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Vicki S. McConnell, State Geologist

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LANDSLIDE HAZARD AND RISK STUDY OF THE U.S. HIGHWAY 30 (OREGON STATE HIGHWAY 92) CORRIDOR, CLATSOP AND COLUMBIA COUNTIES, OREGON

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NOTICE

The Oregon Department of Geology and Mineral Industries is publishing this map because the subject matter is consistent with the mission of the Department. The map is not intended to be used for site specific planning. It may be used as a general guide for emergency response planning. Maps in this publication depict landslide hazard areas on the basis of limited data as described further in the text. The maps cannot serve as a substitute for site-specific investigations by qualified practitioners. Site-specific data may give results that differ from those shown on the maps.

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1.0 EXECUTIVE SUMMARY

Landslides and debris flows are common in the Oregon Coast Range due to the combination of high precipitation, steep slopes, and landslide-prone geologic units. Cutting through the northern Coast Range, the U.S. Highway 30 (Oregon State Highway 92) corridor is prone to slope instability. In December 2007, a series of powerful storms produced heavy rainfall causing landslides and severe flooding. Due to the severe damage caused by these storms, the President of the United States issued a disaster declaration that allowed FEMA Hazard Grant funding to become available under FEMA DR-1733-OR. In September, 2010, the Oregon Department of Geology and Mineral Industries (DOGAMI) entered an intergovernmental agreement with Oregon Emergency Management (contract no. DR-1733-OR-14-F) to perform regional landslide hazard evaluation along the Highway 30 corridor in Clatsop and Columbia Counties. The primary purpose of this project was to provide detailed information about landslide hazards and assets at risk in this area. On the basis of the tasks detailed in the original proposal, the five main objectives of this project were to:

- Create a detailed lidar-based landslide inventory
- Create shallow- and deep-landslide susceptibility maps
- Compile and/or create a database of critical facilities and primary infrastructure
- Perform exposure and HAZUS-based risk analyses
- Provide recommendations for city and county landslide hazard regulation

The completed landslide inventory maps a total of 588 landslides within the 90 mi^2 study area with 288 landslide deposits classified as deep and 140 as shallow. Also mapped on the lidar were 150 debris flow deposits and 10 rock fall deposits. Over half (380) of the landslides are classified as historic, having moved in the last 150 years. Of these historic landslides, 80 have recorded dates of movement in the period 1930 to 2011.

Landslides occur on slopes ranging from 10 degrees to 62 degrees, with a mean estimated pre-slide slope of 33 degrees. Depth to slip surfaces for shallow landslides range from 0.5 ft to 15 ft, with an average of 10 ft; depth to slip surfaces for deep landslides range from 15 ft to 369 ft, with an average of 45 ft. The landslide deposits are highly variable in size. The smallest covers an area of approximately 75 ft^2, while the largest deposit covers an area over 177,000,000 ft^2 (4,000 acres). The Wauna landslide, over 5 miles long, is situated near the communities of Wauna and Westport and is the second largest landslide found. Highway 30 and one of the main transmission lines cut across the massive body of the landslide (Figure 1).

Debris flow fans account for a quarter of the landslide failures mapped. Historic accounts indicate that the area has been plagued by catastrophic debris flow events since the 1800s, most notably along Highway 30. Five major debris flows along the highway have damaged residences between 1914 and 2007. Along Highway 30, a number of structures exist on debris flow fan deposits, causing property and people to be vulnerable to these potentially catastrophic events (Figure 2).

This study indicates that the Highway 30 corridor in Columbia and Clatsop Counties is at significant risk from landslide hazards. Landslides cover 25% of the study area, and 33% of the City of Clatskanie is covered by large, deep landslides. The large number of people and structures

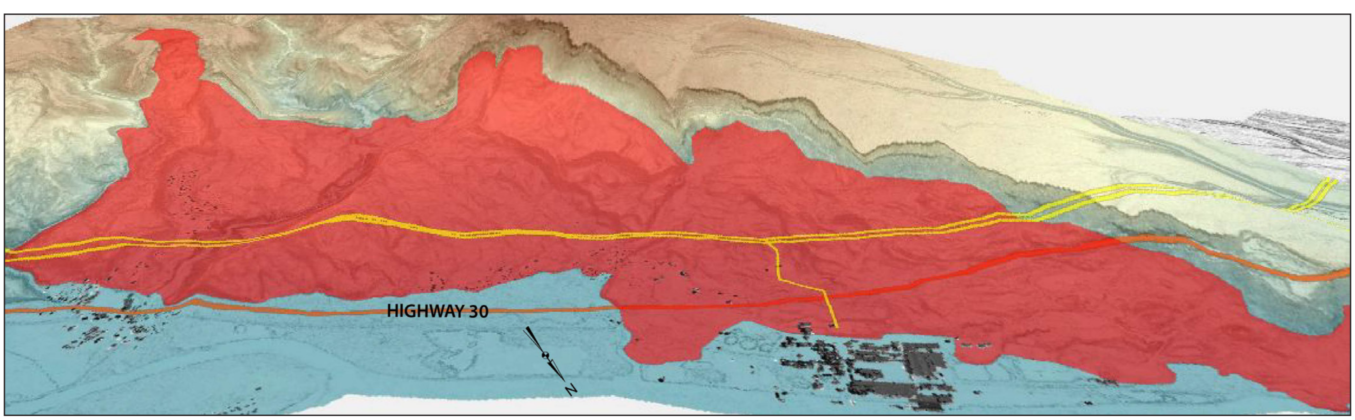


Figure 1. 3D view of the Wauna landslide showing U.S. Highway 30 and electric transmission line (in yellow) crossing the landslide body. Vertical exaggeration is approximately 2×.

residing on these deposits highlights the potential danger present and shows the need for public awareness on landslide hazards.

The landslide susceptibility maps show that this area is highly susceptible to deep and shallow landslides. The high-susceptibility zone for shallow landslides covers 15% and the moderate susceptibility zone covers 32% of the study area. For deep landslides, the high-susceptibility zone covers 28% of the study area and the moderate susceptibility zone covers 15%. Most low-susceptibility zones for both shallow and deep landslides are restricted to the floodplain of the Columbia River.

Exposure and HAZUS-MH (FEMA, 2011) based risk analyses were used to estimate potential losses and damages from landslide hazards. The HAZUS-MH software program allows the user to estimate potential losses from earthquake-induced landslides. The results of these analyses showed that residential buildings are the most exposed asset. Primary infrastructure, mainly roads and electric transmission lines, is also at risk. Sixty-eight percent of the electric transmission lines and 57% of the transmission towers are currently routed on landslide deposits, making the entire system vulnerable. Highway corridors also are exposed, with 76% at risk from shallow landslides. A road closure in this area can have a potentially large economic impact because 6,000 vehicles travel these routes per day. The results from the risk analysis allow planners and first responders to understand where resources should be directed.

The results of this study include this report, a detailed landslide inventory including pre-historic, historic, and active landslides, and a set of susceptibility maps identifying areas at risk for landslides.

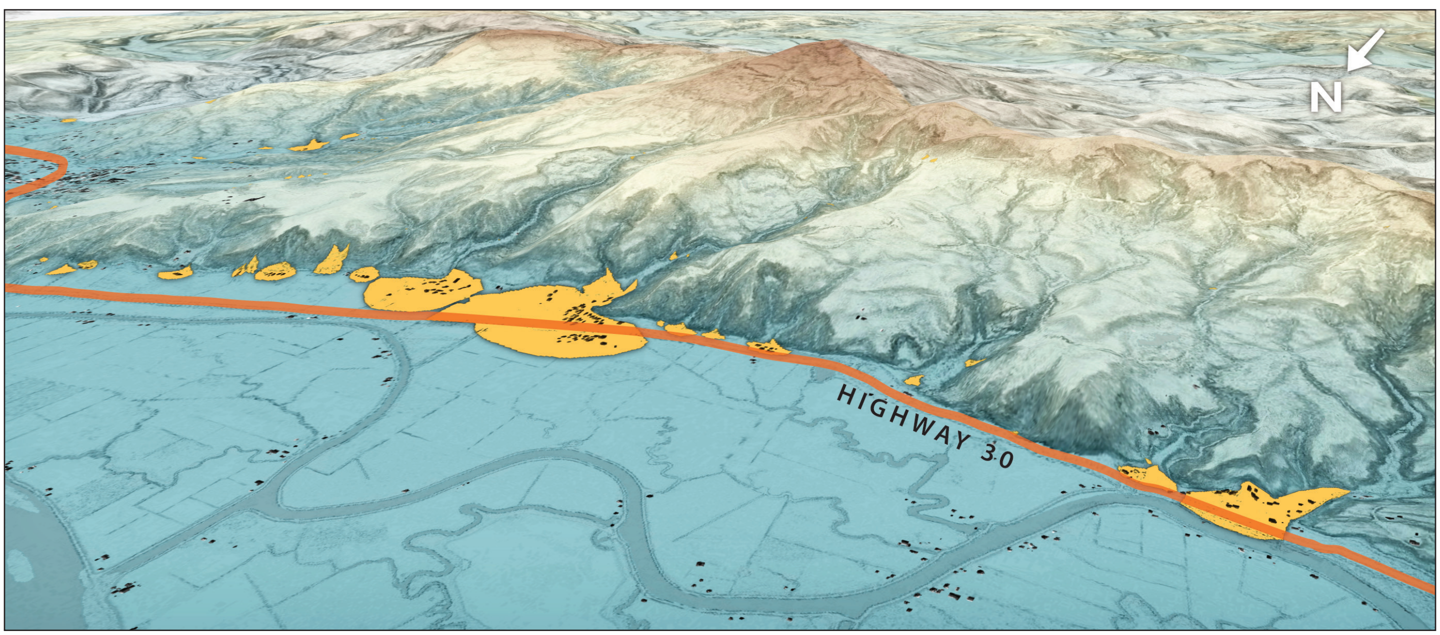


Figure 2. 3D view of debris flows (in orange) along U.S. Highway 30 and structures (in black) residing on the deposits. Vertical exaggeration is approximately 2×.

2.0 INTRODUCTION

In December 2007, a series of powerful storms pummeled the Pacific Northwest, seriously affecting areas in Washington and Oregon. These storms produced heavy rainfall and strong winds that damaged roads and property, downed power lines, triggered landslides, and produced severe flooding. Due to the severe damage caused by these storms, the President of the United States issued a disaster declaration that allowed FEMA Hazard Grant funding to become available under FEMA DR-1733-OR. Historic accounts for this area indicate that landslides are usually triggered by long-duration precipitation events; however, large earthquakes also can induce landsliding.

In September, 2010, DOGAMI and Oregon Emergency Management (OEM) agreed to perform regional landslide hazard evaluation along the U.S. Highway 30 corridor in Clatsop and Columbia Counties. The primary purpose of this project was to provide detailed information about landslide hazards and assets at risk. A lidar-based landslide and asset inventory and landslide susceptibility maps were created. These data were then used to a perform exposure and HAZUS-MH based risk analyses.

The study area is situated in the northern Oregon Coast Range, approximately 60 miles northwest of Portland, and covers 90 mi^2. It spans two counties, Columbia and Clatsop, and includes the communities of Clatskanie, Marshland, Westport, Kerry, and Woodson. Clatskanie is the largest city in the study area with approximately 1,700 residents, followed by Marshland with approximately 460 residents.

The study area is bounded by and parallels the Columbia River to the north, with major road access via Highway 30 and Highway 47 (Figure 3). Highway 30 is a major road corridors between the Columbia River Valley and the north coast. Approximately 6,000 vehicles travel daily through the study area along Highway 30; another 1,000 vehicles travel daily along Highway 47 (ODOT, 2010). A road closure due to a landslide can have a potentially large economic impact due to the moderate traffic flow through the area. A major train corridor also parallels the Columbia River, allowing delivery of freight from the valley to the coast.

Figure 3. Map of study area.

The geology in the study area consists of middle Miocene Columbia River Basalt, early to middle Miocene Scappoose Formation, and Oligocene Pittsburg Bluff Formation. The Columbia River Basalt Group (CRBG) in the study area consists of two units: the Frenchman Springs Member of the Wanapum Basalt Formation and the Wapshilla Ridge and Grouse Creek Members of the Grande Ronde Basalt Formation (Eriksson, 2002; Niem and Niem, 1985).

The Scappoose Formation comprises several lithologic units. The basal beds are composed of fluvial cobbles to basalt conglomerates from the Wapshilla Ridge Member. The middle unit consists of marine sandy siltstone, and the upper unit consists of volcanic litharenite. The Pittsburg Bluff Formation is composed of a micaceous sandy siltstone with lenses containing molluscan fossils and tuff (Eriksson, 2002). These units along with the CRBG were used to create an engineering geology map discussed in section 4.2.2.

Landslides are common with in the study area, especially large, deep landslides and debris flows at the mouths of drainages. Previous geologic maps (Eriksson, 2002; Niem and Niem, 1985; Beaulieu, 1973; Walsh, 1987) show several large, prehistoric landslides within the study area. The most notable is the Wauna slide, situated near the communities of Wauna and Westport (Figure 4). The slide spans approximately 5 miles along the Columbia River. Borings drilled at the Georgia Pacific Wauna Paper Mill show slide debris down to a depth of at least 165 feet below the current surface (Beaulieu, 1973). This means that the failure plane most likely extends below the present Columbia River channel (Figure 5). The borings also show interbeds of alluvium,

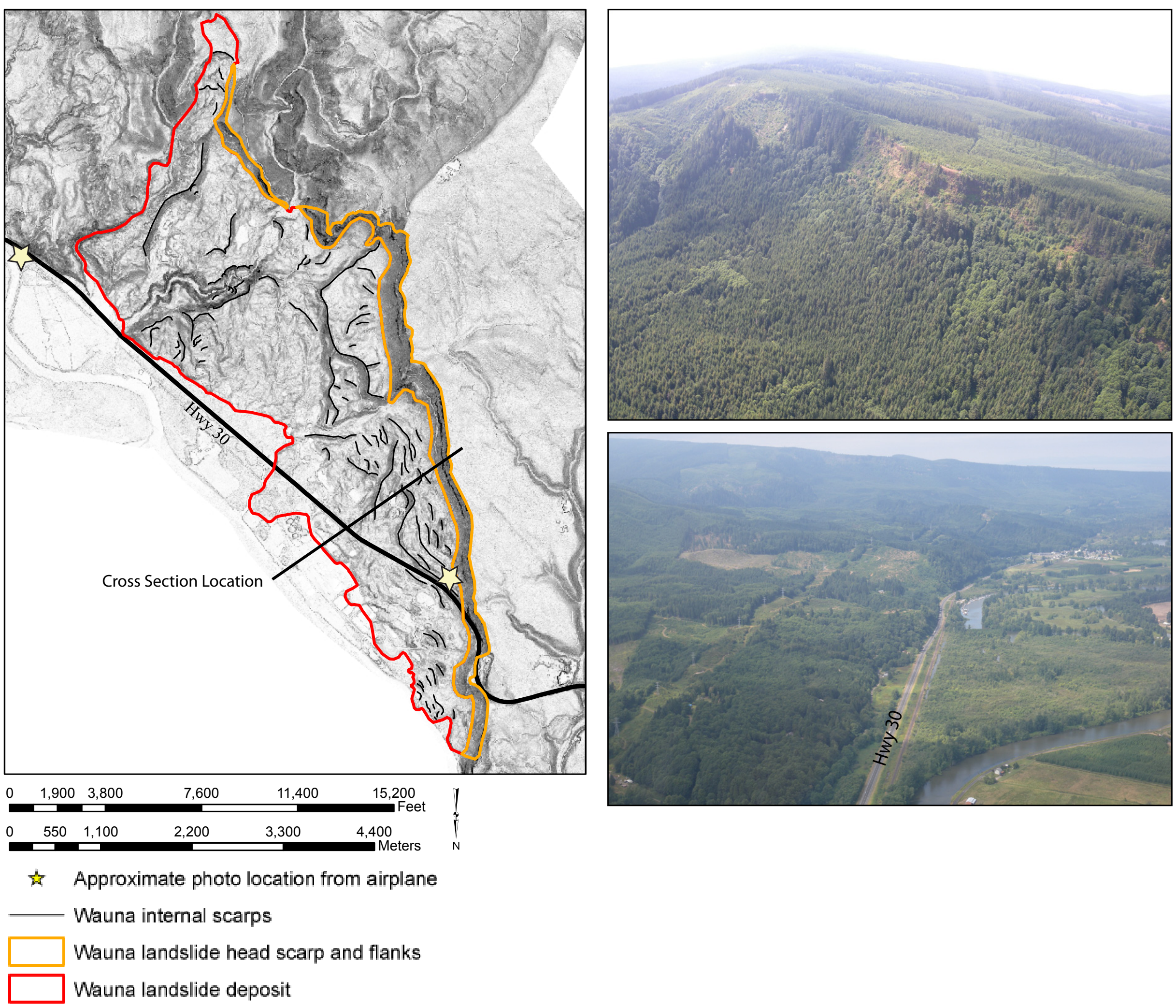


Figure 4. (left) Wauna landslide mapped on lidar-derived slope image. Photographs, oriented northwest, of (upper right) Wauna landslide head scarp and (lower right) hummocky topography within the landslide body were taken at the starred locations on slope image. Labeled cross section is shown in Figure 5.

indicating that the Wauna slide has had multiple failures rather than one catastrophic failure (Beaulieu, 1973). Four borings were interpreted by DOGAMI staff to determine the average depth to the deposit and failure plane. The top of the Wauna landslide at the mill is at approximately 45 feet above sea level, and the failure plane is approximately 175 feet above sea level(Figure 5). This relationship implies that this slide most likely was active during a glacial period when sea level and the elevation of the Columbia River were much lower (Baker, 2002). The borings are included in Appendix A.

Within the study area, 218 historic landslides have been recorded as points with dates of occurrence ranging from 1930 to 2012 (Figure 6). These landslide point locations were compiled from the historic landslide points dataset in the Statewide Landslide Information Layer for Oregon, release 2 (SLIDO-2; Burns and others, 2011), a report by Shaw and others (2008), aerial photo interpretation, and field work. The points from aerial photo interpretation were created by comparing 2009 National Agriculture Imagery Program (NAIP) orthophotos to the 2005 NAIP orthophotos. The landslides included from the photo interpretation most likely occurred during the major 2007 storm events. Of these 218 landslides, 118 occurred along Highway 30 or Highway 47, illustrating the landslide hazard along the major routes through the study area and the tendency of road cuts to fail due to oversteepening or poor drainage.

Historic accounts indicate that the Clatskanie area has been plagued by catastrophic landslide and debris flow events since the 1800s, most notably along Highway 30 within the study area (Shaw and others, 2008). On December 11, 2007, a fill failure created an impounded lake, which then failed catastrophically, sending debris down Eilertsen Creek, covering Highway 30, and destroying structures in the community of Woodson (Figure 7). The debris flow caused lengthy highway closures and significant property damage. In December 1933, a debris flow emanating from OK Creek pushed a house across the highway, killing several people (Shaw and others, 2008). Five other major debris flows along the highway have damaged residences and structures between 1914 and 2007 (Shaw and others, 2008; Figure 8).

Because of historic and recent landslide activity, this study was conducted in order to better understand the hazard and associated risk. Landslides and community assets were mapped throughout the study area. Susceptibility maps were then created to determine where potential landslide hazard areas. Two types of risk were analyzed to see which assets were exposed to landslide hazards. These data can be used to identify ways to reduce the risk to communities and infrastructure in the study area.

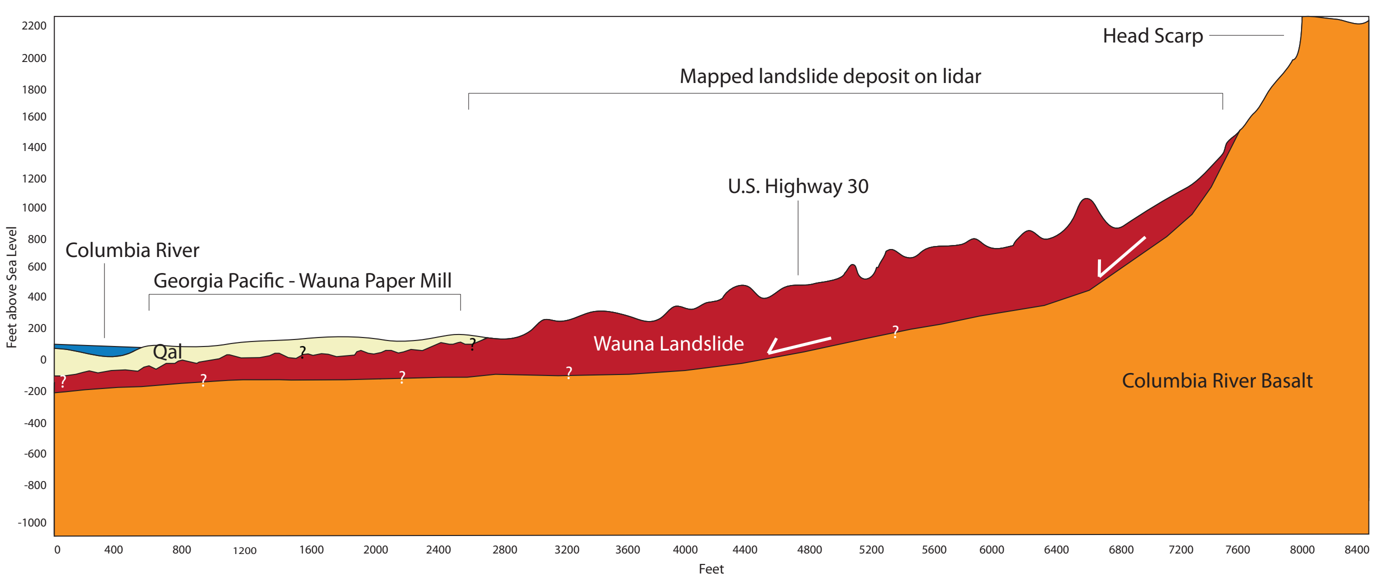


Figure 5. Interpreted cross section of the Wauna landslide showing that part of the slide is overlain by Quaternary alluvium (Qal) and most likely extends below the present Columbia River channel. Cross section location shown in Figure 4.

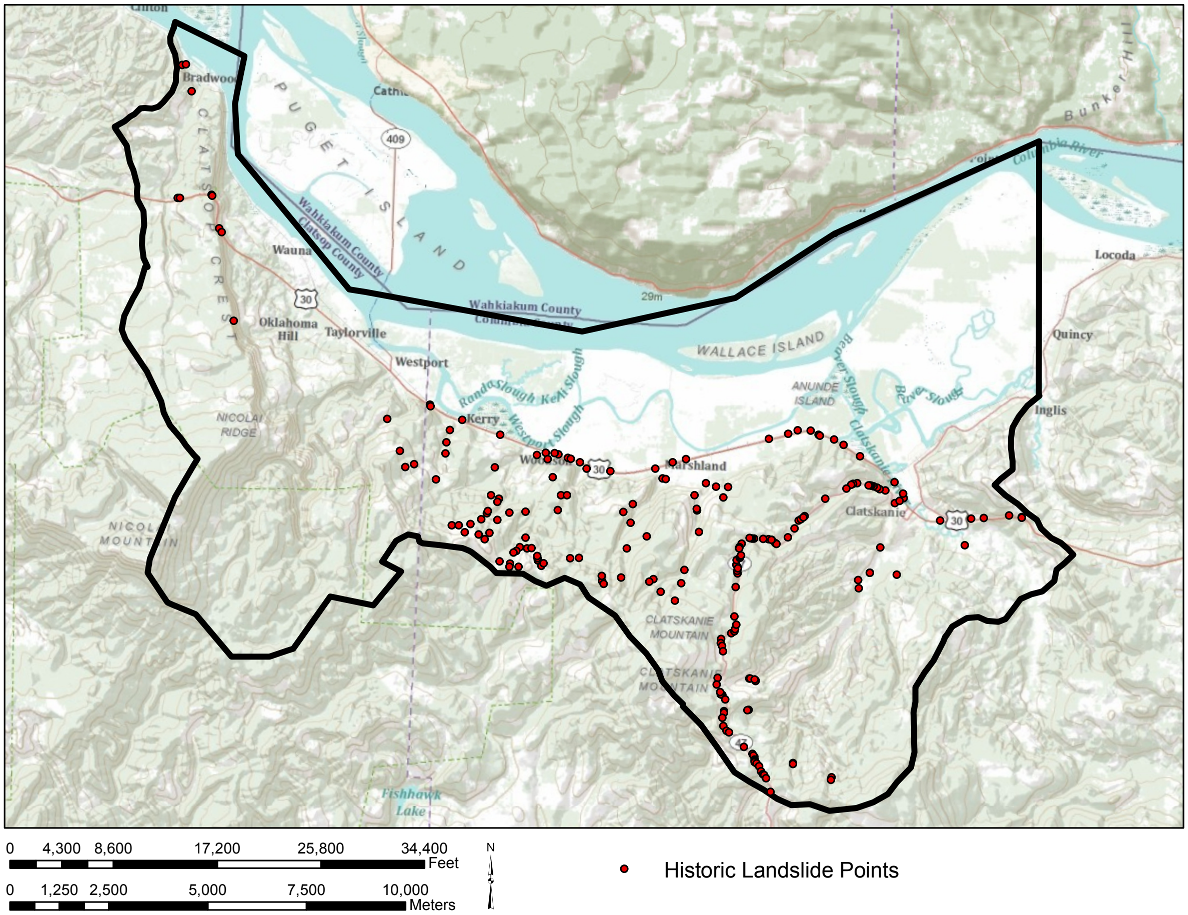


Figure 6. Map of historic landslide points in the study area with failure dates from 1930 to 2012.

Figure 7. December 11, 2007, Woodson debris flow (Shaw and others, 2008).

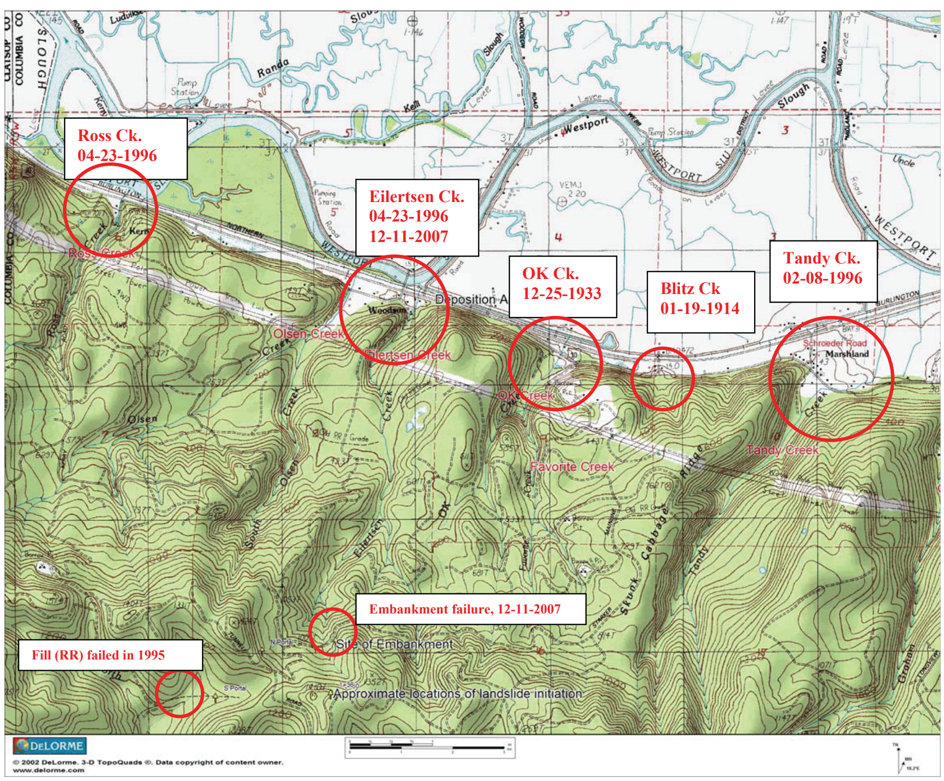


Figure 8. Locations of residences and structures damaged by debris flows along U.S. Highway 30 between 1914 and 2007 (from Shaw and others [2008]).

3.0 ASSETS

3.1 Community Assets Defined

Community assets are defined as the human artifacts necessary to support a community. Generally, this includes people, property, infrastructure, and economic resources. In this study, assets were limited to permanent population, generalized zoning, buildings and critical facilities, and primary infrastructure, as detailed below.

3.1.1 Permanent Population

Permanent population is needed to accurately estimate losses from disasters; however, it is difficult to map this asset because people tend to migrate on hourly, daily, monthly, seasonally, or yearly bases. To model the permanent population (residents) in the study area, a dasymetric mapping technique was applied using 2010 U.S. Census data (Sleeter and Gould, 2007).

3.1.2 Generalized Zoning

Zoning refers to the permitted land use designation such as agricultural, industrial, residential, recreational, or other purposes. To evaluate land assets for this project, county and city tax lot databases were combined to create a layer that identifies generalized zoning information for each piece of property. Data from tax lot databases also include information about the dollar value of the land and any improvements, such as houses. For this project, zoning classes were simplified to commercial, residential, or public.

3.1.3 Critical Facilities

Critical facilities are typically defined as school buildings and emergency facilities such as hospitals and fire and police stations. The definitions and data created in the DOGAMI Statewide Seismic Needs Assessment: Implementation of Oregon 2005 Senate Bill 2 Relating to Public Safety, Earthquakes, and Seismic Rehabilitation of Public Buildings (Lewis, 2007) were used to identify most critical facilities. For this project, energy-generating facilities were also included.

3.1.4 Primary Infrastructure

Primary infrastructure for this study included electric transmission lines, electric towers, electric substations, railroads, and rail bridges. Roads were also included and were grouped as highways, arterial roads, and road bridges.

3.2 Community Assets Methods

3.2.1 Permanent Population Data Methods

Countywide population data published by the U.S. Census Bureau (2010) are available for each of the 50 United States, as well as the District of Columbia and Puerto Rico. Each county is divided into units called tracts, block groups, and blocks. Census blocks, the smallest available unit that can be used to provide population counts, were chosen due to the relatively small size of the study area. However, there is no information within the census data to accurately describe population distribution. Therefore, in order to best assess the distribution of permanent populations within the study area, we applied the methods and the dasymetric mapping tools created by the U.S. Geological Survey (USGS) (Sleeter and Gould, 2007). Initially, we used 2010 census block data (U.S. Census Bureau, 2010) and 2006 land cover data (Fry and others, 2011) developed for the National Land Cover Database (NLCD) to create a new spatial data layer to more precisely illustrate the permanent population distribution within the study area. Upon review of the results, it was clear that the NLCD data did not adequately represent land cover for a small, localized study. To resolve this problem, the tax lot and zoning data, building locations, and aerial photos were used to create a new and more accurate land cover data layer. The resulting feature class was then converted to a raster so that it could be used with the USGS dasymetric mapping tools. A cell size of 60 ft was used so that the final dasymetric output density would reflect a relatable area by which to interpret populations (1 raster cell is ≈ 3,600 ft^2, approximately the area of a single-family home).

3.2.2 Generalized Zoning Methods

A generalized zoning Geographical Information System (GIS) dataset was created with available taxation data for Columbia and Clatsop Counties. Tax lot data files were received from Clatsop County and were downloaded for Columbia County from the Columbia County Assessor's Office website. Duplicates were manually cleaned from the datasets, and a generalized zoning class (residential, commercial, or public) was assigned to each tax lot following a method described by Burns and others (2011). The generalized zoning class was based upon the property classification code for each lot (Appendix B). For Columbia County, a status classification code or description was used in addition to the property classification code to further help with classification. The status classification code designates the type of improvement on each tax lot, which is most commonly associated with structures. In some cases the property classification code indicated commercial use, but the status classification code indicated that the lot was used for a residence. In these cases, the status classification was used. Three tax lots in Columbia County had no property or status classification codes and were assigned the same code as the adjacent properties.

The generalized zoning layer was clipped to the study area, thereby reducing the original size of some of the parcels along the study area boundary. Out of the total 2,798 tax lots, 121 lots were clipped to the study area boundary. In order to determine the real market value (RMV) of the clipped lots, the original parcel area first was divided by the new clipped area, resulting in a percent. This percent was then multiplied by the original RMV value to obtain a more realistic RMV. The RMV did not include the value of any structures and was only the land value of each lot (Burns and others, 2011).

3.2.3 Building Methods

One-foot lidar bare-earth and highest-hit lidar digital elevation models (DEMs) were reviewed to create the GIS database of buildings. The bare-earth DEM (ground surface) was subtracted from the highest-hit DEM (top surface of anything on the land) resulting in a “canopy” (DEM) that shows the height above ground of vegetation and structures. The canopy DEM was then overlain on the highest-hit DEM and classified into two groups, height 5.5–20 ft (above the ground surface) and height from 20–50 ft (above the ground surface) to highlight the buildings (Figure 9).

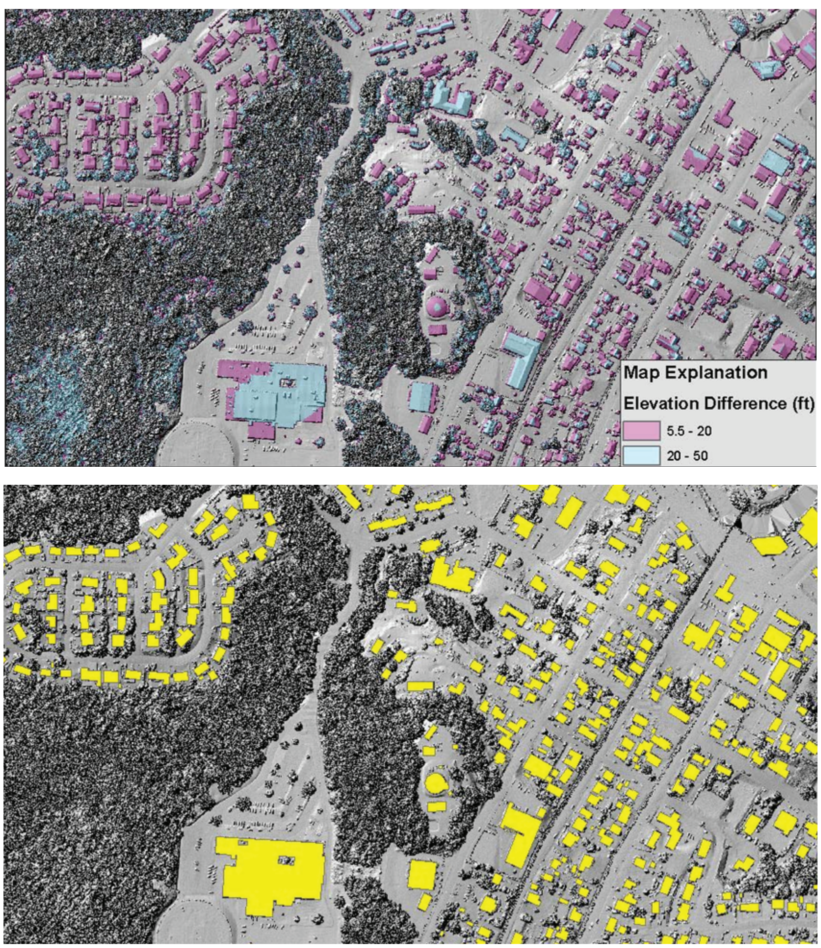


Figure 9. (top) Differential digital bare-earth elevation model (DEM) displaying colored elevation breaks to highlight buildings in the City of Clatskanie and (bottom) final digitized building layer used for analysis.

The purpose of the 5.5–20 ft elevation break was to eliminate cars, tall trees, and short vegetation to help make the buildings stand out. The second elevation break was chosen to highlight buildings taller than 20 ft. Building footprints were then digitized as polygons by DOGAMI staff.

3.2.4 Critical Facilities and Primary Infrastructure Methods

The critical facilities included in this project are schools, police and fire facilities, hospitals, and power generating facilities. The critical facilities were extracted as points from the DOGAMI Statewide Seismic Needs Assessment (Lewis, 2007). Polygons for each facility were then created in GIS using bare-earth and highest-hit lidar DEMs, 2009 NAIP orthophotos, and available tax lot data. The critical facility polygons include any associated buildings, parking lots, and land owned by the facility.

- The primary infrastructure GIS shapefiles include:
- Electric transmission lines as polylines, transmission towers as points, and substations as polygons
- Railroads as polylines and railroad bridges as points
- Highways and arterial roads as polylines and road bridges as points

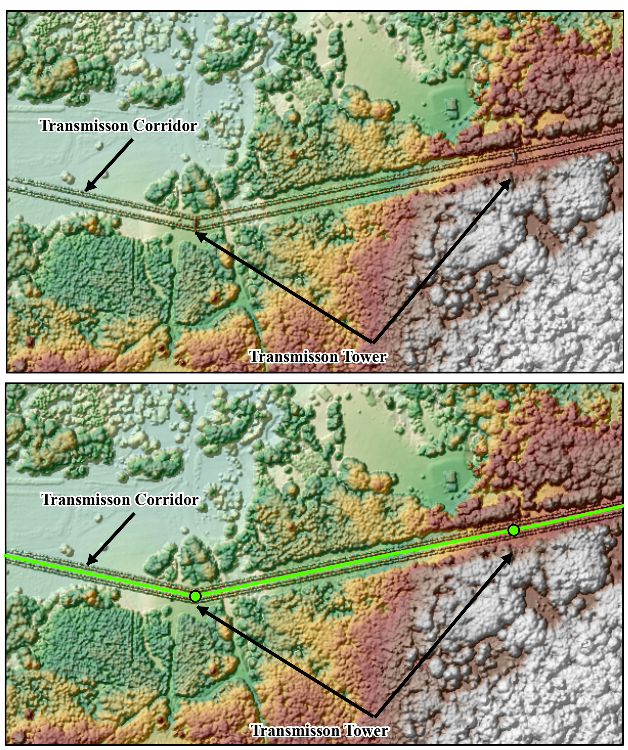


Figure 10. Three-foot highest-hit lidar digital elevation models (DEMs) showing mapped transmission line and towers.

Electric transmission lines, transmission towers, and substations were digitized in GIS by DOGAMI staff using the bare-earth and highest-hit lidar DEMs and 2009 NAIP orthophotos. For transmission lines, the center line rather than each individual conductor was digitized (Figure 10).

Highways, arterial roads, and railroads were extracted from the U.S. Census Bureau TIGER/Line® (Topologically Integrated Geographic Encoding and Referencing) database (U.S. Census Bureau, 2010). Bridges were extracted from the Oregon Department of Transportation database (ODOT, 2008). Several road bridges in the ODOT database were removed from the final dataset as they were determined to be large culverts. Additional roads and bridges not present in the TIGER/Line database were added by digitizing their locations using the bare-earth and highest-hit lidar DEMs and 2009 NAIP orthophotos.

3.3 Asset Results

A summary of asset data for the study area is displayed in Table 1.

Table 1. Summary of asset data for the study area (M=million).

Asset	Count	Area or Length	Value
Permanent population	3	na*	na
Buildings	3	na	na
Generalized Zoning			
Residential parcels	1	12.3 mi^2	$84.58M
Commercial parcels	731	56.9 mi^2	$104.28M
Public parcels	208	10.5 mi^2	$8.54M
Critical Facilities			
Hospital buildings	0	na	na
School buildings	3	na	na
Fire buildings	1	na	na
Police buildings	1	na	na
Power facilities	1	na	na
Infrastructure			
Arterial roads	na	254.1 mi	na
Highways and interstates	na	25.5 mi	na
Road bridges	28	na	na
Electric transmission lines	na	39.1 mi	na
Electric transmission towers	221	na	na
Electric substations	3	na	na
Railroad lines	na	21.8 mi	na
Railroad bridges	12	na	na

*na means not applicable.

3.3.1 Permanent Population Results

There are 3,720 residents in the study area; 45% (~1,650 people) live in the City of Clatskanie (Figure 11). There are 3,044 residents in Columbia County, and 676 residents in Clatsop County.

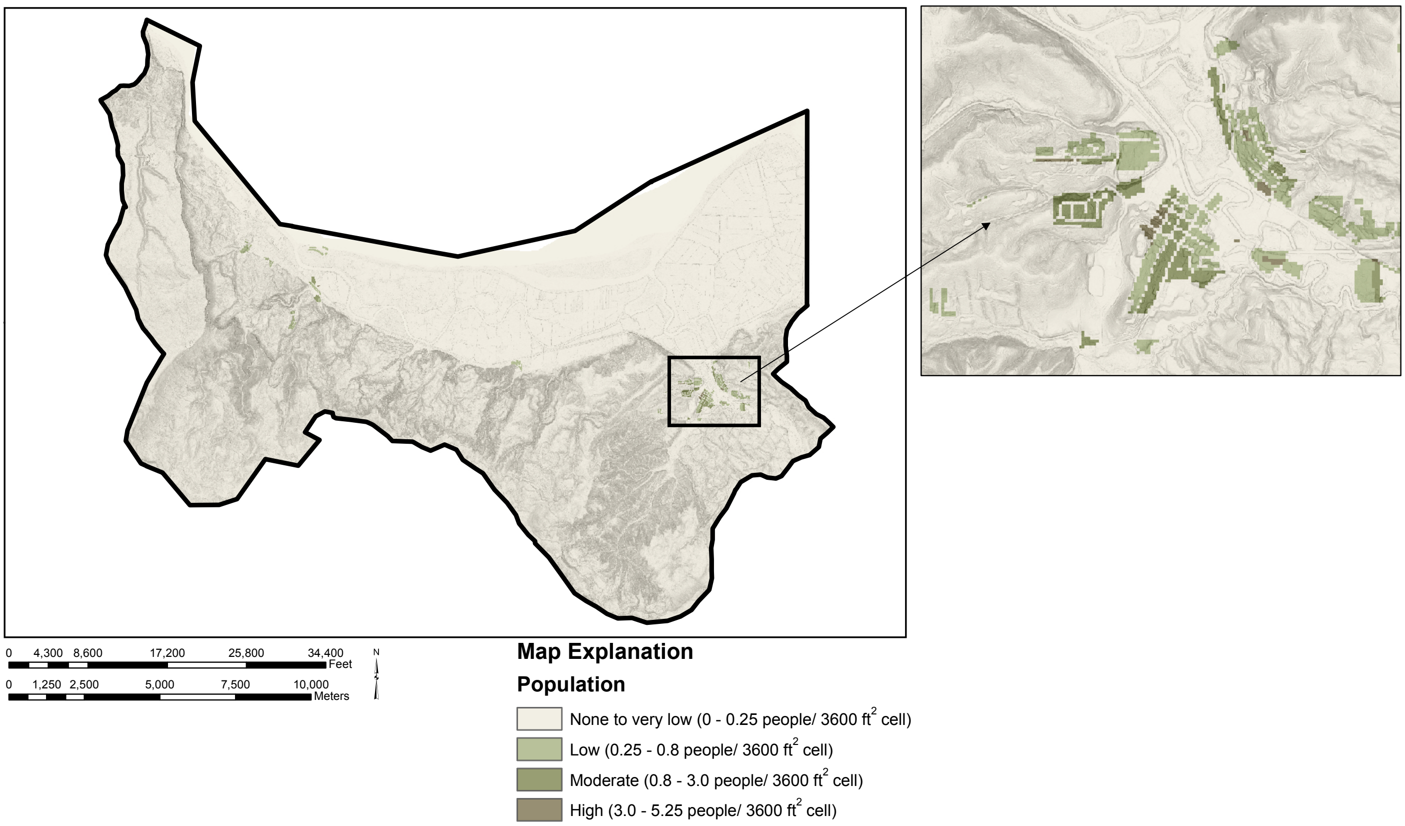


Figure 11. Gridded permanent population data for (left) the study area and (right) detail for the City of Clatskanie.

3.3.2 Generalized Zoning and Building Results

The study area is predominantly commercial parcels (71%) in terms of area (Figure 12), although there are nearly twice as many residential parcels as commercial parcels. The total real market value of the land is $197,393,665, with residential lots comprising 43% and commercial lots 53% of the total value (Table 1).

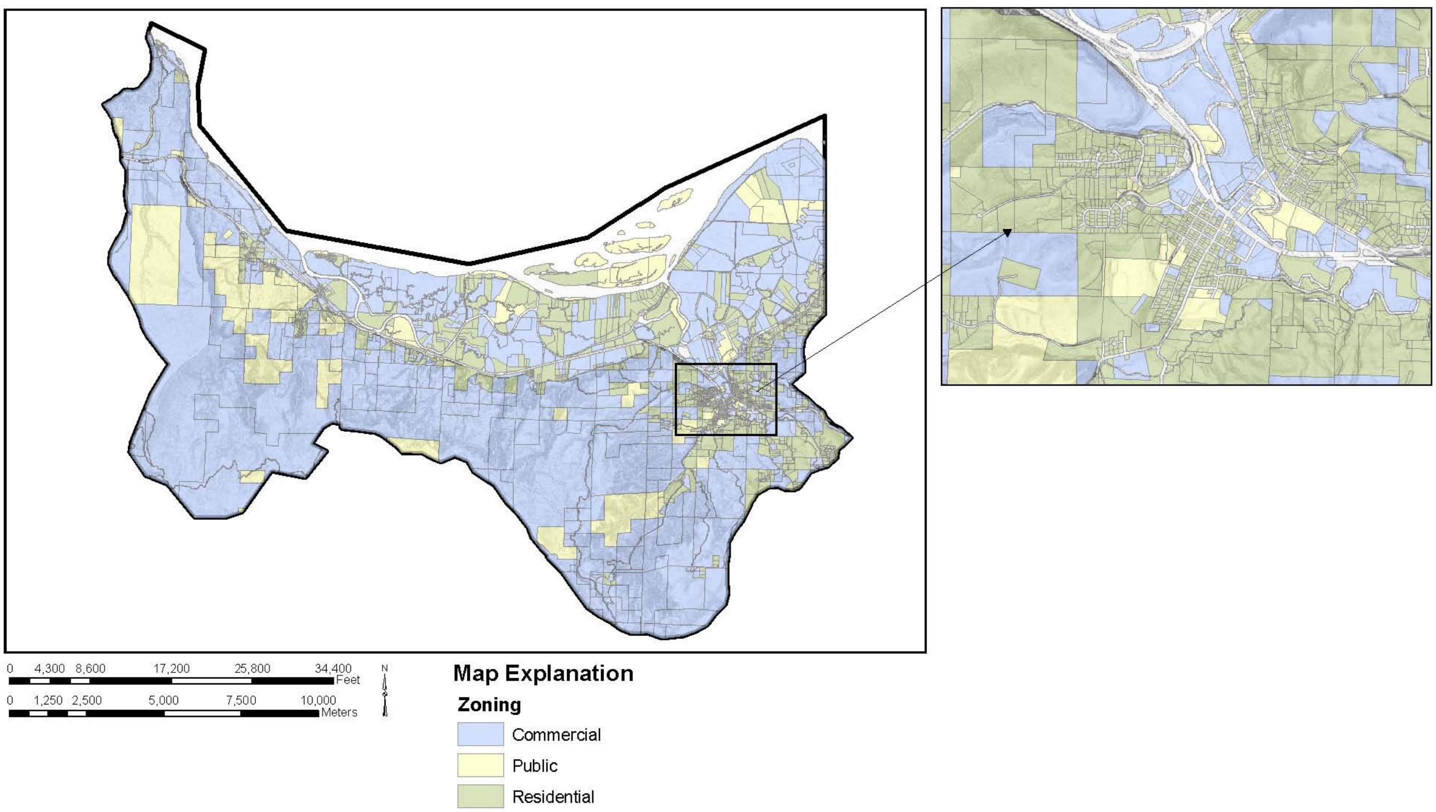


Figure 12. Generalized zoning for (left) the study area and (right) detail for the City of Clatskanie.

3.3.3 Critical Facilities and Primary Infrastructure Results

There are six critical facilities within the study area. The majority of these facilities are in or near the City of Clatskanie (Figure 13, Plate 1). There are approximately 39 miles of transmission lines with 221 towers and 3 substations. The study area includes approximately 25 miles of highway and 254 miles of arterial roads (Table 1).

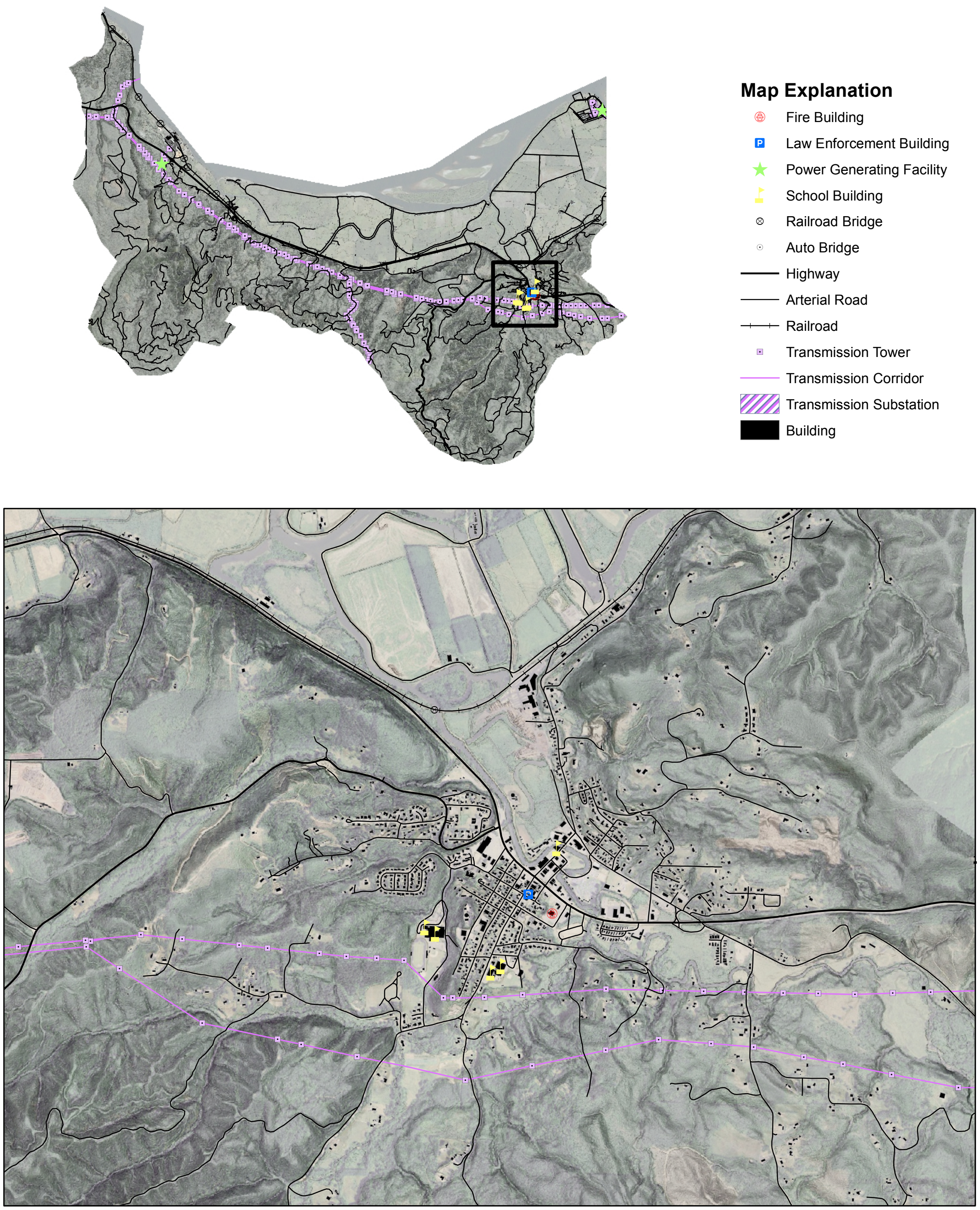
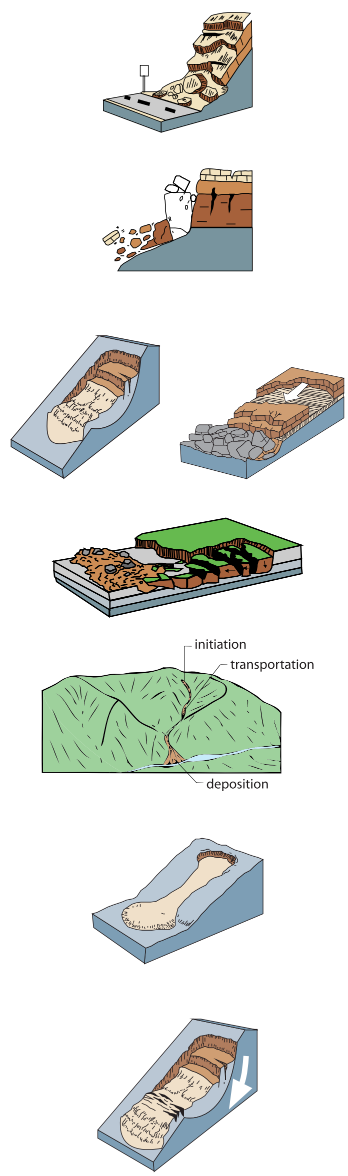


Figure 13. (top) Map showing locations of critical facilities, roads, bridges, railroads, and electric transmission lines, towers, and substations for the study area and (bottom) detail for the City of Clatskanie (indicated by the black box in the top figure). See Plate 1 for larger map.

4.0 LANDSLIDE HAZARDS

4.1 Landslide Hazard Definition

The general term landslide refers to the movement of earth materials down slope. When factors allow the force of gravity acting on a slope to exceed the strength of the rock and soil that make up the slope, the slope will fail, causing soil and rock to slide downhill. Landslide movement can be classified into six types (Figure 14): falls, topples, slides, spreads, flows, and complex. Movement type is often combined with other landslide characteristics such as type of material, rate of movement, depth of failure, and water content in order to more fully describe the landslide behavior. Slope areas that have failed remain in a weakened state and are particularly important to identify as these areas may be susceptible to instability (Burns and Madin, 2009). Although water is the most common trigger for landslides, major earthquake events can also induce slope failures.



Falls are near-vertical, rapid movements of masses of materials, such as rocks or boulders. The rock debris sometimes accumulates as talus at the base of a cliff.

Topples are distinguished by forward rotation about some pivotal point, below or low in the mass.

Slides are downslope movement of soil or rock on a surface of rupture (failure plane or shear-zone).

- **Rotational** slides move along a surface of rupture that is curved and concave.
- **Translational** slides displace along a planar or undulating surface of rupture, sliding out over the original ground surface.

Spreads are commonly triggered by earthquakes, which can cause liquefaction of an underlying layer and extension and subsidence of commonly cohesive materials overlying liquefied layers.

Channelized Debris Flows commonly start on a steep, concave slope as a small slide or earth flow into a channel. As this mixture of landslide debris and water flows down the channel, it pick ups more debris, water, and speed, and deposits in a fan at the outlet of the channel.

Earth Flows commonly have a characteristic "hourglass" shape. The slope material liquefies and runs out, forming a bowl or depression at the head.

Complex landslides are combinations of two or more types. A common complex landslide is a slump-earth flow, which usually exhibit slump features in the upper region and earth flow features near the toe.

Figure 14. Types of landslide movements (modified after Highland [2004] and Burns and Madin [2009]).

Channelized debris flows are one of the most potentially life threatening types of slides due to their rapid movement down channel and the fact that they can travel several miles down slope. Debris flows tend to initiate in the upper reaches of a drainage and pick up water, sediment, and speed as they come down the channel. As a debris flow approaches the mouth of a channel, the material tends to fan out due to the lower slope gradient and lack of confinement. Debris flows also are commonly mobilized by other types of landslides failing on slopes near the channel or from accelerated erosion during heavy rainfall or snow melt.

Landslides are often classified by their depth of failure as deep or shallow. Shallow landslides are defined as failing above the contact between bedrock and the overlying soil, In this study, shallow landslides are defined as having a failure depth less than 15 ft (Burns and Madin, 2009). Deep landslides have failure surfaces that cut into the bedrock and can cover large areas from acres to tens of square miles. Large, deep landslides tend to move relatively slowly (less than an inch per year) but can lurch forward if shaken by an earthquake or if disturbed by removing material from the toe, by adding material to the head scarp, or by the addition of water into the slide mass.

4.2 Landslide Hazard Methods

4.2.1 Lidar-Based Landslide Inventory

Following the methodology of Burns and Madin (2009), a landslide inventory (Plate 2) was created using bare-earth lidar DEMs. Prior to mapping the landslides, the latest geologic maps for the area (Eriksson, 2002; Niem and Niem, 1985; Walsh, 1987) and the Statewide Landslide Information Database for Oregon (SLIDO-2) (Burns and others, 2011) were reviewed to identify any previously mapped landslides. Seven areas had been mapped as landslide deposits; the new lidar data helped accurately delineate the boundaries of these previously mapped slides.

High-resolution, high-accuracy lidar DEMs provide a detailed picture of ground surface geomorphology. Lidar-derived hillshades, slope shades, and contour lines were used to identify geomorphologic features typically associated with landslides such as concave slope depressions, steep scarps, shear zones along the flanks of a landslide, toes, offset drainages, midslope terraces, and hummocky topography (Figure 15). The 2009 NAIP orthophotos were also used to help differentiate between man-made and natural landforms. Landslide features (deposits, flanks, and scarps) were located by systematically panning through the study area at scales ranging from 1:24,000 to 1:4,000 and were mapped at a scale of 1:4,000 (Burns and Madin, 2009).

Tabular data including type of movement, type of material, pre-failure slope angle, area, and volume (Burns and Madin, 2009) were recorded for each mapped landslide deposit and are included in the GIS files. Other tabular attributes are listed in Table 2.

Landslide failure depth was estimated in order to classify each landslide as deep or shallow (Figure 16). This classification is necessary because different models are used to estimate landslide susceptibility on the basis of type of landslide and landslide failure depth. Commonly, shallow landslides are defined as failing above the contact between bedrock and the overlying soil. There is no widely accepted value to differentiate between deep and shallow landslides; however, using criteria from several studies (Sidle and Ochiai, 2006; Burns, 1999; Harp and others, 2006) a division value of 15 ft (4.6 m) has been selected (Burns and others, 2012). For additional details on the selection of this value, refer to Burns and Madin (2009).

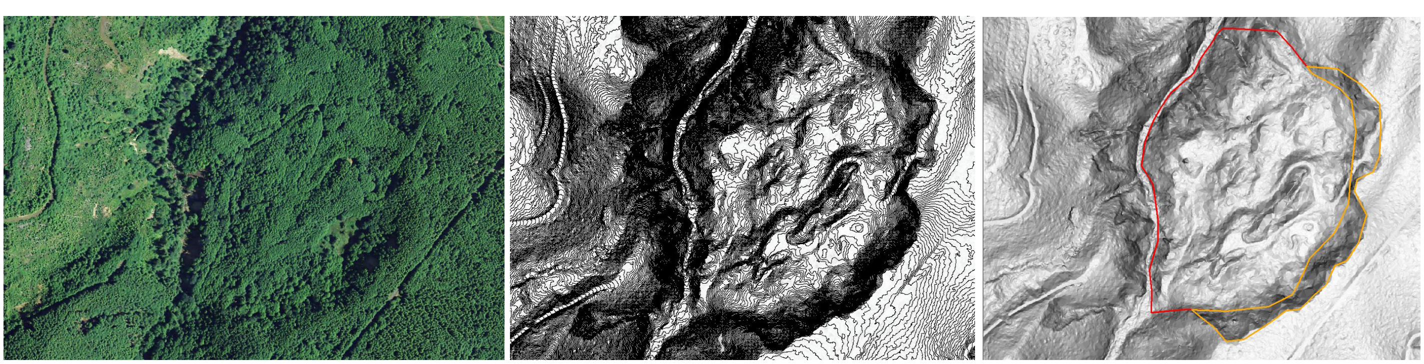


Figure 15. Landslide inventory mapping showing three images of the same area: (left) orthophoto, (middle) lidar-derived slope map with 3-ft contours, and (right) lidar-derived slope shade image with landslide deposit mapped in red and landslide flanks and scarp mapped in orange.

Table 2. Tabular attribute fields for lidar-based landslide inventory geodatabase (Burns, and Madin, 2009).

Field Name	Abbreviated Code	Brief Description
Identification	ID	numeric string
Quadrangle name	QUADNAME	7.5 minute quadrangle name
Unique identification	UNIQUE_ID	"QUADNAME"_"ID"
Mapper name	MAPPER_NAM	name of mapper
Type of movement	Type_Move	type of movement
Movement classification	MOVE_CLASS	classification name
Movement classification code	MOVE_CODE	classification code
Confidence of interpretation	CONFIDENCE	confidence of identification
Estimated age	AGE	estimated age
Date of last movement	DATE_MOVE	date of last known movement
Landslide name	NAME	landslide name
Geology	Geol	geologic unit
Adjacent slope	SLOPE	adjacent slope angle
Head scarp height	HSHEIGHT	change in elevation from bottom to top of head scarp or change in elevation from top to toe of fan
Failure depth	FAIL_DEPTH	estimated failure depth
Fan depth	Fan_DEPTH	estimated depth of fan
Deep-shallow	DEEP_SHAL	deep or shallow seated
Horizontal distance HS to IS1	HS_IS1	horizontal distance from head scarp to internal scarp no.1
Horizontal distance IS1 to IS2	IS1_IS2	horizontal distance from internal scarp 1 to internal scarp 2
Horizontal distance IS2 to IS3	IS2_IS3	horizontal distance from internal scarp 2 to internal scarp 3
Horizontal distance IS3 to IS4	IS3_IS4	horizontal distance from internal scarp 3 to internal scarp 4
Average horizontal distance between internal scarps	HDAVE	average horizontal distance between internal scarps
Size of landslide deposit	AREA	size of landslide deposit
Volume of landslide deposit	VOL	volume of landslide deposit

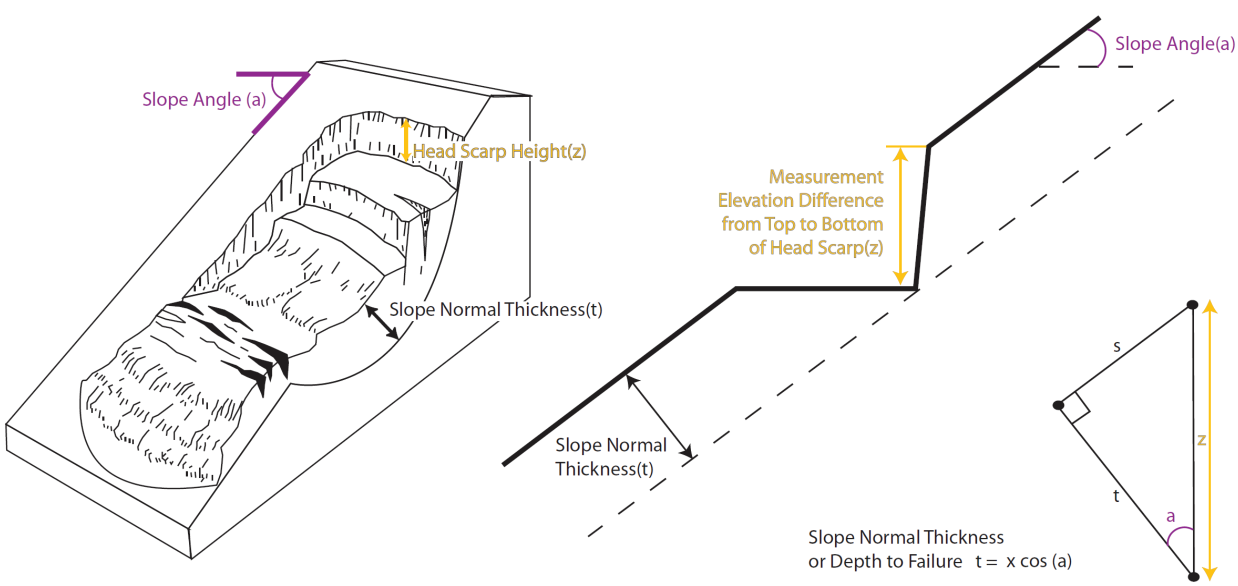


Figure 16. Diagram and equation for calculation of estimated failure depth (Burns and Madin, 2009).

After lidar-based landslide mapping and tabular database entry were completed, ground reconnaissance was performed to field verify identified landslide features. For this project, landslide features were also viewed from a low-flying aircraft. Observations made by ground and air reconnaissance were used to revise the lidar-based landslide inventory, as appropriate.

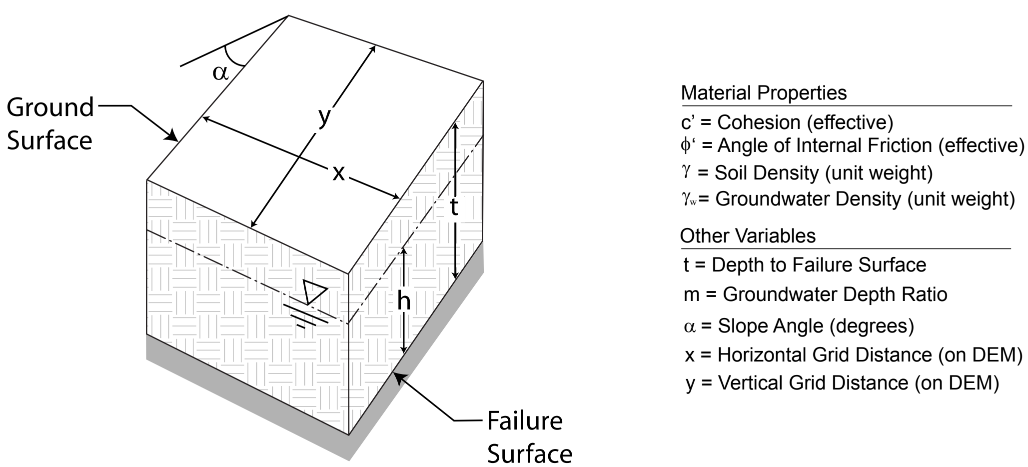
4.2.2 Shallow-Landslide Susceptibility

To create the shallow-landslide susceptibility map (Plate 3), all shallow landslides were queried out of the landslide inventory geodatabase and saved to a separate GIS file. The final shallow-landslide susceptibility zones were established from locations of shallow-landslide deposits and their associated head scarps, factor of safety calculations, and buffers following protocol developed by Burns and others (2012).

The infinite-slope analysis equation was used to calculate the factor of safety (FOS) for shallow landsliding (Figure 17). This equation depends on several data sets including depth to failure surface, groundwater, slope angle, and geologic material properties. Because groundwater can vary spatially and with time, a conservative approach was taken and the ground was considered completely saturated. The slope angles for each grid cell were extracted from the high-resolution lidar-derived digital elevation model (DEM) (Burns and others, 2012).

In order to calculate the factor of safety using the equation in Figure 17, certain geotechnical properties including cohesion, angle of internal friction, soil density, and water density are needed. A new digital engineering geology map was created for the study area using units with similar geotechnical properties (Figure 18). This new map was based upon the new lidar-based landslide inventory and previously mapped geology by Eriksson (2002), Niem and Niem (1985), Beaulieu (1973), and Walsh (1987).

All previously mapped geologic units were merged and simplified into six engineering geology units: alluvium, intact, minimally weathered igneous rock, residual soil on igneous rock, residual soil on sedimentary rock, talus, and deep landslide deposits. The deep-landslide deposits were taken directly from the lidar-mapped landslide inventory. The intact igneous rock outcrops were mapped by looking for near-vertical slopes within the mapped basalt units on the lidar slope map. The talus unit was mapped below intact igneous rock outcrops with measured slope angles ranging from 32 to 85 degrees. This slope range was then used to identify talus deposit areas. All of the other units were merged on the basis of similar material properties. The term residual soil is used because shallow landslides typically fail above the contact between bedrock and the overlying soil. Contacts between geologic units were field verified where possible, but time for field verification was limited.



$$\text{Factor of Safety (FOS)} = \frac{c'}{\gamma\, t \sin\alpha} + \frac{\tan\phi'}{\tan\alpha} - \frac{m\, \gamma_w \tan\phi'}{\gamma \tan\alpha}$$

Figure 17. Infinite-slope analysis: diagram, parameters, and equation (Burns and others, 2012).

Because site-specific material properties were not available, a table of general geotechnical properties for common geologic formations in Oregon was modified from Burns and others (2012) for use in this study (Table 3). The angle of internal friction for talus is based on the average pre-failure slope angle for those deposits. The angle of internal friction and cohesion values for residual soil on igneous rock were averaged from values from Drazba (2008) and Cornforth (2005).

The infinite-slope analysis equation for regional stability is a grid type analysis, so the results are calculated for each individual cell and do not take into account the potential impact of adjacent slopes. The limitation of this approach are discussed in greater detail later in this section and in the shallow-landslide susceptibility protocol (Burns and others, 2012). Due to this limitation, two sets of buffers were applied to the data: 1) Two horizontal to one vertical (2H:1V) buffer on the head scarps of all landslide deposits and (Figure 19), and 2) 2H:1V buffer on all grid cells with a FOS less than 1.5 (Burns and others, 2012).

The first buffer is applied to the head scarp polygon of each landslide. In many cases, the area above the head scarp tends to be relatively flat. This low slope angle translates into an area of low susceptibility when the infinite-slope equation is applied. However, the area above the head scarp can fail retrogressively due to a loss of resisting forces. To account for this retrogressive failure, a 2H:1V buffer was applied around each head scarp to increase the susceptibility for these areas (Figure 19) (Burns and others, 2012).

The second buffer was applied to areas with a FOS less than 1.5. The areas above and below landslide deposits are commonly flat and have a FOS greater than 1.5. However, these areas have the potential to be sites of future landslide head scarps and toes. A 2H:1V buffer was applied to areas with a calculated FOS less than 1.5 to increase the susceptibility of areas that are potentially unstable (Burns and others, 2012). Because the maximum depth for shallow landslides in this study is 15 ft (4.6 m), the 2H:1V buffer is equal to 30 ft (9 m) (Figure 20) (Burns and others, 2012).

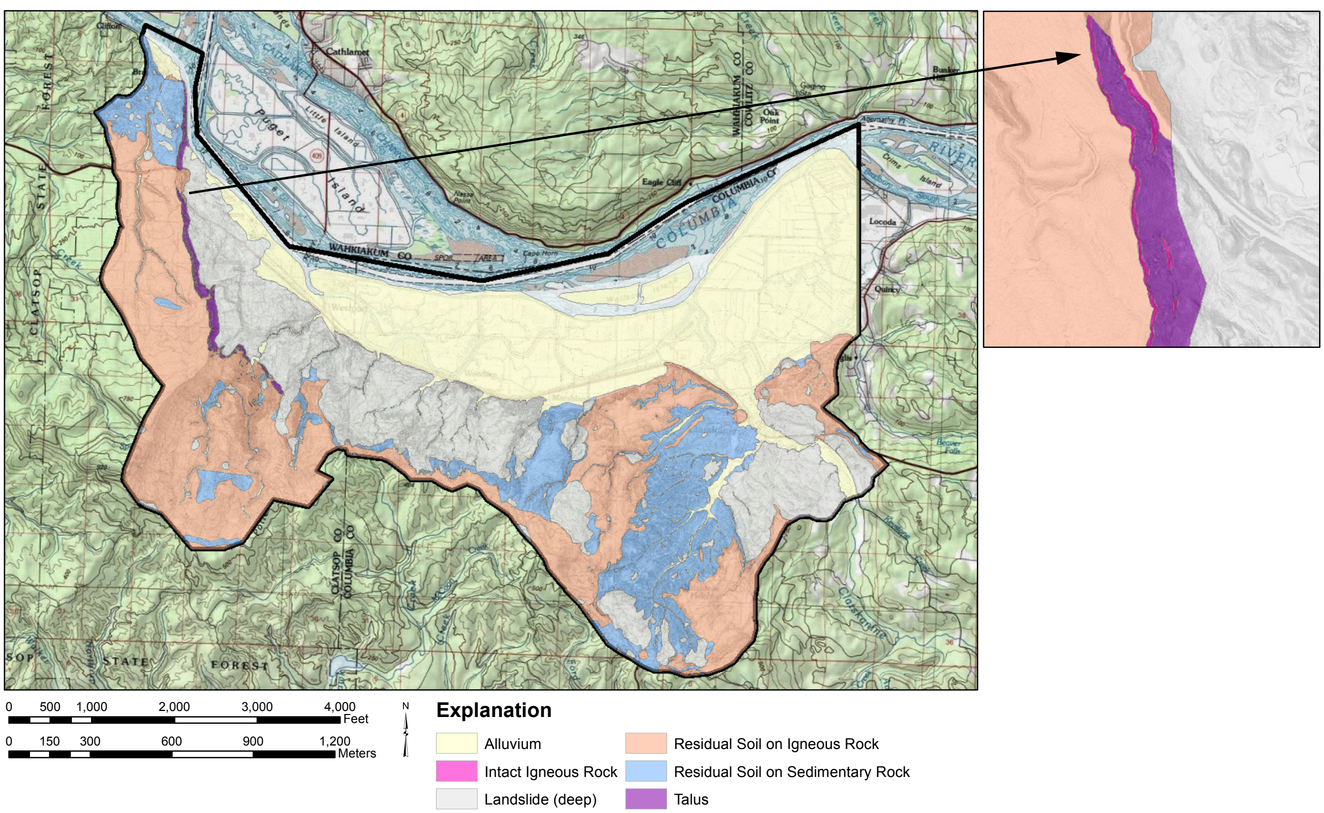


Figure 18. (left) New digital engineering geologic map with (right) detail showing mapped intact igneous rock.

Table 3. General soil and rock material properties (modified from Burns and others [2012]).

	Common Lithologic Description	Common Unit or Formation Name	Common Geologic Unit Label	Raster Value (GeolCode)	Angle of Internal Friction (ϕ) (degrees)	Cohesion (c) (kPa)	Cohesion (c) (lb/ft²)	Unit Weight (Saturated) (kN/m³)	Unit Weight (Saturated) (lb/ft³)
Cohesionless Soils									
Landslide deposit (deep failure)	shearing mainly along deep failure plane	landslide, colluvium	Qls, Qc	1	28	0	0	19	122
Recent alluvium (fine grained)	silt; sand	Quaternary alluvium; loess	Qal, Qff, Ql	2	30	0	0	19	122
Talus	gravel; boulders	gravel fan		3	36	0	0	19	122
Cohesive Soils									
Residual soil on igneous rock	silty clay with boulders	Columbia River Basalt	Tcr	4	28	24	501	19	122
Residual soil on sedimentary rock	silty sand; sandy silt; silty gravel	Troutdale Formation	Tt	5	30	10	209	19	122
Rock									
Basalt/andesite (volcanic rock)	basalt; andesite; dacite	Columbia River Basalt	Tcr	6	35	500	10,440	25	160

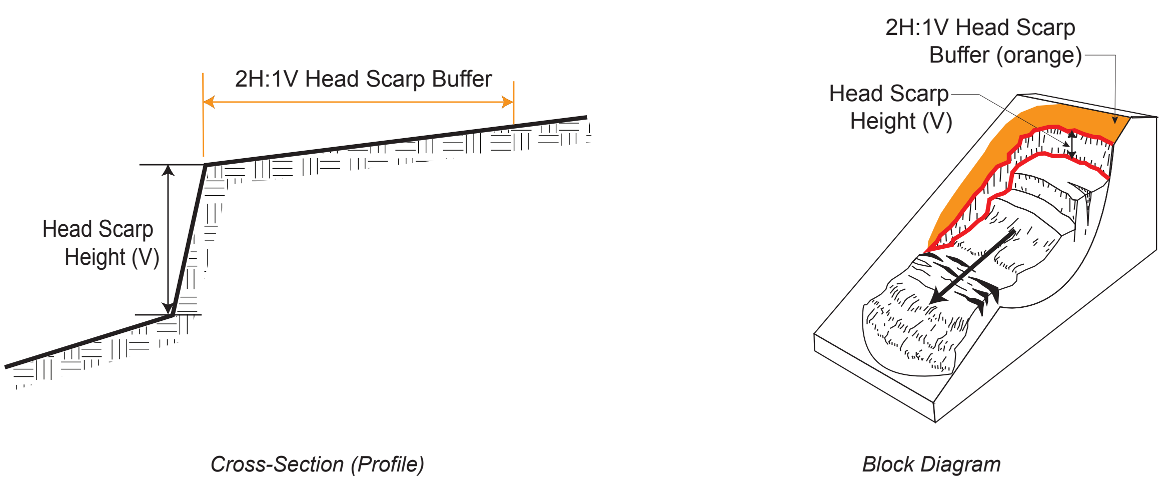


Figure 19. Diagram of the two horizontal to one vertical distance ratio (2H:1V) head scarp buffer (Burns and others, 2012).

Final shallow-landslide susceptibility zones are determined from landslide deposit and head scarp locations, calculations of factor of safety, and buffers. Table 4 displays a susceptibility zone matrix describing factors contributing to high-, moderate-, and low-susceptibility zones (Burns and others, 2012).

4.2.3 Deep-Landslide Susceptibility

To determine deep-landslide susceptibility in the study area (Plate 4), all deep landslides were queried out of the lidar-based landslide inventory. Deep-landslide susceptibility zones were established from locations and proximity to deep-landslide deposits and head scarps, head scarp buffers, susceptible geologic units, slope angles, and mapper judgment, following the procedure described by Burns (2008).

Large, deep landslides can move continually (mainly through creep) over time. Reactivation often is focused upslope near the landslide head scarp and at the landslide toe (Burns, 1998). To account for retrogressive head scarp failure, a buffer was added to each landslide head scarp and flank polygon. Two different factors were considered for the added buffer. First, a 2H:1V buffer was calculated for each head scarp polygon by multiplying each head scarp height by 2. The head scarp height was measured for each landslide, so heights vary from slide to slide. Second, each deep landslide was reviewed to see if it contained measured internal scarps. The average horizontal distance between all internal scarps then was compared to the 2H:1V calculated buffer. The larger of the two numbers, that is, the more conservative number, was chosen to buffer each landslide head scarp polygon (Burns, 2008).

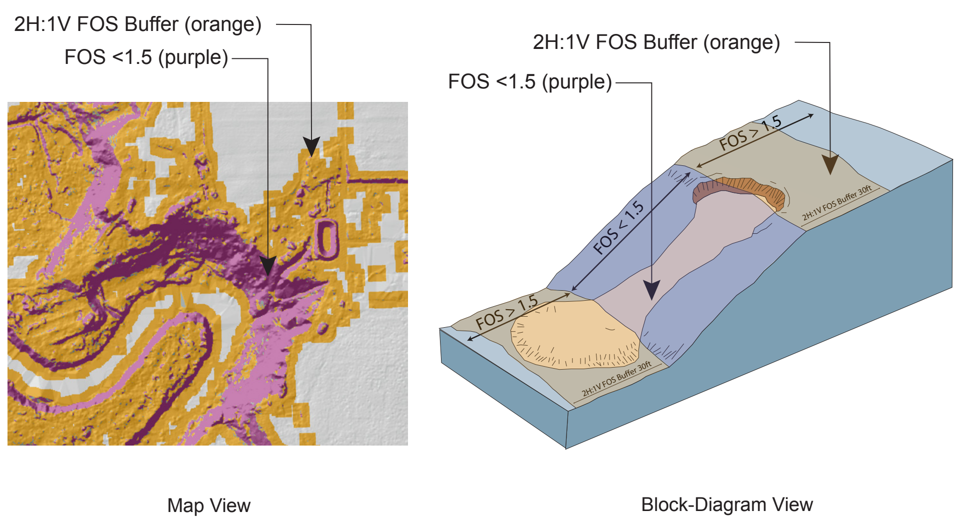


Figure 20. Diagram of the two horizontal to one vertical distance ratio (2H:1V) buffer (Burns and others, 2012).

Table 4. Table 4. Final shallow-landslide susceptibility zone matrix displaying factors contributing to high, moderate, and low-susceptibility zones (Burns and others, 2012).

Contributing Factors	Final Susceptibility Zones		
	High	Moderate	Low
❶ Factor of Safety (FOS)	less than 1.25	1.25 –1.5	greater than 1.5
❷ Landslide Deposits and Head Scarps	included	—	—
❸ Buffers	2H:1V (head scarps)	2H:1V (FOS less than 1.5)	—

To map the area moderately susceptible to deep landslides, the generalized geologic map was overlain with a slope map broken into three classes: slopes greater than 10 degrees, slopes greater than 20 degrees, and slopes greater than 32 degrees. The slope breaks were chosen on the basis of the lowest measured slope (10 degrees) in the landslide inventory database and the average measured slope angle (32 degrees) of the deep landslides; 20 degrees was chosen as the intermediate value between 10 degrees and 32 degrees. The generalized geologic map and slope map along with the other two factors (proximity and judgment), were used to create the boundary between moderate and low deep-landslide susceptibility zones.

4.3 Landslide Hazard Results

A total of 588 landslide deposits were mapped; 9 landslide deposits are located within or touching the boundary of the City of Clatskanie. Landslide deposits cover approximately 25% of the study area. Deep landslide failures were more common that shallow failures: 288 of the mapped landslides are classified as deep and 140 are classified as shallow. Slides occur on slopes ranging from 10 degrees to 60 degrees with a mean estimated pre-slide slope of 33 degrees. Of the 588 landslide deposits, 201 are classified as prehistoric (>150 years old).

There are 80 landslides with recorded dates of movement from 1930 to 2010. Of these dated landslides, 85% are failures on steep slopes (35 degrees) within the weathered soil of the marine sedimentary rocks or within older landslide deposits. These failures tend to be shallow flow failures (earth or earth and rock flows). Fifteen of the 80 deposits are debris flows; two landslides impacted Highway 30 in 2007. The Woodson debris flow in 2007 closed the highway and damaged homes (Figure 21).

Depth to failure surfaces for shallow landslides ranged from 0.5 ft to 15 ft, with an average of 10 ft. Depth to failure surfaces for deep landslides ranged from 15 ft to 369 ft, with an average of 45 ft. The landslide deposits are highly variable in size. The smallest failure covers an area of approximately 75 ft^2, while the largest deposit covers an area over 4,000 acres.

Figure 21. Mud and debris on highway 30 from the Woodson debris flow (Shaw and others, 2008).

Debris flows, combination rock and earth flows, and earth flows are the most common types of landslides (Table 5). These failure types account for approximately 70% of all mapped deposits. Fifty-eight percent of the earth and/or rock flows are deep failures. Debris flows are the most common failure type within the study area. Eight of the debris flow fans intersect or cross Highways 30 or 47 and fifteen are within 200 ft of the roadway.

While the landslides types discussed above are more common, deep, complex landslides (rock slide translational/rotational + earth flows and rock slide translational + earth flows) cover the highest percentage of the study area (Table 5). This includes the Wauna landslide (Figure 4), which is approximately 5.5 mi^2 (3,500 acres). The failure plane of this large landslide most likely exists below Highway 30 and the existing Columbia River Channel bottom.

Approximately 15% of the study area is classified as highly susceptible to shallow landslides, and 32% is classified as moderately susceptible. Forty-seven percent of the study area is classified as having low potential for shallow landsliding. The area of low potential is restricted to the flat area north of Highway 30, near the Columbia River.

Approximately 28% of the study area is classified as highly susceptible to deep landslides, and 15% is classified as moderately susceptible. Fifty-seven percent of the study area is classified as having low potential for deep landsliding. The area of low potential is predominately north of Highway 30, near the Columbia River.

These landslide inventory and susceptibility maps were designed for regional applications and should not be used as an alternative to site-specific studies in critical areas.

Table 5. Number and extent of individual landslide deposits in the study area by movement type from landslide inventory.

Landslide Type	Count	Area (mi^2)	Percent Landslide Deposits	Percent of Study Area
Earth slide rotational + earth flow	5	0.03	0.86%	0.03%
Earth flow	107	0.05	18.42%	0.06%
Earth slide rotational	3	0.003	0.52%	0.00%
Earth slide translational	7	0.006	1.20%	0.01%
Debris flow	150	0.98	25.82%	1.09%
Debris slide translational	18	0.0003	3.10%	0.00%
Rock fall	10	0.6	1.7%	0.7%
Rock slide rotational	24	0.3	4.13%	0.33%
Rock slide translational	41	0.4	7.06%	0.44%
Rock flow + earth flow	148	1.2	25.47%	1.33%
Rock slide translational/rotational	1	0.006	0.17%	0.01%
Rock slide rotational + earth flow	54	1.9	9.29%	2.11%
Rock slide translational + earth flow	15	5.2	2.58%	5.78%
Rock slide translational/rotational + earth flow	5	12.6	0.86%	14.00%

5.0 RISK ASSESSMENT

The landslide inventory, susceptibility data, and asset datasets were used to conduct a landslide risk assessment of the study area. Currently, no standard of practice exists for performing landslide risk analysis; therefore, two methods, a HAZUS-MH assessment and an exposure analysis, were used to attain a comprehensive estimate of the assets at risk within this study area (Burns and others, 2011). The HAZUS-MH assessment identifies the potential damages and losses that can be incurred from landslides during a major earthquake. The exposure analysis provides an evaluation of assets at risk to landslide hazards.

5.1 Risk Assessment Methods

5.1.1 Earthquake-Induced Landslide Risk Assessment Method (HAZUS-MH)

HAZUS-MH is a computer program developed by the Federal Emergency Management Agency (FEMA), the National Institute of Building Sciences (NIBS), and a number of other public and private partners (FEMA, 2011). The program models a variety of natural disaster scenarios, including earthquakes, hurricanes, and floods, and estimates regional damages and losses such as building damage, lifeline damage (roads and utilities), and injuries.

A number of default asset databases exist in the HAZUS-MH program. Most of the data do not reflect local conditions. The majority of the default asset databases, including critical facilities and primary infrastructure, are spatially located, but their locations may be imprecise. The main building stock database (mostly residential, commercial, and other nonessential buildings), however, is generalized into square footage by occupancy and by structural type per the census tract. This results in a lack of spatial accuracy that, from an earthquake hazard perspective, may not be as important because the entire tract would experience approximately the same ground motion. However, from a landslide hazard perspective the spatial component becomes more important. In order to summarize/estimate the number of buildings, the program divides the total square footage into buildings with the applied damage from the earthquake. For this study area, HAZUS-MH estimates that there are 4,575 buildings. The DOGAMI lidar-based building inventory contains 3,818 buildings. This difference makes sense due to the fact that the analysis area in HAZUS-MH is larger than this project's study area, which is discussed as a limitation later in this section.

To better account for local variability, HAZUS-MH software is designed to incorporate user-specific updates to the hazard and asset databases (FEMA, 2011). For this project, the landslide hazard data were updated. No asset data were revised to be put into the program because detailed building-specific data are needed. Although HAZUS-MH has limitations, it is the only risk analysis program that can produce estimates such as causalities and fatalities (Burns and others 2011; CREW, 2003; FEMA, 2011).

HAZUS-MH analysis can be performed at state, county, census tract, and census block levels. For this project, HAZUS-MH was run at the census tract level because this level is the most detailed level provided for the earthquake module. Two census tracts for Columbia and Clatsop Counties were included in the HAZUS-MH analysis. Although the extent of the two tracts is much larger than the study area, no major communities that could potentially skew the results occupy the portions of the two tracts outside of the study area.

The HAZUS-MH software was used to model an arbitrary crustal magnitude 6.7 (6.7M) earthquake scenario for three levels of landslide hazards following the method developed by Burns and Mickelson (in press). These three scenarios model only earthquake-induced landslides caused by a fairly substantial earthquake and do not include debris flows or precipitation-induced landslides. These are worst case scenarios and do not relate to seasonal landslide hazards. The three scenarios are:

- **Scenario 1:** Earthquake with no landslide hazard (landslide hazards scale set to 0 out of 10)
- **Scenario 2:** Earthquake with detailed landslide hazard (landslides hazards derived from detailed lidar-based mapping performed as part of this project)
- **Scenario 3:** Earthquake with landslides set to almost maximum (landslide hazards scale set to 9 out of 10)

These scenarios were chosen in order to estimate the range of potential damage and losses (from minimum to maximum) that can be expected from landsliding during a major earthquake in the study area. Scenario 1 is a best-case scenario because no landslides would occur during the earthquake. Scenario 2 is a more realistic scenario, and Scenario 3 is a worst-case scenario where landslides occur almost everywhere. By running HAZUS-MH with and without landslide hazards an estimate of the damage and loss incurred by just the landslides can be determined. This is done by subtracting the Scenario 1 result from the Scenario 2 result (Burns and Mickelson, in press).

No known potentially active fault system exists within the study area; therefore, an arbitrary fault was developed by examining the known magnitudes and fault locations in relative proximity. The Gales Creek fault (6.7M) was selected as a model due to its proximity to the study area. Figure 22 shows the location of the arbitrary fault and the census tracts within the study area.

Loss ratios, rather than absolute numbers, were calculated, because absolute numbers can be inaccurate at the local scale. For example, instead of examining the absolute count of buildings at various damage levels, the ratios of buildings in each estimated damage class to the total buildings in the HAZUS-MH database were evaluated. The loss ratios are very likely to be in a realistic range and could be compared to the much more accurate local database collected as part of this project to obtain a realistic absolute number. The total damage and economic loss values from the HAZUS-MH analyses are most likely underestimates due to the low quality and quantity of the input data, especially the infrastructure data (Burns and others, 2011).

5.1.2 Exposure (At-Risk) to Landslide Hazards Method

The second risk assessment performed as part of this study was an evaluation of assets exposed to landslide hazards. The exposure analysis was conducted using Esri ArcGIS® software by overlaying the landslide hazards and asset datasets. For example, a building is considered to be exposed to the landslide hazard if it is within or touching a selected hazard zone. Exposure was determined through a series of spatial and tabular queries between landslide hazard zones (Table 6) and assets (Table 7).

Table 6. Hazard zones used in landslide exposure analysis.

Landslide Hazard Zone
Existing landslides
Existing debris flow fans
Moderate susceptibility to shallow landslides
High susceptibility to shallow landslides
Moderate susceptibility to deep landslides
High susceptibility to deep landslides

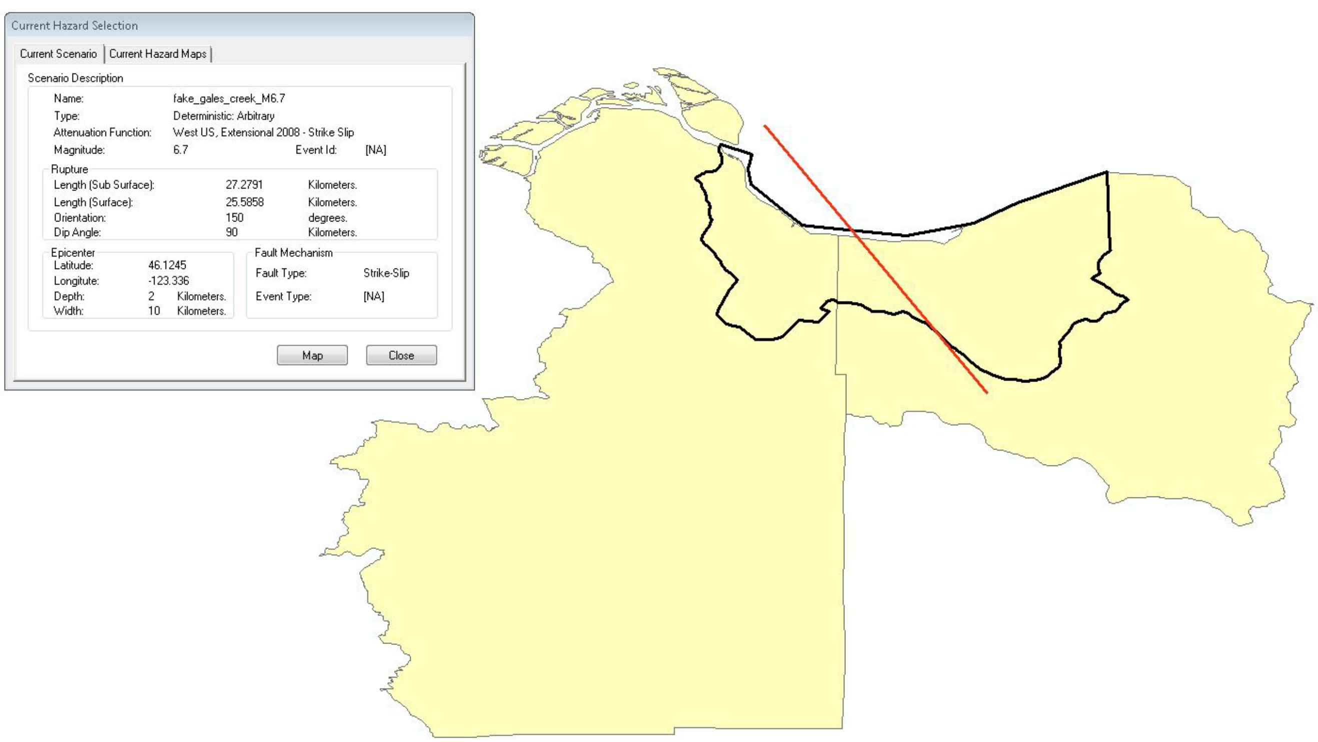


Figure 22. (left) HAZUS-MH (FEMA, 2011) scenario description with arbitrary fault details used in analysis. (right) Location of the arbitrary fault (red line) in study area (black outline).

Table 7. Assets and asset units used in landslide exposure analysis.

Asset	Reporting Unit
Residents	count
Buildings	count
Generalized zoning	number of parcels, square miles; dollar value per exposed are of parcel
Critical Facilities	
Fire buildings	count
Police buildings	count
School buildings	count
Hospital buildings	count
Energy generating facilities	count
Primary Infrastructure	
Electric substations	count
Electric towers	count
Electric transmission lines	miles
Road bridges	count
Railroad bridges	count
Highways	miles
Arterial roads	miles

Asset exposure was reported either as the count of features or as the area or length of the feature, as summarized in Table 7. All asset layers were clipped to each hazard. A more conservative method would be to spatially query the data to see if the asset data intersects with the hazard data. The clipped method was chosen because the hazard data and asset data locations were accurately located on lidar and therefore provide precise results on how much or how many of the assets are exposed to each hazard. To calculate real market value (RMV) for the clipped tax lots, the parcel area was first divided by the new clipped area to obtain the percentage of the tax lot exposed to the hazard. This percentage was then multiplied by the RMV value so that a realistic exposed RMV could be obtained (Burns and others, 2011).

5.2 Risk Assessment Results

5.2.1 Earthquake-Induced Landslide Risk Assessment Method (HAZUS-MH) Results

Three different HAZUS-MH scenarios were performed to estimate damage and losses that can be expected from landsliding during a major earthquake in the study area. This type of analysis was chosen because a major earthquake is a possibility in this area and it will be likely trigger landslides. Detailed reports for each scenario are provided in Appendix C. The results show that moderate damages and losses will occur in any of the three earthquake scenarios, with economic loss ratios ranging from 5.9% to 9.7% ($126,800,000 to $210,700,000) of the total assets, depending on the level of landslide hazard included. Total economic loss values, however, are likely underestimated due to the low quality of the asset databases within the HAZUS-MH program, especially the critical facilities and infrastructure data. Loss ratios are likely to be more appropriate estimates, but these are likely to be inaccurate as well. These inaccuracies are discussed in the section 6.

A summary of building and social impacts estimated from the HAZUS-MH earthquake analysis Scenario 1 (no landslides) is provided in Table 8. The analysis estimates that 29% of the buildings will be at least moderately damaged. According to the HAZUS data, the majority of the buildings are wood frame structures. Moderate damage to this type of structure would include cracks along walls and windows and toppling of tall masonry chimneys. While the analysis estimates that nearly 29% of the buildings would incur moderate damage, the analysis estimates only one fatality. Casualties and fatalities were estimated at midday (2 pm) as a worst case scenario.

Table 8. HAZUS-MH scenario results. Loss ratios (in bold), rather than absolute numbers, are likely to represent a more realistic range of values, because absolute numbers can be inaccurate at the local scale within HAZUS-MH.

	Scenario 1	Scenario 2	Scenario 3
Buildings (moderate damage)	874	825	826
Buildings (extensive damage)	351	649	659
Buildings (destroyed)	93	179	182
Total buildings (moderate to destroyed)	1318	1653	1667
Building damage count ratio	**28.80%**	**36.10%**	**36.40%**
Building loss ($)	52,120,000	101,590,000	102,800,000
Building $ loss ratio	**8.70%**	**17%**	**17.20%**
Residents needing shelter	17	70	71
Casualties	26	37	37
Fatalities	1	2	2
Total economic loss ($)	126,800,000	176,410,000	210,700,000
Total economic loss ratio	**5.90%**	**8.20%**	**9.70%**

Scenario 2 run in HAZUS-MH was an earthquake event with landslide hazards derived from detailed lidar-based mapping. The analysis estimates that 36% of the buildings would be at least moderately damaged; 87% of these buildings are residences. Building loss estimates for the two census tracts totaled $502M for residential and $95M for commercial, illustrating that the majority of the buildings in this area are for residential use. The building loss ratio increased from 29% in Scenario 1 to 36% in Scenario 2 (Table 8).

By subtracting the results from the two scenarios (Scenario 2 minus Scenario 1), damage and losses due solely to landslides can be examined (Table 9). The total economic loss ratio due to landslides is 2.3%. Building loss and total economic losses both total approximately $49M, suggesting that the monetary losses from landslides are primarily due to damage to buildings, not damage to the infrastructure and lifelines (highway, potable water, waste water, natural gas, communications).

Table 9. Summary of damage and loss estimates due solely to landslide hazards. Loss ratios (in bold), rather than absolute numbers, are likely to represent a more realistic range of values, because absolute numbers can be inaccurate at the local scale within HAZUS-MH.

	Loss
Buildings (moderate damage)	–49
Buildings (extensive damage)	298
Buildings (destroyed)	86
Total buildings (moderate to destroyed)	335
Building damage count ratio	**7.3%**
Building loss ($)	49,470,000
Building $ loss ratio	**8.3%**
Residents needing shelter	53
Casualties	11
Fatalities	1
Total economic loss ($)	49,610,000
Total economic loss ratio	**2.3%**

For Scenario 3, the earthquake module was run with landslide hazards set to 9 out of 10. The building loss ratio, compared to Scenario 2, did not increase, and the total economic loss ratio increased by only 1% (Table 8). Casualties slightly increased, and one additional fatality was calculated.

5.2.2 Exposure (At-Risk) Method Results

Complete results of the exposure analysis are listed in Appendix D.

Of the total population, 30% is at risk from existing landslides (Table 10). From the landslide susceptibility maps, residents are also susceptible to deep (45% exposed) and shallow (60% exposed) landslides. Similarly high numbers of buildings are at risk to landslide hazards. Forty-three percent of the buildings are exposed to deep landslides, and 68% are exposed to shallow landslides. All six critical facilities touch a shallow landslide susceptibility zone (moderate or high); however, less than 0.2% of the area covered by these facilities is actually covered by the hazard, indicating a low potential to serious building damage. For this analysis, critical hazard facilities include the buildings and the associated land owned by the facility.

Sixty-eight percent of all arterial roads and 77% of the highway corridors are exposed to high or moderate shallow landslide susceptibility (Table 11). The electric transmission lines and towers also have extensive exposure to potential shallow and deep landsliding. Seventy-six percent of the corridors are potentially exposed to shallow landslides and 77% to deep (Table 11). Almost two thirds of the electric transmission lines traverse existing landslide deposits; 57% of the towers are located on landslide deposits. The electric transmission lines and towers have minimal exposure to debris flow deposits.

Exposure analysis also was run on the three zoning classes. A complete breakdown of counts, area, and value for residential, commercial, and public tax lots is listed in Appendix D. The value of all tax lots exposed to landslide hazards, regardless of zoning, is shown in Table 13. Of the total $200M real market value for the land within the study area, approximately 50% is at risk from shallow landslides and 40% from deep landslides (moderate plus high susceptibility) (Table 13). Roughly 25% of the land is exposed to existing landslide deposits.

Table 10. Summary of landslide and community asset exposure for the study area.

	Permanent Population		Buildings		Critical Facilities	
	(Count)	(% Covered by Hazard)	(Count)	(% Covered by Hazard)	(Count)	(% Covered by Hazard)
Existing landslides	1,111	30%	994	26%	0	0%
Existing debris flow fans	348	9%	431	11%	0	0%
Moderate susceptibility to shallow landslides	1,743	47%	2,151	56%	6	0.19%
High susceptibility to shallow landslides	487	13%	449	12%	5	0.03%
Moderate susceptibility to deep landslides	536	14%	598	16%	0	0%
High susceptibility to deep landslides	1,149	31%	1,023	27%	0	0%

Table 11. Arterial roads and highways at-risk to landslide hazards in the study area.

	Arterial Road		Highway and Interstate	
	(mi)	(% covered)	(mi)	(% Covered)
Existing landslides	60.4	24%	3.7	15%
Existing debris flow fans	4.7	2%	1.4	5%
Moderate susceptibility to shallow landslides	162.4	64%	19.3	76%
High susceptibility to shallow landslides	9.4	4%	0.2	1%
Moderate susceptibility to deep landslides	32.2	13%	7.8	31%
High susceptibility to deep landslides	78	31%	6.8	27%

Table 12. Electric transmission lines and towers at-risk to landslide hazards in the study area.

	Electric Transmission Lines		Electric Transmission Towers	
	(mi)	(% Exposed)	(Count)	(% Exposed)
Existing landslides	24.3	62%	127	57%
Existing debris flow fans	0.2	1%	1	0%
Moderate susceptibility to shallow landslides	16.5	42%	117	53%
High susceptibility to shallow landslides	13.4	34%	31	14%
Moderate susceptibility to deep landslides	3.4	9%	14	6%
High susceptibility to deep landslides	26.6	68%	143	65%

Table 13. Tax lots at risk for landslide hazards in the study area.

	Total Tax Lots			
	Count	Area (mi^2)	Value ($)	Value (% Exposed)
Existing landslides	1,016	19.5	47,231,491	24%
Existing debris flow fans	336	0.8	6,524,526	3%
Moderate susceptibility to shallow landslides	2,532	26.5	76,319,038	39%
High susceptibility to shallow landslides	2,175	13.4	24,587,907	12%
Moderate susceptibility to deep landslides	672	13.0	28,471,402	14%
High susceptibility to deep landslides	1,046	24.2	51,984,349	26%

6.0 CONCLUSIONS AND RECOMMENDATIONS

The results of this study indicate that the Highway 30 corridor in Columbia and Clatsop counties is at high risk from landslide hazards. Debris flows cover a relatively small portion of the area but are historically frequent. Debris flows are generally restricted to channels and mouths of small steep streams, but because of their speed, debris flows threaten both lives and property. Shallow and deep landslides cover a much wider area, are less historically frequent, can occur over a much wider area, and can threaten property but rarely lives.

Debris flows are one of the most common landslide types within the study area and occur almost exclusively during periods of prolonged or intense rainfall. The high number of debris flow fans mapped and the relatively high frequency of debris flow events illustrates the potential danger in this area. Many buildings and people reside on debris flow fans. This creates a life safety issue as well as a high potential for property damage should a debris flow occur. Debris flows tend to initiate on the steep slopes surrounding the communities but deposit on the flat areas where the people and structures exist. Historical records indicate that debris flows have damaged property in the area since the early 1900s; one debris flow on Christmas Day, 1933, killed several residents.

In 2007, two debris flows impacted and destroyed structures in the communities of Woodson and Marshland. The Tandy Creek drainage in Marshland is particularly prone to debris flows in high rainfall events. This drainage has two mapped fans with a high-confidence designation, but historic accounts also pinpoint this drainage as problematic. This is alarming because 90 structures are built at the mouth of the channel on the mapped fans. Before the 2007 event, a debris flow in 1996 destroyed one home and seriously damaged others. Three other high-confidence debris flow fan deposits emanating from other drainages near Marshland have been mapped. One-hundred forty-nine structures are exposed to those debris flow areas, with an estimated 102 people living on the fans.

While debris flows can damage structures, they have a tendency to not damage the roads in this area. Flows instead deposit over the roads, resulting in road closures. The Woodson debris flow along Highway 30 resulted in the highway being closed for several days. This can have a large economic impact in the area as approximately 6,000 people travel this section of Highway 30 daily.

Debris flows are dangerous because they are fast moving and can occur with almost no warning during periods of heavy rainfall. Due to the large number of structures and people living on the fans, and the historic debris flow activity around Marshland, several safety actions should be undertaken. Making the public aware of the hazard in their area is crucial to help them understand the associated danger and how they can prepare themselves. Fliers can be passed out to help educate residents about debris flows and landslides. Examples of helpful flyers include *The Homeowners Guide to Landslides* (Burns and others, n.d.) and the DOGAMI fact sheet *Landslide hazards in Oregon* (DOGAMI, 2006). Residents can also refer to the USGS fact sheet Debris-flow hazards in the United States (Highland and others, 1997).

Actions to better understand local debris flow risk and to mitigate that risk might include:

- Detailed modeling of debris flow hazard zones to completely define susceptibility
- Geologic research to assess long term rates of debris flow occurrence
- Development of a state or local level debris flow warning system
- Engineered mitigation structures at high-risk sites
- Restriction of development on high risk sites
- Buyout of existing structures in high risk areas

Landslides cover 25% of the study area, with 21% of that area comprising deep landslides. Nine deep landslide deposits exist within the Clatskanie city limits, covering 33% of the city. While this number seems small compared to the 588 mapped in the study area, the large number of structures (309) and people (496) residing on the deposits highlight the potential danger within the community. The majority of the structures exist on three large, prehistoric, combination rock-slide/flow deposits.

Because these prehistoric landslides have the potential to move again in the future, there is a high potential for property loss or damage. These large slides are often hard to mitigate and involve cooperation from several entities (city and land owners) as the slides can span entire neighborhoods. To reduce the likelihood of a slide reactivating, a public awareness campaign could be undertaken to educate home/land owners on the landslide hazards in their areas and how to reduce their risk. Also, residents on mapped landslide areas should participate in a neighborhood risk reduction program where all affected land owners (city and public) help reduce to the overall risk. Risk reduction measures should include:

- Minimizing irrigation on slopes
- Avoiding removing material from the base of slopes
- Avoiding adding material or excess water to top of slopes
- Draining water from surface runoff, down-spouts, and driveways well away from slope and into storm drains or natural drainages
- Consulting an expert to conduct a site-specific evaluation if considering major construction

The susceptibility maps produced for this study show that this area has a high potential for landslides in the future. Forty-seven percent (high and moderate combined) of the area is susceptible to shallow landslides and 43% to deep landslides. The City of Clatskanie is especially susceptible to shallow landslides, with 65% of the city limits covered by the hazard zones (moderate and high combined). Thirty-seven percent of the city is susceptible to deep landslides. The areas susceptible to deep landsliding most likely involve the reactivation of an adjacent, existing deep slide, making the areas where this type of landslide can occur somewhat predictable. The shallow landslides, on the other hand, can occur almost anywhere the hazard is mapped. Due to these high percentages, the risk reduction measures listed above should be communicated to the public.

The maps and GIS databases created as part of this study are intended to provide users with basic information regarding landslides and susceptibility to landslides within the Highway 30 corridor. The maps and GIS databases contain useful information to guide site-specific investigations for future development, to assist in regional planning and development, to mitigate existing landslides and slopes, and to prepare for emergency situations, such as storm events and earthquakes. This information is not appropriate for site-specific evaluations, but it is valuable for regional screening for landslides and selection of appropriate areas on which to focus site-specific studies. The maps and GIS databases are particularly suitable for the activities listed below:

- Public awareness campaigns
- City/county development regulation-ordinance
- Public works planning and operations
- Environmental and sustainability issues
- Regional risk-reduction planning and activities
- Neighborhood scale risk-reduction activities
- Avoidance of very high hazard areas
- Emergency management
- Buyouts in very high or life-threatening hazard areas

A life-safety action plan also can be enacted. When the National Weather Service issues a debris flow warning as part of a flood warning, local emergency managers can relay that information to residents located on mapped debris flow fans. This could entail a local emergency notification system directed by the county or city or a reverse 911 call being put out to residents on fans when a debris flow warning is issued, alerting them to the potential danger. Emergency management buyouts are another option; the county or city buys the land directly in front of the active channel so that no structures can be built.

The results of the risk analysis portion of this study revealed which assets are at risk to landslide hazards and gave estimates of damages and losses due to landslides induced by a fairly substantial earthquake. Both the HAZUS-MH results and the exposure analysis show that the buildings/structures are the most exposed asset. Scenario 2 (earthquake with landslide hazard) estimates that 87% of the buildings with at least moderate damage would be residences. The total economic loss ratio for this scenario is 8.2% with approximately 30% of the total losses attributed solely to landslides. Building loss and total economic losses due to landslides triggered by an earthquake total approximately $49,500,000 (Table 9). This suggests that the monetary loss from landslides is primarily due to building damage and not damage to the infrastructure and lifelines (highway, potable water, waste water, natural gas, and communications). However, damage to any part of the infrastructure or lifelines could cause the whole system to fail.

Residential buildings make up 70% of the total building related loss. This high percentage is not surprising given the fact that 66% of the tax lots are zoned residential. Commercial lots account for only 17% of the total building related loss. These commercial lots, however, may be impacted by other hazards during an earthquake like lateral spread and liquefaction, which were not assessed in this study.

For comparison, building loss ratios due to landslide hazards in Astoria (Burns and Mickelson, in press) are comparable (38%) to this project; however, the total economic loss ratio for Astoria is significantly higher at 64%. The low total economic loss ratio (8%) for this project is most likely due to the fact that, unlike Astoria, the primary infrastructure (mainly Highway 30) and lifelines are not located on landslides. The low ratio could also be due to limitations with the HAZUS-MH default asset data. For instance, Highway 30, the main transportation lifeline through the study area, was not accurately located in the default database, and other lifelines could be mislocated as well. Another potential problem is the relative size of the census tracts compared to the small study area. In Astoria, the census blocks are much smaller and more accurately reflect potential losses.

The results provided by HAZUS-MH are likely inaccurate for this study area. The program is designed to work at a national or state scale but not small project areas. The area for this project is very small, and this will affect the accuracy of the results. Also, this area is rural; large census tracts input into the program could obscure the results. Another limitation of the HAZUS-MH program is that the buildings are not spatially located. Furthermore, HAZUS-MH generalizes user-supplied landslide data and does not use spatially located susceptibility categories (1–10). Instead of using the spatially distributed susceptibility category values located throughout each tract, the program looks at the value at the centroid of the tract and then applies that value to the entire tract.

The reliability of the HAZUS-MH results for this project, especially the loss and damage estimates due solely to earthquake-induced landslides, is decreased due to four main limitations: 1) the HAZUS-MH default databases can be spatially inaccurate, 2) the general building stock is not spatially located, 3) the census tracts are much larger than the study area, and 4) the landslide data are generalized. Due to the limitations of the HAZUS-MH software, it is not recommended that this program be used for small study areas like this project.

The exposure analysis shows that 68% of the buildings are exposed to areas with high and/or moderate susceptibility to shallow landslides and 43% to deep landslides, and 26% are currently residing on mapped landslide deposits. Although the HAZUS-MH results do not associate high amounts of damage and losses with infrastructure and lifelines, the exposure analysis showed that these assets are at risk. Sixty-one percent of electric transmission lines and 57% of electric towers are routed or placed on existing landslide deposits. Additionally, the susceptibility maps show that more than 75% of electric transmission lines are exposed to shallow or deep landslides. Similarly, 77% of highway corridors are exposed to shallow landslides. These high percentages indicate that the majority of these lifeline systems are at high risk from landslide hazards.

The primary purpose of this study's risk analysis portion is to provide users with an understanding of the general landslide risk, to enable future risk prioritization, and to focus resource allocation toward high-priority areas. With these risk assessment results, landslide risk can be managed through activities listed below:

- Identify vulnerable areas that may require planning considerations
- Engage stakeholders
- Assess the level of readiness and preparedness to deal with a disaster before disaster occurs
- Estimate potential losses from specific hazard events (before or after a disaster hits)
- Decide how to allocate resources for most effective and efficient response and recovery
- Prioritize mitigation measures that need to be implemented to reduce future losses

7.0 ACKNOWLEDGMENTS

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8.0 REFERENCES

Baker, D. L., 2002, Holocene (2-16 ka) sedimentation in the Columbia River estuary: Portland, Oreg., Portland State University, M.S. thesis, 261 p.

Beaulieu, J. D., 1973, Environmental geology of inland Tillamook and Clatsop Counties: Portland, Oreg., Oregon Department of Geology and Mineral Industries Bulletin 79, 65 p., scale 1:62,500.

Burns, S. F., 1998, Landslides in the Portland area resulting from the storm of February, 1996, *in* Burns, S. F., ed., Environmental, groundwater, and engineering geology: Applications from Oregon: Belmont, Calif., Star Publishing, p. 353–365.

Burns, S. F., Harden, T. M., and Andrew, C. J., [n.d.], Homeowner's guide to landslides: recognition, prevention, control, and mitigation: Portland, Oreg., Portland State University, and Federal Emergency Management Agency Region X, Bothell, Wash., 12 p. Web: http://www.oregongeology.org/sub/Landslide/homeowners-landslide-guide.pdf.

Burns, W. J., 1999, Engineering geology and relative stability of the southern half of Newell Creek canyon, Oregon City, Oregon: Portland, Oreg., Portland State University, Department of Geology, M.S. thesis, 143 p., 3 pl.

Burns, W. J., 2008, Regional landslide hazard maps of the southwest quarter of the Beaverton quadrangle, West Bull Mountain Planning Area, Washington County, Oregon: Portland, Oreg., Oregon Department of Geology and Mineral Industries, Open-File Report O-08-09, 17 p., scale 1:8,000.

Burns, W. J., and Madin, I. P., 2009, Protocol for inventory mapping of landslide deposits from light detection and ranging (lidar) imagery: Portland, Oreg., Oregon Department of Geology and Mineral Industries, Special Paper 42, 30 p.

Burns, W. J., and Mickelson, K.,A., in press, Landslide inventory, susceptibility maps, and risk analysis of the city of Astoria, Clatsop County, Oregon: Portland, Oreg., Oregon Department of Geology and Mineral Industries.

Burns, W. J., Mickelson, K. A., and Saint-Pierre, E. C., 2011, Statewide landslide information layer for Oregon (SLIDO), release 2: Portland, Oreg., Oregon Department of Geology and Mineral Industries, Digital Data Series SLIDO-2, 41 p., 1 pl., scale 1:750,000.

Burns, W. J., Madin, I. P., and Mickelson, K. A., 2012, Protocol for shallow-landslide susceptibility mapping: Portland, Oreg., Oregon Department of Geology and Mineral Industries, Special Paper 45, 27 p.

Cornforth, D. K., 2005, Washington Park Station slide, in Landslides in practice: investigation, analysis, and remediation/preventative options in soils: Hoboken, N. J., John Wiley and Sons, Inc., p. 507–513.

CREW (Cascadia Region Earthquake Workgroup), 2003, HAZUS scenario for a Cascadia Subduction Zone earthquake. Available on CD-ROM from the Cascadia Region Earthquake Workgroup, c/o Bob Freitag, Executive Director, email bfreitag@mindspring.com. Internet http://www.crew.org/.

DOGAMI (Oregon Department of Geology and Mineral Industries), 2006, Landslide hazards in Oregon: Portland, Oreg., Oregon Department of Geology and Mineral Industries, fact sheet, 2 p. Web: http://www.oregongeology.org/pubs/fs/landslide-factsheet.pdf.

Drazba, M. C., 2008, Landslide susceptibility map for shallow landslides for the West Hills of Portland, Oregon using GIS and lidar: Portland, Oreg., Portland State University, M.S. thesis, 77 p.

Eriksson, A., 2002, Stratigraphy, structure, and natural gas potential of Tertiary sedimentary and volcanic units, Clatskanie 7.5-minute quadrangle, northwest Oregon: Corvallis, Oreg., Oregon State University, M.S. thesis, scale 1:24,000.

FEMA (Federal Emergency Management Agency), 2011, HAZUS-MH, FEMA's tool for estimating potential losses from natural disasters: Available on CD-ROM from the Federal Emergency Management Agency (FEMA) or the National Institute of Building Sciences 1090 Vermont Avenue, NW, Suite 700 Washington, DC, 20005-4905, phone (202) 289-7800, fax (202) 289-1092, e-mail HAZUS@nibs.org or http://www.fema.gov/HAZUS/.

Fry, J., Xian, G., Jin, S., Dewitz, J., Homer, C., Yang, L., Barnes, C., Herold, N., and Wickham, J., 2011, Completion of the 2006 National Land Cover Database for the conterminous United States: Photogrammetric Engineering and Remote Sensing, v. 77, no. 9, p. 858–864.

Harp, E. L., Michael, J. A., and Laprade, W. T., 2006, Shallow-landslide hazard map of Seattle, Washington, U.S. Geological Survey Open-File Report 2006-1139, 20 p.

Highland, L., compiler, 2004, Landslide types and processes: U.S. Geological Survey Fact Sheet 2004-3072 (ver.1.1), 4 p.

Highland, L., Ellen, S. D., Christian, S. B., and Brown, W. M., III, 1997, Debris-flow hazards in the United States: U.S. Geological Survey Fact Sheet 176-97, 4 p. Web: http://pubs.usgs.gov/fs/fs-176-97/fs-176-97.pdf.

Lewis, D., 2007, Statewide seismic needs assessment: implementation of Oregon 2005 Senate Bill 2 relating to public safety, earthquakes, and seismic rehabilitation of public buildings: Portland, Oreg., Oregon Department of Geology and Mineral Industries, Open-File Report O-07-02, 140 p.

Niem, A. R., and Niem, W. A., 1985, Oil and gas investigation of the Astoria Basin, Clatsop and northernmost Tillamook Counties, Northwest Oregon: Portland, Oreg., Oregon Department of Geology and Mineral Industries, Oil and Gas Investigation OGI-14, scale 1:100,000.

ODOT (Oregon Department of Transportation), 2008, Hwynet GIS database, ODOT GIS Unit. Web: http://www.oregon.gov/DAS/EISPD/GEO/sdlibrary.shtml.

ODOT (Oregon Department of Transportation), 2010, Traffic Counting Program http://www.oregon.gov/ODOT/TD/TDATA/tsm/tvt.shtml, accessed April 17, 2012.

Shaw, S., Hinkle J., and Seward, J., 2008, Geotechnical assessment of the December 2007 debris flow complex in Eilertsen Creek, Woodson, Oregon: Salem, Oreg., Oregon Department of Forestry, 73 p. Web: http://www.oregon.gov/odf/docs/odf_rpt_07_debris_flow_eilertsen_crk_woodson.pdf

Sidle, R.C., and Ochiai, H., 2006, Landslides: processes, prediction, and land use,: Washington D.C., American Geophysical Union, Water Resources Monograph 18, 312 p.

Sleeter, R., and Gould, M., 2007, Geographic information system software to remodel population data using dasymetric mapping methods: U.S. Geological Survey Techniques and Methods 11-C2, 15 p.

U.S. Census Bureau, 2010, TIGER/Line® database. Web: http://www.census.gov/geo/www/tiger/tgrshp2010/availability.html

Walsh, T. J., 1987, Geologic map of the Astoria and Ilwaco quadrangles, Washington and Oregon: Olympia, Wash., Washington Department of Natural Resources, Open-File Report 87-2, scale 1:100,000.

APPENDIX A: WELL LOGS AT GEORGIA PACIFIC WAUNA PAPER MILL

CLAT 53779

Oregon Water Resources Department
725 Summer Street NE, Suite A
Salem Oregon 97301
(503) 986-0900
www.wrd.state.or.us

Application for Well ID Number

RECEIVED
FEB 25 2011
WATER RESOURCES DEPT
SALEM OREGON

Do not complete if the well already has a Well I.D Number.

I. OWNER INFORMATION

Current Owner Name *(please print)*: Georgia Pacific Consumer Products, LP
Mailing Address: 92326 TAYLORVILLE Rd
City: Clatskanie State: OR Zip: 97016
Mailing Address *(to send Well I.D.)*: 92326 TAYLORVILLE Rd
City: Clatskanie State: OR Zip: 97016

II. WELL INFORMATION *(Do not complete this section if the well report is attached.)*

Township: 8 N (North/South) Range: 6 W (East/West) Section: 22
Tax Lot: 0100 County: Clatsop 1/4 NW 1/4
Street Address of Well: 92326 TAYLORVILLE City: CLATSKANIE, OR
Owner at time the well was constructed, (if known): Crown Zellarbach
If the property had a different street address in the past:

III. GENERAL WELL INFORMATION *(Do not complete this section if the well report is attached)*

Use of Well (domestic, irrigation, commercial, industrial, monitoring): Monitoring
Date Well Constructed: 7/22/86 Total Well Depth: 75.1 Casing Diameter: 2
Other Information: Well C-1

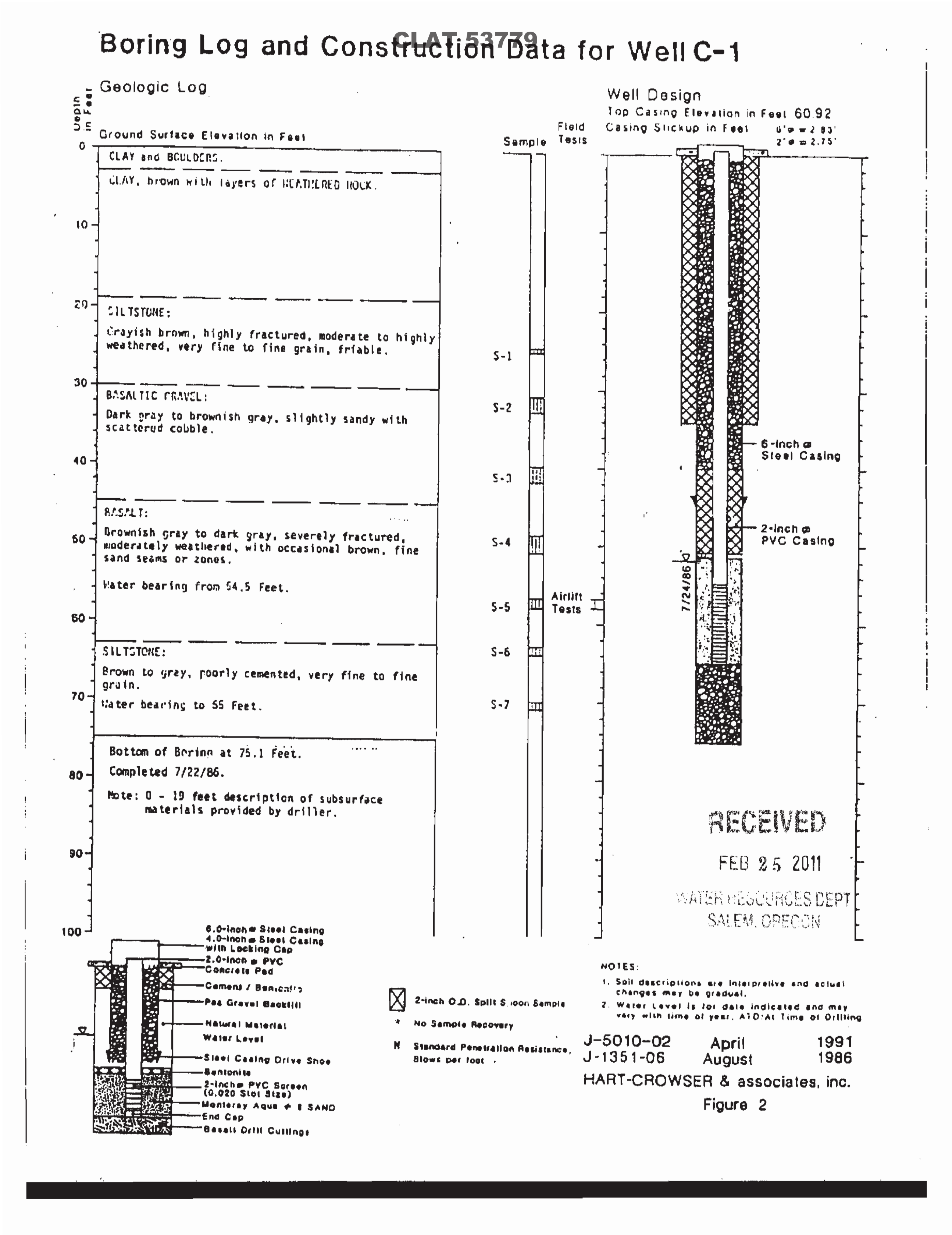
SUBMITTED BY *(please print)*: Al Deichsel
PHONE: 503-455-3370 FAX: 503-455-3469

Send application to Oregon Water Resoureces Department; 725 Summer St NE, Suite A; Salem, Oregon 97301-1266; fax (503) 986-0902. Applications are processed and Well I.D. Numbers are mailed every Wednesday.

For Official Use Only by the Oregon Water Resources Department:

Received Date:	Well Log Number:	Well Identification #:
	CLAT 53779	106564

Last Update: 11/04/08 Well I.D. Number/ 1 WCC


CLAT 53779
Boring Log and Construction Data for Well C-1
Geologic Log
Depth in Feet
Ground Surface Elevation in Feet
CLAY and BOULDERS.
CLAY, brown with layers of WEATHERED ROCK.
SILTSTONE:
Grayish brown, highly fractured, moderate to highly weathered, very fine to fine grain, friable.
BASALTIC GRAVEL:
Dark gray to brownish gray, slightly sandy with scattered cobble.
BASALT:
Brownish gray to dark gray, severely fractured, moderately weathered, with occasional brown, fine sand seams or zones.
Water bearing from 54.5 Feet.
SILTSTONE:
Brown to grey, poorly cemented, very fine to fine grain.
Water bearing to 55 Feet.
Bottom of Boring at 75.1 Feet.
Completed 7/22/86.
Note: 0 - 19 feet description of subsurface materials provided by driller.
0
10
20
30
40
50
60
70
80
90
100
Sample
Field Tests
S-1
S-2
S-3
S-4
S-5
S-6
S-7
Airlift Tests
Well Design
Top Casing Elevation in Feet 60.92
Casing Stickup in Feet
6"ø = 2.83'
2"ø = 2.75'
6-Inch ø Steel Casing
2-Inch ø PVC Casing
7/24/86
RECEIVED
FEB 25 2011
WATER RESOURCES DEPT
SALEM, OREGON
6.0-Inch ø Steel Casing
4.0-Inch ø Steel Casing with Locking Cap
2.0-Inch ø PVC
Concrete Pad
Cement / Bentonite
Pea Gravel Backfill
Natural Material
Water Level
Steel Casing Drive Shoe
Bentonite
2-Inch ø PVC Screen (0.020 Slot Size)
Monterey Aqua # 8 SAND
End Cap
Basalt Drill Cuttings
2-inch O.D. Split Spoon Sample
* No Sample Recovery
N Standard Penetration Resistance, Blows per foot
NOTES:
1. Soil descriptions are interpretive and actual changes may be gradual.
2. Water Level is for date indicated and may vary with time of year. ATD:At Time of Drilling
J-5010-02 April 1991
J-1351-06 August 1986
HART-CROWSER & associates, inc.
Figure 2

CLAT 53780

Oregon Water Resources Department
725 Summer Street NE, Suite A
Salem Oregon 97301
(503) 986-0900
www.wrd.state.or.us

Application for Well ID Number

RECEIVED
FEB 25 2011
WATER RESOURCES DEPT
SALEM, OREGON

Do not complete if the well already has a Well I.D Number.

I. OWNER INFORMATION

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II. WELL INFORMATION *(Do not complete this section if the well report is attached.)*

Township: 8 N (North/South) Range: 6 W (East/West) Section: 22
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Street Address of Well: 92326 TAYLORVILLE City: CLATSKANIE, OR
Owner at time the well was constructed, (if known): Crown Zellarbach
If the property had a different street address in the past:

III. GENERAL WELL INFORMATION *(Do not complete this section if the well report is attached)*

Use of Well (domestic, irrigation, commercial, industrial, monitoring): Monitoring
Date Well Constructed: 7/29/86 Total Well Depth: 195.31 Casing Diameter: 2
Other Information: Well C-2

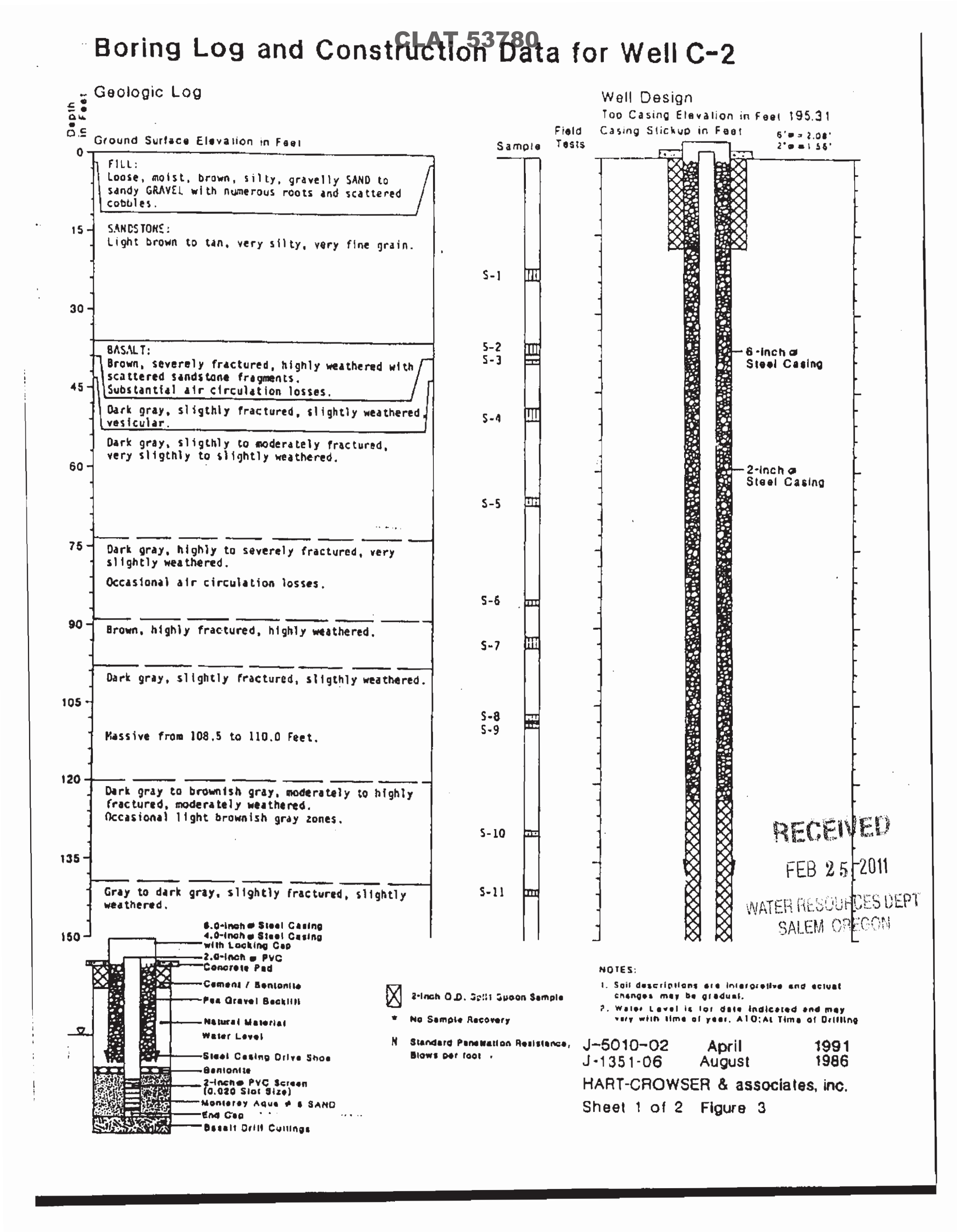
SUBMITTED BY *(please print)*: Al Deichsel
PHONE: 503-455-3370 FAX: 503-455-3469

Send application to Oregon Water Resoureces Department; 725 Summer St NE, Suite A; Salem, Oregon 97301-1266; fax (503) 986-0902. Applications are processed and Well I.D. Numbers are mailed every Wednesday.

For Official Use Only by the Oregon Water Resources Department:

Received Date:	Well Log Number:	Well Identification #:
	CLAT 53780	L-106565

Last Update: 11/04/08 Well I.D. Number/ 1 WCC


CLAT 53780
Boring Log and Construction Data for Well C-2
Geologic Log
Depth in Feet
Ground Surface Elevation in Feet
FILL:
Loose, moist, brown, silty, gravelly SAND to sandy GRAVEL with numerous roots and scattered cobbles.
SANDSTONE:
Light brown to tan, very silty, very fine grain.
BASALT:
Brown, severely fractured, highly weathered with scattered sandstone fragments.
Substantial air circulation losses.
Dark gray, sligthly fractured, slightly weathered, vesicular.
Dark gray, sligthly to moderately fractured, very slightly to slightly weathered.
Dark gray, highly to severely fractured, very slightly weathered.
Occasional air circulation losses.
Brown, highly fractured, highly weathered.
Dark gray, slightly fractured, sligthly weathered.
Massive from 108.5 to 110.0 Feet.
Dark gray to brownish gray, moderately to highly fractured, moderately weathered.
Occasional light brownish gray zones.
Gray to dark gray, slightly fractured, slightly weathered.
0
15
30
45
60
75
90
105
120
135
150
Sample
Field Tests
S-1
S-2
S-3
S-4
S-5
S-6
S-7
S-8
S-9
S-10
S-11
Well Design
Top Casing Elevation in Feet 195.31
Casing Stickup in Feet
6"ø = 2.08'
2"ø = 1.56'
6-inch ø Steel Casing
2-inch ø Steel Casing
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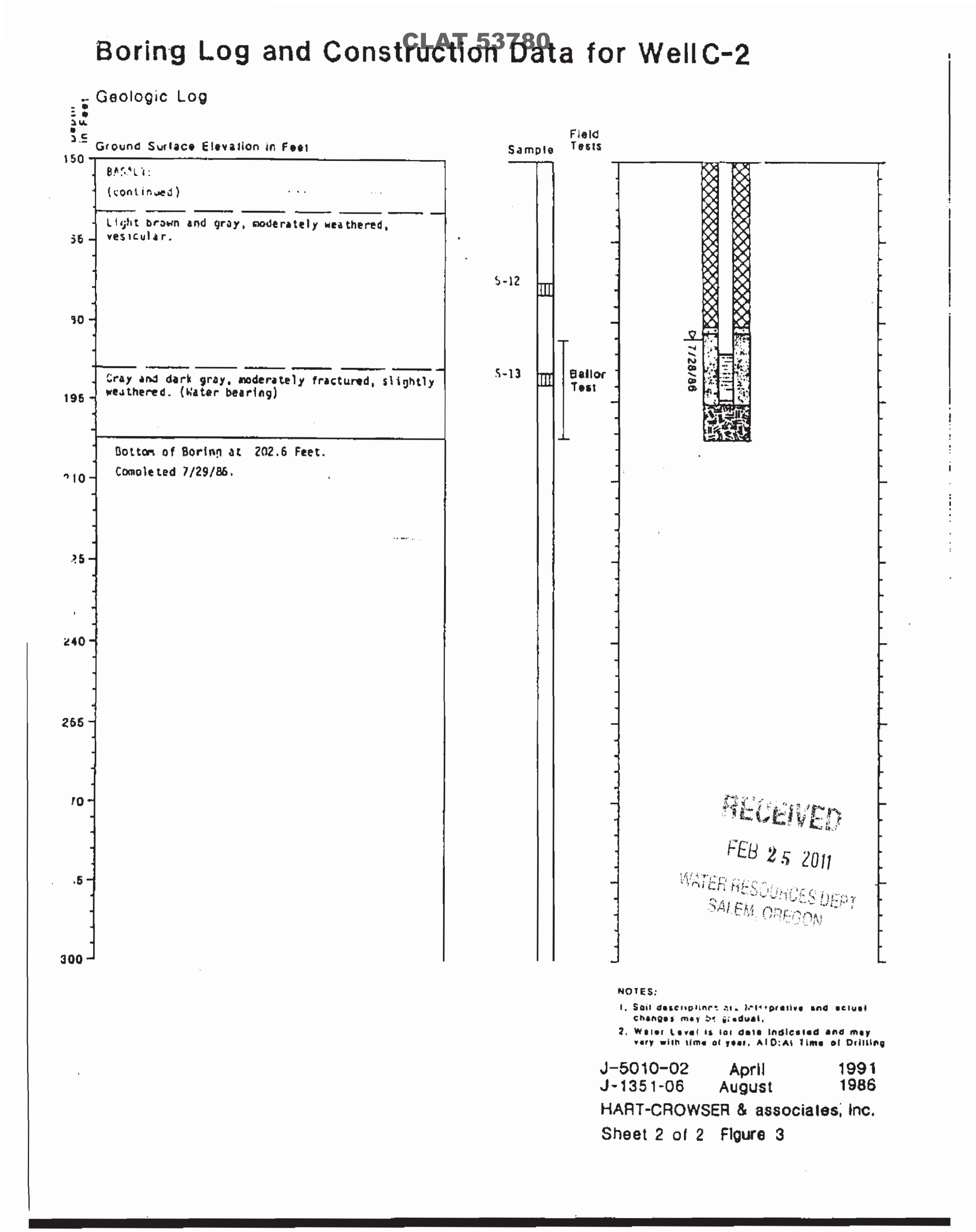
6.0-inch ø Steel Casing
4.0-inch ø Steel Casing with Locking Cap
2.0-inch ø PVC
Concrete Pad
Cement / Bentonite
Pea Gravel Backfill
Natural Material
Water Level
Steel Casing Drive Shoe
Bentonite
2-inch ø PVC Screen (0.020 Slot Size)
Monterey Aqua # 8 SAND
End Cap
Basalt Drill Cuttings
2-inch O.D. Split Spoon Sample
* No Sample Recovery
N Standard Penetration Resistance, Blows per foot
NOTES:
1. Soil descriptions are interpretive and actual changes may be gradual.
2. Water Level is for date indicated and may vary with time of year. ATD: At Time of Drilling
J-5010-02 April 1991
J-1351-06 August 1986
HART-CROWSER & associates, inc.
Sheet 1 of 2 Figure 3


CLAT 53780
Boring Log and Construction Data for Well C-2
Geologic Log
Depth in Feet
Ground Surface Elevation in Feet
BASALT:
(continued)
Light brown and gray, moderately weathered, vesicular.
Gray and dark gray, moderately fractured, slightly weathered. (Water bearing)
Bottom of Boring at 202.6 Feet.
Completed 7/29/86.
Sample
Field Tests
S-12
S-13
Bailer Test
7/28/86
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SALEM, OREGON
NOTES:
1. Soil descriptions are interpretive and actual changes may be gradual.
2. Water Level is for date indicated and may vary with time of year. ATD: At Time of Drilling
J–5010–02 April 1991
J-1351-06 August 1986
HART-CROWSER & associates, Inc.
Sheet 2 of 2 Figure 3

CLAT 53781

Oregon Water Resources Department
725 Summer Street NE, Suite A
Salem Oregon 97301
(503) 986-0900
www.wrd.state.or.us

Application for
Well ID Number

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Do not complete if the well already has a Well I.D Number.

I. OWNER INFORMATION

Current Owner Name *(please print)*: Georgia Pacific Consumer Products, LP
Mailing Address: 92326 TAYLORVILLE Rd
City: Clatskanie State: OR Zip: 97016
Mailing Address *(to send Well I.D.)*: 92326 TAYLORVILLE Rd
City: Clatskanie State: OR Zip: 97016

II. WELL INFORMATION *(Do not complete this section if the well report is attached.)*

Township: 8 N (North/South) Range: 6 W (East/West) Section: 22
Tax Lot: 0100 County: Clatsop 1/4 NW 1/4
Street Address of Well: 92326 TAYLORVILLE City: CLATSKANIE, OR
Owner at time the well was constructed, (if known): Crown Zellarbach
If the property had a different street address in the past:

III. GENERAL WELL INFORMATION *(Do not complete this section if the well report is attached)*

Use of Well (domestic, irrigation, commercial, industrial, monitoring): Monitoring
Date Well Constructed: 8/4/86 Total Well Depth: 185.70 Casing Diameter: 2
Other Information: Well C-3

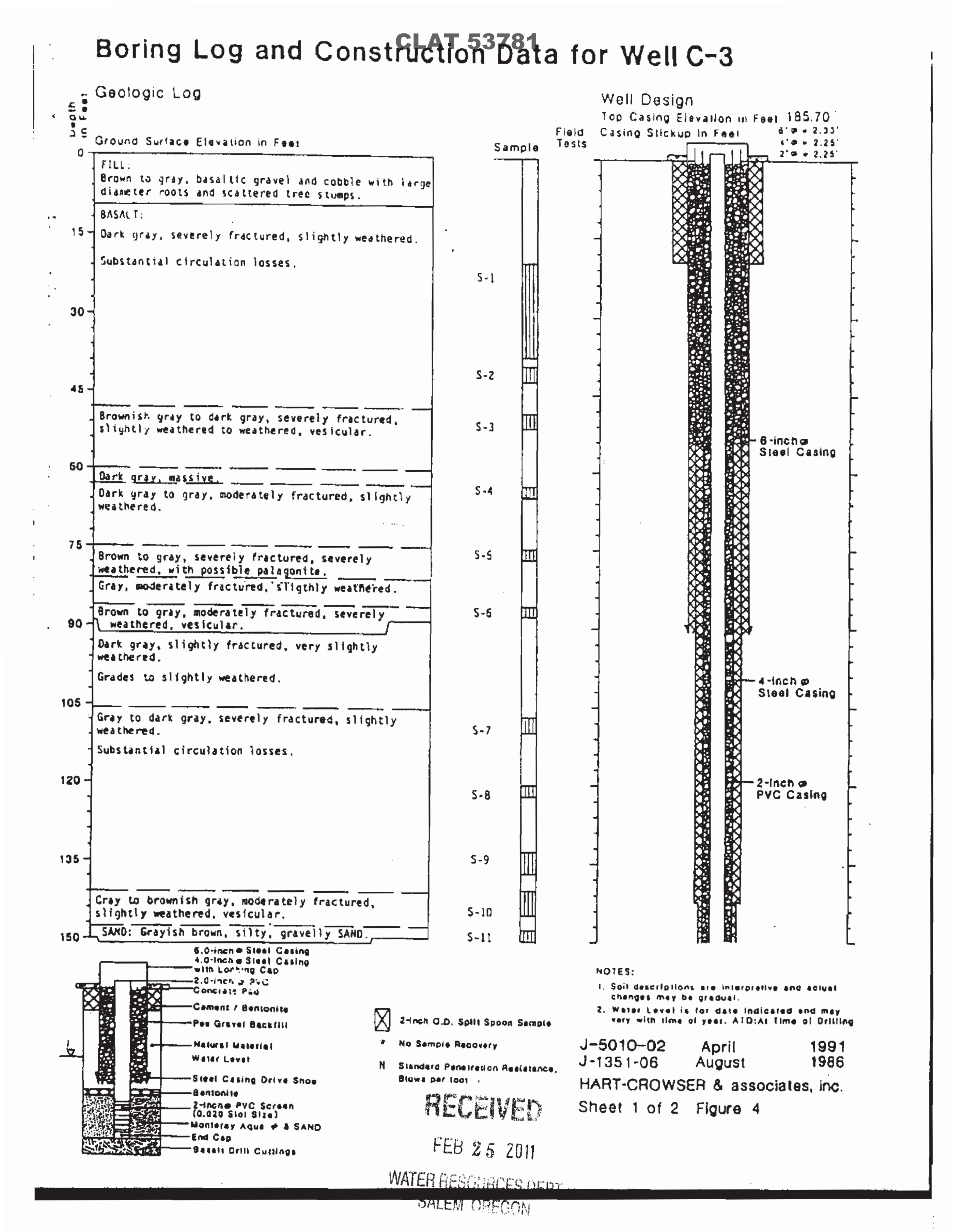
SUBMITTED BY *(please print)*: Al Deichsel
PHONE: 503-455-3370 FAX: 503-455-3469

Send application to Oregon Water Resoureces Department; 725 Summer St NE, Suite A; Salem, Oregon 97301-1266; fax (503) 986-0902. Applications are processed and Well I.D. Numbers are mailed every Wednesday.

For Official Use Only by the Oregon Water Resources Department:

Received Date: Well Log Number: CLAT 53781 Well Identification #: 106566

Last Update: 11/04/08 Well I.D. Number/ 1 WCC


CLAT 53781
Boring Log and Construction Data for Well C-3
Geologic Log
Depth in Feet
Ground Surface Elevation in Feet
0
15
30
45
60
75
90
105
120
135
150
FILL:
Brown to gray, basaltic gravel and cobble with large diameter roots and scattered tree stumps.
BASALT:
Dark gray, severely fractured, slightly weathered.
Substantial circulation losses.
Brownish gray to dark gray, severely fractured, slightly weathered to weathered, vesicular.
Dark gray, massive.
Dark gray to gray, moderately fractured, slightly weathered.
Brown to gray, severely fractured, severely weathered, with possible palagonite.
Gray, moderately fractured, sligthly weathered.
Brown to gray, moderately fractured, severely weathered, vesicular.
Dark gray, slightly fractured, very slightly weathered.
Grades to slightly weathered.
Gray to dark gray, severely fractured, slightly weathered.
Substantial circulation losses.
Gray to brownish gray, moderately fractured, slightly weathered, vesicular.
SAND: Grayish brown, silty, gravelly SAND.
Sample
S-1
S-2
S-3
S-4
S-5
S-6
S-7
S-8
S-9
S-10
S-11
Field Tests
Well Design
Top Casing Elevation in Feet 185.70
Casing Stickup in Feet
6"ø = 2.33'
4"ø = 2.25'
2"ø = 2.25'
6-inch ø Steel Casing
4-inch ø Steel Casing
2-inch ø PVC Casing
6.0-inch ø Steel Casing
4.0-inch ø Steel Casing with Locking Cap
2.0-inch ø PVC
Concrete Pad
Cement / Bentonite
Pea Gravel Backfill
Natural Material
Water Level
Steel Casing Drive Shoe
Bentonite
2-inch ø PVC Screen (0.020 Slot Size)
Monterey Aqua # 8 SAND
End Cap
Basalt Drill Cuttings
2-inch O.D. Split Spoon Sample
* No Sample Recovery
N Standard Penetration Resistance, Blows per foot
NOTES:
1. Soil descriptions are interpretive and actual changes may be gradual.
2. Water Level is for date indicated and may vary with time of year. ATD:At Time of Drilling
J-5010-02 April 1991
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Sheet 1 of 2 Figure 4
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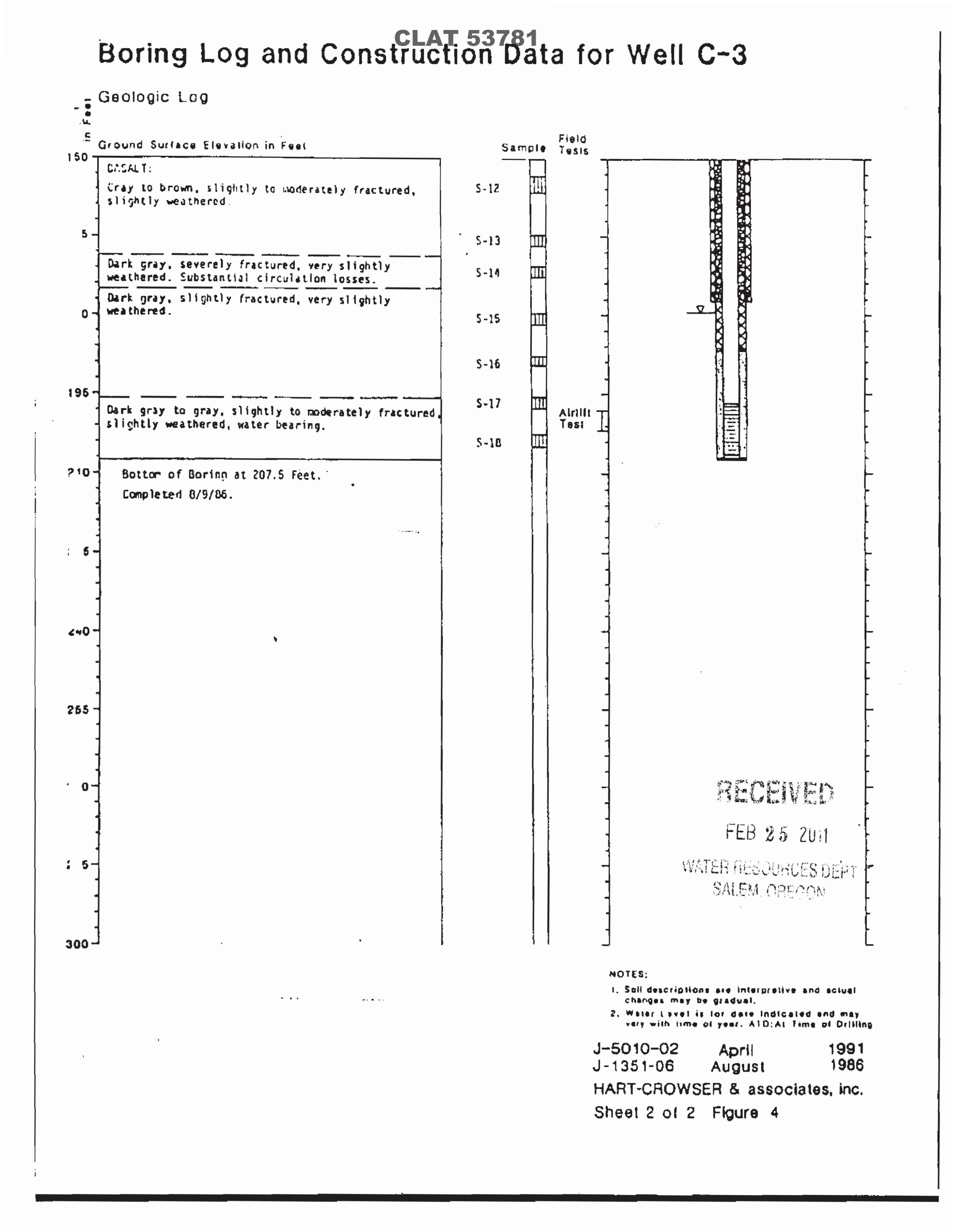
CLAT 53781
Boring Log and Construction Data for Well C-3
Geologic Log
Ground Surface Elevation in Feet
Sample
Field Tests
BASALT:
Gray to brown, slightly to moderately fractured, slightly weathered.
Dark gray, severely fractured, very slightly weathered. Substantial circulation losses.
Dark gray, slightly fractured, very slightly weathered.
Dark gray to gray, slightly to moderately fractured, slightly weathered, water bearing.
Bottom of Boring at 207.5 Feet.
Completed 8/9/86.
S-12
S-13
S-14
S-15
S-16
S-17
S-18
Airlift Test
150
5
0
195
210
240
255
300
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SALEM, OREGON
NOTES:
1. Soil descriptions are interpretive and actual changes may be gradual.
2. Water Level is for date indicated and may vary with time of year. ATD: At Time of Drilling
J-5010-02 April 1991
J-1351-06 August 1986
HART-CROWSER & associates, inc.
Sheet 2 of 2 Figure 4

CLAT 53782

Oregon Water Resources Department
725 Summer Street NE, Suite A
Salem Oregon 97301
(503) 986-0900
www.wrd.state.or.us

Application for
Well ID Number

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SALEM, OREGON

Do not complete if the well already has a Well I.D Number.

I. OWNER INFORMATION

Current Owner Name *(please print)*: Georgia Pacific Consumer Products, LP
Mailing Address: 92326 TAYLORVILLE Rd
City: Clatskanie State: OR Zip: 97016
Mailing Address *(to send Well I.D.)*: 92326 TAYLORVILLE Rd
City: Clatskanie State: OR Zip: 97016

II. WELL INFORMATION *(Do not complete this section if the well report is attached.)*

Township: 8 N (North/South) Range: 6 W (East/West) Section: 22
Tax Lot: 0100 County: Clatsop 1/4 NW 1/4
Street Address of Well: 92326 TAYLORVILLE City: CLATSKANIE, OR
Owner at time the well was constructed, (if known): Crown Zellarbach
If the property had a different street address in the past:

III. GENERAL WELL INFORMATION *(Do not complete this section if the well report is attached)*

Use of Well (domestic, irrigation, commercial, industrial, monitoring): Monitoring
Date Well Constructed: 8/14/86 Total Well Depth: 260.20 Casing Diameter: 2
Other Information: Well C-4

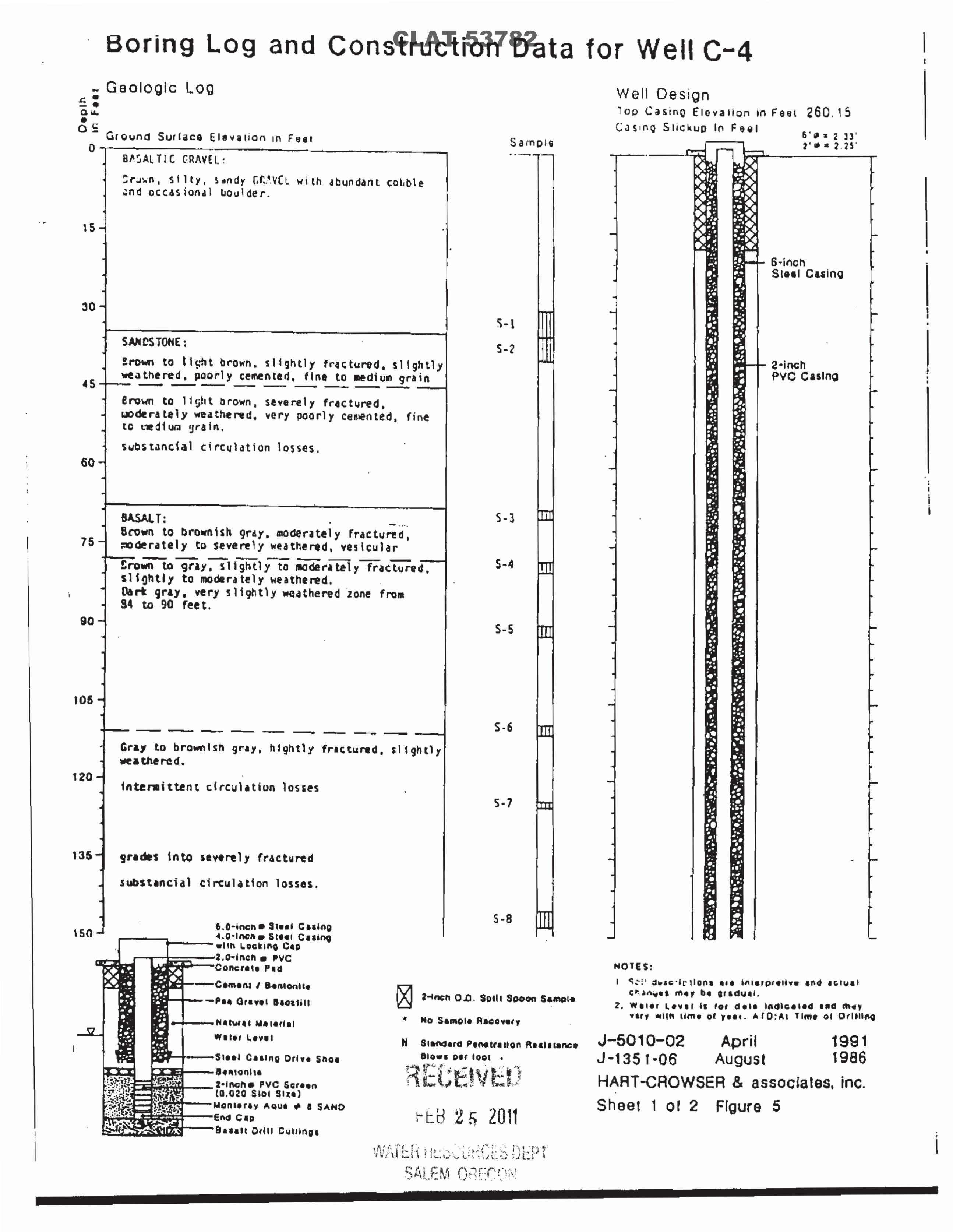
SUBMITTED BY *(please print)*: Al Deichsel
PHONE: 503-455-3370 FAX: 503-455-3469

Send application to Oregon Water Resoureces Department; 725 Summer St NE, Suite A; Salem, Oregon 97301-1266; fax (503) 986-0902. Applications are processed and Well I.D. Numbers are mailed every Wednesday.

For Official Use Only by the Oregon Water Resources Department:

Received Date:	Well Log Number:	Well Identification #:
	CLAT 53782	106567

Last Update: 11/04/08 Well I.D. Number/ 1 WCC


CLAT 53782
Boring Log and Construction Data for Well C-4
Geologic Log
Depth in Feet
Ground Surface Elevation in Feet
0
15
30
45
60
75
90
105
120
135
150
BASALTIC GRAVEL:
Brown, silty, sandy GRAVEL with abundant cobble and occasional boulder.
SANDSTONE:
Brown to light brown, slightly fractured, slightly weathered, poorly cemented, fine to medium grain
Brown to light brown, severely fractured, moderately weathered, very poorly cemented, fine to medium grain.
substancial circulation losses.
BASALT:
Brown to brownish gray, moderately fractured, moderately to severely weathered, vesicular
Brown to gray, slightly to moderately fractured, slightly to moderately weathered.
Dark gray, very slightly weathered zone from 84 to 90 feet.
Gray to brownish gray, hightly fractured, slightly weathered.
intermittent circulation losses
grades into severely fractured
substancial circulation losses.
Sample
S-1
S-2
S-3
S-4
S-5
S-6
S-7
S-8
Well Design
Top Casing Elevation in Feet 260.15
Casing Stickup in Feet
6"⌀ = 2.33'
2"⌀ = 2.25'
6-inch Steel Casing
2-inch PVC Casing
6.0-inch ⌀ Steel Casing
4.0-inch ⌀ Steel Casing with Locking Cap
2.0-inch ⌀ PVC
Concrete Pad
Cement / Bentonite
Pea Gravel Backfill
Natural Material
Water Level
Steel Casing Drive Shoe
Bentonite
2-inch ⌀ PVC Screen (0.020 Slot Size)
Monterey Aqua # 8 SAND
End Cap
Basalt Drill Cuttings
2-inch O.D. Split Spoon Sample
* No Sample Recovery
N Standard Penetration Resistance Blows per foot
NOTES:
1. Soil descriptions are interpretive and actual changes may be gradual.
2. Water Level is for date indicated and may vary with time of year. ATD: At Time of Drilling
J-5010-02 April 1991
J-1351-06 August 1986
HART-CROWSER & associates, inc.
Sheet 1 of 2 Figure 5
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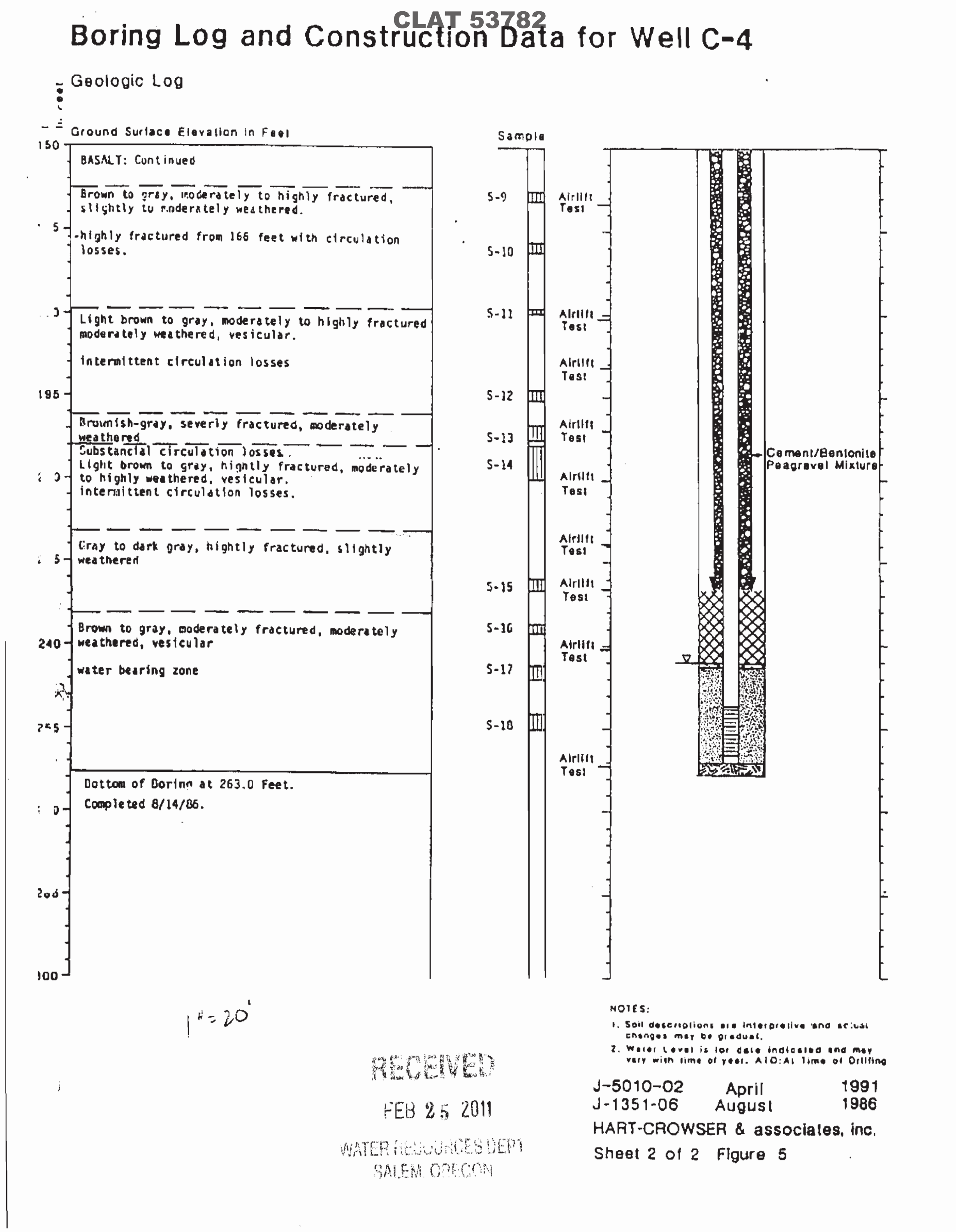
CLAT 53782
Boring Log and Construction Data for Well C-4
Geologic Log
Ground Surface Elevation in Feet
Sample
BASALT: Continued
Brown to gray, moderately to highly fractured, slightly to moderately weathered.
-highly fractured from 166 feet with circulation losses.
Light brown to gray, moderately to highly fractured moderately weathered, vesicular.
intermittent circulation losses
Brownish-gray, severly fractured, moderately weathered
Substancial circulation losses.
Light brown to gray, hightly fractured, moderately to highly weathered, vesicular. intermittent circulation losses.
Gray to dark gray, hightly fractured, slightly weathered
Brown to gray, moderately fractured, moderately weathered, vesicular
water bearing zone
Bottom of Boring at 263.0 Feet.
Completed 8/14/86.
150
195
240
300
S-9
S-10
S-11
S-12
S-13
S-14
S-15
S-16
S-17
S-18
Airlift Test
Cement/Bentonite Peagravel Mixture
1" = 20'
NOTES:
1. Soil descriptions are interpretive and actual changes may be gradual.
2. Water Level is for date indicated and may vary with time of year. ATD: At Time of Drilling
J-5010-02 April 1991
J-1351-06 August 1986
HART-CROWSER & associates, inc.
Sheet 2 of 2 Figure 5
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WATER RESOURCES DEPT
SALEM, OREGON

APPENDIX B: GENERALIZED ZONING CLASSIFICATION

B.1 Columbia County

Property Classification Code	Property Classification Code Descriptiou	Status Classification Code Description	Generalized Zoning
003	Miscellaneous, Centrally Assessed		Commercial/Residential
010	Unbuildable(Size,Deq Denial, Etc) Zoned Residential		Residential
020	Unbuildable(Size, Deq Denial, Etc) Zoned Commercial		Commercial
030	Unbuildable(Size,Deq Denial, Etc) Zoned Industrial		Commercial
040	Unbuildable(Size, Deq Denial, Etc) Zoning Not Significant		Commercial/Residential/Public
100	Vacant Land, Zoned Residential		Residential
101	Residential Improved, Zoned Residential		Residential
109	M S Improved, Zoned Residential		Residential
200	Vacant Land Zoned Commercial		Commercial
201	Commercial Improved Zoned Commercial		Commercial/Residential
206	Commercial, Marina/Moorage	Houseboat (floating home) Class 3	Residential
207	AU M S Parks, Regardless Of Zone		Residential
300	Vacant Land, Zoned Industrial		Commercial
301	Industrial Improved, Zoned Industrial	Mach. & Equip. State	Commercial/Public
303	Industrial Land And Buildings		Commercial
308	Industrial, County Responsible Ipr Processed		Commercial
330	Industrial, Aggregate Mine		Commercial
338	Industrial, Aggregate Mine County Responsible Ipr Processed	Single wide	Residential
400	Vacant H&B Use Tract Land, Zoning Not Significant		Residential
401	Improved H&B Use Tract, Zoning Not Significant		Residential/Commercial
409	M S H&B Use Tract, Zoning Not Significant		Residential
541	Improved H&B Use Farm, Rcvg Farm Def, Zoned Non-Efu		Residential
549	M S H&B Use Farm, Recvng Farm Def, Zoned Non-Efu		Commercial/Residential
550	Vacant H&B Use Farm, Recvng Farm Def, Zoned Efu	Industrial Land And Buildings	Commercial
551	Improved H&B Use Farm, Rcvg Farm Def, Zoned Efu		Commercial/Residential
559	M S H&B Use Farm Land, Rcvng Farm Def, Zoned Efu		Commercial/Residential
580	Agriculture, Mostly Farm Rural Mult Spec Asmts		Commercial
581	Agriculture, W /Imps -Mostly Farm Rural Mult Spec Asmts		Commercial/Residential
600	Vacant H&B Use Forest, Not Designated, Zoning Not Significant		Commercial
640	Vacant H&B Use Tract Forest/Wlo, Designated, Zoning Not Significant		Commercial
641	Imprvd H&B Use Tract Forest/Wlo, Designated, Zoning Not Significant		Residential/Commercial
649	M S H&B Use Tract Forest/Wlo, Designated, Zoning Not Significant		Residential/Commercial
680	Forest Land, Land Only-Mostly Forest Rural, Mult Spec Asmts		Public/Commercial
681	Forest Land, Withimps-Mostly Forest Rural, Mult Spec Asmts		Public/Residential
689	M S H&B Use Fl,Mltpl Sp Asmt, Fl Predominant Zn Not Significant		Residential
701	Improved 5 Or More Units, Zoned Multi-Family And Ms Park Improved		Residential/Commercial
781	Multiple Housing, Low Income Special Asmt		Residential
800	Recreation, Land Only		Public
910	Church - Vacant		Commercial
911	Church - Improved		Commercial/Residential
920	School- Vacant		Public
921	School - Improved		Public/Residential
930	Cemetery - Vacant		Commercial
931	Cemetery - Improved		Residential
940	City - Vacant		Public
941	City - Improved		Public/Residential/Commercial
950	County - Vacant		Public
951	County - Improved		Public/Commercial/Residential
960	State Owned - Vacant		Public
961	State Owned - Improved		Public
970	Federally Owned - Vacant		Public/Residential/Commercial
981	Benevolent, Fraternal Ownership - Improved		Public/Residential
990	Port Properties Or Other Municipal Properties - Vacant		Public
991	Port Properties Or Other Municipal Properties - Improved		Public/Commercial

B.2 Clatsop County

Property Classification Code	Property Classification Code Description	Status Classification Code Description	Generalized Zoning
003	Miscellaneous		Residential
010	Miscellaneous Residential Properties		Residential
033	Improved Industrial		Commercial
100	Residential land Only		Residential
101	Improved Residential Property		Residential
109	Mobile Home		Residential
200	Commercial land Only		Commercial
201	Improved Commerical Land		Commercial
300	Industrial land Only		Commercial
301	Improved Industrial Land		Commercial
303	Industrial land And Buildin.~s		Commercial
400	Tract Land Only Is Parcels Of Varying Sized Where The Best Use For Development Is For A Suburban Or Rural Homesite		Residential
409	Mobile Home Land Account Only		Residential
431	Residential Property Where Highest And Best Use And Zoning Are Noncomforming		Residential
540	Vacant Non-Efu Farm And Rangeland		Commercial
541	Improved With Buildings Non-Efu Zone Farm And Range Property		Commercial
600	Forestland Is Vacant With Highest And Best Use For Growing And Harvesting Trees Of A Marketable Species		Commercial
641	Forest Property Is Improved With Building for Highest And Best Use Is Something Other Than Growing And Harvesting Trees		Residential
660	Vacant Small Tract Forestland Property		*Commercial
661	Improved Small Tract Forestland Property Where Highest And Best Use Is Something Other Than Growing And Harvesting Trees	Mobile home	Residential
707	Manufactured Home Park/Court		Residential
911	Improved Church		Commercial
920	Vacant School		Public
930	Vacant Cemetery		Commercial
950	Vacant County		Public
960	Vacant State		Public
971	Improved Federally		Public
990	Vacant Port Properties Or Other Municipal Properties		Public
991	Improved Port Properties Or Other Municipal Properties		Public
			• No attributes

APPENDIX C: HAZUS-MH DATA REPORTS

Hazus-MH: Earthquake Event Report

Region Name: highway 30

Earthquake Scenario: Scenario 1: No landslide hazard (landslide hazards set to 0 out of 10)

Print Date: May 01, 2012

Totals only reflect data for those census tracts/blocks included in the user's study region.

Disclaimer:
The estimates of social and economic impacts contained in this report were produced using Hazus loss estimation methodology software which is based on current scientific and engineering knowledge. There are uncertainties inherent in any loss estimation technique. Therefore, there may be significant differences between the modeled results contained in this report and the actual social and economic losses following a specific earthquake. These results can be improved by using enhanced inventory, geotechnical, and observed ground motion data.

Table of Contents

General Description of the Region

Hazus is a regional earthquake loss estimation model that was developed by the Federal Emergency Management Agency and the National Institute of Building Sciences. The primary purpose of Hazus is to provide a methodology and software application to develop earthquake losses at a regional scale. These loss estimates would be used primarily by local, state and regional officials to plan and stimulate efforts to reduce risks from earthquakes and to prepare for emergency response and recovery.

The earthquake loss estimates provided in this report was based on a region that includes 2 county(ies) from the following state(s):

Oregon

Note:
Appendix A contains a complete listing of the counties contained in the region.

The geographical size of the region is 611.27 square miles and contains 2 census tracts. There are over 3 thousand households in the region which has a total population of 8,968 people (2002 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 4 thousand buildings in the region with a total building replacement value (excluding contents) of 598 (millions of dollars). Approximately 93.00 % of the buildings (and 84.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 1,290 and 274 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

Hazus estimates that there are 4 thousand buildings in the region which have an aggregate total replacement value of 598 (millions of dollars) . Appendix B provides a general distribution of the building value by State and County.

In terms of building construction types found in the region, wood frame construction makes up 67% of the building inventory. The remaining percentage is distributed between the other general building types.

Critical Facility Inventory

Hazus breaks critical facilities into two (2) groups: essential facilities and high potential loss facilities (HPL). Essential facilities include hospitals, medical clinics, schools, fire stations, police stations and emergency operations facilities. High potential loss facilities include dams, levees, military installations, nuclear power plants and hazardous material sites.

For essential facilities, there are 0 hospitals in the region with a total bed capacity of 0 beds. There are 6 schools, 3 fire stations, 1 police stations and 0 emergency operation facilities. With respect to high potential loss facilities (HPL), there are 1 dams identified within the region. Of these, 0 of the dams are classified as 'high hazard'. The inventory also includes 35 hazardous material sites, 0 military installations and 0 nuclear power plants.

Transportation and Utility Lifeline Inventory

Within Hazus, the lifeline inventory is divided between transportation and utility lifeline systems. There are seven (7) transportation systems that include highways, railways, light rail, bus, ports, ferry and airports. There are six (6) utility systems that include potable water, wastewater, natural gas, crude & refined oil, electric power and communications. The lifeline inventory data are provided in Tables 1 and 2.

The total value of the lifeline inventory is over 1,564.00 (millions of dollars). This inventory includes over 196 kilometers of highways, 19 bridges, 4,997 kilometers of pipes.

Table 1: Transportation System Lifeline Inventory

System	Component	# Locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	19	291.00
	Segments	13	892.90
	Tunnels	0	0.00
		Subtotal	**1,183.80**
Railways	Bridges	0	0.00
	Facilities	0	0.00
	Segments	31	91.80
	Tunnels	0	0.00
		Subtotal	**91.80**
Light Rail	Bridges	0	0.00
	Facilities	0	0.00
	Segments	0	0.00
	Tunnels	0	0.00
		Subtotal	**0.00**
Bus	Facilities	0	0.00
		Subtotal	**0.00**
Ferry	Facilities	1	1.30
		Subtotal	**1.30**
Port	Facilities	7	14.00
		Subtotal	**14.00**
Airport	Facilities	0	0.00
	Runways	0	0.00
		Subtotal	**0.00**
		Total	**1,291.00**

Table 2: Utility System Lifeline Inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	50.00
	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**50.00**
Waste Water	Distribution Lines	NA	30.00
	Facilities	2	150.50
	Pipelines	0	0.00
		Subtotal	**180.50**
Natural Gas	Distribution Lines	NA	20.00
	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**20.00**
Oil Systems	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**0.00**
Electrical Power	Facilities	1	124.30
		Subtotal	**124.30**
Communication	Facilities	0	0.00
		Subtotal	**0.00**
		Total	**374.80**

Earthquake Scenario

Hazus uses the following set of information to define the earthquake parameters used for the earthquake loss estimate provided in this report.

	f
Type of Earthquake	Arbitrary
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-123.34
Latitude of Epicenter	46.12
Earthquake Magnitude	6.70
Depth (Km)	2.00
Rupture Length (Km)	25.59
Rupture Orientation (degrees)	150.00
Attenuation Function	West US, Extensional 2008 - Strike Slip

Building Damage

Building Damage

Hazus estimates that about 1,317 buildings will be at least moderately damaged. This is over 29.00 % of the buildings in the region. There are an estimated 92 buildings that will be damaged beyond repair. The definition of the 'damage states' is provided in Volume 1: Chapter 5 of the Hazus technical manual. Table 3 below summarizes the expected damage by general occupancy for the buildings in the region. Table 4 below summarizes the expected damage by general building type.

Table 3: Expected Building Damage by Occupancy

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Agriculture	9	0.45	6	0.48	6	0.66	3	0.85	1	1.23
Commercial	49	2.39	36	2.99	48	5.49	27	7.58	10	11.11
Education	3	0.13	2	0.17	2	0.28	1	0.39	1	0.58
Government	2	0.11	1	0.06	1	0.08	0	0.08	0	0.09
Industrial	28	1.37	17	1.40	22	2.56	12	3.47	4	4.82
Other Residential	523	25.63	394	32.47	456	52.18	256	72.93	67	72.48
Religion	4	0.17	3	0.27	4	0.46	2	0.65	1	0.96
Single Family	1,425	69.75	755	62.16	335	38.29	49	14.05	8	8.73
Total	**2,042**		**1,215**		**874**		**351**		**93**	

Table 4: Expected Building Damage by Building Type (All Design Levels)

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	1,649	80.76	917	75.49	414	47.40	59	16.74	8	9.04
Steel	25	1.20	15	1.27	29	3.33	19	5.55	8	8.47
Concrete	25	1.23	18	1.51	24	2.78	15	4.23	5	5.01
Precast	18	0.90	10	0.83	17	1.92	12	3.53	4	4.57
RM	3	0.16	1	0.10	2	0.23	1	0.42	0	0.39
URM	34	1.66	30	2.50	41	4.68	25	7.11	13	13.54
MH	288	14.09	222	18.30	347	39.66	219	62.42	55	58.97
Total	**2,042**		**1,215**		**874**		**351**		**93**	

*Note:
RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Essential Facility Damage

Before the earthquake, the region had 0 hospital beds available for use. On the day of the earthquake, the model estimates that only 0 hospital beds (0.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 0.00% of the beds will be back in service. By 30 days, 0.00% will be operational.

Table 5: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		At Least Moderate Damage > 50%	Complete Damage > 50%	With Functionality > 50% on day 1
Hospitals	0	0	0	0
Schools	6	0	0	3
EOCs	0	0	0	0
PoliceStations	1	0	0	0
FireStations	3	0	0	3

Transportation and Utility Lifeline Damage

Table 6 provides damage estimates for the transportation system.

Table 6: Expected Damage to the Transportation Systems

System	Component	Number of Locations				
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 %	
					After Day 1	After Day 7
Highway	Segments	13	0	0	13	13
	Bridges	19	1	0	18	18
	Tunnels	0	0	0	0	0
Railways	Segments	31	0	0	31	31
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Light Rail	Segments	0	0	0	0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	0	0	0	0	0
Ferry	Facilities	1	1	0	1	1
Port	Facilities	7	5	0	7	7
Airport	Facilities	0	0	0	0	0
	Runways	0	0	0	0	0

Note: Roadway segments, railroad tracks and light rail tracks are assumed to be damaged by ground failure only. If ground failure maps are not provided, damage estimates to these components will not be computed.

Tables 7-9 provide information on the damage to the utility lifeline systems. Table 7 provides damage to the utility system facilities. Table 8 provides estimates on the number of leaks and breaks by the pipelines of the utility systems. For electric power and potable water, Hazus performs a simplified system performance analysis. Table 9 provides a summary of the system performance information.

Table 7 : Expected Utility System Facility Damage

System	# of Locations				
	Total #	With at Least Moderate Damage	With Complete Damage	with Functionality > 50 %	
				After Day 1	After Day 7
Potable Water	0	0	0	0	0
Waste Water	2	2	0	0	2
Natural Gas	0	0	0	0	0
Oil Systems	0	0	0	0	0
Electrical Power	1	0	0	0	1
Communication	0	0	0	0	0

Table 8 : Expected Utility System Pipeline Damage (Site Specific)

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	2,499	236	59
Waste Water	1,499	119	30
Natural Gas	999	41	10
Oil	0	0	0

Table 9: Expected Potable Water and Electric Power System Performance

	Total # of Households	Number of Households without Service				
		At Day 1	At Day 3	At Day 7	At Day 30	At Day 90
Potable Water	3,452	75	0	0	0	0
Electric Power		0	0	0	0	0

Induced Earthquake Damage

Fire Following Earthquake

Fires often occur after an earthquake. Because of the number of fires and the lack of water to fight the fires, they can often burn out of control. Hazus uses a Monte Carlo simulation model to estimate the number of ignitions and the amount of burnt area. For this scenario, the model estimates that there will be 0 ignitions that will burn about 0.00 sq. mi 0.00 % of the region's total area.) The model also estimates that the fires will displace about 0 people and burn about 0 (millions of dollars) of building value.

Debris Generation

Hazus estimates the amount of debris that will be generated by the earthquake. The model breaks the debris into two general categories: a) Brick/Wood and b) Reinforced Concrete/Steel. This distinction is made because of the different types of material handling equipment required to handle the debris.

The model estimates that a total of 0.02 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 50.00% of the total, with the remainder being Reinforced Concrete/Steel. If the debris tonnage is converted to an estimated number of truckloads, it will require 800 truckloads (@25 tons/truck) to remove the debris generated by the earthquake.

Social Impact

Shelter Requirement

Hazus estimates the number of households that are expected to be displaced from their homes due to the earthquake and the number of displaced people that will require accommodations in temporary public shelters. The model estimates 27 households to be displaced due to the earthquake. Of these, 17 people (out of a total population of 8,968) will seek temporary shelter in public shelters.

Casualties

Hazus estimates the number of people that will be injured and killed by the earthquake. The casualties are broken down into four (4) severity levels that describe the extent of the injuries. The levels are described as follows;

- Severity Level 1: Injuries will require medical attention but hospitalization is not needed.
- Severity Level 2: Injuries will require hospitalization but are not considered life-threatening
- Severity Level 3: Injuries will require hospitalization and can become life threatening if not promptly treated.
- Severity Level 4: Victims are killed by the earthquake.

The casualty estimates are provided for three (3) times of day: 2:00 AM, 2:00 PM and 5:00 PM. These times represent the periods of the day that different sectors of the community are at their peak occupancy loads. The 2:00 AM estimate considers that the residential occupancy load is maximum, the 2:00 PM estimate considers that the educational, commercial and industrial sector loads are maximum and 5:00 PM represents peak commute time.

Table 10 provides a summary of the casualties estimated for this earthquake

Table 10: Casualty Estimates

		Level 1	Level 2	Level 3	Level 4
2 AM	Commercial	0	0	0	0
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	0	0	0	0
	Industrial	0	0	0	0
	Other-Residential	12	2	0	0
	Single Family	6	1	0	0
	Total	**18**	**3**	**0**	**0**
2 PM	Commercial	9	2	0	1
	Commuting	0	0	0	0
	Educational	5	1	0	0
	Hotels	0	0	0	0
	Industrial	2	0	0	0
	Other-Residential	3	1	0	0
	Single Family	2	0	0	0
	Total	**20**	**5**	**1**	**1**
5 PM	Commercial	10	3	0	1
	Commuting	1	1	1	0
	Educational	0	0	0	0
	Hotels	0	0	0	0
	Industrial	1	0	0	0
	Other-Residential	4	1	0	0
	Single Family	2	0	0	0
	Total	**18**	**5**	**2**	**1**

Economic Loss

The total economic loss estimated for the earthquake is 126.80 (millions of dollars), which includes building and lifeline related losses based on the region's available inventory. The following three sections provide more detailed information about these losses.

Building-Related Losses

The building losses are broken into two categories: direct building losses and business interruption losses. The direct building losses are the estimated costs to repair or replace the damage caused to the building and its contents. The business interruption losses are the losses associated with inability to operate a business because of the damage sustained during the earthquake. Business interruption losses also include the temporary living expenses for those people displaced from their homes because of the earthquake.

The total building-related losses were 59.12 (millions of dollars); 20 % of the estimated losses were related to the business interruption of the region. By far, the largest loss was sustained by the residential occupancies which made up over 63 % of the total loss. Table 11 below provides a summary of the losses associated with the building damage.

Table 11: Building-Related Economic Loss Estimates

(Millions of dollars)

Category	Area	Single Family	Other Residential	Commercial	Industrial	Others	Total
Income Losses							
	Wage	0.00	0.17	1.91	0.09	0.09	2.27
	Capital-Related	0.00	0.07	1.91	0.06	0.04	2.07
	Rental	0.56	0.44	0.79	0.02	0.05	1.86
	Relocation	2.10	1.45	1.18	0.11	0.52	5.36
	Subtotal	**2.66**	**2.14**	**5.79**	**0.28**	**0.69**	**11.57**
Capital Stock Losses							
	Structural	3.38	1.72	1.94	0.41	0.67	8.12
	Non_Structural	15.46	5.68	5.20	1.29	1.65	29.29
	Content	5.05	0.96	2.28	0.80	0.75	9.84
	Inventory	0.00	0.00	0.09	0.19	0.02	0.30
	Subtotal	**23.89**	**8.37**	**9.51**	**2.70**	**3.09**	**47.55**
	Total	**26.54**	**10.51**	**15.30**	**2.98**	**3.79**	**59.12**

Transportation and Utility Lifeline Losses

For the transportation and utility lifeline systems, Hazus computes the direct repair cost for each component only. There are no losses computed by Hazus for business interruption due to lifeline outages. Tables 12 & 13 provide a detailed breakdown in the expected lifeline losses.

Hazus estimates the long-term economic impacts to the region for 15 years after the earthquake. The model quantifies this information in terms of income and employment changes within the region. Table 14 presents the results of the region for the given earthquake.

Table 12: Transportation System Economic Losses
(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Highway	Segments	892.86	$0.00	0.00
	Bridges	290.98	$10.65	3.66
	Tunnels	0.00	$0.00	0.00
	Subtotal	**1183.80**	**10.60**	
Railways	Segments	91.85	$0.00	0.00
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**91.80**	**0.00**	
Light Rail	Segments	0.00	$0.00	0.00
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Bus	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Ferry	Facilities	1.33	$0.56	42.20
	Subtotal	**1.30**	**0.60**	
Port	Facilities	13.98	$4.73	33.87
	Subtotal	**14.00**	**4.70**	
Airport	Facilities	0.00	$0.00	0.00
	Runways	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
	Total	**1291.00**	**15.90**	

Table 13: Utility System Economic Losses

(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Potable Water	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Distribution Lines	50.00	$1.06	2.13
	Subtotal	**49.97**	**$1.06**	
Waste Water	Pipelines	0.00	$0.00	0.00
	Facilities	150.50	$38.42	25.53
	Distribution Lines	30.00	$0.53	1.78
	Subtotal	**180.50**	**$38.96**	
Natural Gas	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Distribution Lines	20.00	$0.18	0.92
	Subtotal	**19.99**	**$0.18**	
Oil Systems	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**$0.00**	
Electrical Power	Facilities	124.30	$11.54	9.28
	Subtotal	**124.30**	**$11.54**	
Communication	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**$0.00**	
	Total	**374.76**	**$51.74**	

Table 14. Indirect Economic Impact with outside aid

(Employment as # of people and Income in millions of $)

LOSS		Total	%

Appendix A: County Listing for the Region

Clatsop,OR

Columbia,OR

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Oregon					
	Clatsop	2,973	161	26	188
	Columbia	5,995	341	69	410
Total State		**8,968**	**502**	**95**	**598**
Total Region		**8,968**	**502**	**95**	**598**

Hazus-MH: Earthquake Event Report

Region Name: highway 30

Earthquake Scenario: Scenario 2: Detailed landslide hazard (landslides hazards mapped on lidar)

Print Date: May 01, 2012

Totals only reflect data for those census tracts/blocks included in the user's study region.

Disclaimer:
The estimates of social and economic impacts contained in this report were produced using Hazus loss estimation methodology software which is based on current scientific and engineering knowledge. There are uncertainties inherent in any loss estimation technique. Therefore, there may be significant differences between the modeled results contained in this report and the actual social and economic losses following a specific earthquake. These results can be improved by using enhanced inventory, geotechnical, and observed ground motion data.

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General Description of the Region

Hazus is a regional earthquake loss estimation model that was developed by the Federal Emergency Management Agency and the National Institute of Building Sciences. The primary purpose of Hazus is to provide a methodology and software application to develop earthquake losses at a regional scale. These loss estimates would be used primarily by local, state and regional officials to plan and stimulate efforts to reduce risks from earthquakes and to prepare for emergency response and recovery.

The earthquake loss estimates provided in this report was based on a region that includes 2 county(ies) from the following state(s):

Oregon

Note:
Appendix A contains a complete listing of the counties contained in the region.

The geographical size of the region is 611.27 square miles and contains 2 census tracts. There are over 3 thousand households in the region which has a total population of 8,968 people (2002 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 4 thousand buildings in the region with a total building replacement value (excluding contents) of 598 (millions of dollars). Approximately 93.00 % of the buildings (and 84.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 1,290 and 274 (millions of dollars) , respectively.

Hazus-MH: Earthquake Event Report

Region Name: hwy30_ls_suscept_new_fault

Earthquake Scenario: fake_gales_creek_M6.7

Print Date: May 01, 2012

Totals only reflect data for those census tracts/blocks included in the user's study region.

Disclaimer:
The estimates of social and economic impacts contained in this report were produced using Hazus loss estimation methodology software which is based on current scientific and engineering knowledge. There are uncertainties inherent in any loss estimation technique. Therefore, there may be significant differences between the modeled results contained in this report and the actual social and economic losses following a specific earthquake. These results can be improved by using enhanced inventory, geotechnical, and observed ground motion data.

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The earthquake loss estimates provided in this report was based on a region that includes 2 county(ies) from the following state(s):

Oregon

Note:
Appendix A contains a complete listing of the counties contained in the region.

The geographical size of the region is 611.27 square miles and contains 2 census tracts. There are over 3 thousand households in the region which has a total population of 8,968 people (2002 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

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The replacement value of the transportation and utility lifeline systems is estimated to be 1,290 and 274 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

Hazus estimates that there are 4 thousand buildings in the region which have an aggregate total replacement value of 598 (millions of dollars) . Appendix B provides a general distribution of the building value by State and County.

In terms of building construction types found in the region, wood frame construction makes up 67% of the building inventory. The remaining percentage is distributed between the other general building types.

Critical Facility Inventory

Hazus breaks critical facilities into two (2) groups: essential facilities and high potential loss facilities (HPL). Essential facilities include hospitals, medical clinics, schools, fire stations, police stations and emergency operations facilities. High potential loss facilities include dams, levees, military installations, nuclear power plants and hazardous material sites.

For essential facilities, there are 0 hospitals in the region with a total bed capacity of 0 beds. There are 6 schools, 3 fire stations, 1 police stations and 0 emergency operation facilities. With respect to high potential loss facilities (HPL), there are 1 dams identified within the region. Of these, 0 of the dams are classified as 'high hazard'. The inventory also includes 35 hazardous material sites, 0 military installations and 0 nuclear power plants.

Transportation and Utility Lifeline Inventory

Within Hazus, the lifeline inventory is divided between transportation and utility lifeline systems. There are seven (7) transportation systems that include highways, railways, light rail, bus, ports, ferry and airports. There are six (6) utility systems that include potable water, wastewater, natural gas, crude & refined oil, electric power and communications. The lifeline inventory data are provided in Tables 1 and 2.

The total value of the lifeline inventory is over 1,564.00 (millions of dollars). This inventory includes over 196 kilometers of highways, 19 bridges, 4,997 kilometers of pipes.

Table 1: Transportation System Lifeline Inventory

System	Component	# Locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	19	291.00
	Segments	13	892.90
	Tunnels	0	0.00
		Subtotal	**1,183.80**
Railways	Bridges	0	0.00
	Facilities	0	0.00
	Segments	31	91.80
	Tunnels	0	0.00
		Subtotal	**91.80**
Light Rail	Bridges	0	0.00
	Facilities	0	0.00
	Segments	0	0.00
	Tunnels	0	0.00
		Subtotal	**0.00**
Bus	Facilities	0	0.00
		Subtotal	**0.00**
Ferry	Facilities	1	1.30
		Subtotal	**1.30**
Port	Facilities	7	14.00
		Subtotal	**14.00**
Airport	Facilities	0	0.00
	Runways	0	0.00
		Subtotal	**0.00**
		Total	**1,291.00**

Table 2: Utility System Lifeline Inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	50.00
	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**50.00**
Waste Water	Distribution Lines	NA	30.00
	Facilities	2	150.50
	Pipelines	0	0.00
		Subtotal	**180.50**
Natural Gas	Distribution Lines	NA	20.00
	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**20.00**
Oil Systems	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**0.00**
Electrical Power	Facilities	1	124.30
		Subtotal	**124.30**
Communication	Facilities	0	0.00
		Subtotal	**0.00**
		Total	**374.80**

Earthquake Scenario

Hazus uses the following set of information to define the earthquake parameters used for the earthquake loss estimate provided in this report.

	f
Type of Earthquake	Arbitrary
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-123.34
Latitude of Epicenter	46.12
Earthquake Magnitude	6.70
Depth (Km)	2.00
Rupture Length (Km)	25.59
Rupture Orientation (degrees)	150.00
Attenuation Function	West US, Extensional 2008 - Strike Slip

Building Damage

Building Damage

Hazus estimates that about 1,653 buildings will be at least moderately damaged. This is over 36.00 % of the buildings in the region. There are an estimated 179 buildings that will be damaged beyond repair. The definition of the 'damage states' is provided in Volume 1: Chapter 5 of the Hazus technical manual. Table 3 below summarizes the expected damage by general occupancy for the buildings in the region. Table 4 below summarizes the expected damage by general building type.

Table 3: Expected Building Damage by Occupancy

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Agriculture	8	0.45	5	0.47	5	0.65	5	0.72	2	0.93
Commercial	44	2.36	31	2.94	43	5.26	38	5.79	14	7.81
Education	2	0.12	2	0.16	2	0.26	2	0.32	1	0.42
Government	2	0.11	1	0.07	1	0.08	0	0.06	0	0.06
Industrial	26	1.40	15	1.41	20	2.47	17	2.57	6	3.36
Other Residential	483	25.88	348	32.93	419	50.83	348	53.66	99	55.19
Religion	3	0.16	3	0.26	4	0.44	3	0.54	1	0.71
Single Family	1,298	69.53	652	61.75	330	40.02	236	36.35	56	31.52
Total	**1,866**		**1,056**		**825**		**649**		**179**	

Table 4: Expected Building Damage by Building Type (All Design Levels)

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	1,490	79.84	787	74.55	408	49.48	294	45.24	69	38.62
Steel	22	1.20	13	1.27	26	3.16	25	3.82	10	5.51
Concrete	22	1.19	16	1.47	22	2.66	21	3.21	7	3.72
Precast	17	0.90	9	0.82	15	1.84	16	2.42	5	3.07
RM	3	0.15	1	0.10	2	0.22	2	0.31	1	0.31
URM	31	1.66	26	2.47	37	4.46	33	5.15	16	8.67
MH	281	15.06	204	19.31	315	38.18	259	39.85	72	40.10
Total	**1,866**		**1,056**		**825**		**649**		**179**	

*Note:

RM	Reinforced Masonry
URM	Unreinforced Masonry
MH	Manufactured Housing

Essential Facility Damage

Before the earthquake, the region had 0 hospital beds available for use. On the day of the earthquake, the model estimates that only 0 hospital beds (0.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 0.00% of the beds will be back in service. By 30 days, 0.00% will be operational.

Table 5: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		At Least Moderate Damage > 50%	Complete Damage > 50%	With Functionality > 50% on day 1
Hospitals	0	0	0	0
Schools	6	0	0	3
EOCs	0	0	0	0
PoliceStations	1	0	0	0
FireStations	3	0	0	3

Transportation and Utility Lifeline Damage

Table 6 provides damage estimates for the transportation system.

Table 6: Expected Damage to the Transportation Systems

System	Component	Number of Locations				
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 %	
					After Day 1	After Day 7
Highway	Segments	13	0	0	13	13
	Bridges	19	1	0	18	18
	Tunnels	0	0	0	0	0
Railways	Segments	31	0	0	31	31
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Light Rail	Segments	0	0	0	0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	0	0	0	0	0
Ferry	Facilities	1	1	0	1	1
Port	Facilities	7	5	0	7	7
Airport	Facilities	0	0	0	0	0
	Runways	0	0	0	0	0

Note: Roadway segments, railroad tracks and light rail tracks are assumed to be damaged by ground failure only. If ground failure maps are not provided, damage estimates to these components will not be computed.

Tables 7-9 provide information on the damage to the utility lifeline systems. Table 7 provides damage to the utility system facilities. Table 8 provides estimates on the number of leaks and breaks by the pipelines of the utility systems. For electric power and potable water, Hazus performs a simplified system performance analysis. Table 9 provides a summary of the system performance information.

Table 7 : Expected Utility System Facility Damage

System	# of Locations				
	Total #	With at Least Moderate Damage	With Complete Damage	with Functionality > 50 %	
				After Day 1	After Day 7
Potable Water	0	0	0	0	0
Waste Water	2	2	0	0	2
Natural Gas	0	0	0	0	0
Oil Systems	0	0	0	0	0
Electrical Power	1	0	0	0	1
Communication	0	0	0	0	0

Table 8 : Expected Utility System Pipeline Damage (Site Specific)

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	2,499	236	59
Waste Water	1,499	119	30
Natural Gas	999	41	10
Oil	0	0	0

Table 9: Expected Potable Water and Electric Power System Performance

	Total # of Households	Number of Households without Service				
		At Day 1	At Day 3	At Day 7	At Day 30	At Day 90
Potable Water	3,452	75	0	0	0	0
Electric Power		0	0	0	0	0

Induced Earthquake Damage

Fire Following Earthquake

Fires often occur after an earthquake. Because of the number of fires and the lack of water to fight the fires, they can often burn out of control. Hazus uses a Monte Carlo simulation model to estimate the number of ignitions and the amount of burnt area. For this scenario, the model estimates that there will be 0 ignitions that will burn about 0.00 sq. mi 0.00 % of the region's total area.) The model also estimates that the fires will displace about 0 people and burn about 0 (millions of dollars) of building value.

Debris Generation

Hazus estimates the amount of debris that will be generated by the earthquake. The model breaks the debris into two general categories: a) Brick/Wood and b) Reinforced Concrete/Steel. This distinction is made because of the different types of material handling equipment required to handle the debris.

The model estimates that a total of 0.03 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 50.00% of the total, with the remainder being Reinforced Concrete/Steel. If the debris tonnage is converted to an estimated number of truckloads, it will require 1,200 truckloads (@25 tons/truck) to remove the debris generated by the earthquake.

Social Impact

Shelter Requirement

Hazus estimates the number of households that are expected to be displaced from their homes due to the earthquake and the number of displaced people that will require accommodations in temporary public shelters. The model estimates 109 households to be displaced due to the earthquake. Of these, 70 people (out of a total population of 8,968) will seek temporary shelter in public shelters.

Casualties

Hazus estimates the number of people that will be injured and killed by the earthquake. The casualties are broken down into four (4) severity levels that describe the extent of the injuries. The levels are described as follows;

- Severity Level 1: Injuries will require medical attention but hospitalization is not needed.
- Severity Level 2: Injuries will require hospitalization but are not considered life-threatening
- Severity Level 3: Injuries will require hospitalization and can become life threatening if not promptly treated.
- Severity Level 4: Victims are killed by the earthquake.

The casualty estimates are provided for three (3) times of day: 2:00 AM, 2:00 PM and 5:00 PM. These times represent the periods of the day that different sectors of the community are at their peak occupancy loads. The 2:00 AM estimate considers that the residential occupancy load is maximum, the 2:00 PM estimate considers that the educational, commercial and industrial sector loads are maximum and 5:00 PM represents peak commute time.

Table 10 provides a summary of the casualties estimated for this earthquake

Table 10: Casualty Estimates

		Level 1	Level 2	Level 3	Level 4
2 AM	Commercial	0	0	0	0
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	0	0	0	0
	Industrial	0	0	0	0
	Other-Residential	14	3	0	0
	Single Family	18	3	0	0
	Total	**33**	**6**	**0**	**1**
2 PM	Commercial	12	3	0	1
	Commuting	0	0	0	0
	Educational	7	2	0	1
	Hotels	0	0	0	0
	Industrial	2	0	0	0
	Other-Residential	3	1	0	0
	Single Family	5	1	0	0
	Total	**29**	**7**	**1**	**2**
5 PM	Commercial	12	3	1	1
	Commuting	1	1	1	0
	Educational	0	0	0	0
	Hotels	0	0	0	0
	Industrial	1	0	0	0
	Other-Residential	5	1	0	0
	Single Family	7	1	0	0
	Total	**27**	**7**	**2**	**2**

Economic Loss

The total economic loss estimated for the earthquake is 176.41 (millions of dollars), which includes building and lifeline related losses based on the region's available inventory. The following three sections provide more detailed information about these losses.

Building-Related Losses

The building losses are broken into two categories: direct building losses and business interruption losses. The direct building losses are the estimated costs to repair or replace the damage caused to the building and its contents. The business interruption losses are the losses associated with inability to operate a business because of the damage sustained during the earthquake. Business interruption losses also include the temporary living expenses for those people displaced from their homes because of the earthquake.

The total building-related losses were 101.59 (millions of dollars); 17 % of the estimated losses were related to the business interruption of the region. By far, the largest loss was sustained by the residential occupancies which made up over 70 % of the total loss. Table 11 below provides a summary of the losses associated with the building damage.

Table 11: Building-Related Economic Loss Estimates

(Millions of dollars)

Category	Area	Single Family	Other Residential	Commercial	Industrial	Others	Total
Income Losses							
	Wage	0.00	0.30	2.35	0.11	0.12	2.88
	Capital-Related	0.00	0.13	2.33	0.07	0.05	2.57
	Rental	1.39	0.67	0.98	0.03	0.06	3.14
	Relocation	4.94	1.70	1.46	0.13	0.68	8.91
	Subtotal	**6.33**	**2.80**	**7.13**	**0.33**	**0.92**	**17.51**
Capital Stock Losses							
	Structural	9.22	2.17	2.51	0.49	0.92	15.32
	Non_Structural	32.24	7.80	7.27	1.73	2.41	51.45
	Content	9.42	1.60	3.54	1.13	1.20	16.88
	Inventory	0.00	0.00	0.14	0.27	0.03	0.43
	Subtotal	**50.88**	**11.57**	**13.46**	**3.62**	**4.55**	**84.09**
	Total	**57.21**	**14.37**	**20.59**	**3.95**	**5.47**	**101.59**

Transportation and Utility Lifeline Losses

For the transportation and utility lifeline systems, Hazus computes the direct repair cost for each component only. There are no losses computed by Hazus for business interruption due to lifeline outages. Tables 12 & 13 provide a detailed breakdown in the expected lifeline losses.

Hazus estimates the long-term economic impacts to the region for 15 years after the earthquake. The model quantifies this information in terms of income and employment changes within the region. Table 14 presents the results of the region for the given earthquake.

Table 12: Transportation System Economic Losses
(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Highway	Segments	892.86	$5.01	0.56
	Bridges	290.98	$10.65	3.66
	Tunnels	0.00	$0.00	0.00
	Subtotal	**1183.80**	**15.70**	
Railways	Segments	91.85	$0.66	0.71
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**91.80**	**0.70**	
Light Rail	Segments	0.00	$0.00	0.00
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Bus	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Ferry	Facilities	1.33	$0.56	42.20
	Subtotal	**1.30**	**0.60**	
Port	Facilities	13.98	$4.74	33.88
	Subtotal	**14.00**	**4.70**	
Airport	Facilities	0.00	$0.00	0.00
	Runways	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
	Total	**1291.00**	**21.60**	

Table 13: Utility System Economic Losses
(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Potable Water	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Distribution Lines	50.00	$1.06	2.13
	Subtotal	**49.97**	**$1.06**	
Waste Water	Pipelines	0.00	$0.00	0.00
	Facilities	150.50	$39.89	26.50
	Distribution Lines	30.00	$0.53	1.78
	Subtotal	**180.50**	**$40.42**	
Natural Gas	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Distribution Lines	20.00	$0.18	0.92
	Subtotal	**19.99**	**$0.18**	
Oil Systems	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**$0.00**	
Electrical Power	Facilities	124.30	$11.54	9.28
	Subtotal	**124.30**	**$11.54**	
Communication	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**$0.00**	
	Total	**374.76**	**$53.21**	

Table 14. Indirect Economic Impact with outside aid
(Employment as # of people and Income in millions of $)

LOSS		Total	%

Appendix A: County Listing for the Region

Clatsop,OR

Columbia,OR

Hazus-MH: Earthquake Event Report

Region Name: highway 30

Earthquake Scenario: Scenario 3: Almost maximum (landslide hazards set to 9 out of 10)

Print Date: May 01, 2012

Totals only reflect data for those census tracts/blocks included in the user's study region.

Disclaimer:
The estimates of social and economic impacts contained in this report were produced using Hazus loss estimation methodology software which is based on current scientific and engineering knowledge. There are uncertainties inherent in any loss estimation technique. Therefore, there may be significant differences between the modeled results contained in this report and the actual social and economic losses following a specific earthquake. These results can be improved by using enhanced inventory, geotechnical, and observed ground motion data.

Table of Contents

General Description of the Region

Hazus is a regional earthquake loss estimation model that was developed by the Federal Emergency Management Agency and the National Institute of Building Sciences. The primary purpose of Hazus is to provide a methodology and software application to develop earthquake losses at a regional scale. These loss estimates would be used primarily by local, state and regional officials to plan and stimulate efforts to reduce risks from earthquakes and to prepare for emergency response and recovery.

The earthquake loss estimates provided in this report was based on a region that includes 2 county(ies) from the following state(s):

Oregon

Note:
Appendix A contains a complete listing of the counties contained in the region.

The geographical size of the region is 611.27 square miles and contains 2 census tracts. There are over 3 thousand households in the region which has a total population of 8,968 people (2002 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 4 thousand buildings in the region with a total building replacement value (excluding contents) of 598 (millions of dollars). Approximately 93.00 % of the buildings (and 84.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 1,290 and 274 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

Hazus estimates that there are 4 thousand buildings in the region which have an aggregate total replacement value of 598 (millions of dollars) . Appendix B provides a general distribution of the building value by State and County.

In terms of building construction types found in the region, wood frame construction makes up 67% of the building inventory. The remaining percentage is distributed between the other general building types.

Critical Facility Inventory

Hazus breaks critical facilities into two (2) groups: essential facilities and high potential loss facilities (HPL). Essential facilities include hospitals, medical clinics, schools, fire stations, police stations and emergency operations facilities. High potential loss facilities include dams, levees, military installations, nuclear power plants and hazardous material sites.

For essential facilities, there are 0 hospitals in the region with a total bed capacity of 0 beds. There are 6 schools, 3 fire stations, 1 police stations and 0 emergency operation facilities. With respect to high potential loss facilities (HPL), there are 1 dams identified within the region. Of these, 0 of the dams are classified as 'high hazard'. The inventory also includes 35 hazardous material sites, 0 military installations and 0 nuclear power plants.

Transportation and Utility Lifeline Inventory

Within Hazus, the lifeline inventory is divided between transportation and utility lifeline systems. There are seven (7) transportation systems that include highways, railways, light rail, bus, ports, ferry and airports. There are six (6) utility systems that include potable water, wastewater, natural gas, crude & refined oil, electric power and communications. The lifeline inventory data are provided in Tables 1 and 2.

The total value of the lifeline inventory is over 1,564.00 (millions of dollars). This inventory includes over 196 kilometers of highways, 19 bridges, 4,997 kilometers of pipes.

Table 1: Transportation System Lifeline Inventory

System	Component	# Locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	19	291.00
	Segments	13	892.90
	Tunnels	0	0.00
		Subtotal	**1,183.80**
Railways	Bridges	0	0.00
	Facilities	0	0.00
	Segments	31	91.80
	Tunnels	0	0.00
		Subtotal	**91.80**
Light Rail	Bridges	0	0.00
	Facilities	0	0.00
	Segments	0	0.00
	Tunnels	0	0.00
		Subtotal	**0.00**
Bus	Facilities	0	0.00
		Subtotal	**0.00**
Ferry	Facilities	1	1.30
		Subtotal	**1.30**
Port	Facilities	7	14.00
		Subtotal	**14.00**
Airport	Facilities	0	0.00
	Runways	0	0.00
		Subtotal	**0.00**
		Total	**1,291.00**

Table 2: Utility System Lifeline Inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	50.00
	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**50.00**
Waste Water	Distribution Lines	NA	30.00
	Facilities	2	150.50
	Pipelines	0	0.00
		Subtotal	**180.50**
Natural Gas	Distribution Lines	NA	20.00
	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**20.00**
Oil Systems	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**0.00**
Electrical Power	Facilities	1	124.30
		Subtotal	**124.30**
Communication	Facilities	0	0.00
		Subtotal	**0.00**
		Total	**374.80**

Earthquake Scenario

Hazus uses the following set of information to define the earthquake parameters used for the earthquake loss estimate provided in this report.

f

Type of Earthquake	Arbitrary
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-123.34
Latitude of Epicenter	46.12
Earthquake Magnitude	6.70
Depth (Km)	2.00
Rupture Length (Km)	25.59
Rupture Orientation (degrees)	150.00
Attenuation Function	West US, Extensional 2008 - Strike Slip

Building Damage

Building Damage

Hazus estimates that about 1,666 buildings will be at least moderately damaged. This is over 36.00 % of the buildings in the region. There are an estimated 181 buildings that will be damaged beyond repair. The definition of the 'damage states' is provided in Volume 1: Chapter 5 of the Hazus technical manual. Table 3 below summarizes the expected damage by general occupancy for the buildings in the region. Table 4 below summarizes the expected damage by general building type.

Table 3: Expected Building Damage by Occupancy

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Agriculture	8	0.45	5	0.47	5	0.64	5	0.71	2	0.92
Commercial	44	2.36	31	2.95	43	5.25	38	5.74	14	7.73
Education	2	0.12	2	0.16	2	0.26	2	0.31	1	0.42
Government	2	0.11	1	0.07	1	0.08	0	0.06	0	0.07
Industrial	26	1.39	15	1.41	20	2.47	17	2.56	6	3.33
Other Residential	480	25.87	346	32.91	419	50.75	352	53.38	100	54.93
Religion	3	0.16	3	0.26	4	0.44	3	0.53	1	0.70
Single Family	1,291	69.54	650	61.77	331	40.10	242	36.71	58	31.90
Total	**1,856**		**1,053**		**826**		**659**		**182**	

Table 4: Expected Building Damage by Building Type (All Design Levels)

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	1,483	79.88	785	74.60	409	49.56	300	45.51	71	38.95
Steel	22	1.20	13	1.27	26	3.16	25	3.78	10	5.45
Concrete	22	1.20	15	1.47	22	2.66	21	3.17	7	3.68
Precast	17	0.90	9	0.82	15	1.84	16	2.40	6	3.04
RM	3	0.15	1	0.10	2	0.22	2	0.31	1	0.30
URM	31	1.66	26	2.47	37	4.45	34	5.10	16	8.58
MH	279	15.02	203	19.26	315	38.11	262	39.72	73	39.99
Total	**1,856**		**1,053**		**826**		**659**		**182**	

*Note:
RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Essential Facility Damage

Before the earthquake, the region had 0 hospital beds available for use. On the day of the earthquake, the model estimates that only 0 hospital beds (0.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 0.00% of the beds will be back in service. By 30 days, 0.00% will be operational.

Table 5: Expected Damage to Essential Facilities

		# Facilities		
Classification	**Total**	**At Least Moderate Damage > 50%**	**Complete Damage > 50%**	**With Functionality > 50% on day 1**
Hospitals	0	0	0	0
Schools	6	1	0	3
EOCs	0	0	0	0
PoliceStations	1	0	0	0
FireStations	3	0	0	2

Transportation and Utility Lifeline Damage

Table 6 provides damage estimates for the transportation system.

Table 6: Expected Damage to the Transportation Systems

System	Component	Number of Locations				
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 %	
					After Day 1	After Day 7
Highway	Segments	13	0	0	13	13
	Bridges	19	1	0	18	18
	Tunnels	0	0	0	0	0
Railways	Segments	31	0	0	31	31
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Light Rail	Segments	0	0	0	0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	0	0	0	0	0
Ferry	Facilities	1	1	0	1	1
Port	Facilities	7	5	0	6	7
Airport	Facilities	0	0	0	0	0
	Runways	0	0	0	0	0

Note: Roadway segments, railroad tracks and light rail tracks are assumed to be damaged by ground failure only. If ground failure maps are not provided, damage estimates to these components will not be computed.

Tables 7-9 provide information on the damage to the utility lifeline systems. Table 7 provides damage to the utility system facilities. Table 8 provides estimates on the number of leaks and breaks by the pipelines of the utility systems. For electric power and potable water, Hazus performs a simplified system performance analysis. Table 9 provides a summary of the system performance information.

Table 7 : Expected Utility System Facility Damage

System	# of Locations				
	Total #	With at Least Moderate Damage	With Complete Damage	with Functionality > 50 %	
				After Day 1	After Day 7
Potable Water	0	0	0	0	0
Waste Water	2	2	0	0	2
Natural Gas	0	0	0	0	0
Oil Systems	0	0	0	0	0
Electrical Power	1	0	0	0	1
Communication	0	0	0	0	0

Table 8 : Expected Utility System Pipeline Damage (Site Specific)

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	2,499	236	59
Waste Water	1,499	119	30
Natural Gas	999	41	10
Oil	0	0	0

Table 9: Expected Potable Water and Electric Power System Performance

	Total # of Households	Number of Households without Service				
		At Day 1	At Day 3	At Day 7	At Day 30	At Day 90
Potable Water	3,452	75	0	0	0	0
Electric Power		0	0	0	0	0

Induced Earthquake Damage

Fire Following Earthquake

Fires often occur after an earthquake. Because of the number of fires and the lack of water to fight the fires, they can often burn out of control. Hazus uses a Monte Carlo simulation model to estimate the number of ignitions and the amount of burnt area. For this scenario, the model estimates that there will be 0 ignitions that will burn about 0.00 sq. mi 0.00 % of the region's total area.) The model also estimates that the fires will displace about 0 people and burn about 0 (millions of dollars) of building value.

Debris Generation

Hazus estimates the amount of debris that will be generated by the earthquake. The model breaks the debris into two general categories: a) Brick/Wood and b) Reinforced Concrete/Steel. This distinction is made because of the different types of material handling equipment required to handle the debris.

The model estimates that a total of 0.03 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 50.00% of the total, with the remainder being Reinforced Concrete/Steel. If the debris tonnage is converted to an estimated number of truckloads, it will require 1,240 truckloads (@25 tons/truck) to remove the debris generated by the earthquake.

Social Impact

Shelter Requirement

Hazus estimates the number of households that are expected to be displaced from their homes due to the earthquake and the number of displaced people that will require accommodations in temporary public shelters. The model estimates 111 households to be displaced due to the earthquake. Of these, 71 people (out of a total population of 8,968) will seek temporary shelter in public shelters.

Casualties

Hazus estimates the number of people that will be injured and killed by the earthquake. The casualties are broken down into four (4) severity levels that describe the extent of the injuries. The levels are described as follows;

· Severity Level 1: Injuries will require medical attention but hospitalization is not needed.
· Severity Level 2: Injuries will require hospitalization but are not considered life-threatening
· Severity Level 3: Injuries will require hospitalization and can become life threatening if not promptly treated.
· Severity Level 4: Victims are killed by the earthquake.

The casualty estimates are provided for three (3) times of day: 2:00 AM, 2:00 PM and 5:00 PM. These times represent the periods of the day that different sectors of the community are at their peak occupancy loads. The 2:00 AM estimate considers that the residential occupancy load is maximum, the 2:00 PM estimate considers that the educational, commercial and industrial sector loads are maximum and 5:00 PM represents peak commute time.

Table 10 provides a summary of the casualties estimated for this earthquake

Table 10: Casualty Estimates

		Level 1	Level 2	Level 3	Level 4
2 AM	Commercial	0	0	0	0
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	0	0	0	0
	Industrial	0	0	0	0
	Other-Residential	15	3	0	0
	Single Family	19	3	0	0
	Total	**34**	**6**	**0**	**1**
2 PM	Commercial	12	3	0	1
	Commuting	0	0	0	0
	Educational	7	2	0	1
	Hotels	0	0	0	0
	Industrial	2	0	0	0
	Other-Residential	3	1	0	0
	Single Family	5	1	0	0
	Total	**29**	**7**	**1**	**2**
5 PM	Commercial	12	3	1	1
	Commuting	1	1	1	0
	Educational	0	0	0	0
	Hotels	0	0	0	0
	Industrial	1	0	0	0
	Other-Residential	5	1	0	0
	Single Family	7	1	0	0
	Total	**27**	**7**	**2**	**2**

Economic Loss

The total economic loss estimated for the earthquake is 210.70 (millions of dollars), which includes building and lifeline related losses based on the region's available inventory. The following three sections provide more detailed information about these losses.

Building-Related Losses

The building losses are broken into two categories: direct building losses and business interruption losses. The direct building losses are the estimated costs to repair or replace the damage caused to the building and its contents. The business interruption losses are the losses associated with inability to operate a business because of the damage sustained during the earthquake. Business interruption losses also include the temporary living expenses for those people displaced from their homes because of the earthquake.

The total building-related losses were 102.80 (millions of dollars); 17 % of the estimated losses were related to the business interruption of the region. By far, the largest loss was sustained by the residential occupancies which made up over 71 % of the total loss. Table 11 below provides a summary of the losses associated with the building damage.

Table 11: Building-Related Economic Loss Estimates

(Millions of dollars)

Category	Area	Single Family	Other Residential	Commercial	Industrial	Others	Total
Income Losses							
	Wage	0.00	0.30	2.36	0.11	0.13	2.90
	Capital-Related	0.00	0.13	2.34	0.07	0.05	2.59
	Rental	1.42	0.68	0.99	0.03	0.06	3.17
	Relocation	5.02	1.72	1.46	0.13	0.69	9.02
	Subtotal	**6.44**	**2.82**	**7.15**	**0.34**	**0.93**	**17.68**
Capital Stock Losses							
	Structural	9.38	2.19	2.52	0.51	0.92	15.52
	Non_Structural	32.72	7.86	7.30	1.78	2.41	52.07
	Content	9.54	1.61	3.55	1.18	1.20	17.09
	Inventory	0.00	0.00	0.14	0.28	0.03	0.45
	Subtotal	**51.64**	**11.67**	**13.51**	**3.74**	**4.57**	**85.12**
	Total	**58.08**	**14.49**	**20.66**	**4.07**	**5.49**	**102.80**

Transportation and Utility Lifeline Losses

For the transportation and utility lifeline systems, Hazus computes the direct repair cost for each component only. There are no losses computed by Hazus for business interruption due to lifeline outages. Tables 12 & 13 provide a detailed breakdown in the expected lifeline losses.

Hazus estimates the long-term economic impacts to the region for 15 years after the earthquake. The model quantifies this information in terms of income and employment changes within the region. Table 14 presents the results of the region for the given earthquake.

Table 12: Transportation System Economic Losses
(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Highway	Segments	892.86	$32.85	3.68
	Bridges	290.98	$10.65	3.66
	Tunnels	0.00	$0.00	0.00
	Subtotal	**1183.80**	**43.50**	
Railways	Segments	91.85	$1.33	1.45
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**91.80**	**1.30**	
Light Rail	Segments	0.00	$0.00	0.00
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Bus	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Ferry	Facilities	1.33	$0.62	46.67
	Subtotal	**1.30**	**0.60**	
Port	Facilities	13.98	$5.16	36.90
	Subtotal	**14.00**	**5.20**	
Airport	Facilities	0.00	$0.00	0.00
	Runways	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
	Total	**1291.00**	**50.60**	

Table 13: Utility System Economic Losses
(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Potable Water	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Distribution Lines	50.00	$1.06	2.13
	Subtotal	**49.97**	**$1.06**	
Waste Water	Pipelines	0.00	$0.00	0.00
	Facilities	150.50	$43.96	29.21
	Distribution Lines	30.00	$0.53	1.78
	Subtotal	**180.50**	**$44.50**	
Natural Gas	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Distribution Lines	20.00	$0.18	0.92
	Subtotal	**19.99**	**$0.18**	
Oil Systems	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**$0.00**	
Electrical Power	Facilities	124.30	$11.54	9.28
	Subtotal	**124.30**	**$11.54**	
Communication	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**$0.00**	
	Total	**374.76**	**$57.28**	

Table 14. Indirect Economic Impact with outside aid
(Employment as # of people and Income in millions of $)

LOSS		Total	%

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Appendix A: County Listing for the Region

Clatsop,OR

Columbia,OR

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Oregon					
	Clatsop	2,973	161	26	188
	Columbia	5,995	341	69	410
Total State		**8,968**	**502**	**95**	**598**
Total Region		**8,968**	**502**	**95**	**598**

APPENDIX D: ASSETS IN THE STUDY AREA EXPOSED TO LANDSLIDE HAZARDS

	Arterial Road (mi)	Highway and Interstate (mi)	Road Bridge (Count)	Electric Transmission Line (mi)	Electric Transmission Towers (Count)	Electric Substations (Count)	Railroad Line (mi)	Railroad Bridge (Count)
Existing landslides	60.4	3.7	1	24.3	127	2	1	1
Existing debris flow fans	4.7	1.4	2	0.2	1	0	1.2	1
Moderate susceptibility to shallow landslides	162.4	19.3	16	16.5	117	2	14.6	9
High susceptibility to shallow landslides	9.4	0.2	4	13.4	31	2	2.8	0
Moderate susceptibility to deep landslides	32.2	7.8	8	3.4	14	0	5.1	6
High susceptibility to deep landslides	78	6.8	1	26.6	143	2	1.1	1

	Residential Parcels			Commercial Parcels			Public Parcels		
	Count	Area (mi^2)	Value ($)	Count	Area (mi^2)	Value ($)	Count	Area (mi^2)	Value ($)
Existing landslides	719	3.0	28,201,449	236	13.5	17,445,676	61	3.0	1,584,315
Existing debris flow fans	215	0.5	4,974,194	103	0.3	1,429,374	18	0.0	120,958
Moderate susceptibility to shallow landslides	1667	3.6	35,217,124	681	19.8	38,602,197	184	3.0	2,499,717
High susceptibility to shallow landslides	1390	1.5	10,716,196	624	9.7	12,761,918	161	2.2	1,109,793
Moderate susceptibility to deep landslides	371	1.1	9,368,141	252	10.5	18,477,833	49	1.4	625,428
High susceptibility to deep landslides	730	3.3	29,013,674	251	17.4	21,047,838	65	3.5	1,922,837