REPORT
GEOMORPHIC EVALUATION AND CHANNEL MIGRATION ZONE ANALYSIS ADDENDUM
COWLITZ RIVER, NEAR PACKWOOD AND RANDLE, LEWIS COUNTY, WASHINGTON

JULY 20, 2009

FOR
LEWIS COUNTY PUBLIC WORKS DEPARTMENT

GEOENGINEERS

File No 3118-066-03

Report
Geomorphic Evaluation and Channel Migration Zone Analysis Addendum
Cowlitz River, near Packwood and Randle, Washington
File No. 3118-066-03

July 20, 2009

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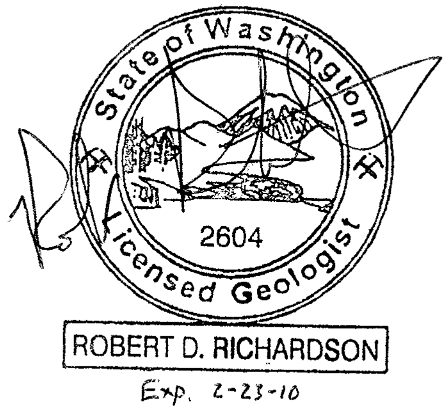

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INTRODUCTION

This report presents the final results of GeoEngineers' re-delineation of the Channel Migration Zone (CMZ) map for the Upper Cowlitz River, dated June 12, 2003. The re-evaluation was requested by Lewis County Public Works Department following a major storm in November 2006 that caused severe flooding and altered channel conditions.

The re-evaluation was conducted in two phases; Phase I, completed in 2007 (Appendix A), included identification of channel areas posing a significant migration hazard to shoreline properties as preliminary evaluation of 2003 CMZ boundary sections that would need modification; Phase II, presented in this report, includes detailed quantitative analyses resulting in a re-delineation of the 2003 CMZ study.

Phase I and Phase II studies were prepared as addendums to the original report prepared by GeoEngineers, entitled "Geomorphic Evaluation and Channel Migration Zone (CMZ) Analysis, Lewis County Washington" for the Upper Cowlitz River dated June 12, 2003. Both Phase I and Phase II studies utilize much of the geomorphic information provided in the 2003 report and covered the same area. However, **CMZ maps presented with this Phase II document revise and replace all portions of the 2003 CMZ maps** extending from Scanewa Lake (southwest of Randle, Washington) upstream to a location immediately north of the former confluence of the Clear and Muddy Forks of the Cowlitz River (Figure 1). This report does not address changes to the Rainey Creek CMZ, which was included in the original 2003 CMZ analysis. The entire modified CMZ and MPA are shown in Plate 1.

PROJECT BACKGROUND

Since GeoEngineers' original CMZ evaluation in 2003, the Upper Cowlitz has been subject to major flooding events as recorded by the USGS stream gauge at Packwood (Gauge Number 14226500) including: 20,700 cfs on January 31, 2003, 16,700 cfs on January 18, 2005, and 42,100 cfs on November 6, 2006.

Prior to the November 2006 event, the Muddy Fork of the Cowlitz River exited a deeply incised canyon and followed a southeast trend toward the mouth of the Clear Fork of the Cowlitz River, where the two channels joined to form the main stem Cowlitz River (shown on Figure 2). During the November 2006 storm, the Muddy Fork River completely abandoned a portion of its former channel and cut a new path across a forested alluvial fan. The relocation of the Muddy Fork channel (avulsion) shifted the confluence with the Clear Fork roughly 5,000 feet downstream from its former location.

The Muddy Fork avulsion caused changes in the physical condition of the main stem Cowlitz River channel downstream of the new Muddy/Clear Fork Channel confluence. Trees and ground cover uprooted during the avulsion were distributed across the Cowlitz channel downstream of the new confluence. Significant bank erosion, coupled with bank recession occurred along both river banks as far downstream as Lake Scanewa. Large volumes of sediment were mobilized from the upper drainage and deposited throughout the project reach affecting channel form and process. And several homes and other infrastructure were damaged as a result of channel adjustment to the avulsion. A complete description of channel and shoreline conditions caused by the November 2006 storm is provided in Appendix A.

A field reconnaissance and geomorphic evaluation following the November 2006 flood indicated that the most significant channel changes occurred throughout and around the alluvial fan at the confluence of the Muddy Fork and Clear Fork, along the shorelines of the Timberline and High Valley communities, in the vicinity of River Ranch Road and upstream of Scanewa Lake (See Appendix A).

PROJECT APPROACH

The approach and methods used to delineate 2003 CMZ boundaries was based on migration rates and other data collected from the existing conditions and historic aerial photographs (1948 to 1999). The basis of migration rate estimates was based on discharge driven bank erosion. Along most river sections the resulting 2003 CMZ and MPA delineation held well, and did a good job of predicting where migration would occur. The calculated distance of migration (the width of the zone) fell short in just a few places, most notably in the Muddy Fork avulsion channel. Following preliminary field visits in January 2007 on the Upper Cowlitz, it became very clear that the Muddy Fork avulsion and significant bank recession were caused primarily by the influx of very large volumes of sediment from landslides and debris flows in the upper watershed. This condition was not recorded in aerial photographs and therefore was not accounted for in the 2003 calculations.

The primary goal of this project was to refine and revise the 2003 CMZ/MPA boundaries to account for the influx of large sediment loads and the response of the channel to such changes. To achieve that goal, GeoEngineers utilized new methods and data not previously available, a newly acquired understanding of various channel responses to sediment loading and developed a unique approach for estimating the magnitude of sediment driven migration and avulsion in braided river systems, Updates to the 2003 CMZ and MPA boundaries were completed by incorporating newly acquired data, improved methods, and the observed channel responses since 2003.

The first phase of the CMZ update was accomplished in 2007 by reviewing new aerial photos from 2003, 2006 and 2007 and by performing aerial and ground reconnaissance. The results of this preliminary work were compiled in GeoEngineers' report entitled "Upper Cowlitz River Preliminary Field Reconnaissance and Channel Migration Hazard Assessment" dated June 20, 2007 (Appendix A). Additional data including high-resolution light detection and ranging (LiDAR) topography flow in 2007 became available for use early in 2008. These new data and analyses were used to modify the original 2003 CMZ and MPA boundaries.

METHODS

New data and methods used in the re-evaluation of the 2003 CMZ are summarized below.

LIDAR AND RELATIVE SURFACE MODEL (RSM)

High-resolution LiDAR topography from 2007 was provided by Lewis County. A Relative Surface Model (RSM) was built from the LiDAR topography to depict the land surface near the river corridor relative to the water surface elevation at the time the LiDAR was flown. As modeled, all surface elevations in the floodplain higher than the water surface can easily be distinguished from surfaces below the modeled water surface elevation. The resulting map shows floodplain features, such as abandoned channels, flood-prone areas, and barriers to flow. These topographic features were later used to expand or contract the CMZ and MPA boundaries depending on the site-specific characteristics. RSM analysis was not available at the time of the 2003 CMZ analysis.

AERIAL PHOTOGRAPHS AND CHANNEL LINES

Aerial photographs and associated digitized channels from 1948, 1970, 1980, 1988 and 1999, were available from the 2003 report, and newly acquired photographs and digitized channels from 2003, 2006, and 2007 were used to update the CMZ and MPA for this report. Digitization of the 2003 and 2007 channel lines was preformed by Lewis County GIS Department. The 2006 channel digitization was completed by GeoEngineers. The method for digitizing lines is described in Appendix A of the 2003 CMZ report (GeoEngineers, 2003).

RECONNAISSANCE

Field work was conducted in 2007 and 2008. Preliminary field work was conducted after the November 2006 flood to document river conditions before the potential loss of time-sensitive information deemed necessary to the Phase II study. More extensive field work was conducted in June 2008 to further evaluate the response of the channel to the 2006 and 2007 storm events.

2007 Phase I Aerial and Ground Reconnaissance

On May 7th, 2007 a reconnaissance team consisting of two GeoEngineers' geologists and a Washington State Department of Ecology (DOE) hydrogeologist flew in a helicopter over the length of the Upper Cowlitz River from Scanewa Lake to the Mt. Rainier National Park boundary. The purpose of the flight was to observe the large-scale conditions and characteristics of the Upper Cowlitz River and to select sites for ground reconnaissance. Observations were documented and compared with aerial photos dated prior to the November 2006 storm. Bank recession was determined by flying (at low altitude) directly over outside channel bends with observable erosion. A tracklog from a Trimble XT GPS recorded the position of the helicopter every five seconds, which was then compared against previously digitized channel lines (Figure 3)

Following the aerial reconnaissance the GeoEngineers field team and a Lewis County representative performed ground reconnaissance on May 8 and 9, 2007. Field sites were selected based on the results of the aerial reconnaissance and the recommendations of the Lewis County staff person and his eyewitness accounts of the November 2006 flood event. Data and observations collected during ground reconnaissance included the composition and condition of the stream bed, banks, and floodplain, high-flow indicators, evidence of erosion and deposition, presence of LWD, channel geometry, levee/revetment conditions, and flood water flow direction (Appendix A).

2008 Phase II Ground Reconnaissance

Field sites were selected based on potential channel migration and potential channel avulsion (as observed in the GIS data base and during previous studies within the project area). The selected sites including those areas with high rates of measured migration, significant changes in channel form over time, accumulated LWD, and the presence of abandoned channels with potential for reactivation. Once the field sites were selected, each site was accessed from the ground (no aerial reconnaissance or in-channel reconnaissance). If bank recession was apparent, bank locations were documented using a Trimble GeoXT GPS. Geomorphic conditions were documented, including observed grain size distributions, bank condition, channel character and the presence of LWD.

GEOMORPHIC REACH DELINEATION

Eight geomorphic reaches were defined for the 2003 CMZ study based on channel form, process, and function. The new data and analyses from 2007 and 2008 resulted in the adjustment of one reach break and the addition two others resulting in ten total reaches, as described in Appendix B. In 2003 one reach encompassed the entire length of river from the upstream project boundary down to the Skate Creek Bridge in Packwood. For this re-evaluation, that reach was divided into three separate reaches to account for variable sediment loading potential, avulsion potential, bank soil composition, and LWD accumulation. Also, in 2003, a reach break was delineated approximately four miles downstream of the Highway 12 Bridge. This reach break has been moved downstream approximately 4.5 miles to include several meander bends exhibiting similar bank soils, erosion, and migration characteristics.

POTENTIAL AVULSION PATHWAYS

Five potential avulsion pathways were assessed based on the results of the RSM analysis, aerial photographs and LiDAR. Longitudinal profiles derived from LiDAR topography for the potential avulsion pathway and main stem channel centerline were created and analyzed in a GIS to evaluate avulsion potential. The length of the longitudinal profiles of each avulsion pathway was normalized to match the corresponding length of the main stem river. In this way, the influence of sinuosity was eliminated from the analysis, and a true comparison of longitudinal profile (gradient) could be made. If the longitudinal profile of the avulsion pathway was generally lower in elevation than that of the main-stem channel, and if the soil was generally erosive (i.e.: not bedrock), then there exists a potential for avulsion. Of the five potential avulsion pathways, two were identified as having sufficient gradient and bed composition to warrant being included as avulsion hazard areas (See Appendix C). One potential avulsion route is located at the confluence of the Muddy Fork and the Clear Fork (the site of the 2006 avulsion). In this area the Muddy Fork could potentially avulse anywhere between its former channel (abandoned in November 2006) and its current channel. The second potential avulsion pathway is on the left bank near Packwood at Teal Lake. At this location, a levee and revetment deflect surface flow from entering Teal Lake, but if a sufficient volume of water breaches or otherwise passes over the levee into Teal Lake, an avulsion through the lake is possible. The two new potential avulsion pathways have been incorporated into the 2008 CMZ and MPA maps.

CHANNEL MIGRATION

Channel migration was measured at representative locations in each geomorphic reach. From discrete migration measurements we calculated migration rates using one of two methods – long term average migration or short term episodic movement. The long-term average was determined by adding the total distance of migration measured between the earliest available aerial photo and the most recent available aerial photo. The migration distances were recorded per bend, per photo set, and per soil type (if different soil types occurred). Lateral, downstream, and upstream migration were noted throughout the study area. The total distance migrated was then divided by the number of years between the first and last photos to determine the average, long-term migration rate. This method is generally suitable for single-thread, meandering streams exhibiting typical meander bend migration or wherever systematic meander bend migration is observed (Rapp and Abbe, 2003) (Figure 4). The short-term, episodic movement was determined by measuring the maximum lateral movement in the channel between any two consecutive photo series separated by 5 years or less. In general, average, long-term rates were used for areas of uniform bend migration, while maximum, short-term rates were used for areas of episodic channel movement (i.e.: braided areas). In reaches where both types of channel migration were observed, the maximum migration rate (short-term or long-term) was used to determine the CMZ and MPA lines for that reach. Ultimately the CMZ and MPA lines were applied using representative long-term migration rates or short-term movements.

Along with channel migration, we also measured current and historic meander bend amplitudes and wavelengths to estimate the limits of lateral and downstream migration. Throughout the historic aerial photo record, we observed that migration rates generally decreased for any given bend over time, until a maximum meander amplitude was achieved. At the maximum meander amplitude, migration rates typically approach zero, and the meander bends are cut off leaving behind an inactive oxbow lake. This observation suggests that the use of long-term migration rates to calculate steady, lateral migration over a 100-year period would yield unreliable results and therefore is not applicable to this project. Additionally, areas with a relatively uniform meander wavelength were used to better predict where new bends may begin to form and propagate. These relationships and channel response mechanisms were applied to the final placement of both CMZ and MPA boundaries, particularly so in reaches with very high rates of measured migration and/or sediment loading.

CMZ and MPA Delineation

In the 2003 report, the CMZ boundary represented 50-years of steady lateral channel movement outside the historic channel occupation tract (HCOT) and the severe MPA represented 5-years, while the moderate (MPA) represented 10 years of channel movement outside of the severe MPA.

The 2003 CMZ and MPAs were re-delineated with the new data and new methods described above. The HCOT remains the baseline from which the CMZ and MPA boundaries are measured. However, the 2008 HCOT incorporates 3 additional photo records unavailable for the 2003 report. As a result, the HCOT was re-created based on the new and old data, by merging all available digitized channel lines. Two potential avulsion areas and high-flow channels were incorporated into the HCOT, including the majority of the 2006 avulsion area, near the confluence of the Clear Fork and the Muddy Fork, and a low-elevation channel that originates at Teal Lake and reenters the main stem several hundred feet to the southwest near the town of Packwood.

The preliminary CMZ boundary was delineated by multiplying the representative migration rate from each reach by 50 years, or by using the maximum distance of measured short-term movement for each reach, whichever value was greater. The preliminary CMZ distances define the preliminary CMZ boundary for each reach and are shown in Table 1. Reach transitions between the preliminary CMZ lines were smoothed manually. The preliminary CMZ was then adjusted to account for the presence of bedrock or other erosion resistant bank material plus a 50-foot buffer. The width of the CMZ was also increased by a factor of safety of 1.5 in Reaches 2 through 7 to accommodate anticipated channel response associated with anticipated sediment deposition in these areas. The CMZ width was expanded along the outside of rapidly migrating meander bends, although the extent of expansion was limited based on the anticipated maximum meander bend amplitude, as discussed above.

The MPA boundaries were drawn in a manner similar to the CMZ, but the severe MPA represents only 10 years of migration with a factor of safety of 1.25x, and the moderate MPA is double the severe MPA.. MPA boundaries were expanded or contracted following the method described above to account for bedrock, sediment deposition, and rapidly migrating meander bends.

RESULTS

The results of our analysis suggest the November 2006 storm event, resulting in avulsion, LWD recruitment, and significant sediment deposition, modified the character and form of the Upper Cowlitz

Channel sufficiently to warrant modification of the 2003 CMZ and MPA boundaries. The 2003 and 2008 CMZ and MPA boundaries were smoothed at reach breaks and/or to accommodate specific characteristics of the reach. The modified CMZ and MPA are summarized below, and the entire modified CMZ and MPA are shown in Plate 1.

The reach-by-reach modified preliminary CMZ and MPA boundaries, without correction for bedrock/erosion resistant material, depositional areas or meander bend amplitude are shown in Table 1. The average meander bend amplitude was measured to be approximately 2,200 feet with a standard deviation of roughly 200 feet. Meander wavelength varied more than the amplitude, but averaged roughly double the amplitude.

In most locations, the 2008 CMZ and MPA boundaries differ only slightly, or not at all from the 2003 CMZ and MPA boundaries. At only a few sites the 2008 and 2003 boundaries differ significantly. Those sites are summarized below:

REACH 1 (NARROW CANYON)

No significant differences in CMZ or MPA were measured in Reach 1, as the channel is confined by highly erosion resistant bedrock on both banks.

REACH 2 (AVULSION AREA)

The results of Phases I and II suggest major storms occurring prior to the development of snow pack could result in high sediment-yield flow capable of causing additional sediment build-up and avulsion across the alluvial fan. Channel adjustment on the Muddy Fork also continues with recent and ongoing bank recession observed on both banks throughout the reach. To accommodate these factors, the 2008 CMZ and MPA lines extend across the entire alluvial fan and much farther to the west than in 2003 (Figure 5a).

REACH 3 AND 4 (BRAIDED CHANNEL SECTION)

The large volume of sediment and accompanying LWD from the 2006 storm event and upstream avulsion created many new bars and/or altered the shape of the high flow corridor within reaches 3 and 4. This condition changed the flow pattern within the channel, resulting in multiple areas where flow impinges upon the banks and causes erosion. Most of these erosion areas are subject to bank recession and were anticipated in the 2003 report. However, calculated 2008 migration rates are greater than estimated 2003 rates, particularly on the right (west) bank. To accommodate the increased migration rates, the CMZ and MPA lines have been adjusted outward, primarily along the right bank especially in Reach 3 (Figure 5b and 5c).

REACH 5 (BRAIDED CHANNEL SECTION)

The CMZ and MPAs were adjusted laterally out along the left bank to accommodate a potential avulsion at Teal Lake. A factor of safety of 1.5 was also added to the CMZ and MPA lines in this area to accommodate a potential increase in sediment influx from Reaches 2 and 3. In several locations along the right bank, both the CMZ and MPA lines have been adjusted inward to accommodate bedrock, which can be much more accurately mapped from LiDAR topography (Figure 5d).

Reach 6 (Straight and Confined)

Only minor adjustments were made to the CMZ and MPA lines in this reach. Overall, Reach 6 is considered to be relatively stable (Figure 5e).

Reach 7 (Hybrid – Braided and Meander Bend Section)

The CMZ and MPAs were adjusted laterally outward along the left bank to account for significant bank erosion observed in 2008. The observed erosion appears to have been caused by sediment accumulation on point bars of bends. The lateral adjustment was limited in this reach by meander bend amplitudes measured throughout the meander bend section of the river, which are approaching the average maximum. Meander bend progradation in this reach is expected to slow significantly, and possibly stop all together, once the maximum meander amplitude reached (Figure 5f).

Reach 8 (Meander Bend Section)

Significant lateral and/or downstream migration of bends in this reach was observed over the last 10 years. The development of a large bar and a related smaller bar, has increased bend sinuosity and caused measured bank recession of approximately 330 feet between 2006 and 2008 near River Ranch Road. The CMZ and MPAs were adjusted laterally outward on both banks to accommodate these increased rates of migration and in anticipation of future bar building and meander bend formation both upstream and downstream.

Improvements in topographic imagery (LiDAR) resulted in the exclusion of one significant abandoned channel from the severe MPA on the right bank near the downstream end of the reach. However, this area is still contained within the larger CMZ (Figure 5g).

Reach 9 (Meander Bend Section)

The modified CMZ and MPA did not change significantly from the 2003 CMZ and MPA. The CMZ was reduced on the right bank in the area of a large historic bend and the severe and moderate MPA lines were reduced on the left bank near the town of Randle. Our interpretation of the detailed LiDAR topography suggests channel migration into these areas is unlikely (Figure 5h).

Reach 10 (Meander Bend Section)

The area immediately upstream of Scanewa Lake has not shown significant migration during the photo record, however, minor bank erosion was observed during helicopter reconnaissance in 2007 suggesting channel widening (Appendix A). The CMZ and MPA were adjusted outward by roughly 25 feet to accommodate channel widening from deposition in slack water of the lake (Figure 5i).

RECOMMENDATIONS

Channel Migration Zone analyses utilize past and present channel conditions to make predictions regarding future channel alignment. Inherent in every CMZ analysis is the assumption that existing channel processes will persist relatively unchanged into the future. Unprecedented variations in channel processes may result in significant changes to channel form, possibly altering the CMZ. Significant changes to channel form are defined as any bank of the active channel or active side channel of the Cowlitz River that have migrated, avulsed, or otherwise moved into a position half way between the HCOT and the current (2009) high MPA. In order to detect significant changes to channel form, frequent monitoring should be conducted by comparing the active channel margins to the HCOT through aerial photo and/or GPS analyses at a minimum of every 5 years, or when new aerial photos become available, or when measurable bank recession is observed in any location (whichever occurs first). For every reach in which significant changes to channel form are documented, the CMZ within that reach should be reevaluated and revised as necessary to accurately convey the new conditions.

Depending on how Lewis County chooses to regulate the CMZ and MPA within the Upper Cowlitz area, there may exist at some point the need for a variance to their regulations regarding development within the CMZ or MPA boundaries. GeoEngineers supports Lewis County's use of the following items (as determined by Lewis County) necessary in order to apply for a variance:

1. Narrative explaining why a variance from current mapping should be allowed
2. General description of the area, including current use of the surrounding property.
3. Accurate topographic map showing:
   - Base elevation and type of instrument used to make determination
   - One foot contours
   - Scale bar
   - North arrow
   - Cross sections showing materials distribution
   - Soil classification and depth to bedrock, accomplished by drilling or excavating test pits
   - Rock type and characteristics of bedrock if present
   - Ordinary high water (OHW) mark and elevation
   - 50-foot, 100-foot, and 200-foot setback from OHW
   - CMZ location(s)
   - Vegetation type and description of density
   - Show location of existing and planned infrastructure including revetments
   - A JARPA may be required in which case all of the requirements for this document must be completed.

LIMITATIONS

We have prepared this report addendum for use by the Lewis County Department of Public Works. This report addendum is intended to accompany the GeoEngineers' "Geomorphic Evaluation and Channel Migration Zone (CMZ) Analysis, Lewis County Washington" for the Upper Cowlitz River dated June 12, 2003. Conditions within the Upper Cowlitz River Watershed may change over time as a result of changes in climate and precipitation, sediment delivery, land use and flood management policies. Our report should not be construed as a guarantee of future conditions in the Cowlitz River watershed or within the Upper Cowlitz River project area.

GeoEngineers believes that the results of the CMZ and MPA analysis provided in this report addendum are reasonable and appropriate; however, fluvial geomorphology is not an exact science, and conditions and interpretations can change with time and the availability of additional or different data. Changes in interpretation or conditions may require that our conclusion and recommendations be modified.

Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices in the field of geomorphology and engineering geology in this area at the time this report was prepared. No warranty or other conditions, express or implied, should be understood. Please refer to Appendix D titled "Report Limitations and Guidelines for Use" for additional information pertaining to use of this report.

Any electronic form, facsimile or hard copy of the original document (email, text, table, and/or figure), if provided, and any attachments are only a copy of the original document. The original document is stored by GeoEngineers, Inc. and will serve as the official document of record.

REFERENCES

GeoEngineers (2003), Geomorphic Evaluation and Channel Migration Zone (CMZ) Analysis, Lewis County Washington.

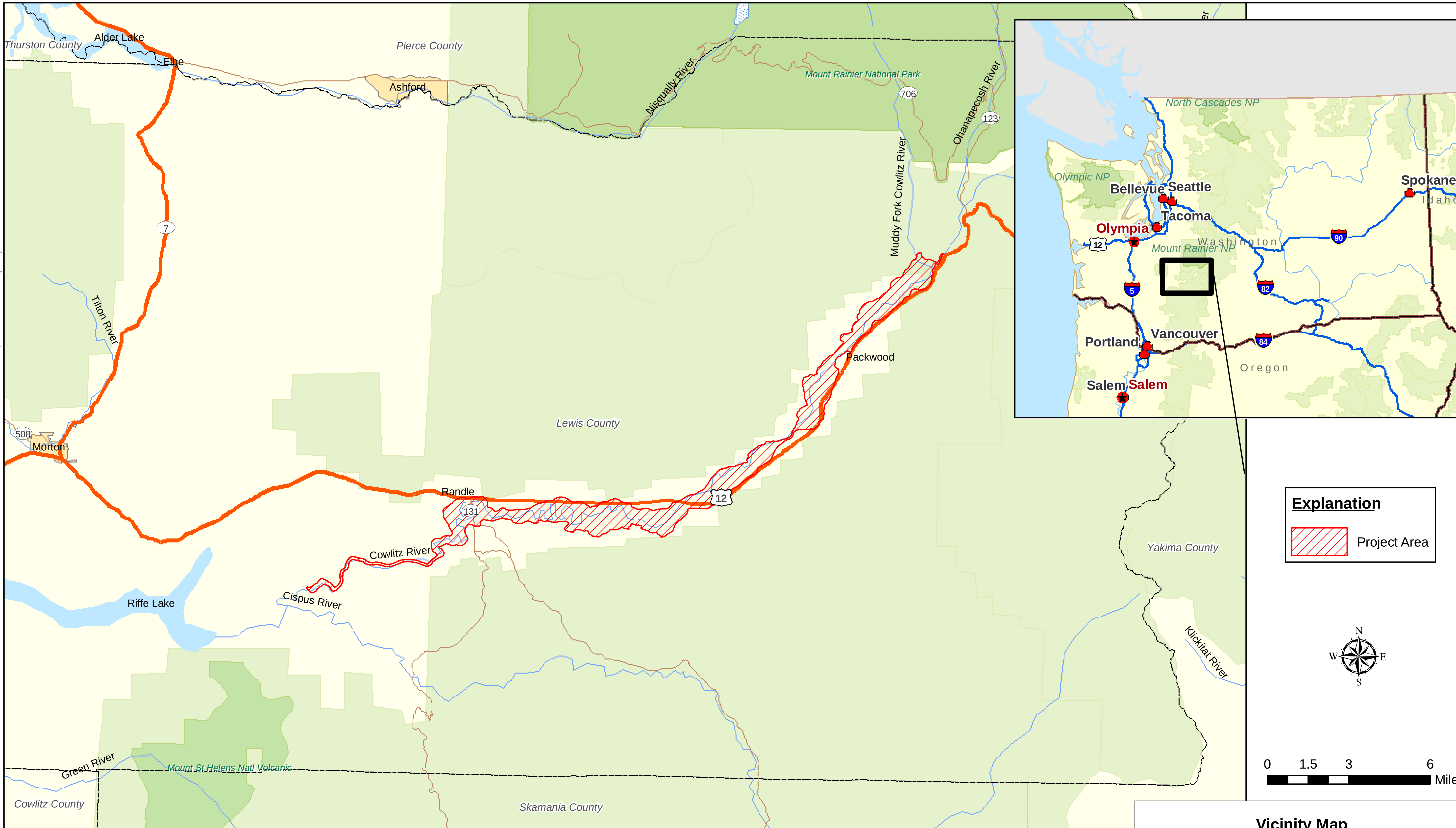
GeoEngineers (2007), Upper Cowlitz River Preliminary Field Reconnaissance and Channel Migration Hazard Assessment.

Rapp, R.G. and Abbe T. (2003), A Framework for Delineating Channel Migration Zones, Washington State Department of Ecology Publication 03-06-027.

Table 1
Preliminary CMZ Migration Distances
Lewis County Public Works Department
Lewis County, Washington

Reach	*Preliminary CMZ Distance (ft)
1	N/A
2	297
3	604
4	849
5	621
6	37
7	879
8	1108
9	175
10	108

*Preliminary CMZ distance represents the calculated maximum distance of lateral migration derived from discrete channel measurements per reach.



Map Revised: 12-16-08 (MGF)

Reference: Base map data was provided by ESRI.

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for infomation 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 oth this communication.

Vicinity Map

Upper Cowlitz River CMZ
Lewis County, Washington

GeoEngineers

Figure 1

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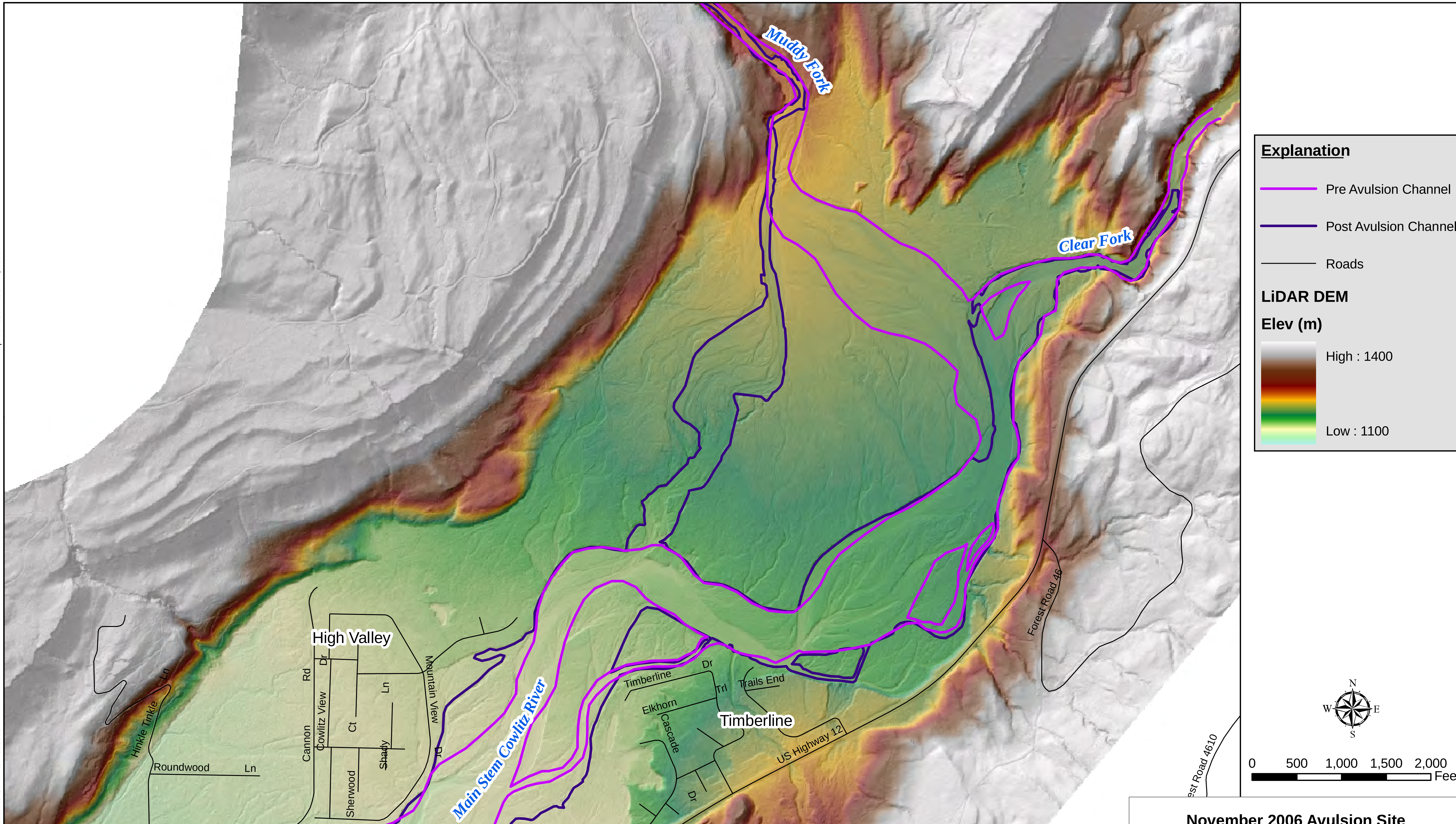

Map Revised: March 27, 2009

Path: P:\3\3118066\03\GIS\MXD\311806603-F2

Office: BOI

Reference: Roads were obtained from Lewis County Tiger Census. LiDAR and 2007 (Post Avulsion) Channel provided by Lewis County.

Notes:
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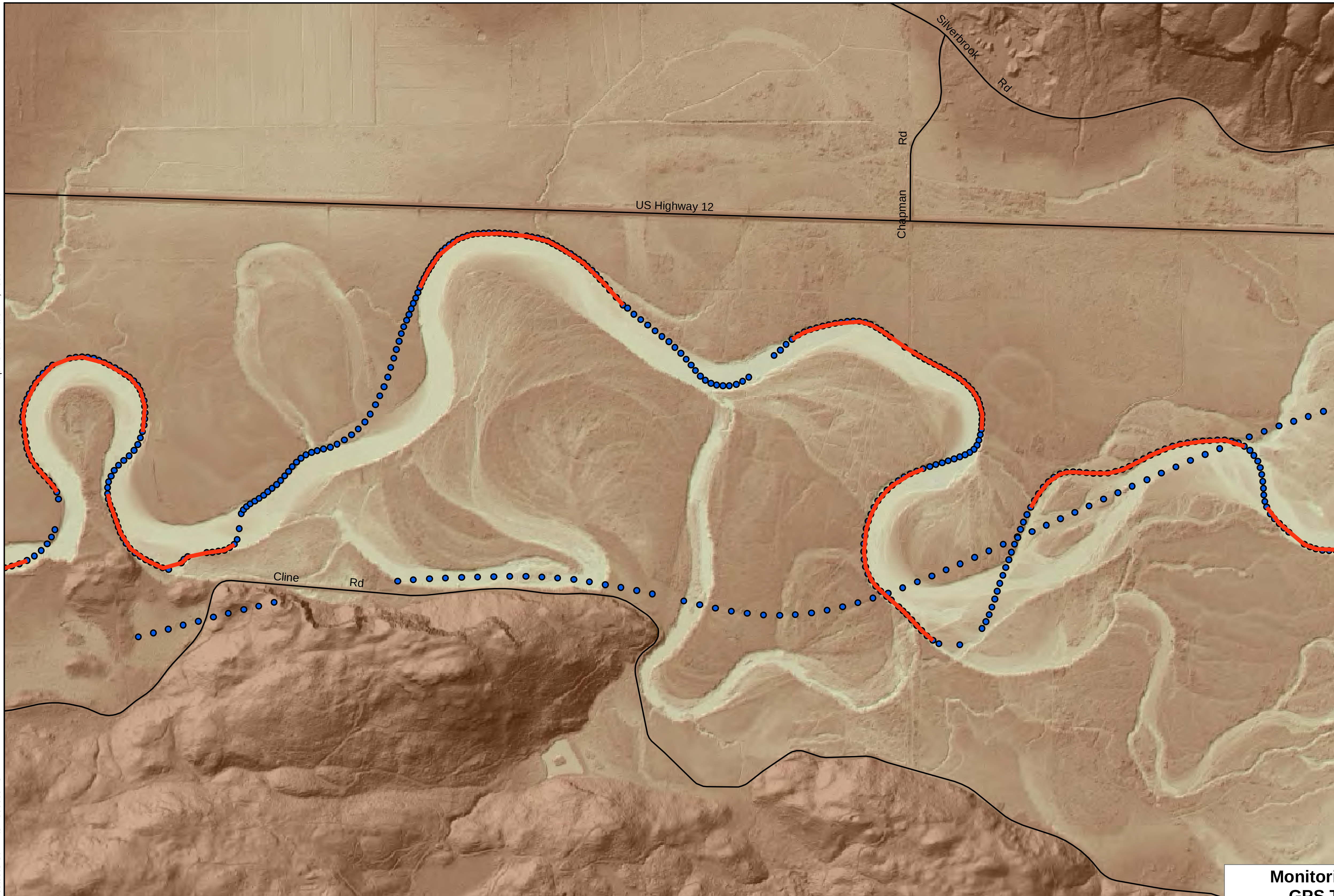
November 2006 Avulsion Site

Upper Cowlitz River CMZ
Lewis County, Washington

GeoEngineers

Figure 2



Explanation

- All GPS TrackLog
- Bends GPS Track Log
- Roads

Relative Surface Model (ft)

High : 20

Low : -20

N
W E
S

0 500 1,000 1,500 2,000 Feet

Reference: Roads were obtained from Lewis County Tiger Census. Relative Surface Model was built from LiDAR provided by Lewis County.

Notes:
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Monitoring Bank Recession With GPS TrackLog via Helicopter

Upper Cowlitz River CMZ
Lewis County, Washington

GeoEngineers

Figure 3

Map Revised: March 27, 2009

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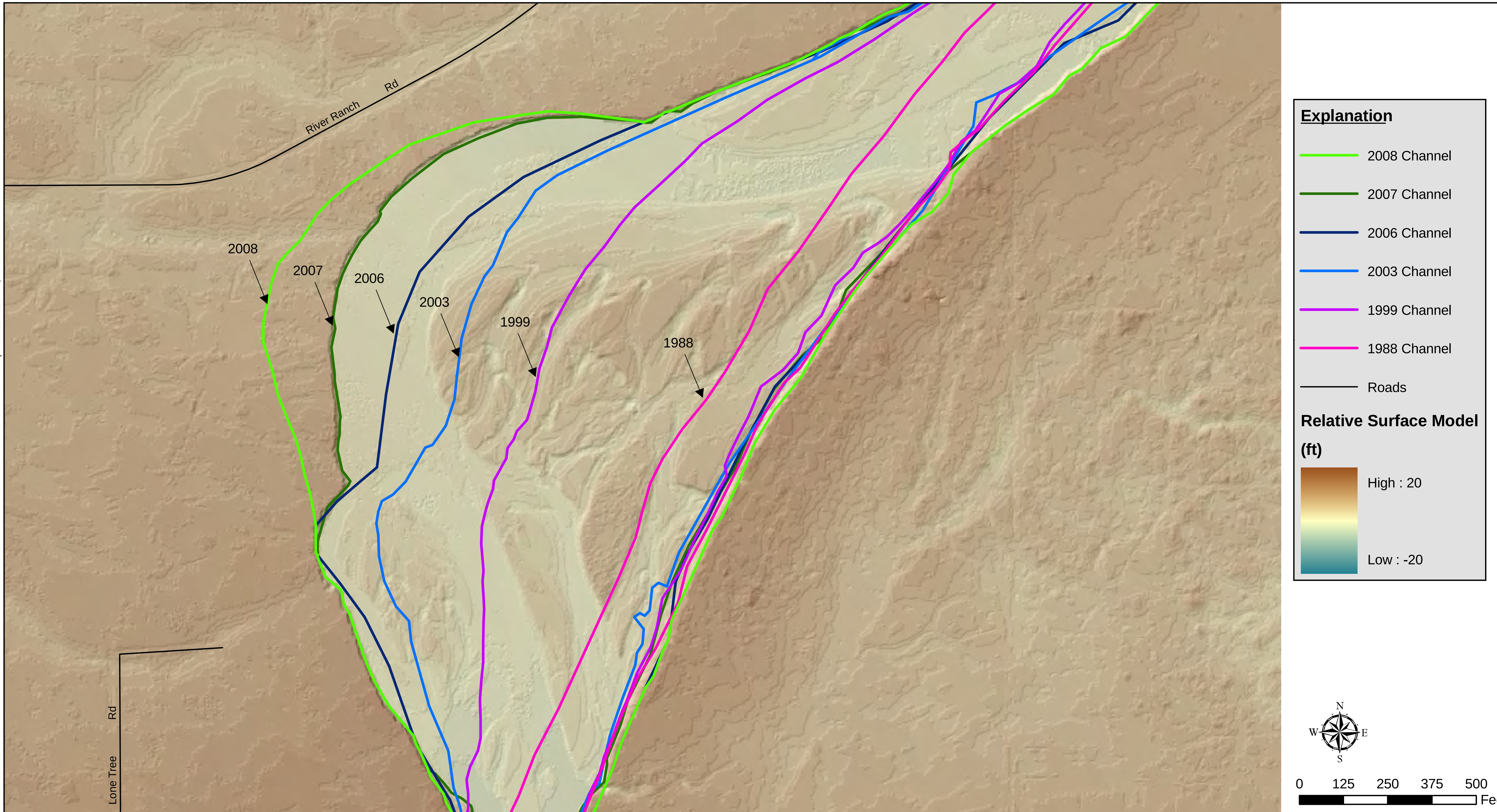

Bend Migration near River Ranch Road

Upper Cowlitz River CMZ
Lewis County, Washington

GeoEngineers

Figure 4

Reference: Roads were obtained from Lewis County Tiger Census. Relative Surface Model was built from LiDAR provided by Lewis County.

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Map Revised: March 27, 2009

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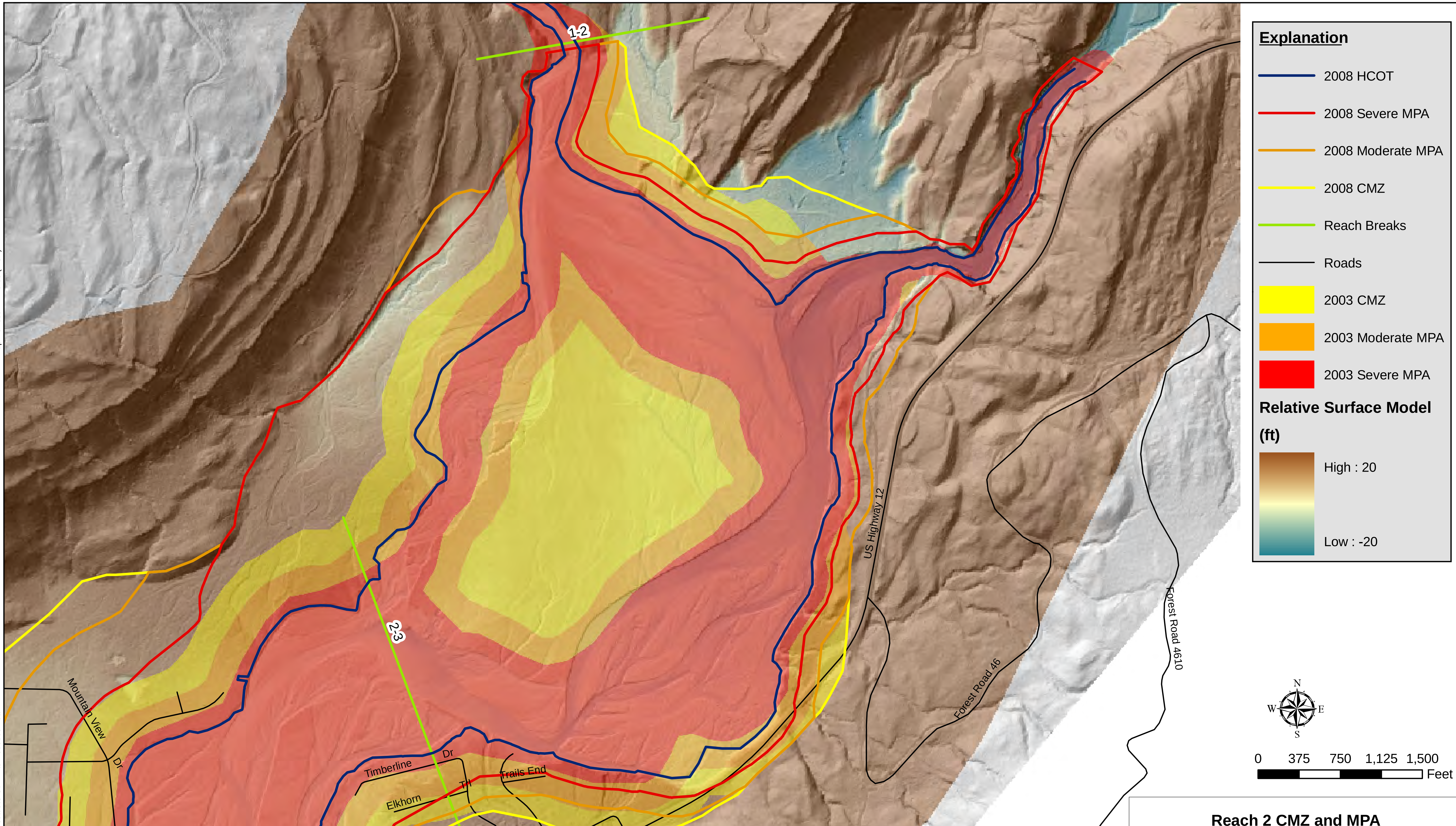

Reference: Roads were obtained from Lewis County Tiger Census. Relative Surface Model was built from LiDAR provided by Lewis County. 2007 aerial photos were provided by Lewis County.

Notes:
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Reach 2 CMZ and MPA

Upper Cowlitz River CMZ
Lewis County, Washington

GeoEngineers

Figure 5a

Map Revised: 12-16-08 (MGF)

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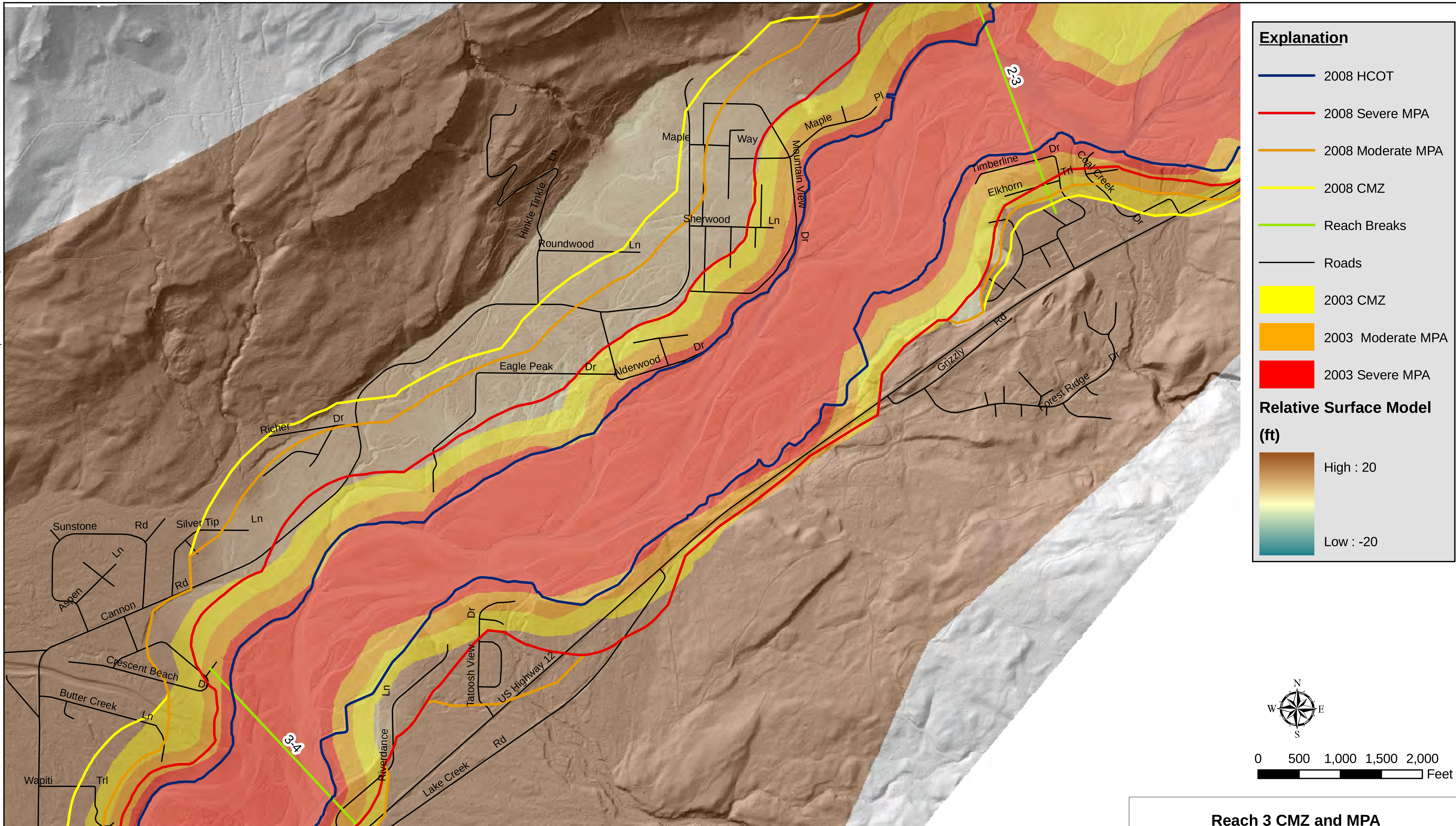

Reference: Roads were obtained from Lewis County Tiger Census. Relative Surface Model was built from LiDAR provided by Lewis County.

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Reach 3 CMZ and MPA

Upper Cowlitz River CMZ
Lewis County, Washington

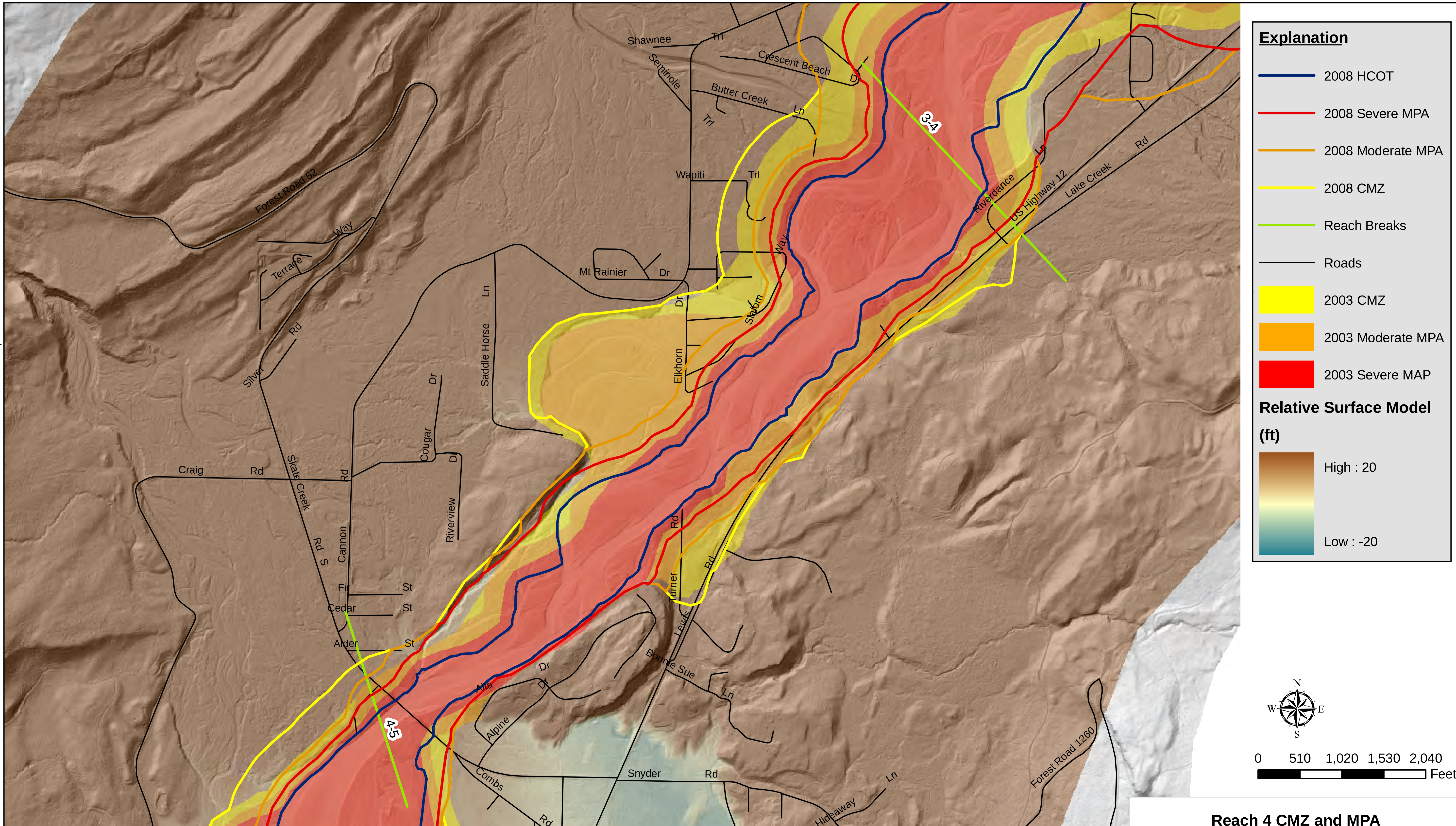
GEOENGINEERS

Figure 5b

Map Revised: March 27, 2009

Path: P:\31\31180066\03\GIS\MXD\311806603-F5b

Office: BOI



Reach 4 CMZ and MPA

Upper Cowlitz River CMZ
Lewis County, Washington

GEOENGINEERS

Figure 5c

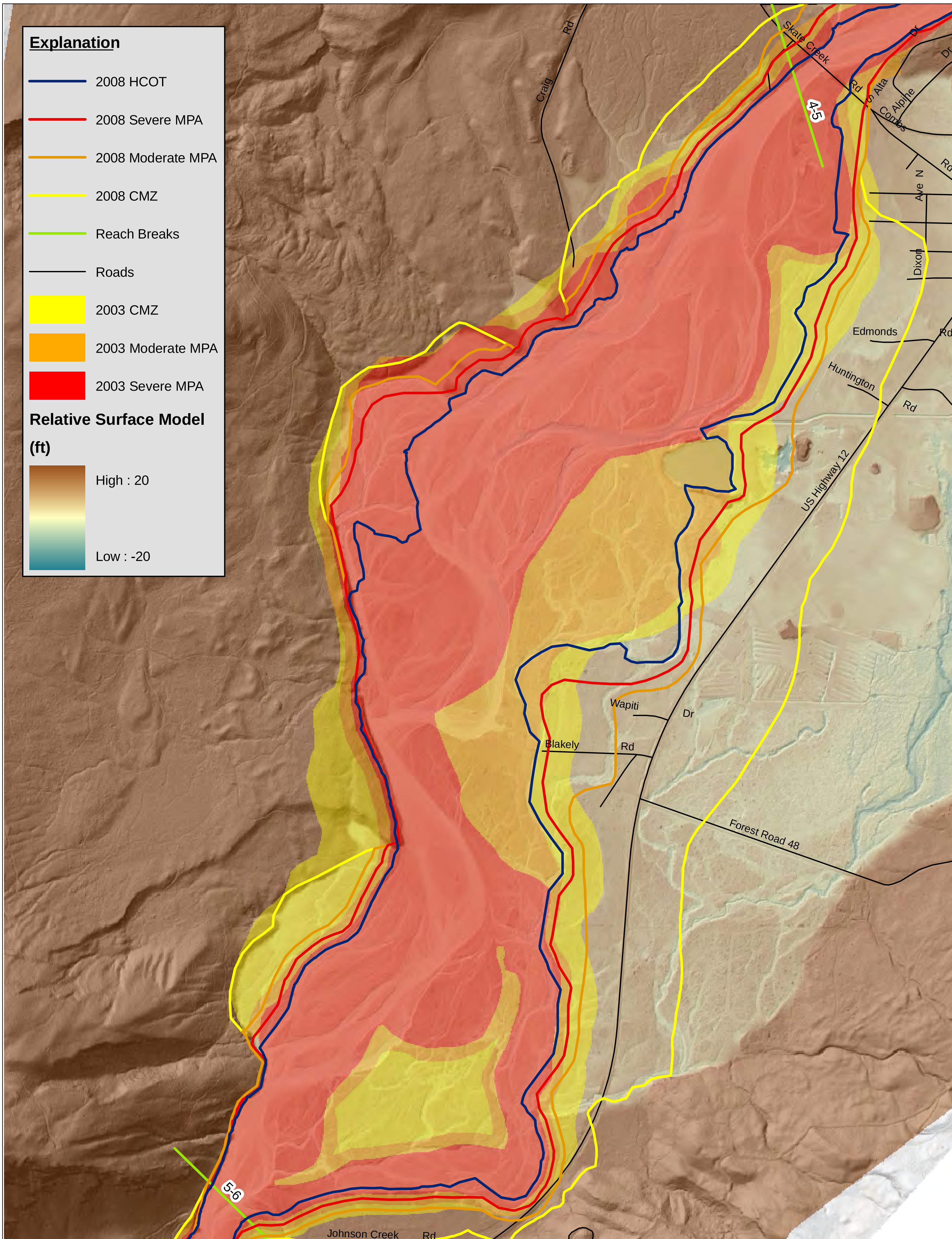
Reference: Roads were obtained from Lewis County Tiger Census. Relative Surface Model was built from LiDAR provided by Lewis County.

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for infomation 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 oth this communication.

Map Revised: March 27, 2009

Path: P:\3\3118066\03\GIS\MXD\3118066603-F5c

Office: BOI



0 500 1,000 1,500 2,000 Feet

N W E S

Reference: Roads were obtained from Lewis County Tiger Census. Relative Surface Model was built from LiDAR provided by Lewis County.

Notes:
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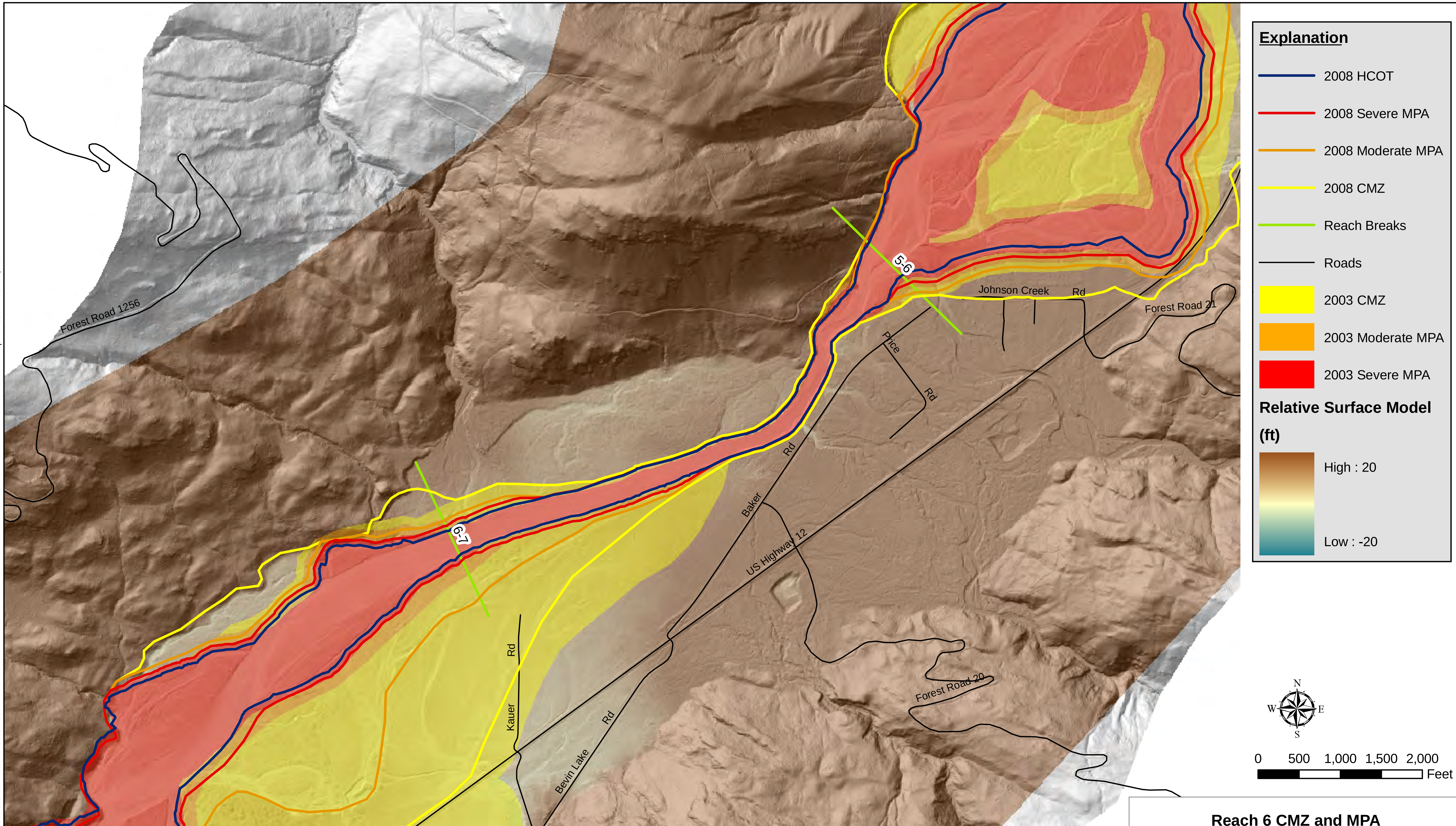
Reach 5 CMZ and MPA

Upper Cowlitz River CMZ
Lewis County, Washington

GEOENGINEERS

Figure 5d



Reference: Roads were obtained from Lewis County Tiger Census. Relative Surface Model was built from LiDAR provided by Lewis County.

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Reach 6 CMZ and MPA

Upper Cowlitz River CMZ
Lewis County, Washington

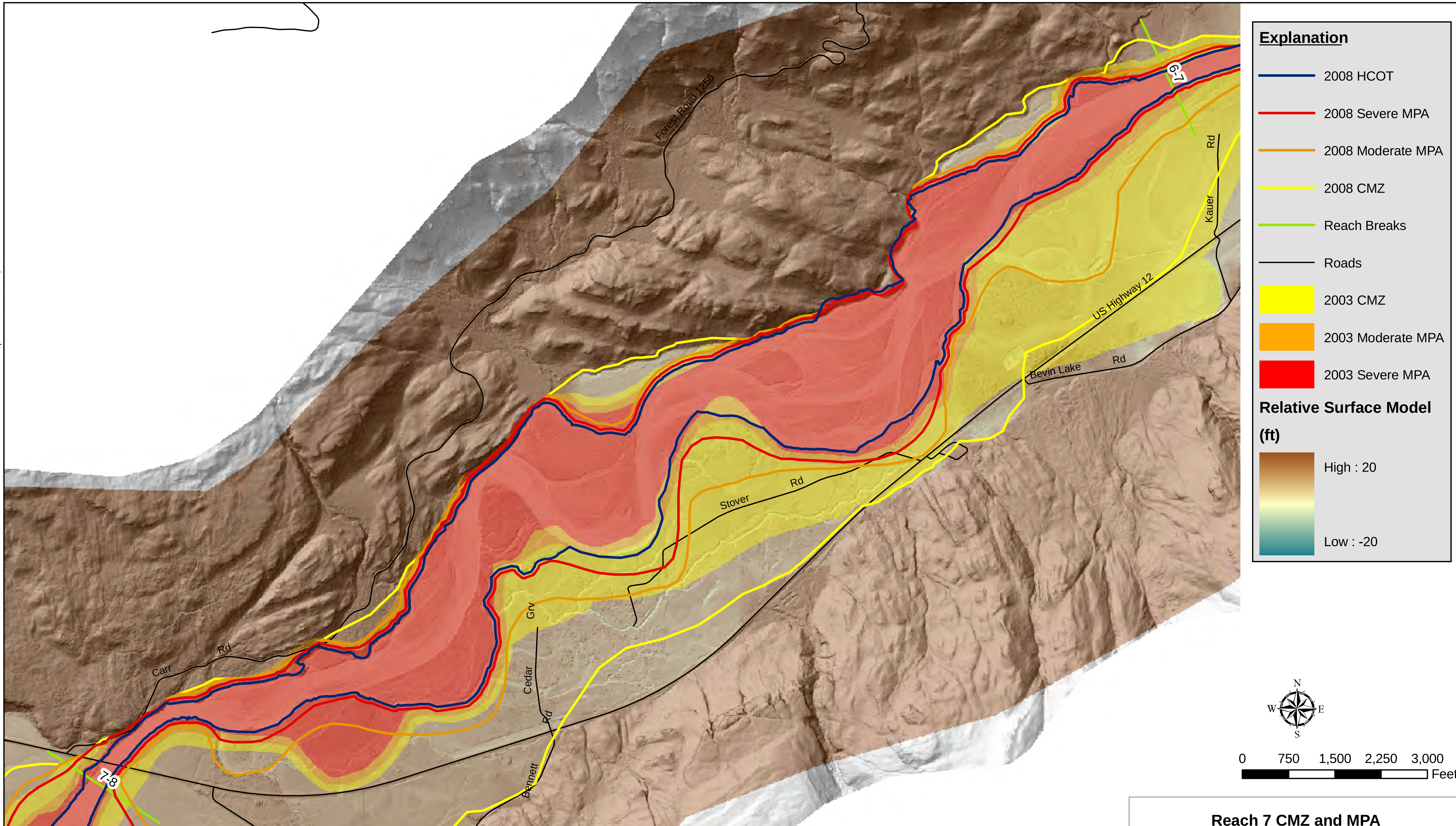
GEOENGINEERS

Figure 5e

Map Revised: March 27, 2009

Path: P:\3\3118066\03\GIS\MXD\3118066603-F5e

Office: BOI



Reference: Roads were obtained from Lewis County Tiger Census. Relative Surface Model was built from LiDAR provided by Lewis County.

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Reach 7 CMZ and MPA

Upper Cowlitz River CMZ
Lewis County, Washington

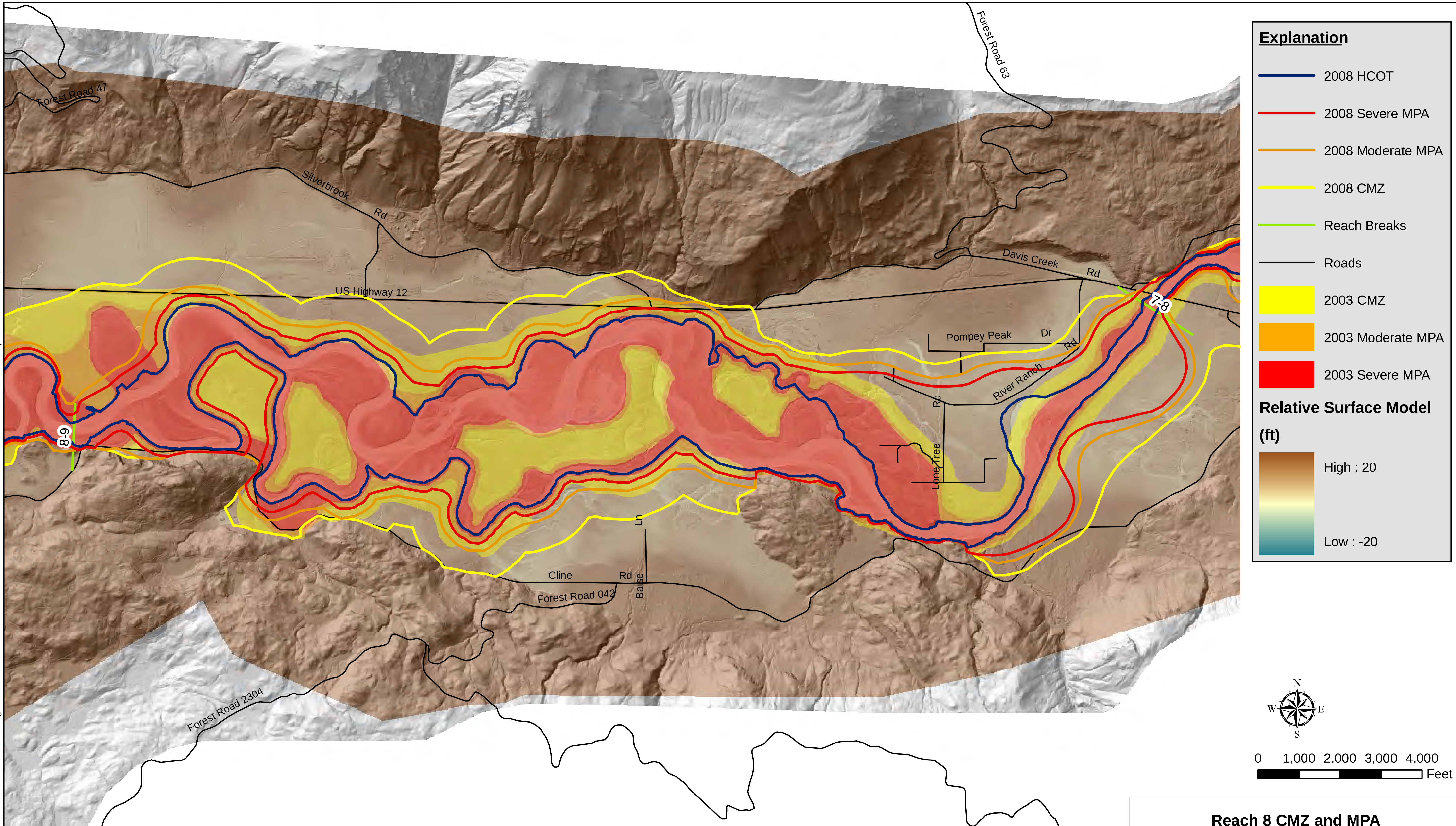
GeoEngineers

Figure 5f

Map Revised: March 27, 2009

Path: P:\3\3118066\03\GIS\MXD\3118066603-F5f

Office: BOI



Reference: Roads were obtained from Lewis County Tiger Census. Relative Surface Model was built from LiDAR provided by Lewis County.

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Reach 8 CMZ and MPA

Upper Cowlitz River CMZ
Lewis County, Washington

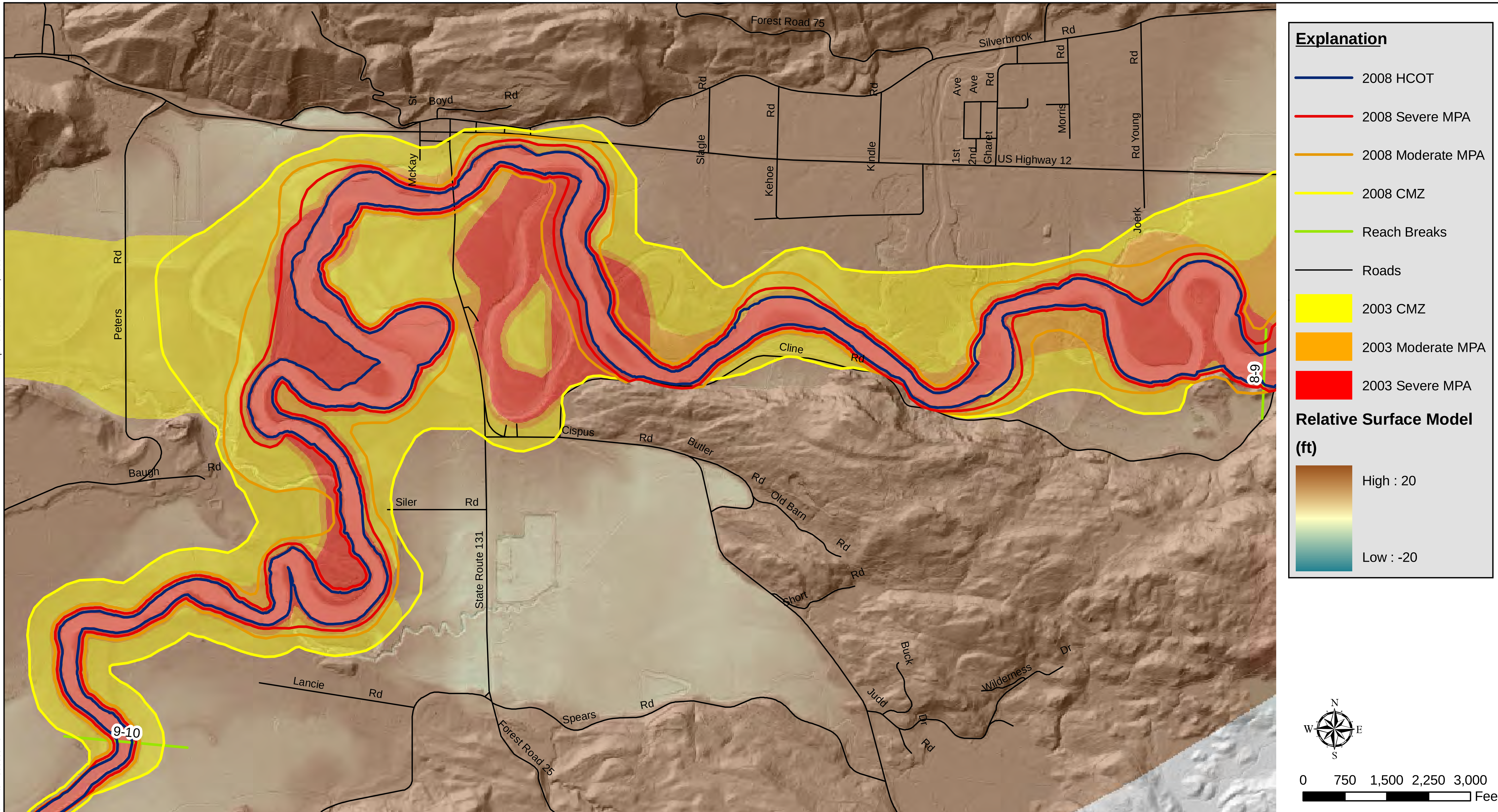
GeoEngineers

Figure 5g

Map Revised: March 27, 2009

Path: P:\3\3118066\03\GIS\MXD\311806603-F5g

Office: BOI



Reference: Roads were obtained from Lewis County Tiger Census. Relative Surface Model was built from LiDAR provided by Lewis County.

Notes:
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Reach 9 CMZ and MPA

Upper Cowlitz River CMZ
Lewis County, Washington

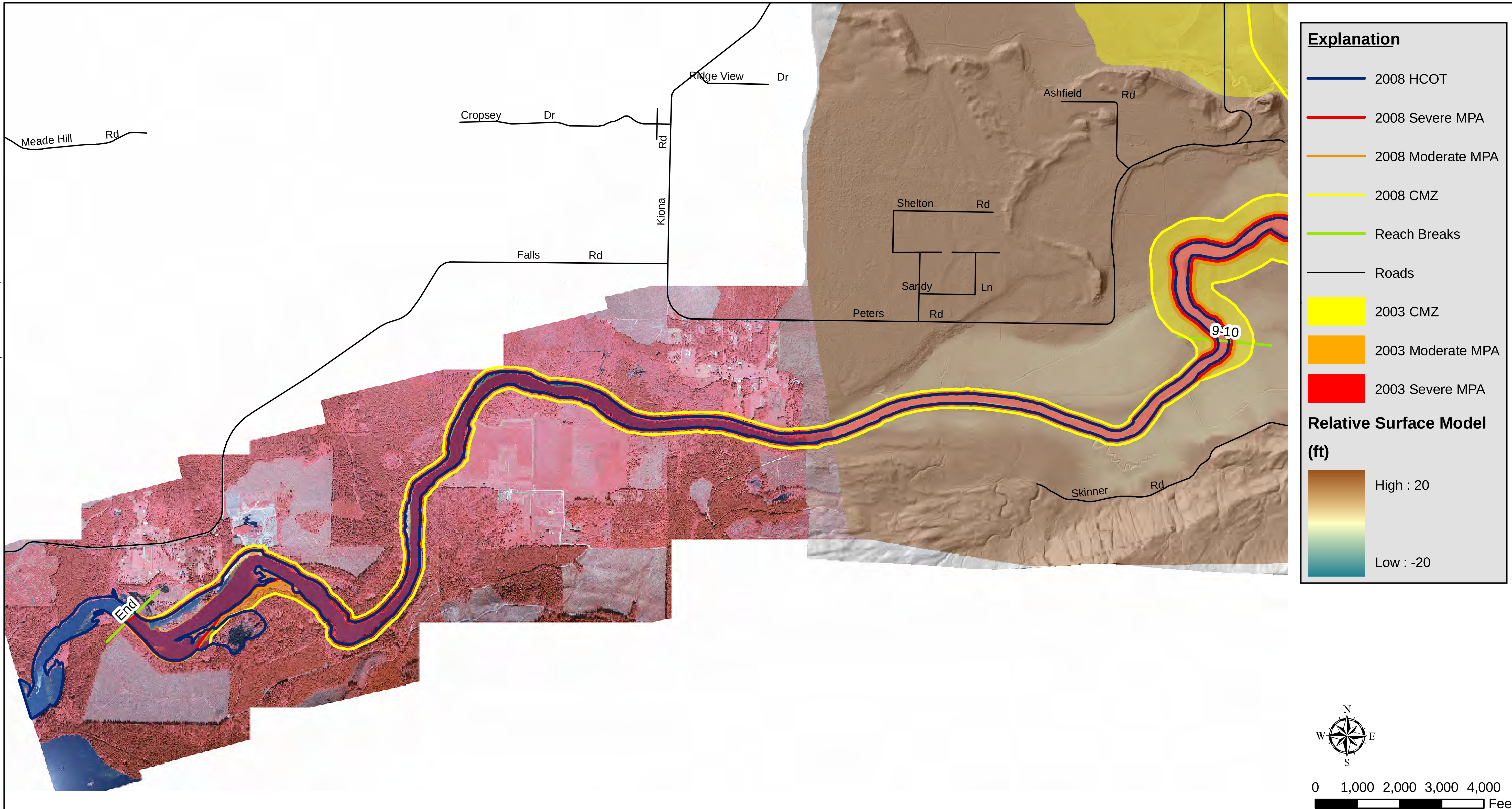
GeoEngineers

Figure 5h

Map Revised: March 27, 2009

Path: P:\3\3118066\03\GIS\MXD\311806603-F5h

Office: BOI



Map Revised: March 27, 2009

Reference: Roads were obtained from Lewis County Tiger Census. Relative Surface Model was built from LiDAR provided by Lewis County. 2007 infrared aerial photos provided by Lewis County.

Notes:
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Reach 10 CMZ and MPA

Upper Cowlitz River CMZ
Lewis County, Washington

GeoEngineers

Figure 5i

Path: P:\3\3118066\03\GIS\MXD\311806603-F5i

Office: BOI

2002 vs 2008 CMZ and MPA

Upper Cowlitz River CMZ
Lewis County, Washington

GeoEngineers

Plate 1

Reference: Roads were obtained from Lewis County Tiger Census. Relative Surface Model was built from LiDAR provided by Lewis County.

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Map Revised: March 27, 2009

Office: BOI Path: P:\3\3118066\03\GIS\MXD\311806603-Plate1

GeoEngineers

Appendix A

"Upper Cowlitz River, Preliminary Field Reconnaissance and Channel Migration Hazard Assessment," by GeoEngineers, Inc., dated June 20, 2007

UPPER COWLITZ RIVER
PRELIMINARY FIELD RECONNAISSANCE AND
CHANNEL MIGRATION HAZARD ASSESSMENT

JUNE 20, 2007

FOR
LEWIS COUNTY

GEOENGINEERS

Upper Cowlitz River
Preliminary Field Reconnaissance and Channel Migration Hazard Assessment
File No. 3118-066-01

June 20, 2007

Prepared for:

Lewis County
2025 NE Kresky Avenue
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Attention: Fred Chapman

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APPENDICES

UPPER COWLITZ RIVER
PRELIMINARY FIELD RECONNAISSANCE AND CHANNEL MIGRATION HAZARD ASSESSMENT

INTRODUCTION

This report summarizes the results of our geomorphic stream reconnaissance and preliminary channel migration hazard assessment conducted for Lewis County Public Works Department (client). The services, requested by Fred Chapman of Lewis County on April 20, 2007, represent a sub-set of work scope tasks presented in GeoEngineers' proposal dated February 23, 2007 regarding an evaluation of Upper Cowlitz River channel conditions resulting from major flooding in November 2006, and potential re-delineation (as needed) of existing Channel Migration Zone (CMZ) boundaries. Because funding for the proposed CMZ analysis and re-delineation project will not be available until late 2007, the current project was authorized to document time-sensitive field data and information that could be lost to future high flow events.

This report includes the following information

- Findings from the field reconnaissance,
- Preliminary qualitative assessment of Upper Cowlitz channel response to the November 2006 storm,
- Identification of existing CMZ boundary sections that will likely need modification, and
- Identification of potential high-migration hazard areas.

PROJECT BACKGROUND AND UNDERSTANDING

GeoEngineers completed the Upper Cowlitz River CMZ in 2002. The CMZ study area included continuous river sections from Scanewa Lake (southwest of Randle, Washington) upstream to a location immediately north of the former confluence of the Clear and Muddy Forks of the Cowlitz River (Figure 1).

Prior to the November 2006 storm event, the Muddy Fork River exited a deeply incised canyon and followed a southeast trending channel towards the mouth of the Clear Fork River, where the two channels joined to form the main stem Cowlitz River (shown on Figure 1). During the November 2006 storm, the Muddy Fork River completely abandoned a portion of its former channel and cut a new channel across a forested alluvial fan. The relocation of the Muddy Fork channel (avulsion) shifted the confluence with the Clear Fork roughly 5,000 feet downstream from its former location, effectively reducing the peak discharge of future flows in the lower Clear Fork reach.

The Muddy Fork avulsion also caused changes in the physical condition of the main stem Cowlitz River channel, downstream of the new Muddy/Clear Fork Channel confluence. Trees and ground cover uprooted during the avulsion were distributed across the Cowlitz channel downstream from the new confluence. Significant bank erosion, coupled with bank recession occurred along both river banks as far downstream as Lake Scanewa.

WORK SCOPE

The purpose of this qualitative analysis was to collect time-sensitive data, including the location and configuration of large woody debris (LWD), locations of high-flow indicators, and physical channel conditions. Our assessment included the following elements:

- Collect and evaluate aerial photographs not included in the 2002 CMZ data base,
- Coordinate the flight of 2007 orthorectified aerial photos,
- Conduct aerial reconnaissance via helicopter,
- Conduct ground reconnaissance, and
- Conduct the preliminary evaluation.

METHODS

Data Collection and Preparation

Orthorectified aerial photos dated October, 2006, available from the National Agriculture Imaging Program (NAIP), were downloaded and projected in a GIS. The edges of the high-flow corridor and main channel banks were digitized at a scale of 1:12,000 and compared with digitized data from the 2002 CMZ GIS to identify areas of bank recession. GIS data, including digitized channels and bars, levees, and the previously delineated CMZ boundaries were uploaded to a Trimble GeoXT global positioning satellite (GPS) receiver equipped with ESRI ArcPad GIS software for use during reconnaissance.

2007 Ortorectified Aerial Photos

GeoEngineers contracted with ETG, Inc. to fly false-color infrared (IR) aerial photographs over the Upper Cowlitz River from Scanewa Lake to roughly 5,000 feet upstream of the current confluence of the Clear and Muddy Forks of the Cowlitz River.

Aerial Reconnaissance

On May 7th, 2007 a reconnaissance team consisting of two GeoEngineers geologists and a Washington State Department of Ecology (DOE) hydrogeologist flew in a helicopter over the length of the Upper Cowlitz River from Scanewa Lake to the Mt. Rainier National Park boundary. The purpose of the flight was to observe the large-scale conditions and characteristics of the Upper Cowlitz River and to select sites for ground reconnaissance. Observations were documented and compared with aerial photos dated prior to November 2006. Bank recession was determined by flying (at low altitude) directly over outside channel bends displaying observed erosion. A tracklog from a Trimble XT GPS recorded the position of the helicopter every five seconds, which was then compared against previously digitized channel lines.

Ground Reconnaissance

Following the aerial reconnaissance the GeoEngineers field team and a Lewis County representative performed ground reconnaissance on May 8th and 9th, 2007. Field sites were selected based on the results of aerial reconnaissance and the recommendations of the Lewis County staff person and his eyewitness accounts of the November 2006 flood event. Data and observations collected during ground reconnaissance included the composition and condition of the stream bed, banks, and floodplain, high-flow indicators, evidence of erosion and deposition, presence of LWD, channel geometry, levee/revetment conditions, and flood water flow direction.

GEOMORPHIC SETTING

The Muddy Fork of the Cowlitz River originates from glacial meltwater on the southeastern flanks of Mount Rainier (Figure 1). Below the glaciers, the Muddy Fork enters a U-shaped valley with large areas of sediment storage before passing through a narrow, bedrock-confined slot canyon. At the mouth of the slot canyon is a large, forested, alluvial fan and the confluence with the Clear Fork of the Cowlitz River. Downstream of the alluvial fan, the Upper Cowlitz River can be separated into two principle sections: 1) a braided section from the Highway 12 Bridge upstream, and 2) and a meander-bend section from the Highway 12 Bridge downstream. The braided section is characterized as having many branches separated by bars. Braided channels generally share three principle characteristics, 1) erodible banks, 2) abundant sediment load, and 3) rapid and frequent variations in discharge. Braided channels are generally shallow and migrate rapidly within the braided area as bars are eroded and re-deposited within the channel corridor. The channel corridor (often referred to as the high-flow corridor) may migrate and/or widen episodically over time.

The meander-bend section is characterized as a primarily single-threaded channel dominated by meander-bend migration. Meander bend migration involves erosion of the outside bank of a bend coupled with concurrent deposition of sediment along the inside bank of the same bend. This process results in the lateral movement of the channel, while maintaining consistent channel shape and width.

FINDINGS

COLLECTION AND ANALYSIS OF NEW DATA

Comparison of the 2006 digitized channel banks with previously digitized channel lines from the 2002 CMZ GIS data set revealed several areas of bank recession and/or channel migration. These locations were mapped for future analysis and observed during reconnaissance.

2007 ORTHORECTIFIED AERIAL PHOTOS

ETG, Inc. flew the aerial photos on May 14th, 2007 and is currently in the process of orthorectifying the photos with an expected completion date of June 30th, 2007. The orthorectified photos will be used in the future to digitize 2007 channel lines for comparison with previous years in order to determine areas of bank recession, potential future hazard areas, and locations of LWD accumulation.

RECONNAISSANCE

Upper Drainage Basin

The aerial reconnaissance provided a holistic, large-scale perspective of the Upper Cowlitz River and its drainage basin. The aerial reconnaissance team flew into the upper drainage basin of the Muddy Fork, situated inside Mount Rainier National Park. The National Park Service had reported numerous debris flows originating in this area (personal communication, Paul Kennard, Mount Rainier National Park Geomorphologist). The reconnaissance team observed no evidence of residual deposits from recent debris flows in the upper drainage basin or in the slot canyon immediately downstream. However, large sediment storage areas in the upper drainage basin were observed to be full or nearly full of sediment (Photo 1). There were also no residual debris flow deposits or LWD jams observed in the narrow slot canyon immediately downstream.

Abandoned Muddy Fork Channel

As the Muddy Fork emerges from the narrow slot canyon the valley widens significantly forming an alluvial fan. An alluvial fan is a convex, depositional landform that often takes the shape of a fan or cone spread over a relatively flat surface. Alluvial fans typically develop where channelized flow passes onto an unconfined, lower gradient area. In this setting, fan building is typically a long term process involving sediment deposition resulting in generally unstable landforms characterized by frequent avulsions and flooding over the entire fan surface.

During the November 2006 event, there was an avulsion of the Muddy Fork Channel across the alluvial fan, abandoning a portion of the channel (Figure 2a and 2b). At the avulsion site, a longitudinal profile (Chart 1) revealed a sharp decrease in gradient, and a cross section (Chart 2) measured up to 8 feet of deposition within the high-flow corridor of the abandoned Muddy Fork. At the downstream end of the abandoned channel up to 4 feet of sand was observed overlying coarse sediment consisting primarily of cobbles and small boulders (Photo 2). Deposition appeared to extend in a continuous mantle across the width of the abandoned channel resulting in a relatively flat surface, and southward across the alluvial fan (Photo 3). Scattered LWD is present within the abandoned channel; in most cases the observed LWD was only partially buried in sand at the time of the site visit. No log jams were observed in the abandoned channel.

New Muddy Fork Channel

The width of the new Muddy Fork Channel varies from roughly 75 to 500 feet. Based on field observations the new channel incised up to roughly 8 feet below the elevation of the pre-flood forest floor (Photo 5). The banks of the new channel consist predominantly of older alluvial fan deposits overlain in turn by up to 4 feet of recent sand and alluvium. Field observations also indicate that numerous large trees were toppled and/or torn up by the roots, and transported downstream.

Logjams near the mouth of the new channel appear to be deflecting flow against the right bank causing bank erosion (Photo 4). The logjams appear to be well anchored, and do not appear to have moved between December, 2006 and May 2007.

Clear Fork Channel

Prior to the November 2006 avulsion, the Muddy and Clear Fork Rivers joined at the mouth of the Clear Fork, and combined discharges flowed around the perimeter of the alluvial fan. As a result of the avulsion, the confluence of the Clear and Muddy Forks moved approximately 5,000 feet downstream. The 5,000-foot channel section is now occupied only by the Clear Fork resulting in a net loss of discharge in this area.

Bank recession was observed in the Timberline Community along the left bank in this area. Bank erosion photographed in December 2006, documented the partial undermining of a house foundation. By May, 2007 continuing bank erosion further undermined the house causing it to fall into the river (Photo 6). Banks in this area are composed of loosely consolidated alluvial gravel and cobbles with sand.

High-flow indicators were measured up to 5 feet above the floodplain surface in the Timberline Community, but relatively little overbank deposition was observed (Photo 7). A tributary, Coal Creek, enters the main-stem at the location of the Timberline Community. This tributary is known to have flooded and eroded its banks.

Braided River Section

High Valley is on the right bank of the river, downstream of Timberline and immediately downstream of the new, post-avulsion, confluence of the Muddy and Clear Forks of the Cowlitz River (Figure 2a and 2b). Based on comparison of October 2006 orthophotos, and May 2007 field observations an area of significant sediment deposition developed along the right bank against rip-rap immediately upstream of High Valley (Photo 8). Scattered LWD situated on top of the sand deposit is positioned with root wads in the downstream direction, suggesting flow was recirculation in an eddy at the time of deposition.

Downstream of the sand deposit, a pre-existing rip-rap revetment was severely damaged and/or completely removed during the November 2006 event, resulting in significant bank recession and the loss of at least one house. A portion of the lost revetment has been replaced (Photo 9). The bank recession appears to have occurred without concurrent flooding in this area as high-flow indicators recorded flood levels roughly 3 feet below the top of the bank (Photo 10).

Further south, for the remainder of the braided section of the Upper Cowlitz River, many new and altered sediment bars were observed, which have changed low-flow channel patterns, although the position and orientation of the high-flow corridor does not appear to have changed significantly. Low-flow channel changes appear to have deflected stream flow towards channel banks, resulting in localized areas of bank erosion, some of which were mapped using GPS (Photo 11).

Meander Bend Section

The meander bend section of the river extends downstream from the Highway 12 Bridge. Aerial and ground reconnaissance indicates that neither the pattern nor the character of the main channel changed significantly from those recorded prior to the November 2006 event. However, the results of the field reconnaissance did identify several local areas of bank recession, the most significant of which includes the right river bank near River Ranch Road, where up to 200 feet of bank recession was measured since October 2006 using the Trimble GPS (Figure 3). A large gravel bar has formed (since 1999) along the left bank in this area; the bar deflects flow toward the right bank, which is composed of loosely consolidated silt and sand with grass vegetation (Photo 12).

The November 2006 flood deposited sand on the right bank floodplain (Photo 13) and damaged several trailers and outbuildings in the area (Photo 14). High-flow indicators in this area suggest that flood waters reached 6.5 feet above the floodplain surface, flowed overland towards the west/northwest, and reentered the main-stem channel through Davis Creek.

Figure 4 illustrates the locations downstream of River Ranch Road where bank erosion/recession was observed in comparison with channel conditions in 2006. The banks in this area are generally composed of loosely consolidated alluvial sand and silt (Photo 15). Many abandoned channels are visible in aerial photos through this portion of the study area, the majority of which appear to be plugged with relatively old LWD jams (Photo 16). Newly deposited LWD is scattered across the floodplain or accumulated against obstructions such as standing timber (Photo 17).

Upstream of Scanewa Lake

Immediately upstream of Scanewa Lake, several trees along the channel edge were apparently undermined and have fallen into the channel. Local areas of minor bank erosion were also observed, however, no evidence of significant channel migration was observed (Photo 18).

RESULTS

AVULSION EVENT

Deposition of large sediment loads in the abandoned section of the Muddy Fork channel appears to have been the primary catalyst for the November 2006 avulsion. Sediment and debris flow material generated high in the watershed was transported through the slot canyon to the lower channel and alluvial fan where it deposited en masse, significantly aggrading, and filling the channel. Deposition may have been augmented by the formation of a hydraulic backwater at the confluence with the Clear Fork, indicated by the distribution of sediment deposits observed in the field. A hydraulic backwater may have occurred in response to a channel constriction and/or converging flow vectors (i.e.: high-angle stream confluence). As the active Muddy Fork channel filled (8 feet of alluvium measured), water overtopped the banks. Floodwater flowing across the alluvial fan coalesced along the path of least resistance and highest gradient, forming a new channel that ultimately captured all Muddy Fork flow. As continued flow entered the new channel, it incised (up to 8 feet), effectively cutting off flow to the old channel.

The timing of the November 2006 storm appears to have played a crucial role in the delivery of large volumes of sediment to the alluvial fan, and consequently, the avulsion. Storms occurring in the spring and fall can potentially entrain much greater volumes of sediment than mid-winter storms of equivalent discharge, which occur when sediment is bound by ice and buried beneath a deep snow pack.

The occurrence of avulsions on alluvial fans is common but the timing is highly unpredictable. If an avulsion occurs such that flow from the Muddy Fork impinges directly upon the Timberline community, significant bank recession and undermining of structures in this area is likely (Figure 2b).

EXPECTED CMZ BOUNDARY ADJUSTMENTS

The field reconnaissance findings were further evaluated with respect to sections of the 2002 CMZ that will need to be adjusted. As described above, the findings indicate that the major changes in the CMZ will occur throughout and around the alluvial fan, along the shorelines of the Timberline and High Valley communities, and in the vicinity of River Ranch Road. Figures 5a and 5b illustrate all currently identified sections of the CMZ expected to be modified.

PRELIMINARY HIGH HAZARD AREAS

Avulsion Hazards

The alluvial fan carries a relatively high risk of future avulsions. The occurrence of a major storm prior to development of the snow pack could result in a high sediment yield flow event capable of causing other avulsions of the lower Muddy Fork channel. A new channel could form virtually anywhere on the fan, as well as along the perimeter of the fan. The response of new and existing channels to new avulsion routes is highly unpredictable, but will included at a minimum, significant bank erosion and recession in the Timberline and High Valley areas. Figure 2a identifies high hazard areas associated with avulsion.

MIGRATION HAZARDS

Clear Fork Channel

The current Clear Fork channel is adjusting to the effects of the Muddy Fork avulsion. The left bank is subject to continuing erosion and recession, indicated by post-storm bank erosion resulting in the loss of a residential structure. Significant bank erosion is expected to continue along the left bank in the Timberline Community. Migration hazard areas are identified on Figure 5a.

Braided Channel Section

A relatively large volume of sediment was deposited in a large eddy on the right bank immediately below the new confluence of the Muddy and Clear Forks (approximately 4 feet of sand deposition). As the eddy on the right bank filled with sediment, it steered the channel to the left, cutting off the point bar that had formed on the left bank, directing flow against the right bank much farther downstream than before the avulsion. This resulted in bank erosion and bank recession on the right bank downstream of the eddy ultimately undermining at least one house. Bank erosion is expected to continue along the loosely consolidated right bank downstream of the deposited sand as the channel adjusts to the new flow pattern.

Bank erosion in the braided channel section is stochastic, event-driven, and variable over time and location. Increased bank erosion in braided channels is often correlative with areas of deposition and bar building. The large volume of sediment and accompanying LWD from the November 2006 flood and accompanying avulsion has created many new bars and/or altered the shape and position of existing bars within the high-flow corridor of the braided section of the Upper Cowlitz River. This has changed the flow pattern through much of the river, resulting in many areas where flow impinges on banks. These areas may be subject to bank erosion and possible future migration; Figure 5a identifies potential hazard areas.

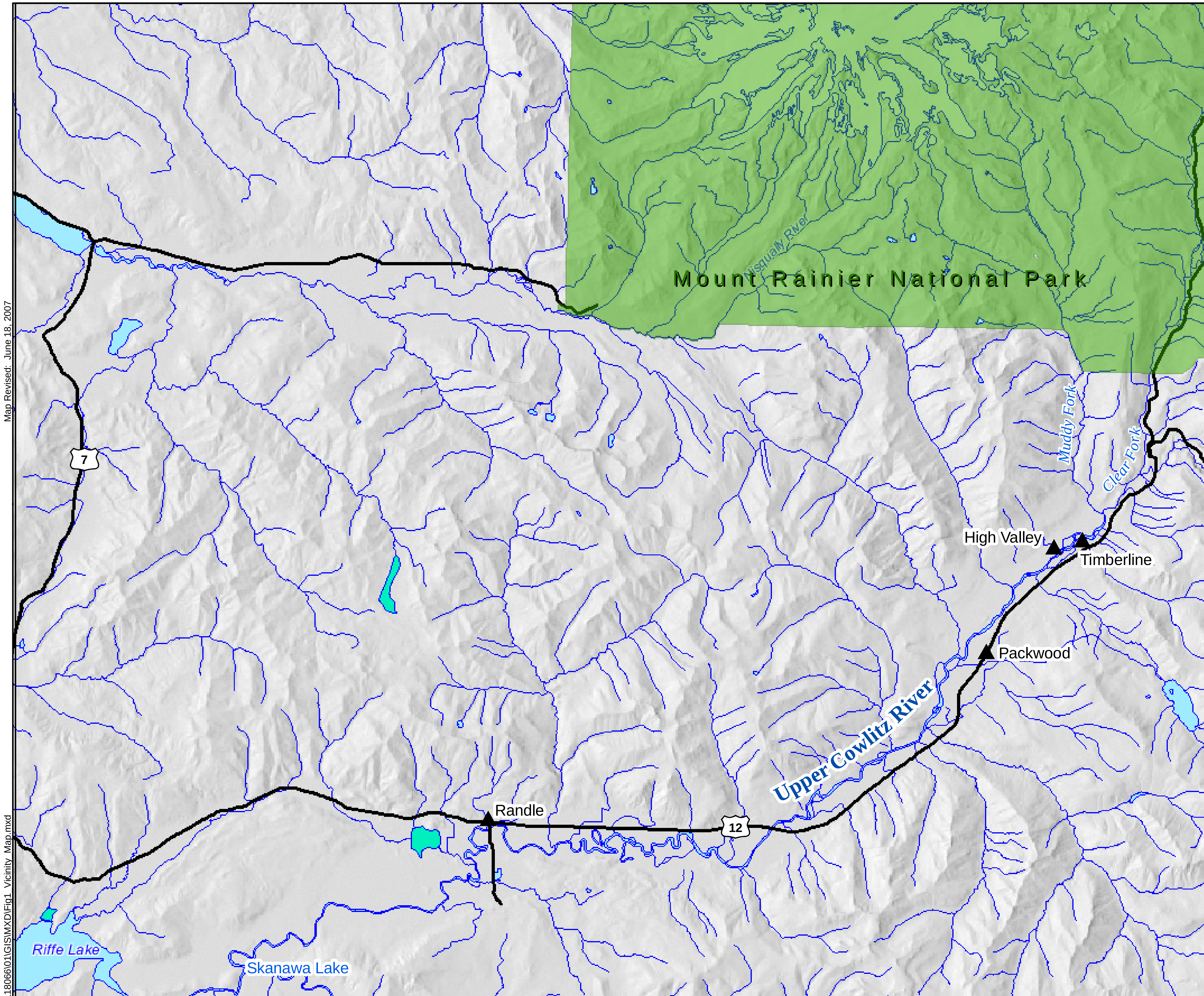
Meander Bend Section

The most notable change in channel pattern through the meander bend section is located near River Ranch Road. Development of a large bar, and a related small bar, resulted in increased channel sinuosity. As sinuosity continues to increase through this reach, stream velocity will diminish, and deposition on the bars will increase perpetuating channel migration. If deposition reduces the hydraulic geometry of the channel by aggrading the streambed, the potential for overbank flow will increase. Flood flow during the November 2006 event diverged from the main-stem in a westerly direction, reentering the channel through Davis Creel. This divergent flood-flow, the gradient, and loose sandy floodplain soils increase the potential for avulsion given possible streambed aggradation in this area.

In the highly sinuous channel section downstream of the River Ranch Road site, bank erosion and recession were observed along several small-radius meander bends. The loose, relatively fine alluvium composing the banks and the predictable nature of meander bend migration suggest channel migration will continue in these areas. Revised migration rates can be calculated once streamlines have been digitized from the 2007 orthorectified aerial photos.

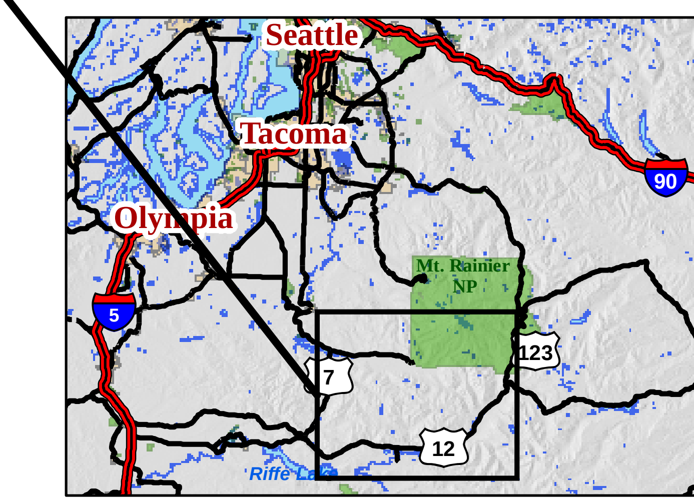
Upstream of Scanewa Lake

The relatively straight reach upstream of Scanewa Lake has not shown significant migration throughout the photo record, but minor bank erosion and fallen trees along the erosive alluvial banks were observed in 2007 indicating that channel widening may be occurring. Secondly, fine-grained sediment was observed in transport through this reach under observed moderate discharge. Upon reaching the slack water of Scanewa Lake, this sediment will be deposited, resulting in aggradation and further potential channel widening. Migration rates and buffers will need to be reevaluated in this area once the 2007 orthorectified aerial photos have been received and analyzed.



Explanation

- State Routes
- Streams (100K)
- Community
- Interstates
- Parks
- Lakes



Miles

0 1 2 4 6 8 10

Reference: State Routes from ESRI Streat Map USA; Streams and lakes from US DNR; 30-meter Hillshade from WA DOE

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Map Revised: June 18, 2007

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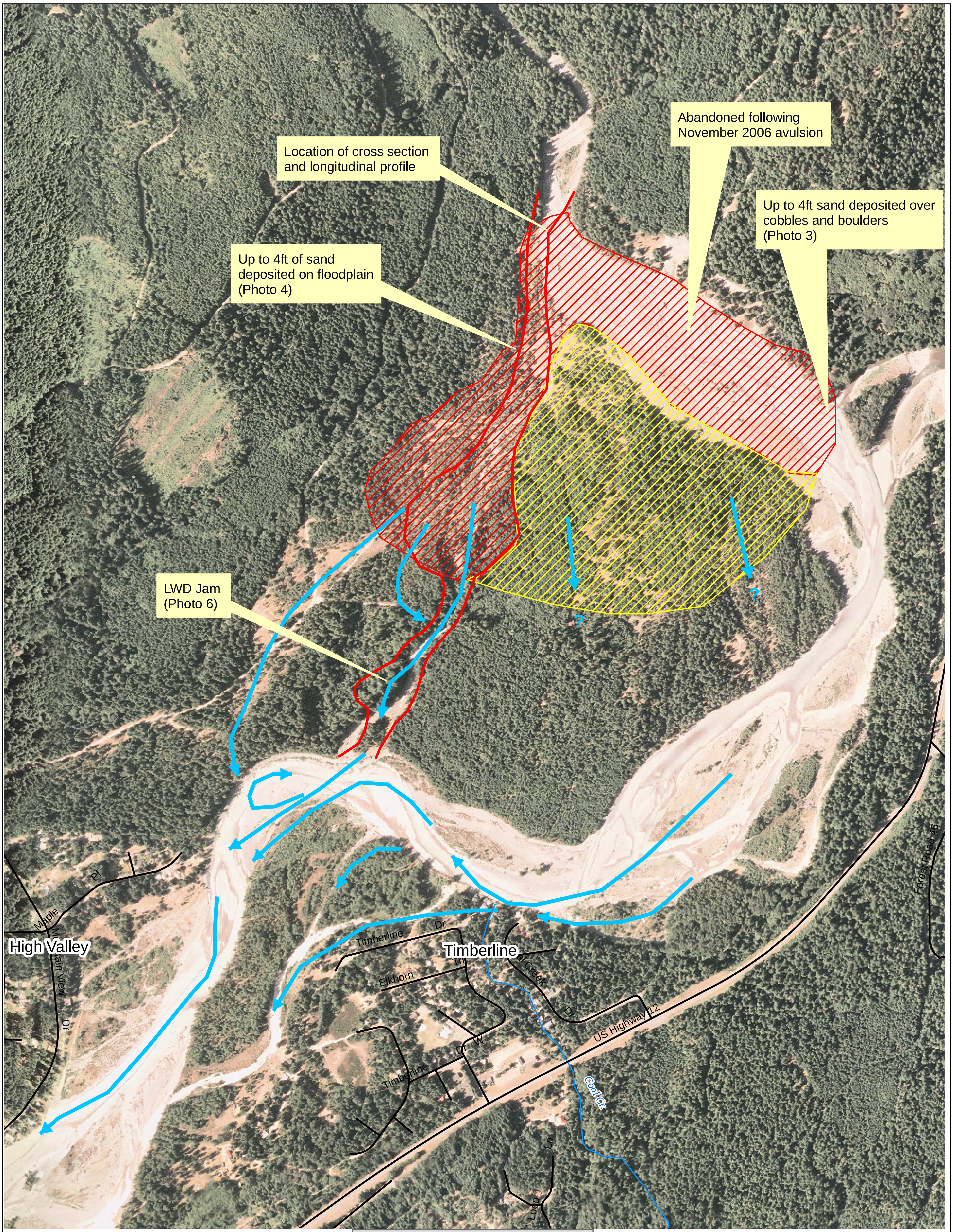
RED

Vicinity Map	
Upper Cowlitz CMZ Assessment -- Lewis Co.	
GeoEngineers	Figure 1



Explanation

- Overland Flood Flow Direction
- Approximate Avulsion Path

Approximate Deposition Area

- Infered
- Observed

0 250 500 1,000 1,500 2,000 Feet

N E S W

Reference:
2006 NAIP orthorectified aerial photos;
Roads from Lewis County;
Approximate avulsion path and deposition area produced by GeoEngineers.

Notes:
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2. This drawing is for infomation 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 document.

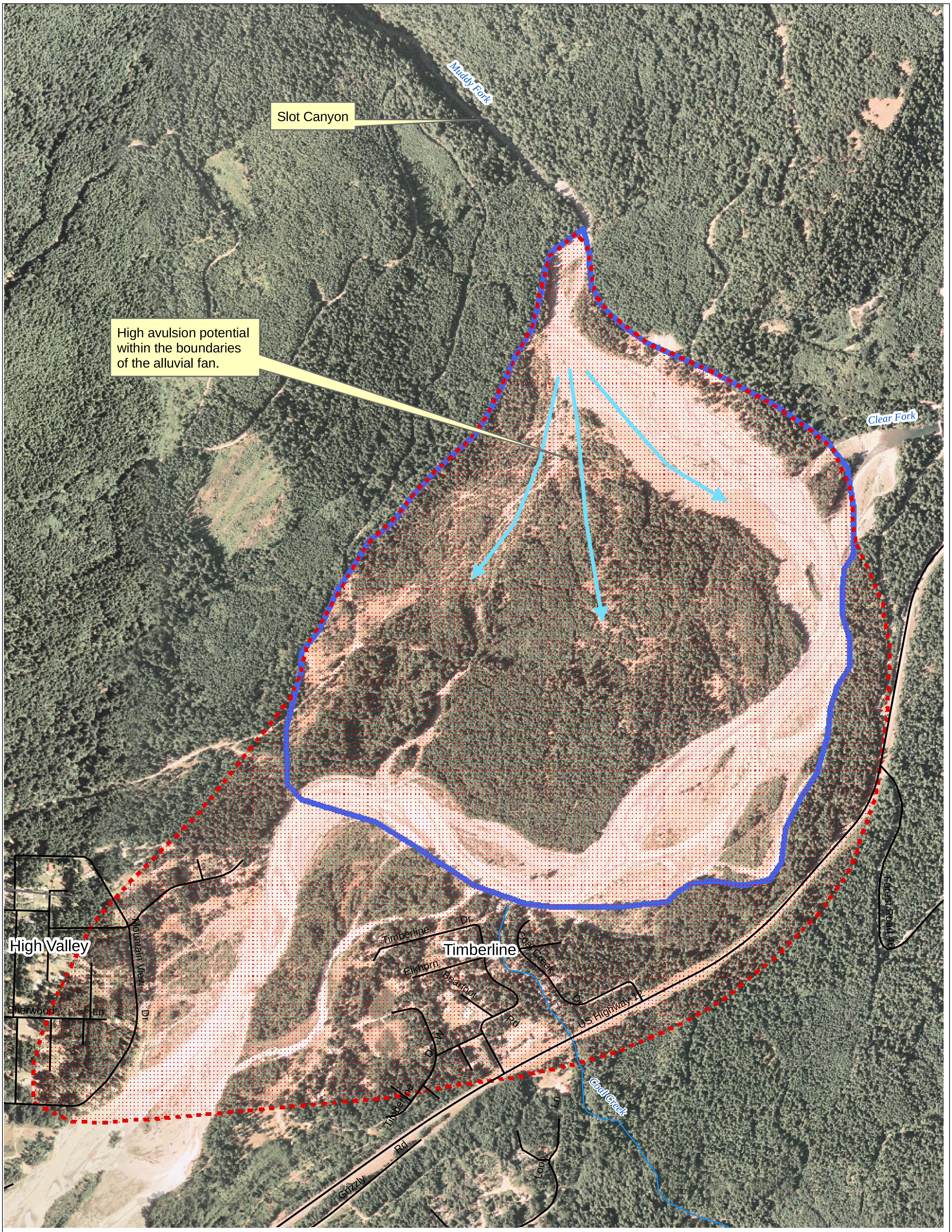
Avulsion Area

Upper Cowlitz CMZ Assessment

GEOENGINEERS

Figure 2a

RED Path: P:\3\3118066\01\GIS\MXD\Fig2_Avulsion_Area.mxd Map Revised: June 8, 2007



Explanation

Possible Avulsion Pathway

High Hazard Area

Alluvial Fan

0 255 510 1,020 1,530 2,040 Feet

N W E S

Reference:
2006 NAIP orthorectified aerial photos;
Roads from Lewis County

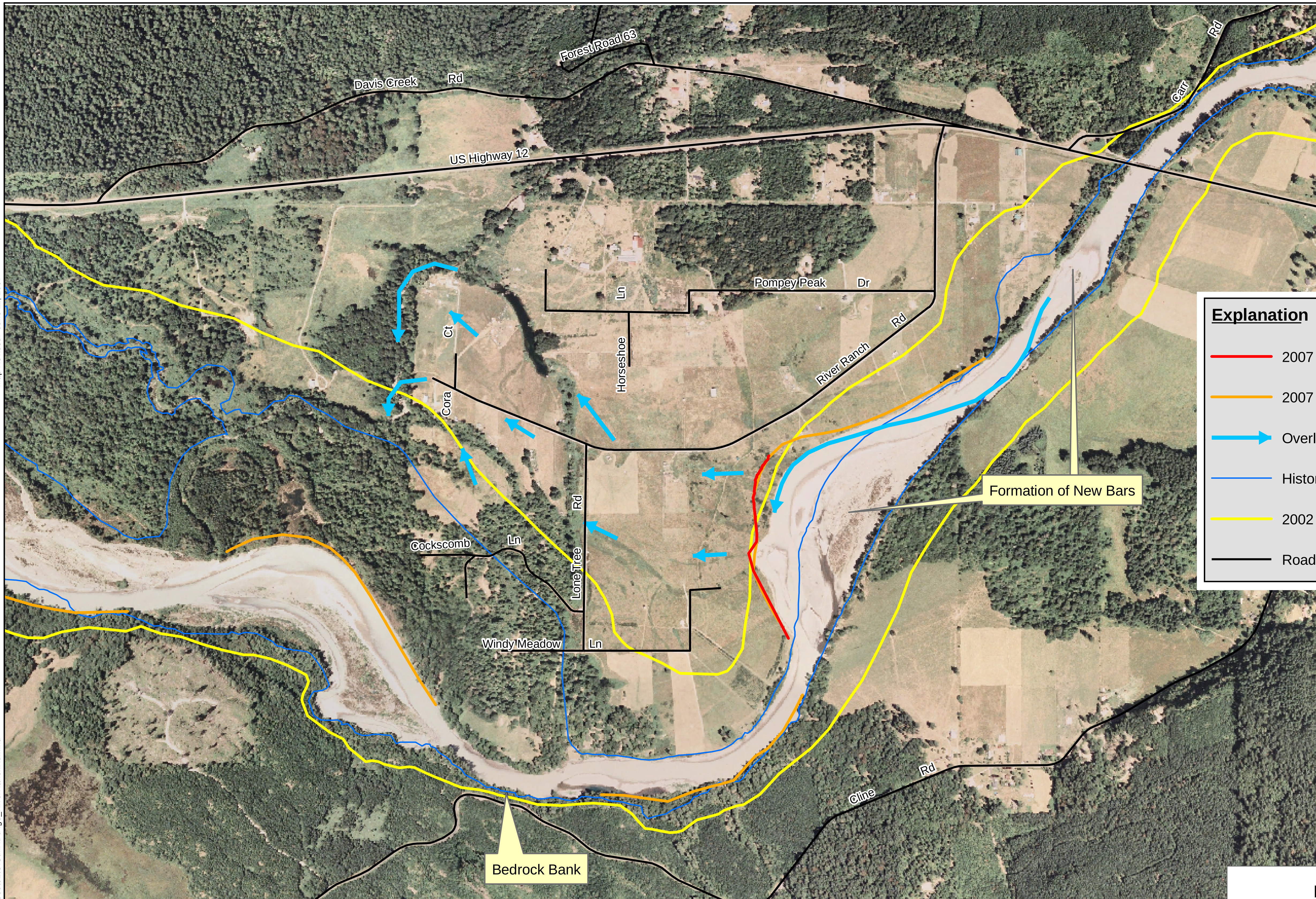
Notes:
1. The locations of all features shown are approximate.
2. This drawing is for infomation purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers,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

Avulsion Area

Upper Cowlitz CMZ Assessment

GEOENGINEERS

Figure 2b



Map Revised: June 11, 2007

Reference: 2006 NAIP Orthorectified Aerial Photos;
Roads from Lewis County

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for infomation 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 document.

Path: P:\3\3118066\01\GIS\MXD\Fig3_RiverRanchRd.mxd

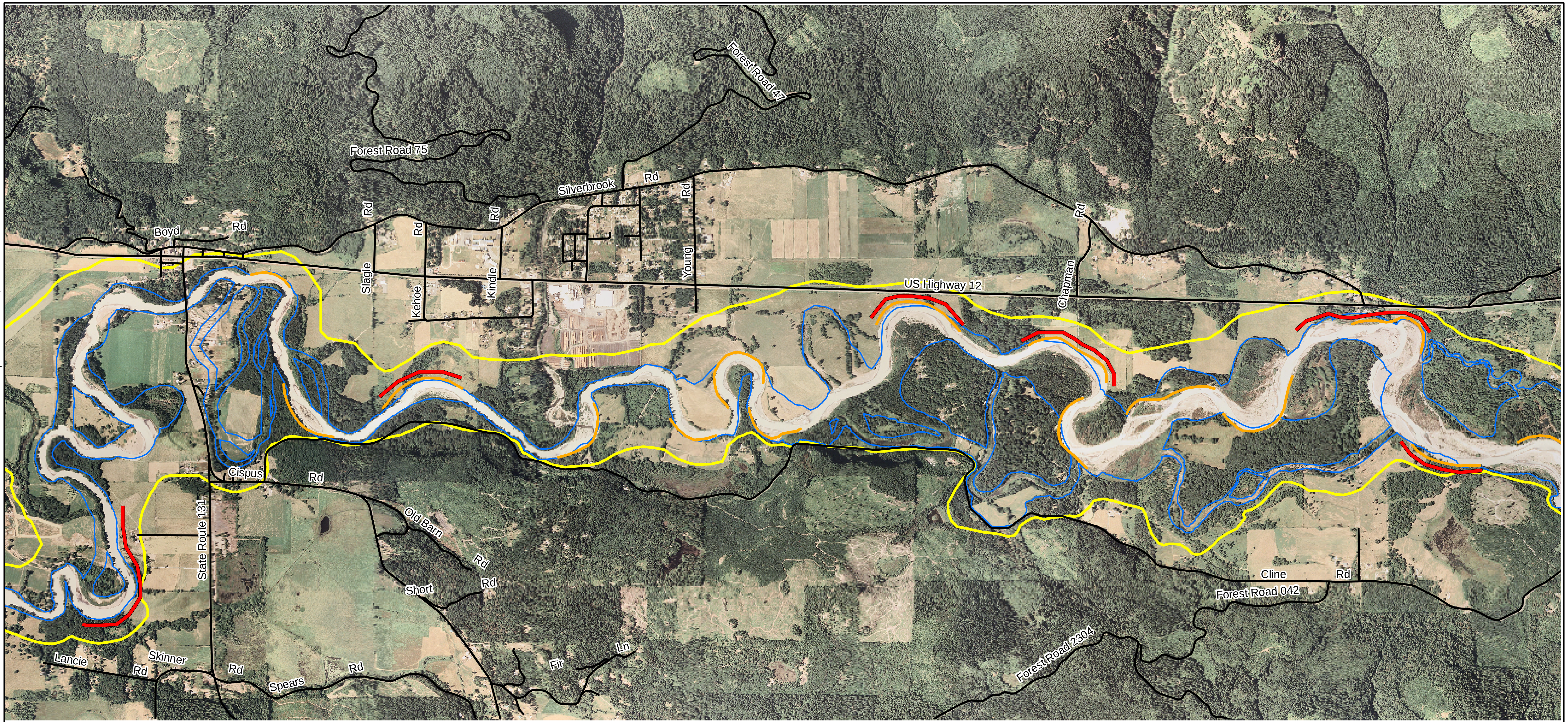
RED

River Ranch Road Area

Upper Cowlitz CMZ Assessment

GeoEngineers

Figure 3



Map Revised: June 18, 2007

Path: P:\3\3118066\01\GIS\MXD\Fig4_Downstream_Meanders.mxd

RED

Explanation

- Roads
- 2007 Bank (GPS helicopter)
- Historic Channel Occupation Tract (1948-1999)
- 2002 CMZ Boundary
- High-Risk Areas

N W E S

0 1,000 2,000 4,000 6,000 8,000 Feet

Reference: 2006 NAIP Orthorectified Aerial Photos;
Roads from Lewis County

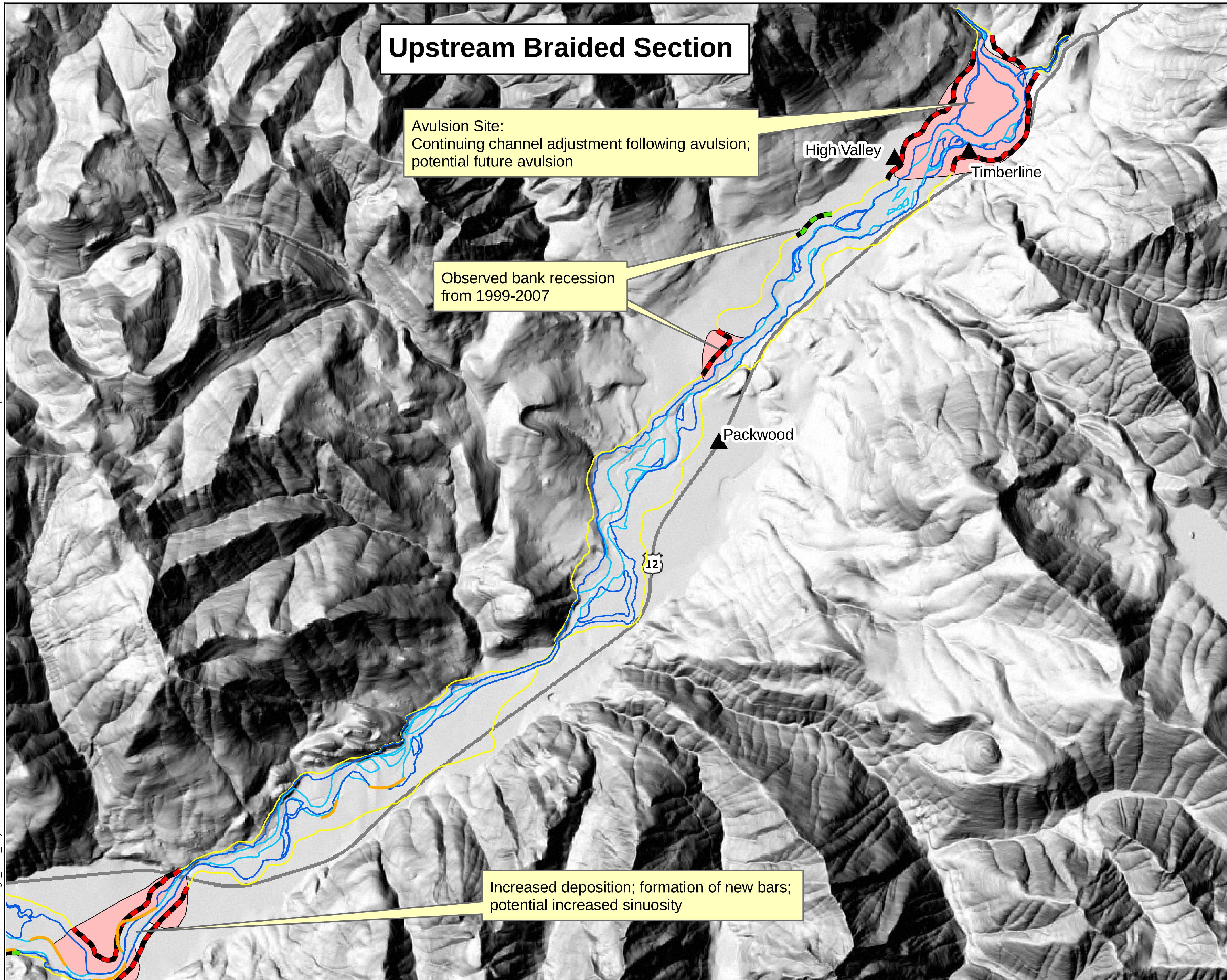
Notes:
1. The locations of all features shown are approximate.
2. This drawing is for infomation purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers,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

Downstream Meanders

Upper Cowlitz CMZ Assessment

GeoEngineers

Figure 4



Explanation

- 2007 Bank (GPS helicopter)
- Future CMZ Adjustment Potential
  - Moderate
  - High
- Historic Channel Occupation Tract (1948-1999)
- 2002 CMZ Boundary
- 2006 River
- Potential Migration Hazard Area
- Community

N W E S

0 0.5 1 2 3 4 Miles

Reference: Streams, Roads, and 10m Hillshade from WA DOE

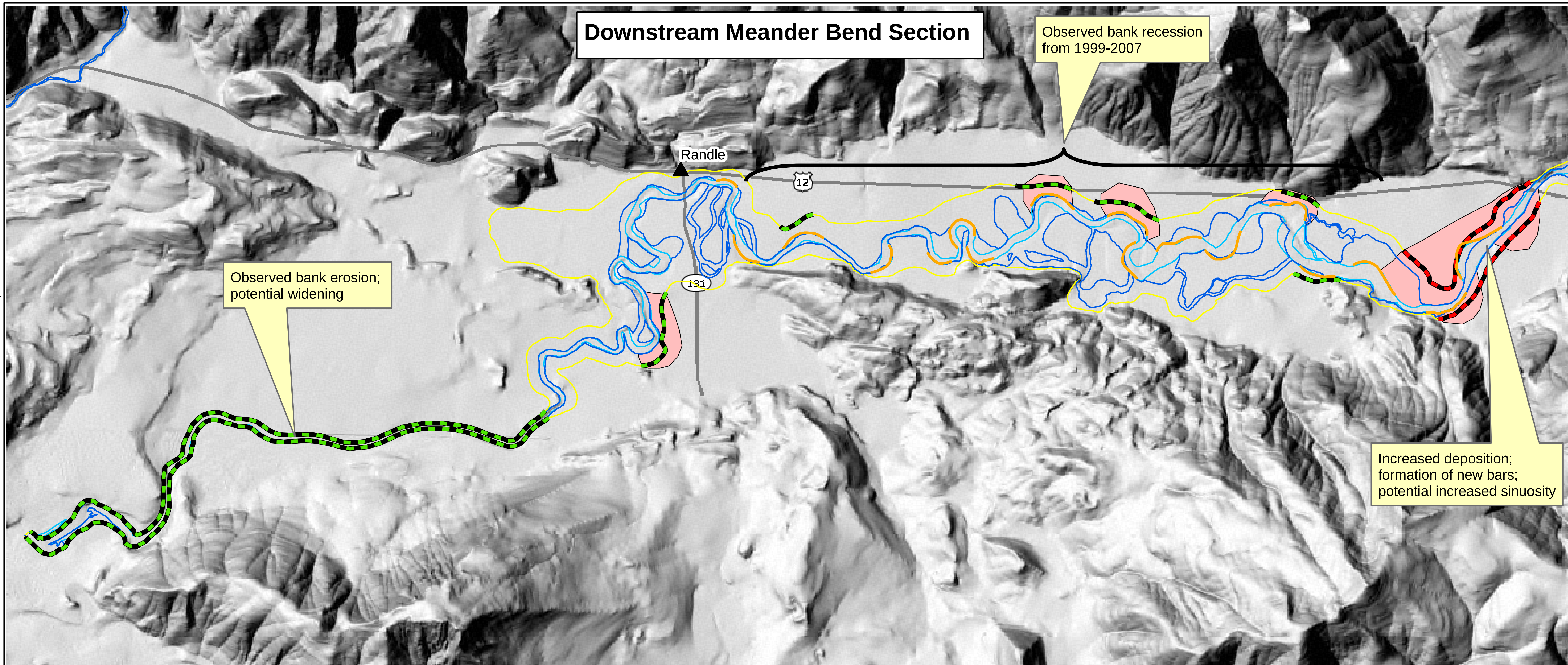
Notes:
1. The locations of all features shown are approximate.
2. This drawing is for infomation purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers,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

Map Revised: June 11, 2007

Path: P:\3\3118066\01\GIS\MXD\Fig5_CMZ_Adjust.mxd

RED

Potential CMZ Adjustment Locations
Upper Cowlitz CMZ Assessment
GeoEngineers — **Figure 5a**



Explanation

2007 Bank (GPS helicopter)

Future CMZ Adjustment Potential

Moderate

High

Historic Channel Occupation Tract (1948-1999)

2002 CMZ Boundary

2006 River

Potential Migration Hazard Area

Community

N S W E

0 0.375 0.75 1.5 2.25 3 Miles

Potential CMZ Adjustment Locations

Upper Cowlitz CMZ Assessment

GeoEngineers

Figure 5b

Reference: Streams, Roads, and 10m Hillshade from WA DOE

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for infomation 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 document.

Map Revised: June 11, 2007

Path: P:\3\3118066\01\GIS\MXD\Fig5_CMZ_Adjust.mxd

RED

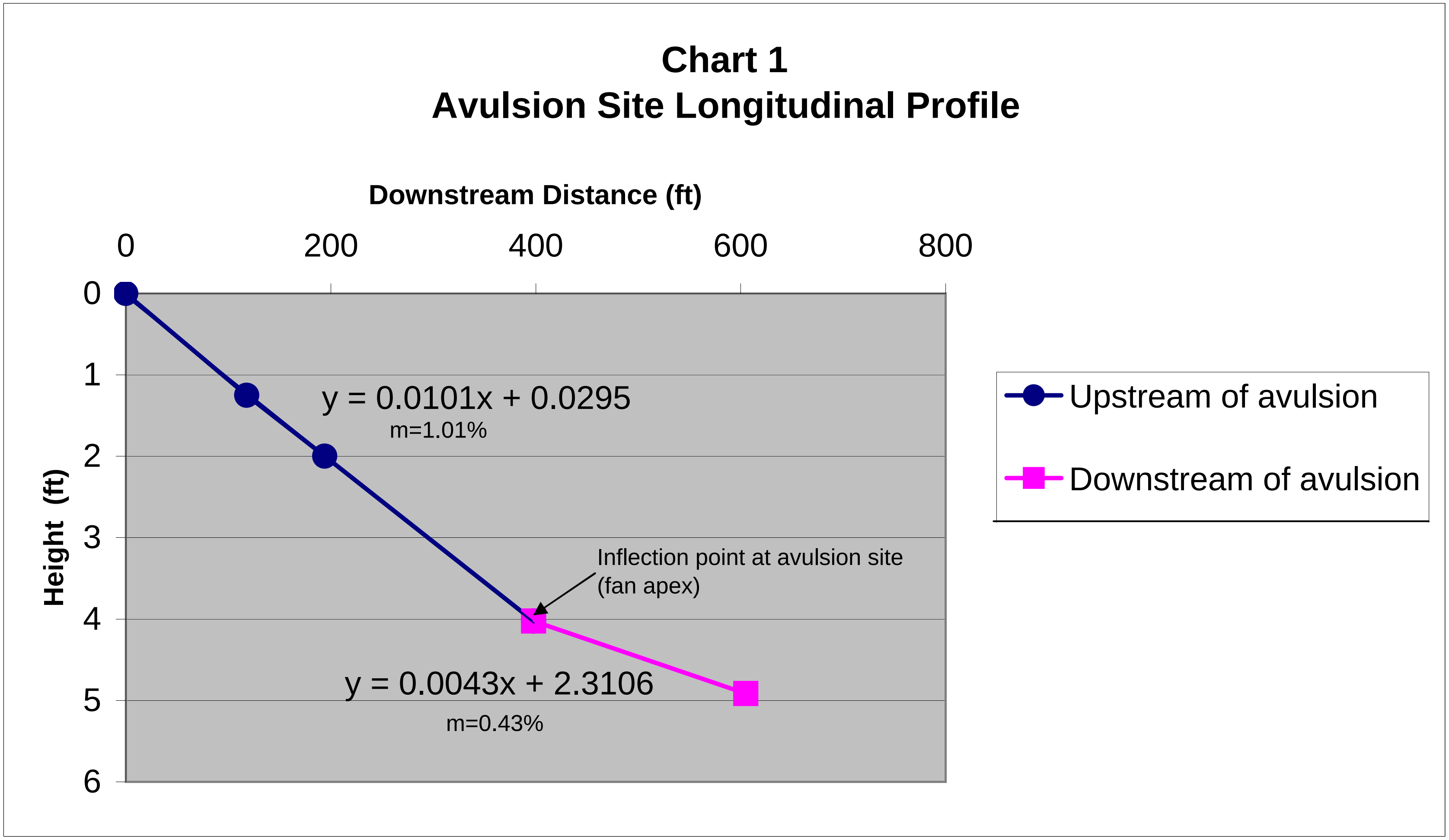


Chart 1
Avulsion Site Longitudinal Profile
Downstream Distance (ft)
0
200
400
600
800
Height (ft)
0
1
2
3
4
5
6
y = 0.0101x + 0.0295
m=1.01%
Inflection point at avulsion site
(fan apex)
y = 0.0043x + 2.3106
m=0.43%
Upstream of avulsion
Downstream of avulsion

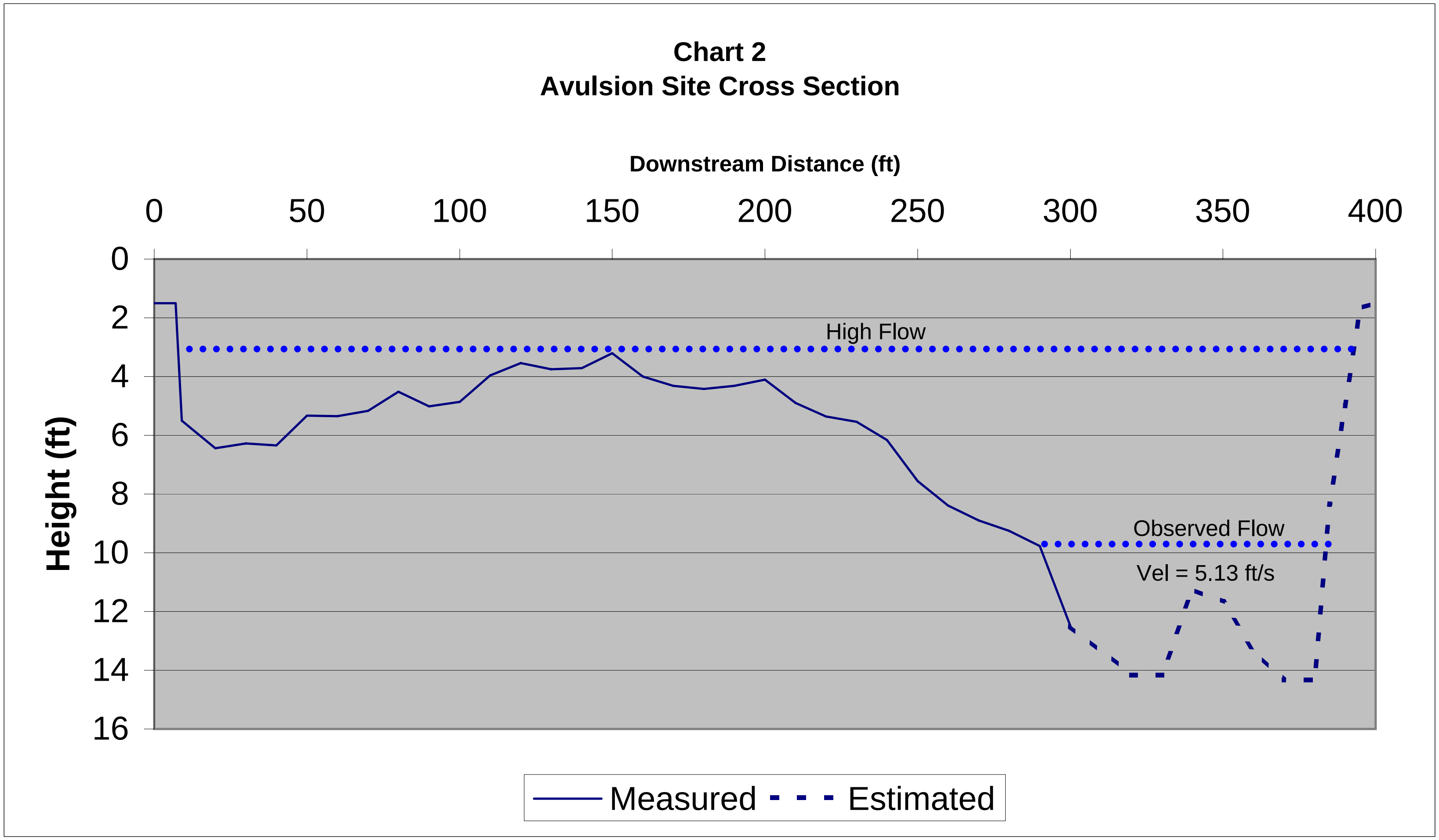


Chart 2
Avulsion Site Cross Section
Downstream Distance (ft)
0
50
100
150
200
250
300
350
400
Height (ft)
0
2
4
6
8
10
12
14
16
High Flow
Observed Flow
Vel = 5.13 ft/s
Measured
Estimated

GeoEngineers

APPENDIX A
APPENDIX A – PHOTOS 1 THROUGH 18

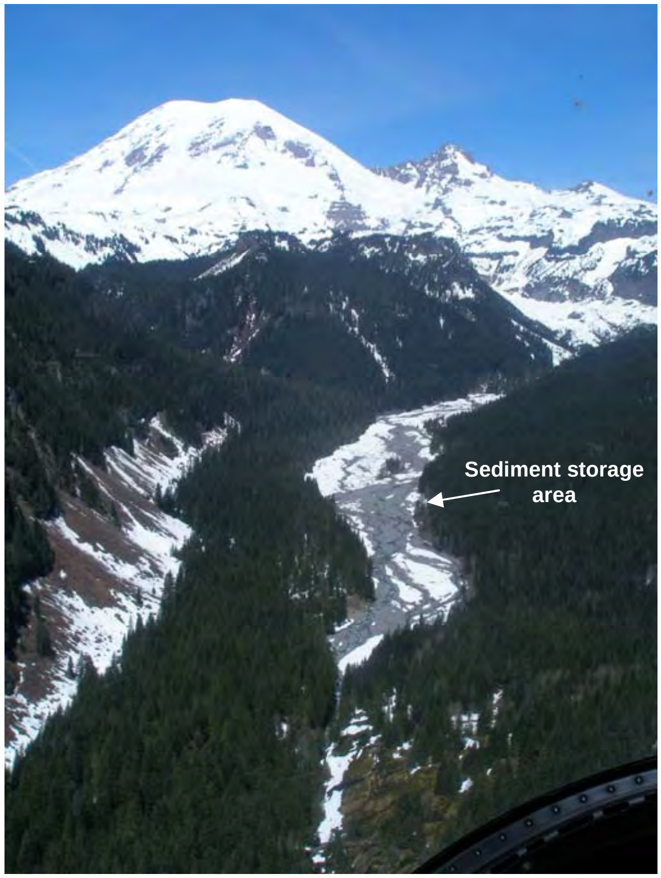


Photo 1: Facing north – Sediment storage area near national park boundary appears full.

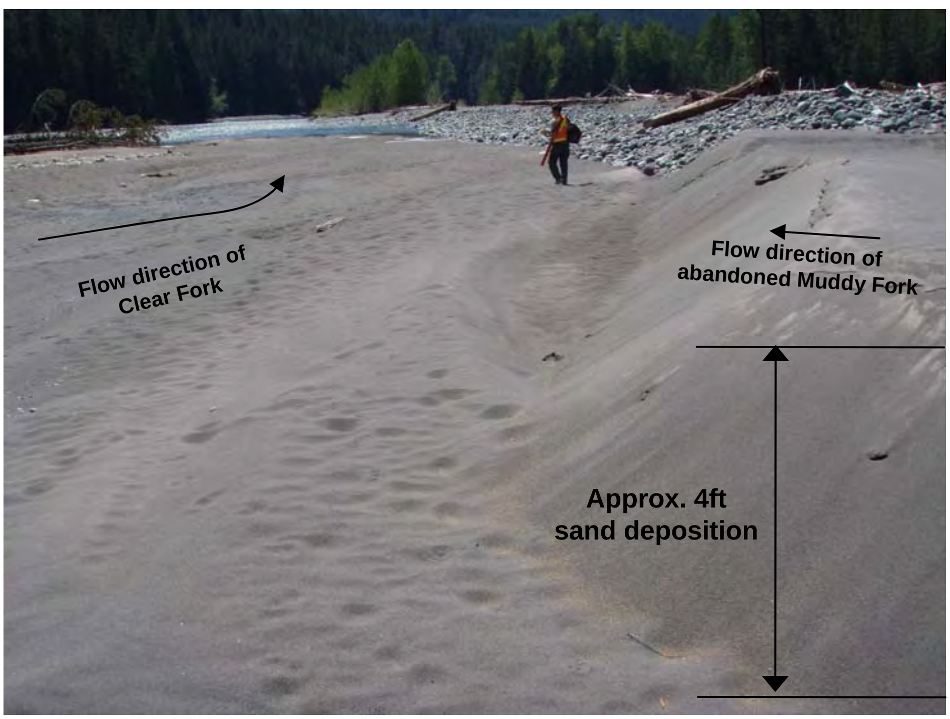


Photo 2: Facing south – Sand deposited by the abandoned Muddy Fork has been eroded by the Clear Fork revealing this exposure

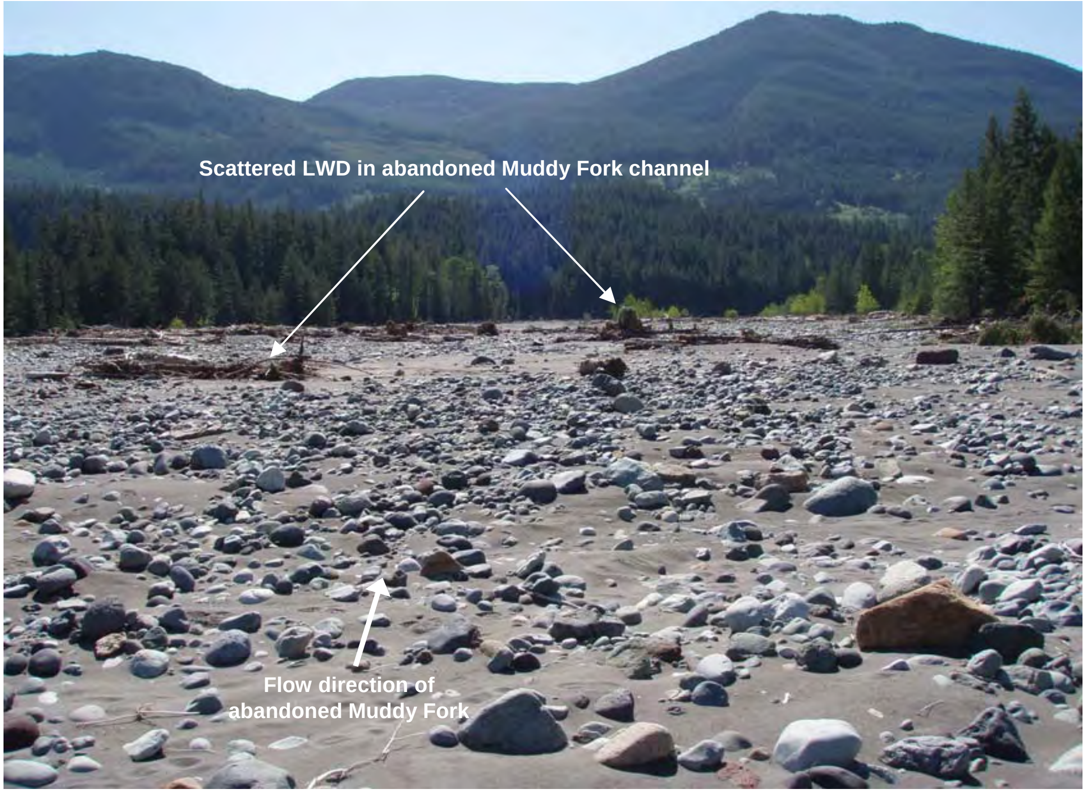


Photo 3: Facing South – Deposition across abandoned Muddy Fork with scattered LWD.

Photo 4: Facing north – LWD jam diverting flow against the right bank near the outlet of the avulsion channel.

RED P:\3\3118066\01\Working\Photo_Figures.ppt

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Photos 3 and 4	
Upper Cowlitz CMZ Assessment	

Photo 5: Facing north – Incision at outlet of Muddy Fork avulsion channel

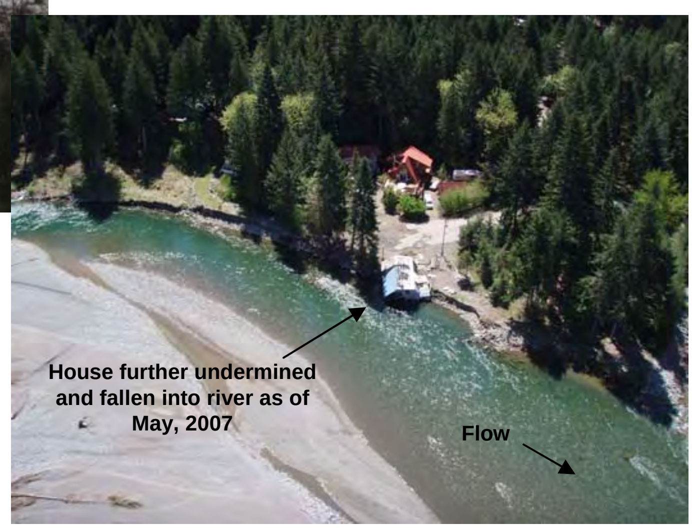

Photo 6: Facing east – Bank recession following November 2006 floods at Timberline.

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Photos 5 and 6

Upper Cowlitz CMZ Assessment

Photo 7: Facing south – Thin layer of sand deposition on the left bank floodplain at Timberline.

Photo 8: Facing north – Sand deposited against rip-rap on the right bank below the avulsion near High Valley community.

Photo 9: Facing south – New rip-rap placed in front of house in High Valley Community.

Photo 10: Facing north – Bank recession in High Valley community resulted in a lost house. No evidence of flow overtopping the bank.

GEOENGINEERS	Photos 9 and 10
	Upper Cowlitz CMZ Assessment

Photo 11: Facing south –Bank erosion on braided river section near Packwood.

Photo 12: Facing south – Erosion of right bank composed of silt and sand near River Ranch Road.

Photo 13: Facing south – Sand deposition on the right bank floodplain along River Ranch Road.

Photo 14: Facing north east – Travel trailers and mobile homes tipped on their sides from high-flows.

Photo 15: Facing east – Erosion of right bank composed of silt and fine sand; near Randle.

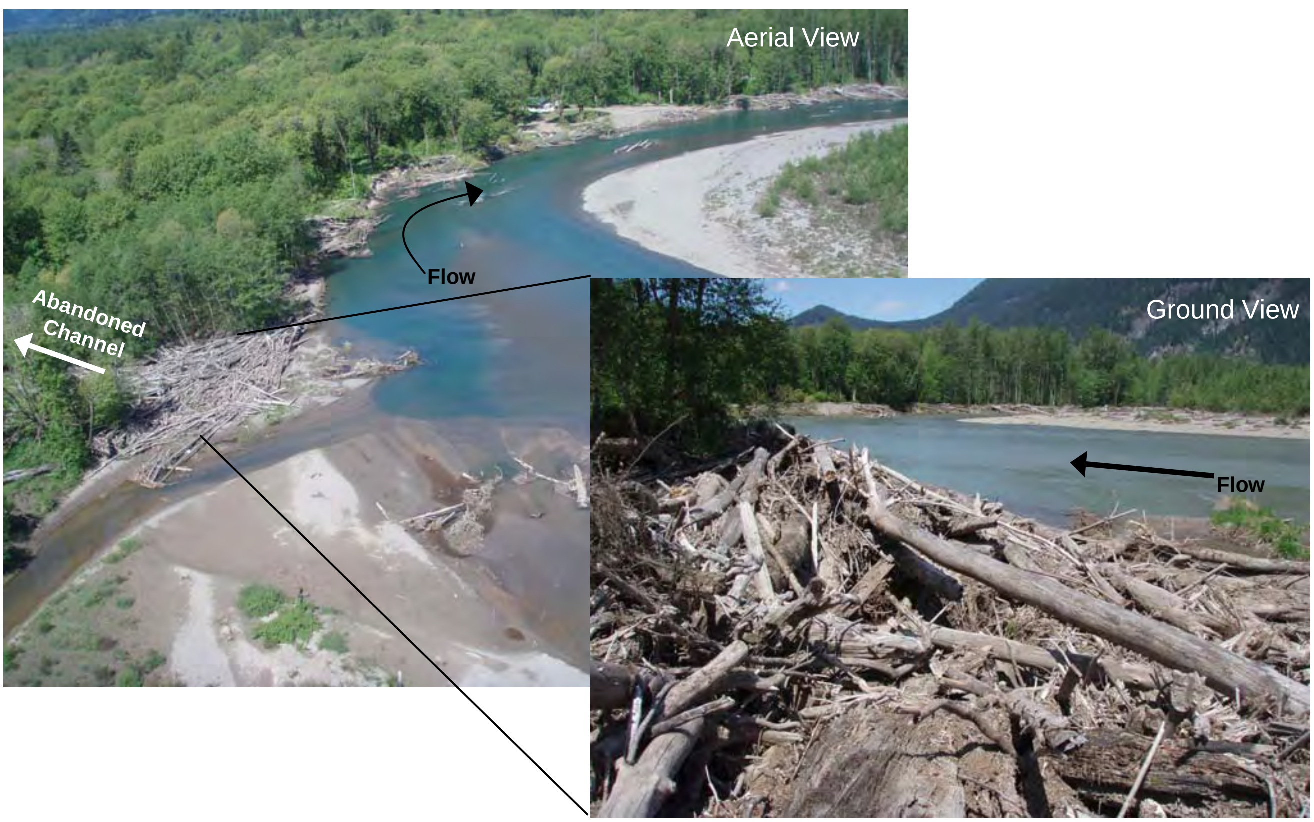


Photo 16: Facing west – Relatively old LWD blocks inlet to abandoned channel of the Upper Cowlitz on the left bank near

GeoEngineers

Photos 15 and 16

Upper Cowlitz CMZ Assessment

RED P:\3\3118066\01\Working\Photo_Figures.ppt

Photo 17: Facing south – LWD accumulated against trees on the right bank floodplain near Randle.

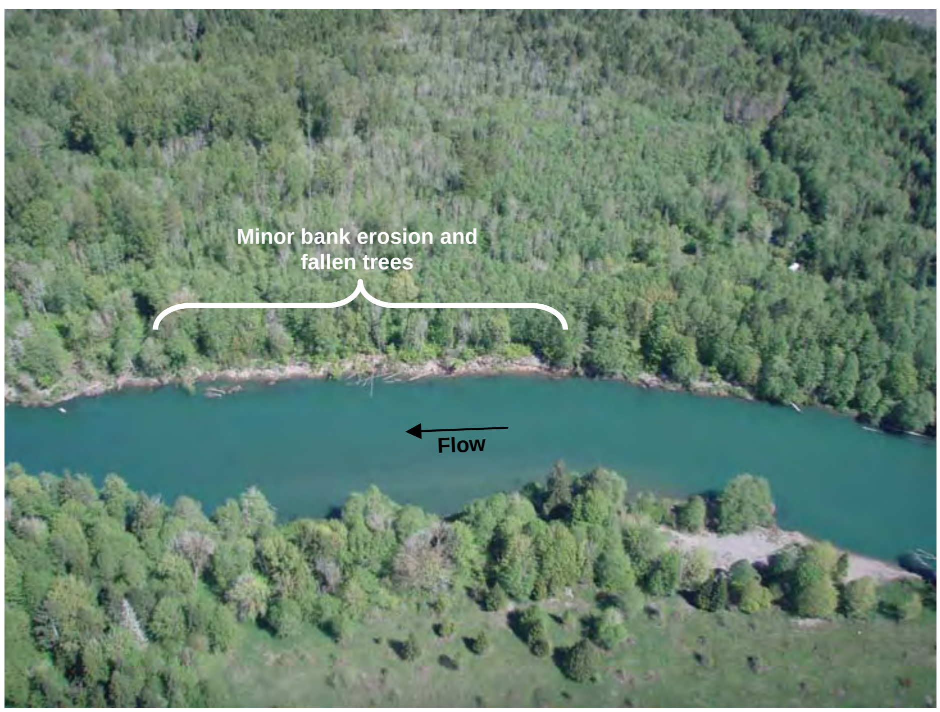


Photo 18: Facing north – Minor bank erosion and fallen trees immediately upstream of Scanawa Lake.

APPENDIX B
GEOMORPHIC REACH CHARACTERISTICS

APPENDIX B
GEOMORPHIC REACH CHARACTERISTICS

REACH 1 FROM MP 0.0 TO 0.3 MUDDY FORK GORGE

Channel Form

Within this project reach, the Muddy Fork consists of an incised gorge in bedrock with no flood plain. The channel form is straight with an average gradient of approximately 1% and nearly vertical cut banks. Bed material consists primarily of boulders and cobbles. Banks are composed of bedrock in the upstream portion of the reach and glacial alpine drift and coarse alluvium in the downstream portion of the reach.

Channel Process

Transport of sediment through the single channel appears to dominate the channel process in this reach. The bedrock on both sides of the bank inhibits lateral erosion.

Channel Function

Channel form and process suggest Reach 1 is a transport-dominated reach with roughly equal amounts of sediment input as output. As sediment is lost to local scour, sediment derived from upstream erosion replenishes the lost bed material maintaining channel form.

REACH 2 FROM MP 0.3 TO 1.5 DYNAMIC AVULSION AREA

General

An avulsion occurred on the Muddy Fork in November of 2006, abandoning several hundred feet of channel and moving the confluence of the Muddy Fork and Clear Fork approximately 5,000 feet downstream from its previous location.

Channel Form

Within this project reach, the Clear Fork consists of a main channel with several side channels creating braided channel pattern within a high flow corridor. The high-flow corridor itself appears to exhibit a sinuous plan-form with a sinuosity of approximately 1.14 (channel length / valley length). Channel geometry consists of nearly vertical cut banks along the outsides of bends with gently sloping point bars on the insides of bends. Bed material is generally composed of large cobbles and boulders with sand filling the granular interstices. Banks are composed of loosely consolidated gravel and cobbles with varying amounts of sand. A small natural levee is forming along the left bank adjacent the abandoned Muddy Fork channel. Log jams and scattered large woody debris (LWD) have accumulated in the lower portion of Reach 2 and appear well embedded and relatively stable within the high flow corridor.

The floodplain between the two Forks of the Upper Cowlitz River forms a broad alluvial fan and consists primarily of boulders, cobbles and sand and is vegetated with evergreen trees.

Channel Process

Deposition appears to be the dominant channel process in reach 2 driving bank erosion and avulsion. Historic aerial photos revealed continuing channel migration on the left bank of the Clear Fork near the

Timberline community since the 2006 avulsion. The Muddy Fork channel appears to be adjusting to the 2006 avulsion by widening its high flow corridor. A relatively large amount of LWD has accumulated in the channel and high flow corridor of the Muddy Fork near its confluence with the Clear Fork, which has exacerbated bank erosion related to channel widening.

The dynamic nature of this reach is further exemplified by the bed material which is generally loose, poorly packed, recently deposited alluvium. The potential for significant additional sediment loading in this reach of the Muddy Fork greatly increases the potential for avulsion which, based on the local topography, could occur at nearly any location on the alluvial fan between the Muddy Fork and Clear Fork. If an avulsion occurs, flow patterns may be affected in the vicinity of the High Valley or Timberline Communities resulting in potential bank recession in these areas.

Channel Function

Channel form and process suggest this reach is currently adjusting to the recent avulsion by widening or otherwise eroding its banks to accommodate the large volume of sediment delivered to the reach during the avulsion. Furthermore, the abundance of available sediment and LWD decreases channel stability resulting in increased channel migration, side-channel development, localized bed scour, and the potential for another avulsion.

REACH 3 FROM MP 1.5 TO 4.3 BRAIDED SECTION

Channel Form

Within this reach the Cowlitz River exhibits a primarily braided channel pattern. The high flow corridor associated with the braided channel has a moderately sinuous plan-form with a sinuosity of approximately 1.2. Numerous sparsely vegetated sediment bars are present throughout the reach. LWD is also present along the banks and on the many of the bars. The majority of each piece of wood is visible on top of the surrounding alluvium, suggesting the LWD is not well embedded and therefore may be subject to downstream transport. Channel geometry consists of wide, shallow channels with numerous islands/bars and terraced banks. Bed material is generally composed of large cobbles and coarse gravel with sand filling the granular interstices. Banks are composed of gravel and cobbles overlain by fine sand with silt. The floodplain is broad and consists primarily of fine sand with silt and is well vegetated with evergreen trees, shrubs, and grass.

Channel Process

Braided channel migration appears to dominate channel process in the study reach. The bed and bank material is generally loose, poorly packed, and lacks significant surface armor suggesting the bed is frequently mobilized. The unconsolidated bank material is subject to frequent erosion resulting in channel migration and the lateral shifting of bars and islands. During field reconnaissance, erosion was especially evident where mature riparian vegetation was absent or vertical banks were greater than the rooting depth of riparian vegetation.

Channel Function

Channel form and process suggest this reach is subject to episodic inputs of large volumes of sediment. In between periods of sediment loading, the channel slowly incises its bed, abandoning the floodplain during all but the largest floods. This was the case during the November 2006 flood, where bank overtopping and flooding was rare. Since the 2006 flood, sediment from Reach 2 has been remobilized and transported into Reach 3 increasing the potential for aggradation and increased rates of bank erosion. Future inputs of sediment will further increase the potential for aggradation and bank erosion in this reach.

REACH 4 FROM MP 4.3 TO 6.5 BRAIDED SECTION WITH CONSTRICTION

Channel Form

This reach is similar in form to Reach 3 with the exception of erosion resistant material on much of the left bank limiting the majority of observed migration to the right bank. The high flow corridor is relatively straight with a sinuosity of approximately 1.05. Numerous sparsely vegetated sediment bars are present throughout the reach. LWD is also present along the banks and on several of the bars. The majority of each piece of wood is visible on top of the surrounding alluvium, suggesting the LWD is not well embedded. Also, the volume of LWD appears to be decreasing compared with upstream reaches. Channel geometry consists of a wide, braided channel with numerous islands/bars becoming narrow and constricted at the downstream end of the reach. Bed material is generally composed of small cobbles and coarse gravel with sand filling the granular interstices.

Banks are composed of gravel and cobbles overlain by fine sand with silt. The left bank is composed primarily of bedrock and dense, erosion resistant glacial sediment. The floodplain consists primarily of fine sand with silt and is well vegetated with evergreens, shrubs, and grass.

Channel Process

Channel processes in Reach 4 are dominated by deposition and bank erosion, with the exception of the downstream third of the reach where the banks are composed of erosion-resistant material. In the downstream third of the reach, the channel becomes constricted, increasing in-stream velocities, resulting in sediment entrainment and increased potential for scour.

Channel Function

Channel form and process suggest Reach 4 is a transitional reach dominated by aggradation and subsequent bank erosion upstream, and high-velocities with accompanying scour downstream.

REACH 5 FROM MP 6.5 TO 10 BRAIDED SECTION WITH LARGE FLOODPLAIN

Channel Form

Reach 5 is braided with a high-flow corridor significantly wider than Reach 4. The high-flow corridor has a moderately sinuous plan-form with a sinuosity of approximately 1.25. Multiple vegetated islands and bars are present throughout the reach. Landslide deposits and other erosion resistant materials compose most of the right bank, while the left bank is composed primarily of loosely consolidated alluvium. The braided river is perched above portions of the floodplain, particularly the low-lying areas on the east side of the town of Packwood.

There is scattered LWD throughout the reach, and the volume of LWD appears to be decreasing compared with upstream reaches. As with upstream, the individual pieces of wood appear to be poorly embedded.

Bed material is generally composed of gravel with cobbles and sand. The floodplain is very broad and consists primarily of sand with silt and is well vegetated with evergreens, shrubs, and grass and is occupied by numerous abandoned side channels.

Channel Process

Deposition and associated channel migration dominate channel processes in this reach. The channel and floodplain broaden significantly downstream of the constriction of the Skate Creek Bridge and bedrock confinement upstream, which reduces the transport capacity of the channel, thereby increasing deposition. Further enhancing the depositional character of the channel is a hydraulic backwater that forms at the downstream end of the reach in response to a constriction downstream.

Channel Function

Throughout Reach 5, the channel functions as a braided stream subject to frequent and sporadic channel fluctuation within the braided high-flow corridor. Furthermore, aggradation will likely continue to impact this reach as a result of the sediment supply derived from upstream sources, the accommodation area for deposition in the broad floodplain, and the hydraulic backwater at the downstream end of the reach.

REACH 6 FROM MP 10.0 TO 11.3 CONSTRICTED REACH

Channel Form

Within this project reach, the Cowlitz River consists of a single straight, deep, narrow channel. The channel is confined on both banks in the central and downstream portion of the reach by bedrock and large boulders and coarse material embedded in a cohesive matrix derived from an ancient mass failure and modern alluvial fan deposition from tributary streams. The bed is generally composed of coarse gravel and cobbles with sand, while the banks are composed of debris flow and alluvial fan deposits overlain by a thin layer of overbank silts and sands. The floodplain has been disconnected from the main-stem under all but the most severe floods.

Channel Process

Sediment transport appears to be the dominate channel process in the Reach 6. The confined channel has incised into the debris flow and alluvial fan material exposing erosion resistant boulders and bedrock in the bed and banks limiting migration.

Channel Function

Channel form and process suggest the project reach is generally stable. Sediment entering the reach from upstream or from tributaries is generally transported through the reach and deposited downstream, and erosion-resistant bank material inhibits bank recession.

REACH 7 FROM MP 11.3 TO 16.3– TRANSITIONAL REACH

Channel Form

Within Reach 7, the Cowlitz River begins to transition from a primarily braided channel plan form to a primarily single-threaded, sinuous plan form. The main channel has a sinuosity of approximately 1.3. Channel geometry consists of nearly vertical cut banks along the outsides of bends with gently sloping point bars on the insides of bends. Bed material is generally composed of coarse gravel with occasional cobbles and sand filling the granular interstices. Banks are composed of silts and sands with ash layers. The floodplain is broad and consists primarily of fine sand with silt and is vegetated with deciduous trees, shrubs, and grass. Numerous side channels and high-flow channels are present in the floodplain, particularly on the left bank.

An oxbow lake (Bevin Lake) is present near the eastern border of the valley. The lake no longer appears to be surficially connected to the current river system except during large floods.

Channel Process

Meander bend migration associated with point bar accreation appears to dominate channel process in the study reach. Meander bend migration involves erosion of the outside bank of a bend coupled with concurrent deposition of sediment along the inside bank of the same bend. This process results in the lateral movement of the channel, while maintaining consistent channel shape and width.

Channel Function

Over the period of record the channel has displayed relatively consistent lateral meander bend migration with a relatively small downstream component to the channel movement. The erosion rates and bar growth at each bend depend on the amount of available sediment entering the reach. As increasing amounts of sediment move through the system from upstream sources, migration rates are anticipated to increase, possibly resulting in a meander bend cut-off avulsion.

REACH 8 FROM MP 16.3 TO 24.5; RIVER RANCH ROAD; MEANDERS AND MIGRATION

Channel Form

Through Reach 8, the river is predominantly single threaded with a meander bend morphology and occasional, side channels. The sinuosity of the main channel is approximately 1.6. Through this reach numerous ancient and historic channel features are present in the floodplains including abandoned channels and oxbow lakes. The relative volume of woody debris in the channel is less than upstream reaches. Channel geometry consists of nearly vertical cut banks along the outsides of bends with gently sloping point bars on the insides of bends. Bed material is generally composed of coarse gravel with sand. Banks are composed of fine sand with silt. The floodplain is broad and consists primarily of fine sand with silt and is vegetated with shrubs and grass with varying amounts of timber. The numerous side channels and floodways located in the floodplain suggest the floodplain is well connected to the river and is fairly active.

Channel Process

Meander bend migration appears to dominate channel process in the study reach. Historic aerial photos revealed up to approximately 650 feet of channel migration in a 61 year period (1945 to 2006). We observed bank erosion on the outsides of most bends, especially where mature riparian vegetation is absent or vertical banks are greater than roughly 3 feet high (greater than rooting depth).

Channel Function

Channel form and process suggest the project reach is generally well balanced between aggradation and incision. Lateral channel migration has increased in severity during the past decade, but bank recession is generally offset by the lateral accretion of point bars.

REACH 9 FROM MP 24.5 TO 34; MEANDERS WITH MINOR MIGRATION

Channel Form

The reach follows a highly sinuous path with a sinuosity of approximately 1.9. Numerous abandoned channels and oxbow lakes are present in the floodplain. Channel geometry consists of nearly vertical cut banks along the outsides of bends with gently sloping point bars on the insides of bends. Bed material is generally composed of fine cobbles and coarse gravel with sand. Banks are composed of fine sand with silt, and cohesive silt and clay in some locations. The floodplain is broad and consists primarily of fine sand with silt and is vegetated with shrubs, grass, and trees.

Channel Process

Channel processes are minimal throughout Reach 9 as a result of low in-channel velocities. Minimal bank erosion was observed, but negligible migration rates were measured along most bends.

Channel Function

Reach 9 is relatively stable, exhibiting minimal meander bend migration, scour, or deposition.

REACH 10 MP 34 TO LAKE SCANAWA

Channel Form

Reach 10 is relatively straight with a sinuosity of 1.2. Channel geometry is relatively uniform with little observable difference between banks on the inside or outside of bends. Bed material is generally composed of sand and silt. The floodplain is narrow and confined between high terraces composed of erosion-resistant cohesive material (glacial till).

Channel Process

The backwater from Lake Scanewa reduces in-channel velocity through Reach 9 creating a lake-like environment promoting deposition of fine particles. Minor channel widening has occurred as the bed slowly aggrades from fine particle deposition over time.

Channel Function

The increased sediment load from the 2006 avulsion may result in greater rates of deposition and therefore bed aggradation and channel widening through Reach 9.

GeoEngineers

APPENDIX C
AVULSION CALCULATIONS

1: Avulsion Potential Workbook

Project:	Upper Cowlitz CMZ
Project Number:	3118-066-03
Client:	Lewis County
Consultant:	GeoEngineers, Inc.

Workbook Description

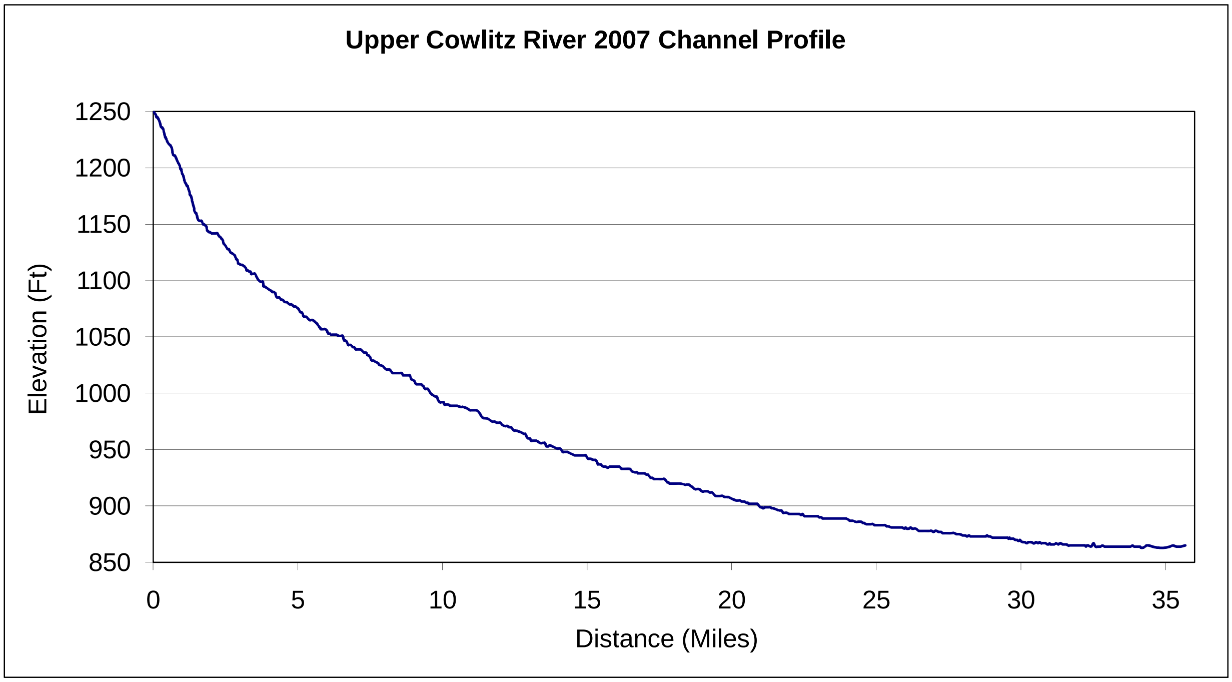
- This workbook is proprietary to GeoEngineers, Inc.
- This workbook contains worksheets used to calculate and display channel profiles.
- Data inputs are highlighted in BLUE, all other cells are calculated automatically.

Filename:	*P:\3\3118066\03\Working\Reporting\Report_Text\[311806603_App_C.xls]Intro*
Project:	Upper Cowlitz CMZ
Project No:	3118-066-03
Client:	Lewis County
Consultant:	GeoEngineers, Inc.
Sub-Consultant:	N/A
Latest Revision:	April 1, 2009
Practicitioner:	Rob R.
	Tricia DeOme

Sheet Titles:	1: Avulsion Potential Workbook
	2: Main Channel Graph
	3: Potential Avulsion Path 1
	4: Potential Avulsion Path 2
	5: Potential Avulsion Path 3
	6: Potential Avulsion Path 4
	7: Potential Avulsion Path 5

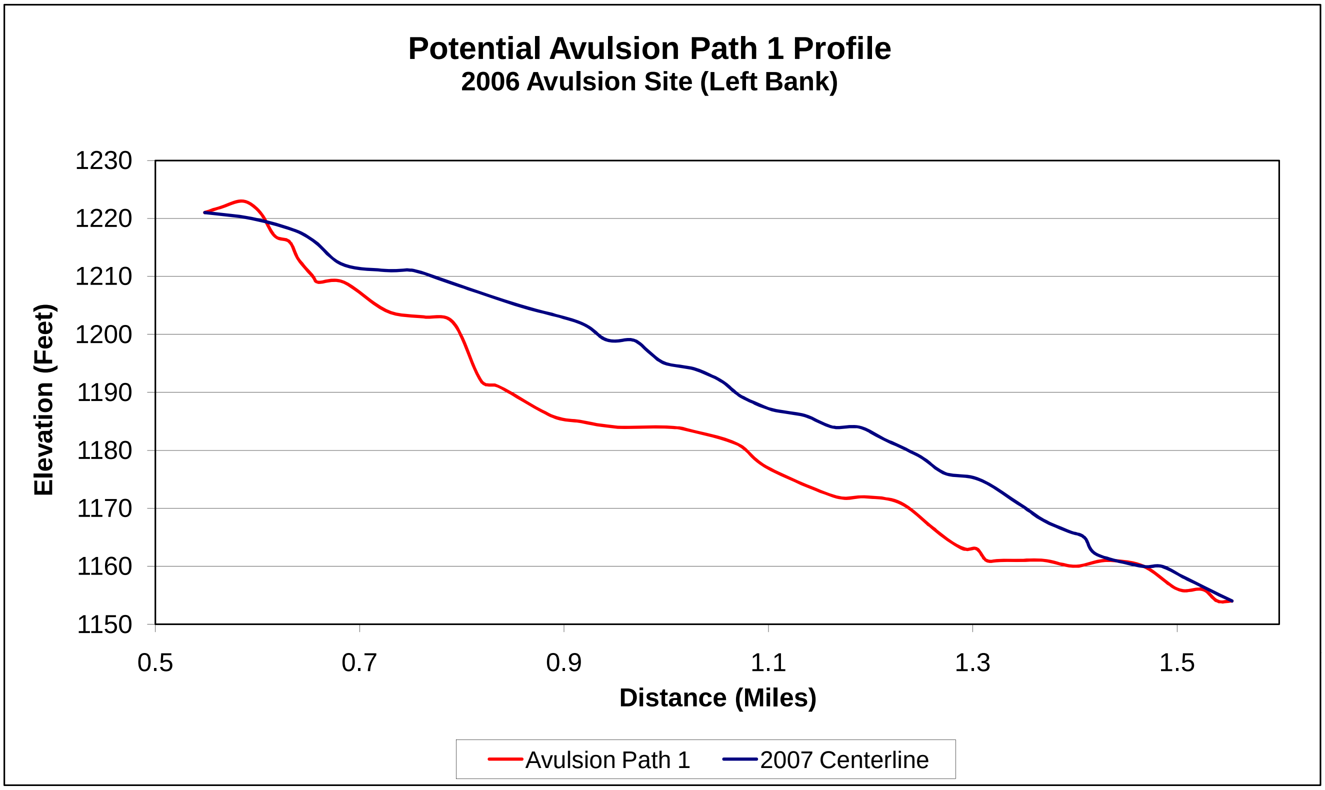
2: Main Channel Graph

Project Name:	Upper Cowlitz CMZ
Project Number:	3118-066-03
Practitioner:	Rob R.
Date last modified:	4/1/2009



3: Potential Avulsion Path 1

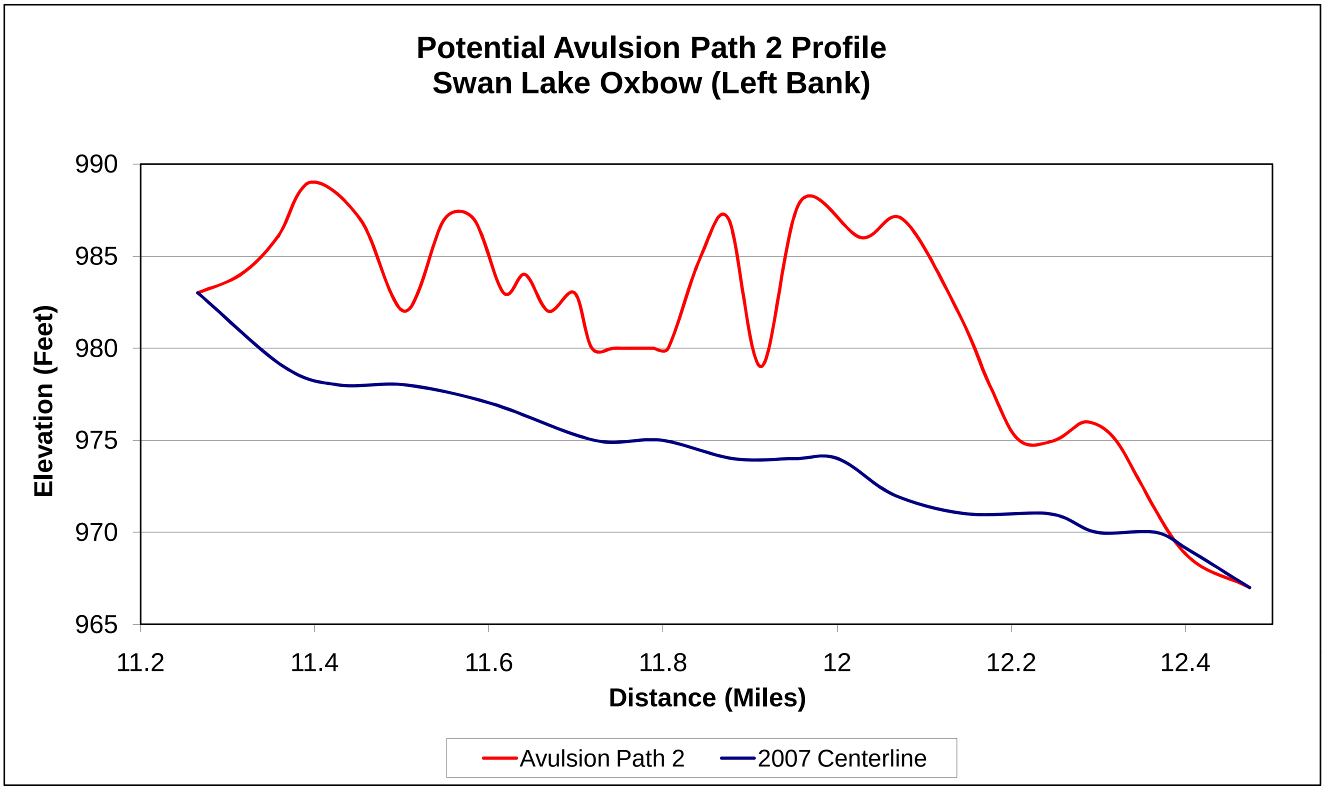
Project Name: Upper Cowlitz CMZ
Project Number: 3118-066-03
Practitioner: Rob R.
Date last modified: 4/1/2009



*Note: Gradients along the profile suggest the potential for avulsion if the Avulsion Path is consistently below the 2007 centerline.

4: Potential Avulsion Path 2

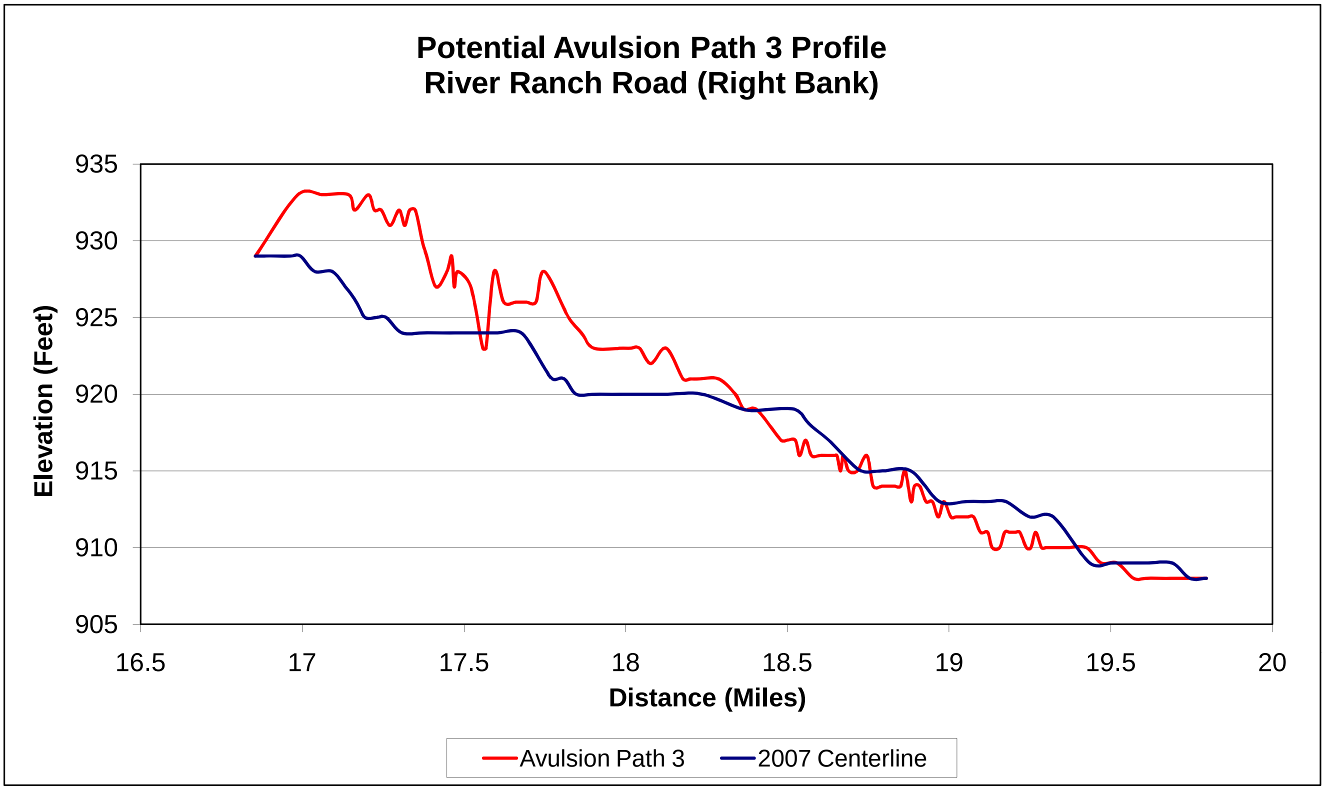
Project Name: Upper Cowlitz CMZ
Project Number: 3118-066-03
Practitioner: Rob R.
Date last modified: 4/1/2009



*Note: Gradients along the profile suggest the potential for avulsion if the Avulsion Path is consistently below the 2007 centerline.

5: Potential Avulsion Path 3

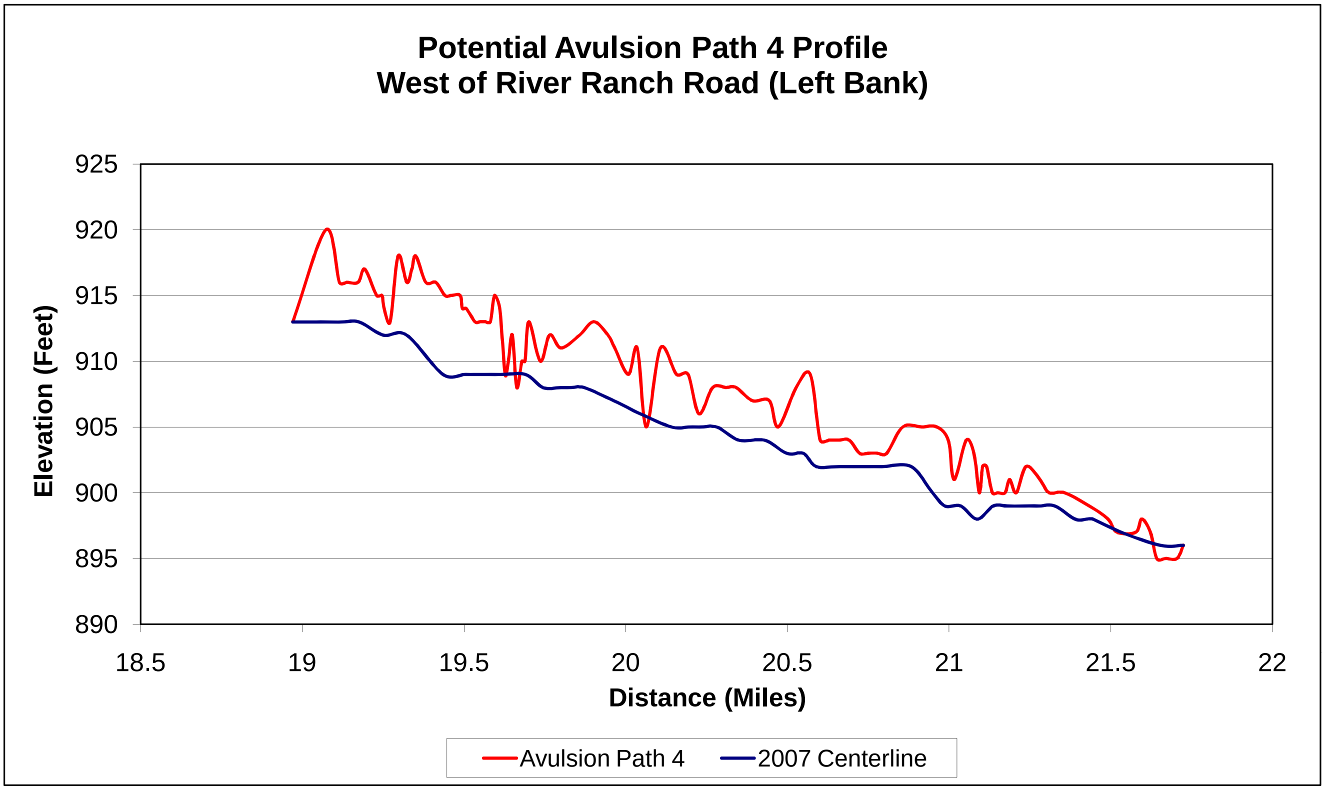
Project Name: Upper Cowlitz CMZ
Project Number: 3118-066-03
Practitioner: Rob R.
Date last modified: 4/1/2009



*Note: Gradients along the profile suggest the potential for avulsion if the Avulsion Path is consistently below the 2007 centerline.

6: Potential Avulsion Path 4

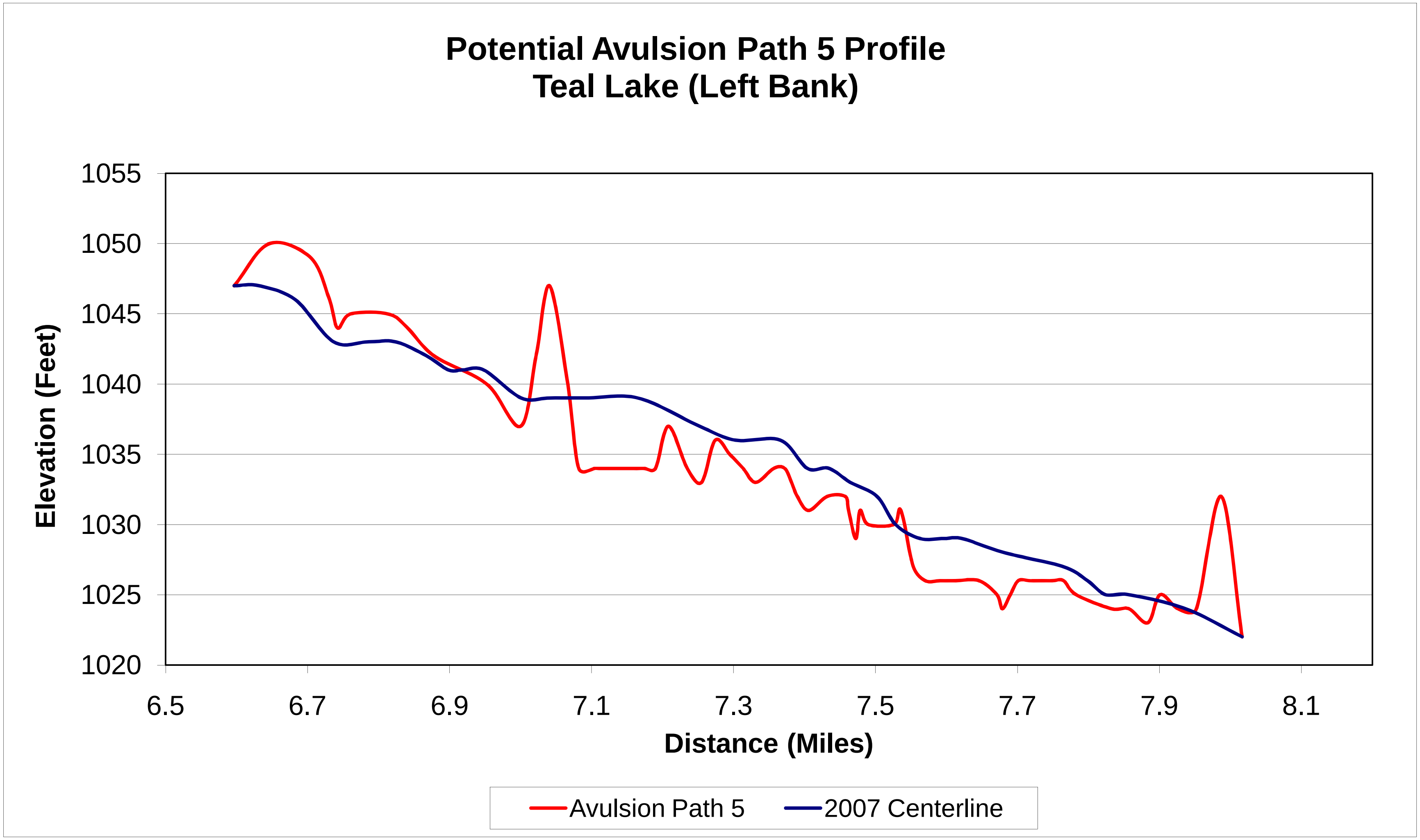
Project Name: Upper Cowlitz CMZ
Project Number: 3118-066-03
Practitioner: Rob R.
Date last modified: 4/1/2009



*Note: Gradients along the profile suggest the potential for avulsion if the Avulsion Path is consistently below the 2007 centerline.

7: Potential Avulsion Path 5

Project Name: Upper Cowlitz CMZ
Project Number: 3118-066-03
Practitioner: Rob R.
Date last modified: 7/20/2009



*Note: Gradients along the profile suggest the potential for avulsion if the Avulsion Path is consistently below the 2007 centerline.

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APPENDIX D
REPORT LIMITATIONS AND GUIDELINES FOR USE

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REPORT LIMITATIONS AND GUIDELINES FOR USE[1]

This appendix provides information to help you manage your risks with respect to the use of this report.

Geologic Services Are Performed For Specific Purposes, Persons And Projects

We have prepared this report for use by the Lewis County Department of Public Works. Conditions within the Upper Cowlitz River watershed may change over time as a result of changes in climate and precipitation, sediment delivery, land use and flood management policies. Our report should not be construed as a guarantee of future conditions in the Cowlitz River watershed or within the Upper Cowlitz River project area.

GeoEngineers structures our services to meet the specific needs of our clients. For example, a geotechnical or geologic study conducted for a civil engineer or architect may not fulfill the needs of a construction contractor or even another civil engineer or architect that are involved in the same project. Because each geotechnical or geologic study is unique, each geotechnical engineering or geologic report is unique, prepared solely for the specific client and project site. No one except Lewis County Department of Public Works should rely on this report without first conferring with GeoEngineers. This report should not be applied for any purpose or project except the one originally contemplated.

A Geotechnical Engineering Or Geologic Report Is Based On A Unique Set Of Project-Specific Factors

We have prepared this report for use by the Lewis County Department of Public Works. Conditions within the Upper Cowlitz River watershed may change over time as a result of changes in climate and precipitation, sediment delivery, land use and flood management policies. GeoEngineers considered a number of unique, project-specific factors when establishing the scope of services for this project and report. Unless GeoEngineers specifically indicates otherwise, do not rely on this report if it was:

- not prepared for you,
- not prepared for your project,
- not prepared for the specific site explored, or
- completed before important project changes were made.

For example, changes that can affect the applicability of this report include those that affect:

- discharge and sediment delivery into the Cowlitz River and its tributaries;
- elevation, configuration, location, orientation or weight new structures in and adjacent to the Cowlitz River floodplain, or
- project ownership.

If important changes are made after the date of this report, GeoEngineers should be given the opportunity to review our interpretations and recommendations and provide written modifications or confirmation, as appropriate.

[1] Developed based on material provided by ASFE, Professional Firms Practicing in the Geosciences; www.asfe.org .

Subsurface Conditions Can Change

This geotechnical or geologic report is based on conditions that existed at the time the study was performed. The findings and conclusions of this report may be affected by the passage of time, by manmade events such as construction on or adjacent to the site, or by natural events such as floods, earthquakes, slope instability or ground water fluctuations. Always contact GeoEngineers before applying a report to determine if it remains applicable.

Most Geotechnical And Geologic Findings Are Professional Opinions

Our interpretations of subsurface conditions are based on our review of existing geologic maps and literature. GeoEngineers reviewed these data and then applied our professional judgment to render an opinion about subsurface conditions throughout the site. Actual subsurface conditions may differ, sometimes significantly, from those indicated in this report. Our report, conclusions and interpretations should not be construed as a warranty of the subsurface conditions.

Read These Provisions Closely

Some clients, design professionals and contractors may not recognize that the geoscience practices (geotechnical engineering or geology) are far less exact than other engineering and natural science disciplines. This lack of understanding can create unrealistic expectations that could lead to disappointments, claims and disputes. GeoEngineers includes these explanatory "limitations" provisions in our reports to help reduce such risks. Please confer with GeoEngineers if you are unclear how these "Report Limitations and Guidelines for Use" apply to your project or site.

Geotechnical, Geologic And Environmental Reports Should Not Be Interchanged

The equipment, techniques and personnel used to perform an environmental study differ significantly from those used to perform a geotechnical or geologic study and vice versa. For that reason, a geotechnical engineering or geologic report does not usually relate any environmental findings, conclusions or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. Similarly, environmental reports are not used to address geotechnical or geologic concerns regarding a specific project.