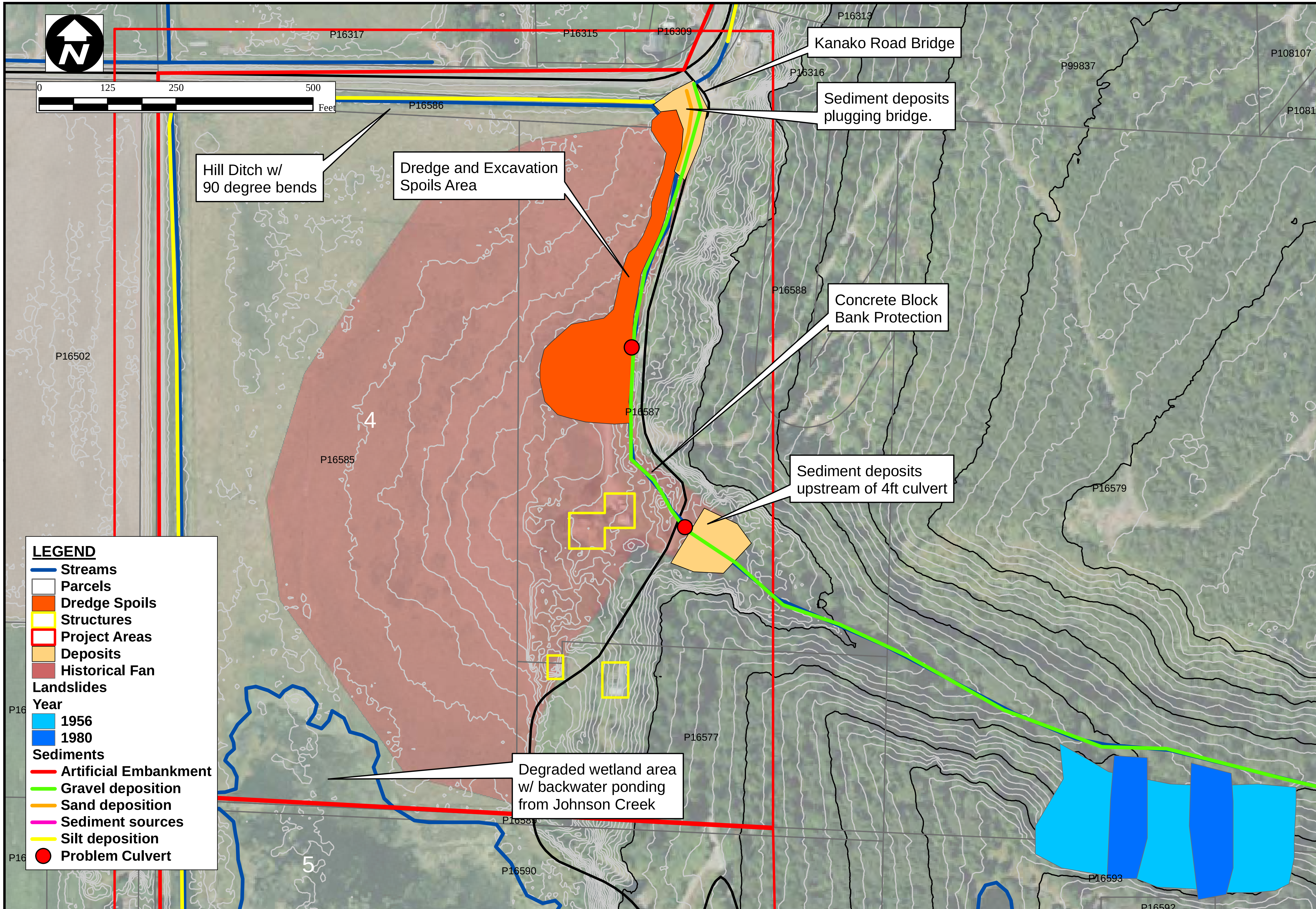

FIGURE 20.
SANDY CREEK
EXISTING CONDITIONS SITE MAP
SKAGIT COUNTY, WASHINGTON

Hydrologic Modeling Flood Runoff Estimates

Hydrologic modeling using HEC-HMS was performed to assess existing and future flood runoff conditions. A detailed summary of the methods for performing the analysis is included in Appendix C. In summary, both the existing and future land use areas of the watershed were modeled and compared to evaluate the potential changes in flood runoff due to changes in the landscape based on the existing Skagit County Comprehensive Plan. For Sandy Creek, the potential growth and build out are fairly minimal under the current Comprehensive Plan, on the order of less than 5 acres as compared to 250 acres of impervious surfaces in Carpenter Creek watershed. This translates to potential increases in flood runoff of 10 cfs, for the 2-year/24-hour event and by 60cfs for the 100-year/24-hour event, if no direct actions are taken to control stormwater runoff (**Table 4 and Figure 21**).

The runoff conditions for Sandy Creek are most likely affected by the cyclical nature of forest operations. The watershed has, and will be, logged in the future and there are likely increases in runoff and sedimentation, even with riparian buffer enforcement. Runoff will decrease as the forest grows and soil conditions improve through protection from raindrop impact, increased rainfall interception, plant transpiration, and improved soil storage. Considering that the watershed is zoned for future forestry operations, and some minor development, it is expected that a range of flood runoff and sedimentation conditions will occur from the cyclic nature of logging and increases in development on hillside areas near the Sandy Creek fan.

Sandy Creek runoff estimates were used as inflow nodes into the HEC-RAS model at the Kanako Lane Bridge. No hydraulic modeling was performed directly on Sandy Creek, although it appears from the historical dredge spoils placement that flow is routed directly to the bridge, where a majority of the problems occur. The HEC-RAS model does show overtopping near the Sandy Creek, Kanako Bridge and at a low spot in the levee profile just downstream from the crossing at approximately the 25-year to 50-year flood event. The model also shows the influence of upstream flooding as a result of the constriction and Sandy Creek inflow under the Kanako Road Bridge.

Table 4. Sandy Creek Existing and Future Flood Runoff Conditions

Event	Precip (in/24hr)	Existing Conditions	Future Conditions	Potential Flood Increase	Percent Increase
		cfs	cfs	cfs	%
2 YR, 24HR	2.25	40	50	10	25%
5 YR, 24HR	2.60	40	70	30	75%
10 YR, 24HR	2.75	50	90	40	80%
25 YR, 24HR	3.25	90	140	50	56%
50 YR, 24HR	3.75	140	190	50	36%
100 YR, 24HR	4.50	220	280	60	27%

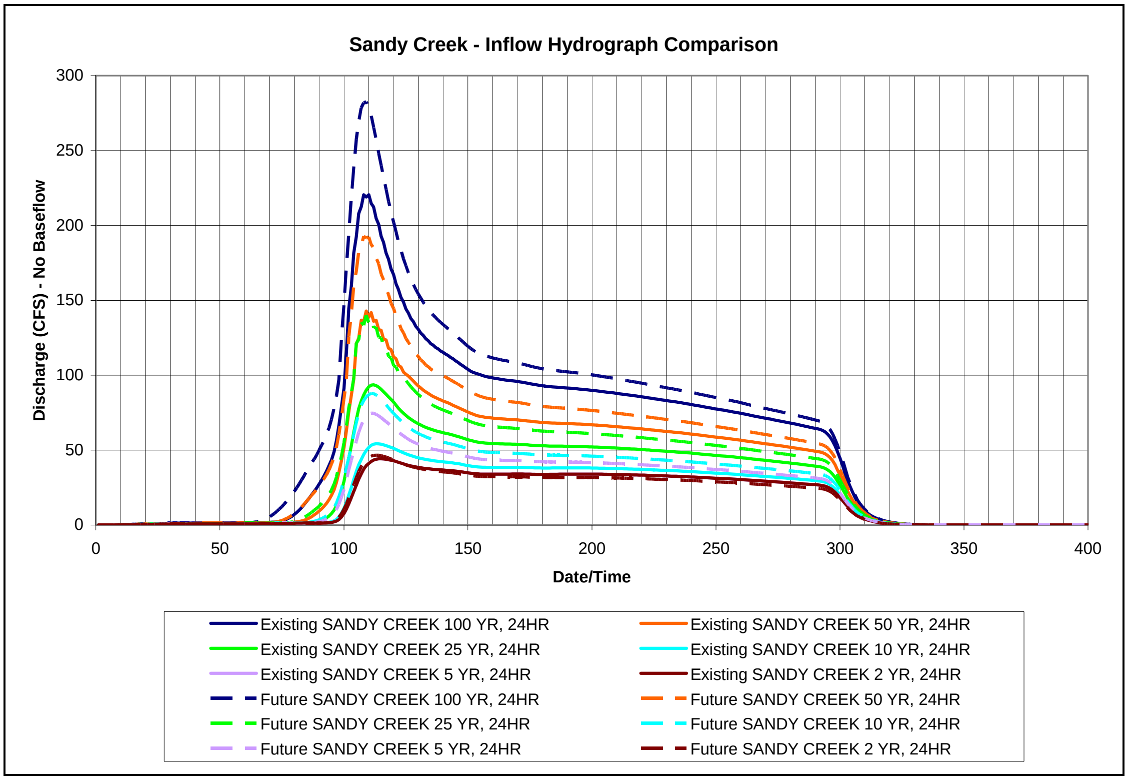

Figure 21. Sandy Creek existing and future flood runoff estimates

Recommendations

The site assessment of Sandy Creek sub-basin shows that a majority of flood and sedimentation problems are related to historical actions and land use activities and that future logging operations and build out are present but less of a concern. With this understanding the investigators focus the discussion on addressing existing flood and sedimentation problems at the Sandy Creek fan and Kanako Bridge. The following is a summary of flood and sedimentation reduction recommendations:

- Evaluate a flood and sediment project at the Sandy Creek fan. Elements of the project should address the poor alignment along the hillside, lack of natural sediment storage and need for periodic dredging, and flooding due to sedimentation under Kanako Bridge and areas upstream from the bridge. The project will likely involve realignment of the lower Sandy Creek, and working with local landowner to dedicate a natural flow path and sediment storage flood easement on the historical alluvial fan. In addition, the alignment of Hill Ditch should be realigned to help reduce flooding and sedimentation at the bridge.

- Integrate the project with Skagit Conservation District plans in degraded wetland area owned by Welts and Benson with downstream Johnson Creek plans. Project has been identified as a potential riparian restoration area by Skagit Conservation District (SCD, 2006). Use dredge spoils materials to provide raised elevations for riparian tree plantings above frequently inundated wetlands.

- Future development on ridgeline areas should be regulated and monitored for stormwater drainage, and focus on minimizing potential for landslides due to poor drainage practices.

- Monitor watershed forestry practices and buffer zones and implement BMPs for stormwater runoff.

3.3 JOHNSON CREEK

Flooding and Sedimentation Assessment

Johnson Creek is a steep drainage with a watershed area of 1.1 square miles. The creek drains the low mountains that flank the east side of the Skagit Valley. Land use within the Johnson Creek drainage is similar to Sandy Creek, but does not have as many recent forestry and logging clear cuts. Land uses are classified as Natural Resource Lands, Industrial and Secondary Forest areas, with a minor amount of Rural Reserve development area located at the mouth of the canyon and alluvial fan area (**see previous Figure 14**).

Johnson creek flows down the main strand of the Devil's Mountain Fault, a strike-slip fault that may still be active (Dragovich et al. 2002). Several distinct geologic processes are at work. Although its watershed is smaller than the next creek north, Sandy Creek, its alluvial fan is larger because the hillslopes along Johnson Creek have been severely destabilized by repeated faulting episodes. Sediment loading to the Johnson Creek fan is derived from the lower half of the watershed, downstream from a peat bog that traps sediment from the upper watershed. The ravine below the peat bog has an average gradient of 9 percent and maximum gradient of 24 percent. The ravine walls are 180 to 380 feet high and form a steep, narrow, inner gorge.

Johnson Creek shows evidence of several repeated landslides. A review of geologic mapping and historical aerial photographs was used to perform a landslide inventory. Canopy openings in steep channels occur when the channel is widened by sediment deposition behind debris dams, or passage of a debris flow or dam-break flood. Freshness of landslide scars was not usually evident because they were shaded or photo resolution was poor. The 1970s photos showed the inner gorge completely forested, but by 1983 the steep north valley wall of the inner gorge was visible in multiple canopy openings. The 1995 photos showed clear evidence of a dambreak flood: a fresh landslide scar with a former pond upstream and eroded channel for hundreds of feet downstream.

The first half mile of the ravine was walked to observe erosion areas and evidence of sediment transport processes. In the first 900 feet of the ravine, the channel was commonly incised 4-6 feet and had eroding banks. Small boulders had been recently transported and deposited on top of sediment deposits (**Figure 22**). Valley wall erosion started about 900 feet upstream of the fence near the fan apex. Landslides and landslide deposits of various ages occurred from 1000 to about 2300 feet upstream from the fan apex. The creek is pinched between the valley wall and landslide deposits, leading to rapid incision that further destabilizes the valley walls, which in turn causes more landslides. The north valley wall has large, planar, unvegetated landslide scars in places. At 2,000 feet there was a broken debris dam and fresh landslide scar that probably corresponds to either the 1995 or 2004 dam-break floods. By 2,500 feet, the valley flattens somewhat and widens, with the creek incised into the valley fill.

At the fan apex near the mouth of the canyon, there are other depositional landforms. There are several boulder berms, which are long, narrow, steep-sided landforms about 3.5 to 5.5 feet high and 25 to 50 feet long (**Figures 22-23**). The berms are formed of coarse sediment and contain small boulders all the way to the top. They appear to be deposited in single flood events, probably dam-break floods. They date to at least two different events, as one berm has 1-4 inch diameter alders growing on it and another 6-9 inch alders. There is a former log jam which has failed and the creek has now incised through the sediment that filled in behind the jam. There are also concrete blocks that appear as remnants of a former dam. The gradient in this zone is 3 to 7 percent. The creek has downcut since the last boulder berm depositional event, but there is still a large sediment load moving through. There are large, fresh-looking, unvegetated bars with imbricated boulders that indicate high-energy transport.

Figure 22. Photo showing boulders in transport positions a short distance upstream from the fan apex.

Figure 23. Boulder berm in the fan apex area

There was no evidence of debris flow, which would scour the channel bottom of sediment deposits and leave sediment berms high above the creek. However, conditions are favorable for a debris flow to occur with; a narrow channel, frequent landslides and a 10-20 percent channel gradient. If a debris flow were to occur, it would probably stop a short distance upstream of the fan apex where the gradient drops below 3 degrees, the threshold for debris flow runout (Benda 1990). Debris flows can mobilize huge amounts of sediment by scouring the channel down to bedrock.

The historic alluvial fan is about 1800 feet long and 900 feet wide (**Figure 24**). The west tip of the fan has been separated from Johnson Creek by the Hill Ditch. The farm buildings were probably located on the fan to get above Skagit River flooding. By 1937, the date of the earliest aerial photographs, Hill Ditch was already present and Johnson Creek had been moved to the along the southern edge of the fan, next to the bedrock valley wall.

Figure 24. Looking west from north side of Johnson Creek alluvial fan.

Over the decades since Johnson Creek was diverted there, the creek has deposited well over 10,000 cubic yards of sediment. The creek is now perched about four feet above the rest of the alluvial fan (**Figures 25-27**). This causes flow to go subsurface and the creek dries up at times during the summer. In most locations, an irregular combination of old, constructed and natural levees keeps the creek in its present location. Gaps in the levee break out when the flow comes up and water crosses the fan and floods the two clusters of buildings on the fan on its way to Hill Ditch. The County has dredged and placed sandbags in the downstream 500 feet of the private road next to the creek during emergency flood operations (Tom Sheehan, Skagit County Emergency Management).

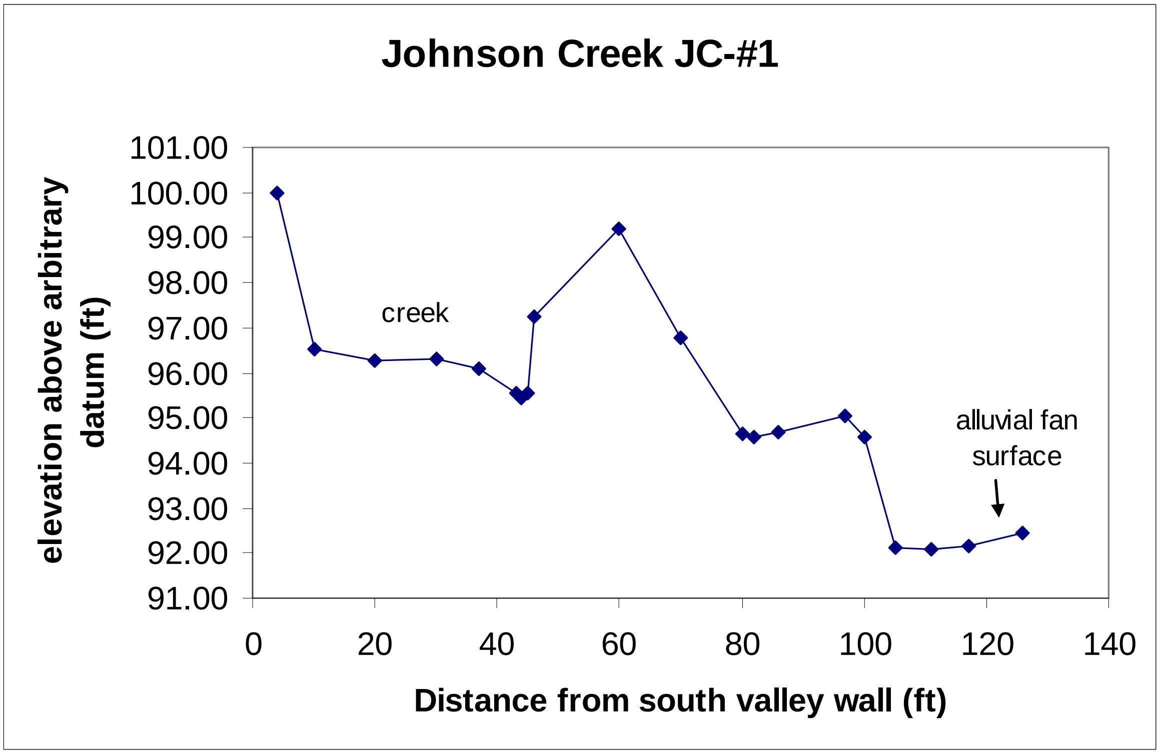

Figure 25. Cross-section JC-1 of Johnson Creek showing stream channel perched on sediment deposits

Figure 26. Photo of perched channel and deposited sediments

Figure 27. Photo of perched channel and deposited sediments

At the downstream end of the fan, the creek drops down and flows for a short distance in a ditch along the private driveway, crosses the driveway in a culvert and enters Hill Ditch (**Figure 28**). Since it was last dredged in 2003 or 2004, the creek has deposited a large sandbar in Hill Ditch that extends 100 feet upstream of the bridge and 280 feet downstream, which was recently removed in September 2006 (**Figure 29**). This sediment deposit, in combination with a low beaver dam, has ponded the flow and backed water up into a large open-water wetland that extends upstream nearly to the Sandy Creek fan. The sediment accumulation has been dredged about every five years since 1990 (Dave Olsen, Diking District #3). Dredging activities and removal of the beaver dam will likely lower backwater pond elevations upstream in the degraded wetland area.

Sediment supply rates to Johnson Creek were estimated based on calculated volumes of dredge spoils and perched sediment and information on dredging rates provided by Diking District and Skagit County staff. The volume estimate based on deposition and dredge spoils was combined with watershed sediment supply to estimate supply rates of coarse and fine sediment (**Figure 30**).

Figure 28. Looking north along levee towards Johnson Road bridge

Figure 29. September 2006 dredge operations at mouth of Johnson Creek

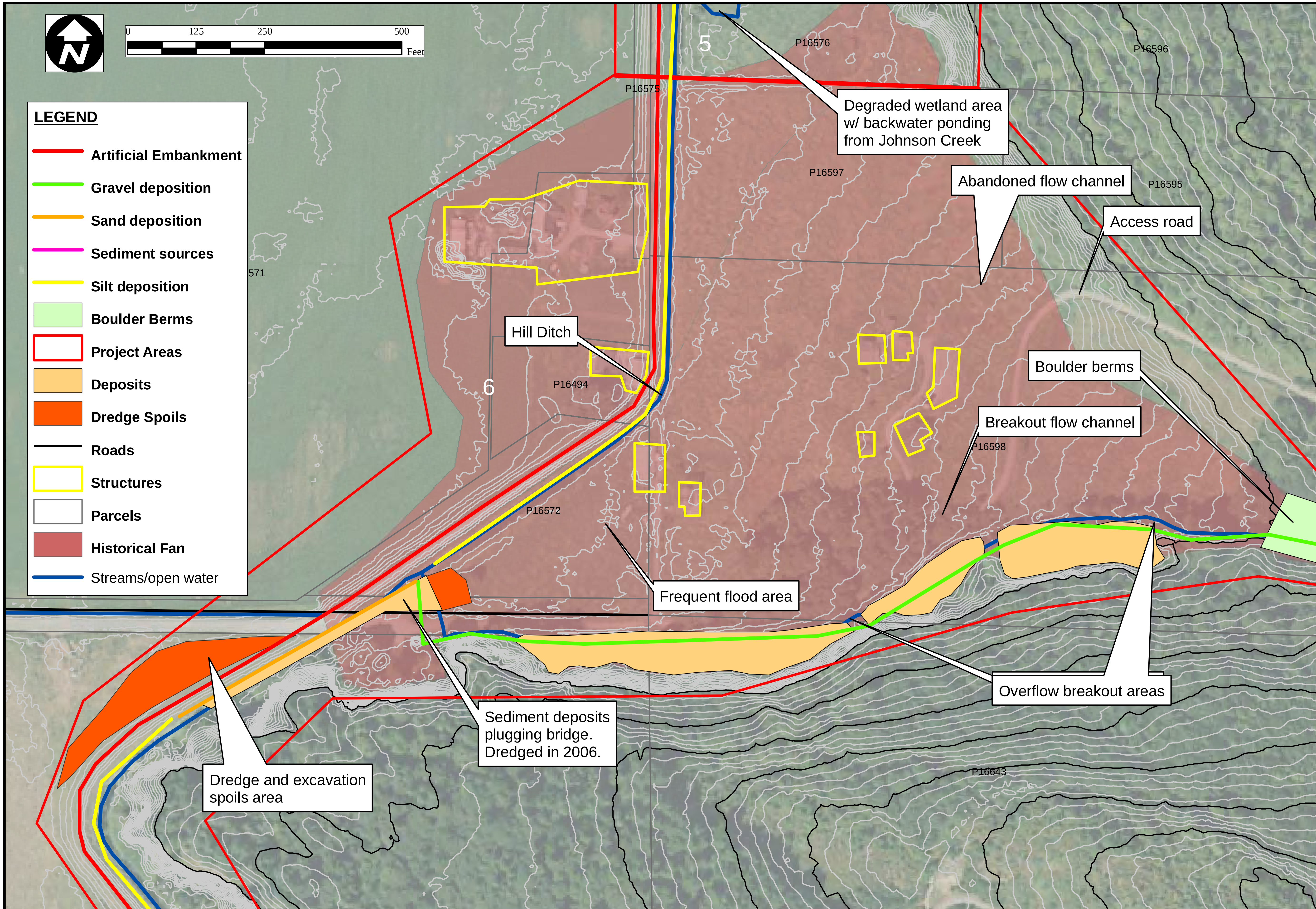

FIGURE 30.
JOHNSON CREEK
EXISTING CONDITIONS SITE MAP
SKAGIT COUNTY, WASHINGTON

For the pre-1990 period, 700 cy/decade of sand were known to be dredged from Hill Ditch at the mouth of Johnson Creek meaning that 2,200 cy/decade of sand were not accounted for. The remaining sand and all of the silt-clay were apportioned between deposition on the alluvial fan (when flow breaks out from the perched channel) and transport downstream in Hill Ditch using assumed sediment trapping ratios. The resulting long-term average estimates of sediment supply from Johnson Creek to lower Hill Ditch are 220 cy/decade of sand and 1,100 cy/decade of silt-clay. Recent dredging was performed during August and September 2006 where it was estimated that 4,500cy of material were dredged, which is considerably higher than the decadal estimate and likely related to the dam-break flood event (**Figure 31**). The post-1990 rates are an order of magnitude higher than the 1,300cy/decade.

A dam-break flood reportedly occurred in July 2004. **Figure 31** shows the deposits from that flood near the fan apex. This flood has been attributed to beaver dam failure because it occurred in summer, according to initial interviews. However, field evidence suggests it was probably caused by a landslide in a steep part of the ravine downstream from the flatter reach that beavers could inhabit.

Figure 31. Photo showing deposits a short distance below the fan apex from a dam-break flood in July, 2005. Photo provided by Tom Slocum, Skagit Conservation District.

Estimation of the long-term average amount of watershed sediment supply by Johnson Creek to the alluvial fan and Hill Ditch was done as follows. The size distribution of sediment from ravine wall landslides was obtained from the soil survey (USDA 1989). The approximate proportion of texture classes for Johnson Creek was estimated to be 30 percent gravel-cobble, 40 percent sand-granule, and 30 percent silt-clay. Using 2,200 cy/decade supply of gravel-cobble the amount of sand and silt-clay were estimated proportionately as 2,900 cy/decade and 2,200 cy/decade, respectively. This gives a total sediment yield of 960 (range 660-1300) t/sq mi/yr, which is reasonable for a steep, small basin with a high rate of landsliding (Larson and Sidle 1980).

The decline in gradient and channel confinement from the fan apex to the mouth causes the size of sediment to decrease rapidly. **Figure 30** shows the maximum sediment diameter in the channel, which declines from boulders at the fan apex (420 mm or 16 inches) to cobbles in the perched channel reach, gravel at the creek mouth, and sand in Hill Ditch. The sand deposit gets finer with distance downstream, ending in very fine sand. At XS JC-1 in the perched channel reach, the median diameter of surface sediment was 17 mm (0.7 inches) gravel. Below XS JC-2 at the fan apex, the median diameter was 40 mm (1.6 inches) gravel.

Design efforts need to account for continued supply and loading of sediment from the watershed, and also understand the potential risk for higher peak flood and sediment flows due to the unstable nature of the ravine's geology. The recent maintenance dredging under Johnson Creek Bridge will be required again in the near future, unless other steps are taken to divert and store sediments in other areas along the fan.

Hydrologic Modeling Flood Runoff Estimates

Hydrologic modeling using HEC-HMS was performed to assess existing and future flood runoff conditions for typical rainfall runoff events. A detailed summary of the methods for performing the analysis is included in Appendix B. In summary, both the existing and future land use areas of the watershed were modeled and compared to evaluate the potential changes in flood runoff due to changes in the landscape based on the existing Skagit County Comprehensive Plan. For Johnson Creek, the potential growth and build out is minimal under the current Comprehensive Plan, on the order of less than 5 acres as compared to 250 acres of impervious surfaces in Carpenter Creek watershed, and therefore no additional increases are expected in rainfall runoff flood events (**Table 5**).

Table 5. Johnson Creek Existing and Future Flood Runoff Conditions

Event	Precip (in/24hr)	Existing Conditions	Future Conditions	Potential Flood Increase	Percent Increase
		cfs	Cfs	cfs	%
2 YR, 24HR	2.25	20	20	0	0%
5 YR, 24HR	2.6	30	30	0	0%
10 YR, 24HR	2.75	40	40	0	0%
25 YR, 24HR	3.25	70	70	0	0%
50 YR, 24HR	3.75	100	100	0	0%
100 YR, 24HR	4.5	150	150	0	0%

The hydrologic analysis does not account for potential dam-break and debris flows, for which there is evidence of occurring in the Johnson Creek watershed. The scale of a debris or dam-break flood can be significantly larger than a typical rainfall-runoff event. An evaluation of probability of occurrence and associated risks at the site should be evaluated within the context of a specific flood and sedimentation study for Johnson Creek. This is especially the case if project recommendations and alternatives have a no-action alternative, whereby houses and structures remain in their current location.

HEC-RAS modeling analysis along Johnson Creek shows similar results to the Sandy Creek area where flood flows overtop the Johnson Creek Bridge area on the order of the 25-year flood event. The model was developed for existing conditions prior to dredging the culvert in the summer of 2006, so this should gain some additional flood capacity in the near term until sediments build up to historic levels.

Recommendations

The site assessment of Johnson Creek sub-basin shows that a majority of flood and sedimentation problems are related to channelization of Johnson Creek and Hill Ditch, and development on the alluvial fan. Future build out and development are less of a concern, similar to Sandy Creek. With this understanding the investigators focus the discussion on addressing existing flood and sedimentation problems at the Johnson Creek fan and Johnson Road Bridge. The following is a summary of flood and sedimentation reduction recommendations:

- Evaluate a flood and sediment project at the Johnson Creek fan. Elements of the project should address a risk-based assessment of the current site conditions (channel alignments, lack of natural sediment storage, and flooding due to sedimentation under Johnson Bridge). The study should develop and evaluate multiple alternatives, including the no-action alternatives, and a range of future project alternatives including partial or full alluvial fan easements at the fan. This would alleviate much of the current flooding problems on the fan, reduce flood risks, and eliminate the need for dredging along Johnson creek. The project will likely involve realignment of the lower Johnson Creek, and working with local landowner to dedicate a natural flow path and sediment storage flood easement on the historical alluvial fan. Compare life cycle costs with future sediment dredging and maintenance.

- Work with local landowners to educate them regarding the risks of owning structures within the alluvial fan and the potential for dam-break and debris flow events.

- Utilize dam-break and two-dimensional modeling software analysis to develop a better understanding of existing conditions and risks, and provide an objective platform to evaluate project alternatives.

- Due to the dynamic nature and potential for debris flows and dam-break floods, the use of in-line sedimentation structures near the apex of the fan should be considered with caution. This could cause the existing channel to completely fill with sediment, triggering a sudden switch of channel location that could bypass the designated sediment storage area.

- Integrate the project with Skagit Conservation District plans in degraded wetland area and with upstream Sandy Creek plans. Construct or connect with an open-water wetland (or utilize existing wetland) between Hill Ditch and the base of the fan to trap fine sediments in areas away from the bridge crossing. Without this project consideration, a sizeable fraction of the sand and finer sediment load would be transported down the alluvial fan to Hill Ditch so dredging would still be required.

3.4 BULSON CREEK

Flooding and Sedimentation Assessment

Bulson Creek has a watershed area of 5.74 square miles and drains low hills on the east side of the Skagit Valley near Conway (**Figure 32**). The watershed has low relief and is underlain by glacial deposits. There is no alluvial fan at the mouth of the creek and previously no reported sediment problems during interviews and research.

The Bulson Creek landscape varies with North Fork Bulson Creek flowing out of the steep, west –facing slopes of Devil's Mountain and the Middle and South Forks originating in the rolling terraces dissected by streams and swales trending northwest. State Route 534, which connects east-west between Conway and Lake McMurray at Highway 9, splits the forks. Both forks cut through incised channels as they reach the west end of the glacial terrace before entering the Skagit valley floodplain and Hill Ditch.

Just less than half of the 5.7 square mile sub-basin is designated as Secondary and Industrial Forest with this area being found mostly on forested, mountainous terrain in the northern portions of the watershed. Approximately 41% is designated as Rural Resource or Rural Reserve along the terrace and rolling hills of the southern portions of the watershed. A Rural Intermediate designation occupies 12% of the sub-basin and this designation allows 1 dwelling unit per 2.5 acres. Approximately half of the designated "Rural Lands" have been developed meaning that a significant change to this landscape can be anticipated with additional development of rural residential use occurring in the future.

Bulson Creek has three forks, each of which has a steeper ravine section between the mainstem creek and upland plateau. The North Fork ravine is 70 feet deep with bedrock cliffs and has an average gradient of 20 percent, much of which is bedrock cascades and falls. The Middle Fork has an average gradient of 5 percent with a steep section of 21 percent. The South Fork has a 5-6 percent gradient without any steeper sections. The ravines of the South and Middle forks are subdued and only 20-30 feet deep, respectively.

Figure 16 shows geology of the Bulson Creek watershed from Dragovich et.al (2002). The mainstem, South Fork, and lower reach of the North Fork flow in flat-bottomed valleys inset within a glaciomarine drift terrace, and the creek rarely encounters the valley edge. The Middle Fork flows through deltaic outwash sands and gravels, which can be quite erodable. The North Fork flows through till and a short section of deltaic outwash gravels, but most of its elevation gain is evidently through bedrock rather than the erodable glacial deposits shown on the geologic map.

Bulson Creek has a low sediment yield due to its combination of low gradient, unconfined valleys with depositional zones that trap sediment, and cohesive fine sediment source materials. Based on limited field inspection, the Middle Fork is by far the largest source of gravel. Very little gravel from the South Fork reaches the confluence with the Middle Fork. The South Fork conveys the gravel load from the Middle Fork down to the confluence zone with the North Fork, which conveys a much smaller load of gravel based on the size and area of gravel bars at the forks.

Figure 33 shows sediment type and maximum sediment size in lower Bulson Creek. The maximum size of sediment decreases from 170 millimeters (7 inches) in the South Fork at the forks to 85 millimeters (3 inches) in the downstream mainstem at cross section BC-1. The median diameter of gravel at BC-1 is 16 millimeters (0.6 inches). The gradient is 1.5 percent near the road and decreases downstream. The bed is a mixture of sand and gravel, with gravel bars and riffles and long, sandy pools in between.

Although much of Bulson Creek's gravel load drops out in depositional zones at the forks and further upstream, some 1-inch-minus gravel continues all the way downstream to Hill Ditch, and fines travel beyond. The bar in Hill Ditch at Bulson Creek has not been dredged, from the memory of the farmer at the creek mouth or the Dike District Commissioner, and is currently estimated at roughly 700 cubic yards. The bar consists mostly of sand and extends 300 feet downstream from the creek, and is about five feet high based on cross section comparisons. The accumulation rate of bar sediment is about 75 to 100 cy/decade, assuming Hill Ditch was built in 1910 or 1934, respectively. This also assumes that the bar has not been dredged since Hill Ditch was constructed.

The Bulson bar causes an abrupt increase in bed elevation, thereby acting as a hydraulic sill and/or constriction and raising upstream water surface elevations and influencing flood overflows that occur at the Bulson Creek confluence and bridge crossing. The Diking and Drainage Districts have indicated that the levee overtops at the Bulson Creek confluence and that these overflows to adjacent farm lands eventually connect with Big Ditch and cross under I-5.

Sediment yield for Bulson Creek was estimated by determining which Sub-basins deliver sediment, estimating the proportion of each sediment size class by Sub-basin based on soil type, and selecting appropriate sediment yields for small watersheds with similar characteristics. The sediment yields for each Sub-basin were adjusted until the results matched the two known parameters: 1) the rate of gravel and sand accumulation in the Hill Ditch (Bulson) bar, and 2) the majority of gravel comes from the Middle Fork ravine. The estimated total sediment delivery rate is about 300 cubic yards/decade, corresponding to a sediment yield for the whole watershed of 10 t/sq mi/yr. This low sediment yield is reasonable for a low gradient watershed with a high proportion of cohesive fine sediment.

During the investigation interviews it was reported that there are several culverts in the Bulson Creek watershed that are problematic (Skagit County and SCD, 2006). Two culverts crossings are found on English Road, on the South and Middle Forks of Bulson Creek.

The eastern set of culverts (Middle Fork Bulson Creek) near the highway to Lake McMurray are a series of four pipes ((2) 24-inch reinforced concrete pipes, (1) 24-inch CMP and (1) 36-inch CMP). Field crews briefly spoke with landowner and they reported that the roadway does flood up to the crown, but remains drivable (**Figure 34**). Overall, it appears that this crossing has nuisance level drainage problems, but the culverts provide capacity and that flooding will occur due to the low elevation of the roadway in a natural floodplain area.

The western culvert (South Fork Bulson Creek) is a 36-inch corrugated metal pipe (CMP) that is fully submerged at low flow with a 30% blockage on the downstream end of the pipe (**Figure 35-36**). The blockage appears to be from erosion and rockfall from the roadway embankment. The materials blocking the culvert are large enough that the creek will not have the capacity to transport the materials. Currently, flows are piped through the blockage. It is expected that the blockage will remain and grow larger and that maintenance should be performed and the embankment secured. Roadway embankment stability could be an issue if continued blockage of the culvert forces flows to pipe through other sections of the roadway embankment, rather than through the culvert. Loss of materials from seepage could potentially cause embankment failure and damage to the road. Replacement of the culvert, installation of a headwall and stabilizing the embankment will alleviate the problem. Plus, fish passage is limited through the blockage.

Other culverts were inspected within the Bulson Creek watershed. The new culvert and fishway on the Lake McMurray highway just east of Bulson Road appear to be functioning properly, providing fish passage through the newly constructed fishway (**Figures 37 and 38**).

The concrete bridge en route to the Sixteen Lake camp has scoured the channel leaving the sewer pipe exposed. The exposed sewer line could be a potential risk and actions should be taken to protect the structure (**Figures 39 and 40**).

It was reported that the Bulson Road culvert does experience flooding and overtopping (SCD, 2006). The sag of the road is in a low lying area, where the stream gradient is low. Raising the roadway and constructing larger culverts is a potential solution to this problem (**Figure 41**).

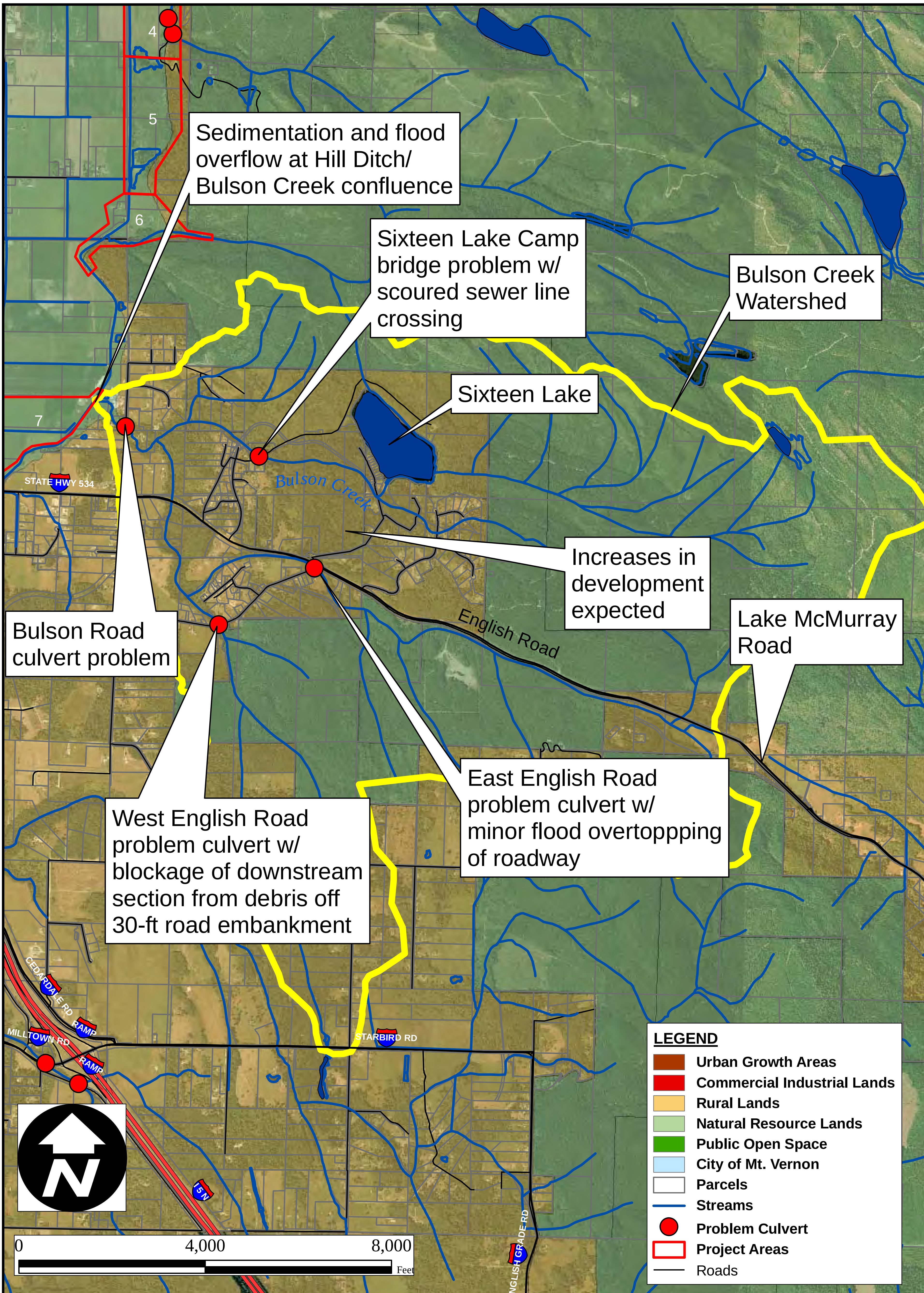

FIGURE 32.
BULSON CREEK WATERSHED MAP

SKAGIT COUNTY, WASHINGTON

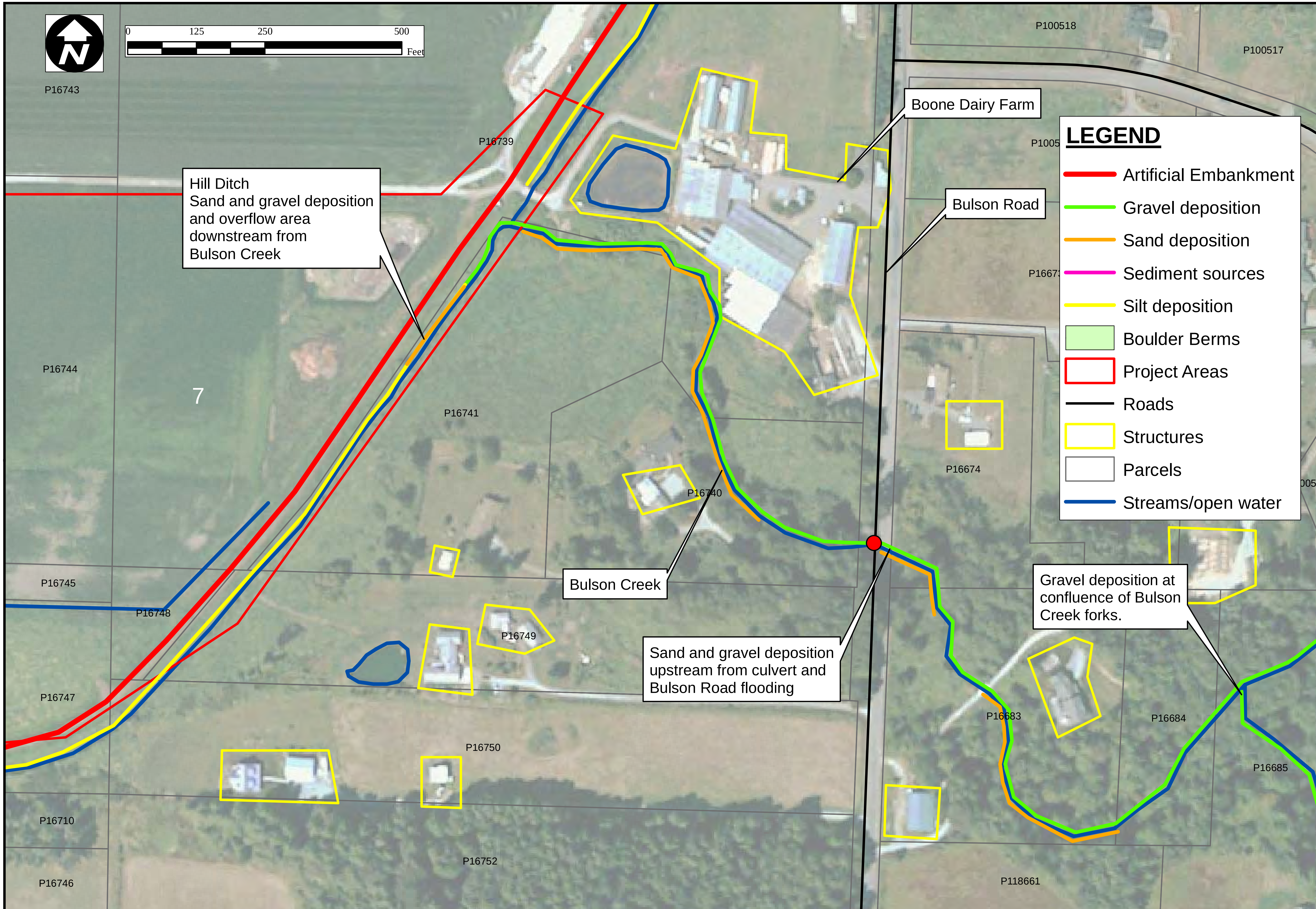

FIGURE 33.
BULSON CREEK
EXISTING CONDITIONS SITE MAP
SKAGIT COUNTY, WASHINGTON

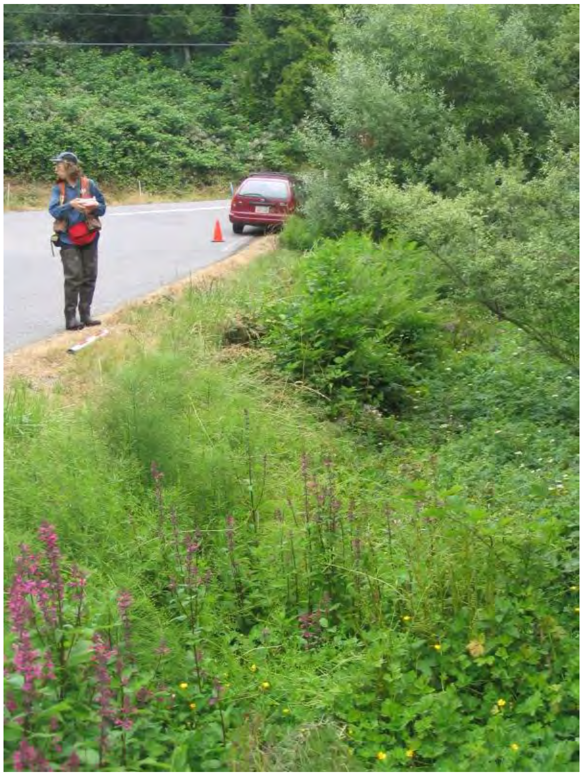

Figure 34. Bulson Creek, upstream side of East English Road culvert

Figure 35. Bulson Creek, Upstream side of West English Road Culvert

Figure 36. Bulson Creek, Downstream side of West English Road Culvert, fully submerged and partially blocked with debris

Figure 37. Looking at new replacement culvert on Bulson Creek on Lake McMurray Highway just East of Bulson Road

Figure 38. Looking downstream at new replacement culvert on Bulson Creek on Lake McMurray Highway just East of Bulson Road

Figure 39. Looking upstream at old culvert (now overflow culvert) on Bulson Creek on Lake McMurray Highway just East of Bulson Road

Figure 40. Bridge crossing N. Fork Bulson Creek on Sixteen Lake Camp Road

Figure 41. Sixteen Lake Camp Road, note exposed sewer main in middle of picture

Figure 42. Bulson Road Culvert Crossing

Hydrologic Modeling Flood Runoff Estimates

Hydrologic modeling using HEC-HMS was performed to assess existing and future flood runoff conditions. A detailed summary of the methods for performing the analysis is included in Appendix B. In summary, both the existing and future land use areas of the watershed were modeled and compared to evaluate the potential changes in flood runoff due to changes in the landscape based on the existing Skagit County Comprehensive Plan. For Bulson Creek, the potential growth and build out estimates approximately an additional 46 acres of impervious and 35 of semi-impervious surfaces are expected for the comprehensive plan. Increases in flood flows are expected on the order of 6% to 13% (**Table 6 and Figure 43**).

The HEC-RAS modeling shows two distinct types of overflow occurring in the Bulson Creek area. The first type are overflows related to tributary runoff during more localized storm events and the second is backwater flooding from the Skagit River. Localized tributary flooding occurs at the Bulson Creek overflow at a similar frequency to the upstream overflows at Johnson, Sandy and Stackpole roads at approximately the 25-year event. Whereas, overflow downstream from there appears to occur at two designated overflow areas. The first is just downstream from Bulson Creek confluence at an elevation of 16-feet (NAVD88) as interpreted from the LIDAR data, and the second is further downstream near the last bridge crossing on Hill Ditch, with an elevation of 15-feet (NAVD88) 1/2 mile upstream from the I-5 crossing.

Table 6. Bulson Creek Existing and Future Flood Runoff Conditions

Event	Precip (in/24hr)	Existing Conditions	Future Conditions	Potential Flood Increase	Percent Increase
		cfs	Cfs	cfs	%
2 YR, 24HR	2.25	100	110	10	10%
5 YR, 24HR	2.6	150	160	10	7%
10 YR, 24HR	2.75	170	190	20	12%
25 YR, 24HR	3.25	240	270	30	13%
50 YR, 24HR	3.75	330	360	30	9%
100 YR, 24HR	4.5	480	510	30	6%

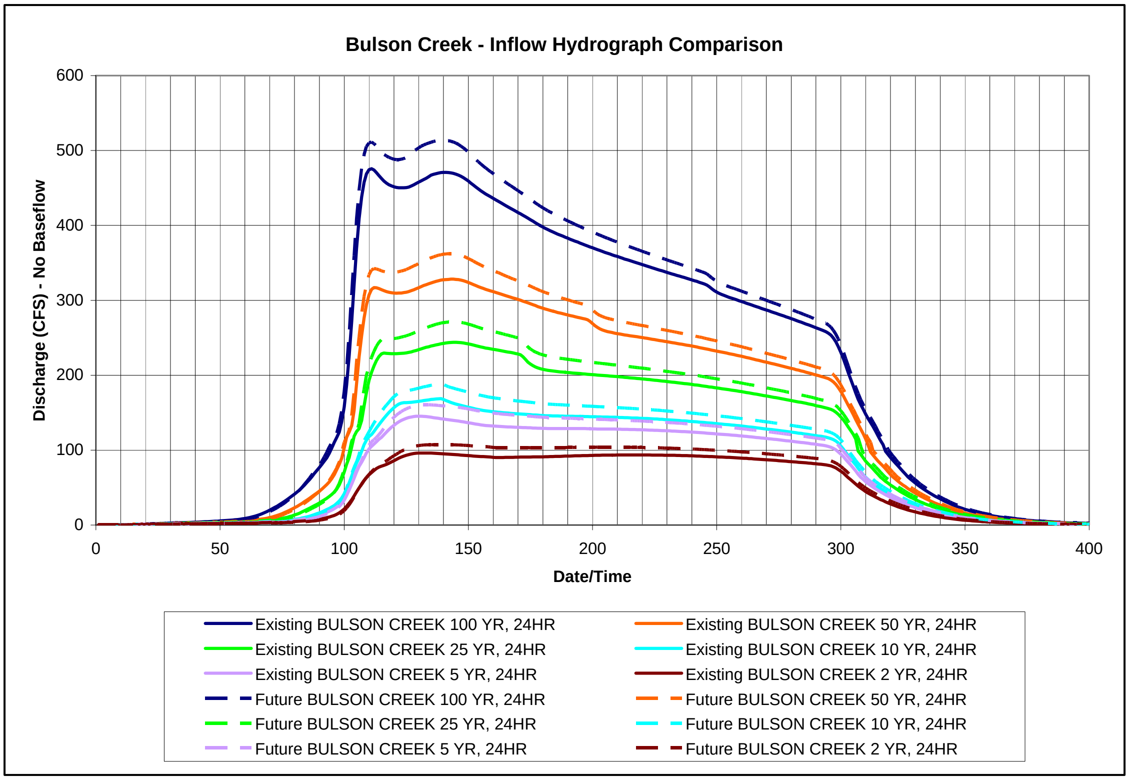

Figure 43. Bulson Creek flood runoff hydrographs

Recommendations

The site assessment of Bulson Creek sub-basin shows that flooding and sedimentation occur at the confluence with Bulson Creek. However, this is perceived as less of a problem due to the fact that there are no public or county roads being directly affected by the overflow and flood areas. The overflow area occurs on farm property at across from the Bulson Creek confluence, which does play a role in the larger flood management scheme for the Carpenter Creek/Hill Ditch/Fisher Sub-basins.

Future build out is of concern in the Bulson Creek watershed with potential increases of 40 acres and 35 acres of impervious and semi-impervious areas expected. The increase in impervious areas will likely increase flood runoff and exacerbate existing problems. With this understanding the investigators recommend focusing on existing sedimentation at the confluence of Hill Ditch and the three watershed culvert problems, with the expectation that they could worsen due to current and future development. It is also recommended to plan and coordinate of future development within the sub-basin. The following is a summary of specific flood and sedimentation reduction and management recommendations:

- Evaluate sediment removal and dredging within Hill Ditch to reduce upstream flooding. Also include the evaluation of a dedicated flood overflow area (levee low spot) along the Hill Ditch at the Bulson Creek confluence. A recommendation was made during the Carpenter Creek and Fisher Watershed Meeting (Sept. 21, 2006) to include potential mitigation for dredging of spawning improvement and habitat enhancement at the mouth of Bulson Creek with Hill Ditch.

- Finalize culvert inventory and project prioritization. Investigate replacement or modification of the problem culverts in Bulson Creek watershed. The problem culverts identified in this study are:
  - West Culvert English Road Culvert, South Fork Bulson Creek
  - Sixteen Lake Camp Road Bridge Crossing, North Fork Bulson Creek
  - Bulson Road Culvert, Mainstem Bulson Creek

- Evaluate stormwater BMPs downstream from larger sub-developments, and implement a private landowner stormwater BMP program for areas with less concentrated housing densities.

- Bulson Creek Sub-basin Planning and Coordination – Skagit County, Diking and Drainage Districts, Conservation Districts, WDFW and The Nature Conservancy should continue to participate in planning and coordination with agencies, developers and landowners in the sub-basin. Specifically, Skagit County needs to actively manage, regulate and review permits with knowledge of the planned growth and resulting increases in stormwater runoff.

3.5 BIG FISHER CREEK

Flooding and Sedimentation Assessment

Big Fisher Creek sub-basin, at 6.3 square miles, is the largest within the Fisher and Carpenter Creek watersheds (**Figure 44**). Approximately 25% of the sub-basin is located in Snohomish County. Big Fisher Creek and its tributaries form in the glacially sculpted hills at the east end, and trend west and north through the rolling glacial terrace formations. The creek cuts through the terrace forming a narrow and deep ravine before crossing under Interstate 5 and emerging on the flats at Fisher Slough.

Initially, the terrace areas were cleared of forests for grazing and farming. Larger estate and horse and grazing uses still are evident along with the development of secondary forests. Approximately 44% of the sub-basin is in Secondary or Industrial Forest in Skagit County and Commercial Forest in Snohomish County. Over half of the land (52%) is zoned in a rural residential land use category, Rural Resource and Rural Reserve in Skagit County and Rural Residential in Snohomish County (1 dwelling per 5 acres). This type of land use is mostly associated with the rolling terrace landscape ("Rural Lands" in **Figure 3**). Larger pastures and scattered silage harvesting is evident over much of this area. A smaller area (4%) is associated with low density rural residential and is found in the transition area between rural residential and forest lands in Snohomish County. Approximately 50% of the rural residential lands have been built on which translates into a considerable changes to the rural character of this landscape in the future as more of the area is developed.

Detailed discussions of Big Fisher sediment supply are provided in the Fisher Slough, Site Assessment and Conceptual Design Plan report (Tetra Tech, 2006). Big Fisher Creek is the primary bedload sediment supply to the Fisher Slough site. The Skagit Conservation District (SCD, 2006) has observed minimal sediment sources in the watershed except in a few locations immediately adjacent to the creek: landslides from the 120-foot-high ravine walls in the first half mile upstream from I-5, erosion of the South Fork tributary ravine just upstream from I-5, and erosion of the channel itself (**Figure 45**).

During the stream assessments, several areas were noted as having potential problems related to flooding and sedimentation. One particular area of note is the erosion and incision of the southeast fork of Big Fisher Creek through advanced outwash gravels, likely resulting from increases in roadway discharge and low-density developments.

The long-term rates of bedload supply to the Big Fisher alluvial fan are likely between 1,100 and 1,500 cubic yards per decade (outer limits of estimate are 700 to 1,700 cy/decade). Short-term rates of bedload supply could be as low as 400 cy/decade during periods without major floods. Assuming bedload is 60 % of total load (based on size distribution of source materials, which are advance outwash and lesser amounts of glacial till) gives an estimated suspended sediment load (medium sand and finer) of about 700 to 1,000 cy/decade. Only a small fraction (10-15%) would be silt or clay based on the composition of the source materials.

The supply of fine sediment is likely fairly low because of the coarse composition of sediment source materials in the ravines. This is borne out by Skagit Conservation District's turbidity monitoring, which only detected elevated turbidity levels during a flooding event in January 2005 (SCD 2006). During that event, turbidity in Johnson Creek exceeded all the other stations, including Fisher and Carpenter Creeks, by a factor of 10. Bi-monthly turbidity samples at Big Fisher Creek at Franklin Road have been made since October 2003. Most samples were under 5 NTU, and the maximum value was 20.1 on 1/18/05 (Skagit County, 2006).

Another area visited during the assessment was the newly constructed fishway under Cedardale Road, just east of the I-5 Crossing. The structure appears to be passing bedload material downstream to Hill Ditch (**Figure 46**). Gravel and cobbles were observed in the pools and along the bed of the 72" CMP culvert crossing under I-5 and the culvert appears to be functioning properly.

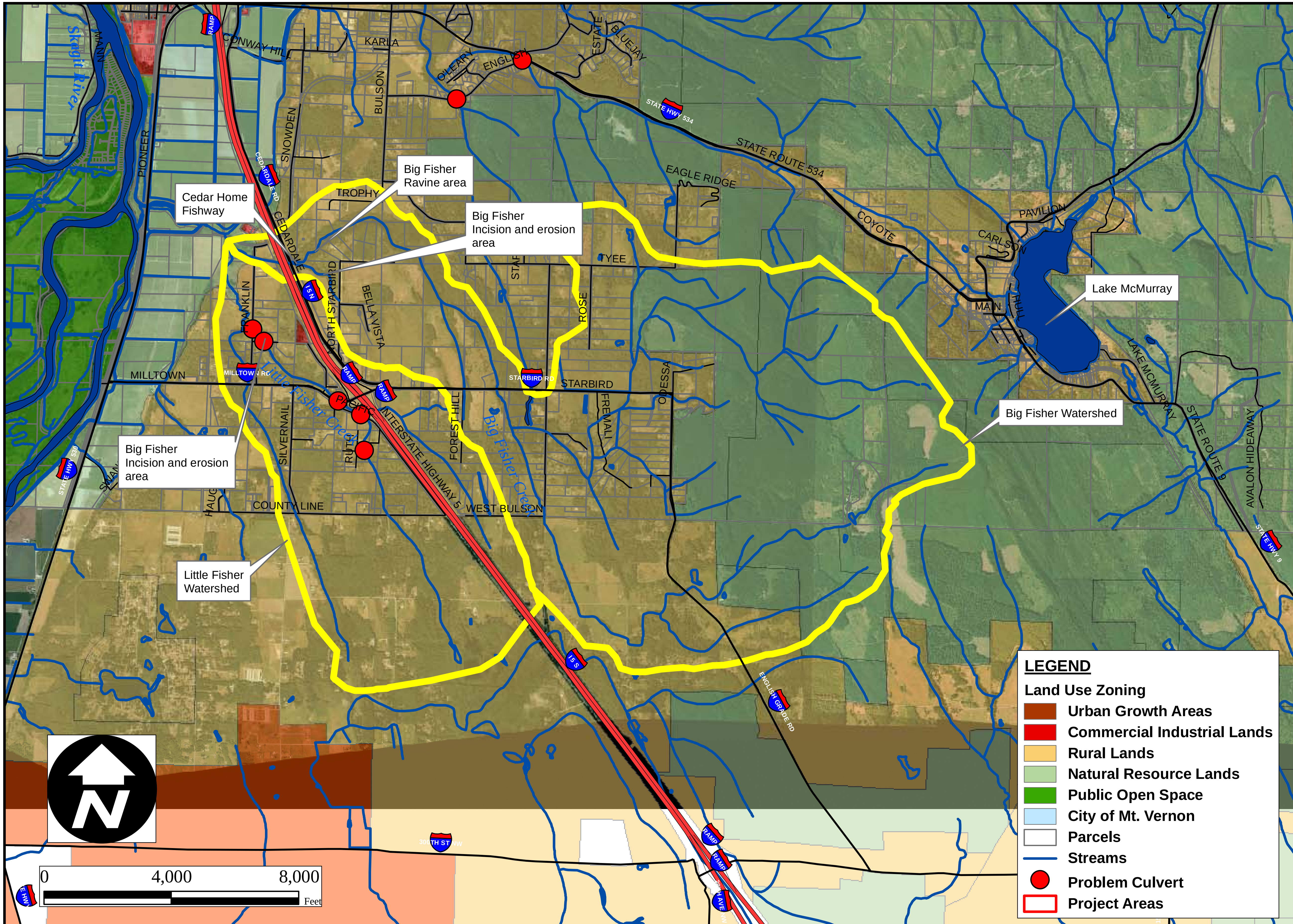

FIGURE 44. BIG FISHER AND LITTLE FISHER WATERSHED MAP

SKAGIT COUNTY, WASHINGTON

Figure 45. Photo showing channel erosion of the southeast fork of Big Fisher Creek

Figure 46. Photo showing fishway underneath Cedardale Road near I-5 crossing

Hydrologic Modeling Flood Runoff Estimates

Hydrologic modeling using HEC-HMS was performed to assess existing and future flood runoff conditions. A detailed summary of the methods for performing the analysis is included in Appendix B. In summary, both the existing and future land use areas of the watershed were modeled and compared to evaluate the potential changes in flood runoff due to changes in the landscape based on the existing Skagit County Comprehensive Plan. For Big Fisher Creek, the potential growth and build out estimates approximately an additional 56 acres of impervious and 36 of semi-impervious surfaces are expected for the comprehensive plan. Increases in flood flows are expected on the order of 13% to 21%, which is considered significant (**Table 7 and Figure 47**). Increases of this magnitude will likely have adverse effects on Big Fisher creek through increased erosion, sedimentation and flooding. Stormwater regulation in the watershed is highly recommended.

Table 7. Big Fisher Creek Existing and Future Flood Runoff Conditions

Event	Precip (in/24hr)	Existing Conditions	Future Conditions	Potential Flood Increase	Percent Increase
		cfs	Cfs	cfs	%
2 YR, 24HR	2.25	110	130	20	18%
5 YR, 24HR	2.6	160	190	30	19%
10 YR, 24HR	2.75	190	230	40	21%
25 YR, 24HR	3.25	290	350	60	21%
50 YR, 24HR	3.75	420	480	60	14%
100 YR, 24HR	4.5	630	710	80	13%

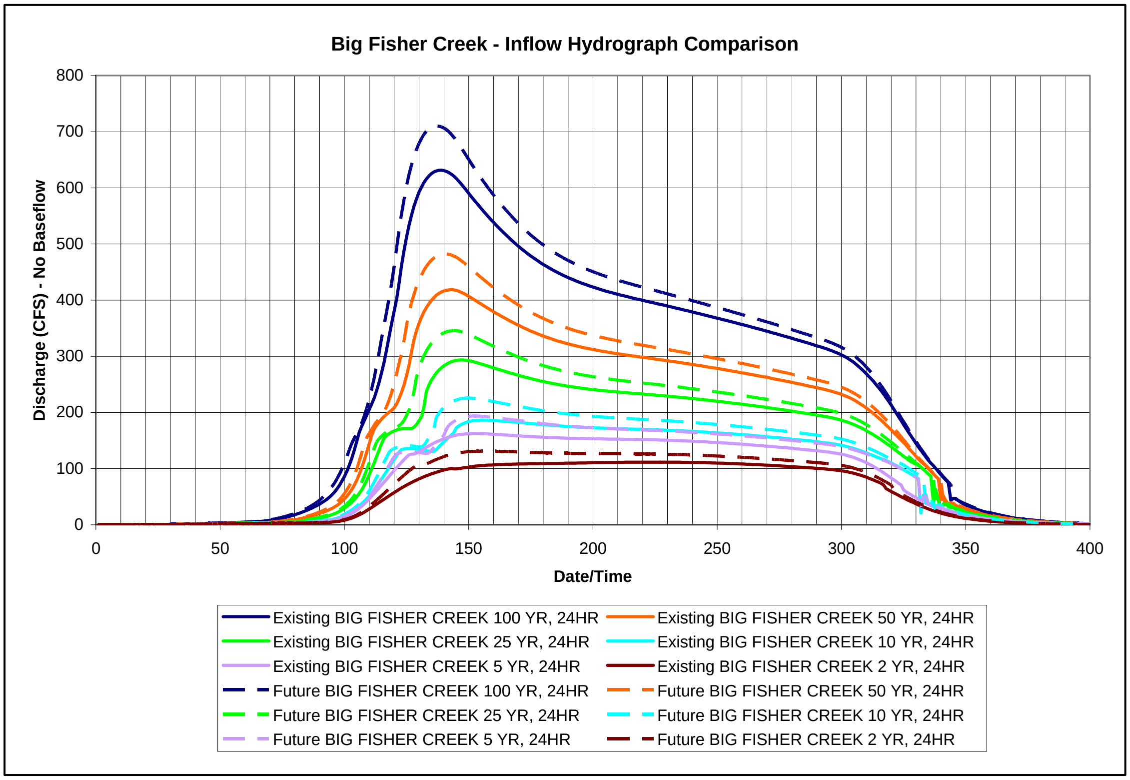

Figure 47. Big Fisher Creek flood hydrographs

Recommendations

The site assessment of Big Fisher Creek sub-basin shows that existing flooding and sedimentation problems have a direct effect on Fisher Slough at the confluence of Hill Ditch, Big and Little Fisher Creeks. Sedimentation at the confluence is problematic and the current flow path erodes the north levee bank. Future increases in runoff and sediment delivery will likely increase the rate of sediment deposition in Fisher Slough.

Within the sub-basin, active erosion and incision in the channel is of concern, as noted for the southeast branch of Big Fisher Creek. This is especially true if future development and build out increase flood flows and sediment transport, the existing erosion and channel incision problems can worsen. The increases in impervious areas will likely increase flood runoff and exacerbate existing problems, as well as limit the effectiveness of flood and sediment storage within the downstream Fisher Slough project.

The following is a summary of recommendations for limiting flood and sedimentation in Big Fisher Creek.

- Agency coordination between Skagit County and Snohomish County for stormwater planning, management and coordination. Stormwater management activities should include identification of existing drainage, flood, sedimentation, water quality and habitat problems, and evaluate opportunities for fixing these problems. In particular, with the potential for additional development, the Counties should focus on stormwater programs that address future development through regulations, enforcement, and education concerning BMPs and retrofit of existing problems by working with local landowners through a stormwater BMP installation program.

- Evaluate the options to limit channel incision and erosion of the Southeast Fork of Big Fisher banks in the upper watershed through installation of instream grade controls using rock or wood structures that will trap bedload sediments and stabilize the channel.

- Finalize culvert inventory and project prioritization. Investigate replacement or modification of the problem culverts in Bulson Creek watershed. A detailed culvert inventory has not been performed for Big Fisher Creek, as no culverts were identified during interviews and discussions. Site visits and inspections should follow up to confirm that culverts are in good condition and functioning properly.

3.6 LITTLE FISHER CREEK

Flooding and Sedimentation Assessment

The Little Fisher sub-basin drains the southern end of the Fisher/Carpenter watershed. This 2.8 square mile area is located entirely on the glacial terrace formation (**See Figure 44**). The landscape is mostly gently rolling with lower drainages and swales associated with northwest trending tributaries. The two forks of Little Fisher Creek become more deeply incised as they approach the confluence with Big Fisher and Fisher Slough, which is on the valley flats.

Approximately 45% of the sub-basin is located in Snohomish County. The entire area is designated in some category of rural residential use, Rural Reserve in Skagit County and Rural Residential in Snohomish County. Approximately 55% of the land has been developed in rural residential, with 45% remaining. This could translate into a landscape that will experience considerable change if future build out and land subdivision takes place.

The amount of sediment delivery to the Fisher Slough site is relatively small from Little Fisher Creek. No landslides or areas of bare ground were visible on air photos of Little Fisher Creek. The ravines are much smaller than the 120-foot deep ravine of Big Fisher Creek, only 40 feet deep on the East Fork and 25 feet deep on the West Fork. Most bedload sediment at the forks was clearly coming from the East Fork, whose ravine has a 7% gradient compared to the West Fork's average gradient of 2.7%. In addition, the East Fork has a higher amount of impervious area that could increase flood magnitude and frequency and the amount of channel erosion (SCD 2006). Abundant gravel was present in the East Fork upstream of Franklin Road but little gravel was present just downstream of I-5. It is therefore likely that most of the sediment originates in the steep ravine section underlain by advance outwash, the most erodable unit in the watershed. The West Fork also has a short section of ravine in the advance outwash soils. Based on field observations, most of the sediment deposits upstream of the Fisher Slough confluence and the sediment load is mostly stored in the alluvial fan at the mouth of Little Fisher's valley.

The resulting estimate of bedload sediment delivery to the valley mouth is about 100 CY/decade. As with Big Fisher Creek, based on the sediment sources (advance outwash and lesser amounts of till) it was assumed that 60% of the sediment supply was bedload and 40% suspended load. Only a small fraction (10-15%) would be silt or clay. An 80% delivery rate for suspended load was used, yielding a suspended load of about 700 CY/decade at the valley mouth. Due to multiple uncertainties, these estimates could be off by approximately 50%.

Other erosion and sediment related observations during field investigations revealed that there is some bank erosion occurring immediately upstream from the Fisher Slough Restoration Site due to cattle access to the stream (**Figure 48**). Riparian plantings, livestock exclusion and watering access points could reduce the effects of current stream accessibility by livestock.

Other observations during the site assessments and interview process were a number of potential culvert problems in the Little Fisher sub-basin. The problems range from fish passage due to shallow culvert depths and perched culverts, to undersized culverts. There are approximately 15-20 culverts on Little Fisher Creek in the upper watershed area. The Skagit Conservation District (SCD, 2006) has identified potential fish passage problems for seven of these culverts, which needs to be investigated and possibly modified in the future.

Another area noted during field investigations and interviews of potential sedimentation problem is the exposed fill areas near the I-5 corridor crossing on the East Fork of Little Fisher.

Figure 48. Livestock access and pedestal erosion, Little Fisher Creek

Hydrologic Modeling Flood Runoff Estimates

Hydrologic modeling using HEC-HMS was performed to assess existing and future flood runoff conditions. A detailed summary of the methods for performing the analysis is included in Appendix B. In summary, both the existing and future land use areas of the watershed were modeled and compared to evaluate the potential changes in flood runoff due to changes in the landscape based on the existing Skagit County Comprehensive Plan. For Big Fisher Creek, the potential growth and build out are estimated to add approximately 56 acres of impervious and 36 of semi-impervious surfaces for the comprehensive plan. Increases in flood flows are expected on the order of 13% to 21%, which is considered significant (**Table 8 and Figure 49**). Increases of this magnitude will likely have adverse effects on Big Fisher creek through increased erosion and flooding. Flow control regulation in the watershed is highly recommended.

Table 8. Little Fisher Creek Existing and Future Flood Runoff Conditions

Event	Precip (in/24hr)	Existing Conditions	Future Conditions	Potential Flood Increase	Percent Increase
		cfs	cfs	cfs	%
2 YR, 24HR	2.25	60	60	0	0%
5 YR, 24HR	2.60	80	90	10	13%
10 YR, 24HR	2.75	90	100	10	11%
25 YR, 24HR	3.25	140	150	10	7%
50 YR, 24HR	3.75	190	200	10	5%
100 YR, 24HR	4.5	260	270	10	4%

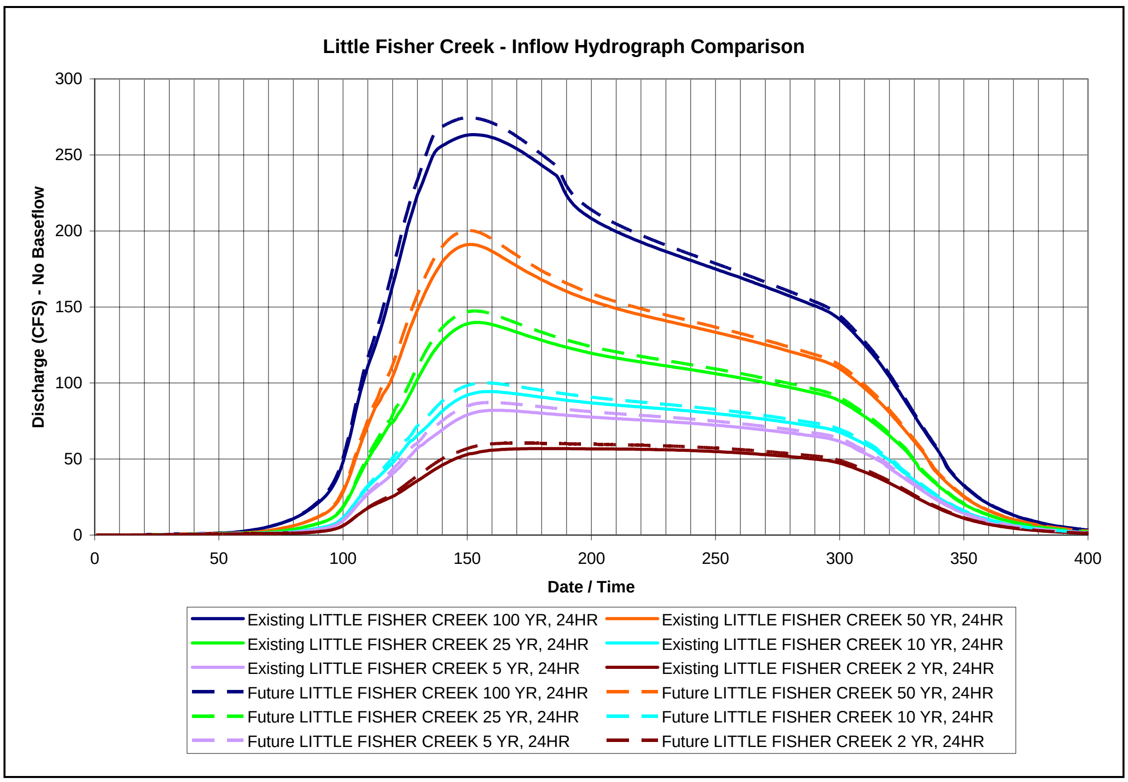

Figure 49. Little Fisher Creek flood hydrographs

Recommendations

The site assessment of Little Fisher Creek sub-basin shows minimal existing flooding and sedimentation problems. Active erosion was noted along areas where cattle had access to the streams and in the fill slope area along I-5 corridor crossing. Little Fisher is similar to other areas, in that increases in impervious areas are expected and could exacerbate exiting flooding and sedimentation problems. Recommendations for Little Fisher Creek are as follows:

- Agency coordination between Skagit County and Snohomish County for stormwater planning, management and coordination. Stormwater management activities should include identification of existing drainage, flood, sedimentation, water quality and habitat problems, and evaluate opportunities for fixing these problems. In particular, with the potential for additional development, the Counties should focus on stormwater programs that address future development through regulations, enforcement, and education concerning BMPs and retrofit of existing problems by working with local landowners through a stormwater BMP installation program.

- Evaluate the options to work with local landowners for livestock management in riparian corridors. Potential projects could include fencing, cattle access watering pads, riparian plantings all designed to reduce pedestal erosion.

- Implement a culvert and drainage assessment in conjunction with SCD fish passage barrier project recommendations.

4.0 CONCEPT DESIGN ALTERNATIVES AND WATERSHED MANAGEMENT STRATEGIES

The site assessment information and recommendations provide the framework for developing concept design alternatives and management strategies to address flood and sedimentation problems throughout the six study sub-basins. This chapter of the report describes several types of general flood and sedimentation projects that can be developed or constructed in each of the sub-basins to alleviate current problems. In addition programmatic watershed planning and management strategies are presented to address the more widespread issues found within the sub-basins.

The site assessments identified several recommendations for future projects within the study sub-basins. Many of the recommendations and potential solutions can be grouped and organized into general categories, which can be delineated into Non-structural and Structural flood control project types.

Non-structural

- Stormwater and floodplain management
- Flood, sedimentation and channel migration and natural hazard area designations
  - Conservation and preservation acquisitions and easements
  - Flood overflow easements
  - Regulation of development
- Floodplain, wetland, alluvial fan restoration
- Low Impact Development
- Public and private outreach, education and support
- Update flood studies and GIS mapping of critical and flood-prone areas
- Livestock riparian management

Structural

- Culvert and bridge retrofit and replacement
- Stormwater BMP installation
- Erosion protection, bank stabilization and grade control
- Flood and sediment control structures
  - Flood and sediment detention basins and dams
  - Levee construction, modification, removal or setbacks
- Sediment removal and dredging

<u>Stormwater and Floodplain Management (Non-structural)</u>

Stormwater management, planning, regulation and enforcement are tools and methods used by the government and special districts for protecting the floodplain, aquatic resources and property. Effective stormwater management requires thorough knowledge of existing regulations and codes related to both stormwater and development. Pertinent sections of the Skagit County Code to stormwater, flood, and water quality are the following:

- Chapter 6.12 COMMISSIONER'S DISTRICTS
- Chapter 6.24 DRAINAGE DISTRICTS
- Chapter 6.36 SKAGIT COUNTY FLOOD CONTROL ZONE DISTRICTS
- Chapter 14.32 DRAINAGE ORDINANCE
- Chapter 14.24 CRITICAL AREAS ORDINANCE
- Chapter 14.34 FLOOD DAMAGE PREVENTION (UNIFIED DEVELOPMENT CODE)
- Chapter 15.20 FLOOD DAMAGE PREVENTION* (BUILDINGS AND CONSTRUCTION)

Typically, the County Code references regulation put forth in the Revised Code of the State of Washington (RCW), and references or adopts manuals and guidance provided by other state and federal authorities. The Skagit County Code frequently references the following manuals and studies for guiding stormwater-, flood- and water quality-related projects (Appendix C):

- Washington State Department of Ecology, Stormwater Management Manual for Western Washington, 2005
- National Flood Insurance Program, 1985. Flood Insurance Rate Map, Skagit County WA, Unincorporated Areas.

One particular area of interest is the language within the current drainage ordinance Chapter 14.32 with respect to how Skagit County is currently practicing Stormwater Management in the County (Skagit County, 2007).

The general provisions of the Skagit County Code Chapter 14.32 Drainage Ordinance states:

> *(1) The requirements of this Chapter are adopted pursuant to the authority granted to Skagit County as set forth in:*
>
> > *(a) RCW 36.70, Planning Enabling Act;*
> > *(b) RCW 36.70A, Growth Management Act;*
> > *(c) RCW 90.71, Puget Sound Water Quality Authority.*
>
> *(2) The Board recognizes that stormwater control technology is a developing and evolving science. In order to ensure that the latest and best technology is utilized in Skagit County, the County hereby adopts by reference the Stormwater Management Manual for the Puget Sound Basin or subsequent manuals adopted by Ecology as Skagit County's Stormwater Design Manual. All references to this Chapter shall include the Stormwater Management Manual for the Puget Sound Basin.*
> *(3) The Administrative Official may amend the Skagit County Stormwater Design Manual, with the approval of the Board, as necessary to reflect changing conditions and technology. All requirements contained in the Skagit County Stormwater Design Manual together with any amendments thereto must be complied with as provided in SCC 14.32.030(6) Applicability.*
> *(4) Water Quality. For circumstances or conditions related to water quality that are not specifically addressed within this Chapter, the preferred method for selection, design, and implementation of stormwater management practices shall be the method(s) outlined in the current edition of the Stormwater Management Manual for the Puget Sound Basin adopted by Ecology.*

The code indicates that the most recent version of the Washington State Department of Ecology will be used as the latest adopted Stormwater Management Manual for Western Washington (WDOE, 2005). The Stormwater Design Manual is currently identified as the preferred guidance by Ecology, but has yet to be fully implemented within Skagit County, Public Works and Planning and Development Services Departments. One area of concern is the manual is focused more on urbanized areas and Skagit County has a number of rural, non-urban areas for which stormwater management manual guidance must further be refined to meet water quality requirements and rules. It is recommended that Skagit County continue to pursue updates of the Stormwater Management drainage

The following are some additional references that can benefit the stormwater and floodplain manager:

- Protecting Floodplain Resources, A Guidebook for Communities, FEMA 1996

- Floodplain Management, A Local Floodplain Administrator's Guide to the National Flood Insurance Program, FEMA Region 10, 2000
- Guidelines for Determining Flood Hazards on Alluvial Fans, FEMA 2000
- Property Acquisition Handbook for Local Communities, FEMA 1998

In addition, the Skagit River Flood Damage Reduction Study (USACE, 2004) is related to this study due to the interrelationship between flood and economic benefits from reducing overflows of the Hill Ditch levee system into the Skagit River floodplain, and the backwater effect of the Skagit Hill Ditch during high flows.

Beyond understanding regulatory codes, the planning and stormwater departments need to have clear lines of communication on existing watershed and drainage conditions, problem areas, upcoming development and land use changes, and stormwater related projects. For the purposes of the Carpenter Creek, Hill Ditch, and Fisher Slough Watersheds, stormwater management and planning should be developing plans to 1) address existing problems, 2) further identify the risks associate with natural flood hazards, and 3) be pro-active in addressing planned development throughout the sub-basins.

<u>Conservation Easements and Acquisition for Flooding, Sedimentation, Channel Migration and Natural Hazard Areas (Non-structural)</u>

Rather than protecting infrastructure and property, conservation easements and acquisition of property are based on the premise to allow for natural flooding, sedimentation, channel migration and natural hazard area protection, conservation and restoration of natural floodplain features and hazard areas,. Conservation and flood easements are used to place restrictions on future development, while allowing frequently flooded agricultural areas to continue to be farmed. Acquisition of real property is used to remove structures from the flood hazard area permanently. The intent is to maintain natural functions and processes of a variety of flood-related landscape features, minimize degradation of the processes, and to limit exposure to flood hazard risks.

In order to implement such a program, studies need to be undertaken to adequately characterize the array of landscape features and historical flood hazard areas including active floodplain areas, alluvial fans, landslide areas, channel migration zones, wetlands and other critical areas within a watershed. Understanding the location and processes of flood- and sedimentation-related landscape features can assist resource managers in targeting floodplain conservation and protection easements and acquisitions of currently functioning areas, as well as in targeting potential problem areas. A prime example of floodplain conservation is the Hamilton relocation project, in which floodplain preservation was found to be a more cost-effective and sustainable solution to natural flooding and sedimentation processes than community relocation from the floodplain.

<u>Channel, Wetland, Floodplain and Alluvial Fan Restoration (Structural and Non-structural)</u>

Restoration of floodplains is another tool, both structural and non-structural, where managers can reactivate and reconnect river and stream systems with historical floodplain areas. These projects can include breaching of levees, reconnection of side channels, floodplain connectivity, and restoration of wetlands and alluvial fan areas. Projects of this type typically involve application of a property easement to protect the restored floodplain resources and project investment. Floodplain and wetland restoration projects can demonstrate multiple benefits including flood control, habitat restoration and improved water quality, allowing managers to leverage funds and grants from multiple resources.

<u>Low Impact Development (LID) (Non-structural)</u>

Low impact development is another effective tool for managing stormwater from potential increases in source runoff quantity and quality of water. Certain aspects of LID practices involve building techniques and site development that reduce the amount of stormwater runoff by dispersing and infiltrating the flow from additional pervious surface through natural site drainage features. Sites requiring installation of Stormwater Best Management Practice (BMP) facilities requiring structures and maintenance are discussed below with other structural flood control measures. LID should be considered as an approach for developing properties in rural residential areas of the study sub-basins that have potential for development.

Public Outreach, Education and Updates of Resource Data and Maps (Non-structural)

Effective management and regulation of floodplain resources and flood hazards requires constant education and outreach with floodplain managers and the public. One of the most effective tools available for today's managers is the utilization of maps and Geographic Information Systems (GIS). Map modernization of a variety of flood-related maps, including Flood Insurance Rate Maps, critical areas, and land use and zoning designations, can benefit floodplain managers, planners, regulators, private sector, and the public. It is highly recommended to continue investment of GIS-related map modernization programs for Skagit County.

Livestock Riparian Management (Non-structural)

The intent of the livestock riparian management program is to work with landowners to control access to river and stream riparian areas through fencing and watering access pads. The program is educational in nature and can be developed to help share costs with the property and livestock owners.

Culvert and Bridge Replacement and Retrofit (Structural)

Many historical culverts and bridges were designed to pass a certain discharge, but the designs did not always account for sediment transport and wood transport, geomorphologic process or fish passage. These structures often need replacement due to undermining of the foundation from scour, burial of the structure from sedimentation, or blockages from debris that can reduce design conveyance capacity and have adverse upstream flooding and sedimentation. In the case of the Carpenter, Hill Ditch and Fisher Slough watersheds, several culverts have been identified for replacement. A full inventory of sub-basin culverts and bridges using GPS, GIS and standardized inspections observation and documentation methods is recommended to help plan and implement wide-scale culvert and bridge replacements in the future.

Stormwater BMP Installation (Structural)

Stormwater BMP installation is a method for controlling increases in flood and sediment runoff due to development. Source control and treatment methods are effective tools for managing the causes of flooding on a project-by-project basis, rather than treating the downstream effects. The difficulty with effective Stormwater BMP is that their effectiveness is realized through widespread acceptance and proper installation. Effective design and enforcement of widespread installation can be difficult to manage for the water resource or regulatory professional. Natural dispersion and infiltration and LID techniques were identified above as non-structural BMPs. Structural BMPs include ponds, swales, vaults, catch basins, filter strips, flow spreaders, bioinfiltration and bioretention, and other infiltration structures requiring some type of annual inspection and maintenance.

Erosion Protection, Bank Stabilization, Grade Control (Structural)

Protection from erosion and channel degradation are typically designed to arrest sediment degradation in some way. Erosion and sediment transport are natural processes, whereby rivers and streams naturally erode and deposit materials, and migrate across their floodplains (for alluvial systems). Bank stabilization is used as a flood control and channel training technique to allow for utilization of floodplain and shoreline areas unrelated to natural processes. The erosion protection, bank stabilization and grade control structures can be installed to halt the adverse effects of changes in the flooding and sedimentation that result from increased development, land use changes, or water resource related infrastructure construction in the stream environment.

Flood and Sediment Control Structures (Structural)
Flood and sediment control structures are large structures used to protect urbanized, agricultural areas with developed resources. Typical flood and sediment control structures include dams, detention basins, channels, gates, drains, pumps, floodwalls and levee systems. These structures are typically designed to protect resources and infrastructure and promote economic development of selected areas.

4.1 SUB-BASIN PROJECT CONCEPT DESIGN ALTERNATIVES AND PRIORITIZATION

As a result of the site investigation, interviews, and hydrologic analysis several concept design alternatives and project areas have been identified as potential opportunities for improving flooding and sedimentation conditions in the Carpenter Creek, Hill Ditch and Fisher Slough Sub-basins.

A descriptive summary of conceptual design alternatives and project elements is provided. Cost summaries are provided for some of the concept alternatives and was developed using the following assumptions and contingencies.

- Real estate (assessor's listed value)
- Construction costs, marked up with taxes (7.8%), contingencies (35%), and cost escalation (5yrs @ 3.5%)
- Planning, engineering, design (PED) and permitting (35% of construction cost)
- Supervision and administration (15% of construction and PED)

Lang Pony Farm – Area 1
The Lang Pony Farm likely acts as a regional stormwater detention facility downstream from the City of Mount Vernon (**Table 9**). The dam has recently had spillway improvements, but has potential opportunities to improve habitat and water quality, while providing flood control benefits. Elements of the Lang Pony Farm Dam modification are:

- Modification of pond, spillway and outlet structure to allow flows for longer periods during the year (SCD, 2006)
- Stream channel restoration to Little Mountain Road
- Culvert replacement and maintenance at Little Mountain Road crossing
- State Haul Road bridge inspection and deck improvement
- Riparian and stream restoration in horse pasture area between State Haul Road Bridge and Carpenter Creek Ravine

Table 9. Lang Pony Farm Area 1 - Concept Design Alternatives Preliminary Costs

Item	Cost Range
Little Mountain Road Culvert	$75,000-$100,000
Lang Dam Spillway Modification	$75,000-$100,000
Tributary Restoration	$50,000-$100,000
State Haul Road Bridge Improvement	$50,000-$100,000
Horse Pasture Restoration	$50,000-$100,000
Annual Budget	$300,000-$500,000

Carpenter Creek Ravine – Area 2
The Carpenter Creek Ravine area is within the Mount Vernon City limits and should be protected against development and the degradation of riparian and streamside areas that results from the naturally erosive

materials and potential sediment supply through the ravine area. The area just downstream from Hickox road should also be considered for protection due to the current riparian and floodplain integrity.

Stackpole Road – Area 3

Carpenter Creek downstream from the Stackpole Creek and Ten Lake Creek confluence is a known flood overflow and current deposition area. The concept alternatives recommended are as follows:

- Identify dedicated flood overflow easement area in flood-prone area west of Stackpole Road. Install riser pipe overflow through roadway to easement area. Evaluate need for flood control berm or levee around easement property.
- Evaluate potential floodplain restoration opportunities along private drives immediately downstream from confluence.
- Dredge existing sediments along Stackpole Road and remove channel vegetation

Sandy Creek Alluvial Fan – Area 4

Sandy Creek has been identified as having recurring flood and sedimentation problems at the Kanako Rd. bridge crossing. The concept alternatives recommended are as follows (**Table 10, Figure 50**):

- Dredge existing sediment plug in Hill Ditch
- Realign Hill Ditch to reduce channel roughness and improve conveyance
- Real estate acquisition
- Remove structures
- Realign Sandy Creek on historical fan and connect with downstream wetland
- Restore riparian areas on alluvial fan
- Identify dedicated flood overflow easement area in flood prone area west of Stackpole Road. Install riser pipe overflow through roadway to easement area. Evaluate need for flood control berm or levee around easement property.

Table 10. Sandy Creek Area 4 - Concept Design Alternatives Preliminary Costs

Item	Cost
Real Estate Acquisition	$198,000
Construction	
Mob/Demob/Prep/Cleanup	$24,000
Dredge Existing Sediment Spoils	$17,000
Realign Hill Ditch to Improve Hydraulics	$200,000
Realign Sandy on Fan and Remove Structures	$94,000
Construction Total[1]	$505,000
Engineering and Design on Construction (25%)	$126,000
Permitting on Construction (10%)	$51,000
Supervision and Administration on Project (12%)	$82,000
Project Total	$962,000

[1]Includes taxes, contingency and escalation

<u>Welts/Benson Wetland Restoration – Area 5</u>

The area between the Sandy Creek and Johnson Creek Fans has potential for flood storage and riparian restoration (SCD, 2006). The concept alternatives need to address flood storage options in the wetland, and should include concepts for improving riparian conditions and lowering stream temperatures, as the area is now a heat sink (**Table 11, Figure 50**).

Table 11. Wetland Restoration Area 5 - Concept Design Alternatives Preliminary Costs

Item	Cost
Real Estate Acquisition	$147,000
Construction	
Earthwork/dredging	$137,000
Plantings	$155,000
Construction Total[1]	$440,000
Engineering and Design on Construction (25%)	$110,000
Permitting on Construction (10%)	$44,000
Supervision and Administration on Project (12%)	$71,000
Project Total	$812,000

[1]Includes taxes, contingency and escalation

<u>Johnson Creek Alluvial Fan – Area 6</u>

Johnson Creek has been identified as a high–priority, frequent dredge location due to the higher rates of sediment supply to the alluvial fan and Hill Ditch. The concept alternatives recommended are as follows(**Table 12, Figure 50**):

- Dredge existing sediment plug in Hill Ditch (took place in Aug. 2006)
- Real estate acquisition
- Remove structures
- Realign Johnson Creek on historical fan and connect on north with downstream wetland
- Restore riparian areas on alluvial fan

- Identify dedicated flood overflow easement area in flood-prone area west of Stackpole Road. Install riser pipe overflow through roadway to easement area. Evaluate need for flood control berm or levee around easement property.

Table 12. Johnson Creek Area 6 - Concept Design Alternatives Preliminary Costs

Item	Cost
Real Estate Acquisition	$535,000
Construction	
Mob/Demob/Prep/Cleanup	$22,000
Dredge Existing Sediment Spoils	$0
Realign Sandy on Fan and Remove Structures	$210,000
Connection w/ Upstream Wetland	$26,000
Construction Total[1]	$1,062,000
Engineering and Design on Construction (25%)	$265,000
Permitting on Construction (10%)	$106,000
Supervision and Administration on Project (12%)	$172,000
Project Total	$1,605,000

[1]Includes taxes, contingency and escalation

Bulson Creek Confluence – Area 7

Bulson Creek is in relatively good condition. The following concept alternatives can help mitigate future development and alleviate current flooding.

- Dredge existing sediment plug in Hill Ditch
- Evaluate fish habitat enhancement as mitigation for dredging just upstream from confluence with Hill Ditch
- Identify dedicated flood overflow easement in flood-prone area west of Stackpole Road. Install riser pipe overflow through roadway to easement area. Evaluate need for flood control berm or levee around easement property.
- Address numerous culvert problems in basin.

Big Fisher Creek – Area 8

During the streamwalk, an area of significant channel degradation and bank erosion was observed on the southeast fork, the likely result of increased development. The concept design is to evaluate and install grade control and bank stabilization opportunities to limit sediment supply to the downstream reaches and potential additional loading to Fisher Slough.

Little Fisher Creek – Area 9

Solutions for Little Fisher Creek need to address problems associated with stormwater runoff from potential development, culvert assessment, and culvert retrofit. Solutions should involve working with landowners for livestock management and grazing practices in riparian and stream areas.

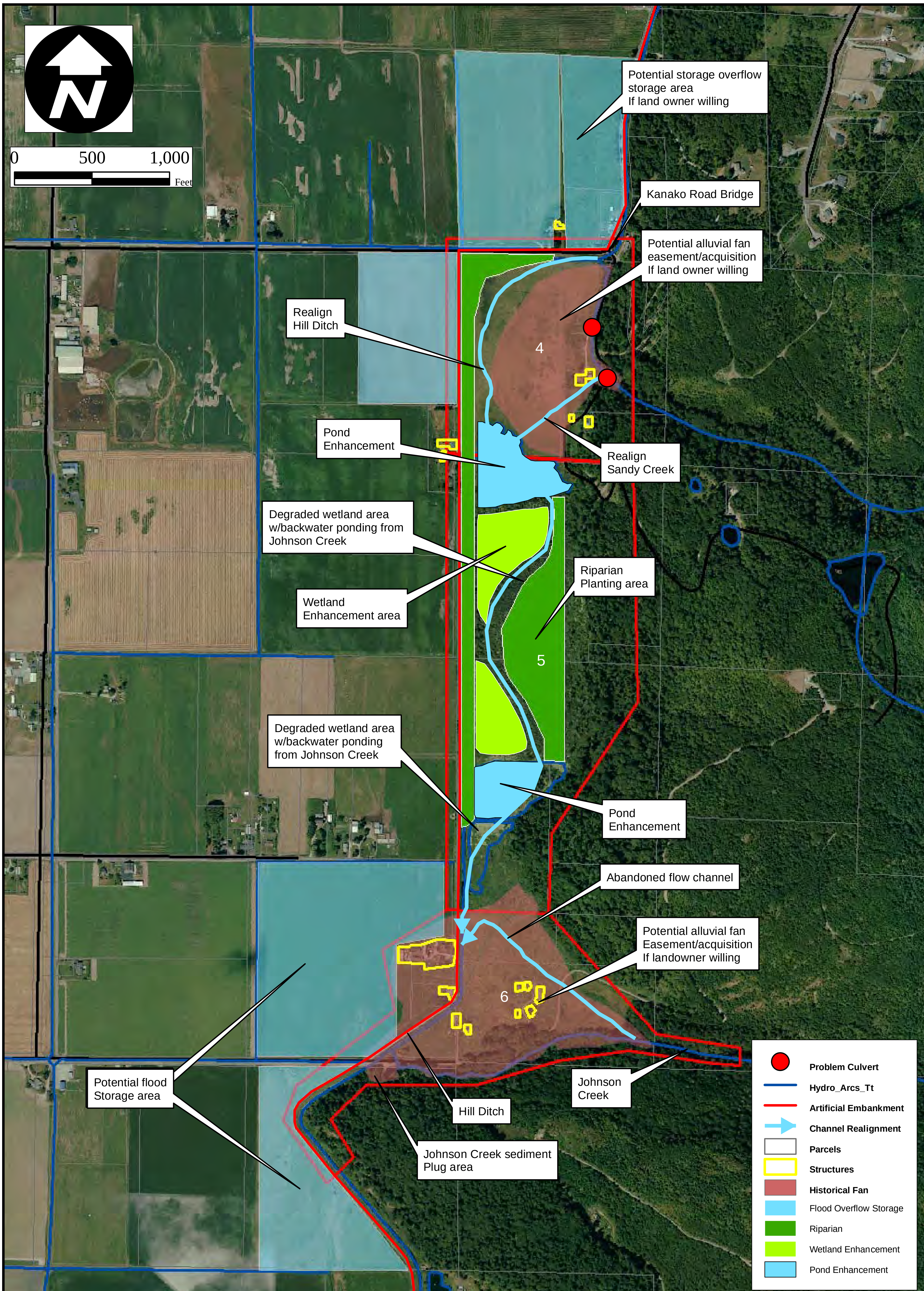

FIGURE 50. SANDY AND JOHNSON CREEKS ALLUVIAL FAN FLOOD REDUCTION AND WETLAND ENHANCEMENT

SKAGIT COUNTY, WASHINGTON

4.2 WATERSHED MANAGEMENT PLANNING, COORDINATION, STUDY ACTIVITIES

In addition to specific concept design projects, it was apparent from the site assessment and interviews that a programmatic watershed planning, coordination, and additional studies are needed to support the recommended concept design projects.

Integrated Watershed Plan

Watershed planning, project implementation, monitoring and adaptive management are continuous activities in today's water resource sector. Watersheds are the environmental foundations for which we construct our society. Water resource managers, planners, engineers and scientists are responsible for continuous work to improve beneficial uses including aquatic life, recreation, water supply, and other miscellaneous uses. In order to ensure a balance is achieve between competing uses and needs, stakeholders must meet at the table, and work together for an integrated and comprehensive watershed plan.

The Carpenter Creek, Hill Ditch, and Fisher Slough sub-basins would benefit from an integrated watershed plan that addresses multiple issues discussed in a variety of separate reports. The recommendation is to pursue development of an integrated and comprehensive sub-basin plan including the following study areas:

- Flood control and sedimentation
- Aquatic life and fisheries
- Agricultural irrigation and drainage
- Water quality
- Land use development
- Stormwater management
- Recreation
- Domestic, commercial and industrial water supply

Implementation and oversight of such a program would require dedicated time from a watershed coordinator, plus funding to execute projects, studies and monitoring, plan updates, oversee operations and maintenance projects and implement capital improvement projects within the watershed plan framework (**Table 13**). The following is an annual cost estimate for the implementing the watershed plan.

Table 13. Concept Design Alternatives Preliminary Costs

Item	Cost
Watershed Coordinator Salary	$50,000
Watershed Coordinator Overhead/Expenses	$150,000
Watershed Plan Study	$180,000
Watershed Annual O&M	$120,000
Capital Improvement Projects[1]	$0
Annual Budget	$500,000
[1] CIP project costs determined annually through plan update	

Programmatic Drainage Facility Management Plan

One element of an integrated watershed plan would address the number of reports of culvert and roadway flooding and fish passage problems throughout the sub-basin. The Skagit County Conservation District has developed a comprehensive list of potential culvert replacements. This list should be reviewed and consolidated with recommendations from the previous section. One of the biggest challenges in managing widespread infrastructure is developing an accurate estimate of the condition of the infrastructure or resource, and then developing a plan for implementing the projects in a timely manner. There are several tools available to expedite both field inventories and resource assessments including GPS survey units and GIS and standard inventory checklists that evaluate conveyance, fish passage, structural damage, geotechnical stability and other pertinent culvert evaluation parameters. The recommendation is to develop a drainage facility management plan for the entire sub-basin would include the following elements:

- Consolidation of current culvert inventory data from Skagit County and Skagit Conservation District and culvert problem reports
- Conduct a comprehensive culvert and drainage infrastructure inventory of all culverts in the basin using standardized GPS location protocols, inventory checklists and GIS mapping
- Assessment and prioritization of culvert replacement needs
- Phased annual development of feasibility plans and cost estimates for capital improvement planning and grant proposals
- Phased annual design and construction of previous year's culvert and drainage funded drainage project recommendations
- Monitoring and expansion of program to other county sub-basins

Programmatic Stormwater Management Planning, Regulation, Enforcement and BMP Implementation

Stormwater management planning in the Carpenter Creek, Hill Ditch, and Fisher Slough watersheds is necessary do to the expected growth in Skagit and Snohomish Counties. Coordination will require monitoring, plan development review and coordination within agencies, between counties, and stakeholders as part of an integrated watershed management plan. Stormwater planners should focus on the problem areas identified in this report, and further flush out the potential effects from increased development as stated in the Skagit County Comprehensive Plan. The areas of specific interest at the time of this report are:

- Carpenter Creek Sub-basin development of Hidden Lakes, Eaglemont 2 and the eastern headwaters area near Andali Road
- Bulson Creek Development
- Big Fisher Creek development in both Skagit and Snohomish Counties
- Little Fisher Creek development in both Skagit and Snohomish Counties

Table 14 is a summary of projected costs to implement the programmatic culvert, drainage and stormwater BMP projects.

Table 14. Concept Design Alternatives Preliminary Costs

Item	Cost	Future Annual Cost
Culvert Inventory and Drainage Study w/ Annual Updates	$200,000	$25,000
Annual Culvert and Drainage Improvement Projects[1, 2]	$350,000	$500,000
Stormwater BMP Management Study w/ Annual Updates	$200,000	$25,000
Annual Stormwater BMP Project Implementation[1]	$150,000	$250,000
Annual Budget	$1,000,000	$800,000
[1] Improvement projects include design and construction to be determined annually from plan and annual updates.		
[2]Culvert costs taken from SCD 2006 to implement in 5-year timeframe w/ 50% markup from original estimate.		

4.3 PROJECTS AND WATERSHED MANAGEMENT PRIORITIES AND RECOMMENDATIONS

The findings of this study were presented to interested stakeholders at a workshop held in the Skagit County offices on Jan. 11, 2007. The participants in the meeting were:

- Skagit County
- The Nature Conservancy
- Dike District #3
- Drainage District #17
- Skagit Conservation District
- Skagit River System Cooperative
- Washington Department of Fish and Wildlife
- Western Washington Agricultural Association

The goals of the workshop were to reiterate the findings of the Initial Flood and Sediment Investigation, and to brainstorm on conceptual design projects and watershed programs that would reduce flooding and improve sedimentation conditions in the Carpenter Creek watersheds. Question, answer and discussions were held for each major conceptual projects identified in Sections 4.1 and 4.2. After reviewing the projects, the group was asked to assess and define project priorities. **Table 15** is a summary outcome of the project prioritization exercise undertaken at the meeting.

A similar exercise is also recommended for the watershed planning, coordination and permit activities. Skagit County should pursue additional discussion and analysis to determine priority watershed management activities and actions. A useful tool in determining watershed scale priorities and management priorities would be the implementation of a designated watershed coordinator whose first responsibility would be the development and implementation of an integrated watershed management plan. In addition, formal adoption and utilization of the Washington Department of Ecology, Stormwater Management Manual for Western Washington is recommended (WDOE, 2005).

Each of the projects ranking 1 through 5 have identified dredging of Carpenter Creek / Hill Ditch, in areas adjacent to tributaries causing significant sedimentation along the ditch, as an activity to improve flood conveyance and sediment storage within the system. The project alternatives were developed in such a fashion that if dredging were to take place, the complimentary channel realignments, flood storage easements, and channel and floodplain restoration activities would be excellent mitigation measures for the dredging activities.

Overall, the highest project priorities (ranking 1, 2 and 3) are the Sandy Creek Alluvial Fan, Welts/Benson Wetland Restoration, and Johnson Creek Alluvial fan projects. The rationale behind selecting these as higher priority projects is that there are existing flood storage and floodplain restoration opportunities related to development mitigation on the Sandy Creek alluvial fan, the associated required project mitigation activities, and exchange of development rights for parcels within Welts/Benson wetland project area. Johnson Creek alluvial fan has less immediate development/mitigation/land-exchange opportunities, but ranks high due to recurring flooding and sedimentation problems. Also there is an increased risk for more significant damages to occur due to the tributary landslide and fault line conditions that contribute to possible debris and dam-burst flooding. The Sandy Creek and Johnson Creek projects both have proposed dredging of Hill Ditch, alluvial fan restoration, channel realignment, and property flood easement acquisition as recommended measures for improving site conditions.

The next priority (ranking 4) is to address the flooding issues on Stackpole Road, where semi-frequent flooding and overtopping of the road occurs. The options on the table include:

- raising the road
- dredge and/or excavation and restoration of floodplain and channel, to increase flood and sedimentation capacity, along the current drainage alignment and adjacent properties
- installation of a flood overflow bypass system (such as a riser pipe crossing) that would drain westerly into agricultural flood storage areas (which would require internal diking and drainage modifications).

The next priority (ranking 5) is to evaluate dredging, flood storage and sedimentation improvements and mitigation activities near the Bulson Creek confluence with Hill Ditch. This area is currently identified as a more frequent flood overflow area and obtaining a dedicated flood easement overflow along a section of the levee with a lower levee profile for controlled spills is a potential opportunity. Mitigation opportunities in the form of floodplain and channel restoration can be found immediately upstream from the Bulson/Hill Ditch confluence to compliment and mitigate for possible dredging activities.

The next priority (ranking 6) is an upstream evaluation of potential flood storage and sedimentation opportunities near the Lang Pony Farm. This activity will require coordination with the City of Mt. Vernon and is primarily concerned with the ongoing development of Eaglemont, Phase 2. The dam is currently inspected by the Washington State Dam Safety Office, for which no problems have been identified. However, there will likely be increased stormwater runoff to the Lang Pony farm area, even with Eaglemont Phase 2 implementing stormwater drainage BMPs and future growth and development are a top watershed management priority.

The final priorities (ranking 7, 8, 9) for the watershed flooding and sedimentation projects are the Big Fisher Creek ravine erosion and grade control project, problem culverts along Little Fisher Creek, and determining the conservation and future status of plans for the Carpenter Creek ravine area, which also requires communication and coordination with the City of Mt. Vernon.

Table 15. Carpenter Creek, Hill Ditch, Fisher Slough Watersheds Flooding and Sedimentation Project Priorities

Sub-basin	Project ID	Project Name	Project Description	Benefits Summary	Cost (TBD)	Existing Opportunities	Prioritization
Carpenter Creek	1	Lang Pony Farm	1A. Pond and dam modification to improve flood storage, low flow release and habitat conditions	1. Increase flood storage to accommodate future upstream development. 2. Improve water quality (temperature) and low flow releases.	$75k - $100k	1. Mitigation for upstream Eaglemont development. Need to coordinate w/ City of Mount Vernon. 2. Dam is curerntly part of Washington State dam safety program.	6
			1B. Downstream channel restoration	Improve cold water native fish habitat to upstream passage terminus at dam. Fish habitat may be marginal due to downstream Hill Ditch.	$50k - $100k		
			1C. Culvert replacement to improve roadway flooding	Decrease flooding of Little Mountain Road.	$75k - $100k		
			1D. Riparian and stream restoration downstream from Little Mountain Road.	1. Improve floodplain connectivity and storage. 2. Improve water quality (temperature) through riparian plantings.	$50k - $100k		
			1E. State Haul Road Bridge Improvement	No direct benefits to flooding or fish habitat. Currently a safety hazard.	$50k - $100k		
			Subtotal Project 1		**$300k - $500k**		
	2	Carpenter Creek Ravine	2A. Protect area from development.	1. Protect geologically sensitive areas from erosion and provide downstream protection from additional sedimentation and flooding along Stackpole Road, Sandy and Johnson Creeks. 2. Continue to provide quality fish habitat.	TBD	Property is currently owned by City of Mount Vernon. Need to coordinate and contact city to determine future status.	9
	3	Stackpole Road Flood Storage Overflow	3A. Levee modification and flood overflow to designated storage and return flow area.	1. Decrease flooding and overtopping of Stackpole Road.	**$500k - $1.0M**	Options include raising the road, restoration of flood and channel capacity along existing drainage alignment, or installing flood overflow bypass to agricultural storage area.	4
Sandy Creek	4	Sandy Creek Alluvial Fan	4A. Dredge existing sediment plug in Hill Ditch.	1. Reduce flooding of Hill Ditch, especially along upstream areas of Stackpole Road and adjacent properties. 2. Reduce need for future maintenance dredging and permitting. 3. Improve water quality (temperature) with riparian plantings. 4. Possible to improve fish passage and habitat with channel realignments.	**$750k - $1.5M**	Adjacent landowners are interested in developing hillside and ridgeline areas next to Sandy Creek. Project mitigation money may be directed to Sandy Creek projects (4, 5 and 6).	1
			4B. Realign Hill Ditch to improve hydraulics.				
			4C. Pursue flood easements and acquisitions on fan (Partial or Full). Remove structures from floodplain. Plant riparian vegetation along fan.				
			4D. Regulate stormwater drainage for ridgeline development.				
	5	Welts/Benson Wetland Restoration	5B. Riparian wetland restoration combined with additional flood and sediment storage	1. Project essential piece of Sandy and Johnson Creek alluvial fan restoration plans. 2.Wetlands may provide fish habitat, but will likely provide waterfowl habitat. 3. Riparian restoration will aid in water quality improvement plans (temperature).	**$750k - $1.0M**	Wetland project is key linkage for Sandy Creek reconnect. Opportunity for mitigation plans with Sandy Creek hillside and ridgeline developments.	2
Johnson Creek	6	Johnson Creek Alluvial Fan	6A. Dredge existing sediment plug in Hill Ditch (Complete FY-06)	1. Reduce long term flooding and sedimentation of Hill Ditch. 2. Decrease flood and sedimentation risk to access road and structures on fan. Johnson has potential for both debris flows and dam-break floods. 3. Little if any benefits to upstream habitat on Johnson Creek.	**$1.5M - $2.0M**	Mitigation for recent dredging activities. Historical and future logging in watershed related to flooding and sedimentation of fan. Planned development is minimal.	3
			6B. Pursue flood easements and acquisitions on fan (Partial or Full). Remove structures from floodplain.				
			6C. Connect project with upstream wetlands enhancement project.				
Bulson Creek	7	Bulson Creek Flood Storage Overflow	7A. Dredge existing sediment plug in Hill Ditch.	Reduces flooding and backwater along Hill Ditch and Bulson Creek. Dredging project should evaluate opportunity for creating spawning or holding side channel, or placement of LWD in downstream areas of Bulson Creek.	**$200k - $300k**	1. Dreding Bulson Creek will reduce backwater effects on Hill Ditch and reduce overflows at Bulson. 2. Working with landowner to designate overflow at existing site. This will provide economic incentive to landowner and specific location to monitor during flood events.	5
			7B. Levee modification and flood overflow to designated storage and return flow area.	Utilizes existing overflow as designated location.			
		Bulson Creek Culvert Replacements	8A. Culvert replacement to improve roadway flooding		TBD		
Big Fisher Creek	8	Big Fisher Bank Stabilization and Grade Control	9A. Install grade control to reduce channel incision and bank erosion		TBD		7
Little Fisher Creek	9	Little Fisher Creek Culverts	10A. Replace undersized culverts for flood reduction and fish passage		TBD		8

Carpenter Creek, Hill Ditch and Fisher Watersheds Planning, Coordination, Permitting and Outreach Focus Areas

Item	Description	Description of Cost	Initial Cost	Future Annual Cost	Prioritization (TBD)
Watershed Coordinator	Provide oversight, management and coordination for all drainage, flood, sediment, water quality and habitat restoration activities, studies and projects in the watershed.	Salary and overhead expenses	$200,000	$200,000	
Watershed Plan Study	Integrate flood and sedimentation, stormwater management and BMPs, water quality, fish habitat restoration studies into singular plan.	Study, data collection, monitoring, analysis, documentation and reporting.	$200,000	$50,000	
Culvert Inventory and Drainage Needs Study	Perform study specific to culverts and drainage in Carpenter Creek, Hill Ditch and Fisher Watersheds.	Study, data collection, survey and inventory, status reporting, feasibility level design, cost estimates and prioritization w/ annual updates over life of project.	$200,000	$25,000	
Annual Culvert Replacement Projects	Begin replacing all culverts demonstrating need, to be completed with 10-year timeframe.	Final design, construction bid packages, construction, monitoring, future O&M of 15 small culvert replacement projects averaging $150k over 10 years. Culvert assessment will determine expected annualized cost. Large culvert replacements not accounted for in budget estimate.	$0	$225,000	
Annual Stormwater BMP Projects	Stormwater management, permit review, contractor coordination, installation of LID practices, regional facilities and retrofit of stormwater BMPs throughout watershed.	Initial stormwater needs evaluated as part of larger watershed plan study. Costs include design, construction contracting, BMP installation, monitoring and O&M estimated at $250k per year. Initial years focus on BMP installation and future years on O&M.	$0	$250,000	

Total costs are approximately $15million over 10 years or $1.5million per year to implement watershed studies, management and coordination and monitoring activities and implement projects. Cost estimate should be evaluated compared to stormwater, diking and drainage district utility funding and possible grant sources to determine feasibility of implementing watershed plans.

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APPENDIX A – INTERVIEW SUMMARIES

Skagit County Public Works Interview w/ Jeff, Eric and Jan on June 27, 2006 (Sue Perkins, Curt Miller, David Cline)	
How much sediment dredged from Sandy and Johnson creeks alluvial fans and how often?	Dredging has been done under regular and emergency operations. Ask Cliff Butler head of PW road operations and Tom Sheehan head of Emergency operations. Barb Hathaway bridge inspector at PW got permit for Sandy dredging (Kanako Lane bridge).
Is there a county geologist who might know of landslide activity in ravines?	Try John Cooper, county geologist
Describe Johnson Creek problems	Johnson Cr. elevated above fan in ditch along side of hill. It pops out of the ditch, crosses road then through buildings on alluvial fan (garage?). This is sandbagged regularly and coarse sediment removed . Other dredged area is sand from Johnson Creek that plugs up Carpenter Cr. The Army Corps removed the Carpenter sediment plug in December 2004 emergency, now Skagit County is applying for permits to do it again this summer. The sand plug backs up lake upstream of Johnson, aggravated by a beaver dam on top of sandy plug. Beaver dam failure upstream on Johnson Creek occurred in summer a couple of years ago causing flooding at fan. Todd Martin is owner at downstream end of fan, Vic Benson upstream along Hill Ditch and David Weltz on Johnson Creek fan.
Describe Sandy Creek problems	Sediment from Sandy Creek piles up under Kanako Road wooden-deck bridge operated by Skagit PW SWM. Sediment shoves Carpenter Creek against bridge abutment. Dredging occurs right at the bridge. Flooding and sediment producing events smaller than Johnson Cr.. Abutment erosion is occurring due to plugging of sediment under bridge. Barb Hathaway is the Bridge inspector.
What do you think would be best solution at Johnson and Sandy Creeks?	County has preliminary layouts of potential options (Jeff McGowan). One option is to send creeks down fans again. Discussion of land owners and proposed land development in area.
Describe flooding and sediment problems on Carpenter Creek upstream of Sandy Cr.	Upstream of ditched section there are no sediment removal issues. It's mostly owned by City of Mt. Vernon. There are a lot more roads than shown on topo map. New subdivisions are under development and Eaglemont golf course. There are flooding but not sediment transport issues in upstream areas. The ditched section was dredged 10-15 years ago -- ask Dave of Diking District 3 for details. There is spawning gravel in the upstream part of the Hill Ditch.
Describe flood and sediment problems on Bulson Creek	Bulson Cr. has much less sediment. There are occasional culvert issues, one was proposed for upgrading but the project lapsed. The Bulson Road culvert is at a drop-out point for sediment, and sediment may not get to Hill Ditch. No known dredging. The creek has a lot of lake and wetland areas so very little of the drainage area contributes sediment. There was a historical gage operated by RWBeck. The eastern English Rd. culvert is undersized. The next culvert to the west is funky. Hwy 534 culvert has been upgraded with a new fishway under it.
Lower Carpenter Creek	Speculated that gravel at the I-5 bridge might have been added as mitigation when some maintenance was done at I-5 & Cedardale Road. Unlikely it got transported from upstream.
Big Fisher Creek	No known flooding or sediment transport issues. There is a fishway under Cedardale Road. The white strip on topo map is the gas pipeline, goes right along Big Fisher on the plateau. The "levee" between Carpenter and Fisher Creeks is the old railroad grade, as is the levee on south side of the Big Drain after it crosses under Fisher Creek

Skagit Conservation District Interview w/ Tom Slocum on June 27, 2006 (Sue Perkins, Curt Miller, David Cline)	
Describe erosion problems on Big Fisher Cr.	-The first half mile of ravine is unconsolidated gravels with slumps and undercut banks and erosion is the worst ½ mile u/s from Cedardale Rd. There are trophy houses on Trophy Lane above N side of ravine. Trees on North canyon wall were cut in places, more unstable than south wall. South side has a buffer. Clearcut on N side around bend. -The small south tributary that enters Big Fisher upstream of Cedardale Rd. has a headcutting erosion area just above confluence. Red sediment. -Just N of Starbird Rd, there is a pasture with some plantings. Cattle upstream trample banks eroding silty soils. One eroding ditch area near County Line.
Describe erosion problems on Little Fisher Cr.	There is a small dam on Little Fisher just upstream of county line. Milltown culvert is undersized. West Fork a wetland above Milltown Rd catches most of sediment from upstream. E. Fork culvert at Franklin Rd. has an eroding area below it. The E. Fk. ravine is pretty eroded. There is erosion at Clarence. He hasn't walked below Bonnie View Road. A vineyard, ditches and large embankment just upstream of I-5 contribute some fine sediment. Most of the gravel drops out below the confluence of the forks.
Describe erosion and culvert problems on Bulson Cr.	Dave Boone owns the farm at the mouth. No issues there; cows are kept out of creek. Farm is on a terrace well above the floodplain. The creek is in really good shape despite all the residential development. Cascade Ridge Dr. between Lake 10 and Benson Creeks has detention ponds. Either there's no sediment, or it settles out at culverts and doesn't go downstream to Carpenter, also there are no buildings on low ground to be flooded by creek. Bulson is called "Compton Cr" on Assessor's Maps. - The culverts are flat and sediment settles out on both sides of (Bulson?) road. Gravel settles out downstream. -English Road culvert on south fork is 36" but almost completely buried in gravel and has a 40-50' high road fill. Maybe it traps the sediment. Blocks fish passage. -English Road culvert near SR 534, on middle fork Bulson looks ok (?). Wetland upstream. Quarry not a sediment source. -The north fork has a high waterfall at the base of the ravine, but can access above falls from subdivision.
Johnson Creek	Historically logged to edges of creek and beaver dams upstream. The creek was realigned and now higher than the access road. David Welts landowner on Johnson. The county dredges every couple of years. Dan McMoran used to work for Skagit Cons. District, walked entire creek. Now works for WSU Extension. There was a beaver dam burst flood (maybe from a lake upstream of creek?)
Sandy Creek	Ravine not walked by SCD. Sandy Creek Bed & Breakfast up Kanako Lane is owned by Vic Benson and David Welts, whose father lives in the house on Sandy Creek alluvial fan. Dredging occurs at bridge.
Lake 10 Creek	Creek has remained stable despite development. Cascade Ridge Dr. between Lake 10 and Benson Creeks has detention ponds. Connects to Carpenter Cr. upstream of Cascade Ridge Drive (different than map shows). Very small creek with wetlands upstream. Goes through subdivision with new culverts that are OK.
Carpenter Creek upstream	Ditch downstream of Cascade Ridge Drive, creek upstream. In 1991, a 3' culvert blew out at entrance to quarry, which scoured the creek. Replaced with bigger, ok culvert. Banks are recovering, no current erosion

	sources. Little Mountain Park section of creek is natural and healthy except one cutbank SE corner of Section 33 (T34). English Creek is step-pool through hobby farm/horse areas. Beaver pond and wetlands near Little Mtn. Rd. Section 27 Eaglemont development had a huge slug of sediment for a couple years (following construction?). Eaglemont 2 is starting. But ponds and wetlands (between it and Carpenter Creek?) Lang's Creek dams on Pony farm have issues and could blow out.

David Welts, Landowner Interview on July 18, 2006 (David Cline)	
Describe flooding and sediment problems on Johnson Creek.	Carpenter Creek has never flooded towards the east and the structures on his property. The areas around his property are wet, due to poor drainage and elevated water tables during flood season, but no flood flow paths towards the structures. About 15-20 years ago, Johnson began to overflow it's banks (minor). The flow to the road was shallow and could be stepped across. Mr. Welts does not perceive Johnson Creek flooding to be a major issue.
Describe dredge and maintenance activities.	The County and Corps have dredged Carpenter Creek in the past. In addition, some private landowners have also dredged, excavated material from Carpenter in the past (once in particular). He also remembers some sediment removal work occurring along Johnson, upstream from Carpenter (once).
Describe other stream and flood characteristics of your property.	The wetland area to the north, towards Benson property, has been wet for quite a long time despite what other neighbors may say.
Are you willing to talk with the County regarding potential flood and sediment mitigation projects.	Yes.

Darren Miller, USGS Phone Interview on July 13, 2006 (David Cline)	
Is USGS currently installing recording equipment in Carpenter and Fisher Creeks?	Yes, the USGS has recently installed three gages in Big Fisher, Carpenter and Nookachamps Creeks.
What data is being collected?	Stage, discharge. Eventually rating curves will be developed. No telemetry, but data will be posted to website every 6-8 months.
What other projects are underway?	USGS is currently involved in seepage study along Skagit River Delta and tributaries and up to 40 groundwater wells will be installed for study.
	Contact Mark Savoca, Hydrologist, USGS for more information. 253.552.1660

Vic Benson Phone Interview on July 7, 2006 (David Cline)	
How long have you owned property?	Vic has grown up and owned the property for 40 years. He remembers when Hill Ditch was dredged more frequently and had more trees and better water quality. He has historical pictures and video if interested.
What is the flood history of Sandy Creek?	Historically, Hill Ditch has broken out upstream from property along Stackpole road. Does not remember recent flooding of Sandy Creek. Currently there are 4' culverts along Sandy Creek that provide adequate capacity.
How have the Hill Ditch/Sandy Creeks changed?	Historically, Vic Claims that tidal backwater affects could be visually seen along Hill Ditch. Since quitting the dredging program about 15 years ago, sediment buildups have caused backwater ponding along ditch and there have been decreases in water quality and loss of trees in flooded areas along hillside downstream from Sandy Creek. His family previously owned a dairy farm on other side (west) of Stackpole that cannot use due to poor drainage and elevated water tables.
What do you think needs to be done to fix the problem? (General discussion – not specific question)	More frequent dredging of Hill Ditch would alleviate flooding and ponding problems.

APPENDIX B – FIELD INVESTIGATIONS

TECHNICAL MEMORANDUM

WATERSHED SITE ASSESSMENTS FOR FLOODING AND SEDIMENTATION PROBLEMS

UPPER CARPENTER CREEK

Carpenter Creek above Sandy Creek has several small tributaries and a total watershed area of 6 square miles. The mainstem creek flows west through a broad upper valley and then southwest through a narrow ravine. The creek flows through recessional outwash deposits that are overlain by fine-grained, glaciomarine drift in the broad upper valley (Dethier and Whetten 1981). The outwash gravels have been mined, with a still-active gravel pit at the mouth of the Carpenter Creek ravine and three older gravel pits in the upper valley that were mined prior to 1961. Upon reaching the west edge of the mountains, Carpenter Creek crosses a short, sloping transitional zone before entering the flat Skagit Valley. It continues south along the east side of the Skagit Valley in Hill Ditch.

Upstream of the Pony Farm tributary, Carpenter Creek has beaver ponds, wetlands, and a very low gradient channel that acts as a sink for coarse sediment. Three tributaries enter the broad, upper valley. Nearly all of their coarse sediment load drops out on the valley floor before reaching Carpenter Creek. The largest tributary originates near 10 Lake and flows north through a bedrock watershed. Its deposits have formed an alluvial fan that stops short of Carpenter Creek. Two smaller, seasonally-dry tributaries flow south through glacial till watersheds that originate in the suburbs of Mount Vernon, including part of the Eaglemont development. Sediment from the larger tributary is trapped in large ponds (former gravel pits and beaver dam ponds) on the Lang Pony Farm property.

The primary source of coarse sediment to upper Carpenter Creek is likely the bed and banks of the ravine. The ravine has an average gradient of five percent and maximum gradient of 11 percent. The ravine walls are 100 feet high and landslides probably occur in infrequent, high-intensity storm events. The creek is currently stable except for one large cut bank in the southeast quarter of Section 33 (Tom Slocum, SCD). At its downstream end, the ravine reach has abundant large cobbles and scattered small boulders, with moderate to slight bank erosion and no instream channel structure. Most of the ravine is within Little Mountain Park and has mature riparian forest and a stable, pool-riffle channel (SCD 2006), and presumably some channel structure from LWD.

After exiting the ravine, Carpenter Creek flows down a gentle, unconfined, alluvial reach with an average gradient of four percent. This reach of Carpenter Creek had severe, localized bank erosion following the sudden failure of a three-foot diameter culvert at the quarry in 1990 (SCD 2006). The undersized culvert was replaced with a 10 foot diameter culvert and banks have reportedly stabilized with no known current erosion sources except localized bank erosion associated with bank armoring between Hickox Road and Cascade Ridge Road. Carpenter Creek is joined on the east by 10 Lake Creek, a steep but stable bedrock channel, and on the west by Stackpole Creek, a low gradient channel with a rock-lined roadside ditches (SCD 2006). The final reach of Carpenter Creek is a very flat ditch, starting a short distance below Cascade Ridge Road.

The declining gradient and lack of valley confinement reduce Carpenter Creek's sediment transport capacity downstream from the ravine. The maximum size of sediment declines from 15-inch boulders just above the gravel pit to gravel, sand, and finally silt in Hill Ditch (Figure 1). Although this is clearly the depositional zone for the creek's coarse sediment load, the amount of sediment appears quite low. 800 cubic yards of gravel were reportedly dredged from this section of Hill Ditch in the 1990s. The ditch has apparently not needed dredging since then. Much of the dredged sediment may have resulted from the 1990 culvert blowout. The low sediment load is attributed to the low level of hydrologic change from development, the broad valley and wetlands that trap sediment from the upper half of the watershed, the relatively gentle relief and undisturbed riparian corridor.

PROJECTED CHANGES TO SEDIMENT LOAD FROM FUTURE DEVELOPMENT

Table 1 shows existing and potential future impervious area as a percent of watershed area, by sub-basin. Currently, the Fisher/Carpenter watershed has an average of 3.2% impervious area which is low for the Puget Sound/I-5 corridor. The highest level of impervious area is 8.8% in Little Fisher Creek, due to I-5 as well as some low-density residential development. If full-build out occurs with exiting zoning, future impervious area could potentially increase to 5.5% for the watershed as a whole. Impervious area would remain quite low in all Sub-basins but Little Fisher and upper Carpenter.

The upper Carpenter Creek watershed has about 2.6 percent existing impervious area (Table z). With current zoning, potential future development could lead to a total of 8.7 percent impervious area. This increase would primarily occur in the Mount Vernon area and would increase flow in the northern tributary creeks. Since coarse sediment from these tributaries does not reach Carpenter Creek, no direct increase in sediment load is expected from the tributaries. Projected flow increases in the mainstem Carpenter Creek itself will likely increase channel erosion in the ravine. However, the amount of channel incision will be limited by abundant large cobbles that can armor the bed as well as energy dissipation from LWD from the mature riparian forest. Sediment deposition rates will likely increase, requiring occasional dredging of the Hill Ditch segment below Cascade Ridge Drive. The creek is unlikely to undergo drastic channel erosion due to upstream natural detention in the tributary ponds, detention ponds in the newer developments, and the fact that Effective Impervious Area will remain below the 10% threshold associated with severely degraded channels (Booth and Jackson 1997).

Table z. Existing and Future Impervious Area as Percent of Watershed Area, by Sub-basin. Effective Impervious Area (connected hydrologically to streams) would be lower.

Sub-basin	Total Area	Impervious Area (acres)		% Impervious Area		
	(acres)	Existing	Potential Future Addition	Existing	Potential Future Total	% Increase IA
Upper Carpenter	3820.9	98.9	232	2.6%	8.7%	235%
Sandy	943.9	0.5	2.9	0.1%	0.4%	580%
Johnson	726.5	3.2	2.4	0.4%	0.8%	75%
Bulson	3676.9	135.3	38.1	3.7%	4.7%	28%
Big Fisher	4032.1	85.1	40.2	2.1%	3.1%	47%
Little Fisher	1764.9	155	26.1	8.8%	10.3%	17%
Total	**14965.2**	**478.0**	**341.7**	**3.2%**	**5.5%**	**71%**

JOHNSON CREEK

WATERSHED GEOMORPHOLOGY AND GEOLOGY

Johnson Creek has a drainage area of 1.14 square miles. The creek drains the low mountains that flank the east side of the Skagit Valley. Johnson creek flows down the main strand of the Devil's Mountain Fault, a strike-slip fault that may still be active (Dragovich et al. 2002). Although its watershed is smaller than the next creek north, Sandy Creek, its alluvial fan is larger because the hillslopes along Johnson Creek have been severely destabilized by repeated faulting.

Sediment load to the Johnson Creek fan is derived from the lower half of the watershed, below a peat bog that traps sediment from the upper watershed. The ravine below the peat bog has an average gradient of 9 percent and maximum gradient of 24 percent according to the USGS topographic map. The ravine walls are 180 to 380 feet high and form a steep, narrow, inner gorge.

The ravine walls are Chuckanut sandstone and Bulson Creek conglomerate (Figure 1, geologic map) with lesser amounts of rhyolite (Dragovich et al. 2002). The geologic map also shows a large landslide deposit in the canyon. It is visible on stereo air photos as a large, down-dropped block with a nearly flat surface. Bedrock on the north side of the fault dips steeply toward the creek, a condition that promotes landsliding. In addition, in places bedrock has been altered into mylonite, a weak rock altered by extreme granulation and shearing.

A landslide inventory was performed using nine sets of historical aerial photographs dating from 1937 to 2004. The 1956, 1976, 1983 and 1995 photos were stereo pairs and provided the most information. Photos were viewed at the NRCS and Wa. DNR offices and the Skagit County i-map website. All photos but 1937 and 2 dates in the 1970s showed landslide scars and streamside canopy openings. (Canopy openings in steep channels occur when the channel is widened by sediment deposition behind debris dams, or passage of a debris flow or dam-break flood). Freshness of landslide scars was not usually evident because they were shaded or photo resolution was poor. The 1970s photos showed the inner gorge completely forested, but by 1983 the steep north valley wall of the inner gorge was visible in multiple canopy openings. The 1995 photos showed clear evidence of a dambreak flood: a fresh landslide scar with a former pond upstream and eroded channel for hundreds of feet downstream. The same areas looked disturbed in later photographs. The canopy openings were not wide enough or continuous enough to look like a debris flow.

A dam-break flood reportedly occurred in July 2004. Figure 2 shows deposits from that flood near the fan apex. This flood has been attributed by others to beaver dam failure because it occurred in summer. However, field evidence suggests it was probably caused by a landslide in a steep part of the ravine downstream from the flatter reach that beavers could inhabit.

The first half mile of the ravine was walked to observe erosion areas and evidence of sediment transport processes. In the first 900 feet of the ravine, the channel was commonly incised 4-6 feet and had eroding banks. Small boulders had been recently transported and deposited on top of sediment deposits (Figure 3). Valley wall erosion started about 900 feet upstream of the fence near the fan apex. Landslides and landslide deposits of various ages occurred from 1000 to about 2300 feet upstream from the fan apex. The creek is pinched between the valley wall and landslide deposits (Figure 4), leading to rapid incision that further destabilizes the valley walls, which in turn causes more landslides. The north valley wall has large, planar, unvegetated landslide scars in places. At 2000 feet, there was a broken debris dam and fresh landslide scar that probably corresponds to either the 1995 or 2004 dam-break floods. By 2500 feet, the valley flattens somewhat and widens, with the creek incised into the valley fill.

There was no evidence of debris flow, which would scour the channel bottom of sediment deposits and leave sediment berms high above the creek. However, conditions are favorable for a debris flow to occur -- narrow channel with frequent landslides, 10-20 percent channel gradient. If a debris flow were to occur, it would probably stop a short distance upstream of the fan apex where the gradient drops below 3 degrees, the threshold for debris flow runout (Benda and Cundy 1990). Debris flows can mobilize huge amounts of sediment by scouring the channel down to bedrock.

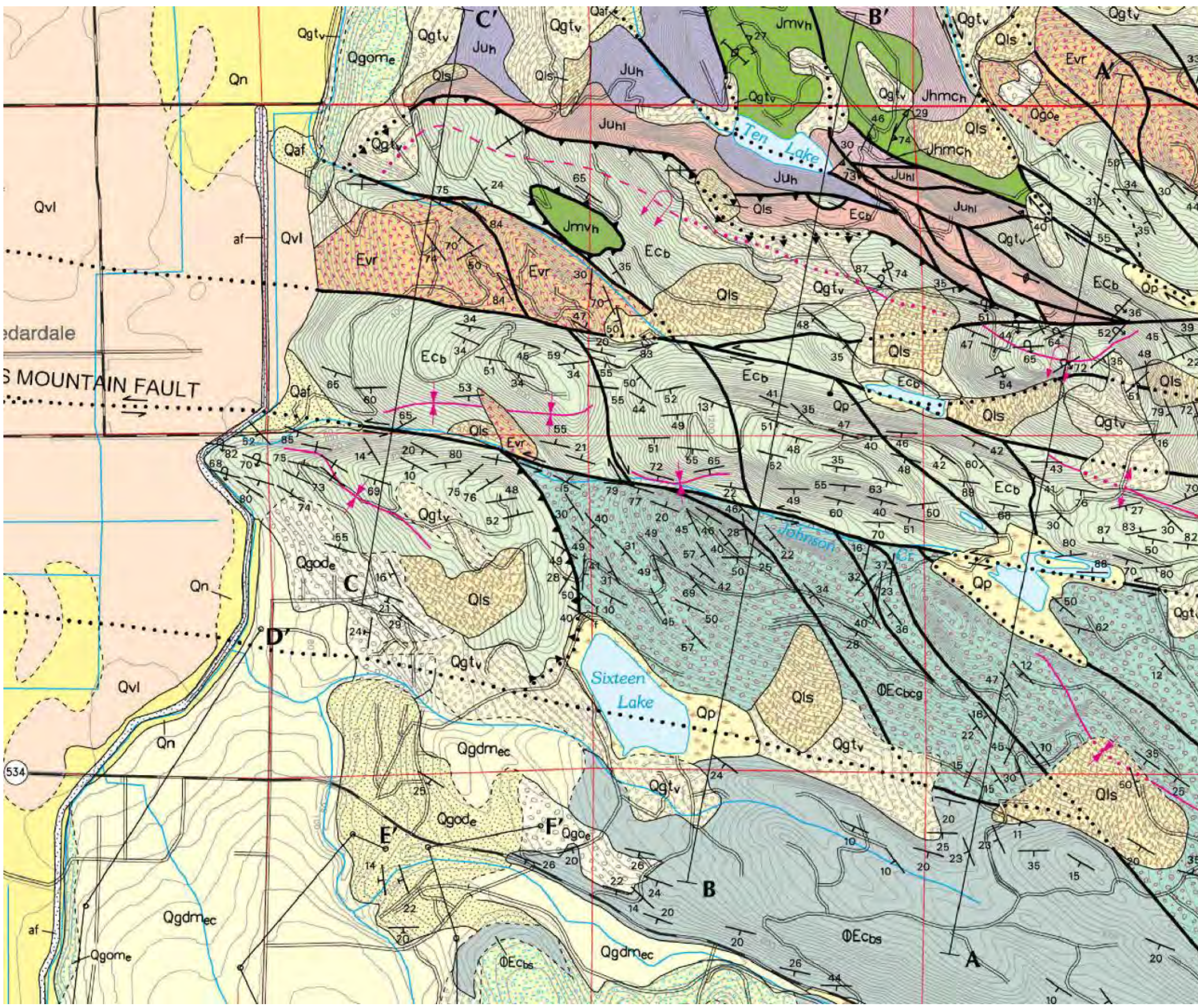

Figure 1. Geologic Map showing (from top to bottom) Sandy, Johnson and Bulson Creeks. From Dragovich et al. (2002).

Figure 2. Photo showing deposits a short distance below the fan apex from a dam-break flood in July, 2005. Photo provided by Tom Slocum, Skagit Conservation District.

Figure 3. Photo showing boulders in transport positions a short distance upstream from the fan apex.

Figure 4. Photo showing incised channel eroding a landslide deposit in the ravine

ALLUVIAL FAN GEOMORPHOLOGY

The historic alluvial fan is about 1800 feet long and 900 feet wide (see main report). The west tip of the fan has been separated from Johnson Creek by the Hill Ditch. The farm buildings were probably located there to get above Skagit River flooding. By 1937, the date of the earliest aerial photographs, Hill Ditch was already present and Johnson Creek had been moved to the far south edge of the fan, next to the bedrock valley wall.

Over the decades since Johnson Creek was diverted there, the creek has deposited well over 10,000 cubic yards of sediment. The creek is now perched about four feet above the rest of the alluvial fan (Figures 5 and 6). This causes flow to go subsurface and the creek dries up at times during the summer. In most locations, an irregular combination of old, constructed and natural levees keeps the creek in its present location. The blue arrows on show areas with gaps in the levee where the creek breaks out whenever the flow comes up. Muddy water crosses the fan and floods the two clusters of buildings on the fan on its way to Hill Ditch. The County has dredged and placed sandbags in the downstream 500 feet of the private road next to the creek during emergency flood operations (Tom Sheehan, Skagit County Emergency Management).

At the fan apex near the mouth of the canyon, the channel is no longer perched but there are other depositional landforms. There are several boulder berms, which are long, narrow, steep-sided landforms about 3.5 to 5.5 feet high and 25 to 50 feet long (Figure 7). The berms are formed of coarse sediment and contain small boulders all the way to the top. They appear to be deposited in single flood events, probably dam-break floods. They date to at least two different events, as one berm has 1-4 inch diameter alders growing on it and another 6-9 inch alders. There is a former log jam which has failed and the creek has now incised through the sediment that filled in behind the jam. There are also concrete blocks the may be remnants of a former dam. The gradient in this zone is 3 to 7 percent. The creek has downcut since the last boulder berm depositional event, but there is still a large sediment load moving through. There are large, fresh-looking, unvegetated bars with imbricated boulders that indicate high-energy transport.

At the downstream end of the fan, the creek drops down and flows for a short distance in a ditch along the private driveway, crosses the driveway in a culvert and enters Hill Ditch. Since it was last dredged in 2003 or 2004, the creek has deposited a large sandbar in Hill Ditch that extends 100 feet upstream of the bridge and 280 feet downstream. This sediment deposit, in combination with a low beaver dam built on top of the, has ponded the flow and backed water up into a large open-water wetland that extends upstream nearly to the Sandy Creek fan. This sediment accumulation has been dredged about every five years since 1990 (Dave Olsen, Diking District #3).

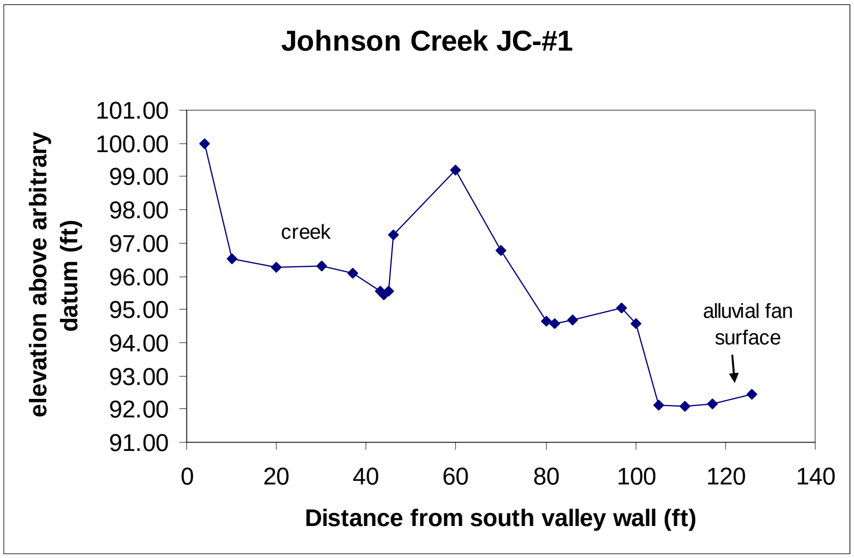

Figure 5. Cross-section JC-1 of Johnson Creek showing stream channel perched on sediment deposits

Figure 6. Photo of perched channel

Figure 7. Boulder berm in the fan apex area

SEDIMENT SIZE

The decline in gradient and channel confinement from the fan apex to the mouth causes the size of sediment to decrease rapidly. Figure x shows the maximum sediment diameter in the channel, which declines from boulders at the fan apex (420 mm or 16 inches) to cobbles in the perched channel reach, gravel at the creek mouth, and sand in Hill Ditch. The sand deposit gets finer with distance downstream, ending in very fine sand.

At XS JC-1 in the perched channel reach, the median diameter of surface sediment was 17 mm (0.7 inches) gravel (Table 1). Below XS JC-2 at the fan apex, the median diameter was 40 mm (1.6 inches) gravel.

Table 1. Johnson Creek surface sediment size from pebble counts

Location	Gradient (%)	D16 (mm)	Median Diameter D50 (mm)	D84 (mm)	Maximum Diameter (mm)
Perched channel deposits along Johnson Creek (XS JC-1)		2	17	48	160
Fan apex (XS JC-2)		7	40	103	420

WATERSHED SEDIMENT SUPPLY RATE

Sediment supply rates to Johnson Creek were estimated based on calculated volumes of dredge spoils and perched sediment and information on dredging rates provided by Diking District and Skagit County staff. The volume estimate based on deposition and dredge spoils was combined with watershed sediment supply to estimate supply rates of coarse and fine sediment. The results were compared to regional sediment yields.

Sediment deposition rates on the alluvial fan

Volume of perched channel deposits was calculated using the end-area method from surveyed cross section JC-1 (Figure 5) and additional cross-sections from the Lidar topography. The volume of dredge spoils along Hill Ditch was calculated from Lidar cross-sections by comparing the sections with dredge spoils to surveyed section HD-5 that had no dredge spoils. From at least 1990 on, dredge spoils were removed from the site. Post-1990 dredging rates were estimated from information from County and Diking District staff.

The estimated gravel deposition rate on the alluvial fan is about 1950 to 2450 cubic yards per decade (Table 2), depending on assumptions about when the creek was moved to the edge of the fan and when dredging started. The estimated sand deposition rate at Hill Ditch is about 700 cy/decade, though it has been more rapid (1500 cy/decade) in the last few years due to the 2004 dam-break flood. The total of gravel plus sand is about 2600 to 3200 cubic yards per decade. These rates reflect the sediment supply of the last 7 to 9 decades. Future sediment supply could be much higher if a debris flow were to occur.

The final column of Table 2 shows bedload sediment yield on the basis of watershed size. The estimated rates of around 200 to 400 tons/square mile/year are high, but reasonable for a small, steep basin with a large amount of landsliding and channel erosion.

Table 2. Johnson Creek minimum sediment deposition rates on alluvial fan

Location	Volume (Cubic Yards)	Time Period (yr)	Bedload Deposition Rate (CY/decade)	Bedload Sediment Yield [4] (tons/sq mi/yr)
Perched channel deposits along Johnson Creek [1]	13500 +/-1500	1934-2006 or 1910-2006	1900 +/-200 or 1450 +/-150	Gravel
Dredging of Johnson Creek upstream from Hill Ditch (removed from site)	1050 +/-250	1990-2006	650 +/-150	Gravel
Johnson Creek upstream: Sum of deposits plus dredging (gravel)		1934-2006 or 1910-2006	2450 +/-450 [3] or 1950 +/-450 [3]	322 or 257 Gravel
Dredge spoils along Hill Ditch (pre-1990)	3850 +/-750	1934-1989 or 1910-1989	700 +/-150 or 500 +/-100	92 Sand 66
Hill Ditch dredge spoils removed from site (post-1990) [2]	7750 +/-1250 or 17500 +/-22500	2003-2006 or 1989-2006	26000 +/-4000 or 10000 +/-3000	3421 Sand 1316
Total gravel plus sand [5]		**pre-1990 or post-1990**	**2800 +/-600 or 10600 +/-3150**	**368 or 1395**

1. ***Error range reflects uncertainty about Lidar elevation correction factor for brush.***
2. ***Includes 4500 CY dredged September 2006; low estimate assumes 2000 CY for earlier dredging; assumes number of dredging in 1990s assumed same as Big Fisher mouth bar. Higher rates since 1990 may be due to two dam-break floods.***
3. ***Error reflects uncertainty about when dredging started: assumed 1960 or 1910/1934.***
4. ***1.5 tons per cubic yard***

Assumes the same gravel deposition rate in both periods due to lack of data

Watershed sediment supply

The deposition rates in Table 2 underestimate the total supply of sediment to the alluvial fan for the following reasons:
1) sediment (mostly fine) deposits on the fan whenever flow breaks out away from the perched channel
2) some silt, clay and sand continue downstream in Hill Ditch
3) additional dredge spoils may have been removed from the vicinity.

Estimation of the long-term average amount of fine sediment supplied by Johnson Creek to the alluvial fan and Hill Ditch was done as follows. The size distribution of sediment from ravine wall landslides was obtained from the soil survey (USDA 1989). The approximate proportion of texture classes for Johnson Creek was estimated to be 30 percent gravel-cobble, 40 percent sand-granule, and 30 percent silt-clay (Table 3). Using 2200 cy/decade supply of gravel-cobble from Table 2, the amount of sand and silt-clay were estimated proportionately as 2900 cy/decade and 2200 cy/decade, respectively. This gives a total sediment yield of 960 (range 660-1300) t/sq mi/yr, which is reasonable for a steep, small basin with a high rate of landsliding (Larson and Sidle 1980).

For the pre-1990 period, 700 cy/decade of sand were known to be dredged from Hill Ditch at the mouth of Johnson Creek meaning that 2200 cy/decade of sand were not accounted for. The remaining sand and all of the silt-clay were apportioned between deposition on the alluvial fan (when flow breaks out from the perched channel) and transport downstream in Hill Ditch using assumed sediment trapping ratios. The resulting long-term average estimates of sediment supply from Johnson Creek to lower Hill Ditch are 220 cy/decade of sand and 1100 cy/decade of silt-clay (Table 3). Post-1990 rates have likely been at least an order of magnitude higher.

Table 3. Johnson Creek total estimated long-term average sediment load based on Soil Survey proportions of size fractions

Size Fraction	Soil # 48 downstream half of canyon Proportions (%)	Soil #28 upstream half of canyon, plus valley walls Proportions (%)	Selected proportions for Johnson Creek (%)	Total Sediment Load (Range) Extrapolated from Known Gravel Load (CY/decade)	Amount not accounted for in Table 2 (CY/decade)	Assumed proportion/rate deposited on fan from cross-fan flow (CY/decade)	Amount going downstream in Hill Ditch (CY/decade)
Gravel + Cobble	35	25	30	2200 (1950-2500) *known*	0	0	0
Sand + Granule	35	45	40	2900 (2000-3900)	2200 (1300-3200)	90% 1980 (1170-2880)	220 (130-320)
Silt + Clay	30	30	30	2200 (1500-1900)	2200 (1500-2900)	50% 1100 (750-1450)	1100 (750-1450)
Total of All Size Fractions	100	100	100	7300 (5400-8300)	4400 (2800-6100)	3080 (920-4330)	1320 (880-1770)
Total Sediment Yield (t/sq mi/yr)				960 (660-1300)			

CONCLUSIONS AND RECOMMENDATIONS FOR JOHNSON CREEK

The sediment load of Johnson Creek is far higher than the other Sub-basins in the Carpenter Creek watershed. This is probably due to the watershed's steep topography and location on the main strand of the Devil's Mountain Fault.

The following approaches are recommended:

1. Allow the creek to reoccupy all, or at least a sizeable portion of, its historic alluvial fan. This would alleviate much of the current flooding problems on the fan itself and the need for dredging along Johnson creek.
2. Construct an open-water wetland (or utilize existing wetland) between Hill Ditch and the base of the fan to trap fine sediment. Without this, a sizeable fraction of the sand and finer sediment load would be transported down the alluvial fan to Hill Ditch so dredging would still be required.
3. The Total Sediment Load column in Table 3 can be used for planning the area needed for long-term (~100 year) sediment storage on the alluvial fan. It should be recognized that short-term (less than 10 years) sediment supply could easily be more than 10 times higher than the average rates in Table 3.
4. Any solution should anticipate rapid sediment deposition at the fan apex following a debris flow or dam-break flood. This could cause the existing channel to completely fill with sediment, triggering a sudden switch of channel location that could bypass the designated sediment storage area.

The following approaches are not recommended due to the high sediment load and potential for catastrophic events:

1. The boulder-berm zone on the apex of the fan is a high-energy environment subject to sudden deposition of bouldery deposits. Sediment storage facilities there would be highly likely to fail.

2. Sediment storage facilities farther down the fan would be less likely to be directly destroyed by debris impact or scour, but would likely fill up or be bypassed in the event of a large sediment-producing event such as a dam-break flood. For instance, the recent dam-break flood has required 2 dredging of sand in two to three years totaling 6500 to 9000 CY and probably yielded nearly an equal amount of silt and clay that would also deposit in a sediment pond, plus at least 2000 CY of gravel.

SANDY CREEK

WATERSHED GEOMORPHOLOGY AND GEOLOGY

Sandy Creek has a drainage area of 1.48 square miles. The creek drains the low mountains that flank the east side of the Skagit Valley. The creek flows down a splay fault within the Devil's Mountain Fault Zone, a strike-slip fault zone that may still be active (Dragovich et al. 2002). Although Sandy Creek's watershed is larger than Johnson Creek to the south, its alluvial fan is smaller because the sediment supply is lower. The hillslopes and channel appear far more stable, suggesting that the splay fault has been far less active than the main fault that Johnson Creek follows.

The Sandy Creek ravine has an average gradient of 12 percent and maximum gradient of 22 percent according to the USGS topographic map. The creek has two forks, the south fork being flatter. The ravine walls are 160 to 220 feet high and form a steep, narrow, inner gorge. The ravine walls are underlain by glacial Vashon till and (mostly) Chuckanut sandstone along the mainstem, rhyolite on the south fork, and a mixture of rock types on the north fork (Dragovich et al. 2002; Figure 1 same geologic map as Johnson Creek). Although not shown on the geologic map, dense glacial till is commonly exposed in the creek bottom below the forks.

The first half mile of the ravine was walked to observe erosion sources and sediment transport processes. The first 500 feet upstream from the fan have a slightly entrenched, plane bed channel without? gravel bars. The channel steepens and the next 500 feet have a step-pool channel that is incised 3-5 feet deep. The channel then steepens to a cascade with some bedrock falls. Revegetated landslide scars were observed at 1600 and 2300 feet upstream from the alluvial fan. The only active erosion sources were local areas of eroding streambanks -- mostly very dense glacial till that appears to erode slowly (Figure 8), but some alluvium as well further downstream. The bed and banks were generally erosion-resistant materials. Overall, the creek appeared to be transporting very little sediment. The inner gorge was densely forested, and many boulders and cobbles were covered with moss (Figure 9). Abundant sandstone boulders formed stable steps in the channel.

A landslide inventory was performed using nine sets of historical aerial photographs dating from 1937 to 2004. Photos were viewed at the NRCS and Wa. DNR offices and the Skagit County i-map website. The 1937 aerial photograph showed that the ravine walls and creek bottom had recently been clear-cut as far upstream as the bend. No landslides or channel response were visible in 1937 but the photo resolution was quite poor. Definite landslides were visible only in the 1956 and 1983 air photos. The 1956 photos showed two recent narrow landslides about one mile upstream of the forks, with a long reach of open-canopy channel immediately upstream. In addition, there was a large, forested landslide scar on the south valley wall near the mouth of the ravine. In 1983, 2 narrow landslides occurred within the same large landslide scar. The slides were located directly beneath a new house that had been built on the ridge crest. There was a possible narrow landslide far upstream in the 1998 photos, but it may have been a bedrock chute. Overall, the Sandy Creek watershed has had long periods of low sediment supply punctuated by occasional, mostly small, landslides.

Figure 8. Photo of eroding glacial till streambank in ravine.

Figure 9. Photo of moss-covered boulders in ravine

ALLUVIAL FAN GEOMORPHOLOGY

The historic alluvial fan is about 600 feet long and 1200 feet wide (Figure x 11X 17). Hill Ditch goes around the fan and abuts it only on the north edge where Sandy Creek discharges. By 1937, the date of the earliest aerial photographs, Hill Ditch was already present and Sandy Creek had been moved to the far northeast edge of the fan, next to Kanako Lane and the valley wall. It flows upstream toward Hill Ditch, which it joins just downstream of a County-maintained bridge at the entrance to Kanako Lane. Sediment deposits have accumulated in the 10 years or so since the last dredging and now nearly block the bridge opening. The current bridge was constructed in 1983. Dredging the bridge and Hill Ditch has typically been done every 5 or 6 years but is less frequent now due to difficulty obtaining permits (Dave Olsen, Diking District 3; and Cliff Butler? Skagit County Public Works).

Over the decades since Sandy Creek was diverted there, thousands of cubic yards of sediment have been dredged from the creek. Most of the dredge spoils have been placed west of the creek. The creek has been repeatedly dredged deeply enough that it has not become perched above the alluvial fan. The dredge spoils form a barrier preventing the creek from flowing onto the fan (Figure 10). Since Kanako Lane is a private road, there are no records kept about dredging or flooding problems on the fan. No emergency operations have been done there (Tom Sheehan, Skagit County Emergency Management). There is a depositional zone above the upstream culvert and the spoils levee is fairly low, so that is likely where problems tend to occur. The gradient in the culvert zone is 0.46%.

Upstream from the second culvert, the channel is no longer a roadside ditch and assumes natural channel dimensions. The gradient in the fan apex reach is 3 percent and there are no depositional landforms other than small bars and a floodplain.

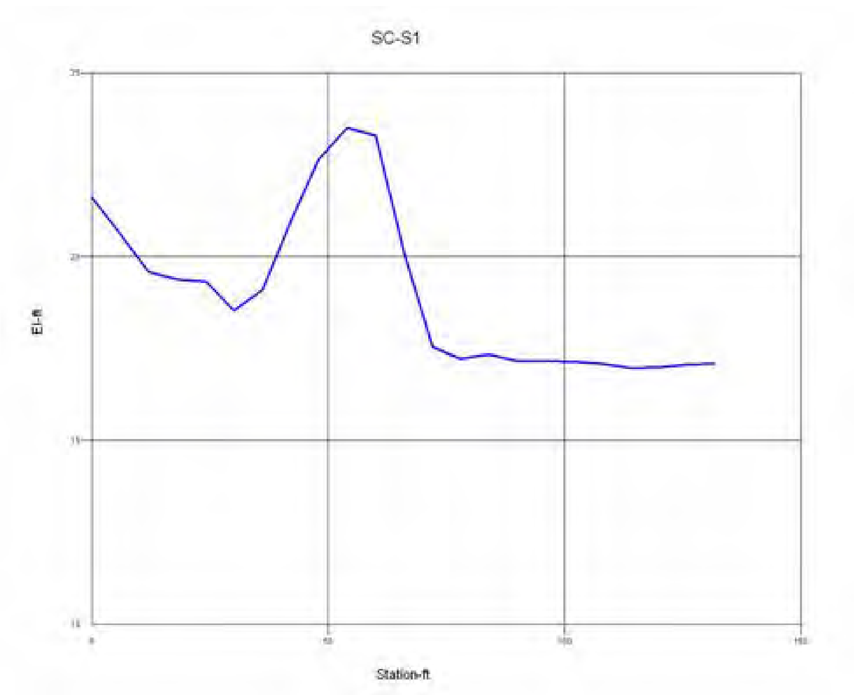

Figure 10. Cross-section looking upstream, showing Sandy Creek to the left of the dredge spoils at the edge of the valley wall.

SEDIMENT SIZE

The decline in gradient and channel confinement from the fan apex to the mouth causes the size of sediment to decrease rapidly. The maximum sediment diameter in the channel, which declines from large cobbles at the fan apex (190 to 280 mm; 7 to 11 inches) and upper fan, to small cobbles in the lower ditched channel reach. The ditch keeps the flow confined enough to convey small cobbles all the way to the creek mouth. The deposits in Hill Ditch are primarily gravel and sand. The sand deposit gets finer with distance downstream.

In contrast to the coarsest particles, the median diameter of sediment was fairly constant throughout the length of the fan. The median diameters fell in the coarse gravel class, at about 29 mm or 1.1 inches (Table 4). At the fan apex cross-section, the gravel/small cobble sediment load was moving through around a framework of large cobbles that move much less frequently.

Table 4. Sandy Creek surface sediment size from pebble counts

Location	Gradient (%)	D16 (mm)	Median Diameter D50 (mm)	D84 (mm)	Maximum Diameter (mm)
Ditched channel 20 ft. upstream of bridge		12	29	50	90
Ditched channel along side of fan (XS SC-1)		12	33	80	220
Fan apex (XS SC-2)	3.1	10	27	84	280

SEDIMENT SUPPLY

Sediment supply rates to the Sandy Creek alluvial fan were estimated based on calculated volumes of dredge spoils, information on dredging rates provided by Diking District and Skagit County staff, and estimated rates of landsliding and bank erosion. The results were compared to regional sediment yields.

The volume of dredge spoils along Sandy Creek was calculated using the end-area method from LiDAR-generated cross sections of the spoils (Table 5). There were nearly 5000 cubic yards of dredge spoils, yielding a rate of 500 to 650 cy/ decade depending on when they started accumulating. The bedload sediment yield is between 51 and 66 tons/sq mi/yr if all the sediment came from Sandy Creek.

Dave Olsen (Diking District #3) observed that Sandy Creek delivers very little fine sediment to Hill Ditch. After at least 10 years accumulation since the last dredging, the sandbar only goes 22 feet downstream compared to 280 feet on Johnson Creek only three years after dredging. The amount of sediment available to be removed at the Kanako Lane bridge was estimated at about 200 cubic yards based on a LiDAR cross-section through the bar and the elevation of sediment relative to the bridge. Dredging was done following the 1990 and 1995 floods. The resulting rate is about 350 cy/decade, of which about 90 cubic yards would be sand. This seems reasonable compared to 700 cy/decade of sand removal at the mouth of Johnson Creek.

There is uncertainty about how long the bridge has been dredged and whether prior to 1990 the spoils may have been placed along Sandy Creek instead of hauled away. The final row of Table 5 assumes dredging at the bridge since it was constructed in 1983.

Table 5. Sandy Creek dredge spoils and dredging rates

Location	Volume (Cubic Yards)	Time Period (yr)	Bedload Deposition Rate (CY/decade)	Bedload Sediment Yield[2] (tons/sq mi/yr)
Dredge spoils along creek and private road (done by property owners)	4650 +/- 900	1934-2006 or 1910-2006	650 +/-150 or 500 +/-100	66 or 51 Mostly Gravel
Dredging of bridge and Hill Ditch (County and Diking District #3); spoils removed	600 +/-150[1]	1990-2006	350 +/-100	35 75 % Gravel 25 % Sand
Sum of dredge spoils, plus dredging since bridge built in 1983	5650 +/-1150	1934-2006 or 1910-2006	800 +/-150 or 600 +/-150	81 or 61

1. Includes deposits scheduled to be dredged 2006; error reflects uncertainty about depth of dredging.
1.5 tons per cubic yard

The average rate of landslide delivery to Sandy Creek is between 250 and 550 cy/decade (Table 6). The lower rate assumes the forested landslide visible in the 1956 air photo was ancient and the higher rate assumes it occurred in about 1940. Rough estimates of streambank erosion of till, gravelly alluvium and glaciomarine drift banks were made for each size fraction, totaling between 50 and 550 cy/decade. Total sediment supply comes to between 300 and 1100 cy/decade for all size fractions. This corresponds to a watershed sediment yield of about 30 to 110 cy/sq mi/yr, which is about one tenth of Johnson Creek and about 10 times greater than Bulson Creek. This order of magnitude seems correct. Rather than a steady load, the sediment supply from the creek comes in pulses following landslides followed by one to several decades with low supply.

Table 6. Sandy Creek total estimated sediment supply, divided into size fractions based on field observation of bank erosion texture and Soil Survey proportions for landslides

Size Fraction	Landslides Soil #28 gravelly loam (%)	Landslide Delivery to Creek (CY/decade)	Streambank Erosion (CY/decade)	Total Sediment Delivery (CY/decade)	Sediment Yield (t/sq mi/yr)
Gravel + Cobble	25	50-150	10-150	60-300	6-30
Sand + Granule	45	100-250	20-200	120-450	
Silt + Clay	30	100-150	20-200	120-350	
Total of	100	250-550	50-550	300-1100	30-111

All Size Fractions					

There is a discrepancy between the 600 to 800 cy/decade gravel volume calculated from dredge spoils (Table 2) and 60 to 300 cy/decade supply rate of gravel from landslides and streambank erosion (Table 3). Possible explanations include:

- The dredge spoils along Sandy Creek may not all have come from the creek. Fill may have been hauled in, as well as dredge spoils from Hill Ditch.
- Landslides were much coarser grained (higher gravel content) than indicated by the soil survey.
- Additional landslides occurred during periods without air photographs
- Dredging started in the late 1800s which would reduce the dredging rate to about 500 cy/decade.

CONCLUSIONS AND RECOMMENDATIONS FOR SANDY CREEK

Sandy Creek has a much lower sediment load than Johnson Creek. The recent sediment load has been quite low due to a probably lack of landslides near the mouth in the last 20+ years. Consequently, a greater number of alternatives appear feasible for Sandy Creek.

Allowing the creek to reoccupy at least a portion of its alluvial fan would have the to lower degree of risk and would eliminate this source of Hill Ditch flooding and the need for dredging at the Kanako Lane bridge. For purposes of planning long-term (century-scale) sediment storage in the alluvial fan, use about 500 CY per decade (the low end of the error range rates in Table 5).

Moving the Kanako Lane bridge upstream from Sandy Creek's confluence with Hill Ditch would eliminate the need for dredging at the bridge. Sediment deposits would still tend to block Hill Ditch with resulting effect on upstream flood.

The risk of a sediment pond near the apex of the alluvial fan failing, or filling in a single year, is much lower than for Johnson Creek. For evaluating smaller sediment-storage facilities, it should be recognized that individual landslides could deliver 200 to 2000 CY of sediment to the channel that could be rapidly moved downstream in a short period. Although we found no evidence of historic dam-break floods or debris flows, they are possible given the confinement and gradient of the canyon and could destabilize what is currently a fairly stable ravine with a low sediment load. Sandy Creek does have a sizeable alluvial fan, indicating that periods with higher sediment loads have likely occurred in the past and could potentially occur again.

BULSON CREEK

WATERSHED GEOLOGY AND GEOMORPHOLOGY

Bulson Creek has a watershed area of 5.74 square miles and drains low hills on the east side of the Skagit Valley near Conway. The watershed has low relief and is underlain by glacial deposits. There is no alluvial fan at the mouth of the creek and no reported sediment problems.

Bulson Creek has three forks, each of which has a steeper ravine section between the mainstem creek and upland plateau. The North Fork ravine is 70 feet deep with bedrock cliffs and has an average gradient of 20 percent, much of which is bedrock cascades and falls. The Middle Fork has an average gradient of 5 percent with a steep section of 21 percent. The South Fork has a 5-6 percent gradient without any steeper sections. The ravines of the south and middle fork are subdued and only 20-30 feet deep, respectively.

Figure 1 (same geologic map as Johnson and Sandy) shows geology of the Bulson Creek watershed from Dragovich et.al (2002). The mainstem, South Fork, and lower reach of the North Fork flow in flat-bottomed valleys inset within a glaciomarine drift terrace, and the creek rarely encounters the valley edge. The Middle Fork flows through deltaic outwash sands and gravels, which can be quite erodable. The North Fork flows through till and a short section of deltaic outwash gravels, but most of its elevation gain is evidently through bedrock rather than the erodable glacial deposits shown on the geologic map.

SEDIMENT

Based on limited field checking, the Middle Fork is by far the largest source of gravel. Very little gravel from the South Fork reaches the confluence with the Middle Fork. The South Fork conveys the gravel load from the Middle Fork down to the confluence zone with the North Fork, which conveys a much smaller load of gravel based on the size and area of gravel bars at the forks.

The map (see main report) shows sediment type and maximum sediment size in lower Bulson Creek. The maximum size of sediment decreases from 170 millimeters (7 inches) in the South Fork at the forks to 85 millimeters (3 inches) in the mainstem creek at cross section BC-1. The median diameter of gravel at BC-1 is 16 millimeters (0.6 inches). The gradient is 1.5 percent near the road and decreases downstream. The bed is a mixture of sand and gravel, with gravel bars and riffles and long, sandy pools in between.

Although much of Bulson Creek's gravel load drops out in depositional zones at the forks and further upstream, some 1-inch-minus gravel continues all the way downstream to Hill Ditch. The bar in Hill Ditch at Bulson Creek has never been dredged in the memory of the farmer at the creek mouth or the Dike District Commissioner. The bar consists mostly of sand as shown in Figure (11 x 17 map) and extends 300 feet downstream from the creek. The bar is about five feet high based on a comparison of cross section HD-8 with cross section HD-7 upstream from the bar. The bar causes an abrupt step-up in the bottom of Hill Ditch.

SEDIMENT SUPPLY RATE TO HILL DITCH FROM BULSON CREEK

Bulson Creek has a low sediment yield due to its combination of low gradient, unconfined valleys with depositional zones that trap sediment, and cohesive fine sediment source materials.

The bar in Hill Ditch is about 700 cubic yards. The accumulation rate of bar sediment is about 75 to 100 cubic yards/decade, assuming Hill Ditch was built in 1910 or 1934, respectively. This also assumes that the bar has never been dredged since Hill Ditch was constructed.

Sediment yield was estimated by determining which Sub-basins deliver sediment, estimating the proportion of each sediment size class by Sub-basin based on soil type, and selecting appropriate sediment yields for small watersheds with similar characteristics. The sediment yields for each Sub-basin were adjusted until the results matched the two known parameters: 1) the rate of gravel and sand accumulation in the Hill Ditch bar, and 2) the majority of gravel comes from the Middle Fork ravine.

Table 7 shows the resulting estimate of sediment delivery by size fraction. The estimated total rate is about 300 cubic yards/decade, corresponding to a sediment yield for the whole watershed of about 10 t/sq mi/yr. This low sediment yield is reasonable for a low gradient watershed with a high proportion of cohesive fine sediment.

Table 7. Estimated sediment delivery rates from Bulson Creek to Hill Ditch in cubic yards per decade

Silt +Clay	Sand+Gravel	Gravel	Total
200 +/-100	100 +/-50	30+/-20	330 +/-170

<u>References Cited</u>

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APPENDIX C – TECHNICAL MEMORANDUM

HYDROLOGIC RUNOFF AND HYDRAULIC MODELING

1.0 HYDROLOGY AND HYDRAULICS

The following technical memorandum summarizes the hydrologic and hydraulic assessment of Fisher Slough and the contributing watershed. Items addressed in this section include:

- Summary of the hydrologic characteristics of the Carpenter Creek Watershed
- Peak flood magnitude and frequency from the contributing sub-basins of the Carpenter Creek Watershed in particular Sandy Creek, Johnson Creek, Bulson Creek, Big Fisher Creek, and Little Fisher Creek.
- Development of HEC-HMS runoff hydrographs.
- HEC-RAS Carpenter Creek (Hill Ditch) Routing

1.1 Watershed Characteristics

Fisher Slough's 23 square mile watershed has six contributing sub-basins with varying watershed characteristics (area, stream lengths, land-use, soil types, and % imperviousness). The soil type, land-use and percent imperviousness, are combined to develop a weighted Curve Number for each sub-basin and summarized in **Table 1**. Readers are referred to Figure 1 for an overview of the watershed.

Table 1. Fisher Slough Watershed Characteristics

Basin Name	Area (Sq. Miles)	Stream Length (Miles)	Weighted CN
Carpenter Creek	5.5	8.9	62.7
Sandy Creek	1.5	2.7	60.0
Johnson Creek	1.1	3.1	60.1
Bulson Creek	5.8	6.4	61.1
Big Fisher Creek	6.3	7.1	65.9
Little Fisher Creek	2.8	3.0	70.6
Carpenter Creek Watershed	23.0	31.3	63.7

Land Use and Land Cover

The areal estimates of existing land use and land cover were developed from the 2001 National Land Cover Dataset (NLCD). Areal estimates of future land use were based on full built-out conditions of the current zoning as shown in the Skagit and Snohomish County Comprehensive Plan (2000, and 2005). Spatial representations of the broad variety of land uses and land cover were simplified into the following six general categories:

- Bare land
- Forest
- Agriculture and pasture land
- Rural development
- Urban development
- Water

In addition to the 6 general categories of land use, imperviousness was estimated by calculating roadway centerline lengths and typical roadway widths for each sub-basin. On average the roadways represent one percent of the total sub-basin area and was applied to each sub-basin in calculating the weighted curve number for existing conditions.

Soil Delineation

Surface geology and soil cover was determined using the Soil Survey Geographic Database (SSURGO) development by the Natural Resources Conservation Services (NRCS, 1994a; NRCS, 1994b). A similar approach used in determining areas for land use was applied to the surface soils maps by overlaying the SSURGO dataset in GIS with the sub-basin delineations. Soils were classified based on the SCS hydrographic soil identifiers and areas were tabulated within GIS.

Precipitation Distribution

Precipitation depths for the watershed were derived from two data sources which include:

- NOAA Precipitation-Frequency Atlas of the Western United States (NOAA, 1973)
- Isopluvial Boundaries for Western Washington (Schaefer et al., 2002)

A single mean depth was assumed for the watershed and is summarized below in **Table** . An SCS 24-hour Type 1A storm distribution was applied to each of these depths. Mean annual rainfall for the area is approximately 37 inches (NWS, 1965).

Table 2. Precipitation Depths for Carpenter Creek Watershed

Return Period, Duration	(NOAA, 1973) Depth (in)	(Schaefer et al, 2002) Depth (in)
2 Yr, 24 Hour	1.69	2.25
5 Yr, 24 Hour	2.24	2.60
10 Yr, 24 Hour	2.48	2.75
25 Yr, 24 Hour	2.88	3.25
50 Yr, 24 Hour	3.21	3.75
100 Yr, 24 Hour	3.50	4.50

1.2 USGS Rainfall Runoff Estimates

Initial runoff estimates were developed using the USGS were used to estimate peak discharge rates and flood frequencies of storm events for each of the sub-basins (Sumioki et al., 1998). Applying the regression equations with drainage areas, precipitation and return period coefficients shown in **Table 3** produces the values shown in Table 16. These estimates were used to check and compare with HEC-HMS modeling output results.

Table 3. Magnitude and Frequency of Discharge for Carpenter Creek Watersheds

Return Period	Carpenter Creek	Sandy Creek	Johnson Creek	Bulson Creek	Big Fisher Creek	Little Fisher Creek
	Q(cfs)	Q(cfs)	Q(cfs)	Q(cfs)	Q(cfs)	Q(cfs)
2	90	30	20	100	110	50
10	170	50	40	170	180	90
25	200	60	50	210	230	110
50	240	80	60	240	260	130
100	260	80	70	270	290	140

1.3 HEC-HMS Modeling

A HEC-HMS hydrologic model developed by the US Army Corps of Engineers Hydrologic Engineering Center (HEC) was constructed for each of the six Fisher watershed sub-basins. When developing a hydrologic, precipitation runoff model, the following processes are modeled.

- Losses – SCS Curve Number
- Transform – SCS Unit Hydrograph
- Baseflow – Constant Monthly
- Sub-basin Routing – Muskingham Cunge

Losses – SCS Curve Number

The SCS curve number (CN) estimates the total excess precipitation from a storm based on an empirical curve number that takes into account soil cover, land use, and antecedent moisture conditions. Two scenarios of CNs were developed; existing and future. CNs for this study were derived from the union of the SSURGO dataset and land use datasets and basin delineations. The existing condition scenario assumed the typical impervious coverage as discussed within the literature (NRCS, 1986). Future conditions incorporated expected changes in impervious coverage for each land use based on the Skagit and Snohomish County comprehensive plans. For both scenarios no soil moisture accounting was performed and it was assumed average antecedent runoff condition existed prior to the onset of the storm. The initial un-calibrated CNs are summarized below in **Table 4**.

Table 4. Initial Area Weighted CN for the Carpenter Creek Tributaries

Basin Name	Area (Sq. Miles)	Existing Weighted CN	Future Weighted CN
Carpenter Creek	5.5	62.7	73.5
Sandy Creek	1.5	60.0	76.1
Johnson Creek	1.1	60.1	60.1
Bulson Creek	5.8	61.1	72.1
Big Fisher Creek	6.3	65.9	74.5
Little Fisher Creek	2.8	70.6	74.1
Carpenter Creek Watershed	23.0	63.7	73.5

Transform – SCS Unit Hydrograph

SCS unit hydrograph method was used in transforming excess precipitation into runoff. Lag estimates were determined for each sub-basin using the approach identified in "*Urban Hydrology for Small Watersheds*" (NRCS, 1986).

Baseflow – Constant
A constant baseflow estimate for each sub-basin is summarized in **Table 5** and is based on streamflow gaging conducted in September 2000 (Pitz et Al., 2000). These values only represent summer low flow and will need to be revised to reflect winter conditions.

Table 5. Baseflow estimates for Carpenter Creek Sub-basins

Basin Name	Baseflow CFS)
Carpenter Creek	0.50
Sandy Creek	0.20
Johnson Creek	0.10
Bulson Creek	0.80
Big Fisher Creek	0.50
Little Fisher Creek	0.50

Tributary Routing – Muskingham-Cunge
The Muskingum-Cunge channel routing model was chosen for tributary routing. The respective lengths of the streams were based on stream centerline delineations provided by Skagit County GIS. The channel section geometry parameters that were required for this routing model were obtained from data collection efforts performed in June of 2006. Slopes were determined from either data collection efforts or extrapolating elevations from the 10-meter DEM. Channel and floodplain Manning's roughness estimates were based on visual observations in the field (Barnes, 1967) and ranged from 0.042 to 0.065 for in-channel and 0.080 to 0.120 for floodplain roughness. The sensitivity of these values was not explored.

Channel routing was necessary for all sub-basins except Carpenter Creek and Johnson Creek. Further dividing of the sub-basins was required to combine analogous reaches of the basins or to incorporate hydraulic control points (e.g. culverts, bridges, etc.). Routing of Hill Ditch itself was performed within an unsteady hydraulic model (HEC-RAS) and will be discussed in a later section. The following discussion only addresses the routing of the tributary basins to Hill Ditch.

HMS Existing Conditions Modeling and Calibration
There is limited stream flow gaging data available within the watershed except for a small dataset from 1949 through 1970 of annual peak discharge in the upper Carpenter Creek sub-basin (USGS Gage #12200700). Without sufficient observed data to calibrate the hydrologic model a comparison with regional regression equations was performed to qualitatively assess the modeling results and to perform a simple calibration of the basins.

Calibration of the existing condition model was conducted by comparing the NOAA based precipitation HMS results with the regression based discharges. This precipitation dataset was chosen to calibrate the model since the source data is the same used to develop the regressions for the region. Sensitivity of the CNs and Lag estimates was conducted to evaluate the watershed's response to each parameter. Adjustments to CNs and lag resulted in all predictions falling within the standard error of the regressions (Approximately +/-50%). Using the calibrated CNs and lag estimates an improved precipitation dataset (2002) that incorporates more years of gaged precipitation was selected. Comparison of the HMS results showed that during low return period event (≤ 25YR) the model predicted peak discharge rates similar to those calculated with the regressions. However during high return period events (≥ 50YR) the HMS model predicts higher peak discharges by 37% to 177%.

The reliability of predicted discharges should be used with caution since without adequate streamflow gaging a typical calibration of the model was not conducted. Future modeling efforts should compare these results with surrounding watershed with sufficient gaging records to provide a better assessment of runoff experienced within the watersheds.

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The reliability of predicted discharges should be used with caution since without adequate streamflow gaging a typical calibration of the model was not conducted. Future modeling efforts should compare these results with surrounding watershed with sufficient gaging records to provide a better assessment of runoff experienced within the watersheds.

HMS Modeling of Future Conditions

Future conditions were modeled using information developed in the landscape assessment, future conditions analysis. In all sub-basins, except Johnson Creek, peak runoff estimates increased for the future conditions modeling. Since no significant changes in land use practices within the Johnson Creek watershed the existing and future hydrographs were the same.

Figures 1-6 summarize the HEC-HMS modeling results for existing and future conditions at the mouths of the tributaries to Carpenter Creek (Hill Ditch).

Figure 1.
Figure 2.
Figure 3.
Figure 4.
Figure 5.
Figure 6.
Figure 7.
Figure 8.
Figure 9.
Figure 10.

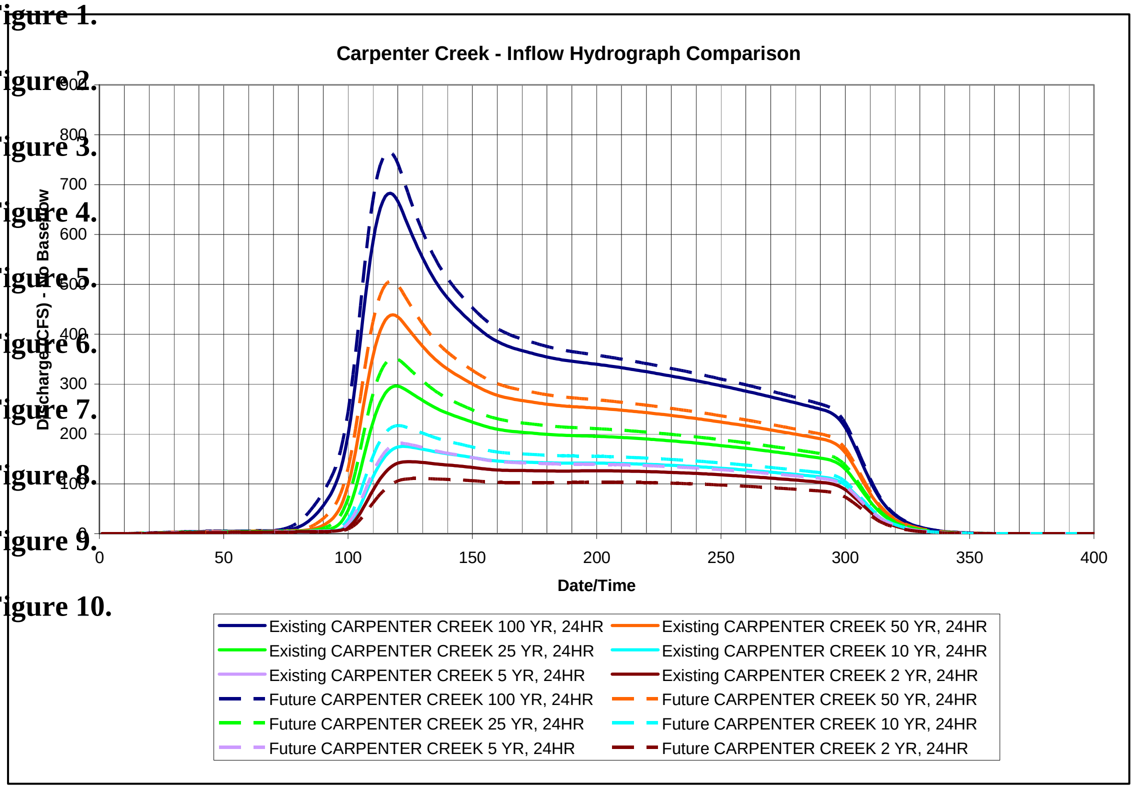


Figure 1. Comparison of Carpenter Creek Existing and Future Conditions Hydrographs

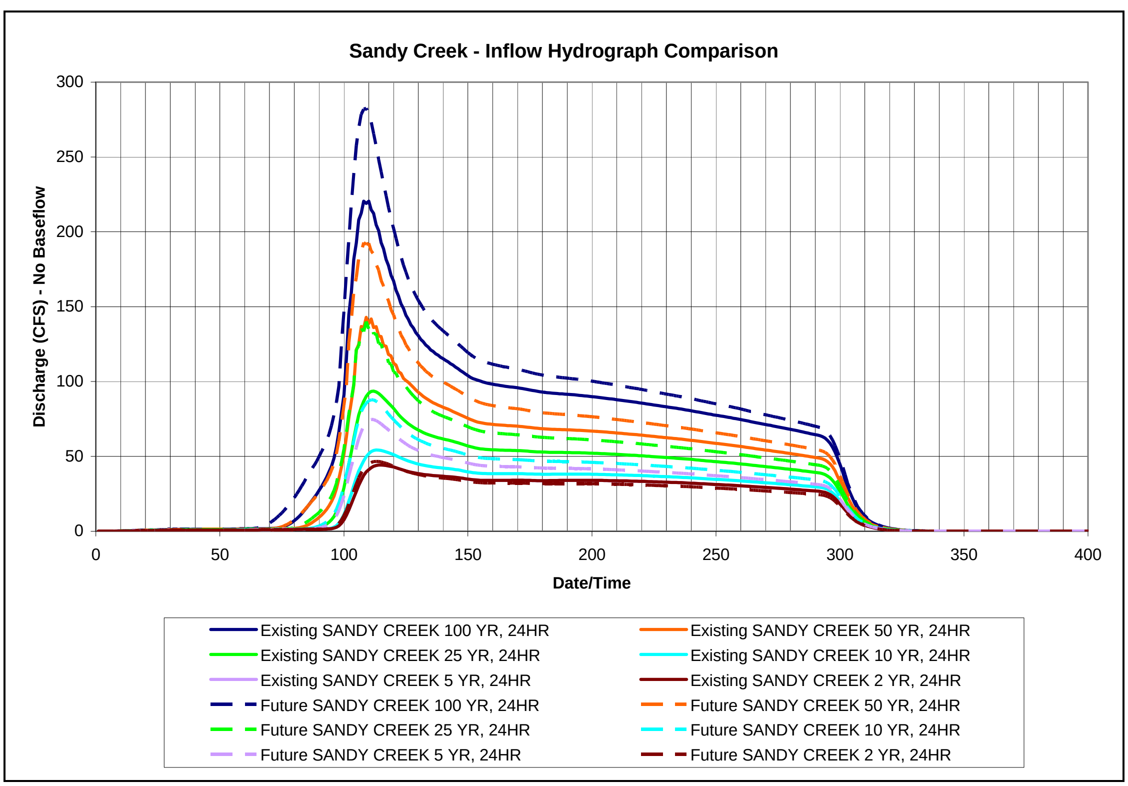


Figure 2. Comparison of Sandy Creek Existing and Future Conditions Hydrographs

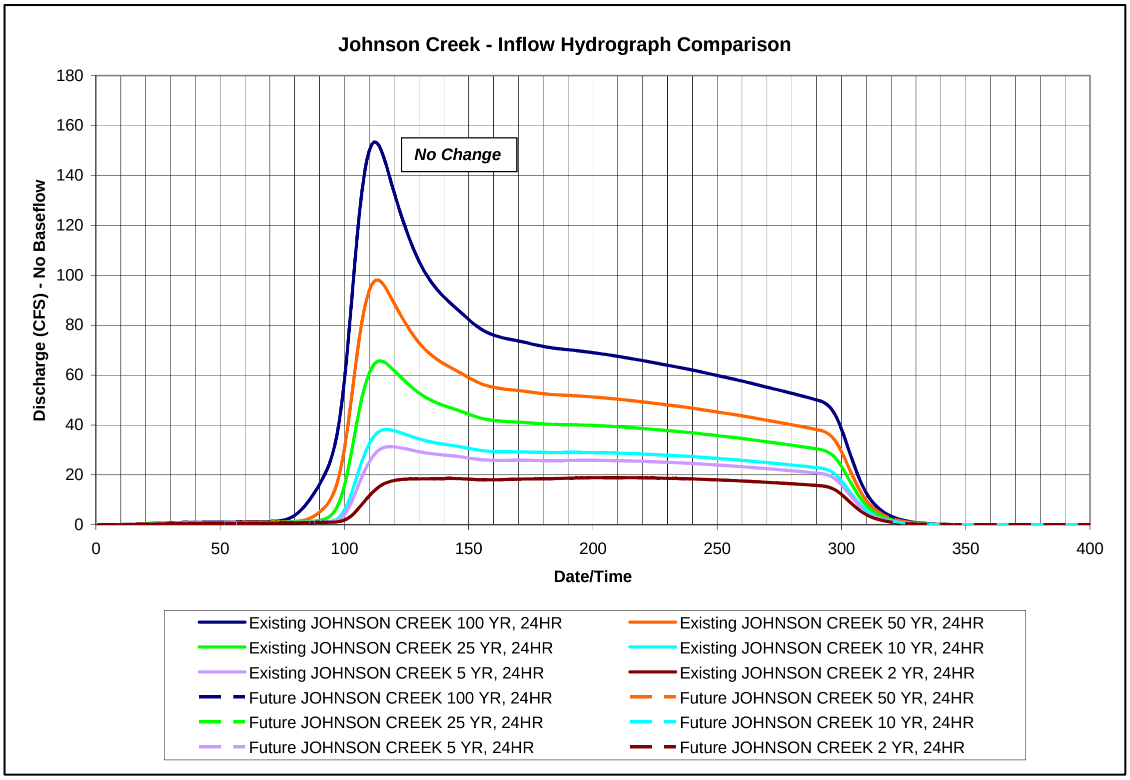


Figure 3. Comparison of Johnson Creek Existing and Future Conditions Hydrographs (No Change)

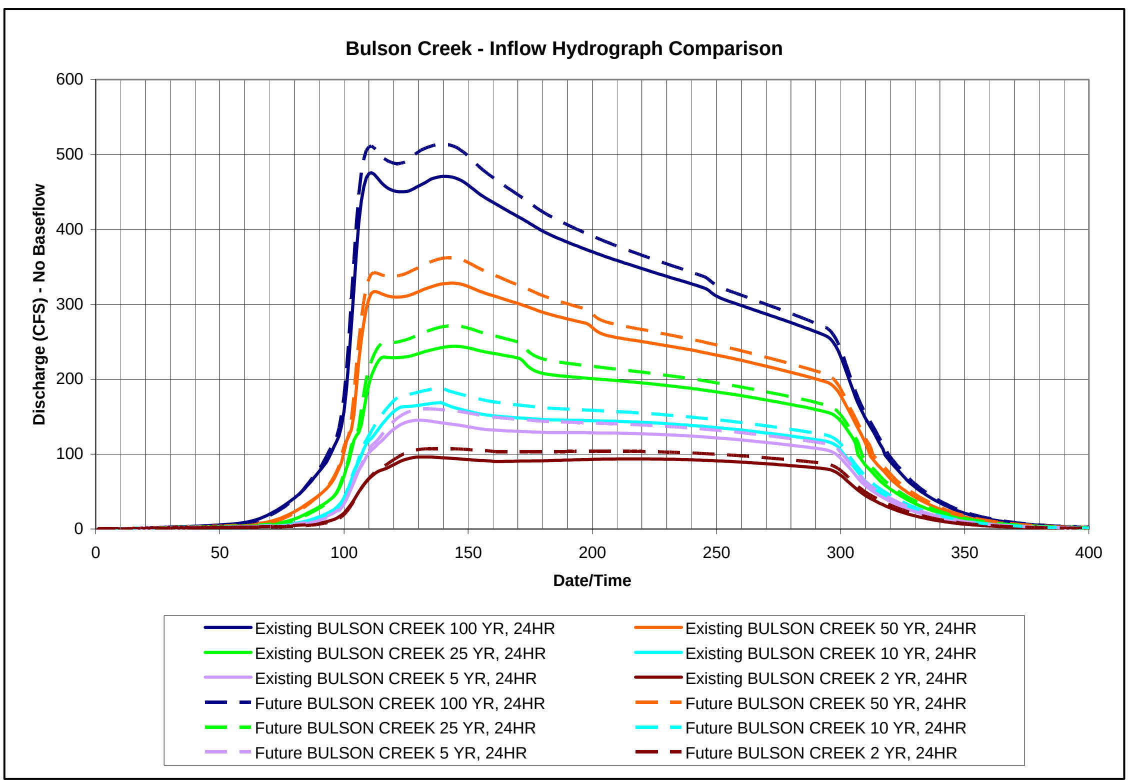


Figure 4. Comparison of Bulson Creek Existing and Future Conditions Hydrographs

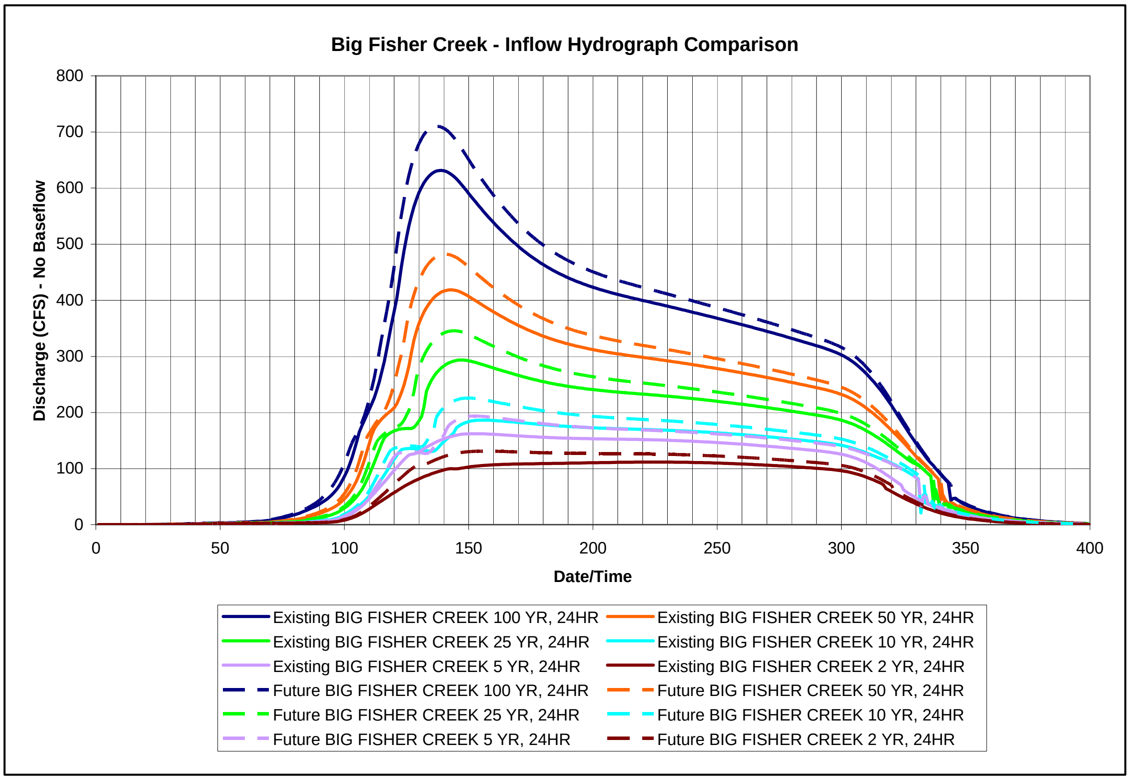


Figure 5. Comparison of Big Fisher Creek Existing and Future Conditions Hydrographs

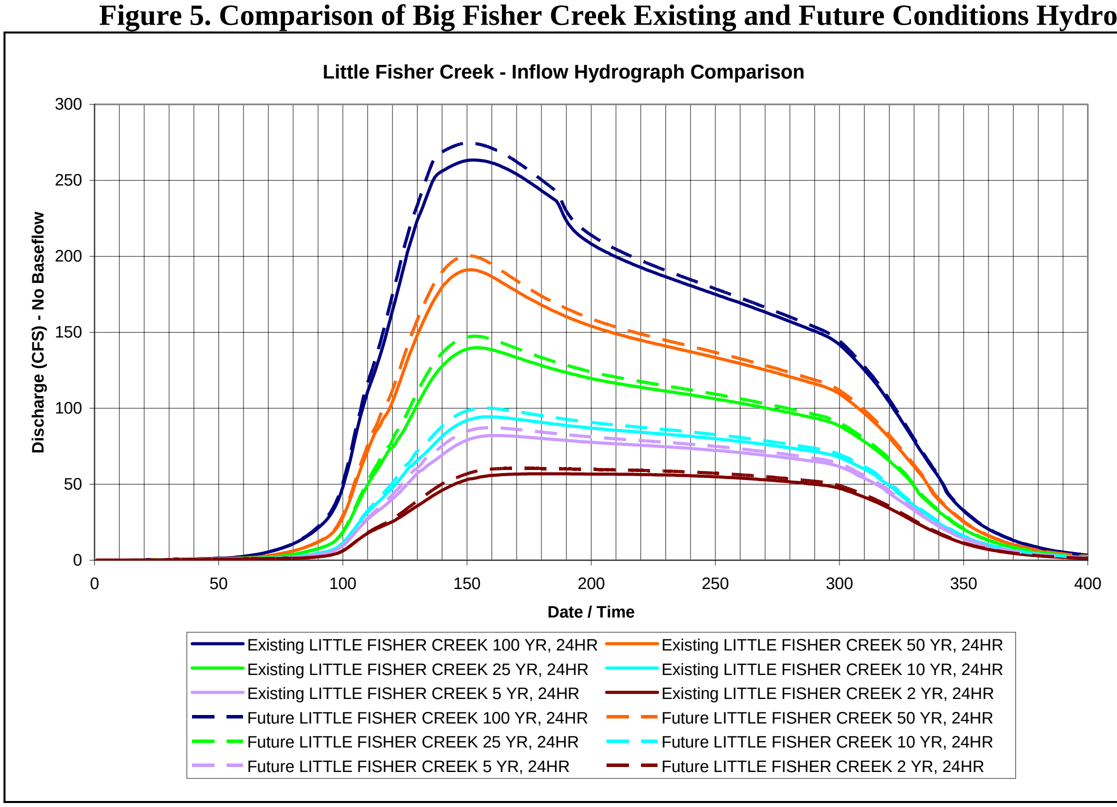


Figure 6. Comparison of Little Fisher Creek Existing and Future Conditions Hydrographs

1.4 HEC-RAS Carpenter Creek – Hill Ditch Routing

Hydraulic modeling of the existing and future condition hydrographs was performed along Carpenter Creek (Hill Ditch) using an un-steady state, hydraulic model developed by the US Army Corps of Engineers HEC (HEC-RAS). The purpose of this model is to route tributaries hydrographs along Carpenter (Hill Ditch) to the confluence with Fisher Slough. There is significant losses and attenuation along the ditch, which is several miles long and extremely low gradient (**Figure 7**). At times, the ditch flows upstream as the Skagit River rises. Big and Little Fisher Creeks hydrographs were not routed as they flow directly into Fisher Slough.

The HEC-RAS unsteady flow model used cross section survey data collected in June 2006 and the LIDAR data set to develop model geometry. The model was constructed as a linear channel with four inflow tributaries (Carpenter, Sandy, Johnson, Bulson). The downstream boundary condition was modeled as an unsteady (rising and falling stage) based on the Corps Skagit River Flood Study, UNET model output.

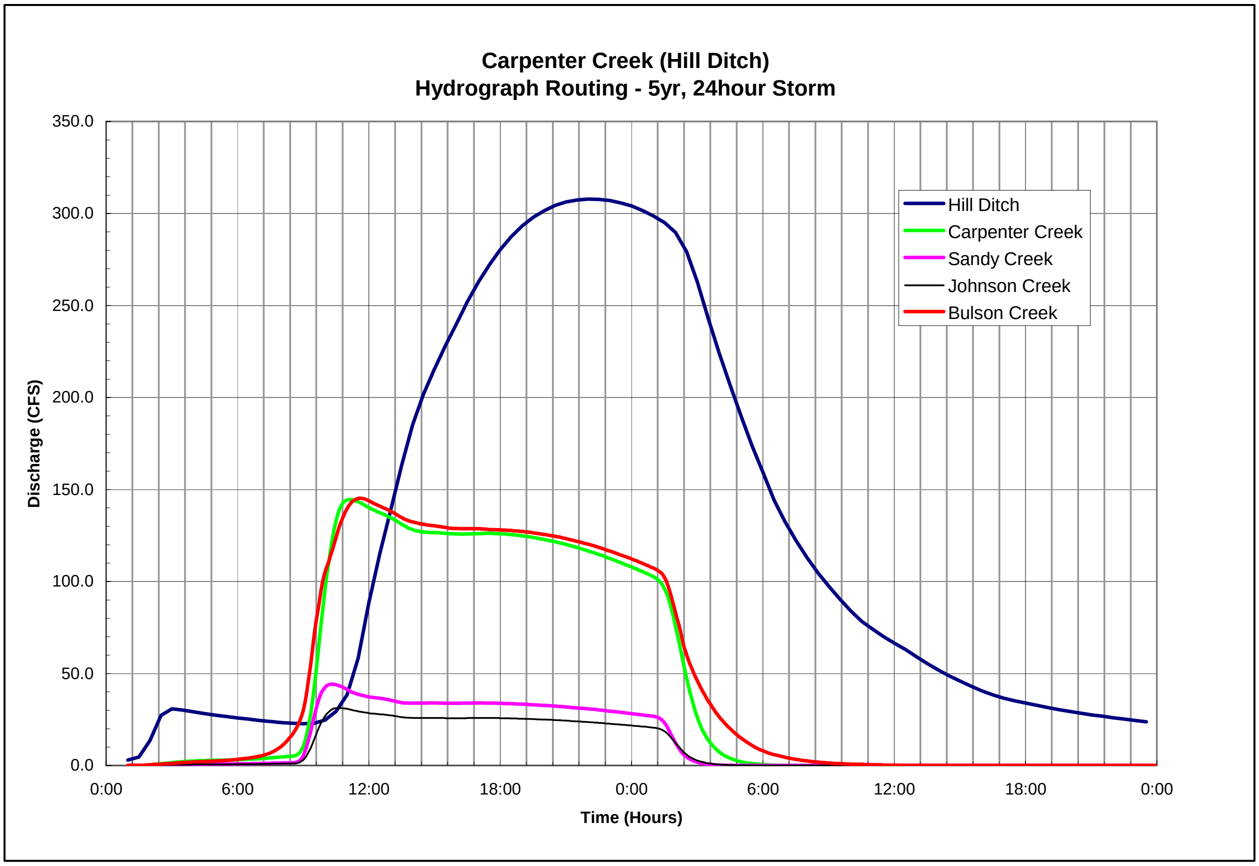


Figure 7. Fisher Watershed Tributaries Routed Hydrographs for 5-year Event

<u>Fisher Watershed Modeling Output Summary</u>

Using the hydrologic runoff and routing estimates from the previous sections, **Table 6** summarizes the flow rates used to model hydraulic conditions along Carpenter Creek/Hill Ditch and inflows to the Fisher Slough project site.

Table 6. Runoff estimates for Fisher watershed sub-basins

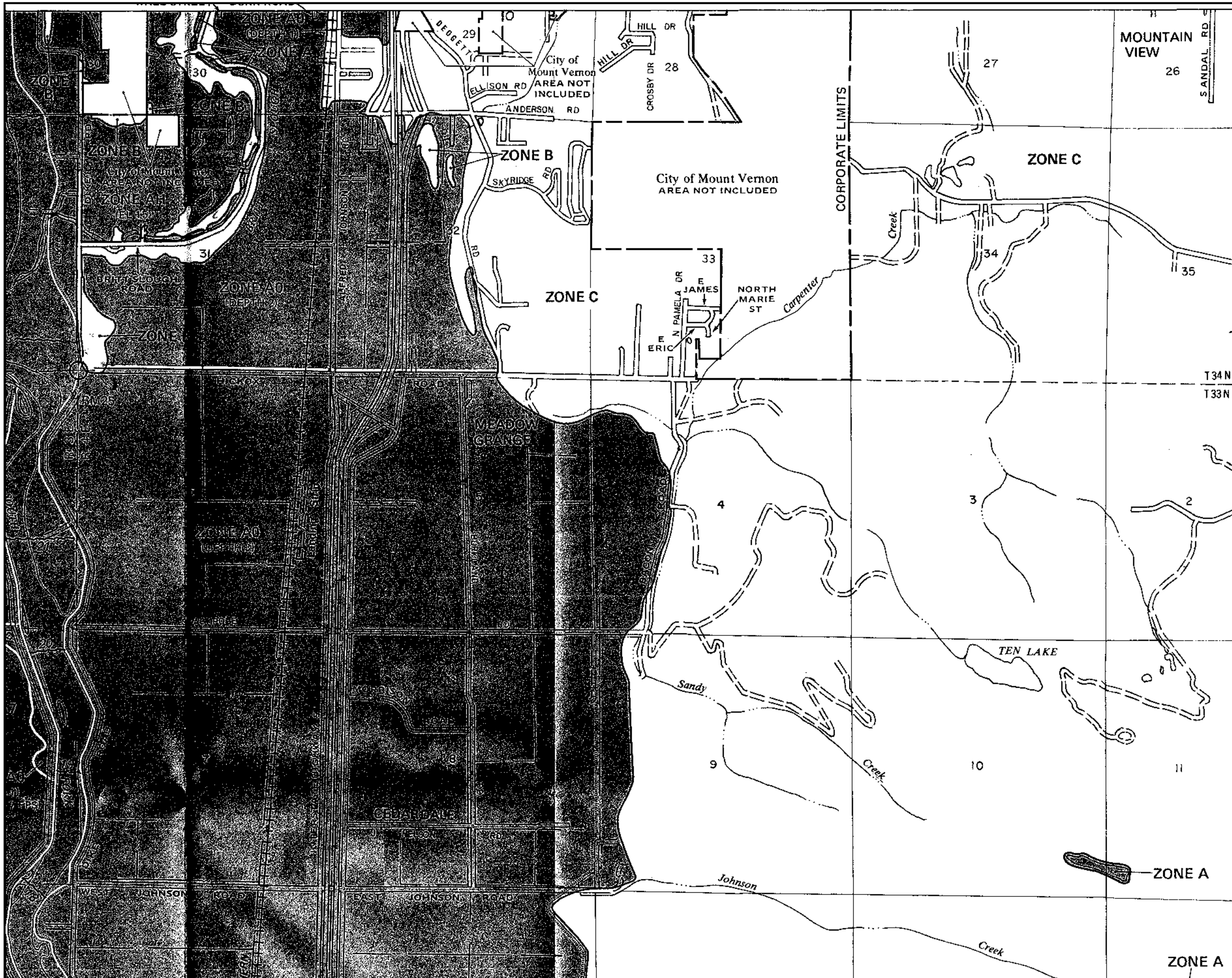
Event	Precip (in/24hr)	Existing Conditions						
		Carpenter Creek	Sandy Creek	Johnson Creek	Bulson Creek	Big Fisher Creek	Little Fisher Creek	Hill Ditch[1]
		cfs	cfs	cfs	cfs	cfs	cfs	cfs
2 YR, 24HR	2.25	90	40	20	100	110	60	290
5 YR, 24HR	2.60	140	40	30	150	160	80	310
10 YR, 24HR	2.75	180	50	40	170	190	90	340
25 YR, 24HR	3.25	300	90	70	240	290	140	490
50 YR, 24HR	3.75	440	140	100	330	420	190	600
100 YR, 24HR	4.50	680	220	150	480	630	260	700
Event	**Rainfall Intensity (in/24hr)**	**Future Conditions**						
		Carpenter Creek	**Sandy Creek**	**Johnson Creek[2]**	**Bulson Creek**	**Big Fisher Creek**	**Little Fisher Creek**	**Hill Ditch[3]**
		cfs	**cfs**	**cfs**	**cfs**	**cfs**	**cfs**	**cfs**
2 YR, 24HR	2.25	110	50	20	110	130	60	290
5 YR, 24HR	2.60	180	70	30	160	190	90	310
10 YR, 24HR	2.75	220	90	40	190	230	100	340
25 YR, 24HR	3.25	350	140	70	270	350	150	490
50 YR, 24HR	3.75	510	190	100	360	480	200	600
100 YR, 24HR	4.50	770	280	150	510	710	270	700

[1] Hill Ditch routed hydrograph at Fisher Slough project site

[2] Johnson Creek has no planned changes in land use build out

[3] Hill Ditch routed hydrograph future same as existing conditions, indicates that future additional flows will be lost in upstream flooding prior to Fisher Slough project site

APPENDIX D – FEMA, FLOOD INSURANCE RATE MAPS, SKAGIT COUNTY, WASHINGTON (UNINCORPORATED AREAS)



APPROXIMATE SCALE

2000 0 2000 FEET

NATIONAL FLOOD INSURANCE PROGRAM

FIRM
FLOOD INSURANCE RATE MAP

SKAGIT COUNTY, WASHINGTON
(UNINCORPORATED AREAS)

PANEL 425 OF 550
(SEE MAP INDEX FOR PANELS NOT PRINTED)

COMMUNITY-PANEL NUMBER
530151 0425 C

EFFECTIVE DATE:
JANUARY 3, 1985

Federal Emergency Management Agency

APPROXIMATE SCALE

2000 0 2000 FEE

NATIONAL FLOOD INSURANCE PROGRAM

FIRM
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