March 13, 2009

GeoEngineers

Confederated Tribes of the Chehalis Reservation
P.O. Box 536
Oakville, Washington 98568

Attention: Lennea Magnus, Planning Director

Subject: Comprehensive Flood Hazard Management Plan for the Confederated Tribes of the Chehalis Reservation
GEI File No. 8773-014-00 and -01

We are pleased to transmit to you a copy of the Comprehensive Flood Hazard Management Plan, which has been prepared to comply with the requirements of Washington Administrative Code 173-540-040, and in compliance with the Flood Control Assistance Account Program (FCAAP) grant that was awarded to the Chehalis Tribe by Washington State. A 100-year flood map was prepared for use with this Plan. The modeling approach used to develop the map is sufficient to map the 100-year flood event, but is not consistent with the formal FEMA standard. No in-stream flood control measures were proposed in this plan; therefore, an alternatives and impacts analysis was not conducted. Our approach to preparation of this Plan and the flood map were approved by you and by Kevin Farrell, Floodplain Management Specialist for the Washington State Department of Ecology. This Plan document was finalized by GeoEngineers, Inc. and Herrera Environmental Consultants after receiving comments subsequent to having been presented to the public as a review draft.

Attached find:

- One hard copy of the final Plan
- CD with Plan document in PDF format

We have prepared this plan for the exclusive use of the Confederated Tribes of the Chehalis Reservation and regulatory agencies.

Within the limitations of scope, schedule and budget, our services have been executed in accordance with the generally accepted practices in this area at the time this Plan was prepared. The information in this plan relied on the sources listed in the Bibliography section of the document, as well as supplemental data provided by the Tribe. No warranty or other conditions express or implied, should be understood.

Thank you the opportunity to work with you on this Plan.

Respectfully submitted,

GeoEngineers, Inc.

Mary Ann Reinhart, LG, LEG
Associate

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# Comprehensive Flood Hazard Management Plan

For

# Confederated Tribes of the Chehalis Reservation

Prepared by

GeoEngineers, Inc.

and

Herrera Environmental Consultants, Inc.

March 17, 2009

GeoEngineers

HERRERA ENVIRONMENTAL CONSULTANTS

# Table of Contents

## List of Tables



## List of Figures



## APPENDICES

# CONFEDERATED TRIBES of the CHEHALIS RESERVATION

**Resolution No. 2009 - 51**

**Of the Confederated Tribes of the Chehalis Reservation**

**Re: Adoption of the Comprehensive Flood Hazard Management Plan (CFHMP)**

**Whereas:** the Business Committee of the Confederated Tribes of the Chehalis Reservation is the duly constituted governing body of the Chehalis Indian Tribe, in accordance with the Constitution and By-laws adopted by voting members of the Tribe and approved by the Commissioner of Indian Affairs; and

**Whereas:** the Business Committee is responsible for protecting and enhancing the social, health, educational and economic well-being of Tribal members; and

**Whereas:** The Chehalis Indian Reservation is situated within the Chehalis flood basin and experiences frequent flooding impacting the majority of reservation lands; and

**Whereas:** The Confederated Tribes of the Chehalis Reservation applied for and was awarded a grant by the State of Washington Department of Ecology under the Flood Control Assistance Account Program (FCAAP) to fund preparation of a Comprehensive Flood Hazard Management Plan (CFHMP) which was prepared in general accordance with Washington Administrative Code (WAC) 173-145-040; and

**Whereas:** The Chehalis CFHMP was prepared with the participation of the Chehalis people and reservation residents; and

**Whereas:** The Chehalis CFHMP represents the commitment of the Chehalis Tribe to reduce risks to the Chehalis people, reservation residents and property from flooding hazards.
**Now Therefore Let It Be Further Resolved:** That the Chehalis Business Committee hereby adopts the Chehalis Comprehensive Flood Hazard Management Plan.

**Certification:** This Resolution, Number 2009-51, was duly considered and approved at a regularly scheduled meeting of the Chehalis Business Committee held on April 28, 2009, at which a quorum was present. The vote being 3 For, 0 against, with 0 Abstentions and with the Chairman not voting.

Signed:

David Burnett, Chairman
Chehalis Tribe

Attested:

Cheryle Starr, Secretary
Chehalis Tribe

P.O. BOX 536 • OAKVILLE, WA. 98568
AC 360-273-5911 • FAX 360-273-5914

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
PO Box 47600 • Olympia, WA 98504-7600 • 360-407-6000
711 for Washington Relay Service • Persons with a speech disability can call 877-833-6341

April 20, 2009

Honorable David Burnett, Chairman
Confederated Tribes of the Chehalis Reservation
PO Box 536
Oakville, WA 98568

Honorable Chairman Burnett:

The purpose of this letter is to inform you that the Department of Ecology hereby approves the 2009 Confederated Tribes of the Chehalis Reservation Comprehensive Flood Hazard Management Plan (CFHMP). The plan document, and the process used in its development, was successful in identifying and prioritizing feasible measures for dealing with floodplain management issues. The plan also provides a nexus with other Tribal land use policies and regulations. This plan will guide the Tribe's policy decisions in a way that mitigates the potential for flood damages and considers the issue of resource protection. We are particularly pleased with emphasis on non-structural flood risk reduction policies and practices.

The Comprehensive Flood Hazard Management Plan (CFHMP) was funded, in part, by the Department of Ecology Flood Control Assistance Account Program (FCAAP). These plans are a prerequisite for receiving additional funding through FCAAP for flood hazard reduction projects. Our procedures require that the plan be reviewed by certain agencies and Ecology staff to assure that the plan meets the requirements of WAC 173-145-040, and is consistent with federal, state, and Tribal floodplain management regulations. Not only does this qualify the local government for future FCAAP funding, but it is also a basic qualification for several other Federal and State grant programs.

I encourage you to forward copies of your plan to the Federal Emergency Management Agency (FEMA) Region X, and to the Emergency Management Division of the State Military Department for their reference. Access to the plan by thee agencies may expedite eligibility

Sincerely,

Gordon White
Program Manager
Shorelands and Environmental Assistance Program

Cc: Kevin Farrell, Ecology
Dan Sokol, Ecology
Mark Riebau, FEMA
Lennea Magnus, Chehalis Tribe

# I. OVERVIEW

## I. A. Authority and Funding

The Confederated Tribes of the Chehalis Reservation (Chehalis Tribe) was awarded a grant by the State of Washington Department of Ecology (Ecology) under the Flood Control Assistance Account Program (FCAAP) to fund preparation of this Comprehensive Flood Hazard Management Plan (CFHMP). An addendum to the original grant awarded additional funds by Ecology to evaluate the effect of Black River discharge on Chehalis River flooding within the Chehalis Reservation. The Chehalis Tribe provided matching funds to complete this project.

## I. B. Plan Development Process

December 2007 Flood. Source: Chehalis Tribe

This CFHMP is prepared in accordance with Washington Administrative Code (WAC) 173-145-040. The WAC states that the "Area of coverage for the comprehensive plan shall include, as a minimum, the area of the 100-year frequency floodplain within a reach of the watershed of sufficient length to ensure that a comprehensive evaluation can be made of the flood problems for a specific reach of the watershed. The plan may or may not include an entire watershed…Either the meander belt or floodway must be identified on aerial photographs or maps that will be included with the plan." The Chehalis Reservation is not included on existing Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRMs). Neither is the Reservation

included on flood maps prepared by adjacent jurisdictions (Thurston and Grays Harbor counties). The Chehalis Tribe has been using a flood map that was developed using the 1977 U.S. Geological Survey (USGS) flood map and updated information from the U.S. Army Corps of Engineers after the 1996 flood event. In this Plan development, a map more consistent with the 100-year recurrence interval floods experienced on the Chehalis Reservation since 1977 was desired in order to better assess possible flood hazards. Given the available resources for the plan, a 100-year flood map consistent with FEMA approach standards could not be produced, and an alternative approach was adopted. The approach involved the development of a 100-year flood inundation map for the Chehalis Reservation and adjacent properties based on available Light Detection and Ranging (LiDAR) data contracted by the Chehalis Tribe in November 2007, observed and surveyed high water elevations from the December 2007 flood, and available hydrology for the Chehalis and Black rivers. The approach and methods used for developing the floodplain map are described in Section III.B.

The CFHMP development process included cooperation and input from the Chehalis Reservation Business Committee officials, staff of various Tribal departments, public outreach meetings, and Washington State Department of Ecology staff. Lennea Magnus, Planning Director, was the main contact for the Chehalis Tribe.

The draft CFHMP, dated January 20, 2009, was sent out by the Chehalis Tribe for public review and comment. The following were contacted with a request for review: Chehalis Tribe, Washington State Department of Ecology, Bureau of Indian Affairs, Thurston Regional Planning Council, Thurston County, Grays Harbor County, City of Centralia and Chehalis River Basin Flood Authority, . Review comments are summarized in Appendix A.

### I. B. 1. Public Meetings and Advisory Group

The following table provides a list of Advisory Group members for this Plan.

| Name | Position |
|---|---|
| **Lennea Magnus** | Planning Director, Confederated Tribes of the Chehalis Reservation |
| **Amy Loudermilk** | Transportation Planner/Grantwriter, Confederated Tribes of the Chehalis Reservation |
| **Mark White** | Natural Resources Director, Confederated Tribes of the Chehalis Reservation |
| **Glen Connelly** | Environmental Programs Specialist, Confederated Tribes of the Chehalis Reservation |
| **Ralph Wyman** | Public Safety Director, Confederated Tribes of the Chehalis Reservation |
| **Ena Myers** | Assistant General Manager, Confederated Tribes of the Chehalis Reservation |
| **David Burnett** | Chairman, Confederated Tribes of the Chehalis Reservation |
| **Kevin Farrell** | Floodplain Management Specialist, Washington State Department of Ecology |

A kickoff meeting with the Advisory Group was held on January 17, 2008. Important agenda items discussed at the meeting included clarification of the Tribe's key objectives for this Plan, GeoEngineers' proposed approach for developing the floodplain map, observations from the December 2007 floodplain reconnaissance, and possible mitigation strategies to be included in this Plan.

The Chehalis Tribe sponsored two public meetings on June 4, 2008. The purpose of the meetings was to discuss flood/hazard related topics with residents on the Chehalis Reservation. The first meeting was held around the noon hour; the second after work hours. The community was invited to stop by the Tribal headquarters and to receive information and give input regarding three plans being prepared by the Tribe: this CFHMP, the Chehalis Tribe Hazard Mitigation Plan and the FEMA Mitigation application (subsequent to December 2007 flooding). Sixteen Tribal members and reservation residents attended the first meeting, and 12 Tribal members and reservation residents attended the second meeting.

A meeting with the Advisory Group was held at the Tribal headquarters on September 11, 2008. GeoEngineers and Herrera presented the preliminary results of our 100-year Recurrence Interval Flood Surface map. The group discussed potential hazard areas for flooding, flooding issues, and possible mitigation strategies.

Notes from the public and advisory group meetings are provided in Appendix B. Public notice of this Plan also has been accomplished by the following: 1) an article was published in the December Tribal newsletter; and 2) copies of the draft Plan were provided at the Tribe's General Council meeting on January 20, 2009.

### I. B. 2. Determination of Need for Flood Control Work: Short-term and Long-term Goals of the CFHMP

Approximately 75 percent of the Chehalis Reservation is located on an active floodplain that is subject to significant flooding up to five times annually. In the last three decades, the Chehalis Reservation has experienced several very large floods, including the 1986, 1990, 1996 and 2007 floods, each of which ranked as a flood of record.

Flooding within the Chehalis Reservation restricts access to the Reservation for periods of one or more days, isolating portions of the Reservation, and may cause failure of individual water and waste water systems. Flooding of Chehalis Reservation lands requires immediate evacuation of non-residents, invacuation of residents (that is, keeping people within a building or other location while a dangerous situation exists outside the building or location), and severely limits access to basic goods and services. Severe flooding also can contribute to the formation of swift-moving water in floodways that is capable of significantly endangering residents and their property. Flooding of this type can affect more than two-thirds of the Chehalis Reservation. The consequences of floods within the Chehalis Reservation have been very costly in terms of human life, property and economic health. Significant damage has occurred to public and private investments, interrupted public services and schools and closed businesses. Flooding from 15-year and greater recurrence interval storms is severe, and endangers roads and many structures within the floodplain.

The Chehalis Indian people historically occupied a large area within the Chehalis River watershed and have been located on the Chehalis Reservation since the 1850s. As the longest inhabitants of this land, the Chehalis people take its preservation very seriously. Tribal members hold the Chehalis and Black Rivers with great respect, and accept all aspects of river behavior (including flooding) as a functioning part of their community. Their respect for the river's behavior is reflected in the Native meaning of Chehalis, which is "shining and shifting sands." The Tribal members wish to preserve the historic character and natural environment of the Chehalis and Black rivers and their floodplains, and thus prefer to avoid mechanical and structural in-stream measures to reduce

flood hazards on their Reservation. Subsequently, accommodating river movement, flooding and erosion, rather than confining the river or containing its flows, is a primary objective of this Plan.

Given that flooding on the Chehalis Reservation is inevitable and that the Chehalis Tribe does not wish to constrain the rivers, the long-term goals of this Plan are as follows:

1. Protect and preserve the lives, health, safety and well-being of the people living on the Chehalis Reservation.

2. Reduce repetitive damages and costs associated with flooding.

3. Protect the Reservation from negative impacts of upstream floodplain development.

Responses and concerns voiced by Tribal members during the June 4, 2008 public meeting generally support the selection of these goals. Numerous individuals noted that they would like to see floodplain obstructions and upstream levees removed. They also would like the Chehalis Tribe to ensure the protection, operation and safety of critical infrastructure, including roads, and potable water and sewage systems on the Reservation during flooding.

Short-term goals of this Plan are intended to address the previous lack of 1) a science-based 100-year recurrence interval flood map for the entire Chehalis Reservation (update the 1977 USGS flood map), and 2) written record of hazard areas associated with flooding, and flood-related processes such as channel migration within and adjacent to the Chehalis Reservation. The product of this short-term goal is generation of the 100-year flood inundation surface map with hazard areas indicated, as presented on Figure 4 and Plate 1. The flood map will be used as a tool for planning and permitting by the Chehalis Tribe.

### I. B. 3. Project Approach

An alternative approach approved by Ecology was developed for modeling the extent of the 100-year flood. The model was based on three elements: updated hydrology for the Chehalis River, creation of a hydraulic model derived from 2007 LiDAR data, and collection of 2007 flood data and eyewitness interviews. A hydraulic model was used to estimate water surface elevations for the 100-year recurrence interval flood event. First, existing hard-copy and digital data related to flooding and flood damage in and around the project area were collected and assessed.

The Chehalis Tribe provided hard-copy and geographic information system (GIS) data including ortho-rectified aerial photographs, oblique aerial photographs, LiDAR obtained during a subcontracted flight in November 2007, survey 2007 flood elevation data, maps, planning documents, and eyewitness accounts from Chehalis Reservation residents and Tribal staff. This Plan also used publicly available hydrologic gauge data for the Chehalis and Black rivers, and LiDAR images for areas outside the Chehalis Reservation boundaries.

Stream gauge data and hydrologic calculations were used to estimate the 100-year recurrence interval flow on the Chehalis and Black rivers. The results then were entered into a computer-generated hydraulic model used to estimate flood heights across the Chehalis Reservation. The output from the hydraulic model and the LiDAR digital elevation models of the project area were combined to produce a relative surface model (RSM), which depicts the approximate 100-year flood inundation area. Field data collected for this study, including the GPS and survey data of

2007 flood elevations, were used to calibrate the RSM model results. From this map, hazard areas were identified and then corroborated with on-the-ground observations.

Additionally, a geomorphic assessment of the Chehalis and Black rivers and selected areas of the floodplain was performed by documenting and evaluating physical conditions observed at the time of two site visits. Specifically, field reconnaissance efforts focused on recording the locations and extent of bank erosion, bank armoring with riprap, scour, streambed and bank composition, large woody debris (LWD) accumulations, and other potential impacts to flood conveyance on both the Black River and Chehalis River.

Just prior to the authorization of this Plan, the December 2007 flood inundated the Chehalis Reservation. GeoEngineers was dispatched by the Chehalis Tribe to document time-sensitive floodplain conditions and flood elevation indicators, as surveyed by the Chehalis Tribes' surveyor. The 2007 field data and discussions with Tribal members suggest a significant difference between the 2007 and previous flood events on the Reservation; specifically the Chehalis River crested faster than previously observed. As a result, the available time for emergency response and evacuation decreased significantly. This departure from previous major flood events represents a significant threat to "human health and safety" and was deemed a key goal of the CFHMP.

Based on the results of the 2007 floodplain reconnaissance and review of pre-2007 floodplain data, two issues arose regarding the influences of Black River flows and upstream development on the Chehalis River. The role of the Black River on flooding, particularly near the confluence of the Black River with the Chehalis River, was not well understood prior to preparation of this CFHMP. Following a meeting with Kevin Farrell and the Chehalis Tribe on April 17, 2008, Ecology provided a supplemental grant to the Chehalis Tribe to include hydraulic modeling of the Black River with the flood mapping of the Chehalis Reservation. The notes from the April 2008 meeting with Kevin Farrell are provided in Appendix B.

Upstream development in the Chehalis-Centralia area has been identified by the Chehalis Tribe as an important issue to be covered in this Plan, primarily with respect to potential implications of the systematic reduction in floodplain storage that has occurred over the course of many decades. Lewis County completed their CFHMP in September 2008 as the Chehalis Tribe CFHMP was in preparation. The implication of upstream development on flooding within the Chehalis Reservation will be discussed in subsequent sections of this Plan.

### I. B. 4. Plan Organization

This Plan's organization and contents are as follows:

- Section I – Overview
- Section II – Description of Watershed
- Section III – River Dynamics in Project Area
- Section IV – Planning and Regulatory Context
- Section V – Conclusions and Proposed Mitigation Measures
- Section VI – Definitions, Acronyms and Bibliography

- Appendices –
    - Appendix A - Review Comments for Draft CFHMP Dated January 20, 2009
    - Appendix B - Meeting Minutes
    - Appendix C - Methodology for Floodplain Mapping and Geomorphic Analysis
    - Appendix D – Interlocal Agreement Between the Chehalis Tribe and Grays Harbor County
    - Appendix E - Project Approach and Quality Assurance Plan (QUAP) Memorandum
- Color Plate: 100-year Flood Map for Chehalis Reservation

# II. DESCRIPTION OF WATERSHED

## II. A. Introduction

The study area evaluated in this Plan primarily includes the Chehalis River and Black River floodplains situated within the boundaries of the Chehalis Reservation, and the floodplain area surrounding the Reservation and other Tribal properties (Figure 1: Vicinity Map and Tribal Properties). The area included in the 100-year flood RSM includes the Chehalis River floodplain between Moon Road and the City of Oakville, and the Black River floodplain between its confluence with the Chehalis River and the bridge crossing at Moon Road (Figures 2 and 3: aerial photograph and LiDAR digital elevation model). The study area is bounded to the north by the Black Hills of the Capital Forest and to the south by the Doty Hills. This area includes Willamette Creek, a groundwater-fed tributary to the Black River and an overflow channel of the Chehalis River and Harris Creek, a tributary to the Chehalis River originating in the Black Hills.

Tribal-owned properties located outside of the boundaries of the reservation also are shown in Figure 1. Some of these properties are located outside of the reservation boundary but within the study area used in the development of the RSM. Flooding hazards for properties located outside of the study area are described qualitatively in this Plan, based on information provided by members of the Tribe. The properties owned by the Tribe and located outside of the Reservation include the following:

- Porter properties. Agricultural floodplain located near Porter approximately seven miles downstream of the Chehalis Reservation. These properties are located within the 100-year flood boundary mapped by FEMA.
- Wickett properties located northwest of the reservation and downstream of the Sickman-Ford bridge. These properties are located within the 100-year flood boundary mapped by FEMA.
- Anderson Road. Properties at the intersection of Anderson Road and U.S. Highway 12 include the convenience store. These properties are located within the 100-year flood boundary mapped by FEMA.
- Independence Road. The Tribe owns approximately 2,300 lineal feet of the old railroad right-of-way within Thurston County up to the Grays Harbor County line. The Tribe also owns approximately 2.5 miles of the old railroad right-of-way within Grays Harbor County, west of Independence Creek.
- Restau properties. Includes forested riparian floodplain areas on both sides of the river approximately 3,000 feet upstream of the Balch Road crossing. These parcels include the Eaton, Jacobs Lake, Gerhard and Peterson properties.

- I-5 sign property. One small (1.1-acre) parcel located on the west side of I-5 north near Grand Mound.
- Grand Mound properties. This includes the 43-acre property where the Great Wolf Lodge is located, and the Flea, Jones, West and Bigler properties located south of Grand Mound, between Old Highway 99 SW and I-5. These properties are not located within the 100-year flood boundary mapped by FEMA.

## II. B. Drainage Basins

The Chehalis River and Black River basins vary greatly in size and character. The Chehalis River basin covers an area of approximately 1,174 square miles at the downstream extent of the study area near Oakville. The basin is primarily rural, with the exception of intense development near the cities of Centralia and Chehalis. Upstream of Centralia and Chehalis, the basin splinters into several moderate-sized (100-square-mile) tributary basins, including the Skookumchuck River, the Newaukum River, and the South Fork Chehalis River basins. The uppermost portion of all of these tributary basins is composed mostly of undeveloped timberlands.

The Black River basin drains approximately 138 square miles, or 12 percent, of the drainage area of the Chehalis River basin upstream of the study area, and is reasonably well-developed. The headwaters of the Black River are at Black Lake, the hydrology of which has been significantly altered because of the siphoning of flow from the lake into Percival Creek, which drains to the Puget Sound. Black Lake and its surroundings are relatively densely populated, although the floodway downstream of the lake is flat and protected by a series of public properties, including the Black River Habitat Management Area and the Mima Mounds Natural Area Preserve.

June 2008. Black River from Howanut Road. Source: Herrera Environmental Consultants

The highest elevation in the headwaters of the Black River basin is 2,660 feet, within the Black Hills of the Capital State Forest. The highest elevations in the headwaters of the Chehalis River basin range from 3,061 feet at Boistfort Peak in the Willapa Hills to 3,773 feet at Huckleberry Peak in the headwaters of the Skookumchuck River.

## II. C. Geology and Geomorphology

The physical characteristics of the study area have been shaped by previous glacial and fluvial processes. There is evidence for at least seven advances of glacial ice into the Puget Lowland during the Quaternary Period (1.5 million to 10,000 years ago) (Troost et al. 2003). The maximum southern extent of the ice sheet bordered the eastern edge of the Black Hills and terminated along a line running approximately one mile northeast of Rochester and through Grand Mound (Logan 1987). Blockage of the Strait of Juan de Fuca by glacial ice turned the Puget Lowland into a large lake that filled with water until it found a new outlet draining south via the Black River, into the Chehalis River, and thence to the sea (Troost et al. 2003). The modern Black River and Chehalis River valleys are now "underfit," that is, the present rivers are too small to have carved their own valleys.

December 2007 Flood. Glacial terrace or "island" upon which Tribal headquarters is located is apparent. Source: Chehalis Tribe

Within the study area, the floodplain width ranges up to approximately 1.8 miles wide except where it is narrows because of the presence of two glacial terraces, and is artificially constrained by roads, bridges and railroads (Figures 2 and 3). The glacial terraces are remnants of the depositional surface formed by sediment-laden meltwater flowing south from the Puget Lowland during the last glacial advance. The glacial terraces now stand 10 to 15 feet above the modern floodplain and consist of coarse gravel and cobbles exposed in the eroding banks. The topographic signature left by these ancient meltwater channels atop these terraces, shown on the

LiDAR maps, suggests a braided river system carrying a high sediment load from the melting ice sheet draining into the proglacial lake that once filled the Puget Lowland. Additionally, the width of the glacial outwash channels, as scaled from the LiDAR topography, is approximately twice that of the modern Chehalis River. This ancient morphology contrasts sharply with the morphology of the present Chehalis River. Incision and reworking of the glacial gravels by the shifting Chehalis and Black rivers has formed a complex network of oxbow lakes, sloughs, side channels and wetlands surrounded by riparian forests.

A dynamic river, the Chehalis River is largely unconstrained throughout the reservation. Old maps, photographs, and the Chehalis Tribe's oral history document the sometimes dramatic movement of the river through migration, accretion, and avulsion. However, artificial features and land-use activities have substantially altered natural channel migration processes and the floodplain morphology at several locations. Additional testament to the historical river migration is given by the many remnants of former channels, including oxbow ponds and sloughs, that are still observable adjacent to the river throughout the study area. In some cases, the former channels are utilized by small streams that drain valley walls and flow to the main stem river. An example of one such stream is Willamette Creek, which extends along Howanut Road before draining into the Black River. Most likely, Willamette Creek occupies a former channel of the Chehalis River; the creek currently is fed by groundwater springs and seasonal overbank flows from the Chehalis River.

Accumulations of large woody debris are present on gravel bars within the Chehalis and Black river channels in quantities that are likely less than what existed prior to European settlement and land clearing of the area. Trees large enough to provide key members for the formation of stable log jams were not observed growing in existing riparian areas, from which they would be recruited by natural channel migration processes. Highways, secondary roads, railroad grades and bank armoring placed along these transportation corridors generally restrict channel migration and reduce the potential for wood recruitment.

Within the study area, the Chehalis River is spanned by one bridge (Sickman-Ford Bridge at South Bank Road) and an abandoned bridge crossing at Balch Road. In addition to the bridges themselves, road fill placed for both bridge approaches artificially constricts the floodplain. The earthen approach to the Sickman-Ford Bridge constricts the floodplain width from 2,600 feet down to 980 feet at the bridge crossing. Similarly, remnants of the former Balch Road Bridge fill approaches constrict the floodplain from 2,600 feet down to 920 feet wide. The effects of these artificial constrictions to flooding are described in Section III.

June 2008. Sickman-Ford Bridge. Source: Herrera Environmental Consultants

The Black River is spanned by three bridges within the study area: Moon Road, U.S. Highway 12, and Howanut Road bridges. Artificial fill embankments and approaches associated with these bridge crossings constrict the floodplain to various degrees. Levees within the study area, but outside the Reservation have been constructed at two locations and serve to constrain the channel. One levee extends along the right (west) bank of the Black River from the US 12 bridge to approximately one-half mile upstream. Another levee, a push-up levee constructed by a private landowner, is located on the left (west) bank of the Chehalis River downstream of the Sickman-Ford Bridge.

Artificial fill associated with infrastructure, as well as agricultural activities, can limit meander movement and isolate side channels or sloughs. In an investigation of the main stem Chehalis between the Satsop and Wynoochee rivers, approximately 20 miles downstream of Oakville, Ralph et al. (1994) found 28 sites where former off-channel areas, sloughs and side channels were still in existence, but had been isolated from the main river channel by past land use actions. Similar restrictions on natural channel migration processes exist within the study area. Riprap utilized by Thurston County for road protection appears to restrict the natural migration of the Chehalis River along Independence Road southeast of the reservation and immediately upstream of Independence Creek. At this location, the placement of riprap along Independence Road has reduced the width of the channel migration zone to less than 800 feet.

Approximately 1,200 feet of riprap protects the right (east) bank of the Chehalis River immediately upstream of the confluence with the Black River. Additional riprap associated with the abandoned Union Pacific Railroad grade parallels the Chehalis River along the entire southern edge of the floodplain. Although most of the railroad grade runs along the base of the Doty Hills, the railroad constrains the floodplain and migration of the river at two locations, where it crosses the outlets of

Independence Creek and Garrard Creek. U.S. Highway 12 and the Burlington Northern Santa Fe (BNSF) railroad grade also reduce the width of the floodplain by approximately 850 feet, or 9 percent, along the northern edge of the floodplain. The influence of these artificial features and land use activities on channel dynamics and flooding are discussed further in Section III.

## II. D. Sediment Supply and Transport

Published studies addressing Chehalis River sediment loading are limited and somewhat outdated. Glancy (1971) collected suspended sediment at 19 locations throughout the Chehalis River basin during water years 1962 through 1965 to estimate the sediment yield of the basin and identify sediment source areas. For the mainstem channel and tributaries above Porter (located approximately 7 miles downstream of Oakville), Glancy (1971) found that the mainstem Chehalis River above Doty, the South Fork Chehalis River, and the Newaukum River had the highest sediment yields. The Skookumchuck and Black Rivers had relatively low sediment yields. The average annual suspended sediment yields from tributary basins upstream of Porter varied from 20 tons per square mile for the Black River near Oakville to 469 tons per square mile for the Chehalis River near Doty. In general, Glancy (1971) found that subbasins with high rainfall and steep slopes generated the highest sediment yield. Differences in subbasin sediment transport rates were largely attributed to changes in channel characteristics and human land use.

Sediment sources within the basin include weathered bedrock, glacial sediments, and alluvial deposits. Sediment sources reported by Glancy (1971) included reworking of landslide debris and erosion of alluvium along major channel reaches. Erosion of the sedimentary and volcaniclastic rocks of the Willapa Hills in the headwaters of the mainstem and South Fork Chehalis River are capable of producing prodigious amounts of sediment. The increase in sediment supply from the construction of logging roads and landsliding on steep slopes associated with industrial forestry practices, such as those that occurred throughout the headwaters of the Chehalis River and most of its tributaries are well documented (Swanson and Dyrness 1975, Sullivan and Duncan 1980, Madaj 1982, Grant and Wolff 1991, Bunn 2003). These factors were again initiated during the storm of December 2007, when numerous landslides and debris flows were triggered on steep slopes that had been recently cleared of timber (DNR 2007).

June 2008. Eroding glacial terrace on Chehalis River. Source: Herrera Environmental Consultants

Other sources of sediment within the study area include bank soils composed of floodplain deposits (gravel, sand and silt) supplied by erosion associated with channel migration processes. The volume of sediment delivered by channel migration and bank erosion may be offset by the deposition of sand and gravel on point bars and within abandoned channels, and the deposition of finer sediment across the floodplain during overbank flows. Under these conditions, the sediment flux through a floodplain reach is said to be in a state of dynamic equilibrium if the volume of sediment eroded equals the volume of sediment deposited. The question of whether the study area is in a dynamic equilibrium can be addressed by comparing suspended sediment measurements made upstream and downstream of the study area (Glancy 1971). The difference between the average annual amount of sediment entering the study reach (as measured at Grand Mound and at Littlerock for the Black River) and the amount of sediment leaving the reach (as measured at Porter) is roughly 7 percent, which is well within the margin of error for the suspended sediment measurements. Based on these results, sediment supply and deposition within study reach of the Chehalis River was likely in a state of dynamic equilibrium during the early 1960s when these measurements were made. The results of Glancy (1971) also suggest that channel morphology within the study reach would be quite responsive to changes in upstream sediment production and supply, particularly so from changes in land use activities that have occurred since the 1960s/70s studies were completed.

An example of how land use can upset the dynamic equilibrium between sediment supply and channel response can be found by examining the consequences of timber harvest in the Skokomish River basin of Mason County. Increased sediment supply from intensive timber harvest practices in the South Fork Skokomish River basin during the 1940s and the filling of the river bed with this sediment by as much as three feet by the 1960s is cited as the main cause of the increased frequency of overbank flooding on the mainstem Skokomish River (Stover and

Montgomery 2001). Whether or not the timber harvest practices in the headwaters of the Chehalis River basin could have a similar effect on flooding in the lower Chehalis River now or in the future has not been investigated.

## II. E. Vegetation

The unique character of the lands surrounding the Chehalis Reservation is caused, at least in part, by the interaction of past geomorphic processes and the actions of the early inhabitants. Prior to European development, lowland areas supported extensive wetlands surrounded by riparian forests. The drier areas of the floodplain supported a prairie ecosystem managed with periodic burning for subsistence by Upper Chehalis descendents. Euro-American farmers cleared the forests and converted most of the prairies to agriculture and grazing. The Chehalis Reservation, however, is unique in that it still contains a relatively intact (second-growth) riparian forest, unlike adjacent reaches within the Chehalis River valley, which have been converted to agriculture.

Over the last century, the Chehalis Reservation has been impacted by invasive plant species such as: Scotch broom, reed canarygrass, Himalayan blackberry and Brazilian elodea. Himalayan blackberry has become firmly established in many of the riparian zones, displacing some native plants such as elderberry and oceanspray. Reed canarygrass has migrated into some of the tributaries and wetlands, displaced important native species such as cattails and skunk cabbage, and has reduced some of the functionality of those wetlands. The Chehalis Tribe funds an annual effort to replant riparian areas with native tree species, in an effort to shade out the invasive species and recruit native plants back into the shoreline and wetland habitats. Brazilian elodea, a robust aquatic plant has been impacting river flows and increasing sedimentation in the Chehalis River near the reservation. The Chehalis Tribe has worked with several neighboring jurisdictions to remove the plants and slow the spread of this invasive species and repair natural river functions.

## II. F. Climate

Climate information was ascertained from numerous hydrologic studies of surrounding areas. In general, the project area and the basins that drain to it have a temperate maritime climate with cool, dry summers and mild, wet winters. Precipitation is highly dependent on altitude. Low-lying areas receive this precipitation predominantly as rain, while higher elevations receive a significant proportion as snow. Low-lying areas near the cities of Centralia and Chehalis receive approximately 45 inches of average annual rainfall. The headwaters of the Skookumchuck and Newaukum rivers receive up to 100 inches of annual rainfall. The greatest precipitation within the basin occurs in the Willapa Hills, where the average annual water-equivalent precipitation is as high as 135 inches. Average annual precipitation in the Black Hills is less than other areas and ranges as high as 90 inches (Daly et al. 2003).

## II. G. Historical Land Use

The indigenous population of the Chehalis originally occupied a specific geography within the Chehalis watershed, and “Chehalis” is a collective name for several Shalishan Tribes living on the Chehalis River, its affluent, and in Grays Harbor. Although the Chehalis people have lived on a reservation since the 1850s, important archaeological, cultural and historic sites are scattered throughout the original indigenous geography.

The Chehalis Tribe did not sign a treaty, but land was set aside for the Chehalis Reservation by executive order in 1864. In 1939, the Confederated Tribes of the Chehalis Reservation was formed and approved by the federal government, and its Constitution was amended in 1973. The Chehalis Reservation is approximately 5,000 acres in size and consists of agricultural areas,

residential neighborhoods and forested stands. The current and historical paths taken by the Chehalis and Black rivers dominate the Chehalis Reservation. The current river channels within the Chehalis Reservation contain approximately 10 miles of the Chehalis River, and the principal fish harvested are spring chinook salmon, coho salmon, fall chum salmon, fall/summer chinook salmon and winter steelhead.

Historically surrounded by thick forests, the Chehalis Reservation currently has over 2,700 acres of forested stands. There are many stands of white oak and Douglas fir, as well as riparian areas consisting of a mixture of western red cedar, big leaf maple, cottonwoods and alder trees. Many of the stands are second-growth populations that resulted from the heavy logging that occurred on the Chehalis Reservation within the past 100 years. Although significant portions of the Chehalis Reservation and the Chehalis River Basin were cleared of timber and converted to agricultural use during the 20th century, there remains significant use of Indian allotment trust lands for commercial timber harvest.

The regular flooding of the rivers has created fertile soils in the valley. The rich soils combined with the long growing season provide a productive agriculture zone. Agriculture became prevalent in the valley and on the Chehalis Reservation once European settlers moved to the area in the late 1800s. At the peak of farming activities on the Reservation, there were approximately 1,100 acres of land used for raising crops, such as hay or alfalfa, or pasturelands for livestock. Historically, agricultural uses also included the raising of dairy and beef cows, hogs and pigs, and poultry, as well as Christmas tree farming. In the late 1970s, the number of small family farms began declining. By 1977, agricultural uses included 1,469 Indian-owned acres in commercial timberland and 300 Indian-owned acres in farmland. Additional farming uses of non-Indian land accounted for approximately 120 additional acres within the Chehalis Reservation.

At one time, there were many villages in the Upper Chehalis region. Elders of the Chehalis Tribe have identified major village sites as they remembered from years previous, including at the mouth of the Black River and at Grand Mound. A very large settlement once stood at Grand Mound; its name was ‘aqáygt, meaning “long prarie.” Where the Black River enters the Chehalis River near Oakville, there was a village called s ‘àc ə l’t, or “made lake.” Within the village lived one or more extended families or “house groups,” each occupying its own longhouse (a large house approximately 80 to 100 feet long) constructed from cedar planks. During the summer months when the house was vacant, the boards were lowered and fresh air let in (Bellon et al., 2001).

Gaining a livelihood from the resources of the land and waters demanded adjustment to seasonal patterns. The Upper Chehalis Tribe followed the natural cycle of the flora and fauna of their territory and moved about a great deal during the course of the year to collect certain kinds of foods. The large quantity of wetlands, riparian areas and water features, along with unique land features such as acres of natural prairie lands, provide habitat for a great variety of flora and fauna. A strong reliance on fish in the subsistence economy of the Upper Chehalis is typical of a river people, but they also relied heavily on deer, elk and smaller game that frequented their territory. Various species of fish were caught at certain places. Large quantities of fish, meat, roots and berries were dried or smoked, then stored inside the longhouse. Camas bulbs, roots of bracken fern, wild sunflower, wild carrots, acorns and hazelnuts formed a part of the Chehalis diet. Berry picking was an important activity during summer months. Entire families might camp at the berry-picking grounds, the women and children picking and preparing the fruit while the men went to fish, hunt and compete in horse races. In order to encourage the growth of berries and camas, the Upper Chehalis would burn the prairie lands every two or three years. “In the old days we gathered sacred roots and berries. We fished the Chehalis, Black, Cowlitz, Satsop, Wynoochee,

Elk, Johns, Skookumchuck and Newaumkum rivers. Our people fished and hunted from the mountains, across the prairie, to Grays Harbor and the lower Puget Sound. In the old days, the baskets carried and stored our foods. We relied upon the baskets, the rivers, the land, the roots, the berries, the fish, and the animals. Our lives were tied together by the Creator" (Bellon et al., 2001).

## II. H. Stream Flow Analysis

The USGS maintains 17 gauges in the Chehalis River basin, the nearest of which are at Porter (Gauge # 12031000, approximately 7 miles downstream of the project area) and Grand Mound (Gauge # 12027500, approximately 5 miles upstream of the project area). Since April 2005, the Washington State Department of Ecology has maintained a stream flow station on the Black River at the U.S. Highway 12 Bridge (Station #23E060). The USGS maintained a gauge on the Black River at Littlerock (Gauge #12029000) from 1945 to 1950. Historical flow data from these monitoring stations provide the basis for determining the 100-year discharge.

### II. H. 1. Previous Flood Hazard Mapping

Flood hazard mapping adjacent to the Chehalis and Black rivers has been completed by FEMA for Thurston, Grays Harbor and Lewis counties; however, early floodplain mapping did not include the entirety of areas within the Chehalis Reservation. In April 1976, Thurston County identified all of the rivers and streams requiring detailed and approximated studies within the county. The 100-year floodplain and floodway maps requested by Thurston County were completed by FEMA in December 1981; the Chehalis Reservation was not included on the Chehalis River or Black River maps. The completed maps were adopted by Thurston County as part of the Flood Hazard Ordinance in November 1982. Of particular relevance to this study are the segments of the Chehalis and Black rivers east (upstream) of Anderson Road, which coincides with the county line, and defines the downstream extent of the 1981 study area.

The 100-year floodplain and floodway maps for Grays Harbor County and Lewis County (excluding areas within the Reservation) were completed by FEMA in 1986. Portions of adjoining Lewis County were updated in 2006. FEMA and the Washington State Department of Ecology are currently updating the flood hazard maps for Grays Harbor and Lewis counties. Map updates for Thurston County are expected to be completed within the next three to five years.

In 1977, the U.S. Department of the Interior, Bureau of Indian Affairs, Planning Support Group, prepared a comprehensive plan for the Tribe titled "Confederated Tribes of the Chehalis Reservation, Human and Natural Resources" (U.S. Bureau of Indian Affairs, 1977). The report thoroughly documented tribal demographics, tribal government structure, land use including soils, geology and flooding, recreation development and industrial development. The flood inundation map contained in the report utilized USGS data and a 1977 USGS water resource study to prepare a 50-year inundation map.

# III. RIVER DYNAMICS IN PROJECT AREA

Assessment of river dynamics in the project area included a review of previous reports and historical flood damage, field reconnaissance, an analysis of historical flow data, and hydrologic and hydraulic modeling. The methods used to collect data and perform the analyses are presented in Appendix C. The following sections present the results of the assessment of river dynamics in the project area.

## III. A. Flood Damage History

Four of the largest floods recorded on Chehalis River occurred after the FEMA floodplain map was completed in 1981; the floods occurred in 1986, 1990, 1996 and 2007. Using the 1981 FEMA flood elevations as a baseline, the relative flood frequencies of the 1990 and 1996 events computed by the U.S. Army Corps of Engineers (USACE) were 400 and 600 years, respectively. Based on the 1998 USACE update, the 1990 and 1996 flood frequencies were downgraded to 70- and 100-year events, respectively. To date, the flood of record occurred on December 4, 2007. Based on a regression of all peak annual flows performed for this Plan, the frequency of the 2007 event is approximately 150 years. A summary of 10 ten floods on records with highest peak discharge measured at the Grand Mound gauge is provided in Table 1.

**Table 1. Summary of the Top 10 Peak Annual Floods at Grand Mound (USGS Gauge #12027500)**

| DATE | PEAK DISCHARGE (CUBIC FEET PER SECOND [CFS]) |
|---|---|
| 12/07/2007 | 79,100 |
| 02/09/1996 | 74,800 |
| 01/10/1990 | 68,700 |
| 11/25/1986 | 51,600 |
| 01/21/1972 | 49,200 |
| 12/29/1937 | 48,400 |
| 11/25/1990 | 48,000 |
| 12/21/1933 | 45,700 |
| 12/05/1975 | 44,800 |
| 01/26/1971 | 40,800 |

In addition to being the greatest flood on record with respect to peak discharge, flood depth and area of floodplain inundation, the 2007 flood was unique in that the water rose faster and receded more rapidly on the Reservation than previous large floods. Immediately following the 2007 flood, the Office of Washington State Climatologist (Mote et al. 2008) conducted an analysis of precipitation and stream flow data for the Chehalis basin. Mote et al. (2008) found that the daily average flow at Grand Mound was lower in 2007 than in 1996. This indicates that a smaller volume of water was delivered to the Reservation during the 2007 flood than the flood volume delivered during the 1996 flood, but the water was delivered over a shorter period of time, resulting in the highest instantaneous peak flow on record.

Mote et al. (2008) concluded that the damaging flood of December 4, 2007, on the Chehalis River resulted from exceptionally heavy rainfall that was confined to the vicinity of the Willapa Hills, as evident from rainfall records and from the USGS analysis of flows at Doty. The discharge estimated at Doty on December 3 (after floodwaters destroyed the instrument) appears to have been double the previous record set in 1996. Rainfall in the rest of the basin and in surrounding areas was heavy, but in most cases ranked only in the top 10 events of the instrumental record. Public and private damage within the Reservation resulting from the recent 2007 flood and previous flooding is presented in the following section.

### III. A. 1. Public and Private

December 2007 Flood. Source: Chehalis Tribe

The Chehalis Reservation is subject to minor flooding up to five times annually. The frequency of flooding is caused by the unique geologic and physical environment of the Chehalis Reservation. These minor floods occur on the west, central, and eastern areas of the Chehalis Reservation, and cover up to half of the Reservation for periods of one or more days. Although minor, these smaller events tend to limit access to residential and commercial areas of the Chehalis Reservation, isolating specific neighborhoods for periods of up to two days and occasionally disrupting services including individual wells and waste water systems.

Flood events with an approximate recurrence interval of the five-year event cover the majority of the reservation. Flooding of local roads limits access to and from higher ground atop the two glacial terraces, which are above the 100-year flood elevation. These two areas become isolated "islands" during most flooding events. Flood-related impacts to the Chehalis Reservation typically increase with an increase in the significance of the flood event.

Flood events with an approximate recurrence interval greater than 15 years are severe enough to jeopardize roads, bridges, property fences, outbuildings, wells and septic systems, and other structures (including private residences) constructed before the adoption of the Chehalis Flood Damage Prevention Ordinance (see Section IV). During such floods, residents of the central part of the Chehalis Reservation must be evacuated to higher ground. During past events, flooding has resulted significant damages to private and commercial properties and the evacuation of people from homes built on low ground. During such events, it may be difficult or impossible to leave the reservation for up to seven days. A tragic example of the isolation created by flooding occurred during the 1996 flood, when the Tribe experienced a fatality resulting from the inability to access emergency medical care.

Major floods resulting in severe impacts, including evacuation of people from residences in low-lying areas, and the inundation of major access roads, such as U.S. Highway 12, has historically occurred every 9 to 11 years. Consecutive years of major flooding (double floods) occur about every 20 years.

The 1996 flood covered 75 percent of the reservation with measured flood depths up to 10 feet. All access routes, including Howanut Road, Anderson Road, and Moon Road were under one to four feet of fast-moving water. U.S. Highway 12, which provides access to many secondary roads, also was flooded, and Interstate 5 was flooded and closed for several days. To improve emergency access, in 2002 the Tribe rebuilt Anderson Road. They elevated and straightened portions of the road and fitted it with nineteen (19) culverts to allow passage of most flood waters beneath the road. A hydraulic model was prepared prior to engineering and design of the road, assuring that the road construction resulted in no net loss of floodplain storage. Modifications to Anderson Rd. have decreased the loss of access resulting from flooding from two to five times per year to once every four years.

During the 2007 flood, the water moved swiftly and covered the Chehalis Reservation to record water depths within 24 hours of notification of flooding. At the east end of the Chehalis Reservation, water overtopped Anderson Road. Up to two feet of water overtopped U.S. Highway 12 and flowed into the Black River east of Anderson Road. Southeast of the Reservation, Independence Road was overtopped near the bridge and a section of the Chehalis River channel migrated south and eroded a portion of the abandoned railroad grade. The central portion of the Chehalis Reservation, at the confluence of the Chehalis and Black rivers, was flooded from U.S. Highway 12 south to the abandoned railroad grade. Floodwater ponded upstream of the western glacial terrace and rose high enough to overtop Blockhouse Road and flow down Harris Creek. Between the glacial terrace and Oakville, bridges and culverts were overtopped, road pavement was damaged, and houses were flooded. At the west end of the Reservation, portions of Balch Road were damaged and the east approach to the Sickman-Ford Bridge was overtopped and damaged. Elsewhere within the Chehalis Reservation, gravel driveways and rural roads were scoured clean of gravel. Wells and septic systems were swamped and well heads were overtopped.

Five homes in the central area of the Reservation (on Howanut Road, on the east-west segment just south of the Black River) were inundated in 2007, with up to 4 feet of water. Of these five homes, two had not previously reported flood damage. Requests have been sent to FEMA for the three homes that have experienced repeat flood damage: elevation is being required for two homes, and buyout and demolition by the Chehalis Tribe is being requested for the third. This third house is located in an area zoned for recreational use, and the Chehalis Tribe intends to revert the land to only recreational use if the proposed project is funded.

Properties owned by the Tribe and located outside of the Chehalis Reservation experienced various degrees of flooding, or no flooding at all, in 2007. The convenience store, which was constructed one foot above the 1996 flood elevation at the intersection of Anderson Road and U.S. Highway 12 location, experienced a half foot of flooding, resulting in damage to floors and product. The Porter and Wickett properties located downstream of the Reservation were inundated with flood waters; however, these properties experienced only minor damage from the December 2007 flood. Damage included sediment deposition in fields and damage to fencing from the accumulation of flood debris. No structures on these properties were damaged by the December 2007 flood.

Other undeveloped properties owned by the Tribe and located south of the Chehalis Reservation also experienced flooding in December 2007. However, the Great Wolf Lodge, located south of Grand Mound, outside of the 100-year floodplain, did not experience flooding in 2007. East of the Chehalis Reservation, Interstate 5 was flooded, resulting in the closure of a 20-mile section of the highway for four days. Ivanov (2008) estimated economic losses of $45 million from the closure of Interstate 5 as a result of freight delays, job losses, loss of sales tax revenue, and the loss of personal income. Some of these economic losses were felt on the Reservation because of the closure of Tribal businesses (Lucky Eagle Casino, Eagle's Landing Hotel, and two convenience stores) and the associated loss of retail sales and revenue.

## III. B. Results of Floodplain Mapping and Geomorphic Analysis

Hydrologic regression analyses and detailed LiDAR floodplain topography were combined to create a hydraulic model (HEC-RAS) for the Chehalis and Black rivers in the vicinity of the Chehalis Reservation. The calibrated hydraulic model calculated flood heights for the 100-year flood across the study area. The 100-year flood height elevations were subtracted from the ground surface elevations derived from the LiDAR digital elevation model to create a relative surface model (RSM). The RSM depicts flood depths during the 100-year recurrence interval flood, subject to the limitations of the HEC-RAS model, LiDAR, and modeling assumptions. Based on documentation of previous flooding, the flood areas in the RSM were adjusted for levees, roads, and railroads that blocked flow to floodplain areas, creating an approximate 100-year flood inundation map.

The 100-year RSM reveals extensive, valley-wide flooding, with local flooding up to 20 feet deep. Areas with the greatest flood depths are located in the vicinity of the Black River and Chehalis River confluence and in the area immediately upstream of the Sickman-Ford Bridge. The two relatively high-relief glacial terraces ("islands") in the middle of the Chehalis Reservation remain dry. The hydraulic model and resulting RSM completed for this Plan are generally consistent with anecdotal observations, and indicate that flooding throughout the project area is extensive and primarily a result of high discharge from upstream, with only secondary backwater effects caused by natural and artificial obstructions within the study area.

The hydraulic model and inundation map both suggest that a hydraulic backwater increases flood depths by up to 3.5 feet immediately upstream of the Sickman-Ford Bridge and upstream of the abandoned Balch Road bridge during a 100-year recurrence interval flood. The backwater effects at these bridge crossings are the result of constrictions formed by the long, earthen approaches for these bridges. A third hydraulic backwater indicated by the model is located in the vicinity of the Black River and Chehalis River confluence. This backwater raises valley-wide flood levels by up to four feet over an area of approximately 950 acres of the floodplain. This backwater is likely caused by the natural constriction of the floodplain between the glacial terrace to the north and the relatively high floodplain ground to the south. A flood conveyance channel has developed on the floodplain on the left bank immediately downstream of the Sickman-Ford bridge. A high potential for scour in this area is suggested by velocity profiles on the left bank in the HEC-RAS model and by turbulent flow observed in aerial photographs taken during the February 1996 flood.

There are two known discrepancies between the inundation depths predicted by the hydraulic model and the observed flooding conditions. The first discrepancy is situated near the intersection of 188th Ave. and Moon Road, directly east of the high-relief glacial terrace or "island", upon which the Tribal headquarters is located. The results of the HEC-RAS model and RSM predict flood surface elevations lower than the floodplain surface elevations, suggesting that this area should be emergent during a 100-year flood. However, historical aerial photographs and direct

observations clearly indicate that this area is fully inundated, with no emergent areas, during significant flood events. Field surveys indicate that actual 100-year flood elevations in this area are roughly one to four feet higher than those predicted by the HEC-RAS model, as shown on the RSM. This discrepancy in the model is largely a result of the local topography and the limitations of the HEC RAS model. At flood state, Chehalis River discharge is constricted by the "island" and Independence Road. This constriction likely sets up a hydraulic backwater condition, creating a bulge in the water surface elevation extending across the channel and over the floodplain. In the area east of the "island", the local topography is higher than the modeled 100-year flood elevation, and that it is inundated is evidence to the scale of the hydraulic bulge. It is highly likely that the backwater bulge rides up over the topography adjacent to the "island" and spills around it, resulting in slightly lower flood elevations to the north and south. Because HEC-RAS is a one-dimensional model, it cannot predict this lateral variability of flood elevations in this area. This area is represented by the blue hachuring depicted in Figure 4.

The second discrepancy is in the area north of U.S. Highway 12 and the BNSF railroad, downstream of the Black River Bridge. Although the modeled 100-year floodwater elevations exceed the elevation of land, this area did not flood in 2007. This area is hydraulically disconnected from the Chehalis and Black river floodplain by the elevated road and railroad prisms, both of which act as levees during a 100-year flood event. This area is represented by the brown hachuring shown in Figure 4.

### III. C. Hazard Areas

Flood-related erosion hazards identified from aerial photographs, field reconnaissance, interviews with Tribal staff, and results of the hydraulic modeling are categorized as follows: bank erosion, channel migration, and avulsion. Hazard areas include those areas located within the Chehalis Reservation, and those areas located outside the Reservation that appear to adversely affect the Reservation as a result of the actions of others (e.g., riprap placement and levee construction by county agencies and private property owners). Flood-related erosion hazard areas identified during the geomorphic evaluation are summarized in Table 2. The hazard areas were ranked as high, medium or low to indicate the relative likelihood that the hazard will occur within the next 10 years and the risk posed to surrounding property, infrastructure and public safety.

**Table 2. Summary of Flood-related Erosion Hazards Identified within the Study Area[1]**

| LOCATION | FEATURE | HAZARDS | RISKS | HAZARD RATING |
|---|---|---|---|---|
| 1. Independence Road along Chehalis River at southeast corner of the Chehalis Reservation (south of Moon Road). | Floodplain artificially constricted by Independence Road. | Historical channel migration into Independence Road has occurred in the past. Riprap placed by Thurston County to stabilize the left bank along the road may be increasing velocities and forcing the Chehalis River to erode elsewhere. This constriction is forcing floodwaters to flow north around the nearby glacial terrace and may be increasing flood elevations in this area. | • Unknown downstream effects within Reservation from channel response caused by bank stabilization measures.<br>• Loss of portions of Independence Road from bank erosion (outside of the Reservation boundary).<br>• Loss of residential property between the river and road (outside of the Reservation boundary). | Medium |
| 2. Independence Road along Chehalis River at southeast corner of the Chehalis Reservation (south of Smith Road). | Artificial floodplain constricted by Independence Road and the abandoned railroad grade. | The focus of bank erosion has been migrating downstream along Independence Road and currently is eroding into the abandoned railroad embankment. Riprap placed by Thurston County to protect the road is failing and has been transported and deposited downstream within the Reservation. Bank armoring along Independence Road is affecting natural channel migration processes and causing the meander south of Smith Road to migrate west into the Reservation. The glacial terrace limits further migration to the west. | • Loss of portions of Independence Road from bank erosion (outside of the Reservation boundary).<br>• Avulsion of the Chehalis River through the railroad grade into agricultural fields outside of the Reservation.<br>• Loss of residential property behind the railroad grade (outside of the Reservation boundary).<br>• Channel migration into private property at the end of Smith Road. | High |
| 3. Downstream of the end of Fitzgerald Road. | Bank erosion along the toe of the glacial terrace ("island"). | The Chehalis River is eroding west into the glacial terrace along the right bank. Migration rates are unknown, but likely very low because of the resistance of the coarse gravels exposed in the bank and the relatively low, historical migration rate as determined from a review of historical aerial photographs taken from year to year. | Loss of agricultural/grazing property on the right bank because of channel migration. No infrastructure or buildings are threatened. | Low |
| 4. End of Balch Road within right bank floodplain | Artificial floodplain constriction formed by the approach to the abandoned bridge crossing. | The roadway fill for the former bridge crossing constricts the floodplain and acts as a weir. The hydraulic model suggests the bridge approach artificially increased flood depths by up to 3.5 feet upstream of the constriction. | Increased flooding upstream of the former bridge crossing. The effects of removing this constriction are unknown. | Medium |

| LOCATION | FEATURE | HAZARDS | RISKS | HAZARD RATING |
|---|---|---|---|---|
| 5. Sickman-Ford Bridge approach on right bank floodplain | Artificial floodplain constriction formed by the earthen bridge approach. | The eastern approach (which replaced an elevated trestle) constricts the floodplain and acts as a weir. The hydraulic model suggests the bridge approach artificially increased flood depths by up to 3.5 feet upstream of the constriction. | • Increased flooding upstream of the bridge crossing. The effects of removing this constriction are unknown.<br>• Damage or loss of the roadway caused by scour from overtopping flows. | High |
| 6. Left bank downstream of the Sickman-Ford Bridge | High-flow channel through left bank floodplain | This area is at risk of an avulsion of the Chehalis River through agricultural fields and into an oxbow lake that could reconnect with the mainstem downstream of Oakville. The lack of mature riparian vegetation in the avulsion path increases the risk of the channel establishing a new course through this area with each successive flood event. | Avulsion of the Chehalis River into agricultural fields and away from the Reservation. | Medium |
| 7. Harris Creek downstream of Blockhouse Road | Bridge and culvert crossings at Blockhouse Road, Elma Gate Road, and South Bank Road/State Street. | Results of the hydraulic modeling indicate that Cemetery, Blockhouse, and Slate roads all are overtopped by the 100-year flood event. Flooding may be associated with high velocities as flood water is forced around the north side of the glacial terrace. | Damage or loss of the roadway crossing Harris Creek resulting from undersized culverts. | Medium |

[1] See Figure 4 for locations.

# IV. PLANNING AND REGULATORY CONTEXT

## IV. A. Guiding Principles of Chehalis Reservation Land Use Ordinances and Policies

Since 2001, the Chehalis Tribe has permitted all building, construction and land moving activities within the Reservation boundaries under Title 21, Permitting Code, Confederated Tribes of the Chehalis Reservation.

In this ordinance, the Tribe identified the following guiding principles:

- The Confederated Tribes of the Chehalis Reservation was established for the exclusive and permanent use of the Chehalis Indian Tribe.
- The Chehalis Tribe has the jurisdiction and the duty to protect the quality of the environment within the boundaries of the Chehalis Indian Reservation.
- The Chehalis Reservation is a small land base that must provide for the economic, residential, cultural, recreational and governmental needs of the Chehalis tribal community, now and in the future.
- The Chehalis Reservation contains ecologically sensitive lands, culturally sensitive historic and archaeological sites, and the Black and Chehalis Rivers. Any action adversely affecting these and all areas within the Reservation ecosystem adversely affects the Chehalis Indian Tribe.
- The Chehalis Business Committee concurs with federal legislation and policies that stress environmental protection such as the National Environmental Protection Act, Coastal Zone Management Act, Clean Air Act and Clean Water Act.

These principles influenced the subsequent development of the Tribe's land use ordinances and policies. The primary land use document that followed, the Chehalis Reservation Comprehensive Land Use Plan and Chehalis Zoning Ordinance, was adopted in 2004.

This Chehalis Reservation CFHMP utilizes these same guiding principles to preserve, protect and enhance the Reservation environment.

June 2008. Natural floodplain environment on Chehalis Reservation.
Source: Herrera Environmental Consultants

## IV. B. Additional Regulatory Context for the Chehalis Reservation

Following the third and fourth Guiding Principles (as bulleted in Section IV. A), the Chehalis Tribal government must provide for the economic, residential, cultural, recreational and governmental needs of the Chehalis tribal community, now and in the future while protecting its ecologically sensitive lands, culturally sensitive historic sites, archaeological sites and the quality of portions of Willamette Creek and the Black and Chehalis rivers – all on a small land base of 4,215 acres. Any action adversely affecting these and all areas within the Reservation ecosystem adversely affects the Chehalis Tribe. The approach of the Chehalis Tribe to land use planning emphasizes the compatibility of land uses on the Chehalis Reservation to the natural environment of the reservation. This natural environment includes flooding, cultural sites such as areas used for fishing, hunting and gathering natural products such as camas bulb. The Tribe has the jurisdiction and the duty to protect the quality of the environment within the boundaries of the Chehalis Reservation.

As a small land base, the Chehalis Reservation receives disproportionately large impacts resulting from the floodplain actions and policies of upstream neighboring Thurston and Lewis Counties. Therefore, the Chehalis Tribes' regulatory environment must support:

1) The protection of the essential Indian and Tribal character of the Chehalis Reservation in its entirety,
2) The suitability of the natural environment to support a specific land use action,
3) The protection of the natural resources and natural features of the Chehalis Reservation from contamination, pollution and other degradation,
4) The protection and enhancement of the habitat of all types of fish, forestry and wildlife resources, particularly the Chehalis River Basin and associated habitat that are critical components of the ecosystem that support fish resources, and
5) Minimize or eliminate adverse impacts that would result from locating developments in environmentally sensitive areas.

At the same time, demands on land use during the past 20 years have changed dramatically in the rural South Puget Sound and on the Chehalis Reservation from an emphasis on recreation, agriculture and timber to expansion of residential developments. Several factors, including cheaper land and construction costs in the far south-Sound region and the natural appeal of the Reservation's rural setting, began to exert pressure on the reservation and surrounding areas. By the mid-1980s, 65 percent of the Tribe's total acreage had been converted to non-Indian ownership and was in fee status. Non-Indian land owners were increasingly interested in purchasing cheap floodplain properties and developing pastoral acreage on the Reservation.

## IV. C. Floodplain Regulation on the Chehalis Reservation

In addition to adhering to the Guiding Principles, regulation of land use has developed within the context of the pervasiveness and frequency of flooding of reservation lands.

Resolution #1997-44, RE: Approval of a Flood Disaster Prevention Ordinance, was the first land use regulation ordinance adopted by the Tribe. It was signed into tribal law on October 31, 1997. One month earlier, the Tribe had submitted an application for participation in the National Flood Insurance Program to FEMA.

This landmark document entered into the tribal code book as the direct result of the devastating flood of February 1996, which stood as the flood of record until December 2007. During the 1996 flood, the only outside access to the Reservation was by helicopter. As stated previously in Section III., homes in the central area of the Chehalis Reservation were inundated, roads and driveways were damaged, and water well and septic systems were compromised. Elders, residents and children were evacuated from their homes by rowboat and transported to the tribal center, where a make-shift emergency shelter was provided.

In the spring following the 1996 flood event, the Chehalis Tribe submitted a Hazard Mitigation Grant Program (HMGP) application to elevate five homes. As a part of the application process, the Chehalis Flood Disaster Prevention Ordinance was approved and adopted by the Tribe. The adoption of the ordinance appropriately laid the foundation for future land use planning.

In the eleven years since the adoption of the Flood Disaster Prevention Ordinance, one home (2003) was built in the floodplain for a tribal Elder on allotment trust land and one tribal enterprise (2002) was built in the floodplain. Both structures were permitted for construction at 18 inches above base flood elevation (BFE); BFE is based on the flood elevations of the 1996 flood. At the time the enterprise was permitted, the Tribe adopted a policy requiring that a hydraulic analysis, including documents certifying no net loss of flood storage capacity, be submitted prior to commercial development in the floodplain.

As noted earlier, the Tribe adopted Title 21, Permitting Code which required permits to be obtained for construction, road construction, culvert and drainage construction, construction of flood-related activities, dredging, drilling, dumping, filling, diking, riprapping and clearing and grading activities. Applicants were required to submit a written application and complete an environmental checklist prior to the start of any named activities. The code was applied to all land owners, regardless of trust or fee status, within the boundaries of the Chehalis Reservation and on off-reservation Indian-owned lands.

In 2003, the Chehalis Tribe began the process of drafting land use ordinances and policies to regulate development of lands within the reservation and to strengthen and improve floodplain protection. In early spring 2004, a moratorium on building permits was imposed while land use policies were written. Following public notification and hearings, the Chehalis Reservation Comprehensive Land Use Plan and Chehalis Zoning Ordinance were adopted in December 2004.

Both Grays Harbor and Thurston counties submitted written comments supporting the Tribe's land use ordinances. In June 2008, the Tribe and Grays Harbor County entered into an Interlocal Agreement which designates the Tribe as the lead entity for all land use planning and development permitting including county fee lands within the Chehalis Reservation boundaries. A copy of the Interlocal Agreement is provided in Appendix D.

Specific features of these ordinances supporting floodplain protection include 1) restrictions on development within 300 feet of the Chehalis and Black rivers and within 150 feet of Willamette Creek, 2) a complete restriction of Planned Unit Development residential sites within the floodplain and 3) a requirement to seek Special Use Permits for any and all proposed floodplain activities including maintenance of grandfathered uses.

One of the significant challenges of the Tribe's floodplain management has been providing floodplain mapping to support the Flood Damage Prevention Ordinance. Standard FEMA floodplain mapping has not included Indian trust lands. To address this issue, the Tribe has utilized the flood

inundation mapping in the Tribe's original comprehensive plan, "Confederated Tribes of the Chehalis Reservation, Human and Natural Resources" (U.S. Bureau of Indian Affairs, 1977).

The 1977 mapping, based on the January 1972 flood, described as a 50-year event, has served as the base flood map for the Chehalis Tribe since the adoption of the 1997 ordinance. From 2000 to 2002, a hydraulic study, utilizing 1996 flood of record data, was performed in conjunction with the redesign of the Chehalis Reservation's primary access road, Anderson Road. This contemporary study verified the accuracy of 1977 mapping.

## IV. D. Relevant Regulations of Adjacent Jurisdictions

Jurisdictions adjacent to the Chehalis Reservation have implemented the following flood hazard management plans: Thurston County Flood Hazard Management Plan (1999), Grays Harbor Comprehensive Flood Hazard Management Plan (2001), and the Lewis County Comprehensive Flood Hazard Management Plan (2008). The following provides comment from the Chehalis Tribe on features of each plan or other pertinent regulations of these jurisdictions that are relevant to the Chehalis River and Chehalis Reservation.

### IV. D. 1. Thurston County

The Black River floodplain, which covers 10.5 square miles of Thurston County, and the Chehalis River floodplain, which covers 8.1 square miles of Thurston County, overlap the Chehalis Reservation flood hazard areas. One and one-half square miles, or about 10 percent, of the Chehalis Reservation overlaps Thurston County in the far southwestern corner of the county. One hundred percent of the overlap area is within the floodplain.

Thurston County's Critical Areas Ordinance (1993) prohibits locating residences within the 100-year floodplain, except within an older subdivision. The effect of this restriction is substantial as it applies to all future residences built in the county. The Tribe applauds Thurston County's commitment to prohibiting building new residences in the floodplain.

Thurston County does, however, permit rebuilding of replacement homes in previously permitted floodplain areas, including areas along the southern bank of the Chehalis River that are impacted by accretion and avulsion. Thurston County has attempted to manage flooding of roads and homes in this area over the past 20 years by placing riprap along the river bank in the Independence Road area. This area is a highly active section of the river and past attempts at placing riprap have resulted in movement of rock debris from failed projects into the river, and into a river reach located within the Chehalis Reservation. The eroded fill material is likely to be accumulating in the channel, thereby reducing the dimensions of the channel and reducing flow capacity. Subsequently, the result is more frequent overtopping events.

June 2008. Riprap placed on bank of Chehalis River by Thurston County, downstream of Independence Road bridge. Source: Herrera Environmental Consultants

Thurston County also has adopted and administers a Shorelines Master Program, which encourages agriculture, forestry and non-intensive recreational uses of lands within the 100-year floodplain. Thurston County requires elevating of structures "known to be inundated" even if they are located outside of the mapped 100-year floodplain.

Thurston County's 1999 Flood Hazard Management Plan identified one flood-related road project on the Chehalis Reservation for improvement in the next 20 years. The project was called the "Chehalis Tribe Access" and identified improvements to Anderson Road, the Reservation's access road. "It would elevate these roads and provide adequate bridging so as to not create a dike or levee. The goal is to allow Anderson Road and 188th Avenue SW to flood no more frequently than U.S. Highway 12. The eastern half of Anderson Road lies in Thurston County, while the western half lies in Grays Harbor County." This project was completed by the Tribe with funding from the Bureau of Indian Affairs in October 2002. Thurston County served as the lead county in permitting portions of the project outside the reservation boundaries and in securing rights-of-way for the project.

### IV. D. 2. Grays Harbor County

Ninety percent of the Reservation is overlapped by the southeastern-most portion of rural Grays Harbor County. The Chehalis River flows along the southern boundary of the Chehalis Reservation and flows through Grays Harbor County to the Pacific Ocean. Grays Harbor is located at the downstream end of the Chehalis River drainage. While the majority of flooding on the Reservation overlaps Grays Harbor County, the basin drainage originates in Lewis County.

The Chehalis Tribe commends Grays Harbor County in recommending non-structural alternatives in their CFHMP, including floodplain and drainage course regulation, floodplain boundary reviews, consideration of flood storage conservation easements, development of flood hazard public education programs and better coordination within the county.

Section 2, Capital Improvement Projects, of the Grays Harbor County CFHMP continues to allow for the use of berms as a protective measure for individual properties and drainage canals in urban areas. Grays Harbor County also permits commercial and residential building within the floodplain with minimum elevation standards and anchoring of structures.

In 2008, the Tribe and Grays Harbor County signed an Interlocal Agreement recognizing the Chehalis Tribe's administrative authority to conduct land use planning and permitting within the exterior boundaries of the Chehalis Reservation on both fee and trust parcels.

### IV. D. 3. Lewis County

Lewis County and the Chehalis Reservation floodplain planning and management overlap in the Chehalis River Basin. While the Reservation is located 6 miles north of the actual county boundary, the large Chehalis Basin drainage covers the entirety of the Chehalis Reservation and substantial portions of Lewis County. Seven tributaries of the Chehalis River – Skookumchuck River, China Creek, Salzer Creek, Dillenbaugh Creek, Newaukum River, South Fork Newaukum River and South Fork Chehalis –are located in Lewis County. Eleven of Lewis County's sixteen federally-declared flooding disasters involved the Chehalis River.

Washington State has established a multi-jurisdictional floodplain management organization called the Chehalis River Basin Flood Authority (Lewis County CFHMP, Section 2 - Policies). The authority comprises eleven volunteer members who signed an interlocal agreement. The Chehalis Tribe is a member of the Flood Authority. Section 2 states that the organization shall "help blend and direct policies and projects that are proposed within the boundary of the Flood authority". The Tribe is unsure of the meaning of the term "blend" with respect to policies and projects. The Tribe, while it is a participant in the Flood Authority's effort, does not at this time support the Authority's direction of any proposed projects that are within the Tribe's jurisdiction.

Lewis County's two most populated cities, Centralia and the City of Chehalis, are located adjacent to the Chehalis River, with portions of the cities lying in the floodplain. The municipalities continue to permit filling and commercial development within the floodplain under FEMA rules, requiring construction be elevated one foot above the county's base flood elevation (BFE). The Tribe is concerned about the cumulative impacts of continued and plentiful commercial development and filling within the floodplain. Lewis County's most current flood map was drawn in the 1980s, and does not accurately reflect the three major floods with greater elevations than the county's BFE that occurred in 1990, 1996 and 2007. This discrepancy allows for floodplain development that would not otherwise be permitted if the flood map used was up-to-date.

The Tribe is very concerned about structural mitigation projects that may be proposed by Lewis County under Section 3 - Flood Hazard Mitigation Strategy Development, and discussed again in Section 6.4.1.3. A number of the proposed mitigation projects are structural in nature and would require construction of substantial facilities such as levees or regional detention facilities. The Chehalis Reservation lands are a major storage area for flooding of the Chehalis River Basin. Structural projects involving levees could increase the elevations of floodwaters on the Chehalis Reservation.

# V. CONCLUSIONS AND PROPOSED MITIGATION MEASURES

## V. A. Conclusions

The key flood hazard issues, or flood-related problems, identified on the Chehalis Reservation include the following:

- **Steadily increasing discharges (over the last three to four decades) that define the "flood of record" also increase the flood elevations associated with the defined 100-year flood event.** This trend presents unique challenges regarding the Tribe's floodplain utilization and management policies.

- **Changes in the character and behavior of flooding observed over the course of the last several significant flood events**. These changes include the marked increase of flood elevations over shorter time periods and shortened flood cresting between the cities of Chehalis and Centralia, and the Chehalis Reservation. This has resulted in a general decrease in the available emergency warning and response times at the Reservation.

- **Complete loss of access during large floods, effectively cutting off the Reservation from outside resources.** As a result, evacuation of non-residents (employees, students, clients and customers) is difficult and many residents are left stranded with limited supplies and no road access for emergency response vehicles.

- **Flow paths of deep and fast-flowing (DFF) water across the Chehalis Reservation appear to be changing in response to general changes in flooding characteristics.** Current floodplain regulations do not adequately address or account for such changes in floodplain conveyance routes; these changes represent a new flood hazard. General flood elevations on the floodplain in the Reservation and DFF water zones currently are not accurately modeled. This would require additional scientific studies (addressed in Section V.C.)

- **Artificial and naturally-occurring obstructions to floodwater conveyance across the floodplain are causing significant backwater conditions**, resulting in ponding and super-elevation of flood waters. These conditions cause property inundation and road overtopping, which can damage roads and prohibit access.

- **The Chehalis Tribe has a newly adopted Emergency Preparedness and Response Plan (May 2008), but currently does not have a formal emergency warning system. Even with an Emergency Preparedness and Response Plan in place, life, health and safety risks may continue.** Floods have damaged residences, and disrupted individual residential water and sanitation facilities. The inundation also inhibits timely emergency response, which has resulted in the death of a Tribal member. The majority of the individual residential wells and septic system are maintained, repaired and replaced by the Tribe under the Indian Health Service sanitation programs. Affected water and sanitation remain disrupted for a minimum of six weeks following the end of major flood events; eight to ten months of disruption is possible, including the time needed to assess the damaged system, make application to the Indian Health Service for repairs, and obtain a

design for the repairs. To date, the community's wastewater treatment plan and community sanitation system near the Tribal center have not been disrupted.

- **Current and proposed future floodplain development and flood mitigation practices upstream of the Reservation represent an increase in flood hazard to the Tribe.** Continued development of the floodplain will continue to decrease valuable flood storage area, and thus increase downstream flood volumes. Levees proposed by Lewis County and the U.S. Army Corps of Engineers would completely disconnect the Chehalis River from its floodplains and divert the increased flood volume downstream to the Chehalis Reservation. Both of these storage reduction issues have a potential to result in an increase in flood volumes (and thus elevations) received at the Reservation,

- **Changes in the physical character and behavior of the Chehalis River adjacent to the Reservation may increase the frequency, and elevation of flooding, and possible increase existing rates of channel migration.** Factors influencing these changes include aggradation (filling) of the channel caused by an increase in upstream erosion, continuous failure of fill placed near Independence Road by Thurston County, and increased sediment transport resulting from landslides and some logging practices within the watershed. Other influences include changes in climate and the increasing intensity of Pacific Northwest storms. Measures adopted by jurisdictions upstream of the Chehalis Reservation can help reduce the threat that future flood events will increase in magnitude caused by the effects of land-use practices within the basin. The Tribe currently holds a seat on the board of the new Chehalis River Basin Flood Authority.

## V. B. Proposed Mitigation Measures

Given their regard for natural riverine processes, the Chehalis Tribe prefers to avoid structural in-channel measures intended to reduce flooding or prevent channel migration. However, the Chehalis Tribe takes the position that much can be done to reduce both the hazards and negative effects of significant flooding within the Chehalis Reservation.

Hazard mitigation measures were selected 1) to further the goals of this CFHMP, as identified in Section I.B.2, and 2) to address flood hazard issues identified in Section V.A. The Chehalis Tribe identified 18 mitigation measures, consisting of structural and non-structural approaches. For the purpose of this CFHMP, structural measures are those that change or modify existing landforms, residential or Tribal structures, and/or infrastructure (roads, bridge, utilities, etc.) as a means of reducing flood related hazards. Non-structural measures are those that avoid or minimize flood-related hazards by emphasizing alternatives that manage human activity and development.

The selected projects were assigned a relative priority rank of high, medium or low. The prioritization system is based on the potential for a proposed mitigation measure to reduce vulnerability to a flood hazard, and its ability to successfully address one or more key issues identified above. Criteria used to assign prioritization ranking are defined in Table 3.

**Table 3. Criteria Used to Prioritize Projects**

| PRIORITIZATION CRITERIA | PRIORITIZATION RATING | | |
|---|---|---|---|
| | LOW | MEDIUM | HIGH |
| Project Effectiveness | Achieves goal effectively | Is moderately effective in achieving goal | Is very effective in achieving goal |
| Time to Implement | Many years | Several years | Three or fewer years |
| Permanence | Temporary | Short lifespan | Relatively permanent |
| Relative Cost | Very expensive | Moderately Expensive | Inexpensive |
| Technical Feasibility | Difficult to implement | Moderately able to implement | Easily implemented |
| Social/Political Feasibility | Unpopular/affects few | Able to implement with political cost | Popular implementation/ affects many |
| Environmental Impact | Significant negative impact | Neither positive nor negative impact | Positive impact |

The potential sources of funding to implement the selected projects are provided in Table 4. The funding sources have been identified by agency and programs. Because agency programs are continually updated and undergoing changes on emphasis, funding levels, and staffing, it will be necessary for the Tribe or other responsible jurisdiction to contact the individual agencies to verify details of the programs.

**Table 4. Potential Sources of Funding**

| IMPLEMENTING AGENCY | PROGRAM | PURPOSE | COMMENTS | FUNDING |
|---|---|---|---|---|
| FEDERAL | | | | |
| Federal Emergency Management Agency (FEMA) | National Flood Insurance Program (NFIP) | Eligibility for flood insurance to communities that adopt approved floodplain management regulations | Encourages formation of Cooperating Technical Communities to update floodplain maps | May be funded based on FEMA's priority of mapping needs |
| | Hazard Mitigation Grant Program | Funds project that will result in long-term impacts and produce repetitive benefits over time. Must have 404 Hazard Mitigation Plan. | Funds generated after presidentially-declared disaster. Administered through Washington Department of Emergency Management | |
| | Public Assistance (for public facilities) | Post-disaster infrastructure repair | Must be constructed to replace damaged facility-mitigation only permitted to comply with current standards. Must comply with Endangered Species Act. | |
| | Cooperative Technical Community Initiative | To encourage local communities to coordinate planning, e.g., channel migration zones, erosion zones, etc. | | Grants to counties |
| | Flood Hazard Mitigation Program | | | Grants |
| | Project Impact | Achieving disaster-resistant communities | Fosters public and private partnerships. Community can encompass entire county, or portions of a county. | Project Impact status determined by FEMA |
| U.S. Geological Survey (USGS) | Educational; data collection | Topographic, geological and water resources data collection<br>County contracts with the USGS for installation of stream gauges data collection | | For stream gauges |

| IMPLEMENTING AGENCY | PROGRAM | PURPOSE | COMMENTS | FUNDING |
|---|---|---|---|---|
| Bureau of Indian Affairs (BIA) | Indian Reservation Roads (IRR)<br><br>IRR Bridge Program (IRRBP)<br>IRR High Priority Projects (IRRHPP)<br>IRR Construction | IRR programs assist federally-recognized tribes to plan, design and construct transportation facilities on Indian reservations. | Tribes submit an annual Transportation Improvement Plan (TIP) to the BIA. Projects receiving IRR funds must be on Tribal TIP. Expenditures are limited to approved IRR inventory facilities. | Planning, annual allocation to tribes<br><br>IRRBP competitive grants to tribes<br>IRRHPP competitive grants to tribes<br>Annual allocation to tribes |
| STATE | | | | |
| Division of Emergency Management – Department of Military Affairs | State Hazard Mitigation Grant Program | Administers FEMA's mitigation programs, including 404 hazard mitigation programs | Declared disaster | Competitive grants to counties |
| Salmon Recovery Funding Board | Endangered Species Act as enforced by National marine Fisheries Service (NMFS) Authority | Supports salmon recovery by funding habitat protection and restoration projects and activities that produce sustainable and measurable benefit for the fish | Lower Columbia Recovery Board – submit through lead entity, Water Resource Inventory Area (WRIA) | Two funding cycles per year |
| Department of Ecology | Flood Control Assistance Account Program (FCAAP)<br>Administers NFIP | Projects and plans for flood hazard management planning and building flood prevention projects | | Grant application due winter of odd-numbered years |
| Department of Transportation | | Technical/design assistance to city and county road projects<br>Serves as an instrument of the FHWA when channeling federal funds for city/county projects | | |

| IMPLEMENTING AGENCY | PROGRAM | PURPOSE | COMMENTS | FUNDING |
|---|---|---|---|---|
| County Road Administration Board | Rural Arterial Program (RAP)<br>County Arterial Preservation Program (CAPP) | Reconstruction of rural arterial roads<br>To assist counties in preserving their paved arterial system | | |
| COUNTY | | | | |
| Thurston Regional Planning Council (TRPC) | Surface Transportation Program (STP) | TRPC, the Thurston County Regional Transportation Planning Organization (RTPO) awards FHWA funds passed through the state to the RTPO for distribution to member jurisdictions. Funds must be used to improve the safety of existing transportation facilities. | | Competitive grants |
| Grays Harbor County | Road Fund, Public Works Department | | | |

### V. B. 1. Structural Mitigation Measures

The structural mitigation measures proposed by the Chehalis Tribe for this CFHMP are as follows:

1) Raise Moon Road south of U.S. Highway 12 in a manner to improve emergency access during flooding. This project would include smoothing the grade of the road to remove dips, and installation of appropriately-sized culverts to allow floodwater passage.

2) Remove road embankment fill under Balch Road, which currently acts as a levee. This project would increase river conveyance during flooding and reduce upstream flood levels.

3) Install culverts under South Bank Road along the approach to the Sickman-Ford bridge. Prior to its reconstruction, the old road was elevated on piles and did not obstruct Chehalis River's high discharge flows. The goal of this project is to increase conveyance of floodwaters, prevent backwater conditions from developing, and thus reduce the potential for increased flood surface elevations upstream of the road.

4) Install large-diameter culverts beneath State Road at Harris Creek. Currently, State Road acts as a levee and obstructs the flow of floodwater across the floodplain, resulting in backwater pooling behind the existing road. The goal of this measure is to improve floodwater passage across the floodplain; this measure also will extend the period of access provided by State Road during significant flood events.

5) Replace U.S. Highway 12 bridge at Black River. The existing bridge is a multi-span, steel truss and concrete beam structure constructed in 1932 and provides important access for the Reservation between SR 8 and Interstate 5. Currently, the bridge and road prism constrict high flows. This hydraulic condition is causing bank erosion and bed scour, which prompted repairs in 2001 to protect the bridge piers and abutments. The failure of these critical components could result in loss of the bridge during a significant storm event. In addition to the possible loss of access, a joint Tribe/WSDOT study (WSDOT 2005) found that erosive conditions resulting from the constriction likely are degrading existing Black River aquatic and riparian habitat, which is inconsistent with the Tribe's guiding principles. WAC 173-145-040 stipulates that corrective actions for resource losses that may result from in-stream work must accompany an alternatives and potential impacts analysis. However, if designed in an environmentally responsible manner with bioengineered elements, this mitigation strategy will not result in resource loss. Therefore, an alternatives analysis was not conducted for this proposed strategy.

6) Remove push-up levee downstream of the Sickman-Ford bridge. This unpermitted levee was installed by a previous property owner and is not in compliance with U.S. Army Corps of Engineers standards. Removing the levee would increase river conveyance during flooding. The levee may be exacerbating conditions that could lead to an avulsion upstream of the levee.

7) Install floodplain roughening in the floodplain along the left (western) bank of the Chehalis River downsteam of the Sickman-Ford bridge. Grade control structures consisting of LWD placed strategically within the floodplain could be used to increase the floodplain roughness and would reduce the risk of river avulsion through the Wickett property.

U.S. Highway 12 Bridge in December 2007. Source: Chehalis Tribe

The selected structural mitigation projects are summarized in Table 5. The goals were presented in Section I.B.2, and are repeated below.

1. Protect and preserve the lives, health, safety and well-being of the people living on the Chehalis Reservation.

2. Reduce repetitive damages and costs associated with flooding.

3. Protect the Reservation from negative impacts of upstream floodplain development.

**Table 5. Proposed Structural Mitigation Measures**

| MITIGATION STRATEGY | GOALS | PRIORITY RATING | JURISDICTION RESPONSIBLE | POTENTIAL FUNDING SOURCE |
|---|---|---|---|---|
| 1. Raise Moon Road south of U.S. Highway 12 | 1 | High | Chehalis Tribe and Thurston County (50 percent each) | BIA, Thurston County |
| 2. Remove road embankment fill under Balch Road approach (abandoned) | 1, 2 | High | Chehalis Tribe | Grays Harbor County, State of Washington (multiple programs), FEMA, Chehalis Tribe |
| 3. Install culverts under South Bank Road along approach to Sickman-Ford Bridge | 2, 3 | High | Grays Harbor County | Grays Harbor County, State of Washington (multiple programs), FEMA |
| 4. Install large-diameter culverts beneath State Road at Harris Creek | 1, 2 | Medium | Grays Harbor County | FHWA, WSDOT, Grays Harbor County |
| 5. Replace U.S. Highway 12 Black River Bridge | 1,2 | Medium | WSDOT | FHWA, State of Washington (multiple programs) |
| 6. Remove push-up levee downstream of Sickman-Ford Bridge | 1 | Medium | Chehalis Tribe | FCAAP, SRFB, FEMA |
| 7. Install floodplain roughening along left bank of Chehalis River downstream of Sickman-Ford Bridge | 1 | Low | Chehalis Tribe | FCAAP, SRFB, Chehalis Tribe |

Notes:

BIA – Bureau of Indian Affairs
FEMA – Federal Emergency Management Agency
FHWA – Federal Highway Administration
FCAAP – Washington State's Flood Control Assistance Account Program
SRFB – Washington State's Salmon Recovery Funding Board
WSDOT – Washington State Department of Transportation

### V. B. 2. Non-structural Mitigation Measures

December 2007. Elevated house. Source: GeoEngineers

The non-structural mitigation measures proposed by this Plan are summarized below and in Table 6.

1) Implement the Comprehensive Emergency Management Plan for the Chehalis Tribe adopted in May 2008. This plan will address such issues as evacuation routes and prioritization plan, emergency communication system, planning and stocking of emergency shelters, identifying backup generator needs, identification and maintenance of emergency supplies, identifying a procedure list at the medical clinic to ensure medical expertise on the Chehalis Reservation during floods, and planning for emergency transport of food, water, fuel and medical supplies.

2) Improve flood warning procedures. This two-part strategy includes augmenting the existing stream gauges and potentially other warning equipment, as well as improving the dissemination of warning information before and during floods. This strategy needs to be further analyzed, but may include one or more of the following: add another real-time flow gauge closer to reservation; use a warning system that is not dependent on telephone calls, such as text messages; and purchase National Weather hand-cranked radios for every household on the Chehalis Reservation.

3) Develop a community-wide flood hazard educational outreach program. Educate the community on flood hazards and emergency preparedness to increase public awareness. This flood education program will include new information and knowledge of flood warning, response and evacuation procedures. The goal is to help improve citizen and local officials' understanding of floodplain maps and floodplain regulations, floodproofing options, and other information to assist in good decision-making. The Tribe intends to pass on all information and data in this Plan to the community. The Tribe's Project Manager will review existing flood education material and create

new materials, as needed. Tribal program managers will participate in program planning to determine the best ways this flood education can be incorporated into existing programs. The Chehalis Tribe will use a variety of outreach methods, including articles in the Tribe's monthly newsletter, brochures and informational flyers, and community meetings. One such community meeting could coincide with the opening of the new community center. The Chehalis Tribe could also sponsor community events such as filling up water jugs at the community water tank.

4) Acquire facilities and equipment to improve emergency preparedness and responsiveness, such as back-up generators, fuel storage facilities, emergency supply transportation vehicle, etc.

5) Elevate or demolish homes in the floodplain inundated by previous events. Three houses that have experienced repeat flood damage are located along the east-west segment of Howanut Road just south of the Black River.

**Table 6. Proposed Non-structural Mitigation Measures**

| MITIGATION STRATEGY | GOALS | PRIORITY RATING | JURISDICTION RESPONSIBILITY | POTENTIAL FUNDING SOURCE |
|---|---|---|---|---|
| 1. Implement Comprehensive Emergency Management Plan | 1 | High | Chehalis Tribe | FEMA, Chehalis Tribe |
| 2. Improve flood warning procedures | 1 | High | Chehalis Tribe | Chehalis Tribe, FCAAP, FEMA, U.S. Geological Survey |
| 3. Develop flood hazard educational outreach program | 1 | High | Chehalis Tribe | Chehalis Tribe, FEMA |
| 4. Acquire facilities and equipment | 1 | High | Chehalis Tribe | Chehalis Tribe, FCAAP, FEMA |
| 5. Elevate or demolish homes subject to flood inundation | 1.2 | Medium | Chehalis Tribe | FEMA, WA State |

Notes:
FEMA – Federal Emergency Management Agency
FCAAP – Washington State's Flood Control Assistance Account Program
SRFB – Washington State's Salmon Recovery Funding Board

## V. C. Proposed Studies

The following studies were identified to provide the necessary information to accomplish the mitigation measures identified above.

1. Coordinate with the Chehalis River Basin Flood Authority to develop a dynamic model of the middle basin to assess effects of future basin development on the flood hydrology at the Chehalis Reservation. The model should quantify the effects of basin development and new levee construction on the loss of flood storage and attenuation of peak flows. Only a non-steady state model can accomplish this task.

2. Conduct a detailed cumulative downstream flood impacts analysis. The analysis should focus on estimating the total increase in flood surface elevations resulting from all floodplain development projects located upstream of the Chehalis Reservation and constructed since 1990, and all future proposed projects, including future placement of levees, floodplain development, roads and parks.

3. Evaluate river channel responses to influx and deposition of sediment in vicinity of the Chehalis Reservation. Channel aggradation will have an effect on bank erosion and channel migration and on the frequency and magnitude of flooding. Sediment source areas, sediment production mechanisms and sediment transport capacity will play significant roles in the character of future flooding at all Tribal properties.

4. Conduct a study to determine volume, placement, and potential impacts to flooding of failed riprap placed by Thurston County on the Chehalis River bank.. The study should include appropriate in-channel and floodplain hydraulic modeling and analysis.

5. Conduct a channel migration analysis for the Chehalis River from the city of Centralia to the Grays Harbor County Line. Channel migration and possible avulsion of the channel at or near the Chehalis Reservation likely will present a serious flood-related hazard, and could result in the loss of residential structures and infrastructures via bank recession, and from floodwater inundation. The study should include the effects of LWD on channel processes and flood elevations.

6. Construct a two-dimensional (2-D) flow model for the floodplain within Chehalis Reservation boundaries. The purpose of this model is to increase the accuracy of floodplain inundation depths provided by the HEC-RAS/RSM model used for this study. The 2-D model also can be used to identify DFF water areas on the floodplain, which represent a serious flood hazard; this information would greatly strengthen floodplain management regulations.

7. Model the effects of removing/modifying the Sickman-Ford bridge approach and Balch Road. A 2-D model should be developed for this project.

8. Develop a semi-annual monitoring program focused on documenting changes in Chehalis River channel conditions and dimensions. At a minimum, the program should include taking aerial photographs every two years and obtaining LiDAR data every five years or following significant (record) flood events.

9. Identify and conduct studies that would need to be accomplished in order to design the proposed mitigation strategies (such as raising Moon Road). Appropriate modeling and analysis should precede the design phase of any projects.

10. Investigate local conditions in the vicinity of the pushup levee near Wickett properties to assess site specific and downstream impacts during flooding.

11. The historical alignment of Harris Creek was altered by unpermitted placement of fill adjacent to the creek by a previous landowner. Conduct a study to determine the type and volume of the fill, and evaluate if it would be beneficial to remove the fill.

12. Augment the Plan with two-, five- and ten-year recurrence interval flood surface maps. Production of these maps will require recalibration of the existing HEC RAS model to the two-year recurrence interval storm,

# VI. DEFINITIONS, ACRONYMS AND BIBLIOGRAPHY

## VI. A. Definitions

100- year Recurrence Interval Flood: a flood having a one percent chance of being equaled or exceeded in any given year.

Alluvial deposits or alluvium: a general term for recent sediment deposits made by rivers and streams on river beds, floodplains, and alluvial fans.

Avulsion: the abrupt movement of an active channel to a new location in the valley.

Backwater: a hydraulic term referring to increased water depths and decreased in-stream velocity as a result of an obstruction to flow immediately downstream.

Basement: means any area of the building having its floor sub-grade (below ground level) on all sides. [from Washington Model Flood Damage Prevention Ordinance, http://www.mrsc.org/Subjects/PubSafe/emergency/floodord.aspx]

Bathymetry: underwater topography.

Development: means any man-made change to improved or unimproved real estate, including but not limited to buildings or other structures, mining, dredging, filling, grading, paving, excavation or drilling operations or storage of equipment or materials located within the area of special flood hazard. [from Washington Model Flood Damage Prevention Ordinance, http://www.mrsc.org/Subjects/PubSafe/emergency/floodord.aspx]

Digital Elevation Model (DEM): a digital representation of topography generally illustrated in GIS.

Flood Height Indicator: debris or other marker on vegetation or structures in the floodplain that was deposited or caused by peaking floodwater, thereby providing an indicator of the flood height relative to some datum.

Geographic Information System (GIS): computer software used for mapping and analysis of digital geographic data.

Global Positioning System (GPS): a machine that accurately locates its position on the earth's surface by triangulating signals from multiple satellites in orbit around the earth.

Grade Control: a structure or other erosion-resistant object located in the bed of a stream channel that is resistant to erosion and therefore prohibits channel down-cutting immediately upstream of the structure.

HEC-RAS: an acronym that stands for Hydraulic Engineering Center's – River Analysis System. This is a one-dimensional hydraulic model created by the US Army Corps of Engineers.

Hydraulic: of or related to the forces of moving liquids.

Hydrologic: pertaining to the water cycle and often referring to the volume of water in a stream.

Inundation: covered by water.

Large Woody Debris: pieces of wood generally greater than 12 inches in diameter and deposited by or affecting the flow of water in a stream (i.e.: logjam).

Levee: A linear structure or mound of earth that prevents floodwater from inundating the land on one of its sides.

Light Detection and Ranging (LiDAR): A tool incorporating laser technology and aerial reconnaissance to produce high-resolution digital elevation models of land topography.

Lowest Floor: means the lowest floor of the lowest enclosed area (including basement). An unfinished or flood resistant enclosure, usable solely for parking of vehicles, building access, or storage in an area other than a basement area, is not considered a building's lowest floor, provided that such enclosure is not built so as to render the structure in violation of the applicable non-elevation design requirements of this ordinance found at Section 5.2-1(2), (i.e. provided there are adequate flood ventilation openings). [from Washington Model Flood Damage Prevention Ordinance, http://www.mrsc.org/Subjects/PubSafe/emergency/floodord.aspx]

Model: A computer or mathematical simulation of a natural event or system.

Ortho-rectified Aerial Photograph: A flat image of the earth's surface taken from directly overhead by an airplane or satellite that has been geometrically adjusted so that the scale of the photograph is uniform and can be measured as a map.

Oblique Aerial Photos: A flat image of the earth's surface taken at an angle by an airplane that has not been adjusted to a uniform scale.

Recurrence Interval: The period of time between recurring events.

Regression Analysis: A mathematical method of modeling the relationships among three or more variables; in the case of hydrology it is used to calculate discharge on a stream without a suitable gauge by comparing its drainage area and gradient with other near-by streams.

Relative Surface Model (RSM): A digital elevation model that uses a defined surface as its zero-elevation; a flood inundation area can be estimated if the defined surface is set to the flood elevation at strategic locations along a river's corridor.

Scour: erosion of a stream's bed.

Substantial Damage: means damage of any origin sustained by a structure whereby the cost of restoring the structure to its before damaged condition would equal or exceed 50 percent of the market value of the structure before the damage occurred.
[from Washington Model Flood Damage Prevention Ordinance,
http://www.mrsc.org/Subjects/PubSafe/emergency/floodord.aspx]

Substantial Improvement: means any repair, reconstruction, or improvement of a structure, the cost of which equals or exceeds 50 percent of the market value of the structure either:

1) Before the improvement or repair is started: or

2) If the structure has been damaged and is being restored, before the damage occurred. For the purposes of this definition "substantial improvement" is considered to occur when the first alteration of any wall, ceiling, floor, or other structural part of the building commences, whether or not that alteration affects the external dimensions of the structure.

The term can exclude:

1) Any project for improvement of a structure to correct pre-cited existing violations of state or local health, sanitary, or safety code specifications which have been previously identified by the local code enforcement official and which are the minimum necessary to assure safe living conditions, or

2) Any alteration of a structure listed on the National Register of Historic Places or a State Inventory of Historic Places.

[from Washington Model Flood Damage Prevention Ordinance, http://www.mrsc.org/Subjects/PubSafe/emergency/floodord.aspx]

## VI. B. Acronyms

| | |
|---|---|
| 2-D | two-dimensional |
| BFE | base flood elevation |
| BNSF | Burlington Northern Santa Fe |
| CFHMP | Comprehensive Flood Hazard Management Plan |
| DEM | digital elevation model |
| DFF | deep and fast-flowing |
| DNR | Department of Natural Resources |
| Ecology | Washington State Department of Ecology |
| FCAAP | Flood Control Assistance Account Program |
| FEMA | Federal Emergency Management Agency |
| FHWA | Federal Highway Administration |
| FIRM | Flood Insurance Rate Map |
| GIS | geographic information system |
| GPS | global positioning system |
| HEC-RAS | Hydraulic Engineering Centers River Analysis System |

| | |
|---|---|
| HMGP | Hazard Mitigation Grant Program |
| LiDAR | Light Detection and Ranging |
| LWD | large woody debris |
| NFIP | National Flood Insurance Program |
| RSM | relative surface model |
| SRFB | Salmon Recovery Funding Board |
| USACE | U.S. Army Corps of Engineers |
| USGS | United States Geological Survey |
| WAC | Washington Administrative Code |
| WSDOT | Washington State Department of Transportation |

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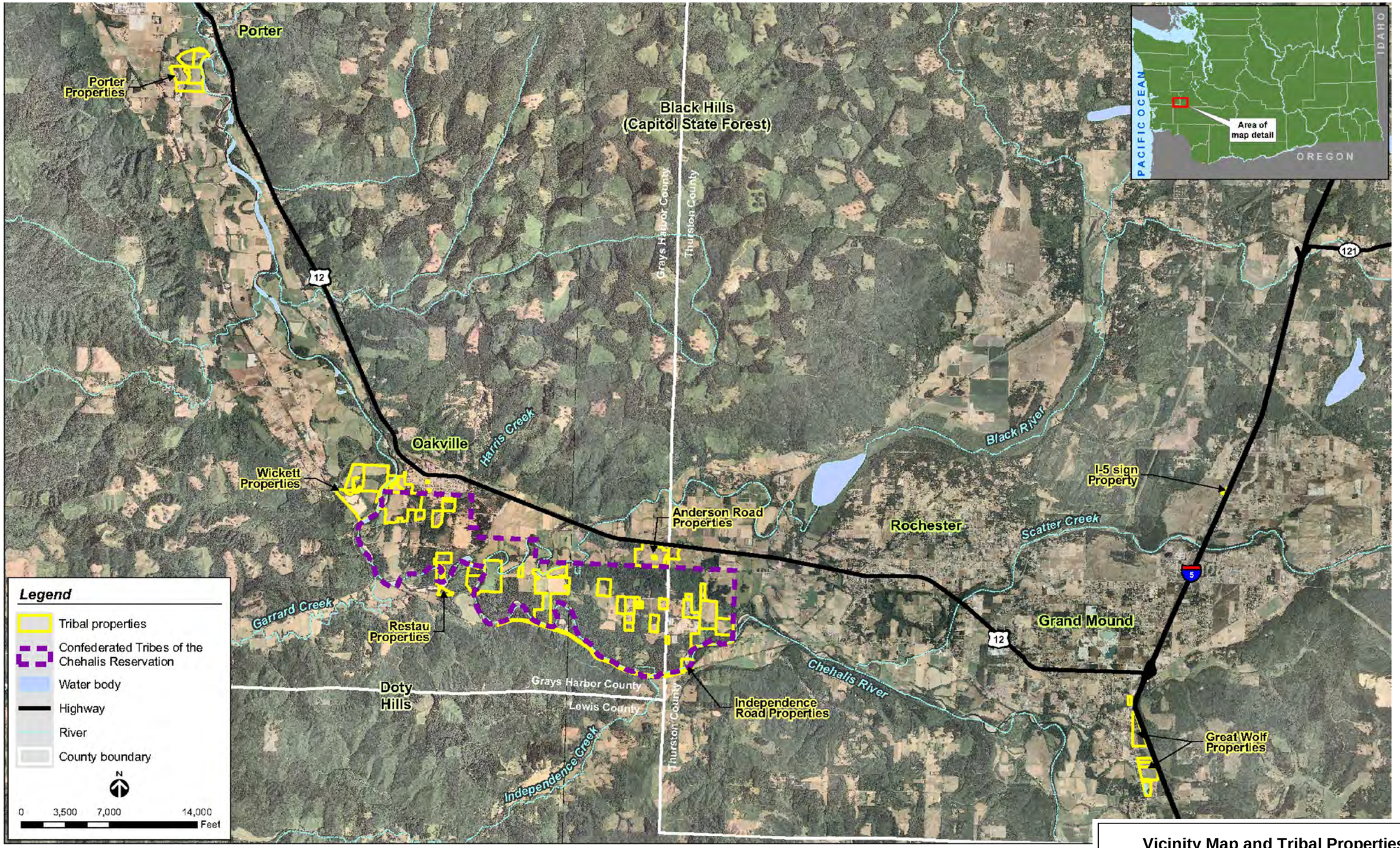



## Notes

1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Reference: The 2006 aerial photographs used in the figure were obtained from the USDA. The Reservation boundary and Tribal Property boundaries were provided by the Confederated Tribes of the Chehalis Reservation.

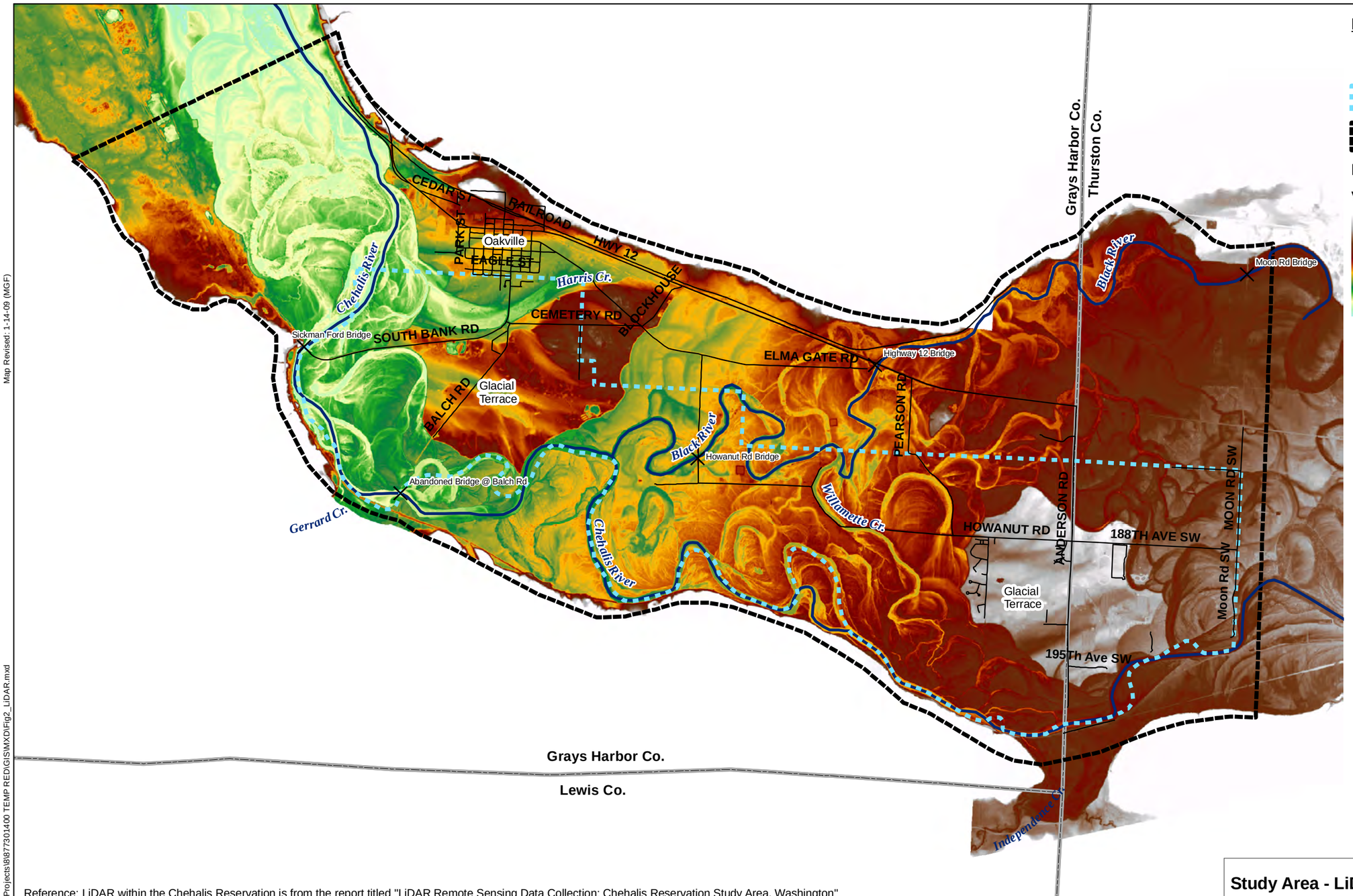
**Vicinity Map and Tribal Properties**

Chehalis Tribe CFHMP

GeoEngineers

**Figure 1**

P:\B\B7730I400 TEMP RED\CAD\B7730I400-FI.DWG\TAB:FIGURE 1 MODIFIED BY MFORMOLO ON Nov 24, 2008 - 16:34




Reference: LiDAR within the Chehalis Reservation is from the report titled "LiDAR Remote Sensing Data Collection: Chehalis Reservation Study Area, Washington" dated 01/23/08, prepared by Watershed Sciences, Inc. for the Chehalis Tribe. LiDAR outside of the Chehalis Reservation is from the Puget Sound LiDAR Consortium; Roads provided by Confederated Tribes of the Chehalis Reservation and the Federal Census Bureau; Tribal boundary and County boundary obtained from the Federal Census Bureau.

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes and should be only used in conjuction with the Comprehensive Flood Hazard Management Plan. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

**Study Area - LiDAR Digital Elevation Model**

Chehalis Tribe CFHMP

GeoEngineers

**Figure 2**

Map Revised: 1-14-09 (MGF)

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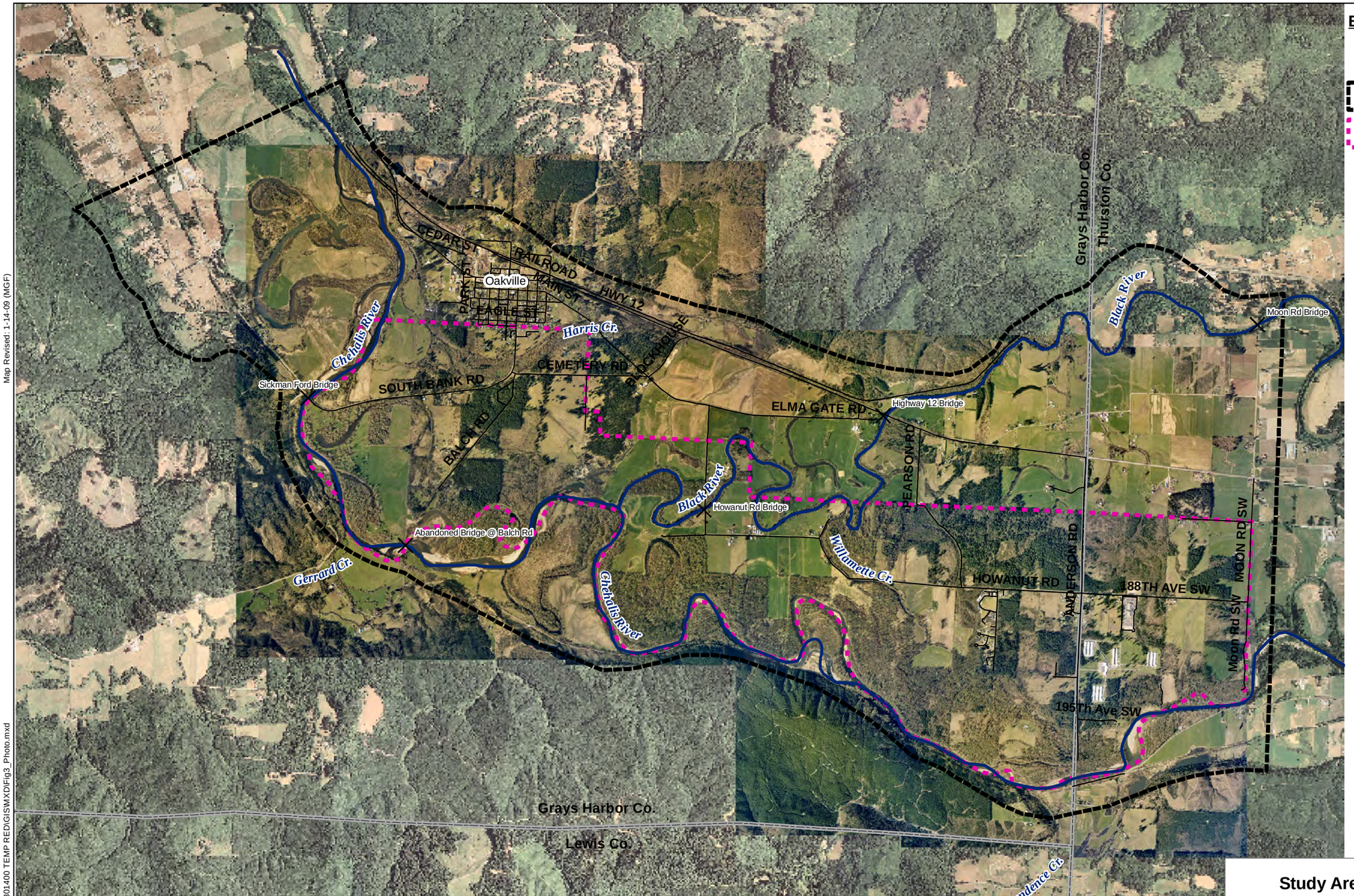
BOI




**Explanation**

- Bridges
- Study Area
- Reservation Boundary

N
W E
S

2,000 0 2,000
Feet

Reference: 2006 aerial photos provided by Confederated Tribes of the Chehalis Reservation and Grays Harbor County;
Roads from Confederated Tribes of the Chehalis Reservation and the Federal Census Bureau;
Tribal boundary and County boundary obtained from Federal Census Bureau.
Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes and should be used only in conjunction with the Comprehensive Flood Management Plan. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

**Study Area - Aerial Photograph**

Chehalis Tribe CFHMP

GeoEngineers

**Figure 3**

Map Revised: 1-14-09 (MGF)

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Map Revised: 1-14-09 (MGF)

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BOI

CEDAR ST
RAILROAD
MAIN ST
HWY 12
PARK ST
Oakville
EAGLE ST
Harris Cr.
CEMETERY RD
Chehalis River
SOUTH BANK RD
BALCH RD
Glacial Terrace
ELMA GATE RD
Black River
PEARSON RD
Willamette Cr.
Gerrard Cr.
Chehalis River
HOWANUT RD
ANDERSON RD
188TH AVE SW
MOON RD SW
Moon Rd SW
Glacial Terrace
195Th Ave SW
Grays Harbor Co.
Thurston Co.
Black River
Grays Harbor Co.
Lewis Co.
Independence Cr.
1
2
2
3
4
5
6
7

**Explanation**

- Hazard Areas
- Bridges
- Observed Emergent
- Observed Submerged
- Reservation Boundary

**100-yr Relative Surface Model (ft)**

Submerged Land (Feet below flood surface)
- 20-15
- 15-12
- 12-9
- 9-6
- 6-3
- 3-0

Emergent Land (Feet above flood surface)
- 0-3
- 3-6
- 6-9
- 9-100

N
W E
S

2,000 0 2,000
Feet

Reference: Tribal boundary and County boundary provided by the Federal Census Bureau;
Roads obtained from the Confederated Tribes of the Chehalis Reservation and the Federal Census Bureau.

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

**Limitations:**

**This recurrence interval flood surface map has been developed using a relative surface model as described in Appendix B of the Comprehensive Flood Hazard Management Plan. This map has not been produced based on FEMA modeling criteria. Flood surface has an estimated vertical error of +/- 2ft. The model predicted in the area shown covered by blue hatching to be emergent but the area was observed to be flooded in December 2007. The model predicted in the area shown covered by brown hatching to be flooded but the area was observed to be dry in December 2007.**

# 100-year Recurrence Interval Flood Surface

Chehalis Tribe CFHMP

GeoEngineers

**Figure 4**

# *APPENDIX A*
## *REVIEW COMMENTS FOR DRAFT CFHMP DATED JANUARY 20, 2009*

# APPENDIX A
# REVIEW COMMENTS FOR DRAFT CFHMP DATED JANUARY 20, 2009

Table A-1 summarizes the comments submitted during the public review period on the draft CFHMP.

**Table A-1. Public Review Comments for Draft CFHMP Dated January 20, 2009**

| REVIEWING AGENCY | COMMENT | CHEHALIS TRIBE RESPONSE |
|---|---|---|
| Washington State Department of Ecology, Kevin Farrell | 1. Section I.B.2. "Suggest changing section title to identify a specific component of WAC 173-148-040(1)." | Renamed as suggested. |
| | 2. Section II.E. "Are there any areas with high infestation on non-native vegetation (canary grass) that can be restored to a native veg class? If so, please identify locations." | Restoration to native vegetation is not part of this Flood Hazard Mitigation Plan; however, text was added in this section to indicate how the Chehalis Tribe is addressing areas with non-native vegetation. |
| | 3. Section II.G. "Expand this section to include more of a cultural resource use of the land." | The section was expanded. |
| | 4. Section II.H.1. With respect to a statement that early floodplain mapping did not include areas within the Chehalis Reservation: "this in not totally accurate. Earlier versions of the Thurston County FIRM's did include mapping of portions of the Chehalis Reservation. However, since the Tribe was not consulted with on the flood mapping, FEMA is recognizing that the Tribe was not officially mapped. Thurston County, when they updated their maps, did not include the previous mapping in the updates." | Comment noted. The statement was revised as follows: "However, early floodplain mapping did not include *the entirety* of the Chehalis Reservation." |
| | 5. Section III. A. "I suggest putting a table in this section showing discharge data." | Table added. All tables in text were subsequently renumbered. |
| | 6. Section III.A.1. With respect to statement that homes in the central area of the reservation were inundated with up to four feet of water in the 2007 flood: "Were these mitigated? If not, please provide a table with property identifying information so these can be targeted for elevation and/or buyout." | A paragraph has been added that describes the damage to the five houses along Howanut Road and the Tribe's request for funds to elevate or demolish three of these structures that have experienced repeat damage. |
| | 7. Section III.A.1. With respect to a statement that wells and septic systems were swamped and well heads were overtopped: "Is there anything we can do to 'floodproof' the wells and septic systems? If so, this should be listed under the project listings." | This statement was not accurate and was deleted. |

| REVIEWING AGENCY | COMMENT | CHEHALIS TRIBE RESPONSE |
|---|---|---|
| | 8. Section III.A.1. "Do we need to include a floodproofing strategy for this non-residential structure [convenience store at intersection of Anderson Road and U.S. Highway 12]?" | This building was permitted to be built 18 inches above the flood elevation, but an error in surveying during construction resulted in construction at only 13 inches above the flood elevation. This difference has resulted in periodic loss of inventory during flooding. The store is insured and is reimbursed when damage occurs. Over the long term, the building will be elevated properly when the site is redeveloped. No edits were made to the CFHMP. |
| | 9. Section IV.C. "Add a copy of the Interlocal Agreement in Addendum?" | Added as Appendix D. |
| | 10. Section V.A. "Suggest modifying this language [last sentence of seventh bullet item] to state the projects have the 'potential' to increase flood volumes. This is not known at this point." | Suggested edit made. |
| | 11. Section V.B. With respect to providing a priority ranking to the selected projects: "these should be ranked in order of priority under each ranking [high, medium, low]. If you have estimate cost for each project this should be included." | The projects were reordered in Sections V.B.1 and V.B.2. Costs were not estimated in preparation of this CFHMP. |
| | 12. Section V.B.2. With respect to proposed mitigation of elevating homes in floodplain inundated by previous events: "please provide addresses or other identifying data." | Identifying information added. |
| | 13. Section V.B.2. "I suggest you break down and list specific projects from the EPRP." | The plan cited in the draft CFHMP was an incorrect title. The Tribe adopted a Comprehensive Emergency Management Plan (CEMP) in May 2008, not an EPRP. The CEMP is an operational document and does not identify specific projects . The title of the plan was changed, however, in the final CFHMP. |
| | 14. Section V.C. "Do you really want to single out a specific location [for failed riprap placed by Thurston County on the Chehalis River bank] or do you want to make more of a blanket statement of the need to study 'rock jobs.'" | The statement was modified to be more inclusive of past riprap placement locations. |
| | 15. Section VI.A. "You should include NFIP required definitions including basement, development, lowest floor, substantial damage, and substantial improvement." | Kevin Farrell provided these definitions and they are included in the final CFHMP. |

| REVIEWING AGENCY | COMMENT | CHEHALIS TRIBE RESPONSE |
|---|---|---|
| Bureau of Indian Affairs, Kayloe Dawson | "Concerning Structural Mitigation Measures: Table 4 (in draft CFHMP) is pretty key information related to flood mitigation measures which may be implemented on the IRR system and incorporated into future transportation projects…It appears these mitigation measures have not been verified with hydraulic modeling (HEC-RAS) as of yet? So, a suggestion for future studies/tasks would be that the structural alternatives could be roughly verified…in HES-RAS as providing positive flood mitigation/improved access. So on Page A-5, this would add another bullet under Task 2. A deliverable of this task would be to update and/or verify the projects and priorities related to Table 4." | Verifying the structural mitigation projects using hydraulic modeling is beyond the scope of this CFHMP, and therefore, Page A-5 (which documented presentation of the project scope to the Tribe) will not be modified. Rather, Section V.C. was modified, as necessary, to address the need for modeling prior to the project design phase. |

# *APPENDIX B*
## *MEETING MINUTES*

## January 17, 2008, CFHMP Services Kick-off Meeting

Tribal Participants:

Lennea Magnus, Amy Loudermilk, Glen Connelly

GeoEngineers Participants

Mary Ann Reinhart, Darrell Sofield

Lennea Magnus opened the meeting and introduced GeoEngineers.

The meeting agenda included the following elements:

- Introduce the consulting project team.
- Confirm / discuss Tribal resources
- Brief discussion of Scope Addendum (field survey regarding Dec. 2007 flood)
- Present preliminary findings from December 2007 field survey.
- Discuss information available from the Chehalis Tribe
- Review and /or discussion of:
    - Scope of work
    - Tasks to be performed by the Tribe
    - Schedule and invoicing.

Darrell Sofield presented the results of GeoEngineers December 2007 floodplain reconnaissance. Comments and questions were addressed during the presentation, and corrections made to the PowerPoint slides. A copy of the PowerPoint presentation is attached to this meeting summary.

**Summer (low flow) field work** proposed in the original scope was discussed. Glen indicated that low water starts in id-June. GeoEngineers envisions that some of the work will be conducted by kayak. Glen said he would like to join GeoEngineers to provide consultation for both the kayak and floodplain surface parts of the reconnaissance.

**Meetings** will be conducted at the Tribal office at the Reservation or in casino meeting room. Lennea said that from mid-June to early July is a bad time in general because of Tribal activities. Therefore, the following was suggested:

A progress meeting and discussion was tentatively set for August. This meeting would satisfy the public meeting requirement for this plan. Lennea suggested a pre-meeting with her and staff followed by a display of posters for review by the Tribal Council and all Tribal members.

**Invoicing** should be submitted monthly. Send to the attention of Lennea or Planning Department. The invoices should show the balance of each task, and include FCAAP-compliant descriptions of work performed.

**Project completion date.** The plan was originally scheduled to be completed in September 2008. However, this will need to be changed since field work will be conducted in July, and the public meeting will not likely be held until August. The completion day was tentatively set for end of October.

Mary Ann received a Tribal organization chart. The Chehalis Business Committee (a subset of the Tribal Council) is at the top of the chart. Lennea stated that we would not be presenting our findings to them, but they will be approving the plan.

The Tribe has chosen not to create a Citizens Advisory Group. The plan will be reviewed and accepted by the Tribal Council and Business Committee. Kevin Farrell (Department of Ecology) will be included in the list of reviewers, and will be "kept in the loop" over the course of the project.

GeoEngineers received some PIE models for Anderson road at the close of the meeting.

**PowerPoint Presentation:**

**Comprehensive Flood Hazard Management Plan Services**
**Kick-off Meeting January 17, 2008**
**For**
**Confederated Tribes of the Chehalis Reservation**

**Agenda**

- Introductions (10 minutes)
  - Project Team
  - Tribe Resources
  - Additional Scoping Update
    - 2007 Flood Recording Field Work
    - Funding
- Dec 2007 Flood Findings (30 minutes)
  - GeoEngineers' Presentation
  - Tribe questions and insight
- Review (50 Minutes)
  - Scope of Services
  - Major collaborative tasks
  - Schedule
  - Invoicing
- Data Collected (5 minutes)

**Team Members**

- Mary Ann Reinhart* - Associate
- Lisa Bona* – Project Manager / Planning Lead
- Darrell Sofield –Technical Lead
- Jon Ambrose, Hydrology

- Chris Brummer (Herrera), Basin and Floodplain Characterization and Hydraulics Review

* Primary Contacts: Redmond Office (425)-861-6000 lbona@geoengineers.com and mreinhart@geoengineers.com

## Resources

### Tribal

- Planning
  - Lennea Magnus –Primary Contact
  - Amy Loudermilk –Grants
  - Don Terry –Chief Building Officer (long time resident)
- Natural Resources
  - Mark White, Director
  - Glen Connelly
- Chehalis Police
  - Ralph Wymer

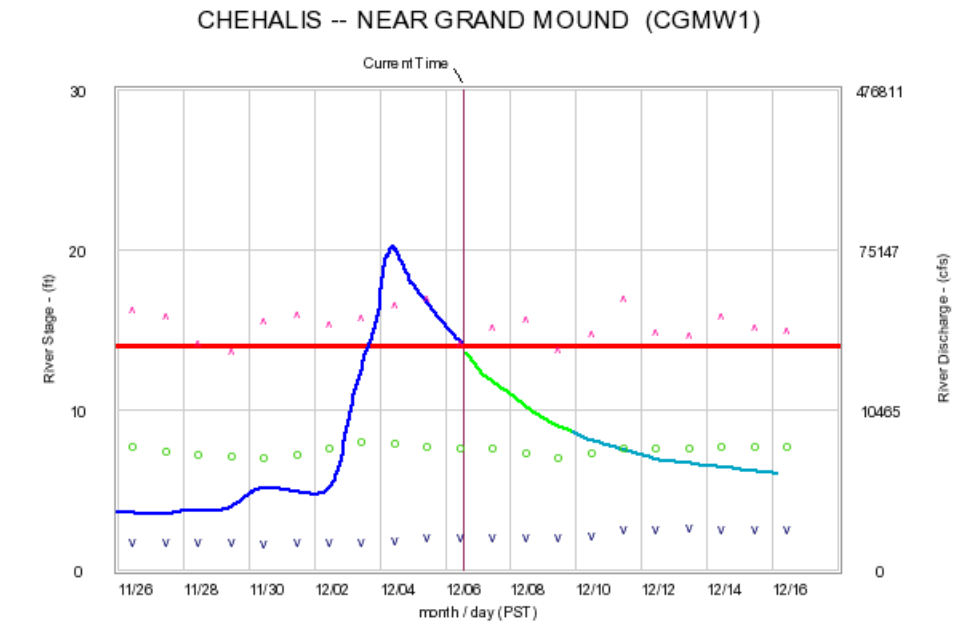
### Non-Tribal

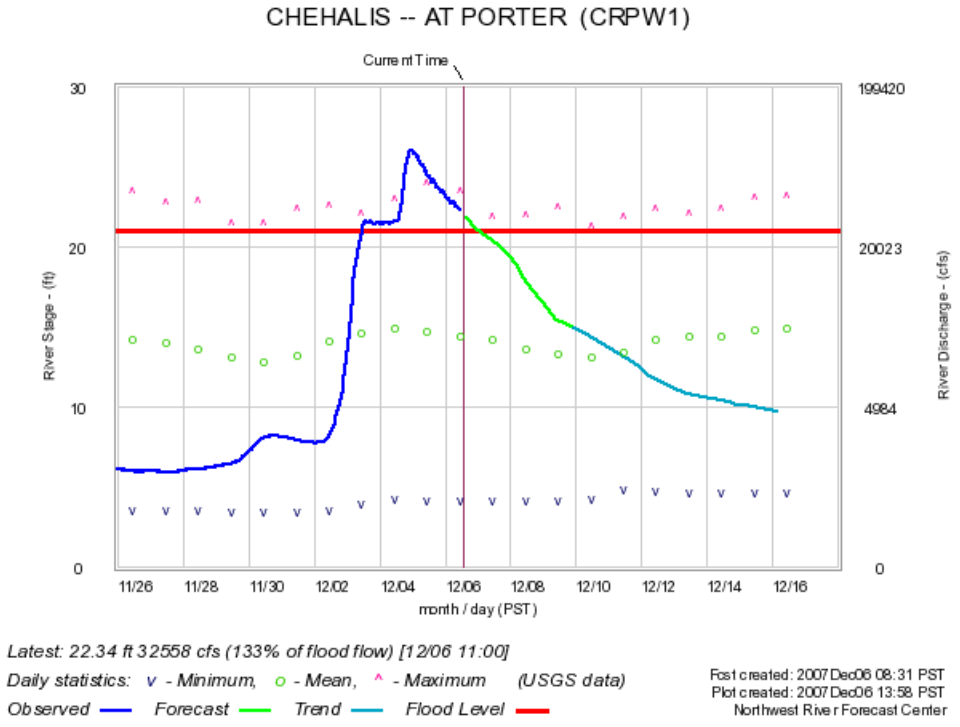
- Jay Salmon
  - Tribe Surveyor and local resident
- Department of Ecology
  - Kevin Farrell

## Preliminary December 2007 Flood Findings

- Data Used
  - Topography
  - Stream Gauge Records (Grand Mound and Porter)
  - Personal Communication with Tribe and Jay Salmon
  - Field Observations
  - Review of Tribe Air photos

## Gauges




## Preliminary December 2007 Flood Findings

- Field Observations: Complex Floodplain with islands and gates

– Regional Geology –Outwash Terraces and Alluvium

- Basic Hydraulic Concept
- What Happened in 2007 (upstream to downstream)

**Flooding Details (upstream to downstream)**

- Grand Mound (Great Wolf Lodge)
- Flats: Independence Rd, Moon Road
- Island: Casino, Tribal Center, Anderson Road
- Confluence: Howanut
- Oakville & Island: Elma Gate, Slate, Balch, South Bank, Sickman-Ford
- Downstream

**Scope**

- **Task 1: Data Collection, Review and Synthesis** (Nov – February)
- **Task 2: 100-yr Flood Elevation Model & Flood Inundation Layers** (January – August)
  - Hydrology
  - LiDAR Review
  - Field Observations
  - Hydraulic Model
  - Calibration and Review
- **Task 3: Geomorphic Evaluation (Channel Performance Analysis)** (January – June)
  - Preliminary Analysis
  - Field Verification
- **Task 4: Comprehensive Flood Hazard Management Plan Preparation** (June – September)
  - 10 Chapters (X Chapters for Tribe)
- **Task 5: Meetings** (as needed)
  - 3 in-person
  - 2 via web/conference

**Task 1: Data Collection**

- Collect, Review, and Synthesize
- Sources:
  - County FPMPs
  - County FIRMs and planned updates

- FEMA, USACE Reports and Models
- USGS, USDA, and WaDNR's photos, maps, gauge data
- Tribal Plans and digital data.

## April 17, 2008, FCAAP/CFHMP Meeting Notes

Kevin Farrell, Ecology – any problems, issues?

Mary Ann Reinhart, GeoEngineers – Quality Assurance Plan (QUAP) to be provided on Tuesday, questions today

- Field reconnaissance following December 2007 flood
- As flood of record, surprises. No flooding at Grand Mound, Chehalis overtopped US 12 and dumped into the Black River.
- Results of field work will be submitted in field map.
- At time of '07 flood, Black was not at flood stage & provided some storage & capacity (Differs from '96 in this respect.)
- One area of concern is Vosper end of river (sediment building), question regarding velocities – could mean more flooding on that side of the reservation.
- Post-processing of LiDAR to refine/develop surface variations & match up with paleoflow indicators to get true picture of event.
- Channel migration "hot spots"
- Pre-exist HEC-RAS data '96 flood
- Update HEC-RAS to '07 flood

Issues: 1. Contributions of Black River to flooding previously hasn't enough been taken into consideration enough
2. GeoEngineers' field staff noted evidence of backwater effect caused by Black River confluence with Chehalis River
3. Concern for upstream influences on Chehalis River (fill & levees)

Question: *As we're putting together QUAP (and there isn't a good example on Ecology's website) we've included general approach and calibration of HEC-RAS model. Need more information on Ecology's requirements for QUAP. Need to know CFHMP as scoped will be sufficient.*

- Need to look up –river & at Black

Kevin – Kevin will talk with Mary Ann on expectations. With Corps project currently in works near city of Chehalis, hesitant to take implementation of Corps project into consideration for this CFHMP – it could be 5 years.

CFHMP- identify current and verifiable risks. Kevin agrees that more investigation into effects of Black River flooding is warranted. Agree that looking at Black River is required to meet requirements for this CHFMP. Kevin recommends that the Tribe provide a request to the state to increase funding for expanding the scope of the CFHMP and required analysis of the 100-year recurrence interval flood inundation map being prepared.

Kevin- Mary Ann type up request for expansion of scope of work. Ecology will carry forward to state.

Kevin will get back with more guide of QUAP format/guidance.

## June 4, 2008, Community Meeting Notes

**FEMA Hazard Mitigation Grant**
**Community Meetings**
**June 4, 2008**
**12pm and 4pm**

On June 4, 2008, the Planning Department conducted two community meetings to collect input on possible solutions for the 4 homes on Howanut Road that were flooded during the December 2007 flood event.

Both community meetings were held at the Chehalis Tribal Center. One was at 12pm, and the second was at 4pm.

There were 17 participants at the 12pm meeting.
There were 21 participants at the 4pm meeting.

All participants completed a survey on possible solutions to protecting the 4 homes on Howanut Road that incur flood damage during major flood events.

A total of 38 surveys were completed. The results are as follows:

Best solution:

- 30 people said that elevating these 4 homes was the best solution.
- 6 people said that demolishing the 4 homes and never building in that location again was the best solution.
- 2 people said that doing nothing at all was the best solution.

Worst solution:

- 20 people said that doing nothing at all was the worst solution.
- 15 people said that demolishing these 4 homes was the worst solution.
- 3 people said that elevating these 4 homes was the worst solution.

Participants were asked the following question: What other thoughts do you have about protecting homes from flooding? The following responses were provided:

- Build out of the flood zone.
- Demolishing these 4 homes is a bad idea – don't want to be homeless.
- If houses are going to be elevated then elevate garages and outbuilding too.
- Houses should have been elevated to begin with or they should not have let anybody move into them in the first place. Raising the houses is a good idea – would be a good idea to have people living in them get renters insurance.
- Remove river obstructions i.e. bridge approaches (gravel) at south Elma, Porter, Sickman Ford Bridge, Independence, Galvin. Let the water flow unobstructed to the sea. Don't build dikes and levees in Centralia and Chehalis!!!
- Make sure health facilities are protected and tested frequently even after the flood.
- If at all possible, put current homes (built in flood areas) on higher foundations with "water ways," with air ventilations to allow for moisture escape. And if all possible build up ground around the river.

- Stop building in the floodplain.
- No more dikes above Grand Mound.
- Don't build any more houses in the valley.
- I think that elevating the homes would be the best and easiest way to protect them other than doing nothing at all.
- If houses are set to be demolished, auction them off first so that a new owner could move the house to a new location out of the floodplain.
- Stop the building in the Centralia and Chehalis area that for many years held the excess flood waters like a reservoir and ran off as the river water levels dropped. The creeks and rivers could be cleared and dredged so the water could run off faster. The rivers are so full of waste mud there is no place for fish to spawn. Some of the pump houses that provide water to homes should be raised or re-plumbed so pump and controls are above the flood level.

## September 11, 2008, Meeting

**Confederated Tribes of the Chehalis Reservation**
**Comprehensive Flood Hazard Management Plan**
**Agenda and Notes for Meeting at Tribal Office, September 11, 2008**

I. Introductions and meeting objectives

   a. Meeting attended by Advisory Group, presentation on preliminary results of 100-year recurrence interval flood map to be given by representatives of Herrera and GeoEngineers

   b. Objectives of presenting the flood map and brainstorming mitigation strategies for the CFHMP.

II. Present 100-year relative surface elevation model. Presented by Chris Brummer of Herrera. PowerPoint presentation attached.

   a. Methods

   b. Model problem areas and solutions

   c. Calibration and level of accuracy

   d. Validation – eyewitness accounts of inundation and damage (2000 aerial photograph)

III. Mitigation strategies – brainstorming session

   a. Problems. The following were presented by GeoEngineers, Herrera and others as major issues: the 2007 flood was flashier and with a higher peak than previous floods. The river reach through the Reservation is the only extended reach without levees to control flooding. There is an impression of decrease in flood storage capacity as the basin upstream is built out. The 2007 flood event resulted in large influxes of sediment throughout the basin as a result of landslides and debris flows exacerbated by a number of factors, such as exposed, logged slopes. The sediment increases result in channel aggradation, reduces the volume of water that the system can convey, increases the flooded area, and may force migration and avulsion of the river into the current floodplain. It is get more difficult to use past results of flooding to predict future events because the baseline conditions also are changing.

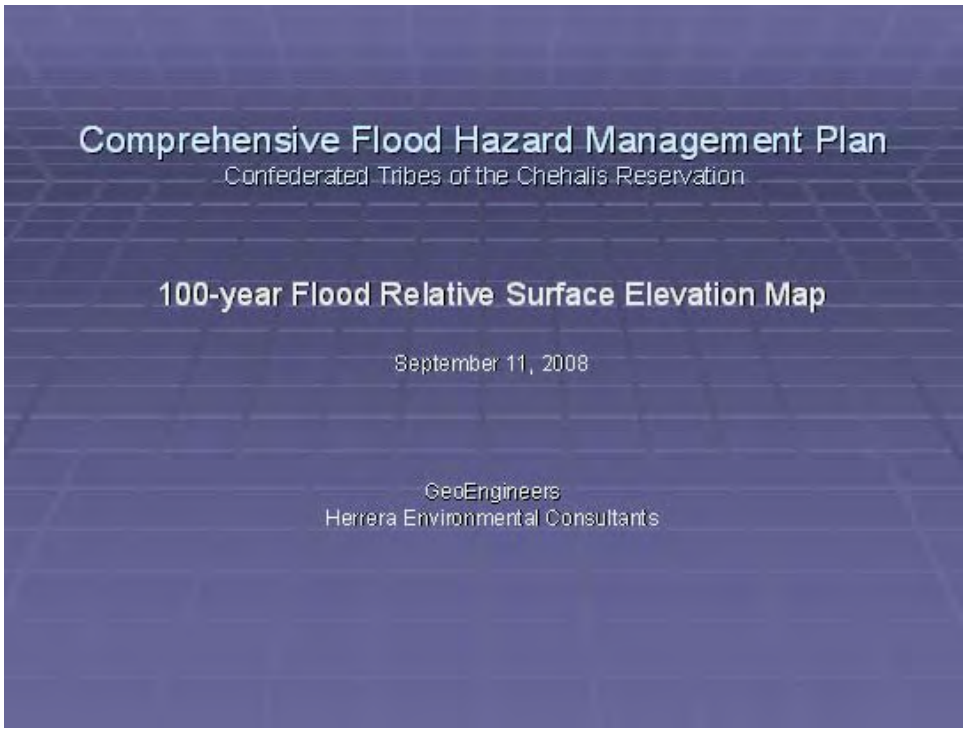
   b. Proposed solutions. A number of mitigation approaches were discussed and proposed for the CFHMP.

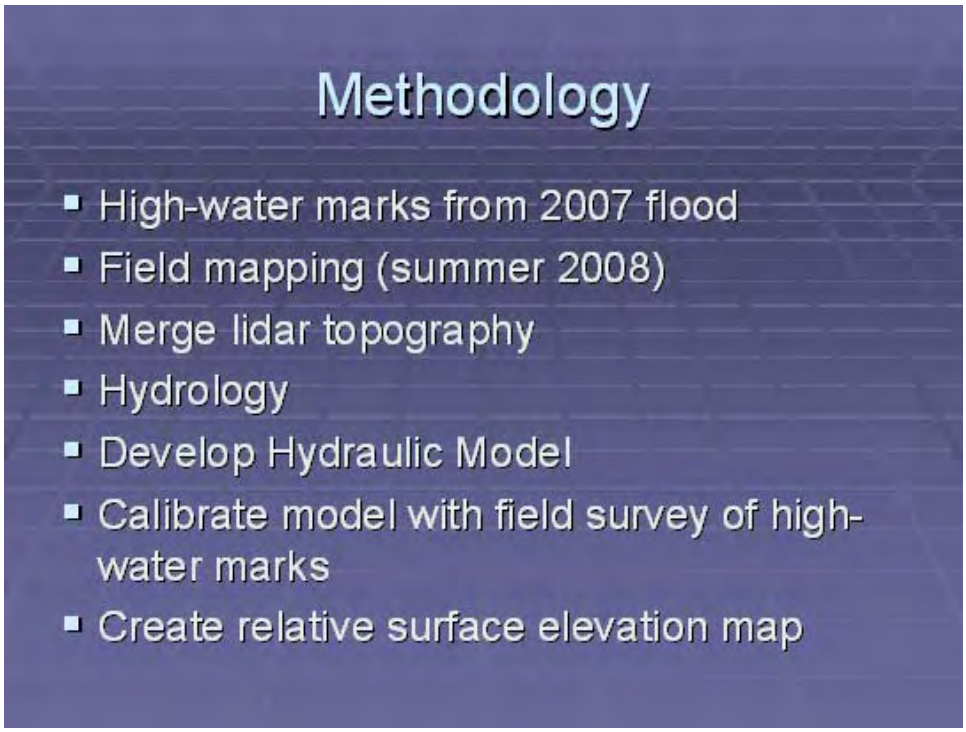
      i. Structural?

      ii. Nonstructural and programmatic

      iii. Necessary studies?

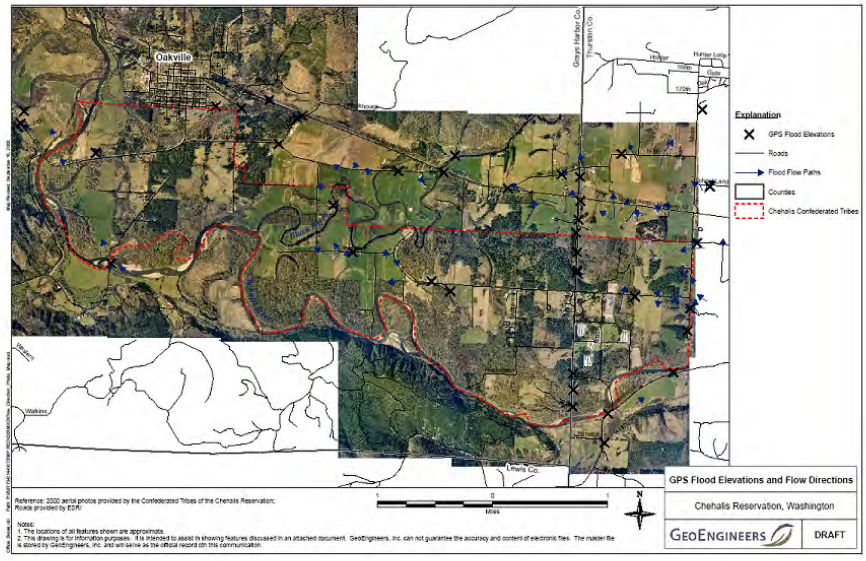
**PowerPoint Presentation:**



# Field Survey during 2007 flood

- High-water marks and locations collected with GPS
- Preliminary elevations determined from lidar
- Elevations checked with survey

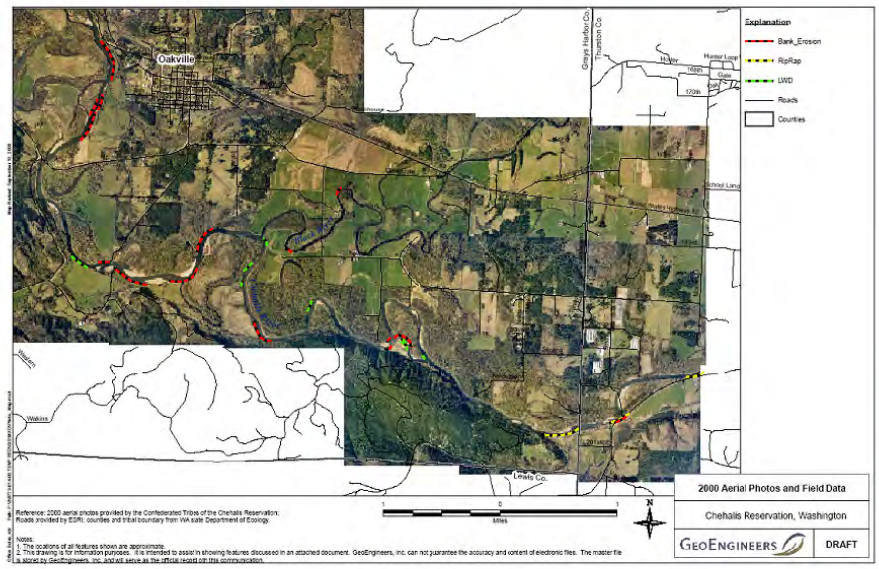


## 2008 Field Mapping

- Floodplain mapping for model
- Identify problem areas
- Collect additional geomorphic data

## Bridges


Bridges

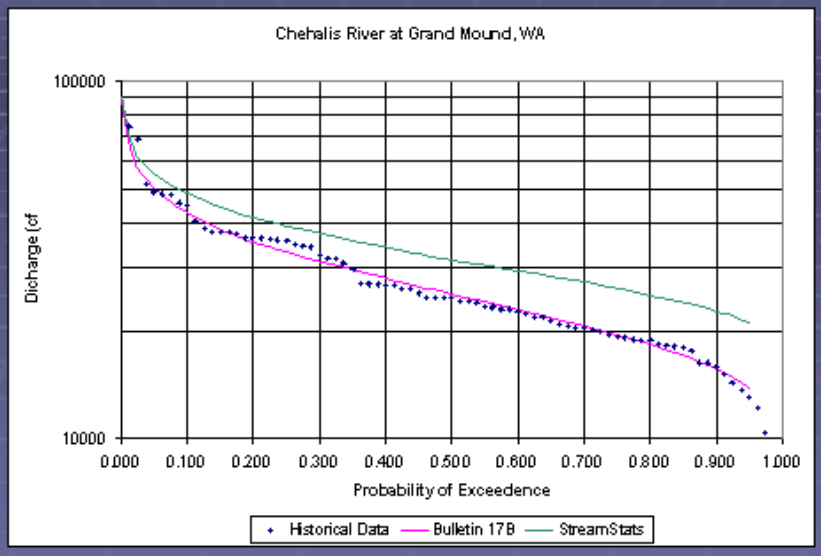



# Merge lidar topography

- Different dates and river flows
- Different resolutions and processing routines
- Vertical errors up to ~2 ft.

# Hydrology

- 100-year flow using three methods
  - Regression of historical data
  - USGS Bulletin 17B
  - USGS StreamStats
- Interpolation between Grande Mound and Porter gauges
- Subtract lidar flows
- Results…



## Historical Flow Data

### USGS 12027500 gauge at Grand Mound

| Rank | Date | Peak Q (cfs) | Ave. Daily Q (cfs) |
|---|---|---|---|
| 1 | 12/04/07 | 79,100 | 61,900 |
| 2 | 02/09/96 | 74,800 | 64,200 |
| 3 | 01/10/90 | 68,700 | 58,500 |
| 4 | 11/25/86 | 51,600 | 46,000 |
| 5 | 01/21/72 | 49,200 | 40,100 |
| 6 | 12/29/07 | 48,400 | 46,300 |
| 7 | 11/25/90 | 48,000 | 38,400 |
| 8 | 12/21/03 | 45,700 | 45,000 |
| 9 | 12/05/75 | 44,800 | 39,100 |
| 10 | 01/26/71 | 40,800 | 36,100 |

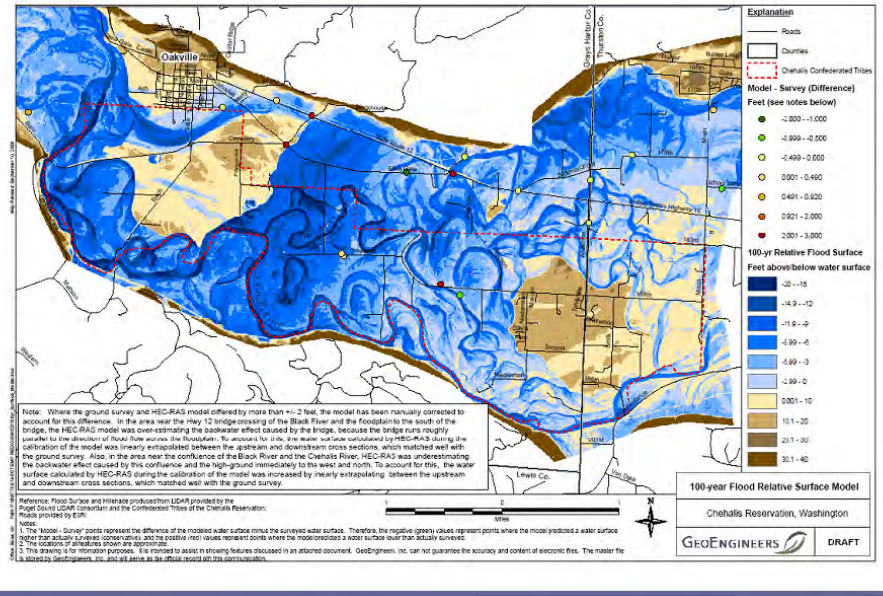
- 100-yr peak Q: 69,760 cfs (Chehalis), 7,210 cfs (Black)
- 2007 flood was ~155-yr event

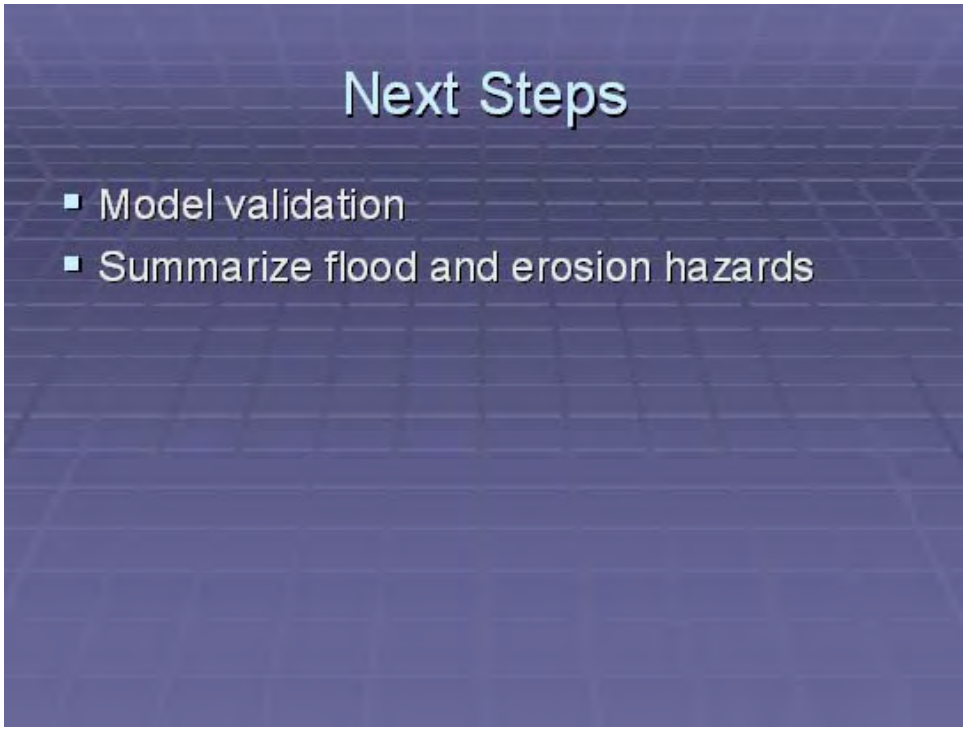
## Hydraulic Model

- HEC-RAS 4.0
- Cross-sections
- Bridges
- Ineffective flow areas
- Channel and floodplain roughness
- Calibration using 2007 high-water marks

# Relative Flood Surface Model

- Map showing 100-year flood depth
- Difference between lidar and model
- Calibration points
- Validation with observations




Next Steps
Model validation
Summarize flood and erosion hazards

# *APPENDIX C*
## *METHODOLOGY FOR FLOODPLAIN MAPPING AND GEOMORPHIC ANALYSIS*

# APPENDIX C
# METHODOLOGY FOR FLOODPLAIN MAPPING AND GEOMORPHIC ANALYSIS

## FIELD RECONNAISSANCE

A field reconnaissance was performed December 17-18, 2007 to document the conditions immediately following the record flood occurring on December 4, 2007. Photographs of flood impacts and locations of high-water indicators and flow directions were mapped using a Trimble GeoXT GPS unit. A second field reconnaissance was performed on June 16-17, 2008. During this second visit, a boat was used to access the Chehalis River and a portion of the Black River throughout the Reservation. A Trimble GeoXT GPS unit was used to document the location of specific channel characteristics including bank erosion, bank revetments, large woody debris (LWD) accumulations, and outcrops of glacial outwash. Additionally, bed and bank grain sizes were documented at select locations. Also during this second field visit, bridge dimensions were measured for entry into the hydraulic model, and channel geometry was recorded at select locations for aid in model calibration.

## LIDAR

The topography for the hydraulic model was obtained from two sources. They include the LiDAR made available by the Puget Sound LiDAR Consortium (PSLC) and LiDAR flown by the Chehalis Tribe. The following steps were taken in order to acquire and use detailed LiDAR topography for the project site:

- Downloaded the PSLC bare earth digital elevation models (DEMs) (6 x 6 grids) for the project area. The following quarter quadrangles encompass the entire project area:
    1) q46123g21b
    2) q46123g22b
    3) q46123g23b
    4) q46123g24b
    5) q46123g33b
- Created a mosaic of the PSLC data into one 6 x 6 grid, and converted to a 3 x 3 grid.
- Acquired the Chehalis Tribe's LiDAR (3 x 3 grid) flown in November 2007
- Built a buffer around the Tribe's LiDAR, with the boundary 500 feet within the reservation perimeter.
- Extracted the PSLC data from the area inside the 500-foot buffer of the Tribe's data. This created a hole in the PSLC data that could be filled by the higher resolution Tribal data, with 500 feet of overlap.
- Created a mosaic of the Tribe's data with the extracted PSLC data, into a new 3 x 3 grid, by blending the overlap area.
- Smoothed the combined grid into a 6 x 6 cell rectangle using the Focal Statistics tool in Spatial Analyst.

## HYDROLOGY

The 100-year flows for the hydraulic model were determined from an analysis of available historical flow data collected by the USGS and additional relationships relating basin area to peak flow. Annual peak discharges were obtained from the two nearest USGS gauges located upstream and downstream of the study area and a gauge located upstream of the study area on the Black River. The upstream gauge on the Chehalis River (USGS Gauge #12027500) is located approximately five miles upstream of the Reservation near Grand Mound. The gauge at Grand Mound has 79 years of historical records dating back to 1928. The downstream gauge on the Chehalis River (Gauge # 12031000) is located approximately seven miles downstream of the Reservation at Porter. The gauge at Porter has 56 years of historical records dating back to 1952.

Since April 2005, the Washington State Department of Ecology has maintained a streamflow station on the Black River at the U.S. Highway 12 Bridge (Station #23E060). Because of the short historical record, this station is of limited value in determining peak flows. The USGS maintained a gauge on the Black River at Littlerock (Gauge # 12029000) from 1945 to 1950 (six years). Historical flow data from these monitoring stations provided the basis for determining the 100-year flow and for flood hazard mapping.

Annual peak discharges were obtained from the USGS for the period of record for each stream gauge. The peak data for each gauge was input into the USGS computer program PeakFQWin, which utilizes methodology from USGS Bulletin 17B to determine a Log-Pearson Type III (LP3) distribution to best fit the data (USGS, 1981). An error message was generated during the PeakFQWin model run of the historical gauge data for the Black River gauge at Littlerock, Washington. This gauge's LP3 distribution was calculated manually utilizing the methodology of Bulletin 17B.

The USGS computer program StreamStats also was utilized to compare and validate the LP3 results for each gauge (USGS, 2008). StreamStats tended to overestimate the flood discharges when compared to the historical stream gauge data. These two regressions and the historical peak flow data are provided in Figures C-1, C-2 and C-3.

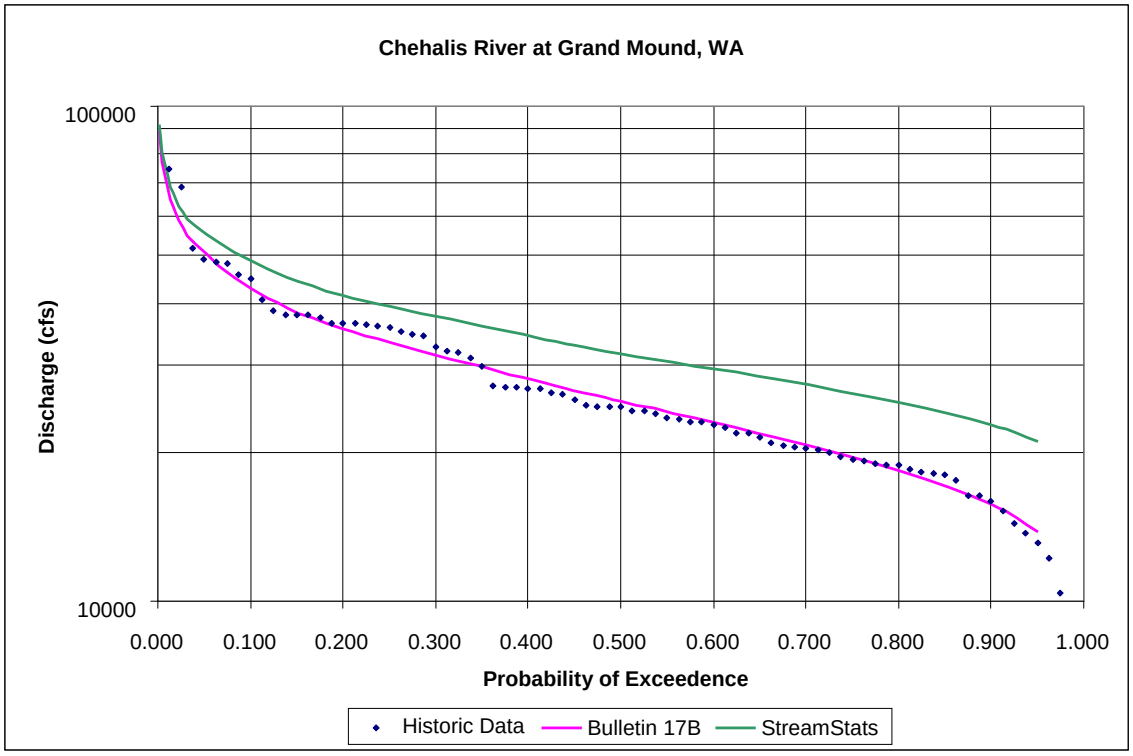



**Figure C-1. Log-Pearson Type III Distribution for the Chehalis River at Grand Mound, Washington**

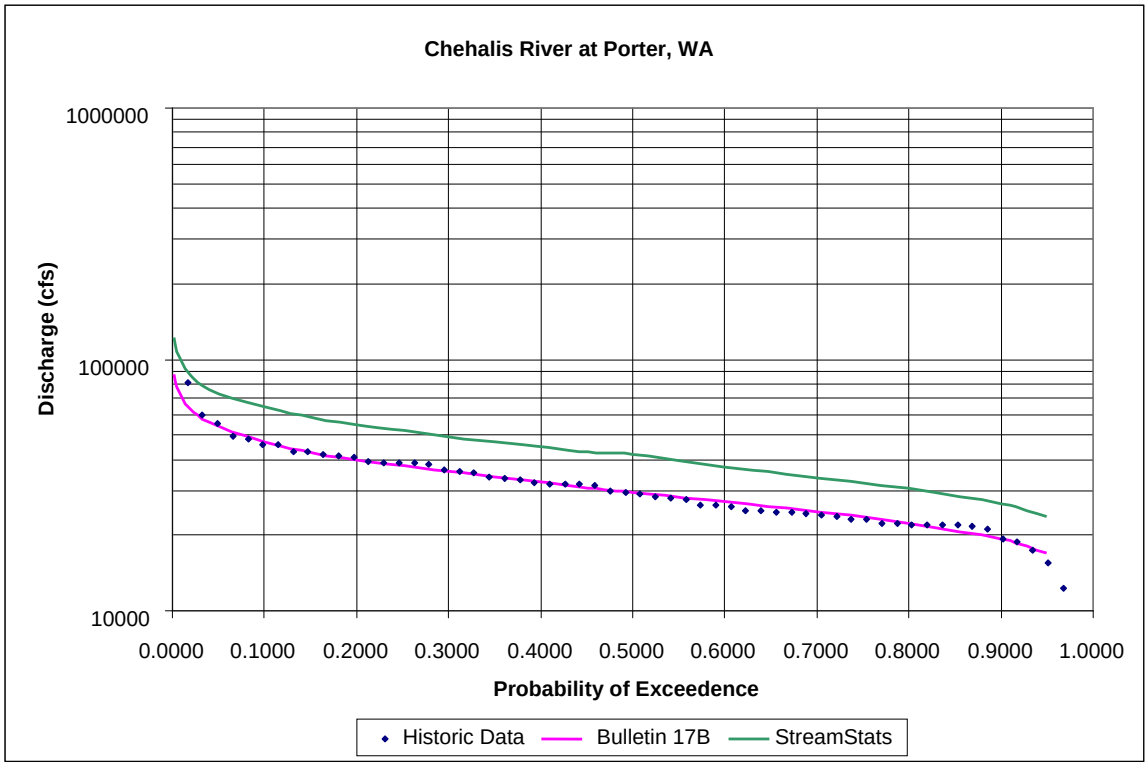



**Figure C-2. Log-Pearson Type III Distribution for the Chehalis River at Porter, Washington**

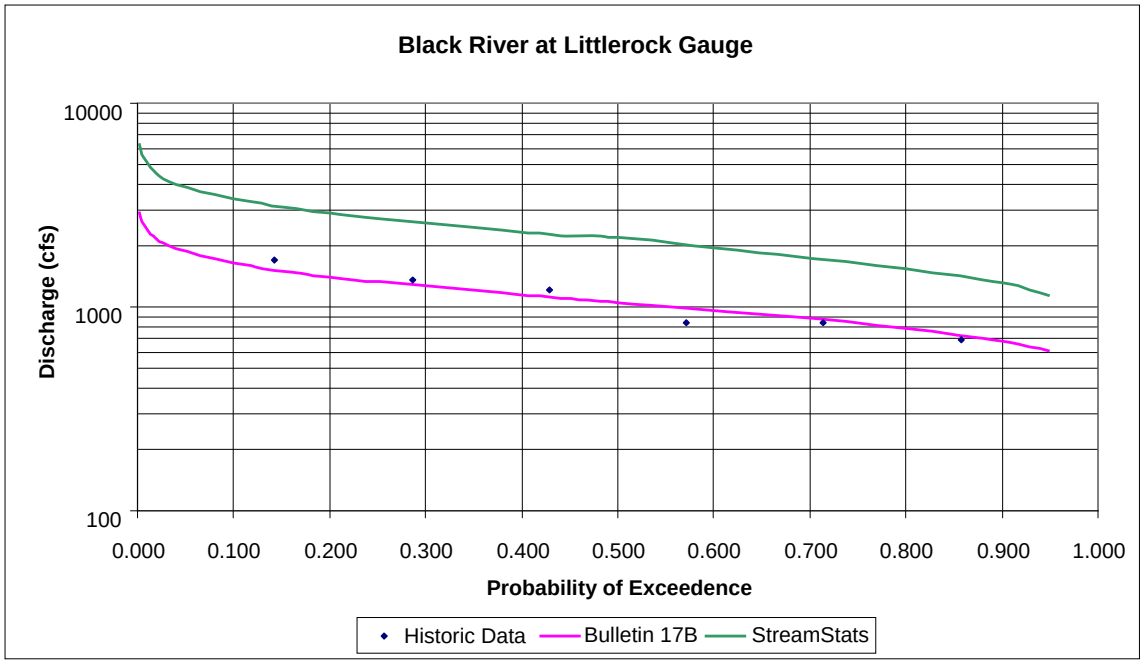



**Figure C-3. Log-Pearson Type III Distribution for the Black River at the Littlerock Gauge**

The Grand Mound and Porter stream gauge data and LP3 distributions were used to determine the flood frequency discharge values on the Chehalis River at the downstream end of the project study area. A simple linear regression between the two gauges based on watershed area was used to estimate the flood discharge values at the downstream end of the project site. As predicted these discharges were below the flood flows estimated by StreamStats. This area regression can be seen in Figure C-4 below.

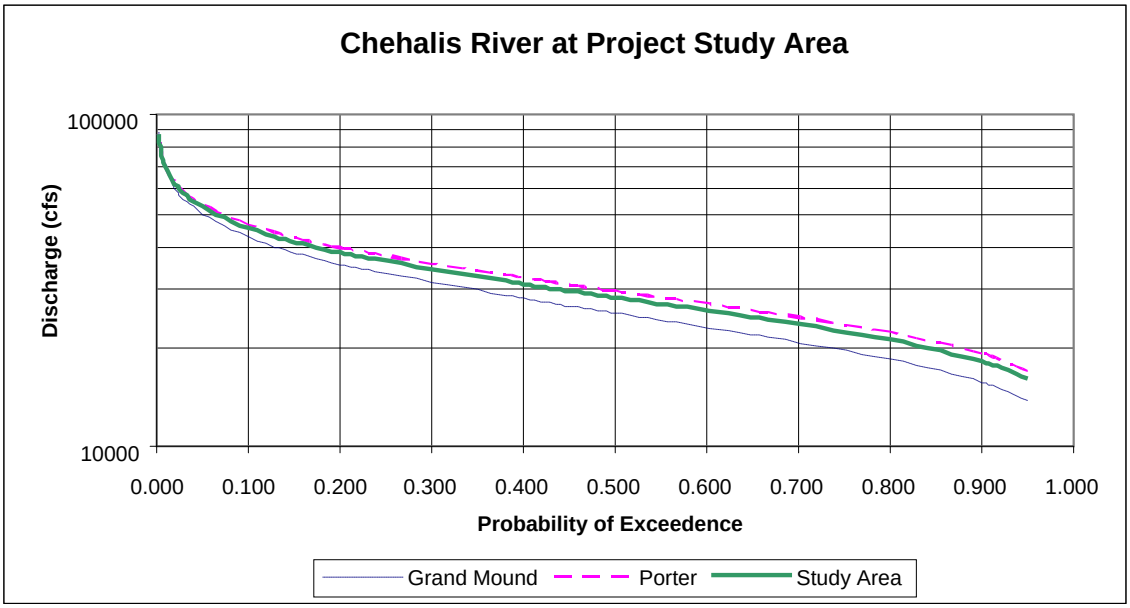



**Figure C-4. Log-Pearson Type III Distribution for the Chehalis River at the downstream end of the Project Site**

Four different methods were used to estimate the flood discharges for the Black River at the confluence with the Chehalis River. These four methods consisted of applying StreamStats, conducting an area ratio of the Black's historical peak flow data, conducting an area ratio of the Chehalis' historical peak flow data, completing an LP3 distribution based on historical flow data for the Chehalis, and estimating the peak daily flow for the Black River based on historical flow data from the Chehalis River gauges, and then completing an LP3 distribution on the estimated yearly peak flow data. These methods are discussed further below.

StreamStats was used to estimate the flood flows on the Black River at its mouth. These estimates were assumed to be an upper bound on the discharges since StreamStats tended to overestimate discharges at the three gauge locations analyzed when compared to their respective historical LP3 distributions.

An area ratio between the Littlerock, Washington gauge and the mouth of the Black River for the LP3 historical distribution also was used to estimate the flood discharges. This method multiplied the estimated LP3 distribution from the Littlerock gauge by 2.20, which is the area of the Black River at its mouth (138.4 $mi^2$) divided by the area of the Black River's watershed at the Littlerock gauge (62.8 $mi^2$). It was assumed that this might underestimate the flood flows because of the short historical record at the Littlerock gauge. This can be seen as 'Scenario 1' in Figure C-5.

The third method consisted of using an area ratio between the Black River watershed and the watershed at the downstream end of the project area and applying it to the estimated LP3 distribution for the Chehalis River at the project study boundary. This method reduced the estimated flood flows on the Chehalis River at the project's downstream end by a factor of 0.12, which is the Black River's watershed area (138 $mi^2$) divided by the watershed area at the downstream end of the project (1174 $mi^2$). From historical flooding observations and monitoring it is known that the Chehalis River and Black River do not peak at the same time. These watersheds also are not hydraulically similar because of large variations in the size of the watersheds, the variation in elevation and land use type. These factors reduce the confidence of this third method for estimating flood discharges. This can be seen as 'Scenario 2' in Figure C-5.

A fourth, more complex method was developed to determine estimated flood discharges for the Black River at the confluence with the Chehalis River. This method employed the longer historical records for the two stream gauges on the Chehalis River. A relationship was developed for each stream gauge between the historical peak flow and its respective daily average flow. This linear relationship provides the ability to estimate the instantaneous peak flow for any given day of the historical record. The instantaneous peak flow from the downstream gauge (USGS Gauge #12031000) was then subtracted from the instantaneous peak flow from the upstream gauge (USGS Gauge #12027500) for every single day that the gauge data overlapped (1952-2008). This difference in peak flows estimates the instantaneous peak flow from the watershed area between the two gauges, which includes the Black River watershed. A ratio factor then was applied to the peak difference to reduce it to the peak flow for only the Black River's watershed. This ratio factor was 0.346, which is the Black River's watershed area (138.4 $mi^2$) divided by the difference in watershed areas between the two gauges (1297.8 $mi^2$ – 898.3 $mi^2$). From daily peak flow data the annual maximum peak flow was selected for each year of record. These annual peak flows were compiled and the methodology described within USGS Bulletin 17B was used to determine an LP3 distribution for the flood frequency flows for the Black River at the confluence with the Chehalis River. The results from this method can be seen as 'Scenario 3' along with the other three methods in Figure C-5 below.

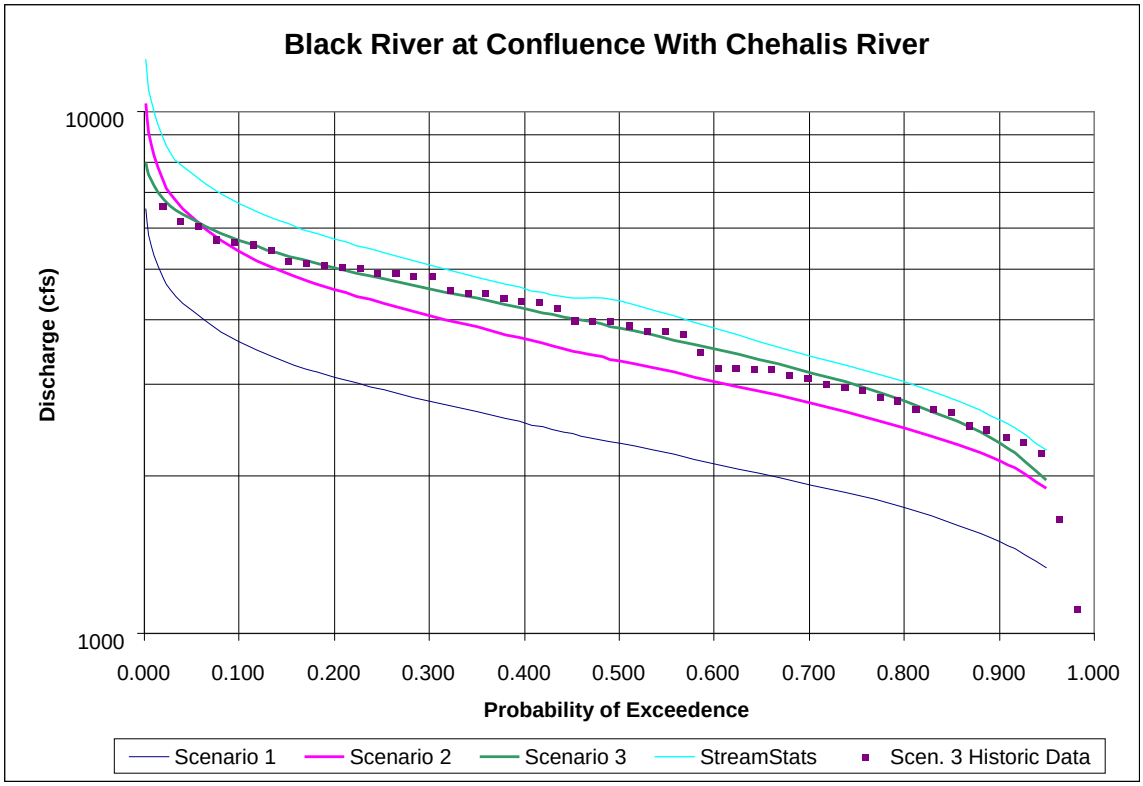



**Figure C-5. Log-Pearson Type III Distribution for the Black River at the Confluence with the Chehalis River**

Ultimately the Chehalis River flood frequencies were based on the area reduction between the LP3 distributions for the Grand Mound and Porter gauge sites as seen in Figure C-4. The final flood frequency data used for the Black River was based on the LP3 distribution from the daily peak flows estimated from the historical daily data from the Porter and Grand Mound stream gauges. This is shown as 'Scenario 3' in Figure C-5. Both of these regressions were used because they were based on actual historical recorded data. A summary of select flood return frequencies and their respective flood discharges can be seen in Table C-1 below.

**Table C-1. Chehalis and Black River Flood Discharges for Select Flood Return Periods**

| EXCEEDANCE PROBABILITY | FLOOD RETURN (YEAR) | DISCHARGE (CFS) | |
|---|---|---|---|
| | | CHEHALIS RIVER | BLACK RIVER |
| 0.1 | 10 | 45,750 | 5,670 |
| 0.04 | 25 | 55,110 | 6,370 |
| 0.02 | 50 | 62,330 | 6,810 |
| 0.01 | 100 | 69,760 | 7,210 |
| 0.002 | 500 | 88,140 | 7,980 |

## HYDRAULIC MODEL

The US Army Corps of Engineers Hydrologic Engineering Center – River Analysis System (HEC-RAS) software version 4.0 was used to build a one-dimensional hydraulic model of the project area. The geometry for the hydraulic model was created using a mosaic of bare-earth LiDAR topography provided by the Puget Sound LiDAR Consortium and the Confederated Tribes of the Chehalis Reservation. The model was built using cross sections spanning the width of the combined Black River and Chehalis River floodplain without incorporating bathymetry. Rather, the appropriate volume of water was subtracted from the Chehalis and Black rivers based on the actual volume of water recorded by gauges and calculated by regression analyses on the days LiDAR was flown.

A total of 33 cross sections were drawn across the entire floodplain using the U.S. Army Corps of Engineers GeoRAS software in a GIS program. Topographic data extracted from the merged LiDAR in GeoRAS was then imported into HEC-RAS 4.0 for each of the 33 cross sections. Bridge geometry recorded during field reconnaissance was added to the appropriate cross sections for the Sickman-Ford Bridge on the Chehalis River and the U.S. Highway 12, Moon Road, and Howanut bridges on the Black River. A single geometry was built to model both the Black River and Chehalis River using the Chehalis River channel as the centerline while the Black River was treated as a floodplain channel. This was done because both channels occupy the same floodplain and because flood discharge from the Chehalis River greatly exceeds that of the Black River.

Manning's n roughness values were estimated from LandSat land cover maps in GeoRAS and field observations collected during the field reconnaissance. The roughness values were imported into HEC-RAS for each cross section. Lastly, the hydrology was entered into the model including the calculated 100-year flood as well as peak flows corresponding to 1972, 1996 and 2007 floods used for calibration. Where the LiDAR water surfaces are uneven at the merger point between the two LiDAR sets, the volume of water in the model was adjusted over the span of the nearest two cross sections so the numerical water discharge volume in HEC-RAS matched the actual discharge volume derived from gauge data respective to each LiDAR flight date. A flow change location was not built into the model at the confluence of the Black River; rather the flow volume from the Black River was incorporated at the upstream end of the model as a result of flood waters passing back and forth between the Black and Chehalis Rivers far upstream of their confluence during low recurrence interval floods. The discharge values observed during the LiDAR flights was broken into three main areas; downstream of the Reservation, the Reservation itself, and upstream of the Reservation. The values for the Chehalis and Black as well as the total discharge between the two for these three distinctive areas are summarized in Table C-2.

**Table C-2. Discharge Observed in the Chehalis and Black Rivers during LIDAR Flights**

| | DISCHARGE (CFS) DURING LIDAR FLIGHT | | |
|---|---|---|---|
| | CHEHALIS RIVER | BLACK RIVER | TOTAL |
| Downstream of the Reservation | 2,940 | 398 | 3,338 |
| Through the Reservation | 2,390 | 493 | 2,883 |
| Upstream of the Reservation | 5,320 | 2,079 | 7,399 |

This modeling approach required a sensitive calibration made possible by a series of flood water elevations recorded during December 2007 flood and aerial photographs from the 1971 and

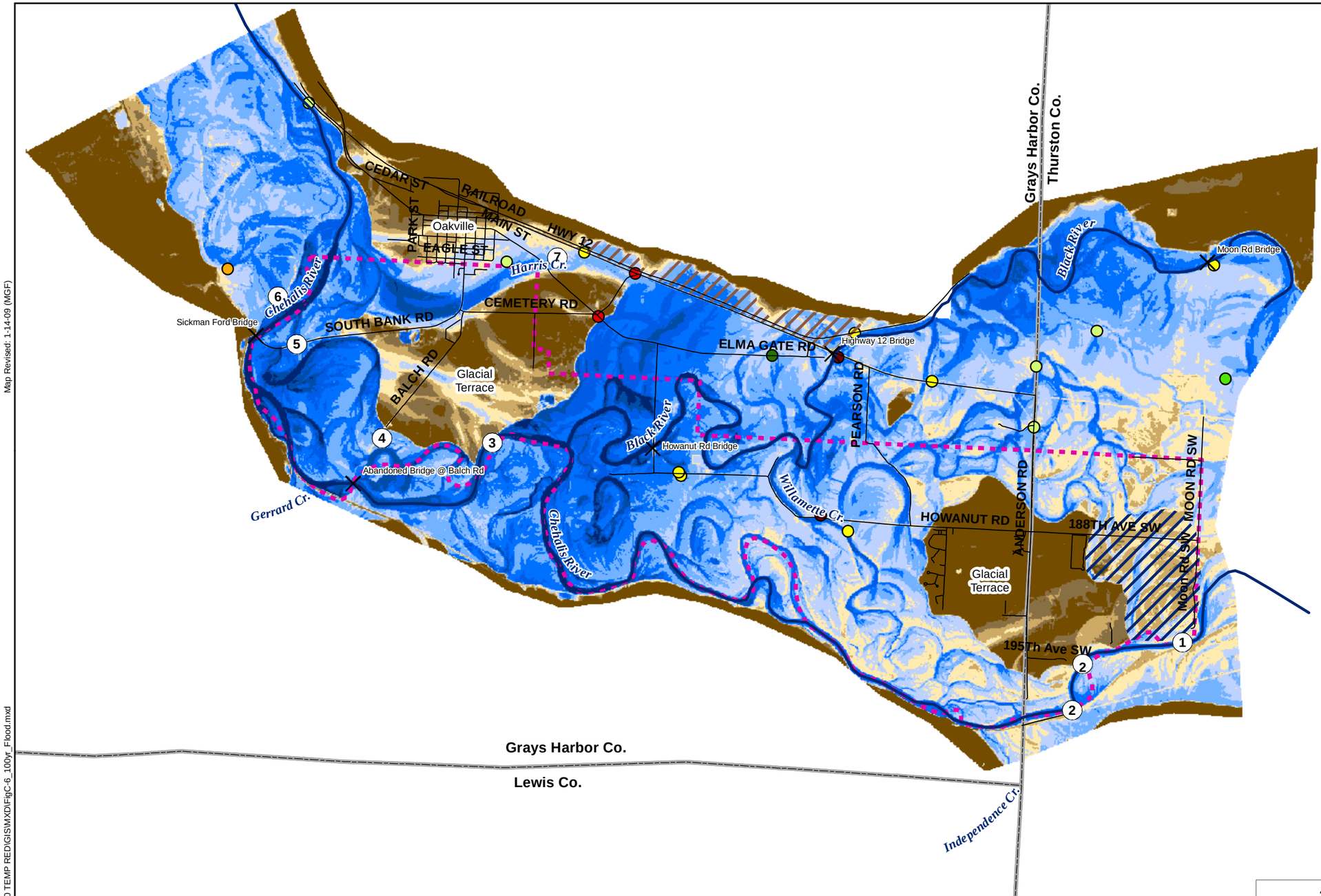
1996 floods. The same volume of water recorded during the 2007 flood was entered into the HEC-RAS model, and then the geometry of the model, including ineffective flow areas and Manning's n variation, was iteratively adjusted until the modeled water surface elevations closely matched the actual surveyed water elevations. This process was repeated for several calibration points marking flood water extents on aerial photos from a 1972 flood and a 1996 flood. See Figure C-6 for the elevation differences between survey data and model results at the calibration points.

Because the model calibration was performed using flood indicators and aerial photos from low-recurrence interval floods only, the HEC-RAS hydraulic model is best suited for modeling only low recurrence interval floods (100-year and 50-year floods) where large volumes of water occupy the Chehalis and Black Rivers' mutual floodplain. The model is not well suited for predicting conditions during high recurrence interval floods (1-year and 2-year floods) where the majority of flow occurs below the LiDAR water surfaces and is therefore outside of the modeling parameters. Also, because HEC-RAS is a one-dimensional model, it does not predict variations in flood surfaces or other hydraulic conditions laterally across the floodplain. Based on these limitations and measured differences between the model output and observed flood heights from December, 2007, the accuracy of the 100-year flood surface is estimated to be within plus or minus 2 feet. An exception to this is the area in the vicinity of 180$^{th}$ Ave and Moon Road where water is known to "bulge" in a manner that is not laterally uniform, and therefore beyond the modeling capability of HEC-RAS. The 100-year flood elevations predicted by the HEC-RAS model in this area are estimated to be roughly one to four feet below the actual 100-year flood elevations.

Map Revised: 1-14-09 (MGF)

Path: P:\18877301400 TEMP RED\GIS\MXD\FigC-6_100yr_Flood.mxd

BOI




**Explanation**

- 1 Hazard Areas
- Bridges
- Observed Emergent
- Observed Submerged

**Difference between Survey and Model (ft)**

**Value = Survey elev. minus Model elev.**

- -2.000 - -1.000
- -0.999 - -0.500
- -0.499 - 0.000
- 0.001 - 0.490
- 0.491 - 0.920
- 0.921 - 2.000
- 2.001 - 3.000
- Reservation Boundary

**100-yr Relative Surface Model (ft)**

Submerged Land (Feet below flood surface)

- 20-15
- 15-12
- 12-9
- 9-6
- 6-3
- 3-0

Emergent Land (Feet above flood surface)

- 0-3
- 3-6
- 6-9
- 9-100

N W E S

2,000 0 2,000

Feet

Reference: Tribal boundary and County boundary provided by the Federal Census Bureau;
Roads obtained from the Confederated Tribes of the Chehalis Reservation and the Federal Census Bureau.

Notes:

1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

**Limitations:**

**This recurrence interval flood surface map has been developed using a relative surface model as described in Appendix B of the Comprehensive Flood Hazard Management Plan. This map has not been produced based on FEMA modeling criteria. Flood surface has an estimated vertical error of +/- 2ft. The model predicted the in area shown covered by blue hatching to be emergent but the area was observed to be flooded in December 2007. The model predicted in the area shown covered by brown hatching to be flooded but the area was observed to be dry in December 2007.**

# 100-year Recurrence Interval Flood Surface

Chehalis Tribe CFHMP

GeoEngineers

**Figure C-6**

# *APPENDIX D*
## *INTERLOCAL AGREEMENT BETWEEN THE CHEHALIS TRIBE AND GRAYS HARBOR COUNTY*

# APPENDIX D
# INTERLOCAL AGREEMENT BETWEEN THE CHEHALIS TRIBE AND GRAYS HARBOR COUNTY

INTERLOCAL AGREEMENT
BETWEEN
CONFEDERATED TRIBES OF THE CHEHALIS RESERVATION
AND
GRAYS HARBOR COUNTY

This agreement is entered into by and between the Confederated Tribes of the Chehalis Reservation (hereinafter "Tribe") and Grays Harbor County, Washington (hereinafter "County") pursuant to the provisions of the Interlocal Cooperation Act, Chapter 39.34 of the Revised Code of Washington, this 11 day of June, 2008.

WHEREAS, the exterior boundaries of the Chehalis Reservation border and are immediately adjacent to properties within the County; and

WHEREAS, included within the exterior boundaries of the Chehalis Reservation are fee lands and fee lands owned by non-Indians; and

WHEREAS, the Tribe and the County are committed to equitable, consistent and predictable land use planning and development permitting authority within the exterior boundaries of the Chehalis Reservation with respect to both Indians and non-Indians and fee land and trust land; and

WHEREAS, the Tribe possesses exclusive land use regulatory authority over individual Indian trust lands, tribal lands and Indian-owned fee lands within the Chehalis Reservation; and

WHEREAS, the Tribe and the County each claim land use regulatory authority over non-Indian owned fee lands within the Chehalis Reservation; and

WHEREAS, the Tribe and County have a long history of government to government relations and cooperation, including, but not limited to land use planning and development permitting; and



RES 2008-79

WHEREAS, the Tribe and the County recognize the benefit to all property owners on the Chehalis Reservation for a close working relationship between each government for land use planning, and development permitting purposes; and

WHEREAS, it is in the best interests of both the County and the Tribe to enter in to this Interlocal Agreement and to jointly designate responsibility for land use planning and development permitting of certain fee lands pursuant to this Agreement.

NOW THEREFORE, for and in consideration of the mutual promises contained herein, the parties hereto hereby agree:

1. The Tribe maintains the following ordinances (hereafter collectively referred to as "the Ordinances") which govern land use planning and development permitting processes and provide due process to all residents and land-owners of the Chehalis Reservation:

   a). Comprehensive Plan;

   b) Permitting Ordinance;

   c) International Building Code;

   d) Construction Safety Ordinance;

   e) Surface Water Management Ordinance;

   f) Water Quality standards;

   g) Zoning Ordinance;

   h) National Electric Code; and

   i) Flood Plain Protection Ordinance.

2. The Tribe has provided copies of the Ordinances to the County and, at such time as the Tribe amends any of the Ordinances, the Tribe shall provide such amendments to the County within 30 days of passage.
3. The County agrees that the Ordinances provide a comprehensive land use planning and development permitting program for lands within the Chehalis Reservation and provides due process protection to all landowners within the Chehalis Reservation.
4. The parties agree that with respect to all lands, including fee lands situated within the exterior boundaries of the Chehalis Reservation, the Tribe shall serve as the lead entity for all land use planning and development permitting related actions and the Tribe shall apply and enforce the Ordinances and all permitting standards established therein on all lands within the Chehalis Reservation.
5. The County recognizes the Tribe's administrative authority for land use planning and development permitting on the Chehalis Reservation and will direct all persons seeking or applying to the County for land use planning or development permits for lands within the exterior boundaries of the Chehalis Reservation to the Tribe to perform the permitting services and requirements as described in this Agreement.
6. The Tribe shall give written notice to the County when it issues a land use planning or development permit for fee land within the Chehalis Reservation that is concurrently situated within the exterior boundaries of Grays Harbor County. Such notice shall occur within 10 days of the issuance of the Tribe's permit.

7. The Tribe shall give written notice to the County when and if it issues a Notice of Violation for fee land within those portions of the Chehalis Reservation associated with the County's interests. Such notice shall occur within 10 days of the issuance of the Tribe's Notice.

8. Any notices to be given under this Agreement shall be personally served on or shall be mailed, postage prepaid, to:

   For the Tribe:

   Chairman
   Chehalis Confederated Tribes
   Business Council
   PO Box 536
   Oakville, Washington 98568

   For Grays Harbor County:

   Chair, Board of County Commissioners
   Grays Harbor County
   100 West Broadway Avenue, Suite 1
   Montesano, Washington 98563-3614

9. This Agreement shall remain in full force and effect unless and until one of the following shall occur:

   a) the parties mutually agree in writing to terminate this Agreement on a date certain; or

   b) either party gives written notice of termination to the other party at least 30 days prior to the effective date of termination.

10. Neither party hereto, by executing this Agreement, waives any claims or rights that it has or may have with respect to issuing land use planning or development permits should this Agreement be terminated for any reason.

11. Nothing herein shall be or be deemed to be a waiver by the Confederated Tribes of the Chehalis Reservation of its sovereign immunity with respect to this Agreement and any rights and obligations under the Agreement.

12. The Tribe does not intend by this Agreement, or by any amendments or attachments to this Agreement, to assume any contractual obligations to anyone other than the County. The County does not intend by this Agreement, or by any amendments or attachments to this Agreement, to assume any contractual obligations to anyone other than the Tribe. There are no third party beneficiaries to this Agreement, and this Agreement shall not be interpreted to create such rights.

13. If any provision of this Agreement is held invalid by a court of competent jurisdiction, either party may, at its option, terminate this Agreement as provided in Paragraph 9 above.

14. This Agreement represents the entire agreement of the parties hereto and shall not be modified except in writing signed by the parties hereto. This Agreement shall become effective and binding upon the parties upon adoption by each of the parties hereto.

In witness whereof, the parties have hereunto set their hands and seals on the date first above written.

Confederated Tribes of the Chehalis Reservation

By: _____

Grays Harbor County

By: Bob Beerbower
~~Albert A. Carter, Chair~~ Bob Beerbower, Pro-tem
Grays Harbor County Board of Commissioners

Attest:

Donna Caton
Donna Caton
Clerk of the Board
Dated:

Approved as to Form:

James D. Beh Deputy
Grays Harbor County Prosecuting Attorney

# *APPENDIX E*
## *PROJECT APPROACH AND QUALITY ASSURANCE PLAN (QUAP) MEMORANDUM*

GeoEngineers

**MEMORANDUM**

8410 154TH AVENUE NE, REDMOND, WA 98052, TELEPHONE: (425) 861-6000, FAX: (425) 861-6050 www.geoengineers.com

**TO**: Lennea Magnus; Confederated Tribes of the Chehalis Reservation

**FROM**: Mary Ann Reinhart

**DATE:** July 8, 2008

**FILE**: 8773-014-00

**SUBJECT**: Project Approach and Quality Assurance Plan

## METHODS AND QUALITY ASSURANCE

The Chehalis Reservation Comprehensive Flood Hazard Management Plan will utilize the results of several types of quantitative and qualitative analyses to identify the extent of floodplain inundation for the 100-year recurrence interval storm, as well as flood related hazards associated with the 100-year storm. The plan will be based in large part on a flood inundation map estimated for the 100-year recurrence interval storm, identification of channel migration "hot spot", and our understanding of public health and safety risks facing Tribal Members, all of which will help identify flood related hazard areas on the Reservation. It is understood that the confederated tribes of the Chehalis Reservations wish to use this plan to support their existing floodplain management regulations. We understand that the Tribe has little to no interest in recommendations focused on constraining the Chehalis River or preventing flood water from passing over tribal lands.

The approach, methods and quality assurance plan developed for this study are outlined below, along with the general approach designed to meet the needs of the Chehalis Tribe and the requirements of the Department of Ecology.

### GENERAL APPROACH

The information necessary for developing the Comprehensive Flood Hazard Management Plan will include the following elements:

- Historic flood damage information,
- Changes in flooding and flood related damages,
- Flood inundation maps for 100 year recurrence interval storms for both the Chehalis and Black Rivers,
- High risk channel migration areas

Information pertinent to the project will be acquired from numerous sources, and treated and/or analyzed using a variety of methods. Where ever practicable, valid data from previous studies will be used to obtain the required input data for the analyses described below. Following is a description of the data and methods that will be used to develop the CFHMP.

### GIS DATA DEVELOPMENT

The spatial data collected for this project was organized in a GIS database. A GIS data base provides a seamless, efficient means by which multiple data sets of various spatial and time scales can be evaluated and compared on a single platform. GIS also provided the tools for extending existing HEC-RAS cross sections across the floodplain.

Six major types of GIS data will be developed; 1) georeferenced digital aerial photographs, 2) stream centerline stationing, 3) a relative surface topographic model, 4) digitized features from modern and historical data sets, and 5) delineation of 100-year flood limits within the Chehalis Reservation project area, 6) channel migration hot spots.

GIS data development and analysis will utilize ESRI's ArcGIS versions 9.1 and 9.2 software. GIS data layers obtained from several different data sources including the Chehalis Tribe, US Geological Survey (USGS), Federal Emergency Management Agency (FEMA) and the Washington Department of Natural Resources (WDNR).

### HISTORIC FLOOD DAMAGE INFORMATION

Flood damage information will be collected from several sources, including Flood Damage Information documented by the Tribe, FEMA flood claims, Local Newspaper articles, Communication with Tribal members and property owners, Review of historic and recent aerial photographs, Review of oblique air photos provided by the Chehalis Tribes and WSDOT.

### CHANGES IN FLOODING AND FLOOD RELATED DAMAGES

This information will be collected from review of historic aerial photographs, river gauge data and personal communication with long term reservation residents, first responders and law enforcement officers. We will also review topographic survey acquired by the Chehalis Tribe and peak flood level field data collected by GeoEngineers staff following the December 2007 storms.

### FLOOD INUNDATION MAPS FOR 100 YEAR STORM

Types of data useful to this project element include:

- Historic and recent aerial photographs and orthophotographs, topographic maps, soil and geologic maps.
- Existing electronic GIS data,
- 2008 LiDAR, flown by Watershed Services for the Tribe
- 2005 LiDAR from the Regional LiDAR consortium
- Existing Flood Insurance Studies and associated HEC-RAS models,
- Recent and historic river gauge data.
- 2007 flood flow elevations obtained from ground survey.

This information will provide a framework for evaluating flood hazards associated with existing channel and floodplain conditions.

Data will be collected from the following sources:

- Confederated Tribes of the Chehalis Reservation,
- Washington Department of Natural Resources (WDNR),
- US Geological Survey,
- Army Corps of Engineers,
- Federal Emergency Management Agency (FEMA),

- Grays Harbor, Thurston and Lewis Counties,
- GeoEngineers' files.

A principal component of the GIS data base is the 2008 LiDAR, which was acquired by the Chehalis Tribes. The LiDAR will be post- processed for use in developing the flood map. The methods and use of LiDAR are discussed in more detail below.

### AERIAL PHOTOGRAPHIC AND MAP ANALYSIS

Aerial photographic and map analysis focused on evaluating flood water pathways, floodplain conditions, and floodplain areas subject to aggressive channel migration.

#### *Aerial Photo Georectification*:

Aerial photographs derived from contact prints or digital scans of prints were georeferenced to a known coordinate system then rectified. Georeferencing is the GIS process by which a digital image is matched to a digital orthophotograph in some projected coordinate system, in this case, Washington State Plane, South NAD 1983 (feet). The process assigns a geographical coordinate to each pixel in the image, fixing the image, pixel-by-pixel, into the chosen coordinate system.

The aerial photographs will be scanned and georeferenced to 2008 LiDAR coordinates and then rectified. Due to inherent distortions when georeferencing older photographs to current orthophotographs, our target Route Mean Square (RMS) error of all the control points was equal to or less than 14 feet.

### DEMS, CONTOURING AND HILLSHADING FROM LIDAR:

LiDAR imagery for the project area was downloaded from the Puget Sound LiDAR Consortium (PSLC) bare earth DEMs (6 x 6 grids). The following quarter quads encompass the entire project area: q46123g21b; q46123g22b; q46123g23b; q46123g24b; q46123g33b.

The PSLC data was combined to form one 6 x 6 grid, which was then converted to a 3 x 3 grid and merged with the Chehalis Tribe's LiDAR (3 x 3 grid). The resulting LiDAR provides coverage including the Black River area, north of the Reservation boundary. Merging was completed using the Focal Statistics tool in Spatial Analyst.

The LiDAR image provides only ground surface elevations (i.e. elevation points below water (bathymetry) are not delivered ). Channel geometries were created in GIS from the same cross sections used in the HEC-RAS model. These bathymetric surfaces were then merged with LiDAR topographic surfaces to generate a continuous ground surface DEM throughout the project area.

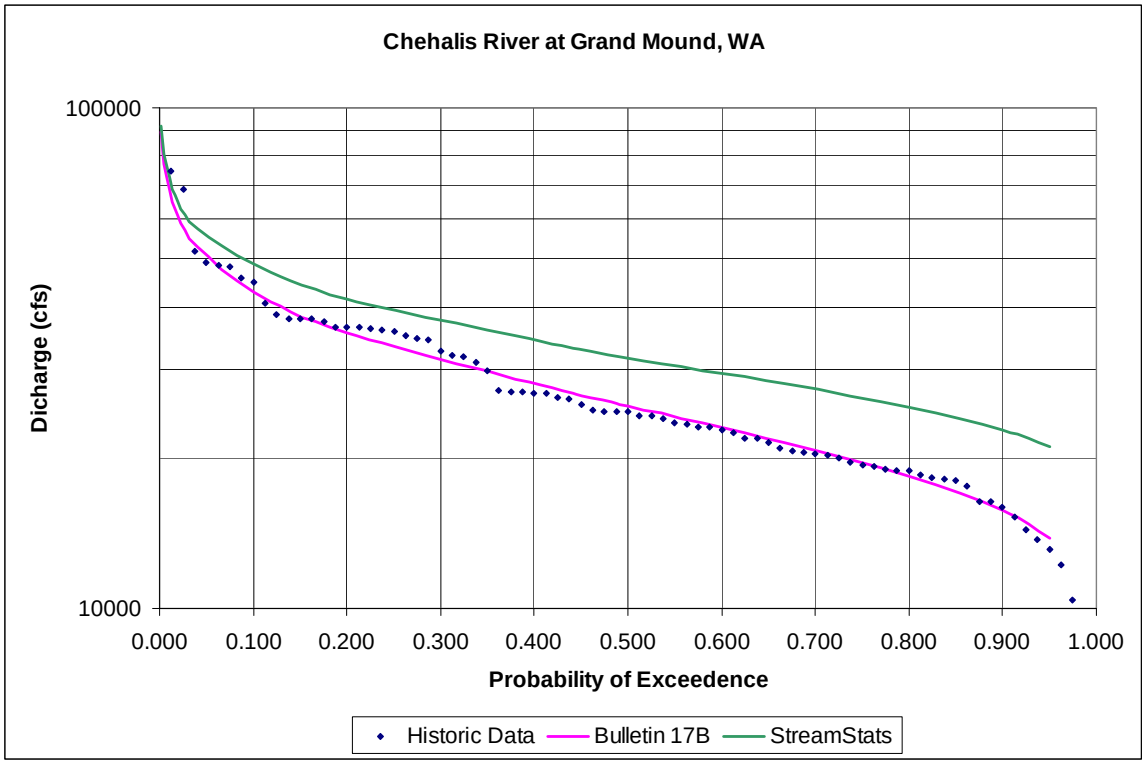
### HYDROLOGY

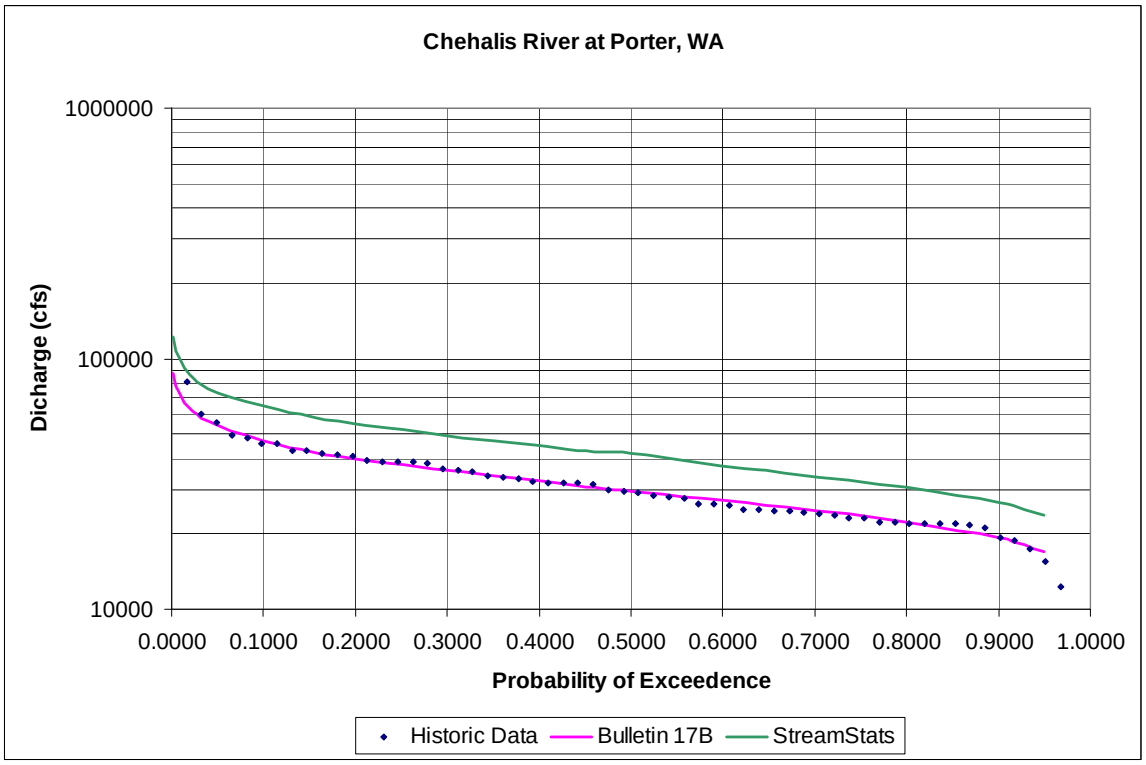
The Chehalis Indian Reservation is located adjacent to the Chehalis River as well as the Black River. Both of these rivers are being analyzed in the Comprehensive Flood Management Plan. To determine the risks associated with each river the flood discharges need to be obtained.

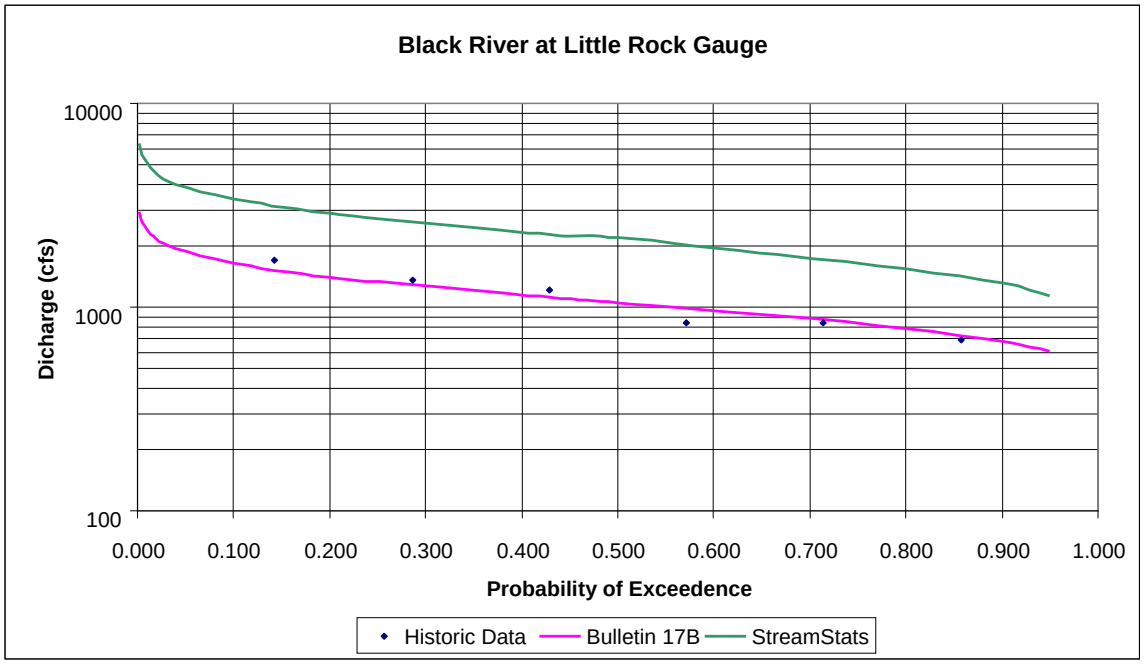
The Reservation is located between two stream gauges maintained by the U.S. Geological Survey (USGS). The upstream gauge (USGS Gauge #12027500) is located near Grand Mound, Washington, located upstream of the Reservation. Downstream the gauge (USGS Gauge #12031000) is located downstream of the Reservation, near the city of Porter, Washington. The gauge at Grand Mound, WA has historical records of 79 years from the water year of 1929 up to the current day. Historic data has been maintained from the water year of 1952 up to the current day for the stream gauge located in Porter, WA. There is also a historic gauge located upstream of the Reservation near Little Rock, Washington on the Black River. This historic gauge was only maintained for a six year period from 1945-1950.

Annual peak discharges were obtained from the USGS for the period of record for each stream gauge. The peak data for each gauge was input into the USGS computer program PeakFQWin, which utilizes methodology from USGS Bulletin 17B to determine a Log-Pearson Type III distribution to best fit the data. An error message was generated during the PeakFQWin model run of the historic gauge data for the Black River gauge at Little Rock, WA. This gauge's LP3 distribution was calculated manually utilizing the methodology of Bulletin 17B.

The USGS computer program StreamStats was also utilized to compare and validate the LP3 results for each gauge. StreamStats tended to overestimate the flood discharges when compared to the historic stream gauge data. These two regressions and the historic peak flow data can be seen in Figures 1, 2 and 3.




Chehalis River at Porter, WA
1000000
100000
10000
Dicharge (cfs)
0.0000
0.1000
0.2000
0.3000
0.4000
0.5000
0.6000
0.7000
0.8000
0.9000
1.0000
Probability of Exceedence
Historic Data
Bulletin 17B
StreamStats


Black River at Little Rock Gauge
10000
1000
100
Dicharge (cfs)
0.000
0.100
0.200
0.300
0.400
0.500
0.600
0.700
0.800
0.900
1.000
Probability of Exceedence
Historic Data
Bulletin 17B
StreamStats

The Grand Mound, WA and Porter, WA stream gauge data and LP3 distributions were used to determine the flood frequency discharge values on the Chehalis River at the downstream end of the project study area. A simple linear regression between the two gauges based on watershed area was used to estimate the flood discharge values at the downstream end of the project site. As predicted these discharges were below the flood flows estimated by StreamStats.

Four different methods were used to estimate the flood discharges for the Black River at the confluence with the Chehalis River. These four methods consisted of StreamStats, an area ratio of the Black's historic peak flow data, an area ratio of the Chehalis' historic peak flow data, and then an LP3 distribution based on historic flow data for the Chehalis.

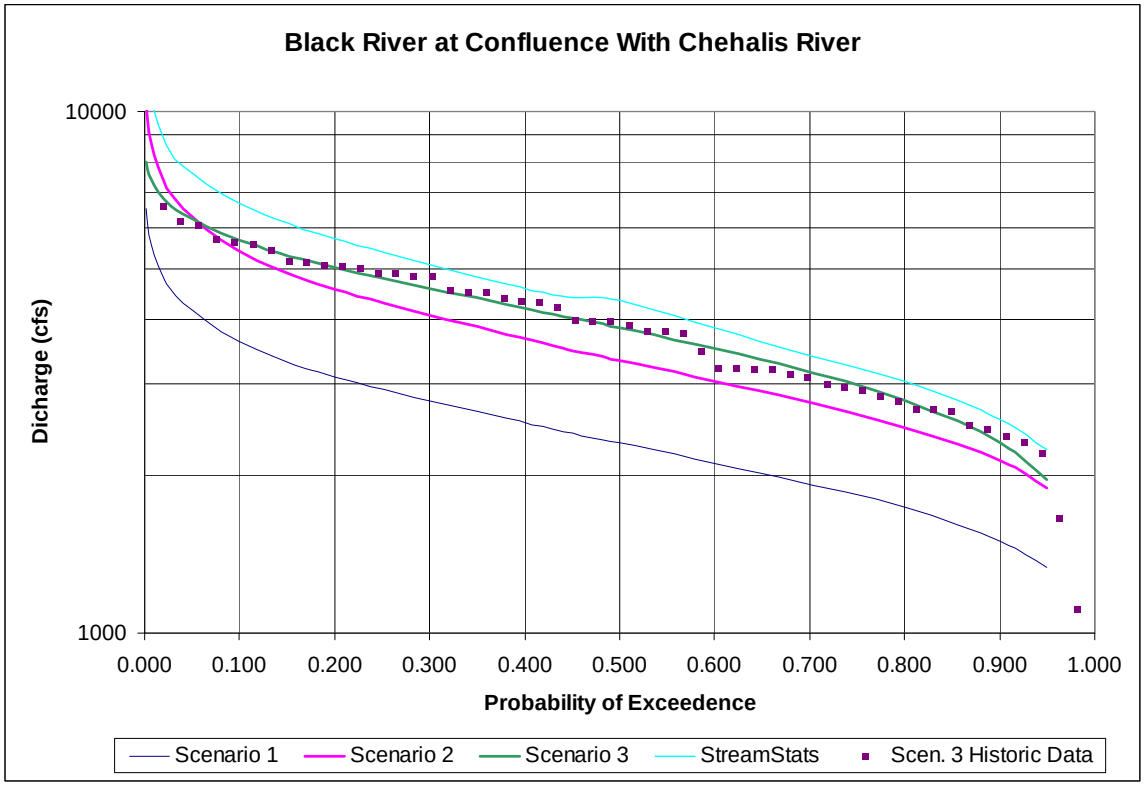
StreamStats was used to estimate the flood flows on the Black River at its mouth. These estimates were assumed to be an upper bound on the discharges since StreamStats tended to over estimate discharges at the three gauge locations analyzed when compared to their respective historic LP3 distributions.

An area ratio between the Little Rock, WA gauge and the mouth of the Black for the LP3 historic distribution was also used to estimate the flood discharges. This method took the estimated LP3 distribution from the Little Rock gauge and multiplied by 2.20 which is the area of the Black River at its mouth (138.4 $mi^2$) divided by the area of the Black's watershed at the Little Rock gauge (62.8 $mi^2$). It was assumed that this might under predict the flood flows due to the short historic record at the Little Rock gauge.

The third method consisted of using an area ratio between the Black River watershed and the watershed at the downstream end of the project area and applied it to the estimated LP3 distribution for the Chehalis River at the project study boundary. This method reduced the estimated flood flows on the Chehalis at the project's downstream end by a factor of 0.12 which is the Black's watershed area (138.4 $mi^2$) divided by the watershed area at the downstream end of the project (1173.6 $mi^2$). From historic flooding observations and monitoring it is known that the Chehalis River and Black River do not peak at the same times. These watersheds are also not hydraulically similar due to large variations in the size of the watersheds, elevations and land use types. These factors reduce the confidence of this third method in estimating flood discharges.

A more complex method was adopted to determine estimated flood discharges for the Black River at the confluence with the Chehalis River. This method employed the longer historic records for the two stream gauges on the Chehalis River. A relationship was developed for each stream gauge between the historic peak flow and its respective daily average flow. This linear relationship provides the ability to estimate the instantaneous peak flow for any given day of the historic record. The instantaneous peak flow from the downstream gauge (USGS Gauge #12031000) was then subtracted from the instantaneous peak flow from the upstream gauge (USGS Gauge #12027500) for every single day that the gauge data overlaps (1952-2008). This difference in peak flows estimates the instantaneous peak flow from the watershed area between the two gauges which includes the Black River's watershed. A ratio factor was then applied to the peak difference to reduce it to the peak flow for only the Black River's watershed. This ratio factor was 0.346, which is the Black River's watershed area (138.4 $mi^2$) divided by the difference in watershed areas between the two gauges (1297.8 $mi^2$ – 898.3 $mi^2$). From daily peak flow data the annual maximum peak flow was selected for each year of record. These annual peak flows were compiled and the methodology described within USGS Bulletin 17B and used for the other historic gauge regressions was implemented to determine an LP3

distribution for the flood frequency flows for the Black River at the confluence with the Chehalis River. The results from this methodology and the other three methods can be seen in Figure 4 below.




## HYDRAULICS MODELING

A LiDAR-based hydraulic modeling approach is being utilized to estimate 100-year flood elevations for the Chehalis and Black River reaches. This approach includes building a HEC-RAS model using the LIDAR surface and determine the volume of water not captured by the LIDAR and subtracting it from the discharge volumes derived from the Hydrology element.

Water volumes for the Chehalis will be determined from gage data recorded on the date the LiDAR was flown. Gage data is not readily available for the Black River therefore; water volume will be estimated from LiDAR and field measurements. The approach will involve determining Black River water surface elevations from the LiDAR, and measuring discharge and water surface elevations in the field. A Manning's approach will then be used to calculate the discharge necessary to attain the elevation documented from the LiDAR surface. Manning's "n"values for will be derived from LandSat land cover data.

### *Calibration*

For the Chehalis River, we will use flow data from both the 2007 and 1996 floods. We will subtract the flows estimated from the above described process and run the discharge through the reach. We will primarily use Manning's "n" values to calibrate the calculated elevations until they match the high flow elevations measured in the field by GeoEngineers in December, 2007, and possibly elevations from the 1996 event, depending on data quality.

To determine the volume of water in the Black during the calibration events (1996 and 2007), we will use the method above.

### *Application of Calibrated Model to Other Flow Scenarios*

If a calibrated model is achieved, we can then apply a wider set of flow data to the models. To do this, we will need to somehow calculate the flow below the LiDAR surface for the Black. Because, for this step we will use a 100-year flood volume determined for the Chehalis by gage data and for the Black possibly by regression analysis.

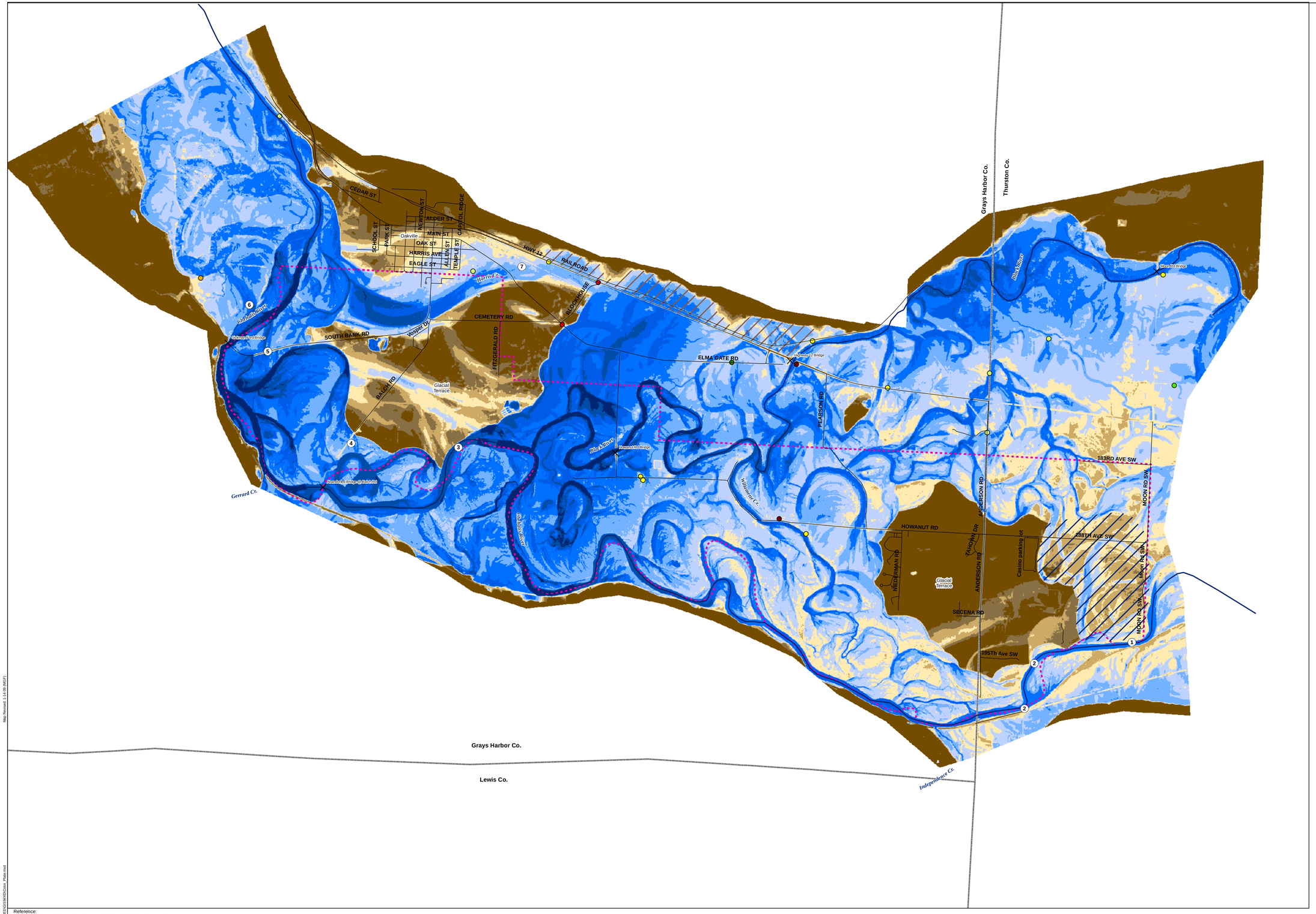
## LiDAR-BASED RELATIVE SURFACE MODEL

The 100-year flood inundation map will be developed from a Relative Surface Model (RSM) for the Chehalis and Black River floodplain. A RSM displays flood surface and/or topographic surfaces relative to a modeled surface.

The RSM method will depict flood surface elevations derived from HEC-RAS results for a 100-year storm event. For this method, the 100-year water surface is exported from HEC-RAS for each cross section in the HEC-RAS model. HEC-GeoRAS then builds a surface in GIS that corresponds to the water surface at each cross section. The elevation of the surface between the cross sections is interpolated by HEC-GeoRAS. The resulting water surface elevations are then subtracted from the topographic elevations (similar to the previous method) resulting in a new surface elevations illustrate the inundated areas corresponding to the specified flood surface generated by HEC-RAS.

## HIGH RISK CHANNEL MIGRATION AREAS

Channel migration "hot spots" will be identified based on review and evaluation of a limited set of historic aerial photographs, recent orthophotographs and LiDAR, field observations and personal communication with Tribal Member and long term residents of the Reservation. The hot spots will be recorded as a shape file in the GIS database.




**Explanation**

- Hazard Areas
- Bridges
- Observed Emergent
- Observed Submerged
- Reservation Boundary

**Difference between Survey and Model (ft)**

**Value = Survey elev. minus Model elev.**

- -2.000 - -1.000
- -0.999 - -0.500
- -0.499 - 0.000
- 0.001 - 0.490
- 0.491 - 0.920
- 0.921 - 2.000
- 2.001 - 3.000

**100-yr Relative Surface Model (ft)**

Submerged Land (Feet below flood surface)
- 20-15
- 15-12
- 12-9
- 9-6
- 6-3
- 3-0

Emergent Land (Feet above flood surface)
- 0-3
- 3-6
- 6-9
- 9-100

N W E S

2,000 0 2,000
Feet

Reference:
Tribal boundary and County boundary provided by the Federal Census Bureau;
Roads obtained from the Confederated Tribes of the Chehalis Reservation and the Federal Census Bureau.

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
3. Flood surface has an estimated vertical error of +/- 2ft (within red hatching error is roughly +/- 4ft).

**Limitations:**

**This recurrence interval flood surface map has been developed using a relative surface model as described in Appendix B of the Comprehensive Flood Hazard Management Plan. This map has not been produced based on FEMA modeling criteria. Flood surface has an estimated vertical error of +/- 2ft. The model predicted in the area shown covered by blue hatching to be emergent but the area was observed to be flooded in December 2007. The model predicted in the area shown covered by brown hatching to be flooded but the area was observed to be dry in December 2007.**

**100-year Recurrence Interval Flood Surface**

Chehalis Tribe CFHMP

GeoEngineers | **Color Plate**

Map Revised: 1-14-09 (MSF)

Path: P:\#417730\400 TEMP REDIG\GIS\MXD\Color_Plate.mxd

BOI