MEMORANDUM

Date: November 2, 2020
To: Andrea McNamara-Doyle, Office of Chehalis Basin
From: Larry Karpack, PE, and Bob Elliot, PE, Watershed Science and Engineering
Cc: Chrissy Bailey, Office of Chehalis Basin; Jim Kramer and Ken Ghalambor, Office of Chehalis Basin consultant staff; Robert Montgomery, Heather Page, and Merri Martz, Anchor QEA, LLC
Re: Local Actions Program Near-term Technical Analyses for Office of Chehalis Basin: Additional Near-term and Long-term Hydrologic and Hydraulic Modeling Options

Overview

This memorandum provides options for additional near-term and long-term hydrologic and hydraulic modeling to inform development and evaluation of the Local Actions Program. These options may be modified based on input from the Technical Advisory Group at the direction of the Office of Chehalis Basin (OCB) prior to consideration by the Chehalis Basin Board.

The Chehalis Basin Board has provided guidance for how they will evaluate a Local Actions Program. Specific to hydrologic and hydraulic modeling, the Board directed that a Local Actions Program should plan for the 100-year flood conditions that are predicted for 2080 when considering outcomes and actions to include in the program. In the near term, the Board has expressed a desire to better understand, and be able to describe to the public, what the 100-year flood conditions are predicted to be in 2080 that the Local Actions Program would be seeking to address. In other words, what should the Board assume now, for its initial planning purposes, the basin's 100-year floodplain might look like in 2080? This planning assumption, which relies on hydrologic and hydraulic modeling, provides the foundation for all the outcome measures agreed to by the Chehalis Basin Board. In the near term, the modeled future floodplain will focus attention on the kinds of actions that can most feasibly reduce risks associated with this expanded floodplain of the future. In the longer term, if the Local Actions Program moves forward as part of the Chehalis Basin Strategy, the Board may choose to require certain levels of protection against future flood conditions as a condition of funding.

For background, hydrologic and hydraulic modeling was performed to inform the State Environmental Policy Act (SEPA) Draft Environmental Impact Statement (EIS) and National Environmental Policy Act (NEPA) Draft EIS. To characterize hydrology of floods on the Chehalis River, a combination of streamflow data from U.S. Geological Survey (USGS) and hydrologic analyses prepared by WEST Consultants for the U.S. Army Corps of Engineers (Corps) was used. To estimate flows for 2080 conditions (used in the SEPA Draft EIS) a Distributed Hydrologic Soil Vegetation Model (DHSVM) hydrologic model of the entire Chehalis Basin was prepared using meteorological data provided by the Climate Impacts Group. A RiverFlow2D hydraulic model was prepared for the Chehalis River, as well as portions of key tributaries that are affected by Chehalis River flooding (WSE 2019a).

This memorandum is organized as follows:

1. Summary of Options
2. Questions for the Technical Advisory Group
3. Methodology for Identifying Additional Tributary Modeling Options
4. Coordination with Basin Communities
5. Analysis of Existing and Potential Future Flood Risk
6. Prioritization of Tributaries for Additional Hydraulic Modeling
7. Detailed Description of Near-term Option
8. Detailed Description of Long-term Options

In preparing this memorandum, our team reviewed comments received on hydrologic and hydraulic analyses conducted in the preparation of the SEPA Draft EIS. A short summary of comments that are relevant to the Local Actions Program, and our responses, is provided in Appendix A. Options for additional hydrologic and hydraulic modeling and analysis described herein account for these comments. Please note that this memorandum does not represent a formal response to comments on the SEPA Draft EIS.

Summary of Options

Near-term Option

A near-term option for evaluating local actions on the mainstem and key tributaries is to use the existing RiverFlow2D hydraulic model. It would provide the best available estimate of flood damage reduction for a Local Actions Program. Similarly, a near-term option would also include using the hydrologic data from the existing RiverFlow2D hydraulic model. If specific areas are identified where the model does not reasonably replicate known historical flood conditions, additional model refinement could be performed. Additional analyses incorporating uncertainty into the model could also be performed to reduce the potential for overstating potential benefits of local flood damage reduction actions.

A near-term option for locations in the basin that are outside of the existing models is to delineate the late-century 100-year floodplain on an interim basis using currently available data and hydraulic models from the Federal Emergency Management Agency (FEMA) and the Chehalis Basin Strategy, and mapping the floodplain using the steps described in this memorandum. An estimated late-century 100-year floodplain would be developed for all tributaries in the Chehalis Basin that are currently mapped by FEMA.

Long-term Options

As described in this memorandum, the mainstem Chehalis River floodplain and coastal flood zones are the areas with the greatest level of potential flood damage. Following these, the next 10 highest ranked areas (in order of potential flood risk) are: Skookumchuck River, Satsop River, Humptulips River, Wynoochee River, Black River, Newaukum River, Hoquiam River, Wishkah River, Mox Chehalis Creek, and Charley and Newskah creeks. Cumulatively, these 10 tributaries account for 79% of all agricultural acreage, 84% of all developable acreage, and 76% of all structures in the tributary floodplains. This information was then cross-referenced with the community concerns described in this memorandum to identify priority locations for additional modeling.

A long-term option for evaluating local actions on the mainstem Chehalis River is the same as the near-term option, with the exception that hydrologic inputs may be adjusted based upon options described in *Local Actions Program Near-term Technical Analyses for Office of Chehalis Basin: Climate Change Modeling Options* (WSE and Anchor QEA 2020). Because detailed hydraulic modeling is already available for the mainstem Chehalis River and portions of some tributaries, the additional hydraulic modeling described in this memorandum focused on the tributaries. Furthermore, because coastal flood hazard zones in Aberdeen and Hoquiam are already being addressed with the North Shore Levee and North Shore West Segment Levee, those areas were also not included in the prioritization described herein.

Long-term options for updating and refining existing models or constructing new models of tributary systems are as follows:

1. Update the Skookumchuck River and Newaukum River tributaries in the Chehalis Basin Strategy RiverFlow2D model (WSE 2019b) and run the model for the late-century catastrophic flood to identify areas of flooding.
2. Construct new hydraulic models of key locations on the Satsop and Wynoochee rivers to evaluate areas of flood concern and inform bank protection actions.
3. Model the Alder Creek and Mill Creek systems and identify locations of flooding and places where flood damage reduction actions might be possible.
4. Model Cloquallum Creek and identify locations of flooding.
5. Refine the model of the South Fork Newaukum River, remap its floodplain, and identify locations where flood damage reduction actions might be possible.
6. Model Salzer Creek to the upstream extent of the FEMA Special Flood Hazard Area (SFHA), remap its floodplain, and identify locations where flood damage reduction actions might be possible.
7. Develop stormwater system modeling and analysis to support a Stormwater Master Plan for the Cities of Aberdeen and Hoquiam.

Questions for the Technical Advisory Group

- In the near term, are there other options for defining the late-century 100-year floodplain for the Chehalis River mainstem and tributaries? What recommendations do you have?
- Are there other hydrologic or hydraulic modeling options or approaches to evaluating the Chehalis River mainstem and tributary areas that should be considered for the longer term? What recommendations do you have?
- What questions, suggestions, feedback, or recommendations do Technical Advisory Group members have for identifying and prioritizing areas for additional modeling in the longer term?

Methodology for Identifying Additional Tributary Modeling Options

To identify additional tributary areas with the greatest potential flood damage, the following tasks were completed:

- Coordinate with floodplain managers and public works staff from local communities to determine:
- Existing or anticipated future locations of significant flood damage, including areas of urban flooding
- Available data or hydraulic models for rivers, creeks, or urban areas known to flood or expected to see increased flooding in the future
- Obtain delineations of all FEMA floodplain boundaries in the entire Chehalis Basin.
- Overlay floodplain delineations with available structure information to identify existing structures at risk of flooding.
- Overlay floodplain boundaries with zoning data to identify areas with greatest potential for future development and increased flood risk.
- Overlay the floodplain boundaries with agricultural zoned properties to identify areas of potential agricultural flood impacts.
- Based on the above information, identify areas with the greatest potential for flood damage.
- Identify additional data necessary to evaluate flood damage and flood risk including topographic data, bathymetric data, and hydrologic and hydraulic models or data.
- Prioritize near-term and long-term options for additional hydraulic modeling.
- Discuss options for additional hydraulic modeling to evaluate flood risks in priority areas and estimate potential costs.

Coordination with Basin Communities

Watershed Science and Engineering (WSE) staff contacted public works officials or floodplain managers at Lewis County, Thurston County, Grays Harbor County, and the cities of Aberdeen, Bucoda, Centralia, Chehalis, Cosmopolis, Elma, Hoquiam, Montesano, and Napavine. Conservation District staff were also contacted, including Lewis, Thurston, and Grays Harbor Conservations Districts. The intent of these conversations was to better understand where significant flood or erosion issues exist, what could be causing these issues (for example, overflowing stormwater systems or overbank flooding from rivers or streams), and where future development might be at risk of flooding and erosion. A summary of key feedback is provided in Appendix B.

Analysis of Existing and Potential Future Flood Risk

To provide an evaluation of current flood risk in Chehalis Basin tributary systems, an analysis was undertaken to determine the number of structures and acreage of agricultural property in the floodplain. The hydraulic model developed for the Chehalis Basin Strategy (WSE 2019b) primarily covers the mainstem Chehalis River and portions of key tributaries. Similar detailed modeling is not available for many of the other tributaries. Appendix C provides a preliminary summary of available hydraulic models within the Chehalis Basin. In order to provide an equivalent comparison between mainstem flood risk and flood risk on tributary systems, the analyses undertaken herein used the FEMA SFHA (also called the FEMA 100-year floodplain). The most recent FEMA floodplain delineations for the Chehalis Basin were downloaded from the FEMA Map Service Center. Floodplains were then differentiated by flooding source. A total of 36 tributary systems were delineated along with the coastal flood zone and the mainstem Chehalis River floodplain. It should be noted that the analyses conducted for SEPA Draft EIS assumed late-century hydrologic conditions whereas FEMA floodplain mapping, and the flood risk analyses described herein, reflect current hydrologic and hydraulic conditions.

As a surrogate for existing conditions flood risk in the basin, an analysis of structures within the FEMA SFHA was completed. Structure locations and shapes for the mainstem and key tributaries (those modeled in the SEPA Draft EIS) were defined using the Chehalis Basin Strategy structure database (Anchor QEA 2017). This dataset was augmented using building footprint delineations available from Microsoft OpenStreetMap (2018). The Chehalis Basin floodplain polygons were “joined” with the composite structures dataset, and structures within the SFHA in each tributary system were counted in GIS. Table 1 summarizes the result of this analysis. As shown in Table 1, there are a total of 14,548 structures within the FEMA floodplain in the Chehalis Basin. Of these, 9,398 are along the mainstem Chehalis River or in the Coastal Flood Hazard Zone surrounding Grays Harbor, or open coastal areas of the Chehalis Basin. There are 5,150 structures within FEMA floodplains of the other 36 mapped tributaries in the basin.

Table 1
Chehalis Basin Structures in the FEMA Floodplain

CATEGORY	STRUCTURES	FLOODING SOURCE (CONT.)	STRUCTURES
All SFHA Zones	14,548	Mox Chehalis Creek	96
Chehalis River Floodplain	3,860	Bunker Creek	84
Coastal Flooding Zones	5,538	Wishkah River	83
All Tributaries	5,150	North Fork Newaukum River	69
FLOODING SOURCE		Mill Creek	65
Chehalis Mainstem	3,860	Lincoln Creek	64
Coastal Flood Zone	3,094	Berwick Creek	47
Coastal/Hoquiam	2,193	Scammon Creek	34
Skookumchuck River	1,863	Newman Creek	33
Satsop River	589	Stearns Creek	30
Newaukum River	295	Dillenbaugh Creek	27
Coastal/Wishkah	251	Coal Creek	24
Wynoochee River	241	Independence Creek	21
Black River	234	Johns River	16
Hoquiam River	205	Rock Creek	14
Humptulips River	183	Elk Creek	13
Salzer Creek	163	Wilson Creek	13
South Fork Newaukum River	144	Delezene Creek	7
Charley and Newskah Creeks	141	Garrard Creek	7
Cloquallum Creek	125	Porter Creek	2
South Fork Chehalis River	109	Davis Creek	1
Scatter Creek	108	Elk River	0

Notes:
Floodplain: FEMA SFHA
Structures layer: WSE Chehalis Structures 2016 layer + Microsoft Building Footprint 2018 layer

In addition to the analysis of structures in the SFHA, the agricultural acreage in the floodplain within each tributary system was determined as an indicator of potential agricultural flood damages. Zoning data for Lewis, Thurston, and Grays Harbor counties were obtained and overlain with the FEMA floodplain. Table 2 summarizes the acreage of agricultural zoned property in the floodplain by tributary system. Finally, an assessment was made of potential additional future flood risk in each tributary system by computing the acreage of higher density zoning in each system. Zoning categories included in this analysis include commercial, industrial, urbanizing, urban growth area (UGA), mixed use, city, town center, urban, and similar designations. A full list of zoning categories used for this analysis is provided in Appendix D. The results of the analysis are summarized in Table 2. As shown in Table 2, approximately 56% of the agricultural property in the basin is located along the mainstem Chehalis River and approximately 44% of higher density zoning is located along the mainstem Chehalis River or within the Coastal flood hazard zone. Thus, 44% of agricultural land and 56% of higher density zoning is located in one of the 36 tributary floodplains.

Table 2
Agricultural and High-Density Zoning Acreages in the FEMA SFHA

FLOODING SOURCE	AGRICULTURAL ZONING IN SFHA (ACRES)	DEVELOPABLE ZONING IN SFHA (ACRES)
TOTAL	**55,755**	**54,213**
Berwick Creek	-	95
Black River	53	2,740
Bunker Creek	40	-
Charley and Newskah Creeks	-	801
Chehalis Mainstem	31,387	14,094
Cloquallum Creek	59	334
Coal Creek	-	23
Coastal Flood Zone	651	8,391
Coastal/Hoquiam	-	1,147
Coastal/Wishkah	-	341
Davis Creek	0	36
Delezene Creek	33	115
Dillenbaugh Creek	-	108
Elk Creek	90	-
Elk River	-	1,494
Garrard Creek	365	109
Hoquiam River	-	3,928
Humptulips River	5,898	6,564
Independence Creek	123	3

FLOODING SOURCE (CONT.)	AGRICULTURAL ZONING IN SFHA (ACRES)	DEVELOPABLE ZONING IN SFHA (ACRES)
Johns River	-	1,196
Lincoln Creek	1,108	-
Mill Creek	-	110
Mox Chehalis Creek	213	697
Newaukum River	758	539
Newman Creek	153	37
North Fork Newaukum River	127	-
Porter Creek	41	62
Rock Creek	75	140
Salzer Creek	15	88
Satsop River	4,378	1,675
Scammon Creek	-	5
Scatter Creek	15	912
South Fork Chehalis River	2,346	1
South Fork Newaukum River	322	25
Skookumchuck River	1,655	3,812
Stearns Creek	32	-
Wilson Creek	-	4
Wishkah River	1,538	2,053
Wynoochee River	4,280	2,537

Notes:
Floodplain: FEMA SFHA separated into tributary subbasins.
Agricultural areas layer and developable areas layer derived from county zoning data.
Results obtained from overlaying zoning data and floodplain data delineated by subbasin.

Prioritization of Tributaries for Additional Hydraulic Modeling

Considering the feedback provided by the communities, together with the flood damage information presented in Tables 1 and 2, the highest priority areas for additional hydraulic modeling were identified. The first step in this process was to individually rank each of the flood sources from most significant to least significant for each of the flood attributes (structures in the floodplain, agricultural acreage in the floodplain, and developable acreage in the floodplain). Next, an overall ranking was developed by taking a weighted average of the individual ranks and then ranking those values. For this analysis, the structure ranking was weighted 50%, the developable acreage ranking was weighted 33.3%, and the agricultural acreage was weighted 16.7%. Table 3 summarizes the results of the weighted ranking for each tributary system sorted by overall rank.

Table 3
Summary and Ranking of Flood Damage Potential

FLOODING SOURCE	AGRICULTURAL ZONING IN SFHA (ACRES)		DEVELOPABLE ZONING IN SFHA (ACRES)		STRUCTURES IN SFHA (COUNT)		OVERALL RANK
TOTAL	55,755	RANK	54,213	RANK	14,548	RANK	
Chehalis Mainstem	31,387	1	14,094	1	3,860	1	1
Coastal Flood Zone	651	10	8,391	2	3,094	2	2
Skookumchuck River	1,655	6	3,812	5	1,863	4	3
Satsop River	4,378	3	1,675	9	589	5	4
Humptulips River	5,898	2	6,564	3	183	11	5
Wynoochee River	4,280	4	2,537	7	241	8	6
Black River	53	20	2,740	6	234	9	7
Newaukum River	758	9	539	16	295	6	7
Coastal/Hoquiam	0	28	1,147	12	2,193	3	9
Hoquiam River	0	28	3,928	4	205	10	10
Wishkah River	1,538	7	2,053	8	83	20	11
Coastal/Wishkah	0	28	341	17	251	7	11
Mox Chehalis Creek	213	13	697	15	96	18	13
Charley and Newskah Creeks	0	28	801	14	141	14	14
Cloquallum Creek	59	19	334	18	125	15	15
Scatter Creek	15	25	912	13	108	17	16
South Fork Newaukum River	322	12	25	29	144	13	17
Salzer Creek	15	26	88	25	163	12	18
South Fork Chehalis River	2,346	5	1	34	109	16	19
Mill Creek	0	28	110	21	65	22	20
Johns River	0	28	1,196	11	16	31	21
Newman Creek	153	14	37	27	33	26	22
Lincoln Creek	1,108	8	0	35	64	23	23
North Fork Newaukum River	127	15	0	35	69	21	24
Berwick Creek	0	28	95	24	47	24	24
Bunker Creek	40	22	0	35	84	19	26
Rock Creek	75	18	140	19	14	32	27
Dillenbaugh Creek	0	28	108	23	27	28	28
Garrard Creek	365	11	109	22	7	35	29
Elk River	0	28	1,494	10	0	39	30
Scammon Creek	0	28	5	31	34	25	30
Delezene Creek	33	23	115	20	7	35	32
Independence Creek	123	16	3	33	21	30	33
Stearns Creek	32	24	0	35	30	27	34
Coal Creek	0	28	23	30	24	29	34
Porter Creek	41	21	62	26	2	37	36
Elk Creek	90	17	0	35	13	33	37
Wilson Creek	0	28	4	32	13	33	38
Davis Creek	0	27	36	28	1	38	39

Excluding the mainstem Chehalis River floodplain and coastal flood zones, the next 10 highest ranked areas (in order) were: Skookumchuck River, Satsop River, Humptulips River, Wynoochee River, Black River, Newaukum River (mainstem), Hoquiam River, Wishkah River, Mox Chehalis Creek, and Charley and Newskah creeks. Cumulatively, these 10 tributaries account for 79% of all agricultural acreage, 88% of all developable acreage, and 81% of all structures in the tributary floodplains.

The weighted rankings were then cross-referenced with the community concerns described previously to identify priority locations for additional modeling. It should be noted that the rankings shown in Table 3 include the mainstem Chehalis River (ranked 1) and the coastal areas around Grays Harbor (ranked 2, 9, and 11). Because the mainstem Chehalis River already has a detailed hydraulic model (WSE 2019b), it was not included in the prioritization. Furthermore, because the coastal flood zones around Aberdeen and Hoquiam are already being addressed with the North Shore Levee and North Shore West Segment Levee, those areas were also not included in the prioritization.

Considering the numerical rankings together with the input from the communities summarized in Appendix B, the following adjustments to the prioritization were made. Grays Harbor noted that the Humptulips has not historically been a source of significant flooding so it was not included in the high-priority areas. Likewise, Charley and Newskah creeks were not noted by the communities as having been a flooding problem in the past. However, the adjacent Alder Creek (not previously mapped by FEMA) and Mill Creek have known significant existing flooding problems identified by Aberdeen and Cosmopolis, so those creeks were swapped in the prioritization. The Wishkah River has recent detailed hydraulic modeling (WSE 2017) using new Light Detection and Ranging (LiDAR) topographic data and a channel bathymetric survey, so it is not recommended for additional modeling. The Hoquiam River ranks high in the flood damage prioritization, but the mapped floodplain is generally the result of only tidal flooding and, as such, additional hydraulic modeling is not recommended. The Skookumchuck and Newaukum rivers are included in the current Chehalis Basin Strategy RiverFlow2D model, but in both cases it is recommended that the channel bathymetric data used in the model be updated based on new channel surveys (which would need to be collected).

With the adjustments noted previously, the top 11 priority tributaries for additional modeling are summarized in Table 4 and shown graphically in Figure 1.

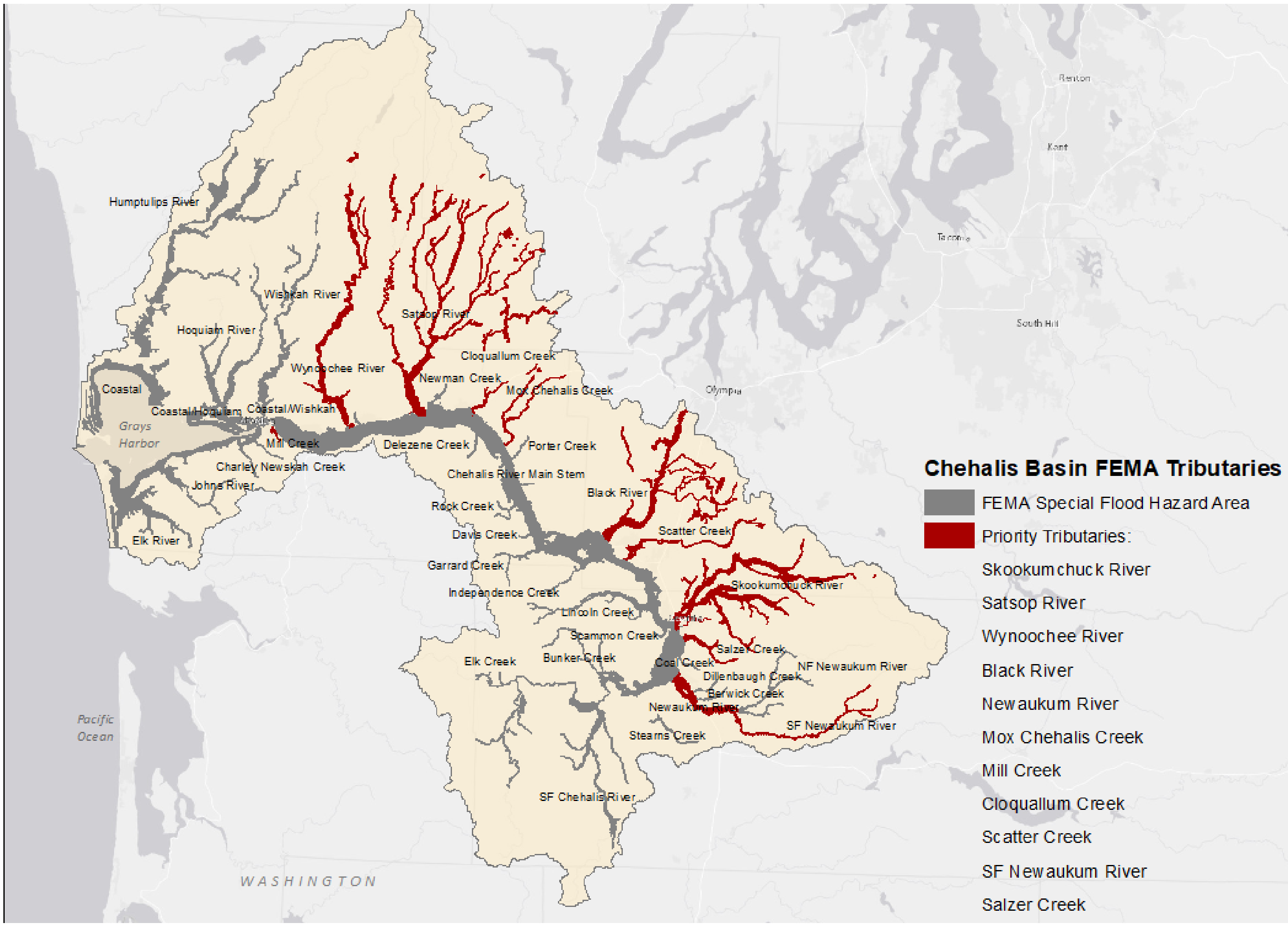
Table 4
Priorities for Additional Hydraulic Modeling

TRIBUTARY (IN ORDER OF PRIORITY)	NOTES	ESTIMATED COST[1]	ESTIMATED DURATION[2]
Skookumchuck River	From mouth to existing dam, high flood damage potential, high community concerns, requires new bathymetric data	\$125,000–\$175,000	4–6 months
Satsop River	Model Satsop Riviera reach and specific locations of bank erosion	\$100,000–\$150,000	3–6 months
Wynoochee River	Model WWTP reach and specific locations of bank erosion	\$50,000–\$100,000	3–6 months
Black River	More research and feedback from Thurston County needed	N/A	N/A
Newaukum River	From mouth to the North Fork/South Fork confluence, high flood damage potential, requires new bathymetric data	\$75,000–\$125,000	4–6 months
Mox Chehalis Creek	There is not enough information currently available to define modeling needs	N/A	N/A
Alder and Mill Creeks	Need modeling of creeks and the downstream flood ponding area near the South Aberdeen levee, community concerns and observed problems	\$250,000–\$350,000	6–9 months
Cloquallum Creek	From mouth to Stamper Road, not identified as high priority by community, needs channel survey data	\$75,000–\$125,000	3–6 months
Scatter Creek	More research and feedback from Thurston County needed	N/A	N/A
South Fork Newaukum River	Significant structures and agricultural property in SFHA, Conservation District identified this area as a priority, NSD RiverFlow2D model available	\$125,000–\$200,000	3–6 months
Salzer Creek	Significant number of structures in SFHA, community identified priority, potential flood storage	\$150,000–\$200,000	3–6 months

Note:
1. Cost estimate for data collection and model development only; alternative analysis and project design would require additional funding.
2. Estimated duration is for project activities only and does not include procurement process or contracting.

NSD: Natural Systems Design
WWTP: wastewater treatment plant

Figure 1
Priority Reaches for Modeling



In addition to the modeling priorities listed in Table 4, the cities of Aberdeen and Hoquiam identified the need for a Stormwater Master Plan that would evaluate current storm drainage infrastructure (e.g., ditches, pipes, detention ponds, pump stations) and provide a plan for improving these systems to reduce flood damages. It is difficult to estimate the cost of such a plan without a more thorough review of the extent of the systems to be modeled and the currently available sources of data. Assuming that additional data collection is not needed (i.e., that the cities have inventories of the pipes, ponds, and pumps that need to be modeled) a ballpark estimate for hydrologic and hydraulic modeling for a Stormwater Master Plan would be $300,000. This assumes the plan only goes as far as modeling and identifying problems but does not investigate solution alternatives, which could be far more expensive.

Near-term Option for Defining Approximate Late-century Floodplains in Tributaries

Additional hydraulic modeling and analysis that may be needed to support implementation of a Local Actions Program cannot realistically be completed prior to March 2021. The level of effort to collect necessary data, develop and calibrate hydraulic models, and use the models to evaluate flooding and develop flood reduction alternatives cannot be done in this short time frame. However, having a better delineation of the expected areal extent of the late-century 100-year floodplain throughout the Chehalis Basin is needed in the near term to inform other aspects of the Local Actions Program. For that reason, a near-term option is provided for preparing an approximate delineation of the late-century 100-year floodplain in tributaries. This option would include the following steps:

i. Develop a comprehensive topographic dataset covering all tributaries mapped by FEMA and listed in Tables 1 through 3. This dataset would use only existing topographic data sources (i.e., no new topographic data collection is proposed).
ii. Obtain and map 100-year flood elevations, or Base Flood Elevations (BFEs), from existing FEMA studies. Estimate current condition BFEs for areas without FEMA BFE data, such as FEMA approximate mapping areas.
iii. Obtain available recent hydraulic models for all tributaries including:
    - Chehalis Basin Strategy RiverFlow2D model of the Chehalis mainstem and portions of key tributaries (b 2019)
    - Wishkah River HEC-RAS 2D model (WSE 2017) with 2017 topographic LiDAR (provided by GeoTerra) and 2017 bathymetric survey (provided by PGS); extends from RM 0 to 13
    - FEMA hydraulic model of Scatter Creek (STARR II 2016)
    - Skookumchuck Riverflow2D model, modified from WSE Riverflow2D with 2017 topo-bathymetric LiDAR (provided by Quantum Spatial) and 2011 Thurston County LiDAR; extends from RM 18 to 22
    - East Fork Satsop Riverflow2D model, using 2017 topo-bathymetric LiDAR (provided by Quantum Spatial); extends from RM 6.6 to 11

- Wynoochee River RiverFlow2D model, using 2017 topo-bathymetric LiDAR (provided by Quantum Spatial); extends from RM 5.6 to 16.7
- South Fork Newaukum HEC-RAS 2D model, using 2017 topo-bathymetric LiDAR (provided by Quantum Spatial) and 2012 Puget Sound Consortium LiDAR; extends from RM 10.6 to 13.2
- Stillman Creek HEC-RAS 2D from RM 0 to about 3.5

iv. Run the available hydraulic models listed in item iii with the late-century catastrophic flood—i.e., a scaled-up version of the current condition 100-year flood, with scalar based on the value used in the SEPA Draft EIS (26%) or an adjusted value based upon options described in *Local Actions Program Near-term Technical Analyses for Office of Chehalis Basin: Climate Change Modeling Options* (WSE and Anchor QEA 2020).

v. For areas with currently available hydraulic models, map the late-century 100-year floodplain directly using model output and terrain surface developed in item i. Compute difference in water surface elevations between the FEMA BFEs and the late-century 100-year floodplain.

vi. For areas without hydraulic modeling, delineate late-century catastrophic floodplain by adjusting FEMA BFEs (item ii) by the average difference determined in item v, and map this elevation using the terrain developed in item i.

vii. Combine the maps developed in items v and vi into a composite late-century catastrophic floodplain.

The estimated cost to complete the short-term option is $75,000 to $100,000. The duration to complete the work is estimated to be 2 months following notice to proceed, assuming all necessary staff resources and models and data sources described previously are available.

Long-term Options for Additional Hydraulic Modeling in Tributaries

The following options for additional hydraulic modeling for the Local Actions Program have been prioritized based on the evaluation of flood damage potential in tributaries and community input described previously:

1. Obtain new bathymetric survey and update the Skookumchuck River and Newaukum River portions of the Chehalis Basin Strategy RiverFlow2D model to incorporate these data. Recalibrate the model as needed and run the model for the late-century catastrophic flood to identify areas of flooding. Estimated cost: $200,000 to $300,000. Estimated duration: 4 to 6 months.
2. Use previously collected topo-bathymetric LiDAR data to construct new models of key reaches on the Satsop and Wynoochee rivers to: 1) provide an evaluation of flood issues near the Satsop Riviera development and near the Montesano wastewater treatment plant (WWTP); and 2) provide modeling support for localized projects to address bank erosion. Estimated cost: $150,000 to $250,000. Estimated duration: 3 to 6 months.

3. Collect new channel bathymetric data and develop and calibrate new hydraulic models for Alder Creek and Mill Creek. Use these models to remap the FEMA floodplains for these systems and to delineate the floodplain for the late-century catastrophic flood. Identify locations of flooding and places where flood damage reduction actions might be possible. Estimated cost: $250,000 to $350,000. Estimated duration: 6 to 9 months.
4. Collect new channel bathymetric data and create a model of Cloquallum Creek. Use the model to remap the FEMA floodplains for the creek and to delineate the floodplain for the late-century catastrophic flood. Identify locations of flooding. Estimated cost: $100,000 to $150,000. Estimated duration: 3 to 6 months.
5. Refine and recalibrate the Natural Systems Design (NSD) RiverFlow2D model of the South Fork Newaukum River as needed. Use the model to remap the FEMA floodplain and delineate the floodplain for the late-century catastrophic flood. It is assumed that the existing topo-bathymetric LiDAR collected in 2017 is adequate for defining the channel in the model. Identify locations of flooding and places where flood damage reduction actions might be possible. Estimated cost: $125,000 to $200,000. Estimated duration: 3 to 6 months.
6. Collect channel survey data and extend the Chehalis Basin Strategy RiverFlow2D model upstream on Salzer Creek to the upstream extent of the FEMA SFHA (approximately 7 miles). Use the model to remap the FEMA floodplain and delineate the floodplain for the late-century catastrophic flood. Identify locations of flooding and places where flood damage reduction actions might be possible. Estimated cost: $150,000 to $200,000. Estimated duration: 3 to 6 months.
7. Develop a Stormwater Master Plan for storm system infrastructure in the cities of Aberdeen and Hoquiam (north of Grays Harbor). The estimated cost assumes that all necessary system inventory data are available and that the plan will identify flood problems under historical and late-century hydrologic conditions. Future work would be needed to identify alternatives to address flooding. Estimated cost: $250,000 to $350,000. Estimated duration: 6 to 12 months.
8. Obtain feedback from Thurston County on the Black River and Scatter Creek, and additional feedback from Grays Harbor County on Mox Chehalis Creek. Use this feedback to formulate options for additional hydraulic modeling on these streams similar to the above options. Estimated cost: $5,000. Estimated duration: 1 month.

References

Anchor QEA (Anchor QEA, LLC), 2017. Technical Memorandum to: Chrissy Bailey, Washington Department of Ecology. Regarding: Chehalis Basin Finished Floor Analysis – 2017 Update. October 6, 2017.

Microsoft OpenStreetMap, 2018. Available at: https://github.com/microsoft/USBuildingFootprints

STARR II, 2016. Hydraulic Analysis: Thurston County, Washington: Scatter Creek, February, Federal Emergency Management Agency, Washington D.C.

WSE (Watershed Science and Engineering), 2017. Technical Memorandum to: Rob Wilson, Lewis County Department of Public Works. Regarding: Wishkah Road Comprehensive Flood Study. May 26, 2017.

WSE, 2019a. Memorandum to: Bob Montgomery, Anchor QEA, LLC. Regarding: Chehalis River Basin Hydrologic Modeling. February 28, 2019.

WSE, 2019b. Technical Memorandum to: Bob Montgomery, Anchor QEA, LLC. Regarding: Chehalis River Existing Conditions RiverFlow2D Model Development and Calibration. February 28, 2019.

WSE and Anchor QEA, 2020. Memorandum to: Andrea McNamara-Doyle, Office of Chehalis Basin. Regarding: Local Actions Program Near-term Technical Analyses for Office of Chehalis Basin: Climate Change Modeling Options. October 2020, in progress.

APPENDIX A
SUMMARY OF SEPA DRAFT EIS COMMENT LETTERS RELATED TO HYDROLOGIC AND HYDRAULIC MODELING

This appendix reviews and summarizes the SEPA Draft EIS comment letters related to hydrologic and hydraulic modeling. The NEPA Draft EIS used the same models as the SEPA Draft EIS but used current hydrologic conditions instead of the 2080 hydrologic conditions analyzed for the SEPA analyses. While a number of hydrologic and hydraulic issues were raised in the comment letters, this appendix focuses on comments that are relevant to a Local Actions Program. Comments related to climate change are addressed in *Local Actions Program Near-term Technical Analyses for Office of Chehalis Basin: Climate Change Modeling Options* (WSE and Anchor QEA 2020). Please note that this appendix does not represent a formal response to comments on the SEPA Draft EIS. This information is being provided to inform a Local Actions Program.

SEPA Draft EIS Comments

Statistical Variations/Uncertainty of Hydraulic Model Results

Comments noted that the hydraulic model has statistical variations that were not reported in the SEPA Draft EIS. For example, one comment noted that the hydraulic model predicted previous flood levels within 0.5 foot of reported values only 48% of the time; the remainder of the time the flood levels are more than 0.5 foot different from reported high water mark elevations. Comments noted that statistical uncertainties are not accounted for in the SEPA Draft EIS.

Flooding Locations in Recent Floods Compared to Hydraulic Model

Comments stated that specific areas in the hydraulic model are shown to be inundated when recent flood events have not inundated those areas (Doty, for example), and areas in the hydraulic model are shown to be dry when recent flood events have inundated the area (Southwest Washington Fairgrounds, for example).

Use of Past Observed Hydrologic Data to Predict Future Floods

Comments noted that past hydrologic data used to determine future flooding from hydraulic models may not be appropriate. Specifically, there are concerns that using synthetic hydrographs developed in 2014 to analyze flood impacts may not be accurate, and gage data after the synthetic hydrographs were developed should be included. Additionally, comments suggest that, because recent floods have been higher, analyses should be focused on the recent floods instead of the full period of record.

Other comments questioned the validity of using observed streamflow gage data when operations will be determined using predictions of streamflow from the National Oceanic and Atmospheric Administration (NOAA) Northwest River Forecast Center. NSD prepared an analysis of 2- to 4-day forecasts from the NOAA model compared to observed flood flows and concluded that "observed flows differs substantially from the flow prediction dataset" that would be used for operation decisions (NSD 2020). NSD recommends using data from the NOAA model in combination with streamflow records to predict operation decisions and related impacts.

Flood Events from Tributaries

Comments noted that the hydraulic modeling does not address flood events where flooding occurs in major tributaries (such as the South Fork Chehalis River, Newaukum River, or Skookumchuck River) but does not occur in the upper Chehalis River. Several comments bring up this concern in various ways, asking, for example, what the impact would be if a 2007 event were to happen on a tributary but not in the upper Chehalis River Basin.

Discussion

Statistical Variations/Uncertainty of Hydraulic Model Results

The RiverFlow2D model used for the SEPA Draft EIS analyses was calibrated to high water marks (HWMs) and observed data at streamflow gages for the flood events of January 2009 and December 2007, and subsequently validated using data from the February 1996 flood. Calibrating and verifying a basin-scale hydraulic model to multiple flood events with a very large set of observed data is extremely challenging. While it is often not possible to match all observed data, comparisons to observed data throughout the floodplain provide a good indication of the model's overall performance. As discussed in the following paragraphs, it is our opinion that the model is well calibrated and therefore is suitable for use to analyze a Local Actions Program in the Chehalis River floodplain.

For the January 2009 flood event, the average error for the Newaukum River and Dillenbaugh Creek HWM points was approximately 0.04 foot. Almost half (66 out of 147) of the simulated results fall within +/- 0.5 foot of the measured HWMs, and about 75% (110 out of 147) within +/- 1.0 foot. Given the large population of HWM points, these results produce a reasonably close calibration. See WSE (2018) for further details and more specific discussion of the original January 2009 model calibration along the Newaukum River and floodplain.

The December 2007 flood event was considerably larger than the 2009 event on the Chehalis River, along both the mainstem and South Fork, which have their headwaters in the Willapa Hills. Considerable HWM peak data exist throughout the model domain including 140 surveyed HWMs as well as observed stage hydrographs at the USGS streamflow gages. There are fewer points, however, along the Newaukum River because the USGS did not collect post-flood data following the 2007 event. There are also no HWM data along the Skookumchuck River where this event was much smaller than January 2009. We are also not aware of any HWM data within the Grays Harbor County portion of the model, between the Black River confluence and Porter.

Simulations were completed for the December 2007 event and results compared to the set of HWM data. Given the large number of HWM points for this particular event that are widely spread throughout the model domain, it is useful to evaluate these on a reach-by-reach basis. Table 1 summarizes the results averaged by reach. Overall and in most reaches, the simulation is close with an average difference within 0.1 foot.

Table 1
Comparison of Computed to Observed Flood Levels for December 2007 Flood

RIVER/CREEK	REACH (RIVER MILE)	NUMBER OF POINTS	AVERAGE DIFFERENCE, FEET
Chehalis River	Potential dam site to Doty gage (RM 108.5–101.5)	5	-2.68
Chehalis River	Doty to South Fork (RM 101.5–88.0)	16	-0.76
Chehalis River	South Fork to Newaukum River (RM 88.0–75.25)	21	-0.13
Chehalis River	Newaukum River to Salzer Creek (RM 75.25–69.5)	10	0.29
Chehalis River	Salzer Creek to Skookumchuck River (RM 69.5–67.0)	20	0.36
Chehalis River	Skookumchuck River to Lincoln Creek (RM 67.0–61.75)	4	0.76
Chehalis River	Lincoln Creek to Black River (RM 61.75–47.0)	38	-0.07
South Fork Chehalis River	Throughout (RM 6.0–0.0)	11	0.16
Dillenbaugh Creek	Lower (RM 0.5–0.0)	3	-0.03
Salzer Creek	Throughout (RM 4.0–0.0)	3	0.14
Skookumchuck River	Lower (RM 1.0–0.0)	2	0.18
Lincoln Creek	Throughout (RM 4.0–0.0)	7	0.56
TOTAL	**All**	**140**	**-0.08**

It should be noted that differences between simulated values in the hydraulic model and observed HWMs can come from many sources, including errors in HWM identification, survey errors, errors in flows used as input to the hydraulic model, and errors in the hydraulic model itself. Because it is not possible to differentiate model errors from observation errors, it is difficult to formulate an approach to addressing only the model errors in the analysis. Furthermore, because the model is generally well calibrated and does not show a bias (over- or under-estimating results), it is our opinion that using the model results without adjustment for statistical uncertainty, i.e., the expected value, is appropriate for a Local Actions Program.

In the case of design of flood reduction facilities, factors of safety or conservative assumptions are often used to ensure facilities are not under-designed. However, the same approach is not generally appropriate to planning-level analyses or evaluation of project benefits because these conservative assumptions can unrealistically inflate project benefits.

Flooding Locations in Recent Floods Compared to Hydraulic Model

The RiverFlow2D hydraulic model does not show significant flooding of Doty in a 100-year flood and does show significant flooding of the Western Washington Fairgrounds. Other specific comments related to errors in the hydraulic modeling were reviewed and determined to be misinterpretations on the part of the commenter or incorrect. Mapping of the 100-year flood has been repeatedly circulated to basin communities and made available to any interested party with a specific request to identify areas where the modeling does not match historical observations. All such comments received by WSE have been evaluated and resolved within the hydraulic model. Therefore, no changes are recommended for the hydraulic modeling related to these comments.

Use of Past Observed Hydrologic Data to Predict Future Floods

Synthetic hydrographs used in the modeling were developed by the Corps (Corps 2013) after the last significant flood in the Chehalis Basin. The data used in that report reflect the largest floods on record in the Chehalis Basin. Hydraulic modeling was performed for 100-year floods as well as historical floods and the flood of record (1996, 2007, 2009). It is our opinion the hydrologic input used in hydraulic modeling is statistically valid and well represents the range of flood conditions that has occurred in the Chehalis Basin.

The second comment on hydrology concerns the accuracy of the National Weather Service (NWS) in predicting flood flows exactly 2 days and 4 days from the time of prediction. However, the comment overlooks the most important metric, which is how accurately the NWS predicts a major flood that would trigger the operation of the proposed dam. Whether the flood peak occurs earlier or later than predicted is not as relevant, because it would be far enough in advance to allow for operation of the dam and to change the operations as needed.

The NSD memorandum does not consider improvements in forecasting that have occurred and will occur in the future with better tools and models and additional data. The NWS adopted a new forecast platform about 7 years ago that will facilitate continued improvement in forecasting. It is reasonable to assume flood forecasting will continue to get more accurate over the life of the project so evaluations based on current forecast technologies and uncertainty are not appropriate for analysis of late-century conditions.

Flood Events from Tributaries

This issue has been raised numerous times in the past and was addressed in earlier phases of the Chehalis Basin Strategy (WSE 2014). The historical climate data show it is not meteorologically possible to have a rainfall event the magnitude of the December 2007 flood occur in most of the other tributaries (including specifically the Newaukum or Skookumchuck basins in the Cascade foothills). The historical streamflow data show that all significant floods in the last 100-years (since data have been recorded) in the Chehalis Basin have included proportionately higher discharge from the upper Chehalis Basin than from Cascade tributaries. This includes the January 2009 flood event, which is near the flood of record on the Newaukum and Skookumchuck rivers, but still had higher proportional flows from the upper Chehalis Basin. This was the case even though it was a less significant event in that basin than 2007 or 1996. Thus, the historical data show that even a moderate rainfall event in the upper Chehalis Basin, coupled with a flood of record type storm on the Cascade tributaries, sees a higher proportion of runoff coming from the upper basin as compared to these tributaries. Regardless, hydraulic modeling of the January 2009 flood has been conducted throughout the Chehalis Basin Strategy to demonstrate the effect that any proposed flood damage reduction project would have on floods centered in the Cascade tributaries. It is recommended that the Local Actions Program use the same approach as used in these previous analyses, considering design events, design events scaled to future conditions, and historical flood events to evaluate a range of hydrologic conditions.

Appendix A References

Corps (U.S. Army Corps of Engineers), 2013. *Chehalis Basin Ecosystem Restoration General Investigation Baseline Hydrology and Hydraulic Modeling - Draft Hydraulics Analysis Report*. Prepared by WEST. September 5, 2013.

NSD (Natural Systems Design), 2020. Memorandum to: Quinault Indian Nation. Regarding: Critical Review of Proposed Chehalis River Basin Flood Damage Reduction Project SEPA DEIS Hydrology Technical Memo 1: Observed and Predicted Flows Relative to FRE Facility Operation. April 22, 2020.

WSE (Watershed Science and Engineering), 2014. Memorandum to: H&H Technical Committee. Regarding: Chehalis Basin Strategy: Reducing Flood Damage and Enhancing Aquatic Species – Re-evaluation of Statistical Hydrology and Design Storm Selection for the Chehalis River Basin. January 31, 2014.

WSE, 2018. Memorandum to: Bob Montgomery, of Anchor QEA, LLC. Regarding: Newaukum River Existing Conditions RiverFlow2D Hydraulic Model Development. October 16, 2018.

WSE and Anchor QEA (Anchor QEA, LLC), 2020. Memorandum to: Andrea McNamara-Doyle, Office of Chehalis Basin. Regarding: Local Actions Program Near-term Technical Analyses for Office of Chehalis Basin: Climate Change Modeling Options. October 2020, in progress.

APPENDIX B
COORDINATION WITH COMMUNITIES

WSE staff contacted public works officials or floodplain managers at 15 communities in the basin and posed the following questions:

1. Are there specific areas in your community with significant flood or erosion issues where you believe additional hydraulic modeling and analysis would help to better understand the situation, and help you develop flood damage reduction alternatives?
2. Are there areas where you anticipate future development might be at risk of flooding, where additional analysis would be helpful to minimize the potential for flood or erosion damage?

A map and matrix of flood damage by location were developed by Anchor QEA and provided to each community. Referring to this figure and table:

1. Confirm or correct the types of flood damage identified by subbasin on the attached subarea map and matrix. The map and table were developed based on our current knowledge and understanding, but we would like to confirm it with on-the-ground experience. You may have received this question already, so please feel free to forward me any feedback you have already provided.

2. Some flooding may be the result of stormwater systems rather than from rivers or streams. This can be due to either old and undersized systems, or the result of poor construction or lack of maintenance of facilities like ditches, culverts, and pipes. Have you identified stormwater flooding problems in your community (if so, can you please provide a description of these)? Are these due primarily due to undersized drainage systems or other issues such as maintenance? What is your current approach for dealing with these stormwater flooding problems?
3. With regard to streambank erosion, what is the extent that erosion is currently damaging or threatening structures? What is the extent that erosion is threatening property? Can you identify specific locations (structures or river miles) significantly affected by channel bank erosion?

Of the 15 communities contacted by WSE, 12 provided feedback via email, phone conversations, or teleconferences in time to be included in this memorandum. Feedback provided is summarized below.

Lewis Conservation District: Flood damages to agricultural properties are widespread but flood dependent and thus there are no particular reaches that stand out as needing modeling more than others. Any reaches (such as South Fork Chehalis) that have not yet been modeled in detail would be good candidates for additional analysis. Many areas, particularly on the North Fork Newaukum, are seeing conversion of agricultural land to residential development and these are likely to have greater flood risk.

Grays Harbor Conservation District: Biggest concern is generally riverbank erosion. Particular locations with erosion problems include the Satsop River above the Monte-Elma Bridge and above the West Fork Bridge. One particular area with high flood risk is the Satsop Riviera, which experiences flooding and is potentially in an avulsion path. Additional modeling and analysis of that reach of the Satsop River would be beneficial. On the Wynoochee River, flooding is generally less of a problem due to the existing dam but erosion is still a significant risk. Agricultural owners generally know that flooding will happen and are able to live with it, but erosion is a more imminent threat in many locations.

City of Centralia: The Skookumchuck River is the most significant flood concern for Centralia. Flooding on the Skookumchuck River may be worsening due to sediment aggradation. The last channel surveys of the Skookumchuck River were in 2000 or earlier. Salzer Valley has flooding and erosion issues that have not been investigated. There are additional flooding and erosion issues on China Creek (being investigated by Rambol), Vinegar Valley, Coffee Creek, and the Goff neighborhood.

City of Chehalis: Coal Creek has experienced flooding but there has not been significant damage. There is some local flooding at National Avenue and on Dillenbaugh Creek. The City maintains the Airport Levee and associated pump stations but does not maintain or operate any other levees or pump stations.

City of Aberdeen: Flooding within Aberdeen includes coastal flooding, riverine flooding, and urban stormwater flooding. A Stormwater Master Plan covering the cities of Hoquiam, Aberdeen, and Cosmopolis is needed because the stormwater systems for these three communities become linked at various locations during periods of high flow. There is limited space for additional development in the coastal floodplain within Aberdeen. As a result, future development would likely be located in lower risk, higher elevation areas. A FEMA flood study has been completed for Wilson Creek but this has not eliminated flooding. Other creeks that experience flooding include Division Creek, Duffy Creek, and Alder Creek. Alder Creek, in the south Aberdeen area overflows and leads to flooding near the outlet of Mill Creek in Cosmopolis.

City of Hoquiam: The proposed North Shore Levee and West Segment will address many of Hoquiam's flooding problems, but not the two most significant problems (the Woodlawn area in East Hoquiam and Endressen Street). The cause of flooding is generally related to high tides and thus additional riverine modeling of these areas may not be necessary. The City operates 12 or 13 stormwater pump stations, but has not had a detailed evaluation of the storm drainage system. A stormwater study was completed in 2000, but it was not adequate to define future needs. Therefore, evaluating stormwater issues (similar to Aberdeen) would be beneficial.

City of Elma: A recent project addressed erosion at the City's wastewater outfall, but upstream erosion may still be an issue. Other creeks with flooding and erosion issues include Cloquallum Creek to the east of town and Vance Creek/Dry Creek to the west. Cloquallum Creek flooding is generally minor but erosion near the Washington State Department of Transportation Bridge has been an issue. New development upstream on Vance Creek may increase downstream flood risk and overflows to Dry Creek, but additional modeling is probably not warranted to address this.

City of Montesano: Additional hydraulic modeling and analysis would be beneficial to understand ongoing erosion at the Montesano WWTP. Modeling would need to include the relic channels on the Wynoochee across from the WWTP. In addition to the Wynoochee, an analysis of Sylvia Creek (several fish barriers located on this creek) could be beneficial but is not a priority.

City of Cosmopolis: Flooding of Mill Creek is a significant issue for Cosmopolis. Modeling and analysis of the creek from the Mill Creek Dam to the outlet at the Chehalis River is needed. A number of properties along the creek have seen flooding. The low-lying area near the Chehalis River levee receives overflows from South Aberdeen (Faragut Street Pump Station) and these exacerbate flooding in that area. An analysis needs to consider the basin hydrology, the existing dam, the channel, the tides, and the storage landward of the existing levee. Updated floodplain maps would be useful to show flood risk and minimize damage potential. A request for modeling and analysis of this area was recently submitted to the Flood Authority, but it is not clear whether it will receive funding or not.

Lewis County Public Works: Several creeks in Lewis County have experienced flooding and would benefit from additional modeling and analysis. These include the following:

- McCormick Creek near Pe Ell, which drains to Rock Creek; erosion has affected the County road and where the creek goes under Highway 6
- Lake Creek, which drains to the South Fork Chehalis near Curtis; the County has observed significant roadway and private property damage
- Deep Creek, which drains to Bunker Creek
- Independence Creek
- Lincoln Creek
- Stearns Creek

Grays Harbor County Public Works: The County has not identified specific rivers or creeks where additional modeling would be helpful. An earlier (WSE 2017) study identified flood issues along Wishkah Road, but funding was not available to address these. The County is not aware of significant flood or erosion issues on the Humptulips River. Satsop River flooding and erosion along roads and bridges is a concern and may be increasing due to sedimentation in the river. Flooding along the Chehalis River remains a significant issue, in particular the duration of flooding.

In addition to the communities listed previously, the Thurston County Conservation District, Town of Bucoda, City of Napavine, and Thurston County Department of Public Works were contacted for input to this memorandum. Unfortunately, input was not obtained from these communities in time for use in the evaluation and prioritization described herein.

Appendix B Reference

WSE (Watershed Science and Engineering), 2017. Technical Memorandum to: Rob Wilson, Lewis County Department of Public Works. Regarding: Wishkah Road Comprehensive Flood Study. May 26, 2017.

APPENDIX C
DRAFT HYDRAULIC MODELS IN CHEHALIS BASIN

Appendix C provides a preliminary summary of hydraulic models within Lewis, Thurston, and Grays Harbor counties for the Chehalis Basin Strategy. Most are detailed models using 1D HEC-RAS or 2D models. These are current or fairly recent models that could be available to use for further analysis. It is important to note that this document does not provide an exhaustive list of potential hydraulic models throughout the basin. This information will be reviewed and revised in consultation with local officials and other experts.

Lewis County

Chehalis River and numerous tributaries (Watershed Science and Engineering [WSE])

This modeling included the entire mainstem of Chehalis River from the proposed Flood Retention Expandable (FRE) facility site near Pe Ell to the mouth of the river near Aberdeen, in addition to extended reaches of many tributaries. The work included modeling of various basin-wide design flood events (2-year to 500-year) as well as modeling of the historical February 1996, December 2007, and January 2009 flood events. Products available from this modeling include hydraulic models, floodplain maps, numerous datasets as used in other analyses, and various reports, memoranda, and presentations.

- Programmatic SEPA EIS (2016, HEC-RAS 1D model)
- Project-level SEPA Draft EIS (2019, RiverFlow2D model)
- Project-level NEPA Draft EIS (2019, RiverFlow2D model)

South Fork Chehalis River (Natural Systems Design [NSD] and/or Interfluve)

- Existing Conditions and Restorative Flood Protection Alternative (NSD, 2016, HEC-RAS 1D and/or 2020, RiverFlow2D models, simulated design flood events (2-, 10-,20-, 100-, 500-year), products available: models and output data)
- Aquatic Species Restoration Plan (ASRP) early action (Interfluve, 2019, RiverFlow2D, products available: ??)

Elk Creek (NSD)

- Existing Conditions and Restorative Flood Protection Alternative (2016, HEC-RAS 1D and/or 2020, RiverFlow2D models, simulated design flood events (2-, 10-, 20-, 100-, 500-year), products available: models and output data)

Bunker Creek (NSD)

- Existing Conditions and Restorative Flood Protection Alternative (2016, HEC-RAS 1D and/or 2020, RiverFlow2D models, simulated design flood events (2-, 10-, 20-, 100-, 500-year), products available: models and output data)

North Fork and South Fork Newaukum Rivers above confluence (NSD)

- Existing Conditions and Restorative Flood Protection Alternative (2016, HEC-RAS 1D model and 2020 RiverFlow2D model, simulated design flood events (2-, 10-, 20-, 100-, 500-year), products available: models and output data)

Dillenbaugh Creek (Skillings Connolly)

- Chehalis Basin Strategy Local Projects (2017, HEC-RAS 1D Model and WWHM model, computed design discharges using WWHM and simulated range of events using HEC-RAS, products available: models, output data, report (on EZView)

Salzer Creek (WSE)

- Local flood evaluation, not part of Chehalis Basin Strategy (2018, HEC-RAS 1D model, simulated design flood events (2-, 10-, 100-year), products available: models, output data, summary of results)

China Creek (Environ)

- Chehalis Basin Strategy Local Projects (2016, HEC-RAS unsteady model, simulated range of design events, products available: model, data, report?)

Skookumchuck River

- Chehalis Basin Strategy Local Projects – Main Street Bucoda (WSE, 2016, HEC-RAS unsteady model, January 2009 and 100-year flood, products available: model, data, summary of results)
- ASRP early action (NSD 2019 revised the RiverFlow2D model, WSE RiverFlow2D model unsteady model, simulated range of design events, products available: model, data, report)
- Federal Emergency Management Agency (FEMA) HEC-RAS model (nearly final; note that Anchor QEA obtained this from FEMA for early action reaches)

Thurston County

Chehalis River and numerous tributaries (WSE) (for model details see above discussion under Lewis County)

- Programmatic SEPA EIS (2016, HEC-RAS 1D model)
- Project-level SEPA Draft EIS (2019, RiverFlow2D model)
- Project-level NEPA Draft EIS (2019, RiverFlow2D model)

Scatter Creek at Independence Road (WSE)

- Local flood evaluation, not part of Chehalis Basin Strategy (2019, RiverFlow2D model, simulated design flood events (2-, 10-, 25-, 100-year), products available: models, output data, alternatives analysis)

Chehalis River and Harris Creek (Environ)

- Chehalis Basin Strategy Local Projects – Sickman Ford Bridge (2012, HEC-RAS 1D unsteady model, 25- and 100-year floods, products available: model, data, report)

Grays Harbor County

Chehalis River and numerous tributaries (WSE) (for model details see above discussion under Lewis County)

- Programmatic SEPA EIS (2016, HEC-RAS 1D model)
- Project-level SEPA Draft EIS (2019, RiverFlow2D model)
- Project-level NEPA Draft EIS (2019, RiverFlow2D model)

Wishkah River (WSE)

- Chehalis Basin Strategy Local Projects – Wishkah Road Comprehensive Study (2018, HEC-RAS 1D and HEC-RAS 2D unsteady models, 10-, 25-, 50-, 100-, and 500-year floods, products available: model, data, report)

Hoquiam River (WSE)

- Chehalis Basin Strategy Local Projects – Aberdeen-Hoquiam North Shore Levee (2019, HEC-RAS 1D and HEC-RAS 2D unsteady models, 2-, 10-, 25-, 100-year floods, products available: model, data, technical memorandum)

Satsop River

- ASRP early action project (NSD 2019 revised the RiverFlow2D model, WSE RiverFlow2D Model, 1-, 2-, 5-, 10-, 25-, -50, 100-year floods, products available: model, data, report, design drawings)
- Chehalis Basin Strategy Local Projects – Farm Pads (2017, WSE, HEC-RAS 2D model, 2-, 10-, 25-, 100-year floods, products available: model, data, technical memorandum)

- Satsop River Restoration Project (2016, WSE, SRH-2D model, 2-, 10-, 25-, 100-year floods, products available: model, data, technical memorandum)
- Satsop River Flood and Erosion Reduction Project (2004, WEST, HEC-RAS 1D model, 2-, 10-, 25-, 100-year floods, products available: model, data, technical memorandum)
- Lower Satsop River Keys Road Flood Protection Project (2019, NSD, RiverFlow2D model, 2-, 10-, 100-year floods, products available: model, data, technical memorandum)

Wynoochee River

- Chehalis Basin Strategy Local Projects – Farm Pads (2017, WSE, HEC-RAS 2D model, 2-, 10-, 25-, 100-year floods, products available: model, data, technical memorandum)
- Corps Ecosystem Restoration Study (2012, WEST, HEC-RAS 1D model, 2-, 10-, 25-, 100-year floods, products available: model, data, technical memorandum)
- ASRP early action project (NSD 2019 revised the RiverFlow2D model, WSE RiverFlow2D Model, 1-, 2-, 5-, 10-, 25-, 50-, 100-year floods, products available: model, data, report, design drawings)

Rivers and Creeks Modeled in FEMA Flood Insurance Studies

The following rivers and creeks in Lewis, Thurston, and Grays Harbor counties have been studied in detail by FEMA. Not all of these rivers and creeks are in the Chehalis Basin. Most of these FEMA studies are probably quite old, dating to the year 2000 or before. Some of these were completed as early as 1984 (Wishkah). Nearly all of these detailed studies would have been completed using steady state 1D hydraulic modeling (HEC-2 or a similar software). The survey data for FEMA studies is typically collected 1 to 4 years before publication of the study, thus survey or other data used in these studies may be 40 years old or older. Models and other supporting data for some of these studies may be available from FEMA but experience shows that FEMA will not have any data for most of these studies. Any available data will likely only be available in hard copy format.

The only way to determine what supporting data are available from FEMA is to make a formal request via the FEMA archives. There is a minimum cost of $300 per request plus additional fees for large requests unless the request is made by a National Flood Insurance Program participating agency for their own use. FEMA estimates it will take a minimum of 2 to 3 weeks to respond to a request.

Lewis County

The following streams were studied by detailed methods:

Stream	Detailed Study Reach From River Mile	to River Mile
Skookumchuck River	0.0	5.80
Chehalis River	60.48	98.0
	99.67	101.63
	105.10	106.97
South Fork Chehalis River	0.0	6.95
Newaukum River	0.0	11.42
South Fork Newaukum River	11.42	23.86
North Fork Newaukum River	0.0	5.25
Middle Fork Newaukum River	0.0	1.25
Tilton River	9.0	21.90
South Fork Tilton River	0.0	1.05
Cispus River	12.20	16.67
Cowlitz River	29.07	36.84
	91.12	131.64
China Creek	0.0	4.55
Coffee Creek	0.0	2.60
Lincoln Creek	0.0	1.12
Dillenbaugh Creek	0.0	5.25
Berwick Creek	0.0	2.98
Hanaford Creek	0.0	3.04
Salzer Creek	0.0	4.62
Salzer Creek-Middle Fork	0.0	0.45
Salzer Creek-South Fork	0.0	4.14
Salzer Creek-North Fork	0.0	0.75
Lake Creek (Tributary to South Fork Chehalis River)	0.0	2.0
Elk Creek	0.0	2.84
Lake Creek (Tributary to Tilton River)	0.0	1.94
Big Creek	0.0	6.20
Olequa Creek	2.0	5.12
	10.05	16.67
Mineral Creek	1.45	4.13
Roundtop Creek	0.0	1.0
Lacamas Creek	3.75	18.50
Siler Creek	0.0	3.40
No Name Creek (Tributary to Siler Creek)	0.0	0.39
Surrey Creek	0.0	1.87
Silver Creek	0.15	1.25
Hall Creek	0.0	3.22
Coal Creek	0.0	2.60

Thurston County

Table 2 – Streams Studied by Detailed Methods

Streams	Downstream Limit of Study	Upstream Limit of Study
Black River	From the western boundary of Thurston County (River Mile (RM) 5.6) upstream	Black Lake
Chehalis River	From the western boundary of Thurston County (RM 52.1) upstream	Southern boundary of Thurston County (RM 60.7)
Deschutes River	Corporate Limits of the City of Tumwater (River Mile (RM) 3.4)	Approximately 7000 feet upstream of the confluence with Thurston Creek (RM 41.6)
Outlet of Black Lake	From Mottman Road Southwest	Black Lake
Percival Creek	Corporate limits of the City of Tumwater at Sapp Road upstream	Trosper Lake
Scatter Creek	From 11,250 downstream of Grand Mound Road crossing at Tenino	Approximately 4,700 feet upstream of the confluence of Scatter Creek Tributary
Scatter Creek Tributary	Confluence with Scatter Creek	State Highway 507
Skookumchuck River	Just upstream Tono-Bucoda Road (Thurston County boundary (RM 5.5)	(River Mile 20.7 (1.2 miles downstream of Skookumchuck Dam))
Woodland Creek	From Pleasant Glade Road NE	Approximately 500 feet downstream of Interstate 5
Yelm Creek	Just upstream Centralia Power Canal Flume	Approximately 2.7 miles upstream Centralia Power Canal Flume

Grays Harbor County

Stream	Limits of Detailed Study
Alder Creek	From confluence with the Chehalis River to 800 feet upstream of Huntley Street
Bush Creek	From confluence with Cloquallum Creek to Cloquallum-Lost Lake Road
Chehalis River	From (River Mile) RM 1.5 to RM 9.2
Cloquallum Creek	From approximately 1.3 miles upstream of U.S. Highway 12 to the confluence with Bush Creek
Dry Bed Creek	From U.S. Highway 12 to 1,000 feet north of Burlington Northern Railroad
East Fork Hoquiam River	From confluence with Hoquiam River to approximately 0.8 miles upstream of confluence with Hoquiam River
East Fork Wildcat Creek	From approximately 370 feet upstream of U.S. Highway 410 to approximately 1,200 feet upstream of McCleary Summit Road
Fry Creek	From confluence with the Chehalis River to 300 feet downstream of Hemlock Street
Grays Harbor	Port of Grays Harbor
Harris Creek River	From Garrard Creek Road to 1,000 feet north of Burlington Northern Railroad
Hoquiam River	From confluence with Grays Harbor to approximately 800 feet upstream of the confluence with Little Hoquiam River
Little Hoquiam River	From confluence with Hoquiam River to approximately 1.9 miles upstream of U.S. Route 101
Mill Creek	From approximately 800 feet upstream of Altenau Street to approximately 250 feet upstream of C Street
Newman Creek	From approximately 2,300 feet downstream of O'Neil Road to the confluence of the East and West Branch Newman Creek
Pacific Ocean Coast	From the Grays Harbor – Pacific County border north to the City of Westport city limits
Pacific Ocean Coast	Within the city limits of the City of Westport
Pacific Ocean Coast	Within the city limits of the City of Ocean Shores
Pacific Ocean Coast	From Ocean Shores City limits north to Copalis Rock National Wildlife Refuge
Pacific Ocean Coast	From Copalis Rock National Wildlife Refuge north to Copalis Head
Pacific Ocean Coast	From 0.3 mile south of State Highway 109 bridge over Joe Creek north for 0.6 mile, near Pacific Beach
Pacific Ocean Coast	From Quinault Indian Reservation south for 1.3 miles, near Moclips
Roundtree Creek	From confluence with Harris Creek to 650 feet north of Burlington Northern Railroad

Satsop River	From approximately 4,500 feet downstream of U.S. Highway 12 to approximately 1.8 miles upstream of the confluence of West and East Fork
Stewart Creek	From confluence with the Wishkah River to the north side of Valley Street
South Bay	From Hunt Club Road south of Laidlaw Island to the Westport city limits
Tributary to Mill Creek at mile 0.15	Entire reach within the City of Cosmopolis limits
Vance Creek	From U.S. Highway 12 to 0.5 mile north of Burlington Northern Railroad
Wilson Creek	From confluence with the Chehalis River to approximately 200 feet upstream of Henry Street
Wishkah River	From the confluence with Grays Harbor to approximately 3,000 feet upstream of the confluence with Stewart Creek
Wynoochee River	Approximately 300 feet downstream of the confluence of Caldwell Creek to approximately 4,200 feet upstream of the confluence with Wedekind Creek

APPENDIX D
LAND-USE CATEGORIES FOR AGRICULTURE AND DEVELOPMENT ANALYSES

Lewis County

ZONE	COMP_CAT	FOR AGRICULTURE ANALYSIS	FOR DEVELOPMENT ANALYSIS
ARL	Agricultural	Yes	
CC	LAMIRD		Yes
City	Cities		Yes
FC	LAMIRD		Yes
Forest	Forest		
FRL-LI	Forest		
Lake	Lake		
MID	UGA - County		Yes
Mine	Mineral		
Park	Parks and Tourism		
RAI	LAMIRD		Yes
RDD-10	Rural		
RDD-20	Rural		
RDD-5	Rural		
RRC-R.5	LAMIRD		
RRC-R1	LAMIRD		
RRC-R10000	LAMIRD		
RRC-R2	LAMIRD		
STI	LAMIRD		Yes
STI	UGA - County		Yes
STMU	LAMIRD		Yes
STMU	UGA - County		Yes
STR-4	LAMIRD		
TSA	Parks and Tourism		
UGA	UGA		Yes
Wilderness	Forest		

Thurston County

ZONECODE	NAME	FOR AGRICULTURE ANALYSIS	FOR DEVELOPMENT ANALYSIS
AC	ARTERIAL COMMERCIAL		Yes
AG	AGRICULTURE	Yes	
AQUATC	AQUATIC		
ARI	AIRPORT RELATED INDUSTRY		Yes
ARI2	AIRPORT RELATED INDUSTRY		Yes
AS	AUTO SERVICES		Yes
BD	BREWERY DISTRICT		Yes
BP	BUSINESS PARK		Yes
C	CEMETERY		
C-1	COMMERCIAL		Yes
C-2	HEAVY COMMERCIAL		Yes
C-3	LARGE LOT COMMERCIAL		Yes
CBC	CAPITOL BOULEVARD COMMUNITY		Yes
CBC2	CAPITOL BOULEVARD COMMUNITY		Yes
CBD	CENTRAL BUSINESS DISTRICT		Yes
CBD 4	CENTRAL BUSINESS DISTRICT 4		Yes
CBD 5	CENTRAL BUSINESS DISTRICT 5		Yes
CBD 5	CENTRAL BUSINESS DISTRICT 5		Yes
CBD 6	CENTRAL BUSINESS DISTRICT 6		Yes
CBD 7	CENTRAL BUSINESS DISTRICT 7		Yes
CC	CORE COMMERCIAL		Yes
CC/CS-H	CAPITOL CAMPUS/COMMERCIAL SERVICE HIGH		Yes
CCD	COMMUNITY COMMERCIAL		Yes
CD	COMMERCIAL DEVELOPMENT		Yes
CO	COMMUNITY OFFICE		Yes
COM	COMMERCIAL		Yes
COSC	COMMERCIAL ORIENTED SHOPPING CENTER		Yes
CS	COMMUNITY SERVICE		Yes
CS	COMMUNITY SERVICE		Yes
DB	DOWNTOWN BUSINESS		Yes
FRL	FORESTLAND		
GB	GREEN BELT		
GC	GENERAL COMMERCIAL		Yes
GC6	GENERAL COMMERCIAL		Yes
HC	HIGHWAY COMMERCIAL		Yes
HD	HIGH DENSITY RESIDENTIAL		Yes

ZONECODE	NAME	FOR AGRICULTURE ANALYSIS	FOR DEVELOPMENT ANALYSIS
HDC-1	HIGH DENSITY CORRIDOR 1		Yes
HDC-2	HIGH DENSITY CORRIDOR 2		Yes
HDC-3	HIGH DENSITY CORRIDOR 3		Yes
HDC-4	HIGH DENSITY CORRIDOR 4		Yes
HI	HEAVY INDUSTRIAL		Yes
HPBD-C	HAWKS PRAIRIE BUSINESS DISTRICT-COMMERCIAL		Yes
HPBDBC	HAWKS PRAIRIE BUSINESS DISTRICT-BUSINESS/COMMERCIAL		Yes
I	INDUSTRIAL		Yes
ID	INSTITUTIONAL DISTRICT		Yes
IND	INDUSTRIAL		Yes
LAKE	LAKE		
LD 0-4	LOW DENSITY RESIDENTIAL 0-4		
LD 3-6	LOW DENSITY RESIDENTIAL 3-6		
LHN	LACEY HISTORIC NEIGHBORHOOD		
LI	LIGHT INDUSTRIAL		Yes
LI-C	LIGHT INDUSTRIAL COMMERCIAL		Yes
LI2	LIGHT INDUSTRIAL		Yes
LTA	LONG TERM AGRICULTURE	Yes	
LTF	LONG TERM FORESTRY		
MD	MODERATE DENSITY RESIDENTIAL		Yes
ME	MINERAL EXTRACTION		
MEI	MAJOR EDUCATIONAL INSTITUTION		Yes
MF	MULTIFAMILY RESIDENTIAL		Yes
MFH	MULTIFAMILY HIGH DENSITY RESIDENTIAL 14-29 UNITS PER ACRE		Yes
MFM	MULTIFAMILY MEDIUM DENSITY RESIDENTIAL 9-15 UNITS PER ACRE		Yes
MFM2	MULTIFAMILY MEDIUM DENSITY RESIDENTIAL 9-15 UNITS PER ACRE		Yes
MGSA	MCALLISTER GEOLOGICALLY SENSITIVE AREA		
MHDC	MIXED USE HIGH DENSITY		Yes
MHP	MANUFACTURE HOUSING PARK		Yes
MHP2	MANUFACTURED HOME PARK		Yes
MMDC	MIXED USE MODERATE DENSITY		Yes
MPC	MASTER PLANNED COMMUNITY		Yes
MR	MILITARY RESERVATION		
MR 10-18	MIXED RESIDENTIAL 10-18 UNITS		Yes
MR 7-13	MIXED RESIDENTIAL 7-13		Yes

ZONECODE	NAME	FOR AGRICULTURE ANALYSIS	FOR DEVELOPMENT ANALYSIS
MS	MEDICAL SERVICE		Yes
MU	MIXED USE		Yes
MU5	MIXED USE		Yes
NA	NISQUALLY AGRICULTURE	Yes	
NATURL	NATURAL		
NC	NEIGHBORHOOD CONVENIENCE COMMERCIAL		Yes
NC	NEIGHBORHOOD COMMERCIAL		Yes
NR	NEIGHBORHOOD RETAIL		Yes
NV	NEIGHBORHOOD VILLAGE		Yes
OS	OPEN SPACE		
OS-I	OPEN SPACE INSTITUTIONAL		
OS2	OPEN SPACE		
OSI-P	OPEN SPACE PARK		
OSI-S	OPEN SPACE SCHOOL		
P/OS	OPEN SPACE PARK		
P/SP	PUBLIC/SEMI-PUBLIC		Yes
PF	PUBLIC FACILITY		Yes
PID	PLANNED INDUSTRIAL PARK		Yes
PO	PROFESSIONAL OFFICE		Yes
PO/RM	PROFESSIONAL OFFICE/RESIDENTIAL		Yes
PP	PUBLIC PARKS TRAILS AND PRESERVES		
PU	PUBLIC USE		
PUD	PLANNED UNIT DEVELOPMENT		Yes
R-14	HIGH DENSITY RESIDENTIAL 14		Yes
R-4	SINGLE FAMILY RESIDENTIAL 4		Yes
R-4-8	RESIDENTIAL 4-8		Yes
R-4CB	SINGLE-FAMILY RESIDENTIAL (CHAMBERS BASIN)		Yes
R-6	MODERATE DENSITY RESIDENTIAL		Yes
R-6-12	TWO FAMILY RESIDENTIAL 6-12		Yes
R-6-12	TWO FAMILY RESIDENTIAL 6-12		Yes
R-6-12	RESIDENTIAL 6-12		Yes
R-6-12	TWO FAMILY RESIDENTIAL 6-12		Yes
R 1/10	RURAL 1/10		
R 1/20	RURAL 1/20		
R 1/5	RESIDENTIAL 1 UNIT PER 5 ACRE		
R/SR	RESIDENTIAL SENSITIVE RESOURCE 2-4 UNITS PER ACRE		Yes
R/SR2	RESIDENTIAL SENSITIVE RESOURCE 2-4 UNITS PER ACRE		Yes

ZONECODE	NAME	FOR AGRICULTURE ANALYSIS	FOR DEVELOPMENT ANALYSIS
R3-6/1	RESIDENTIAL 3-6 UNITS PER ACRE		Yes
R4-16/1	RESIDENTIAL 4-16 UNITS PER ACRE		Yes
R6/8	RESIDENTIAL 6/8		Yes
R8/25	RESIDENTIAL 8/25		Yes
RCC	RURAL COMMERCIAL		Yes
REN - 0.25	RESIDENTIAL EXISTING NEIGHBORHOOD - 0.25 ACRE		Yes
REN - 0.35	RESIDENTIAL EXISTING NEIGHBORHOOD - 0.35 ACRE		Yes
REN - 1.00	RESIDENTIAL EXISTING NEIGHBORHOOD - 1 ACRE		Yes
RES	RESIDENTIAL		Yes
RL1/1	RESIDENTIAL LAMIRD 1/1		Yes
RL1/2	RESIDENTIAL LAMIRD 1/2		Yes
RL2/1	RESIDENTIAL LAMIRD 2/1		Yes
RLI	RESIDENTIAL LOW IMPACT		Yes
RLI 2-4	RESIDENTIAL LOW IMPACT 2-4		Yes
RM-18	RESIDENTIAL MULTIFAMILY 18		Yes
RM-24	RESIDENTIAL MULTIFAMILY 24 UNITS PER ACRE		Yes
RM-H	HIGH RISE MULTIFAMILY		Yes
RMU	RESIDENT MIXED USE		Yes
ROW	ROW		
RR1/5	RURAL RESIDENTIAL 1/5		Yes
RRI	RURAL RESOURCE INDUSTRIAL		Yes
RRR1/5	RURAL RESIDENTIAL RESOURCE 1/5		Yes
SC	SERVICE COMMERCIAL		Yes
SF	SINGLE FAMILY		Yes
SF-D	SINGLE FAMILY DUPLEX		Yes
SF-ES	SINGLE FAMILY ENVIRONMENTALLY SENSITIVE		Yes
SFL	SINGLE FAMILY LOW DENSITY RESIDENTIAL 4-7 UNITS PER ACRE		Yes
SFL2	SINGLE FAMILY LOW DENSITY RESIDENTIAL 4-7 UNITS PER ACRE		Yes
SFM	SINGLE FAMILY MEDIUM DENSITY RESIDENTIAL 6-9 UNITS PER ACRE		Yes
SFM	MEDIUM DENSITY RESIDENTIAL 6-9		Yes
SFM1	SINGLE FAMILY MEDIUM DENSITY RESIDENTIAL 6-9 UNITS PER ACRE		Yes
SFM2	SINGLE FAMILY MEDIUM DENSITY RESIDENTIAL 6-9 UNITS PER ACRE		Yes
SHORES	SHORELINE RESIDENTIAL		Yes
SMU	SAINT MARTINS UNIVERSITY		Yes
T/OS/P	TRAILS/OPENSPACE/PARKS		

ZONECODE	NAME	FOR AGRICULTURE ANALYSIS	FOR DEVELOPMENT ANALYSIS
TC	TOWN CENTER		Yes
TC2	TOWN CENTER		Yes
UR	URBAN RESIDENTIAL		Yes
UR 1/5	URBAN RESERVE 1/5		
URBCON	URBAN CONSERVANCY		
UV	URBAN VILLAGE		Yes
UW	URBAN WATERFRONT		Yes
UWH	URBAN WATERFRONT HISTORIC		Yes
V(U)C	VILLAGE (URBAN) CENTER		Yes
WD	WOODLAND DISTRICT		Yes
WT	WEST TENINO		

Grays Harbor County

DESCRIPTION	FOR AGRICULTURE ANALYSIS	FOR DEVELOPMENT ANALYSIS
Agricultural	Yes	
Agricultural I	Yes	
Agricultural II	Yes	
General Development		Yes
General Development Area		Yes
Industrial		Yes
Lake Quinault		
Recreational - Residential		
Residential		Yes
Rural Development		
Rural Residential		
Satsop Development Park		Yes
Urban Services		Yes
Urbanizing		Yes