

MEMORANDUM

To: Michael See
Skagit County
1800 Continental Place
Mount Vernon, WA 98273

Date: March 10, 2022

From: Chad Drake, PhD, EIT
Derek Stuart, P.E.

NHC Ref. No. 2002084

Re: **Post-November 2021 Flood High Water Mark (HWM) Inventory
Skagit River Downstream of Rockport**

1 INTRODUCTION

In support of an ongoing Skagit River Delta Flood Drainage project with Skagit County, Northwest Hydraulic Consultants (NHC) was requested to conduct high-water measurements along the Lower Skagit River between the Sauk River confluence (near Rockport) and Mount Vernon after a high flow event on November 15-16, 2021. The event produced the 2nd, 16th, and 8th largest peak discharges on record at the USGS stations at Marblemount, Concrete, and Mount Vernon, respectively. The peak discharge and water surface elevation records at each of these USGS stations are summarized in Table 1.1, and the hydrographs are shown in Figure 1.1. This memorandum describes the methods employed and summarizes the high-water mark survey data collected by NHC as part of this effort. All water surface elevations are reported in feet, using the North American Vertical Datum of 1988 (NAVD 1988), unless noted otherwise.

Table 1.1 Peak discharge and water surface elevations recorded along the Skagit River at the Marblemount, Concrete, and Mount Vernon USGS stations

USGS Gage	Peak Discharge (cfs)	Peak Water Surface Level (feet)	Date/Time of Peak ¹	Gage Record Length (years)	Peak Rank
Skagit River at Marblemount (12181000)	63,400 ^A	323.31 ^{A,2}	11/15/2021 03:20 PST	58	2 nd largest
Skagit River near Concrete (12194000)	134,000 ^P	38.93 ^{P,1}	11/15/2021 10:45 PST	104	16 th largest
Skagit River near Mount Vernon (12200500)	127,000 ^A	40.79 ^{A,2}	11/16/2021 03:43 PST	82	8 th largest

^AApproved data by USGS; ^PProvisional data subject to revision by USGS; ¹Gage height, not water surface elevation, reported since no vertical shift provided by USGS. ² Referenced to NAVD 1988 vertical datum

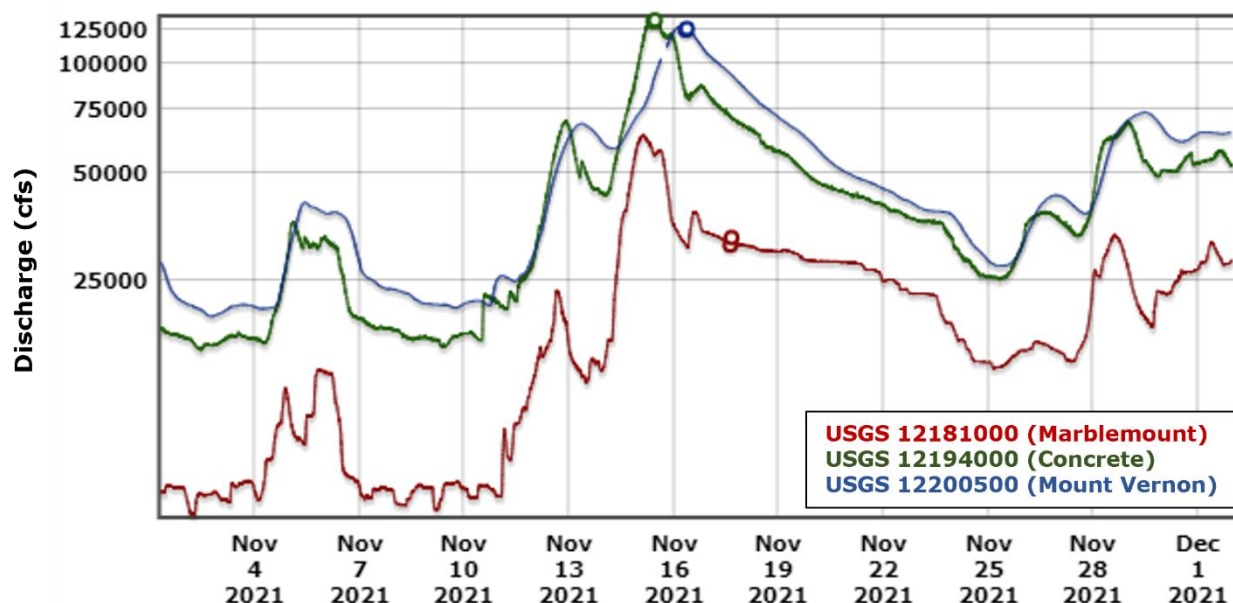


Figure 1.1 Hydrographs observed along the Skagit River at the Marblemount, Concrete, and Mount Vernon USGS stations encompassing the November 15-16, 2021, high flow event

2 METHODOLOGY

Peak water surface elevations from the November 15-16, 2021, high-flow event were collected along the Skagit River between the Sauk River confluence (near Rockport) and Mount Vernon by identifying high-water marks on several field visits following the event. High-water marks (HWMs) are post-flood evidence of the highest elevation reached by floodwaters. Evidence collected for this study included:

- Debris lines of small organic material left behind as the water recedes
- Wash lines indicating the maximum elevation that loose material was removed from the ground surface by floodwaters
- Mud lines of fine sediment deposited up to the peak flood elevation

Upon identification, each high-water mark was evaluated for how precisely it defined the peak flow elevation using the USGS high-water mark uncertainty rating system (Table 2.1). This rating system assigns a level of confidence as to the degree which the mark reflects the highest elevation reached by the floodwaters (Koenig et al., 2016).

Each high-water mark was flagged, photographed, and surveyed with real-time kinematic (RTK) GPS which received corrections via the Washington State Reference Network (WSRN). Surveyed marks with excessive vertical uncertainty (generally greater than 0.5 feet) because of poor connection with GPS satellites due to overhanging and/or dense tree canopy were excluded from the HWM survey dataset.

Vertical datum quality control was established by checking into WSDOT Survey Monument GP29020-55 near Burlington with the RTK and comparing the calculated elevation to the published reference elevation for the site. A good match was achieved, as the surveyed elevation (40.354 feet) was only 0.072 feet lower than the published reference elevation (40.426).

Table 2.1 USGS HWM Uncertainty Rating System (Koenig et al., 2016)

Vertical Uncertainty in Identifying High Water Elevation	Uncertainty Rating
Within ± 0.05 foot	Excellent (E)
Within ± 0.10 foot	Good (G)
Within ± 0.20 foot	Fair (F)
Within ± 0.40 foot	Poor (P)
More than ± 0.40 foot	Very Poor (V)
High-water mark defines the minimum height of the peak, but peak may have been higher to an unknown extent	At least this high (ALTH)

3 SUMMARY OF DATA COLLECTED

As mentioned above, a total of 75 high-water marks were collected at approximately two dozen distinct locations along the Skagit River between Rockport and Mount Vernon for the November 15-16, 2021, high flow event. Of the 75 marks, 50 (67%) were assigned a USGS rating of “excellent” or “good”, 18 (24%) were assigned a rating of “fair”, five (6%) were assigned a rating of “poor”, and two (3%) identified the flood peak elevation as “at least this high.”

Three high water marks collected near the Mount Vernon USGS gage (12200500) were compared to the peak water surface elevations reported by the USGS. This data is summarized in Table 3.1. Two high water marks surveyed by NHC near the USGS gage on the north side of the river were within 0.2 feet of the USGS approved peak water surface elevation of 40.79 feet (one NHC survey mark was 0.16 feet lower and the other was 0.03 feet higher than that reported by the USGS). The third NHC high water mark, a stake placed by Skagit County on the Dike District 17 boat ramp located on the south side of the river 890 feet downstream of the USGS gage, was 0.37 feet lower than the USGS approved elevation, but is not inconsistent with the other observations given the longitudinal distance separating the HWMs.

[This space intentionally left blank]

Table 3.1 Peak water surface elevations surveyed near the Skagit River near Mount Vernon USGS Gage (12200500) as compared to the USGS and National Weather Service (NWS) reported values.

NHC	USGS
40.63 (debris line near USGS gage on north side of river)	40.79 ^A
40.82 (wash line near USGS gage on north side of river)	
40.42 (stake on Dike District 17 boat ramp on south side of river, 890 feet downstream of the USGS gage)	

^AApproved; ^PPreliminary

On the same day that the high-water mark stake on the Dike District 17 boat ramp was surveyed, NHC also surveyed the current water surface elevation on the south side of the river opposite the Mount Vernon USGS gage. The water surface elevation shot was collected on February 25, 2022 at 09:45 PST. The surveyed elevation of 17.75 feet was very close to the current USGS preliminary estimate of 17.78 feet. Although not a high-water mark, this water surface mark provides another verification that the USGS water-levels and those collected by the RTK GPS based on WSRN provided corrections are consistent with one another when adjusted to the NAVD 1988 vertical datum.

4 CONCLUSIONS

Field measurements of peak water surface elevations were collected along the Skagit River between the Sauk River confluence (near Rockport) and Mount Vernon after the November 15-16, 2021, high flow event. The quality ratings of the HWMs included in the inventory range from 'Fair' to 'Excellent' at 68 of the 75 (91%) high-water marks based on the USGS HWM rating system. The two high-water marks surveyed adjacent to the Mount Vernon USGS gage were within 0.16 feet of the USGS approved elevation. This high-water mark dataset provides valuable information for quantifying the spatial extent of flooding and is an important resource for future hydraulic model calibration/validation to be performed by the County, its consultants, or partners in the Skagit River basin.

5 REFERENCES

Koenig, T.A., J.L. Bruce, J.E O'Connor, B.D. McGee, R.R. Holmes, Jr., Ryan Hollins, B.T. Forbes, M.S. Kohn, M.F., Schellekens, Z.W. Martin, and M.C. Peppler. (2016.) Identifying and preserving high-water mark data (No.3-A24). U.S. Geological Survey. DOI: <http://dx.doi.org/10.3133/tm3A24>

APPENDICES

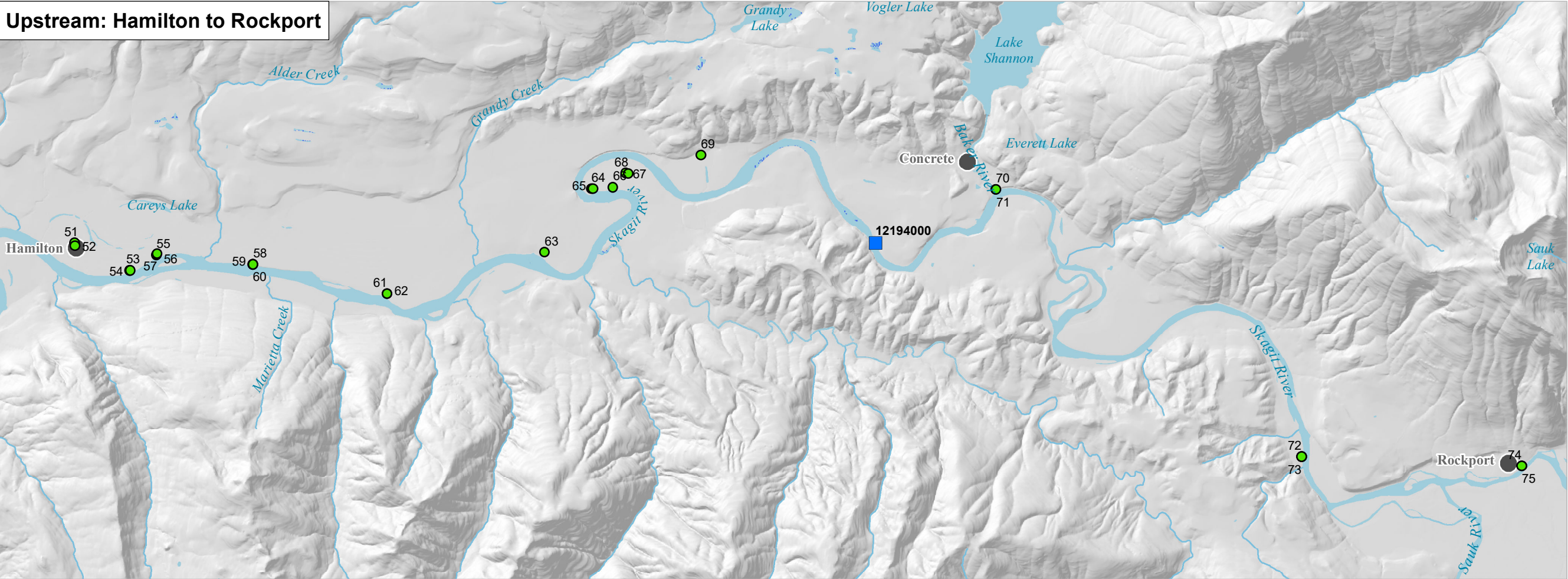
- Table of November 2021 Flood Skagit River High Water Marks, Downstream of Sauk River Confluence
- High-Water Mark Map
- ESRI Point Shapefile of Surveyed High-Water Marks (Digital Transmittal)

Table of November 2021 Flood Skagit River High Water Marks, Downstream of Sauk River Confluence

NHC ID	Northing	Easting	Elevation (Feet NAVD88)	HWM Line Description ^B	Rating
1	530255.880	1274812.089	40.42	STAKED AT PEAK	E
2	530255.831	1274812.100	40.41	STAKED AT PEAK	E
3	531014.110	1275751.176	40.82	WASH	G
4	531059.794	1275776.990	40.63	DEB	G
5	529901.064	1279311.766	41.68	DEB	F
6	529910.935	1279376.472	41.75	DEB	F
7	545523.041	1285602.155	45.07	DEB	F
8	545473.014	1285636.145	45.39	MUD	G
9	545466.022	1285644.699	45.31	DEB	F
10	546193.327	1286852.890	45.39	DEB	G
11	546205.210	1286872.454	45.28	DEB	G
12	546955.714	1286889.767	45.29	DEB	F
13	547002.669	1286896.106	44.90	DEB	F
14	547002.588	1286896.226	44.90	DEB	F
15	546247.173	1286907.946	44.06	DEB	G
16	538533.392	1295426.269	44.61	DEB	ALTH
17	538532.170	1295426.554	44.48	DEB	ALTH
18	545911.481	1297967.020	45.84	DEB	G
19	543903.263	1298343.427	46.36	DEB	G
20	538580.810	1299758.176	44.72	DEB	G
21	538506.015	1299821.852	43.22	DEB	P
22	545028.077	1300276.171	48.63	DEB	F
23	547219.736	1302925.144	49.30	DEB	F
24	546853.027	1303368.525	49.60	DEB	E-G
25	546853.750	1303375.480	49.70	DEB	E-G
26	546856.580	1303384.054	49.76	DEB	E-G
27	546862.170	1303394.046	49.90	DEB	E-G
28	546625.250	1307339.943	51.53	DEB	G
29	544717.112	1317783.532	57.38	DEB	G
30	544717.358	1317813.414	56.90	WASH	G
31 ^A	555464.193	1326211.666	66.36	DEB	G
32 ^A	555468.059	1326224.905	66.51	SEED	G
33 ^A	555180.419	1328306.719	67.91	SEED	G
34 ^A	555180.928	1328307.051	67.97	DEB	G
35 ^A	555180.611	1328307.339	67.99	SEED	G
36 ^A	557201.104	1335963.198	66.63	DEB	G
37 ^A	557201.073	1335963.247	66.70	DEB	G
38	558966.590	1341649.533	76.36	DEB	G
39	558885.019	1341654.166	80.51	WASH	F
40	555134.891	1349479.704	84.55	DEB	G
41	555193.522	1349597.177	84.97	DEB	G
42	559349.110	1351343.719	90.41	DEB	G
43	559349.108	1351343.770	90.39	DEB	G

NHC ID	Northing	Easting	Elevation (Feet NAVD88)	HWM Line Description ^B	Rating
44	559329.564	1351359.622	90.20	DEB	G
45	560444.612	1351491.452	92.24	DEB	G
46	560447.459	1351620.522	93.00	MUD	G
47	560446.865	1351735.816	93.38	MUD	G
48	560444.589	1351839.773	93.45	WASH MUD	G
49	560423.427	1352078.423	93.91	DEB MUD	G
50	560423.418	1352078.539	93.96	DEB MUD	G
51	557432.906	1360147.600	102.49	MUD	G
52	557223.730	1360184.782	102.44	MUD	G
53	555604.491	1363804.679	106.38	DEB	F
54	555607.252	1363850.606	106.97	DEB	F
55	556634.107	1365578.662	107.14	DEB	G
56	556652.467	1365592.110	107.05	DEB	G
57	556712.728	1365638.329	105.70	MUD	F
58	556007.240	1371965.103	112.61	MUD	P
59	556007.183	1371965.137	112.60	MUD	P
60	556007.223	1371965.144	112.57	MUD	P
61	554060.815	1380852.628	121.10	SEED	G
62	554060.851	1380852.702	121.07	SEED	G
63	556795.110	1391266.577	132.71	WASH	F
64	561011.206	1394372.094	146.74	DEB	G
65	561010.344	1394487.042	145.90	DEB	G
66	561098.147	1395794.362	145.59	WASH	G
67	562051.115	1396646.349	150.66	DEB	P
68	562013.147	1396839.362	151.62	WASH	F
69	563225.310	1401632.201	156.55	DEB	F
70	560955.991	1421163.063	183.48	WASH	G
71	560954.287	1421172.337	183.85	WASH	G
72	543270.578	1441392.812	222.65	DEB	F
73	543270.552	1441392.812	222.64	DEB	F
74	542658.840	1455989.324	232.71	DEB	G
75	542658.921	1455989.382	232.70	DEB	G
^A Post collection data review identified that the water-levels observed at HWM IDs 36 and 37 are lower than would be expected given the water-levels at HWM IDs 31-35, approximately 2 miles downstream. Subsequent review did not identify obvious causes for the deviation. ^B WASH = wash line; DEB = debris line; MUD = mud line; ALTH = “at least this high”; and “STAKED AT PEAK” points were staked by Dike District 17 staff that were visually monitoring the flood peak (two GPS observations were taken on the same HWM).					

Upstream: Hamilton to Rockport

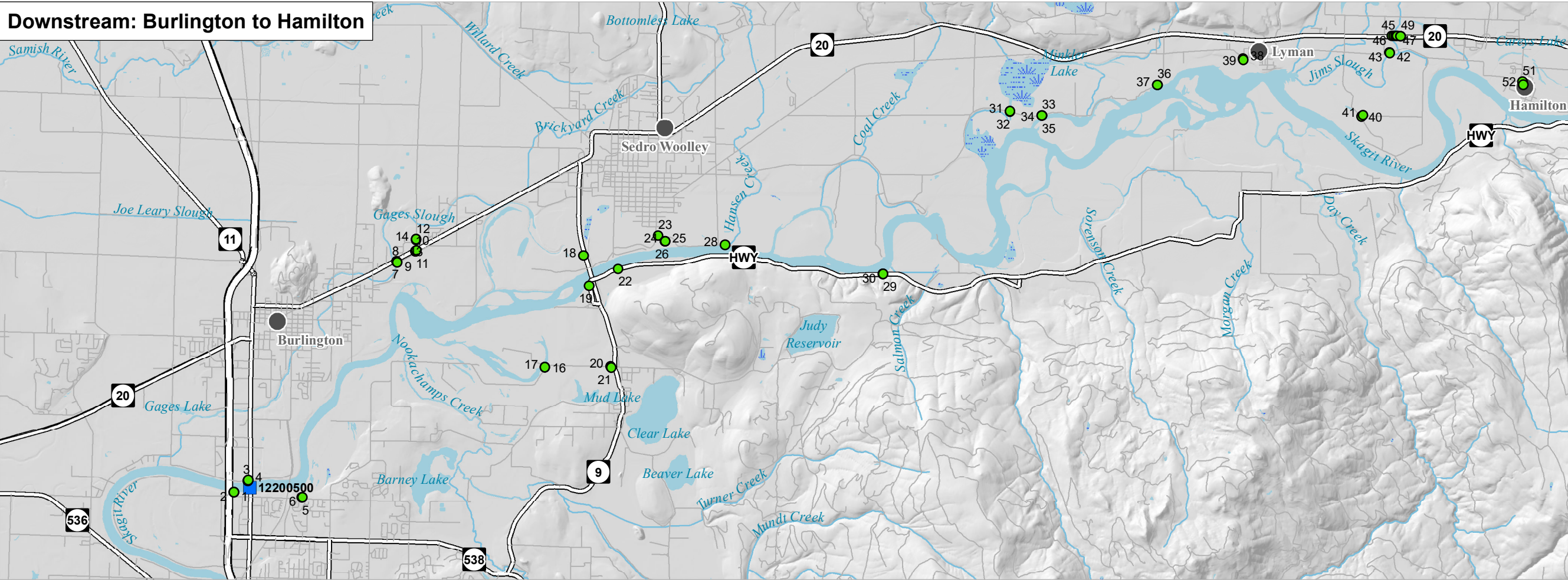


Coordinate System: NAD 1983 HARN
STATEPLANE WASHINGTON NORTH FIPS 4601

Legend

- High Water Mark (NHC)
- USGS Gage

Downstream: Burlington to Hamilton



USGS Data Summary:
Skagit River at Marblemount (12181000): Approved
Peak Discharge: 63,400 cfs (11/15/2021 03:20 PST)
Peak WSE: 323.31 ft-NAVD88

Skagit River near Concrete (12194000): Provisional
Peak Discharge: 134,000 cfs (11/15/2021 10:45 PST)
Peak Gage Height: 38.93 ft

Skagit River near Mount Vernon (12200500): Approved
Peak Discharge: 127,000 cfs (11/16/2021 03:43 PST)
Peak WSE: 40.79 ft-NAVD88



SKAGIT RIVER DELTA
FLOOD DRAINAGE PROJECT
High Water Mark Survey
November 15-16, 2021
High Flow Event **DRAFT**

Date: 04-Mar-2022
Job: 2002084
EXHIBIT 1