Appendix G

ENGINEERING GEOLOGIC FIELD RECONNAISSANCE

DEBRIS SLIDE, EARTH SLIDE, DEBRIS FLOODS, AND AFFECTED PROPERTIES

3208, 3235, 3260, and One Un-Addressed Property, Clipper Road Whatcom County, Washington

Prepared for:

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Washington Department of Natural Resources
Land Management Division

September 3, 2009

WASHINGTON STATE DEPARTMENT OF
Natural Resources
Peter Goldmark - Commissioner of Public Lands

Caring for
your natural resources
... now and forever

TO: Jeff May
Baker District Manager
Department of Natural Resources
919 Township Street
Sedro-Woolley, Washington 98284

SUBJECT: **ENGINEERING GEOLOGIC FIELD RECONNAISSANCE**
Debris Slide, Earth Slide, Debris Floods, and Affected Properties
3208, 3235, 3260, and One Un-Addressed Property, Clipper Road
Whatcom County, Washington

DATE: September 3, 2009

The following Engineering Geologic Field Reconnaissance report presents our findings, and a discussion regarding the debris slide, earth slide, and debris floods that affected the residential properties at 3208, 3235, 3260, and one un-addressed property, Clipper Road in Whatcom County, Washington. The debris slide, earth slide, and debris floods occurred during the January 2009 storm. This reconnaissance report addresses the following issues: 1) were the point-of-initiations of the landslides on DNR-managed lands, 2) were the points-of-initiation in areas of recent management activity, 3) did the management activity contribute to initiation of the landslides, and 4) how much did management activity contribute to initiation of the landslides.

If you have any questions, please call.

Respectfully submitted,

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1.0. INTRODUCTION

At your request we have completed an engineering geologic reconnaissance of the debris slide, earth slide, and debris floods that affected residential structures and private properties located along a stretch of Clipper Road in Whatcom County (Figure 1). At the DNR Northwest Region 2009 Storm Tracking Site the impacted area is identified as 3260 Clipper Road (IIR 09/S/ZGI, Hooks, 2009). Upon our field reconnaissance it was determined that in fact several properties were affected. Those affected properties (owners) are 3208 (Soli), 3235 (Brown), 3260 (Stavik), Moriarty (between 3208 and 3260). The locations of these properties are shown on Figure 2. The slides and associated debris flows and floods were triggered during the early January 2009 storm. The slides initiated in the SE¼ of Section 21 and the NE¼ of Section 28; the affected properties are in the NE¼ of Section 29 and the NW¼ of Section 28, all in T38N, R5E (WBL&M) in the US Geological Survey 7½-minute Deming Quadrangle.

As shown on Figures 1 and 2, the subject properties are located about 2 miles south-southeast of Van Zandt, near the base of the west side of a plateau-like topographic high known as Van Zandt Dike (Figure 1). As shown on Figure 1, Tinling Creek dominates the area above the affected properties. The properties are situated in the Acme Watershed Administrative Unit (WAU). To date Landslide Hazard Zonation mapping has not been undertaken for this area. However, watershed analysis for the Acme WAU was released in 1999 by Trillium Corporation. Some of the debris slides and landslides that developed in response to the January 2009 storm originated in the Acme Watershed Mass Wasting Map Unit (MWMU) #2, others originated in unclassified areas along an adjacent stream. MWMU #2 generally encompasses the mid-slope reaches of Tinling Creek and is described as an area of "Initiation sites of shallow landslides and debris slides. Debris deposits may trigger dam-break floods." This MWMU is classified as a High Mass Wasting Hazard Unit. In this MWMU slope processes are characterized as predominately shallow landslides, debris slides, and initiation sites of dam-break floods. This so labeled portion of Tinling Creek is designated as *Area of Resource Sensitivity Mass Wasting Unit 1* (ARS MW-1). This ARS is accompanied by an involved set of landform descriptions, resource concerns, linkages, and prescriptions. Please see the Acme Watershed Analysis for details. Portions of the impacted areas of the affected properties on the east side of Clipper Road are located within an alluvial fan hazard zone as shown on the *Geologically Hazardous Areas (GHA)* map of the Whatcom County Critical Areas Ordinance prepared in 2006 for Whatcom County Planning & Development.

The purpose of our geologic field reconnaissance was to determine if the points-of-initiation (PI) of the debris slide and earth slide that triggered the debris floods that originated above the affected properties were on DNR-managed lands, observe the site conditions at the PIs, observe the conditions along the path of the debris flows, and note conditions in the areas of deposition. In addition, we were asked to provide a professional opinion, based on the field evidence we observed, as to the natural and, if applicable, the anthropomorphic contributory factors that influenced the development of the debris slides and landslides, as well as the triggering event that caused the slope failures.

2.0. SCOPE OF WORK

Our scope of work included the following tasks:

- Review of pertinent published and unpublished geologic reports and maps in our office files
- Review of pertinent aspects of watershed analysis reports
- Review of an unpublished landslide hazards report
- Review of pertinent information in the DNR electronic database
- Review of pertinent LiDAR imaging in the DNR electronic database
- Review of pertinent aerial photographs in the DNR files at the Northwest Region office
- Review of pertinent portions past and available Forest Practices Applications
- Review of the Initial Incident Report (IIR) for this particular event
- Review of photographs taken shortly after the event
- Field reconnaissance of the PIs and debris-flow tracks
- Field reconnaissance of the depositional area
- Brief discussions with Ms. Stavik
- Photographing pertinent aspects of the debris slide, earth slide, debris-flow track, and depositional area
- Review of pertinent historical rainfall and snowfall data

- Review of available rainfall and snowfall data related to the January 4th to 8th 2009 storm
- Analysis of the resulting data
- Preparation of this field reconnaissance report and accompanying illustrations

In addition there was one meeting with the Northwest Regional Manager and selected assistant Northwest Regional staff, geologists from Washington Division of Geology and Earth Resources, and geologists from the DNR LMD Earth Sciences Program in which the general nature of the proposed reports and estimated schedule of field work and report completion were discussed. No specific site was discussed in any detail.

3.0. LIST OF ILLUSTRATIONS

4.0. PHYSICAL SETTING

The area is dominated by the Van Zandt Dike and the South Fork Nooksack River Valley, also known as Acme Valley (Figure 1). The physical setting of the PI of the debris slides and earth slides, the debris flow tracks, and the area of the affected properties (collective referred to as the “Site”) is characterized by the topography, climate, geology, landslides, and groundwater. Each of these attributes is briefly discussed below.

4.1. TOPOGRAPHY

The topography of the Site is represented by two distinctly different types of terrain (Figures 1, 2, and 3). The debris slide PI and earth slide that initiated the debris flows and floods originated in areas of very steep to locally precipitous hillside topography. The impacted portions of the affected properties are located on relatively gentle terrain of the valley floor. At the Site the west-facing slopes of Van Zandt Dike exhibit an over all average inclination of about 35%. However, locally bedrock cliffs characterized by essentially vertical inclinations up to several tens of feet high are present. The impacted areas of the affected properties are situated on very gently, generally westerly-sloping ground between about 270 to 340 feet elevation. The western edge of the plateau like "top" of Van Zandt Dike is at an elevation of about 1,700 feet, more-or-less. At the Site the west-facing slopes are essentially planner, but are dissected by steep, generally westerly-flowing creeks (Figure 3). Portions of these creeks are characterized by relatively deep channels and steep side-slopes. Waterfalls and bedrock cascades are common. Within the Site, two drainages are important. One is Tinling Creek, which dominates the area of the Site (Figure 3), and a somewhat smaller unnamed creek to the south of Tinling Creek, herein referred to informally as Stavik Creek. The head of Stavik Creek is near the top of the west-facing slope of the Site and thus is characterized by a relatively small drainage basin. On the other hand Tinling Creek extends well past the eastern edge of the Site. The headwaters of Tinling Creek are a little over a mile northeast of the Site. However, the creek, between the headwaters and the Site, takes a circuitous route that goes first north, then west, then south to the Site, covering a distance of about 1½ miles to the eastern edge of the Site. As expected the drainage basin for Tinling Creek (including that area on the west-facing slopes) is much larger than Stavik Creek, being an area of about 676 acres. At the bottom of the slope waters from Stavik Creek flow into Tinling Creek. However, years ago, Tinling Creek was relocated to the south of its original course along Strand Road. Tinling Creek flows westward into the upper reaches of Black Slough which in-turn flows northward, eventually into South Fork Nooksack River.

4.2. CLIMATE

The historical climatic record and pertinent details of the recent storm are briefly presented below. The rain fall data pertinent to the January 2009 storm is generalized with few details. This could change as more information becomes available.

4.2.1. Historic Record – The area of the Site is influenced by a predominantly maritime-type climate with mild wet winters and cool dry summers. The area receives frequent and sometimes intense storms that approach from the Pacific Ocean, about 120 miles to the west.

The nearest weather recording station with a lengthy historic record is located at the Glacier Ranger Station (Western Region Climate Center (WRCC), 2008), about 13¾ miles to the northeast of the Site. The Glacier recording station is some distance away but is at an elevation of approximately 1,000 feet, near the elevations of the PIs (1,300 and 1,600 feet) of the debris slide and earth slide that appear to be the origin of the debris flows and floods. The generally accepted zone of greatest or most frequent rain-on-snow influence in this portion of the Cascades is from 1,600 to 4,000 feet (Trillium Corporation, 1993). The Glacier Ranger Station is well into the foothills of the Cascade Mountains, unlike the sites of the slides in question, which are essentially in the foothills of the front of the ranges. These geographic disparities are important and do not allow a simple inference of the climatic history from one site to the other. However, it appears to be the closest weather station with a historic record of significant length. Though totals at the Site and at the Glacier Recording Station are surely likely to be different (if totals for the Site were available) and the amount of the difference uncertain; it is probably safe to assume that if a large storm resulted in significant precipitation at the Glacier Station then the same storm likely resulted in significant precipitation at the Site. The area of the slides in question is in the rain-dominated zone (1,600 feet or less). The precipitation history is summarized below, keeping in mind that the precipitation history is assumed to be similar, only with likely somewhat lower totals at the Site.

The three periods-of-record (POR) for the Glacier Ranger Station include the following: 1949-1983, 1961-1990, and 1971-2000; in total a 51-year record. (In the station database the tabulated data is reported in this manner.) The WRCC (2008) reports the annual average rainfall at the Glacier Ranger Station varies from about 68⅔ and 71 inches, for PORs 1961 – 1990 and 1971 – 2000, respectively. The mean annual for the 1949 to 1983 POR is 66⅔ inches of rain, with a yearly standard deviation of about 12 inches. The highest recorded January rainfall for the POR was 19½ in 1974; for a December it was 21 inches in 1979. The mean January and December rainfalls are 9⅓ and 10½ inches, respectively. Average daily precipitation in January and December it is about ⅓ of an inch, within a daily range that varies from about one-eight inch to five-eights inches for both months. However, the maximum one-day total in January during the POR is about 3½ inches, while in December it is about 4⅔ inches. It appears that during one very unusual December storm event the daily average rainfall was exceeded by about 1,225%. The mean average snowfall is about 51¾ inches per year over the 1948 to 1982 POR for snowfall. The greatest snowfall in January was 73¾ inches in 1954; in December, 25 inches in 1971. The monthly mean snowfall is about 17 and 8 inches for January and December, respectively. Daily average snowfall for January and December has varied from 0 to about 1¾ inches; however, during extreme events up to at least 17 inches of snow has fallen in a single day. Snow depths at the Glacier station during January average between about 1 and 6⅓ inches over the POR; in December the average for the POR is between 0 to about 1 inch. Over the POR, snow-depth extremes for January range from about 11 inches to about 37¼ inches; for December, the range is from 0 to about 11 inches.

Since 2000 (the end of the POR) the National Climatic Data Center (2009) reports that Whatcom County has experienced one heavy snow event in February 2001, three heavy snow events in January and February of 2002, one heavy rain event in October 2003, a winter-weather mix event in January 2004, heavy rains in November and December 2004, one heavy snow event followed by a flood (heavy rain?) event in January 2005, and finally a flood (heavy rain?) event in November 2006. In December 2008, the area experienced a prolonged period of severe winter weather during which snow accumulations reached about a foot-and-a-half in the low lying areas.

The January 2009 storm followed a several-week period of snow storms, prolonged freezing temperatures, and thick accumulations of snow, even at lower elevations. The available historic climate data were reviewed to determine how often such a sequence of weather events has occurred in the area of the Site. Only the data for the years 1949 to 1983, a 34 year period, from the WRCC contained totals for monthly accumulations of snow and rain. We arbitrarily chose months where the December snowfall equaled or exceeded about 24 inches, and the January rainfall equaled or exceeded 10 inches, attempting to match the snow conditions leading up to the January 2009 storm and the rainfall of that storm. For the time period reviewed there were only two periods that matched these criteria: December/January 1970/71 (snow 30”/rain 13”, respectively) and December/January 1971/72 (snow 45”/rain 13” respectively). It should be noted that in both Januarys there was significant snowfall in addition to the rainfall. It should also be noted that there were several January snowfall and rainfall totals that came close or exceeded the 10-inch minimum (January 1954, ’60, ’68, ’70, ‘74, ‘76, and ’82), but because it is uncertain whether the rain followed the snow or vice-versa it is difficult to be certain how representative these storms would be of the climatic setting leading up to the January 2009 storm. This is because the POR has only monthly totals, not daily totals. Because there are only monthly totals, no daily totals (the POR summaries only report average rain and snow for any given day of the year), it is assumed that from the monthly December snowfall totals, at least about 1½ to 2 feet of snow was present at the end of December, and that a large portion of the January rain fell on the December snow during a several-days storm, in effect a worse-case scenario.

4.2.2. January 2009 Storm – The damaging storm in question began about January 4 and continued to about January 8, 2009, and followed on the heels of the December 2008 snow storms mentioned above. No recording stations are located at the Site. However, interpretation of Doppler-radar imaging of the four day period of rain bracketed above (National Weather Service, 2009) suggests that the area of the Site received about 9 to 11 inches of rain during that period. The January 4 to 8 period was preceded and followed by showers and light rain and snow so that the actual total could be somewhat greater. The time-intensity relationships are uncertain, but likely were characterized by periods of heavy rainfall interspersed with periods of lighter to no rainfall. The amount of snowfall on Van Zandt Dike and the slopes above the affected properties is also uncertain. However, based on the IIR, it appears that the snow pack was about two, and maybe as much as three feet thick (Hooks, 2009). Temperature and wind data from University of Utah TSUNA weather station east of Deming near the base of Sumas Mountain recorded almost three weeks of below or just above freezing temperatures prior to the January 4 to 8 storm. During the storm, temperatures rose over the four day period from below freezing to almost 50°F during the last couple of days of the storm. Also, wind speeds between 20 to 30 mph from the SSW with sustained speeds of 15 to 20 mph were recorded at the weather station during the latter days of the storm (University of Utah, 2009).

4.3. GEOLOGY

The geology of the Site is represented by the underlying bedrock and the surficial deposits that overlie the bedrock. Surficial deposits include the glacial deposits, alluvial fan deposits, soil and colluvium, landslide debris, and artificial fill. A brief description and general distribution of these earth materials is presented below and shown on Figure 3.

4.3.1. Bedrock – The bedrock geology at the Site is represented by the Darrington Phyllite (**Jdp**) and the stratigraphicly overlying Chuckanut Formation (**Tec**) (Dragovich and others, 1997). These rocks are in depositional contact along the northern margin of the Site. The Jurassic age **Darrington Phyllite** is described as a quartzose graphitic phyllite with many crenulations, cleavage planes, and open to tight folding. Quartz veining is locally abundant. In some outcrops the rock is well weathered. Within the Site the Darrington Phyllite was observed cropping out here and there along the length of Tinling and Stavik Creeks. The Eocene age **Chuckanut Formation** is characterized by sandstone interbedded with lesser amounts of siltstone and shale. The sandstone varies from locally laminated to very thick bedded and exhibits a general northeast strike and a moderate (40°) to steep (70°) northerly dip. Locally the bedrock is broken by sets of generally steeply-dipping northeast- and northwesterly-striking joints. Rocks of the Chuckanut Formation crop out on slopes in the northern area of the Site, areas to the north of Tinling Creek.

4.3.2. Surficial Deposits – Glacial Deposits (**Qg**) are composed of poorly stratified accumulation of silt to boulder size sediments. They are exposed along the lower reaches of Tinling Creek, and may be present elsewhere at the Site.

Alluvial fan deposits (**Qf**) are composed of interbedded debris-flow deposits and fluvial sediments. The debris-flow deposits, where exposed, are poorly-stratified, poorly-sorted deposits of coarse angular to rounded cobble- to boulder-size clasts in a matrix of sand, silt, some clay, and occasional organic debris. They are mapped at the mouths of Tinling and Stavik Creeks. As shown on Figure 3, at the Site the valley floor at the base of the slope is characterized by a complex of alluvial fans that have developed at the mouths of the creeks in question and other adjacent creeks.

Soil and **colluvium** (**Qc**) are derived from the mechanical and chemical weathering of the underlying bedrock. These deposits are composed of varying amounts of sand, silt, and clay intermixed with blocks of bedrock and organic debris. Soil mapping published by Goldin (1992) has identified three major soil types on the slopes and top of the plateau and one on the valley floor of the Site. Montborne gravelly loam is mapped on the upper slopes and plateau top, Vanzandt very gravelly loam is mapped on the mid- and lower slopes of the Site. The slopes in the vicinity of Tinling Creek are underlain by Montborne-Rinker complex soils. Within the Site Wiseman very channery sandy loam blanket the valley floor. The Montborne soils are characterized as well drained; having a moderate permeability, but very slow permeability where glacial till is present; moderate water capacity; slow runoff; and slight erosion hazard. Locally perched-water conditions can be present. The Vanzandt soils are characterized as well drained; having a moderate permeability, but very slow permeability where glacial till is present; moderate water capacity; slow to moderate runoff; and slight erosion hazard. The Montborne-Rinker complex soils are characterized as well drained; having a moderate permeability, but very slow permeability where glacial till is present; moderate water capacity; slow runoff; and slight to moderate erosion hazard. Locally perched-water conditions can be present. The Wiseman soils are characterized as excessively drained, having a rapid permeability, low water capacity, slow runoff, and slight erosion hazard. These soils are subject to rare flooding.

The soils form more or less in-place; however, the colluvial deposits are formed by the accumulation of soil moved down slope in response to gravity driven processes (e.g., soil creep, etc.). Herein colluvial deposits are considered to be soil deposits thicker than about 3 to 4 feet. Colluvium locally blankets the mid- and lower slopes of the Site.

Landslide debris (**Qls**) is composed of rock and soil debris. The deposits can vary from being a poorly-sorted mixture of rock debris and soil to being composed of largely intact masses of bedrock with minor amounts of intermixed soil and colluvium. Landslide debris is confined to landslide deposits.

Artificial fill is derived locally from grading for logging roads, skid trails, and landings. It is composed of a mixture of rock, soil, and varying amounts of organic debris. Though it is not shown on Figure 3 its present along the outside margins of roads, skid trails, and landings should be assumed.

4.4. LANDSLIDES

Landslides at the Site are represented by several types of processes. These processes include shallow and deep-seated debris slides, deep-seated and shallow rotational and translational landslides, and rock falls. Nomenclature of Cruden and Varnes (1996) is used herein to classify the various landslide processes.

Landslides, translational rock-block slides and earth-slides, and debris slides were noted at several locations along Tinling Creek during our review of historic aerial photographs (Figure 3). Earth slides and debris slides were also observed at several locations along Tinling Creek during our field reconnaissance (Figure 3). A significant debris slide was observed on the southwest-facing slopes above Tinling Creek (Figure 3). Generally the slides observed varied from a few tens of feet to about 100 feet in length.

Interpretation of the LiDAR generated topographic map of the Site suggests the presence of several relatively large rotational and translational landslides along Tinling Creek (Figure 3). These slides vary in length up to about 600 feet and width to about 500 feet. They are all deep-seated (thicker than 10 feet) with maximum thickness estimated to be up to at least several tens of feet. Most are judged to be currently inactive, though one and portions of another are active (Figure 3). On the channel-side slopes of Tinling Creek numerous relatively small translational landslides were observed during our field reconnaissance. These slides vary in length from about 40- to 100-feet long and 30- to 70-feet wide. They tend to be relatively thin (less than 10- to 15-feet thick). They mostly occur in bedrock and the failure surface for most of these slides appears to be controlled by steeply inclined joints oriented sub-parallel to the slopes of the creek. During the failure process the slide mass of these slides tended to stay more-or-less intact as the slide mass came to rest essentially in the bottom of the creek. In spite of coming to rest in the creek, varying portions of the slide masses are still present and have not been washed away as of the time of our traverse.

A significant size rock fall was observed on the north side of Tinling Creek about 900 feet from the mouth of the creek (Figure 3). The rock fall is about 200-feet long; an estimated 100-feet high, and may be related to other landslide processes affecting the slope at that location. In the channel the rock fall deposit may be up to 10- to 15-feet thick. It appears that the rock fall likely occurred after the main debris slide/flow event, for no debris, except for a few small sticks, were observed on the blocks of rock in the channel.

Just a short distance down stream from the rock fall is a relatively large landslide (Figure 3) that is estimated to be about 170-feet long and about 125 wide. It appears to be rotational-type slide that has been active for perhaps the last 35 to 40 years, and likely has been a source of sediment for some time.

Evidence for recent (storm related) landslide processes along Stavik Creek is rare. Evidence for two or possibly three landslide events was observed (Figure 3). The upper most slide observed became essentially a debris slide that was the initiating event in Stavik Creek. This slide was not particularly large. The other slides present are probably best characterized as debris slides that began as small translational failures in bedrock.

In addition, the alluvial fans that have developed at the mouths of Tinling and Stavik Creeks give testimony to past debris-slide processes. The Whatcom County *Geologically*

Hazardous Areas map recognizes that the topography of the Site, as well as elsewhere along the base of the west side of Van Zandt Dike, is a product, in part, of past landslide and debris slide processes.

4.5. GROUNDWATER

Evidence for shallow groundwater that may have been present prior to the occurrence of the most of the slides was not obvious. Flowing water is present in Tinling Creek from well above the Site to almost the valley floor. In Stavik Creek flowing water was encountered at the upper most debris slide (Figure 3), and again present almost to the valley floor. Considering the length of Tinling and Stavik Creeks in the area of the Site, seeps and springs on the channel side-slopes were rare. This may, in part, be due to the time of the year of our field work. We did observe shallow channels suggestive of concentrated overland flow emanating from the area of some of the debris slide failures; in particular a seep was observed at the head of the debris slide scar above the north side of Tinling Creek. At the PI scar, post-failure erosion and channeling was traceable down slope to Tinling Creek, suggesting high groundwater conditions at the debris slide scar, and flow surface water following development of the debris slide. During our field reconnaissance we observed that locally, the phyllite and sandstone bedrock is characterized by areas of relatively well-fractured bedrock, making the rock mass somewhat permeable. Elsewhere, during earlier reconnaissance of other landslide sites to the north, we noted the spacing of fractures can be quite wide, thus making the rock mass fairly impermeable. It is likely that such subsurface conditions are also present at the Site.

An important factor affecting groundwater, especially at the time of the failures, was the January 2009 storm and the associated phenomenon of rain-on-snow (ROS). It should be noted that the debris slide that developed on the southwest-facing slope above Tinling Creek and the earth slide in Stavik Creek were just at or below the 1,600 foot elevation that is considered to be the lower elevation of the ROS zone. None-the-less, the PIs and surrounding areas were covered by snow prior to the arrival of the early January 2009 rain storm.

5.0. HISTORICAL SETTING

The historical setting of the Site is briefly summarized below. This includes the past landslide history and past forest-practices and land-use history. Interpretation of stereoscopic aerial photography was relied upon for preparation of this section along with past Forest Practices Applications (FPAs) information in the electronic files of DNR Division of Land Management. For a complete list of aerial photography reviewed please see **AERIAL PHOTOGRAPHS REVIEWED** at back of text.

5.1. LANDSLIDE HISTORY

Review of historical aerial photography from various years dating back to 1947 through to 2001 revealed evidence for historic landsliding at the Site. This landsliding was essentially confined to Tinling Creek; very rare historic landsliding was noted along Stavik Creek. This should not be construed to suggest that landsliding was not occurring; only that review of the aforementioned aerial photographs did not reveal evidence for such failures.

In Tinling Creek past landsliding, as revealed during review of the historic aerial photographs, appears to be confined to about four general areas. These areas are shown on Figure 3. In Tinling Creek the first area is about 1,800 feet up the creek from the mouth. Landslides, most likely debris slides, were observed at this location upon review of the 1961 and 1971 aerial photographs. The next area is about 450 feet further up the channel. Here review of the 1961, 1971, 1978, and 2001 aerial photographs showed evidence for landslide activity, again most likely debris slides. The next area is about 3,150 feet up the channel from the mouth. In this area landslide activity was observed on the 1978 aerial photographs. The last area in the Site is an approximately 400-foot long stretch of creek beginning about 800 feet above the just previously noted location. In this stretch of the creek evidence for debris slides (most likely) were observed on the 1978 and 2001 aerial photographs. It should be noted that though several episodes of slope instability were observed over the years, review of the same aerial photographs did not reveal evidence that any of the slides observed on the aerial photographs became debris flows that reached the mouth of Tinling Creek and flowed out across the ground surface of the valley floor.

On the 1978 aerial photographs three possible sites of relatively minor landsliding were noted (Figure 3). One of these sites may be a waterfall.

As noted earlier, Whatcom County Hazards mapping recognizes some areas along the base of the slopes on the west side of Van Zandt Dike as alluvial fan hazard areas. This is likely based on the interpretation by others (Fox and others, 1992; Dragovich and others, 1997; and Trillium Corporation (Acme Watershed Analysis), 1999) that landslides, in this case debris slides, have occurred over the millenniums on the west-facing slopes of Van Zandt Dike; depositing slide debris at the base of the slopes of the Dike and forming alluvial fans that are now recognized hazard areas.

5.2. FOREST PRACTICES AND LANDUSE HISTORY

As noted above the following discussions are based on review of vertical, stereographic aerial photographs and pertinent FPAs. The earliest photographs dated back to 1947.

5.2.1. Forest Practices – Review of the 1947 aerial photographs shows that prior to that time the plateau area of the Site had been logged. Judging from the nature of the canopy observed on the photographs the entry was likely a clear cut some 20 years or so earlier. Within the Site the logging cut across the upper reaches of Tinling Creek and along portions of Stavik Creek, no riparian buffers were included in the harvest. The road system that switch-backs up the hillside south of Tinling Creek is present. This road and associated spurs cross Stavik Creek at three locations and the lower reaches of Tinling Creek at one location. In addition to the areas harvested on the top of the plateau, it appears that a relatively small isolated area on a bench on the plateau slopes was also cut by 1947. Review of the 1955 aerial photographs suggests that additional harvest activity occurred on slopes above the spur road that crosses the lower reaches of Tinling Creek. Between the 1955 and 1987 aerial photographs show essentially no timber harvest activity occurred within the area of the Site below the edge of the plateau. However, it appears that prior to 1961 some harvest activity did take place on the lower slopes between the valley floor and the future State Lands boundary. These harvests were either clear cuts or some type of thinning.

By the time of the 1991 aerial photographs two clear cut harvests had occurred. One was on the relatively gentle lands on the plateau surface north of Tinling Creek and involved some of the same area that had been entered prior to 1947. This sale is identified as Dike Dutchman in the DNR database. However, this time Tinling Creek was buffered, though the vegetation buffer was relatively narrow. The other sale was Strand Extension (The identification used in DNR-managed lands database) south of Tinling Creek. Strand Extension was cut about 1988. Healthy stream buffers were placed between the Sale and Tingling Creek. The buffers appear to coincide with the high hazard area (ARS-MW1) defined around Tinling Creek in the Acme Watershed Analysis. The Strand Extension Sale was not a State Lands sale. At the time of the sale and harvest the land was not owned by DNR. DNR acquired the land later, as part of a land exchange. It appears that the switch-back road was abandoned some time following the Strand Extension harvest and the road crossing on Tinling Creek was pulled about 1990/91 (Wolff, 2003). The 1995 and 2001 aerial photographs show that timber harvest continued in the upper reaches of Tinling Creek. The fills across Stavik Creek appear to be in place on the 2001 aerial photographs, indicating that were pulled sometime after the date of those photographs. In 2004/2005 the areas within the Site and north of Tinling Creek were cut as part of the Jack Straw Aerial Timber Sale. As done earlier with Strand Extension, healthy buffers were placed between the Jack Straw Aerial Sale and Tinling Creek. And, as with Strand Extension, the buffers appear to coincide with the high hazard area (ARS-MW1) defined around Tinling Creek in the Acme Watershed Analysis. At the time of the Jack Straw Aerial Sale the harvest boundaries of the sale complied with or exceeded the Acme Watershed prescriptions for unstable slopes (Wolff, 2003). To the north of Tinling Creek it appears such protected areas included the rock cliffs and the slopes at the base of those rock cliffs.

5.2.2. Land-Use History – Clipper Road is present on the 1947 aerial photographs, so is Strand Road that connects Clipper Road to Washington State Highway 9. The

Stavik residence and associated out buildings are also present. There are no buildings to the north of the Strand/Clipper Road intersection. Aside from the Stavik structures, from 1947 to now land use is overwhelmingly agriculture to varying degrees of intensity. By 2003/2005 a residential structure is present at the 3208 Clipper Road property and by 2009 a residential structure was built on the 3235 Clipper Road property. As noted earlier, decades ago Tinling Creek was diverted from a course that paralleled Strand Road to a course that went south of the Stavik structures (pers. Comm, Ms. Stavik, 2009), through a culvert under Clipper Road, and on toward Black Slough.

6.0. RECONNAISSANCE OBSERVATIONS

The slides and associated debris flows and debris floods that impacted the valley floor portions of the affected properties are reported to have occurred in the early morning hours of January 6th (Pers. comm, Ms Stavik, 2009). The following discussion presents salient field observations regarding the Points-of-Initiation (PI) of the slides, conditions along the debris-flow track, and general observations regarding the area of deposition. This discussion proceeds from the PI, down slope to the areas of deposition. Resulting damage to private property is summarized in the Areas of Deposition discussion.

6.1. POINTS-OF-INITIATION

The debris that blanketed the impacted areas of the affected properties came from two different drainages: Tinling Creek and Stavik Creek. The PI in each creek is discussed below: Tinling Creek first, then Stavik Creek.

Tinling Creek – As noted in **SECTION 4.4**, our reconnaissance of Tinling Creek revealed numerous landslides that had failed from the channel side-slopes into the channel, but in large part only portions of these slides had been washed away. A relatively large and fresh debris slide scar (Figures 4 and 5) was discovered on the southwestward-facing slopes on the north side of Tinling Creek (Figure 3), about 350 feet above the creek in an area of mildly convergent topography. The track of the slide debris derived from this failure could be traced down slope into Tinling Creek as shown on Figure 3. The scar is estimated to be about 90- to 100-feet long, about 40-feet wide, and about 10-feet deep. The head of the scarp is at an elevation of about 1,610 feet and the scarp is estimated to be 6- to 7-feet high. Colluvium is exposed in the head scarp of the scar, Chuckanut bedrock is exposed in the lower area of the scar. Water was observed seeping from the base of the scarp. Adjacent undisturbed slopes vary from just less than 70% to about 80%. Overall slope inclinations are about 65%. The scar is located at the base of a cliff of a bedrock knob in a standing timber area of the Jack Straw Aerial Timber Sale. The slide debris traveled about 700 feet down slope to Tinling Creek. A well defined erosion channel developed in the debris slide scar and on down slope to Tinling Creek. The channel suggests that there was a steady flow of water issuing from the scar following the failure event. No evidence for overland flow into the area of the PI was observed on the slopes above the PI. In our opinion, this slide scar marks the main PI of the debris slide event that coursed down Tinling Creek.

Because of the relatively intact nature of the smaller slides that failed from the side slopes into the creek, it is our judgment that these smaller slides likely failed after the failure at the PI. Below the junction of the slide track and the main channel of Tinling Creek, these smaller slides are not judged to be as significant as the PI. Some of the slides could have been triggered by passage of the main debris slide mass; however most appear to have occurred later. They likely also contributed some volume to the sediment that ultimately was deposited on the affected properties as high water-flows in Tinling Creek eroded away portions of these smaller slides.

Stavik Creek – In Stavik Creek the PI developed at an elevation of about 1,300 feet on the south side of the channel (Figure 6) between the upper two pulled road-crossings (Figure 3). The PI is a modest-size slide estimated to be about 50-feet long, 100-feet wide along the channel bottom, and up to about 5- to 7-feet thick. The channel is not scoured above this slide, but the channel does show evidence for scour below the slide. The side slopes at the PI exhibit inclinations of about 85%. A couple of seeps were noted above the PI, but at the PI water is flowing in the channel. It appears that not all the slide debris associated with the PI was mobilized and perhaps 40% of the total volume of the initial slide is still present.

6.2. DEBRIS-FLOW TRACKS

The debris flow tracks of each PI are discussed below; first Tinling Creek, then Stavik Creek.

Tinling Creek – The debris flow generated by the debris slide described above, upon entering the channel of Tinling Creek traveled about 2,800 feet down the channel, over waterfalls and bedrock cascades to the mouth of the creek. Locally, the debris flow scoured the sides of the channel to a height of 10- to 15-feet above the current channel bottom (Figure 7). About 1,200-feet up slope of the mouth of the creek begins an approximately 150-foot long section of channel that is characterized by a quite reduced inclination in the gradient of the creek (Figure 3). This reach is populated by a boulder field (Figure 8) of pebble size rocks to blocks of rock up to 12x8x12-feet in size. There is a distinct lack of fine-grained sediment in this reach of the creek. This reach is just up channel from the pulled road crossing and a bedrock waterfall.

Also present is an active deep-seated landslide about 850-feet up channel from the mouth of the creek (Figure 3). This slide is a relatively large bowl-like feature estimated to be about 125 feet along the creek and extends up slope about 170 feet. This slide appears to have been active for some time. The slide is in glacial deposits and likely is a continuous source of sediment; at least during times of more severe storm events. The development of this slide does not appear to be related to the road above it for no runoff from the road appears to drain toward the slide. Debris from this slide was probably picked up by the debris flow as it passed by.

As discussed earlier the passage of the debris may have triggered some of the relatively smaller channel-side slides noted in **Section 4.4** (Figure 9). However, it is more likely that most of these slides occurred well after the passage of the debris flow. The general intact nature of the slide deposits where they sit on the channel floor and the lack of evidence that they have been modified by passage of anything but running water suggest that they occurred after passage of the debris flow. Likewise the lack of sediment and rock debris and the lack of organic debris of any appreciable size and amount suggest the rock fall discussed in Section 4.4. also occurred after passage of the debris flow.

Stavik Creek – As the debris flow moved down channel the depth of scour increased; from a depth of 5 to 7 feet or less in the upper reaches (Figure 10) of the creek to locally an estimated 10 feet above the current channel bottom in the lower reaches of the creek. Over all it appears the flow picked up debris and scoured the channel side-slopes as it coursed down the channel of Stavik Creek, but apparently little other modification of the channel slopes occurred. The shown on Figure 3 some scour occurred in the fill of the lowest pulled road crossing. As discussed earlier, an occasional channel side-slope failure developed (Figure 11) following passage of the debris flow.

In both creeks, and in particular Tinling Creek, there still remains slide debris in and along the margins of the channel. Over time it can be expected that this debris will be further mobilized by future storm events, and will meter out of the creeks in varying amounts.

6.3. AREAS OF DEPOSITION

The mouth of Tinling and Stavik Creeks are about 650 feet apart. When the debris flows reached the mouths of the creeks and the valley floor the abrupt change in gradient resulted in deposition of the entrained debris. The depositional processes are best described as a debris flood following criteria developed by Hungr and others (2001).

Debris from Tinling Creek spread out and down the south side of the alluvial fan that has developed at the mouth of the creek (Figure 3) and created a new channel across the south side of the alluvial fan. Debris from Stavik Creek spread out across the entire alluvial fan at the mouth of that creek. Debris from both creeks combined to spread out over an area to the southwest of the mouths of the creeks (Figures 2 and 3). The structures at 3260 Clipper Road were surrounded by debris; the height of the debris being a couple of feet (Figures 12 and 13), and the interior of some of the outbuildings were flooded by a slurry of water and gravel. Very thick deposits of sediment accumulated near the mouth of the creek in the back areas of the property (Figure 14). Portions of the other properties to the southwest (Figure 15) were flooded by a shallow mixture of water, sediment, and small organic debris. The culvert under Clipper Road was blocked. The debris ran down Clipper Road to the south and across Clipper Road and on to properties on the west side of the road (Figure 15). A layer of sand and silt, small rock fragments, and minor amounts of small organic debris was deposited over the approximate area shown on Figure 3. As also noted earlier, deposition of the flood debris forced Tinling Creek to create a new channel across the southern area of the Stavik property; but in the same general area it was in prior to January 2009.

7.0. DISCUSSION

As part of our charge we were asked to determine the following:

1) Were the PIs of the landslides on DNR-managed lands?
2) Were the PIs in areas of recent management activity?
3) Did the management activity contribute to landslide initiation?
4) How much did management activity contribute to landslide initiation?

In this section we provide our observations and opinions with respect to these questions. **Section 7.1.** includes observations and conclusions with respect to questions 1 and 2. **Sections 7.2. to 7.4.** address questions 3 and 4**. Section 7.2.** provides a discussion concerning the likely influence that the January 2009 storm and accompanying ROS conditions might have had on groundwater flow from the adjacent timber sales. **Section 7.3.** summarizes the likely influence that timber harvesting might have had on the development of the slides at the PIs. **Section 7.4.** provides a brief site-specific discussion regarding our opinion as to the degree of causal influence the management activities may have had in development of the landslides and associated debris flows and debris floods.

7.1. LOCATION AND DNR-MANAGED-LANDS

The debris slide and translational earth slide that are the PIs for the debris flows and debris floods that are the subject of this reconnaissance initiated on DNR-managed lands. In the case of Tinling Creek PI the debris slide occurred in a stand of trees bound out of the Jack Straw Aerial Timber Sale. In Stavik Creek the slide occurred in an area that had been managed (cut) about 20 years ago as part of the Strand Extension harvest; at that time the area of the harvest was not part of DNR-managed lands. Stavik Creek was not buffered at the time of the Strand Extension harvest.

7.2. STORM AND ROS INFLUENCES

The January 2009 storm followed a several-week period of rain, snow, and near freezing to freezing temperatures. The PIs are located in the upper portion of the generally accepted rain-dominated zone; however, a classic ROS situation developed anyway. A snow pack estimated to be 2 to 3 feet thick (Hooks, 2009) blanketed the PIs prior to arrival of the rains and accompanying winds and warmer temperatures. As noted earlier, the Tinling PI occurred in a stand of mature trees that date back to before 1947, well over 55 years old (perhaps as much as 75 years old) at the time of the harvest of the Jack Straw Aerial Sale. At the Stavik PI the forest cover was about 20 years old at the time of failure. By standards discussed by Beschta (1995) the trees in the leave area of the Jack Straw Aerial Sale would have constituted a hydrologically mature stand, while the 20-year old regeneration in the Strand Extension sale would have reached about 55% of hydrologic recovery. Analysis by Beschta (1995) of peak flow under clear-cut conditions versus fully-forested conditions in the eastern subWAU of the Acme WAU suggests an increase in peak flow on average of 11% (the range was from about 4% to 20%) following clear-cut harvesting. In the case of the Strand Extension Timber Sale and Stavik Creek, following twenty years regeneration and a 55% hydrologic recovery, the peak flow, and by assumption on our part, the increase in groundwater would be reduced to an average of about 6% (with a possible range of about 2% to 11%) greater than under fully-forested conditions.

This is a somewhat simplified discussion of a set of complex relationships, and caution needs to be exercised when projecting Beschta's (1995) estimates of basin wide hydrologic changes to localized areas. However, it does present a general idea of what range of conditions could likely have been present at the time of the failures.

During the January 2009 storm a ROS condition existed over the entire Van Zandt Dike area; it was not limited to slopes above the 1,600-foot elevation considered to be the lower reaches of the ROS zone. This additional snow pack may have resulted in a greater increase in available groundwater than estimated by Beschta (1995). The Western SubWAU within the Acme WAU has a greater percent of its area in elevations above 1,600 feet, reflecting a greater area within the ROS zone. During storm events in clear cut conditions the Western SubWAU is predicted to have a 20% increase in peak flows as compared to mature forest canopy conditions (Beschta, 1995). Because the January 2009 storm produced ROS conditions at elevations lower than predicted, it would be reasonable to assume resulting peak flows would be greater than those presented by Beschta (1995) for the eastern subWAU. Such an increase could be considered significant. The potential for frozen ground to increase runoff could complicate the calculations and we have not tried to account for this condition in this discussion, largely because we do not know if this condition actually existed at the time of the storm. We suspect it not likely. This discussion is further complicated by work of Coffin and Harr (1992). They showed increased out flow from plantation sites during ROS events was somewhat variable and did not always exceed forested sites. Thus it is very difficult to accurately know exactly how much additional groundwater was actually added to the area of the Jack Straw Aerial Sale as a result of the January storm and associated ROS conditions.

The area of the Site has experienced at least two similar weather events in 1970/71 and 1971/72 during a record of 34 years. Review of the 1971 aerial photographs suggests one possible debris slide in Tinling Creek following the 1970/71 storms, none were noted in Stavik Creek; 1976 aerial photographs did not reveal evidence for landslide or debris slide processes occurring on slopes in either Tinling Creek or Stavik Creek following the 1971/72 storms (though about 5 years had passed). A couple of possible small slides were noted on the 1978 aerial photographs. If these features were actual debris slides they did not initiate debris flows that reached the mouth of Stavik Creek. Review of the 1991, 1995, and 2001 aerial photographs, did not reveal evidence for debris slides in Stavik Creek. This at time when regeneration in the Strand Extension sale would have been young and the slopes of Stavik Creek presumably susceptible to increased shallow landsliding.

7.3. MANAGEMENT AND REVEGETATION INFLUENCES

As noted above the Tinling Creek PI developed on a hillside in a mature stand of trees adjacent to the Jack Straw Aerial Timber Sale; the Stavik Creek PI developed on steep north-facing side-slopes of Stavik Creek in the Strand Extension timber sale, a regenerating stand estimated to be about 20 years old. By today's standards the area where the Stavik Creek PI developed would be recognized as inner-gorge terrain and classified as a potentially unstable landform under our State's forest practice rules. This would require evaluation of the channel adjacent side-slopes of the creek by a qualified expert prior to management activity, following guidelines and criteria discussed in the Washington State Forest Practices Rules (WAC 222-16-050) and Board Manual Section 16. However, when the Strand Extension sale was prepared the current Watershed Analysis and Forest Practice rules (with respect to unstable slopes) were not in effect, thus the creek was not protected by a vegetated buffer. The area around Tinling Creek that was recognized and classified as a high hazard area under the Acme Watershed Analysis (MWMU #2) was not entered (Save for two locations of about .1 to about .3 acres in size, and this apparent "trespass" is likely a GIS error.) during harvest of either the Strand Extension or Jack Straw Aerial Sales (Figure 3).

The intent of retaining leave trees in steep, convergent, or inner-gorge topography is to maintain root strength. In such areas, groundwater is often concentrated and usually becomes channelized surface-water down slope. O'Loughlin and Ziemer (1982) point out that root strength, particularly from smaller roots, is in a strong phase of recovery during the 10- to 15- year period following harvest activities. During this initial 10- to 15-year period root strength recovery and reinforcement can quickly increase from 40% to 70% of total effective pre-harvest values. It would follow that after 20 years a stand of trees would be well on the way to recovery. During our reconnaissance of other debris slide PIs to the north of the Tinling/Stavik Creek area, we have observed that along the lateral margins of landslides originating in mature timber stands, tree-root strength was overcome, and roots were broken by the destabilizing forces of landslide processes. It appears that the extreme quantity of water produced by the rain-on-snow event overwhelmed the root strength at particularly vulnerable sites on the slopes of the west side of the Van Zandt Dike, resulting in landslides originating in all timber stand ages.

In our opinion, the Jack Straw Aerial harvest could have had some effect on development of the Tinling Creek debris slide. Because of the clear-cut conditions of the area above the PI and on the rock knob/ridge, runoff from that area would be greater than under fully-forested conditions. Though as stated above in **Section 7.2**., it is very difficult to know how much more water would be available and how much would be directed toward the site of the Tinling Creek PI. The topography of the knob/ridge would likely shed the great majority of the increased runoff and groundwater away from the PI (Figure 3). However, the joint system in the bedrock probably would channel or direct some of the increased water toward the area of the PI. How much additional groundwater over background levels could be very difficult to determine. Likewise, it is difficult to know with any degree of certainty that the additional water was enough to trigger the slope failure. And, as noted above, the imprecise results of research and contradicting research results make it difficult to draw a conclusive cause-and-effect relationship between management activities and initiation of a specific slide. It should also be kept in mind that review of the 1947 aerial photograph did not reveal evidence for a landslide at this location or in the immediate area following the earlier harvest activity recorded by that photograph.

Conversely, it is also important to understand that landslides occur even where no management activity has ever occurred. Thus far our reconnaissance of the slides that occurred on the west side of Van Zandt Dike in response to the early January 2009 storm revealed several slides that originated in areas that had either never been managed or it had been many decades since the area was last harvested and the tree stand would be classified as hydrologically mature. In addition, the existing hollows, convergent hillside topography, and the alluvial fans at the base of the steep slopes indicate that landslides have occurred periodically in these drainages since the end of the most recent continental glaciation (about 10,000 yrs. BP) to about 150 to 100 years ago, about the time timber harvesting began in the area.

7.4. SITE-SPECIFIC SUMMARY DISCUSSIONS

At each PI there were several factors that could have contributed to the initiation of the debris slides that are the subject of this reconnaissance. These factors include the topography, geology, groundwater conditions, and harvest history. The set of contributory factors are not necessarily the same for each PI. Of course the triggering factor was the January 4^{th} to 8^{th} storm. It should be noted that the slides in question occurred in bedrock and in surficial deposits. The high elevations and steep slopes at the PIs and the steep gradients of the drainage channels provided an environment conducive for rapid down-slope movement once the slides developed.

At the Tinling Creek PI it appears that the fractured nature of the bedrock combined with the steep, broadly convergent topography of the PI to concentrate groundwater. At the Stavik Creek PI, the steep topography of the channel-side slope and the bedrock structure could have been the likely factors contributing to the failure at that site.

The influence of forest practices on the development of the Tinling Creek PI is very difficult to assess. The PI developed in a stand of mature trees adjacent to the Jack Straw Aerial Timber Sale. The area of the PI was characterized by convergent topography and was bound-out of the sale as required by watershed analysis prescriptions.

In our judgment the development of the Tinling Creek debris slide could have been influenced, in some part, by the cumulative effects of timber harvest activities on the knob/ridge above the PI. However, in our opinion, this is very difficult to know for certain or to know how much water could have been directed toward the PI. It should be clearly noted that in spite of heavy rains in November 2006 (following the Jack Straw Aerial harvest) no debris slides developed. Nor, apparently did any slides develop in response to storms following the mid-20th century harvest, also a clear cut. This suggests that in the past the slopes of the Tinling Creek PI were not particularly unstable. The area of the PI likely has been experiencing a long, slow history of decrease in the strength of the earth materials that underlie the slope, but maintained enough strength to resist failure until subjected to a very large stressing event (the January 2009 storm) that overwhelmed the strength of the earth materials at the PI and triggered the failure. This model of slope failure was advanced by Terzaghi in 1950. If the January 2009 storm had been a smaller magnitude storm, it is a real probability that the debris slide might not have developed. It should be noted that it does not appear that overland flow of any noticeable amount from the area above the Tinling Creek PI was delivered to the area of the PI. Thus, with respect to the Tinling Creek PI, and considering the size of the storm, the forest practice activities may have had a relatively low level of influence, if any, in the development of the Tinling Creek debris slide. The January storm may have been of a magnitude that exceeded the climatic conditions that were factored into the development of the forest practice rules that were in effect at the time of the Jack Straw Aerial Timber Sale and harvest. The major reason for the development of the debris slide was the magnitude of the January 2009 storm and the ROS contribution of that weather event to increased groundwater to a site becoming geologically vulnerable.

The debris slide that originated in Stavik Creek apparently began as a modest-size channel side-slope translational earth slide. Though it developed in a drainage that had been clear-cut, it must be realized that it has been about 20 years since the drainage was harvested. The hydrologic maturity of the sale (and the PI) improved over those 20 years and had achieved about 55% recovery at the time of the January 2009 storm, and within five years or so would have been very close to full maturity. It is important to note that the Strand Extension site had been subjected to several severe storm events between when it was cut (about 1988) and January 2009, yet review of the historic aerial photographic coverage of that time interval did not reveal evidence for landsliding on the channel side-slopes of Stavik Creek. Some of these storms occurred early on in the regeneration history of the Strand Extension Timber Sale; a time when the channel side-slopes would have been particularly vulnerable to landsliding.

The many landslides that developed in the channel side-slopes in the high hazard MWMU #2 were not likely PIs for debris flows that flooded the valley floor areas of the affected properties. It appears they developed after the channel was scoured by debris flows. Earlier slides may have been present but there is little evidence for this. However, it is certainly likely that these smaller slides did contribute to the volume of debris washed out of Tinling Creek during the ROS event. Development of many of these slides was likely controlled by the local bedrock geology (planar joint sets and weak bedrock), or by failure of surficial deposits due to localized high groundwater and steep slopes. It should be remembered that these slides occurred in mature stands of trees bound-out of both sales. Passage of the main debris flow may have helped to initiate some of these small side-channel slides or create conditions conducive to their failure. However, it is just as likely that some of these slides would have developed even without the influence of the passage of the debris flow.

In our opinion the Stavik Creek failure was a localized event. The effects of the long-term degradation of hillside strength (Terzaghi, 1950) along with the weak nature of the bedrock and adverse orientation of planar structures in the bedrock, combined with the severe nature of the early January 2009 storm, must be considered as the primary factors in the development of the Stavik Creek earth slide. Review of the climate history suggests the early January storm was comparatively an extreme event. The water introduced by the melting snow and accompanying rainfall on a possibly already weak slope provided the proverbial "straw that broke the camels back" and triggered the slope failures and subsequent debris flood. In other words the Stavik Creek failure most likely occurred as a result of natural causes.

The January 4th to 9th rain-on-snow storm that triggered the landslides that are the subject of this reconnaissance appears to have been a relatively extreme weather event compared to that discussed in the Acme Watershed Analysis. The large volumes of sediment and debris deposited on the several properties was delivered to the properties by the large volumes of water generated by the storm. The landslides certainly provided some of the material and moved sediment down the channel. However, it is our opinion that the majority of the sediment was carried down the channels and across the properties by running water, not landslide processes.

8.0. RECONNAISSANCE LIMITATIONS

This reconnaissance report presents a qualitative assessment of the debris slide, landslides, and associated debris flows and debris floods that impacted the properties located at 3208, 3235, 3260, and an un-addressed property between 3208 and 3260 Clipper Roads in Whatcom County during the early January 2009 storm. The charge of this reconnaissance was to develop an opinion with respect to the following questions:

1) Were the PIs of the landslides on DNR-managed lands?

2) Were the PIs in areas of recent forest-management activity?
3) Did the forest-management activity contribute to initiation of the landslides?
4) How much did the management activity contribute to landslide initiation?
In this reconnaissance report we provided our observations and opinions, with respect to these questions, based on our field reconnaissance and review of office derived data. If new information should become available our geologic interpretations, and thus, our discussion could require modification.

The signatures and stamps for this engineering geologic field reconnaissance report are on the cover letter that accompanies this report; just behind the title page. This report, or any copy, shall be considered incomplete without the cover letter signed with original signatures and stamps or authorized facsimiles of the same.

END

REFERENCES

Beschta, R. L., 1995, Rain-on-snow hydrologic analysis: Acme Watershed Administrative unit, in Acme Watershed Analysis, Section 5.0 Hydrologic change, Appendix 5-1: Crown Pacific Limited Partnership, 1999 (original date 1995?), Acme Watershed Analysis: Unpublished report prepared for Department of Natural Resources, Olympia, Washington, report revised 1999.

Brunengo, M.J., 2001, Part 2. The Van Zandt Dike Landslide and a medley of other mass-movement features in the Samish – south Nooksack trough; in Northwest Geological Society Field Trip – June 2-3, 2001 field trip guidebook: Northwest Geological Society.

Canyon Lake Creek and Kenny Creek Watershed Assessment, 1993, Prepared for Trillium Corporation, preparer unknown, Bellingham, Washington, dated February 1993.

Coffin, B.A., and Harr, R.D., 1992, Effects of forest cover on volume of water delivery to soil during rain-on snow, Final report for Project SH (Rain-On-Snow Field Study), (Originally PROJECT 18): Timber, Fish, & Wildlife series, Sediment, Hydrology, and Mass Wasting Steering Committee.

Crown Pacific Limited Partnership, 1999 (original date 1995?), Acme Watershed Analysis: Unpublished report prepared for Department of Natural Resources, Olympia, Washington, report revised 1999.

Cruden, D.M. and Varnes, D.J., 1996, Landslide types and processes, in Turner, A.K. and Schuster, R.L., Landslides – Investigation and mitigation: Transportation Research Board, National Research Council, National Academy Press, Washington, D.C.

Dragovich, J.D., Norman, D.K., Haugerud, R.A., and Pringle, P.T., 1997, Geologic map and interpreted geologic history of the Kendall and Deming 7.5-minute Quadrangles, western Whatcom County, Washington: Washington Division of Geology and Earth Resources Open File Report 97-2, scale 1:24,000.

Fox, Steve, De Chant, Jennie, and Raines, Mary, 1992, Whatcom County critical areas inventory report, Alluvial fan hazard areas: Unpublished report presumably prepared for County of Whatcom, Washington, dated August 1992.

Goldin, Alan, 1992, Soil survey of Whatcom County area, Washington: U.S. Department of Agriculture, Soil Conservation Service.

Hungr, Oldrich, Evans, S.G., Bovis, M.J., and Hutchinson, J.N., 2001, A review of the classification of landslides of the flow type: Environmental & Engineering Geoscience, v. VII, no. 3.

Hooks, Douglas, 2009, Initial Incident Report (IIR) #09/S/ZGT: unpublished report on file a Northwest Region office.

National Climatic Data Center, 2009, Storm total precipitation, Radar precip est from 6:22 AM PST Sun Jan 04 2009 to 6:42 AM PST Thu Jan 06 2009; National Weather Service, Seattle/Tacoma, WA.

O'Loughlin, Colin, and Ziemer, R.R., 1982, The importance of root strength and deterioration rates upon edaphic stability in steepland forests: Proceedings of I.U.F.R.O. Workshop, P.1.07-00 Ecology of Subalpine Ecosystems as a Key to Management; Corvallis, Oregon; Oregon State University, Corvallis, Oregon; August 2-3, 1982.

Terzaghi, Karl, 1950, Mechanism of landslides, in Paige, Sidney, Chairman, Application of geology to engineering practice (Berkey Volume): The Geological Society of America, Engineering Geology (Berkey) Volume.

University of Utah, 2009, climate data from TSUMA recording station web site: www.met.utah.edu/cgi-bin/droman/time_mesowest.cgi?stn=TSUMA&unit=0&yime=...

Western Regional Climate Center, 2008, Glacier Ranger Station, Washington: http://www.wrcc.

Whatcom County Planning & Development, 2006, Whatcom County critical areas ordinance – Geologically hazardous areas: Unpublished map prepared for Whatcom County Planning & Development, dated February, 2006; scale 1:83,000.

Wolff, Noel, 2003, Jackstraw Timber Sale: unpublished memo, dated July 7, 2003.

AERIAL PHOTOGRAPHY REVIEWED

In the set of aerial photographs reviewed, stereo coverage of the area in question was not always available for the years represented. In those cases observations are based on review of the single photograph. Those years are marked by an *

Date	Flight Line/Frames	Approx. Scale	Medium
8/24/47*	BBK – 5B – 103	1;24,000	B/W
8/6/55*	BBK – 2P – 167	1:24,000	B/W
7/8/61	F.35 – 23, 24	1:12,000	B/W
7/14/71*	NW-H-71 351 – 11B – 13	1:80,000(?)	B/W
7/15/76	NW-C 76-25-130 to 131	1:24,000	Color
6-3-78	NW-78 63C-45, 46, 47	1:12,000	B/W
5/23/83	NW-C-83 13-49 417 to 418	1:12,000	Color
6/26/87	NW87 11-50-67, 69 to 70	1:13,400	B/W
7/3/91*	NW91 16-50-91	1:13,000	B/W
5/26/95	NW-95 30-50-38 to 39	1:12,000	B/W
8/26/01	NW-C-01 58-50-39, 41, 41	1:12,000	Color

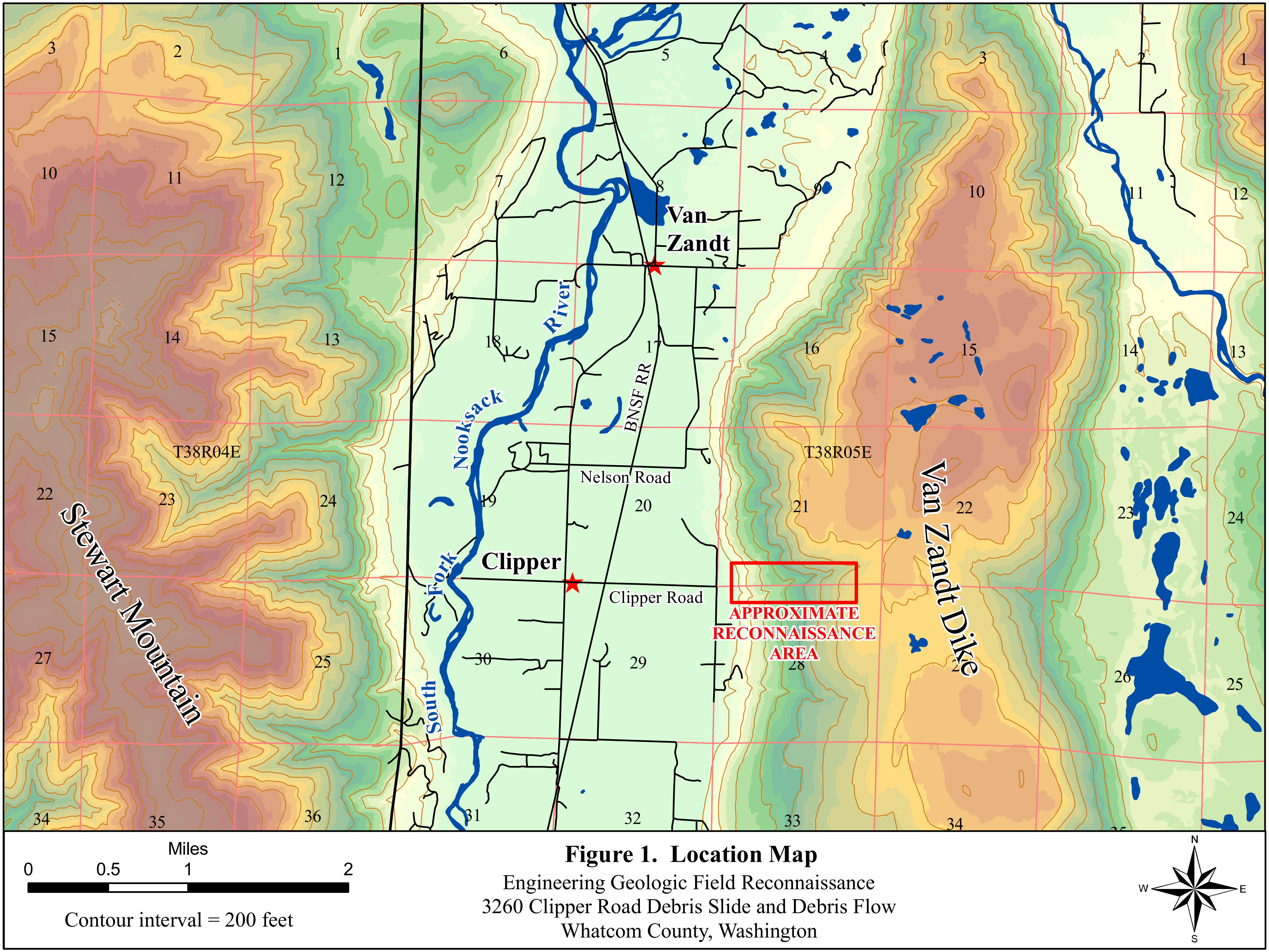


Figure 1. Location Map

Engineering Geologic Field Reconnaissance
3260 Clipper Road Debris Slide and Debris Flow
Whatcom County, Washington

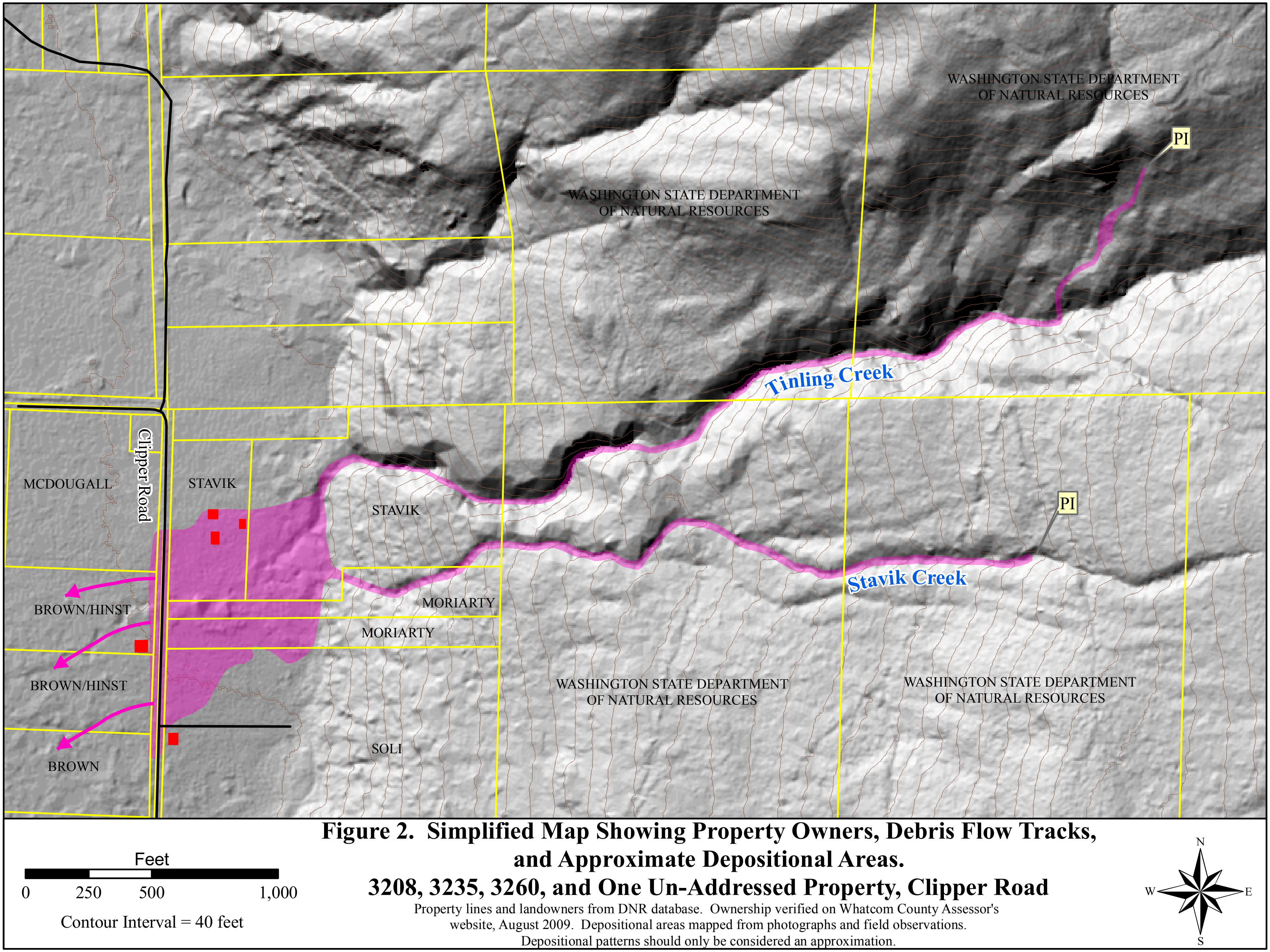


Figure 2. Simplified Map Showing Property Owners, Debris Flow Tracks, and Approximate Depositional Areas.
3208, 3235, 3260, and One Un-Addressed Property, Clipper Road

Property lines and landowners from DNR database. Ownership verified on Whatcom County Assessor's website, August 2009. Depositional areas mapped from photographs and field observations. Depositional patterns should only be considered an approximation.

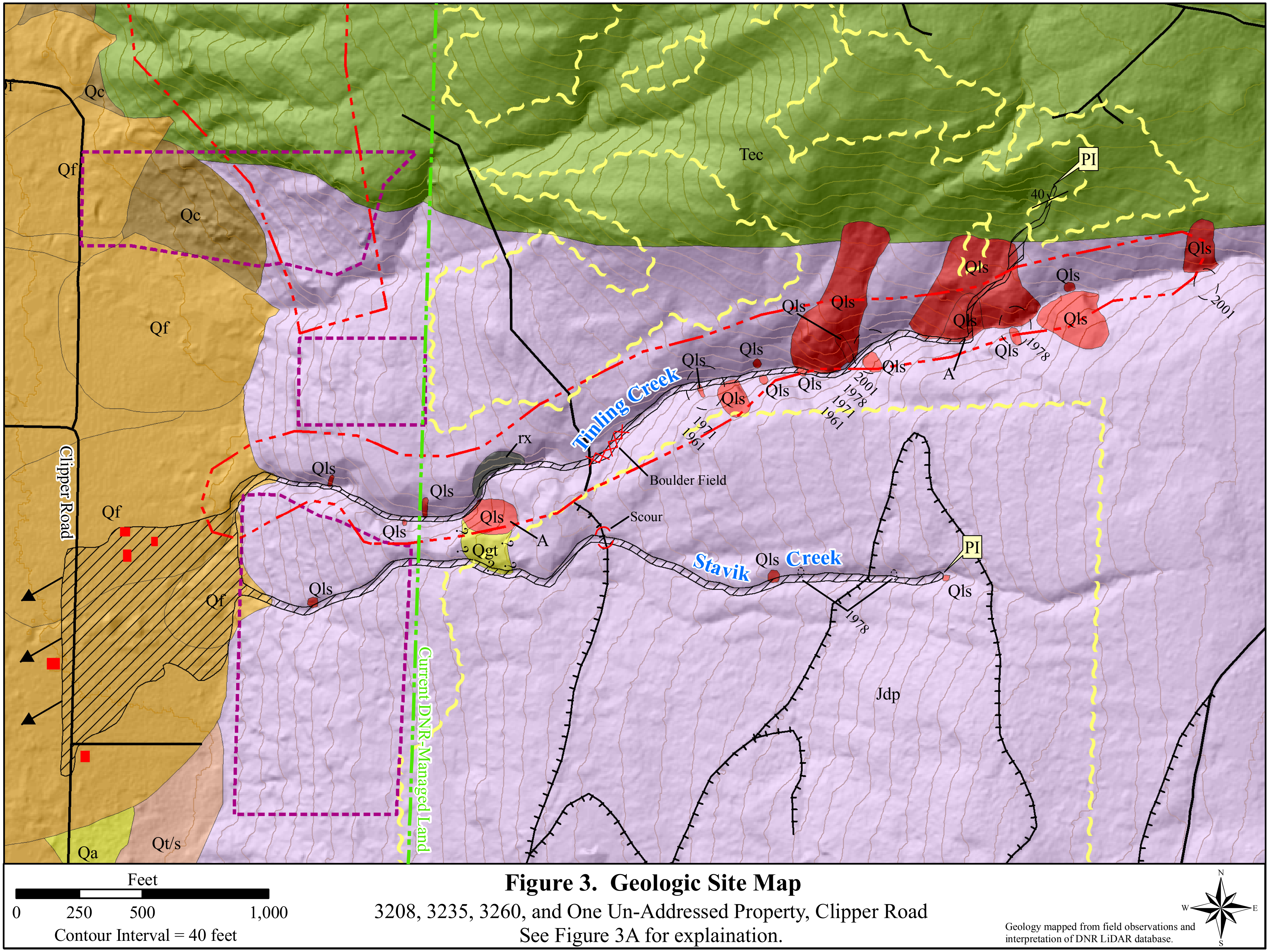


Figure 3. Geologic Site Map

3208, 3235, 3260, and One Un-Addressed Property, Clipper Road

See Figure 3A for explaination.

Geology mapped from field observations and interpretation of DNR LiDAR database.

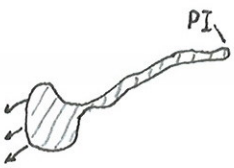
EARTH MATERIALS

Qls	Landslide debris
Qc	Colluvium (likely more extensive than shown)
Qf	Alluvial fan deposits
Qg	Glacial deposits (likely more extensive than shown)
Tec	Chuckanut Formation
Jdp	Darrington Phyllite

MAP SYMBOLS

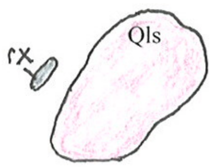
Geologic contact, locally approximate to (?) uncertain

Strike and dip of bedding



Debris slide PI, flow track, and depositional area. Arrows show general direction of flood waters and debris west of Clipper Road.

Small channel side landslide in Bittner Creek



Active channel side-slope landslides observed during field reconnaissance of Tinling Creek. Slides with arrows are deep-seated slides inferred by topographic contours; rx = rock fall

Boundary of Acme Watershed MWMU #2 around Tinling Creek; MWMU #7 on slopes north of Tinling Creek

Boundary of Strand Extension or Jack Straw Aerial Timber Sales

Older harvest boundaries, pre-1980s

Residential structures

Roads; short ticks on abandoned roads

Current State Lands property line.

FIGURE 3A. Explanation for Figure 3. Geologic Site Map

Engineering Geologic Field Reconnaissance
3312, 3334, 3363, and Two Un-Addressed Properties, Clipper Road
Whatcom County, Washington

Figure 4 Aerial view of Tinling Creek PI. Red arrow in the upper right corner of photograph points to PI and debris slide scar. Tinling Creek is in shadowed area through central area of photograph. Photo is inclined due to position of helicopter at time photograph was taken. View looking northwest. (Hooks, 2009)

Figure 5 Ground level view of Tinling Creek PI. Head scarp can be seen in stand of mature trees. View looking northwest. (Hanell, 2009)

Figure 6 Stavik Creek PI. Red arrow points to bare ground in scarp in central area of photograph. View looking south. (Hanell, 2009)

Figure 7 Scoured channel of Tinling Creek. Phyllite bedrock is exposed in sides and bottom of channel. View looking downstream to the west. (Hanell, 2009)

Figure 8 Boulder field in Tinling Creek. Phyllite bedrock exposed. View looking down channel to the west (Hanell, 2009)

Figure 9 Channel side-slope slide. in Tinling Creek. View looking up channel to the east. (Hanell, 2009)

Figure 10 Scoured portion of Stavik Creek. Phyllite bedrock is exposed in channel bottom. Note side-slope slide in left side of photo. View looking down stream to west. (Hanell, 2009)

Figure 11 Channel side-slope slide in Stavik Creek. Phyllite is exposed in slide scar. (Hanell, 2009)

Figure 12 Debris flooded area behind Stavik residence. Note debris up to porch and "new" stream course in left of photograph. View looking southwest. (Hooks, 2009)

Figure 13 Debris against barn walls, Stavik property. View looking northwest. (Hooks, 2009)

Figure 14 Photograph showing thickness of sediment deposited by debris flood from Tinling Creek. View looking east. Maggie for scale. (Hooks, 2009)

Figure 15 View of southern area of Stavik property. Red residential structure at 3235 Clipper can be seen in the background. (Hooks, 2009)