Powell Lake Historical Landslide Inventory

Progress Report

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Forest Investment Account

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Submitted by:

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Introduction

The Powell Lake landslide inventory was carried out as part of a larger landslide hazard mapping project being conducted in TFL 39 and TFL 44. The project includes similar inventories in a number of selected watersheds on Vancouver Island, the Southern Coast Mountains and the Queen Charlotte Islands. The objective of the project is to upgrade the quality of existing terrain and landslide hazard maps in use by Cascadia. The study will attempt to integrate landslide inventories with new or upgraded terrain maps to generate semi-quantitative or “geo-statistically” derived landslide hazard maps to replace or supplement existing, qualitatively derived, five-class terrain stability maps (see D. Maynard and Associates Ltd./Golder Associates Ltd., 2003 and Rollerson, et. al 2005 , for an examples and a discussion of this approach).

The landslide inventories carried out as part of the landslide hazard mapping projects may provide a tool for testing the predictive accuracy of the existing, qualitative terrain stability maps. In the longer term, the intent is to integrate these landslide inventories into coastal watershed assessment projects. The current landslide inventory once the landslide locations are transferred to a GIS base map can also be used as a simple stand-alone landslide hazard map to identify areas where both natural and management-related landslides have occurred in the past and may occur in the future. Landslide inventory maps of this type are commonly used as landslide hazard maps in many parts of the world (see Van Dine, Hungr and Gerath, 1996; Turner and Schuster, 1996).

Study Area

The 2005-06 fiscal year study area comprises a significant portion of the Powell Lake watershed. Powell Lake is located immediately north and northeast of the town of Powell River, B.C. Landslides in the Eldred River basin which drains into the east side of Powell Lake will be added to the inventory in the coming fiscal year.

The study area lies within the Pacific Ranges of the Southern Coast Mountains. Topography is rugged, with elevations ranging from about 50 m above sea level to about 2000 m over distances of tens of kilometers.

Bedrock consists of intrusive rocks of the Coast Plutonic Complex (granodiorite and quartz diorite), rocks from the lower Cretaceous Gambier Group (greenstone, volcanic breccia, argillite, minor conglomerate, limestone and schist) as well as rocks from the upper Triassic Karmutsen group. The upper reaches of the study area are underlain by granitoid gneiss, amphibolite and schist that are Paleozoic in age or older.

Coast Plutonic Complex bedrock accounts for the majority of bedrock found in the watershed. Rocks from this formation are typically diorite and quartz diorite and are coarse-textured (individual crystals are clearly visible to the naked eye), resulting in their breaking down into a predominantly sandy residue which has been incorporated into the local surficial materials. These rocks are sparsely jointed and hard; consequently, they are very strong. This latter characteristic, combined with high resistance to weathering and erosion, results in steep, relatively stable valley sides. Blocky talus slopes, bouldery glacial deposits, especially till, and bouldery stream gravels are characteristic of this area.

Rocks of the Gambier Group are the second most abundant rock type in the watershed. They are found along the east side of Powell Lake from MacMillan Creek south to Goat Island. They consist of metavolcanics (mainly greenstone). They are fine-textured and weather to a combination of gravel, sand, and silt. Till derived from these rocks, therefore, tends to have a matrix that is finer than that of the tills associated with the intrusive rocks. Typically, these volcanic rocks are more closely jointed than intrusive rocks and are usually considered weaker and more susceptible to erosion. Rocks of the Triassic Karmutsen group are the least abundant in the watershed. A small deposit is situated near the headwaters of MacMillan creek. They typically consist of pillowed, brecciated and tholeiitic lavas.

As a result of intense glacial erosion, the main valleys are deeply scoured, classic U-shaped glacial valleys that slope gently into the major trough of the Strait of Georgia. Topography is bedrock-controlled, and surficial materials are thin on the mid to upper slopes. Thick glaciofluvial deposits are present at the mouths of a number of tributary valleys.

The dominant mass movement processes in the study area are debris avalanches, debris flows and snow avalanches on open slopes, snow avalanches and debris flows confined to steep gullies and rock fall and rockslides from sheer valley sides composed of intrusive and metamorphic rocks. Colluvial cones and fans are found at the base of most snow avalanche tracks. Blocky talus slopes are common in the alpine and subalpine areas and at the base of steep walled valley sides.

Climate

The main biogeoclimatic zone which encompasses this area is the Coastal Western Hemlock (CWH) zone. The project area includes the CWH Very Wet Hypermaritime subzone throughout and Alpine Tundra in the higher elevation areas upslope of the Mountain Hemlock biogeoclimatic zone. The CWH Dry Maritime subzone is found on the lower slopes around Powell Lake. The CWH zone has a moist, cool climate with abundant rainfall. It is characteristically the wettest and most productive forest zone in British Columbia. Rain on snow events are common in the elevation band between 300 m and 800 metres. The average annual precipitation at nearby Powell River Airport for the period 1961-1990 was 1,233 mm with the highest precipitation occurring between October and March. The maximum recorded 24-hour precipitation at the Airport over the same period was 80 mm.

Landslide Inventory

Methods and Limitations

The historical air photo review involved stereoscopic inspection of a series of five sets of air photos dating back to 1961 (see Appendix D). The air photo years reviewed included 1961, 1962, 1979, 1988, 1995 and 2001. The air photo scales ranged from approximately 1:15,000 to 1:20,000 for the air photo years 1962 through 1994. The 2001 air photos have a scale of approximately 1:30,000. Landslide locations were marked and numbered on the air photos beginning with the oldest air photos first and progressing to the more recent air photos. The numbering sequence has some anomalies because smaller landslides or landslides hidden by shadows or forest cover were missed on early air photos but were identified on later air photos and then plotted on the original air photos. A moderate amount of cross-referencing was necessary among air photos of different years to ensure that individual landslide locations were only recorded once.

The true world x and y coordinates (Albers coordinate system) of landslides identified on these air photos were determined using a digital orthophoto image developed from the 2001 air photos and MrSID GeoViewer 2.1 software (©Lizardtech Inc. & International Land Systems Inc.). The coordinates of the landslides located on the orthophoto are tabulated in Appendix D. The numbers noted beside each landslide number indicate the x and y coordinates of the landslide, the number of the air photo on which the landslide was first located, and the date of the air photo. The air photo year represents the minimum age for each landslide, but many landslides will have occurred several years before the air photo date. Also tabulated in Appendix D for each landslide are the land use, generalized landform present at the apparent landslide initiation point, a characterization of the terminus or runout zone of the landslide, the presence or absence of forest cover on the landslide track, and the watershed or sub-basin within which the landslide occurred.

Landslide scars in this area often re-vegetate rapidly, and the air photo record has some moderately long gaps; therefore, not every landslide, especially smaller events that occurred in standing timber, will have been identified. Very small features that could not be identified with certainty on the air photos were not recorded as landslides; however, it is likely that in a number of cases, these features were actually small debris slides. Similar limitations of landslide inventories based on air photos have been identified in other studies (e.g., Robertson, et al., 1999). Likewise, it is not possible to tell in most cases if a landslide scar represents more that one event (i.e., that there has been more than one landslide event at a particular location within the period of record).

A number of situations were visible on the air photos where small stream channels on hillslopes or fans appear to have destabilized after logging, stream cleaning or severe rainstorm events. It is possible that a few of these situations may represent debris flows that initiated as a result of channel bed mobilization; but, as there is no way of distinguishing this fact on air photos, these situations were not recorded as landslide events. Similarly, there may be a very limited number of cases where features that were interpreted and recorded as debris flows were actually stream channel destabilization features.

In general, we did not tabulate very small landslides and areas of chronic rockfall in subalpine and alpine areas as it is unlikely that forest practices will directly affect these areas. Similarly, several large rockslides in alpine areas that generated fresh-looking blocky deposits on valley floors were not counted. These landslides will be documented on the terrain map.

The air photo review represents landslides that likely occurred between the mid to late 1950's (i.e., landslides visible on the 1962 air photos) and the summer of 2001. A few of the identified landslides, mainly well-forested natural landslides and some rockslides, likely occurred prior to 1900. Landslides that have occurred since 2001 will be identified and tabulated from operational records maintained by the Stillwater operation of Cascadia. This tabulation will occur as a later phase of the project once terrain mapping has been completed. The terrain mapping phase of the project is expected to take at least two years. This approach ensures that all landslides are accounted for in the final analysis and development of landslide hazard maps.

Plotting Accuracy for Landslide Locations

Very accurate locations of the top (headscarp) of landslide scars visible on air photos can be determined with the MrSID GeoViewer when landslides are visible as either a non-vegetated or forested scar on the 2001 digital orthophoto image. The GeoViewer displays x and y coordinates to the nearest meter. These coordinates are copied directly from the GeoViewer screen to an Excel data file, effectively eliminating data compilation and map plotting errors for landslide coordinates. (These x and y coordinates are used to generate "dot" maps of landslide initiation locations.) A magnification feature on the GeoViewer allows smaller but distinctive landslide scars to be accurately located. Moderately accurate landslide locations (within a few tens of meters) can be determined when a landslide scar is not clearly visible but is located on a distinct geomorphic feature; for example, steep escarpments at river bends, distinct gully headwalls, sharp gully bends and road bends or intersections. Landslides are most difficult to locate on the 2001 orthophoto image when they are small, older, well-vegetated features occurring on uniform or irregular open (planar, convex or concave) slopes. In these cases it is necessary to interpret locations based on nearby and distinctive landscape features. Other factors complicating accurate landslide location in these situations include distortion on the original air photos being examined and abrupt changes in photo tone or shadows on the orthophoto mosaic. Changes in forest cover patterns due to logging also complicate the location of smaller, vegetated landslide features. In some cases smaller landslides that are quite visible early in the air photo record in clearcut areas are difficult to locate with precision on the 2001 digital orthophoto because of rapid tree growth and crown closure in older plantations. The most recent photos (2001) were of moderate quality. The central 2 or 3 lines had areas of apparent lens condensation or "fogging" in the photo centres making it difficult to make a perfectly clear observation of the landscape. This "fogging" may have reduced the accuracy of some of the GeoViewer coordinate locations for the tabulated landslides. There are significant concentrations of shadows in the north half of the map area on some air photos, often in areas where snow avalanching and steep slopes are common. It is possible that these shadows prevented the identification of some landslides, particularly on the 2001 air photos.

Data Analysis

Graphical and tabular analysis of the landslide inventory data was carried out to characterize the land use and general landforms associated with landslide initiation, characteristics of depositional areas, and landslide types within the project area. A selected set of graphs and tables are presented in Appendices A and B, and the results of the graphical and tabular analysis are summarized below.

Results and Discussion

The landslide inventory is dominated by a large number of natural landslides that were identified on the 1961 and 1962 air photography (Figures A1a and A1b; Table B1). Landslides identified on the 1962 air photos account for approximately 46 percent of all the air photo visible landslides in the study area. A number of these likely occurred in the 1950's or earlier but were first observed on the 1961 and 1962 air photos. While the frequency of natural landslides exceeds that of landslides from roads and harvest areas on the 1962 air photos it is quite apparent that the trend is reversed in later years as roads and logging advanced into the watershed. Logging and road-building had progressed only a short distance beyond the margins of Powell Lake and the lower reaches of the Powell Lake by 1962, but after that time roads and logging began to penetrate much further into the watershed. Even though harvesting and roads now occupy many of the lower and mid-valley slopes, there are still large areas of natural forest and alpine in the watershed, suggesting that in general the unit area landslide rates are greater in logged than natural areas.

It is possible that there were one or more large magnitude precipitation events sometime between 1962 and 1979 (see Figures A1a and A1b). There were a moderate number of large (>10,000 m^2) natural landslides (primarily debris flows traveling from upper and mid-slopes to toe slopes) as well as numerous smaller landslides. These landslides are clearly visible on the 1979 air photos, but not the 1962 air photos and show as a distinct peak in Figures A1a and A1b. For whatever reason, the ratio of larger landslides to intermediate sized landslides seems to have been greater for the landslides identified on the 1979 photography (Figure A2; Table B3). The landslide size distribution patterns are quite variable from year to year, possibly influenced in part by year-to-year variations in the locations of logging and road-building in the landscape.

The air photo review identified 81 landslides initiating at logging roads and landings, and 60 landslides initiating in recently harvested areas. There are a total of 881 natural landslides (Figure A1b; Table B1), the majority of which were identified on the 1961 and 1962 air photos.

The landslides identified within the study area start in a variety of morphological settings or landforms (Figure A3; Table B2). The largest number occurred on planar or convex open slopes (53%); a moderate number (41%) occurred in gullies (gully headwalls, 13%; gully sidewalls, 23%, gully channels, 5%). About one percent of the landslides occur along stream escarpments or on scarps along the lower reaches of large gentle gradient gullies. As open slopes occupy a much larger percentage of the landscape than the other features noted above, it seems reasonable to conclude that in the Powell Lake watershed like many other areas, gully headwalls and sidewalls, and stream escarpments are the areas with the highest rates of landslide activity.

There were a large number of environments in the runout or terminal zone of the landslides identified within the study area (Figure A4; Table B2). These environments range from upper, mid and lower slopes through gully channels to fans, tributary streams and mainstem river channels. Approximately twelve percent of the landslides stop in tributary streams or mainstem stream channels. Thirty percent of the landslides stop in gully channels that may or may not have a direct connection to streams. A few gullies lead directly into smaller and some larger streams that are contained within large, valley-floor gullies or inner gorges. That is, there is no intervening fan that separates the gully from the valley-floor stream. In these cases, landslides and/or sediment and woody debris can be routed directly into the stream system rather than depositing on a fan surface. About three percent of the landslides stopped partially on terrestrial surfaces (fans and floodplains) and partially in streams. Nine percent of the landslides appeared to stop on fan surfaces or in the lower reaches of gully channels and on fan surfaces. Seven percent of the landslides reached or entered lakes. The remaining landslides were split between thirty percent that stopped on upper, mid, and lower or toe slopes; three percent that stopped on floodplains or glaciofluvial terraces; and, four percent that stopped on roads. The roads that stopped landslides were generally in the lower portions of the landscape; for example, lower mid slopes and/or toe slopes.

The landslides present in the study area are dominated by debris slide–debris flows or debris flows (60% of all events). These include both channelized events that travel down confined gully channels and landslides that traverse open slopes. The next most frequent landslides are debris slides. These account for about thirteen percent of all landslides. Debris slides occurred over a wide range of environments ranging from open slopes to river and stream escarpments and gully sidewalls. Most debris flows appear to initiate as small debris slides that quickly metamorphose into debris flows. Debris avalanche-debris flows account for eight percent of the total. About eighteen percent of the landslides identified are rockslides or rockfall–rockslides and composite rockslide–debris slides or rockslide–debris flows that are scattered throughout the watershed, generally in steep, upper slope areas.

The size distribution of debris slides is skewed toward the smaller size classes (Table B4). Debris flows on open slopes traveled intermediate distances with debris flows that entered gully systems tending to travel longer distances. The size distribution of debris flows and debris slide–debris flows tends to be more uniformly distributed than that of debris slides but is still dominated by the smaller size classes. The various types of rockslide and rockslide–debris slide combinations tend to be well distributed across the range of size classes, but the size distribution of complex rockslide–debris slide–debris flows tends to be skewed towards the larger size classes.

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Appendix A
Graphical Analysis

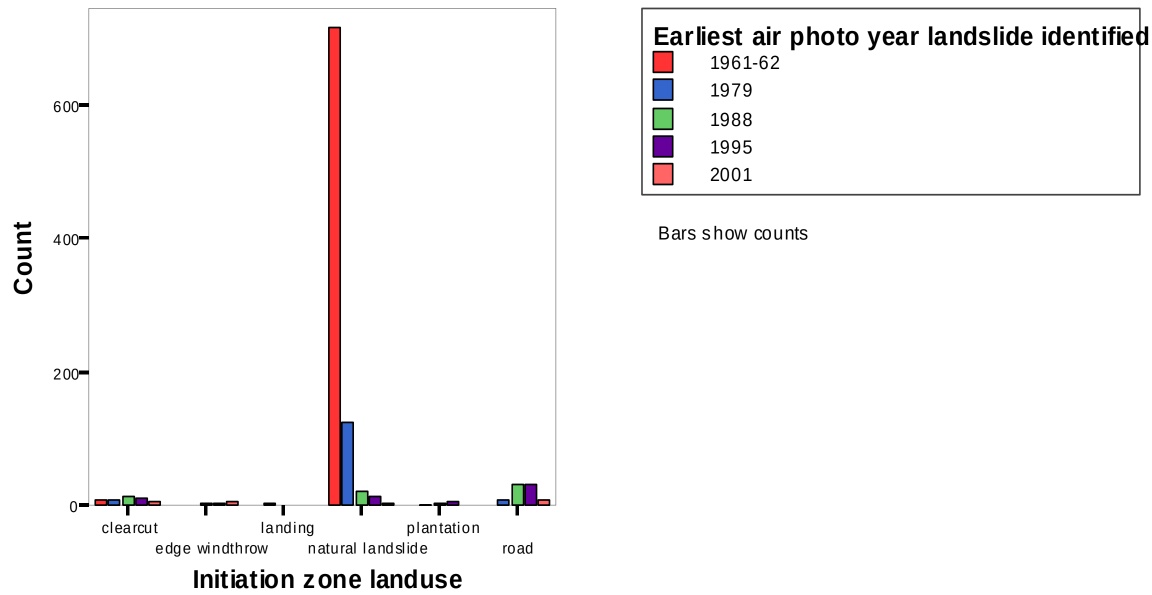

Figure A1a. Landslide distribution by air photo year and land use.

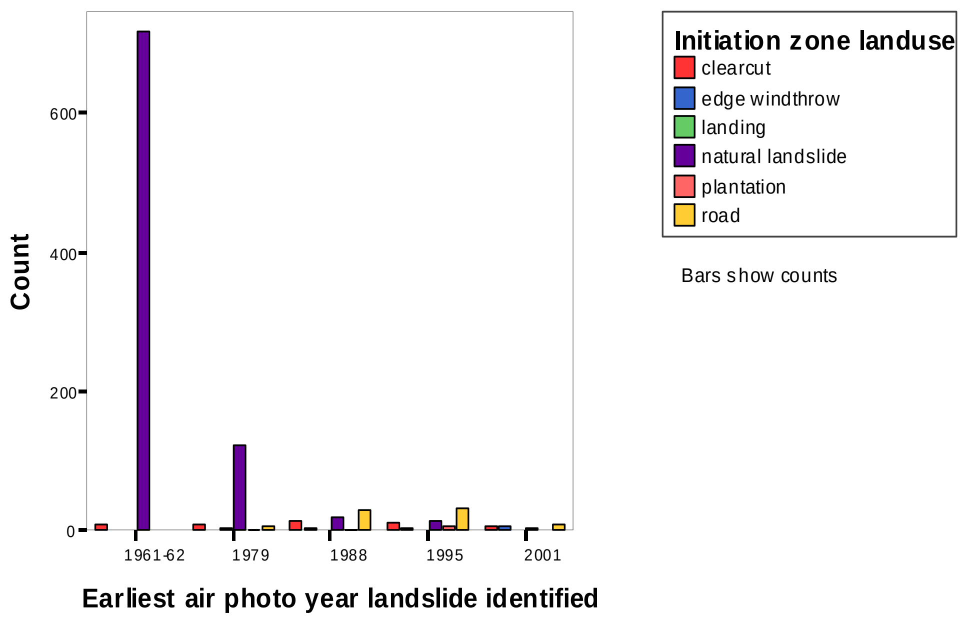

Figure A1b. Landslide distribution by land use and year.

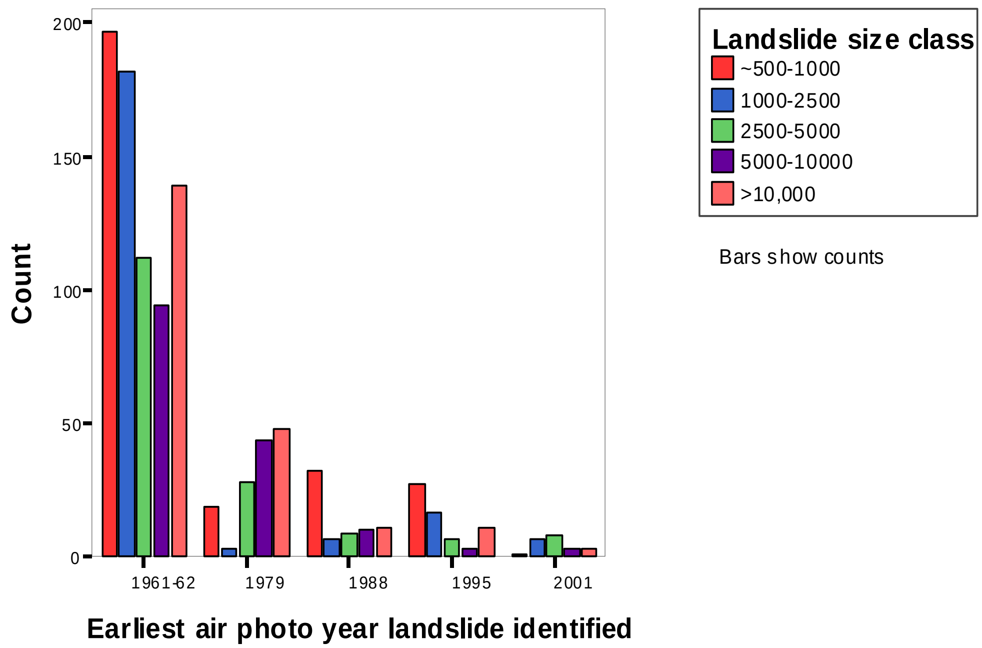

Figure A2. Landslide size distributions by air photo year.

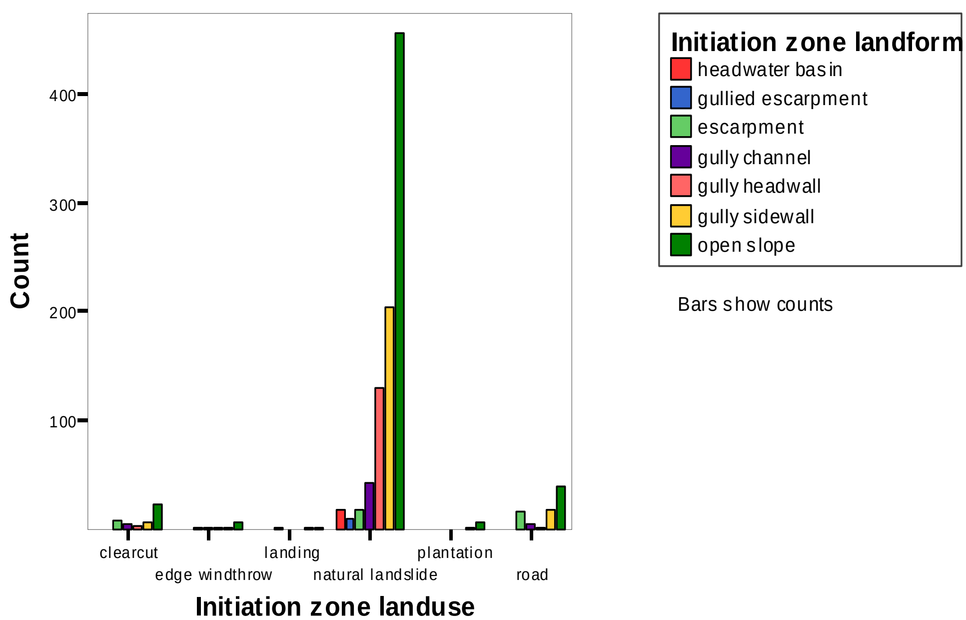

Figure A3. Distribution by landform and land use at the initiation zone of each landslide.

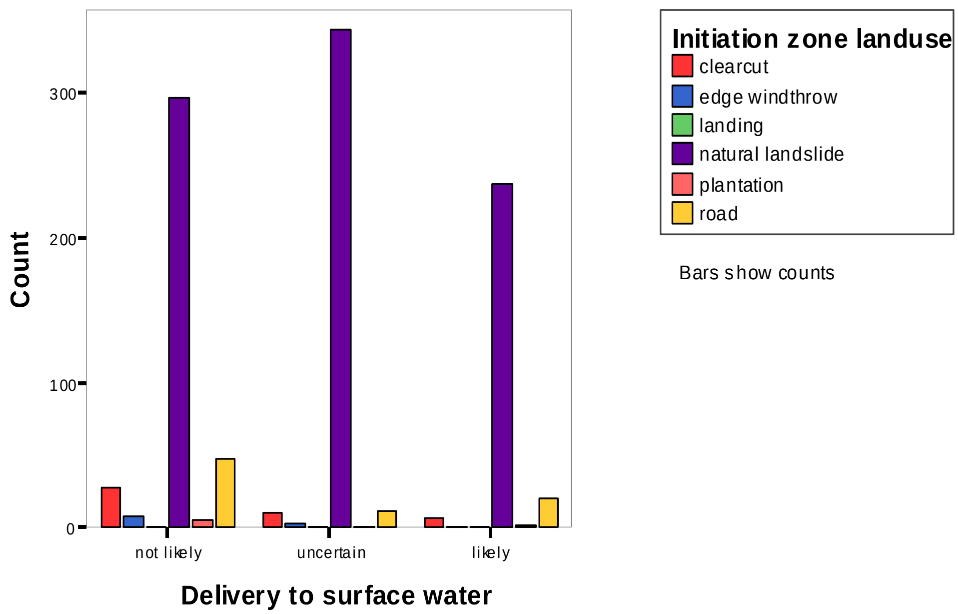

Figure A4. Landslide distributions by delivery versus landuse.

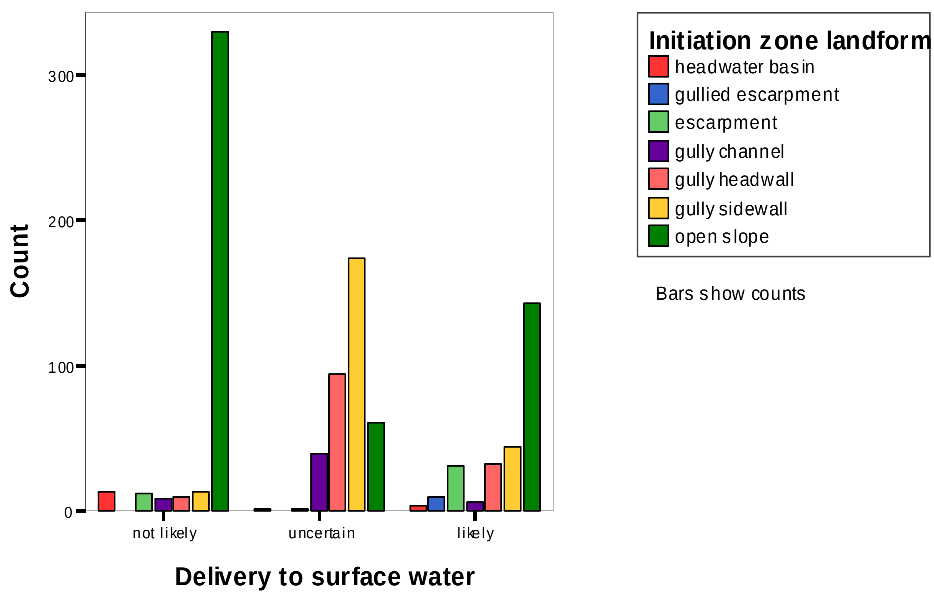

Figure A5. Landslide distributions by delivery versus landform.

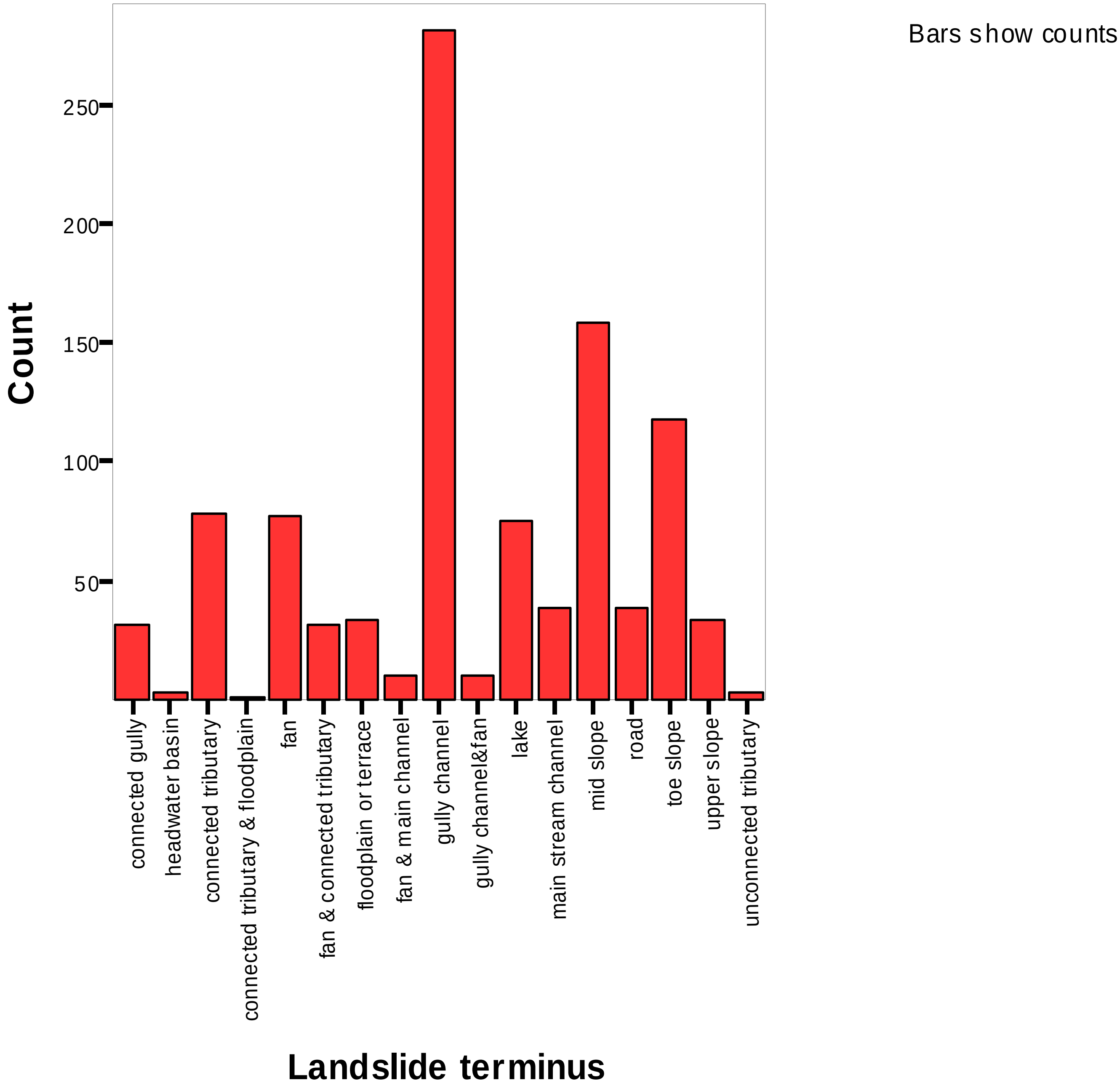

Figure A6. Landslide distributions by terminus.

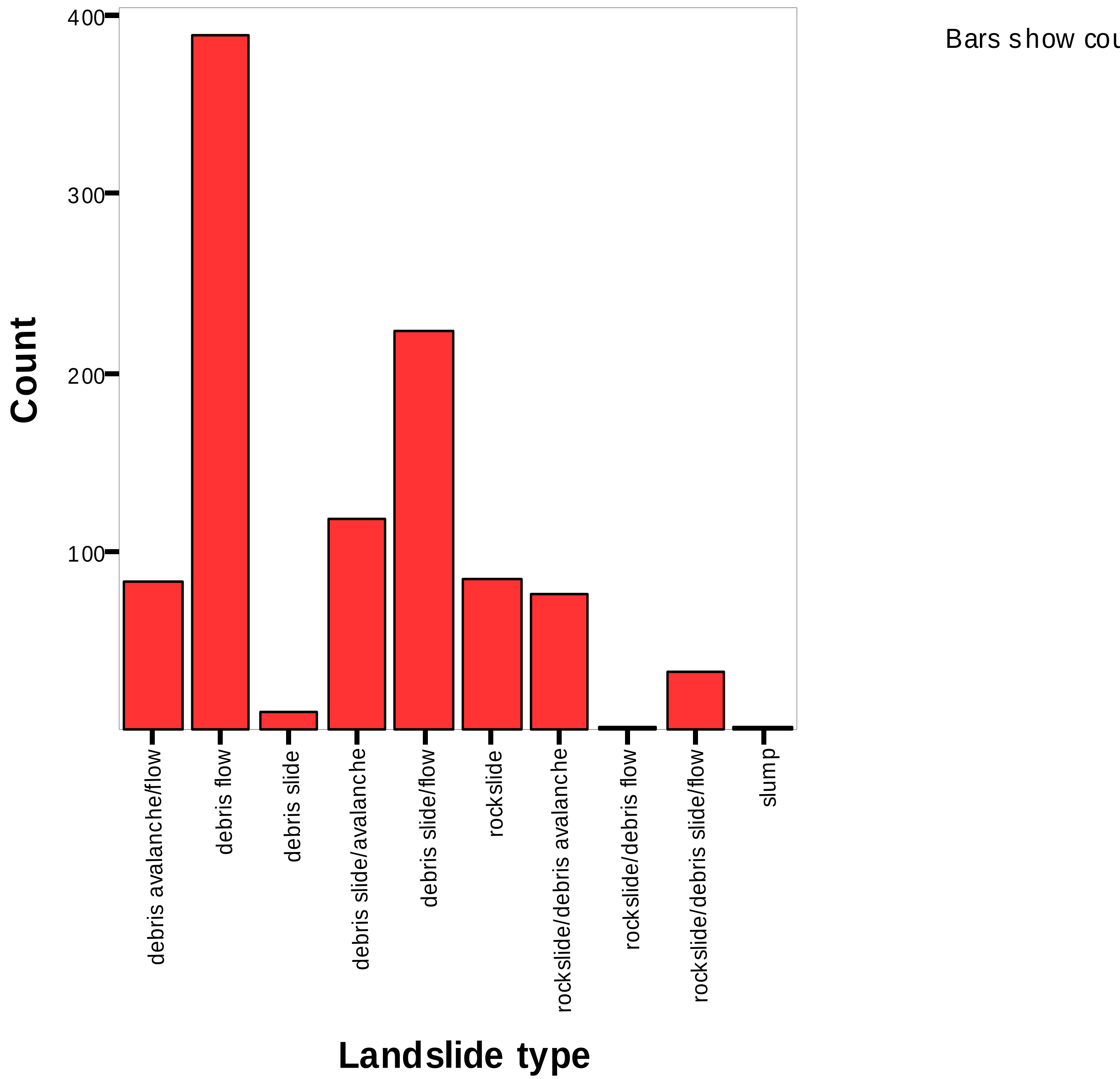

Figure A7. Landslide distributions by landslide type by count.

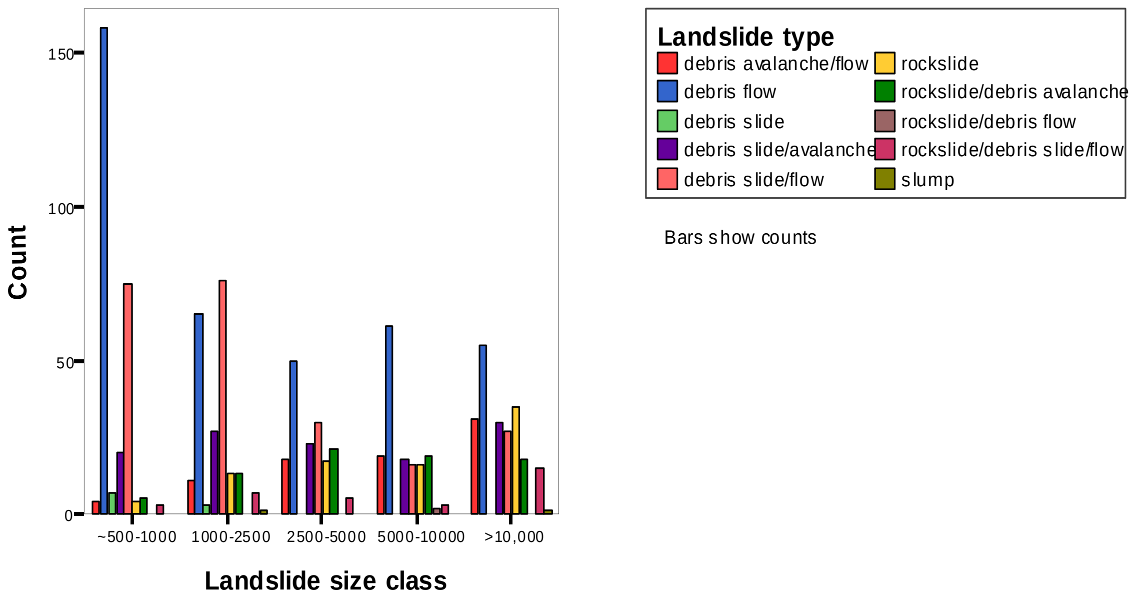

Figure A8. Landslide distributions by landslide type and size class.

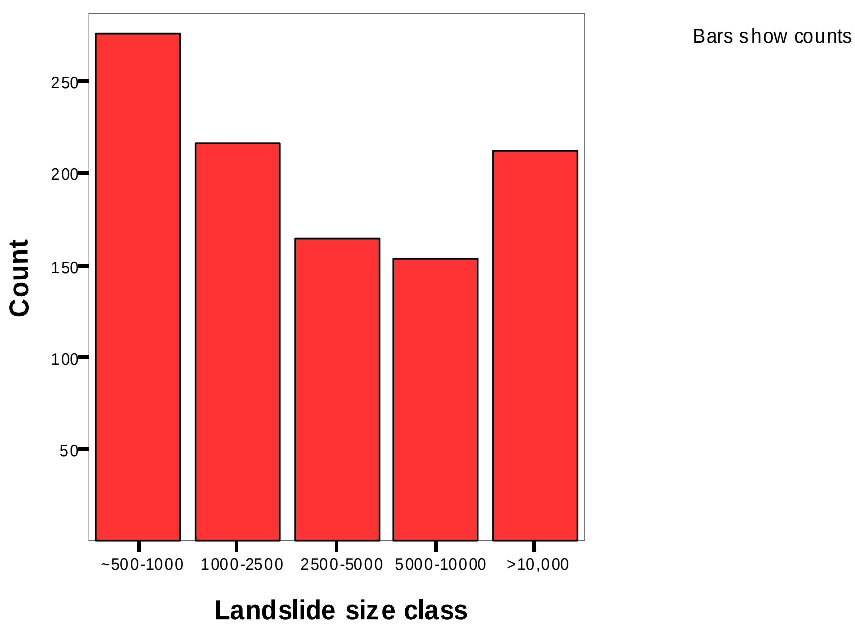

Figure A9. Landslide distributions by size class (square meters).

Appendix B
Summary Tables

Table B1. Landslide distributions by air photo year and land use category.

General land use category	Air photo year	N	% of Total N
Harvest	1962	3	5%
	1979	9	15%
	1988	19	32%
	1995	19	32%
	2001	10	17%
	Total landslides	60	100%
Natural	1962	470	53%
	1979	373	42%
	1988	20	2%
	1995	15	2%
	2001	3	0%
	Total landslides	881	100%
Road	1962	0	0%
	1979	10	12%
	1988	30	37%
	1995	32	40%
	2001	9	11%
	Total landslides	81	100%
Total landslides	1962	473	46%
	1979	392	38%
	1988	69	7%
	1995	66	6%
	2001	22	2%
	Total landslides	1022	100%

Table B2. Landslide distribution summary statistics.

Attribute	N	% of Total N
Landform at initiation point		
escarpment	44	4%
gully channel	53	5%
gully headwall	135	13%
gully sidewall	231	23%
open slope	533	52%
gullied escarpment	9	1%
concave headwater basin	17	2%
Total	1022	100%
Terminus type		
connected gully channel	32	3%
connected tributary	78	8%
fan	77	8%
fan/connected tributary	31	3%
Floodplain, glaciofluvial terrace or valley flat	34	3%
gully channel	280	27%
gully channel fan	10	1%
lake	75	7%
main channel	35	3%
mid slope	158	15%
road	39	4%
toe slope	118	12%
upper slope	34	3%
unconnected tributary	3	0%
concave headwater drainage	3	0%
connected tributary/floodplain	1	0%
fan and main channel	10	1%
inner gorge	0	0%
toe slope/main channel	4	0%
Total	1022	100%

Table B2. Landslide distribution summary statistics (continued).

Landslide type		
debris flow	389	38%
debris slide-debris flow	224	22%
debris avalanche-debris flow	83	8%
debris slide-debris avalanche	128	13%
rock slide-debris avalanche	76	7%
rockslide-debris slide-debris flow	35	3%
slump	2	0%
rock slide	85	8%
Total	1022	100%

Table B2. Landslide distribution summary statistics.—cont'd

Attribute	N	% of Total N
Generalized path		
os-us	33	3%
os-ms	171	17%
os-ts	154	15%
os-f	49	5%
os-flt	26	3%
os-tc	63	6%
os-mc	5	0%
os-gc-ms	5	0%
os-gc-ts	4	0%
os-gc-f	29	3%
os-gc-tc	8	1%
os-gc-mc	4	0%
gh-gc/tc	104	10%
gh-f/c/flt	22	2%
gh-mc	3	0%
gs-gc	211	21%
gs-gc-flt	21	2%
gs-mc	7	1%
es-es	2	0%
os-gc	14	1%
es-ts/f/flt	5	0%
gc-gc/mc/c/f/lk	45	4%
es-mc/tc	37	4%
Total	1022	100%
Estimated size class (m^2)		
500-1000	276	27%
1000-2500	216	21%
2500-5000	164	16%
5000-10000	154	15%
>10000	212	21%
Total	1022	100%

Table B3. Landslide size class frequency by air photo year.

Air photo year	500-1000m^2	1000-2500m^2	2500-5000m^2	5000-10000m^2	>10000m^2	Total
1962	190	164	63	31	25	473
1979	26	21	76	107	162	392
1988	32	7	9	10	11	69
1995	27	17	8	3	11	66
2001	1	7	8	3	3	22
Total	276	216	164	154	212	1022
1962	69%	76%	38%	20%	12%	46%
1979	9%	10%	46%	69%	76%	38%
1988	12%	3%	5%	6%	5%	7%
1995	10%	8%	5%	2%	5%	6%
2001	0%	3%	5%	2%	1%	2%
Total	100%	100%	100%	100%	100%	100%

Table B4. Distribution of landslide size classes by landslide type.

Landslide types	500-1000 m^2	1000-2500 m^2	2500-5000 m^2	5000-10000 m^2	>10000 m^2	Total
debris flow	158	65	50	61	55	389
debris slide-debris flow	75	76	30	16	27	224
debris avalanche-debris flow	4	11	18	19	31	83
debris slide-debris avalanche	27	30	23	18	30	128
rock slide-debris avalanche	5	13	21	19	18	76
rockslide-debris slide-debris flow	3	7	5	5	15	35
Slump	0	1	0	0	1	2
rock slide	4	13	17	16	35	85
Totals	276	216	164	154	212	1022

Table B5. Classification of landslide terminus into stream delivery classes.

Terminus environment	Delivery	No delivery	Total
connected gully channel	0	32	32
connected tributary	78	0	78
Fan	0	77	77
fan & connected tributary	31	0	31
fluvial level or terrace	0	34	34
gully channel	2	278	280
gully channel & fan	0	10	10
Lake	75	0	75
main channel	35	0	35
mid slope	0	158	158
Road	0	39	39
toe slope	1	117	118
upper slope	0	34	34
unconnected tributary	0	3	3
concave headwater basin	2	1	3
connected tributary/floodplain	1	0	1
fan and main channel	10	0	10
inner gorge	0	0	0
toe slope/main channel	4	0	4
Total	239	783	1022

Table B6. Distribution of degree of vegetative cover by air photo year of landslide as estimated from 2001 air photos.

Air photo year	Not vegetated	Partially vegetated	Vegetated	Total
1962	34%	18%	48%	100%
1979	18%	50%	32%	100%
1988	88%	10%	1%	100%
1995	71%	17%	12%	100%
2001	77%	23%	0%	100%
All years	35%	30%	35%	100%

Appendix C
Data Coding Conventions and Abbreviations for the Historical Landslide Inventory

Initiation Zone Land Use

- Natural forest – **nf** – landslide initiates in a natural forest or alpine area
- Clearcut –**cc** – landslide initiates in a clearcut
- Plantation – **p** – landslide initiates in a plantation that appears to be ≥15 - 20 years old
- Road – **rd** – can be either a road cut or road fill
- Landing – **l** – landslide initiates at a landing
- Windthrow – wt – landslide in an area of natural windthrow
- Edge Windthrow – ewt – landslide in an are of windthrow along a setting edge or edge of a VR patch or VR group

Initiation Zone Landforms

- Concave headwater basin – **ch** – a concave, usually upper slope landform that is often located above a gully headwall.
- Open slope – **os** – a generally planar or occasionally convex slope often on a mid or upper slope.
- Escarpment – **es** –the escarpment of a valley bottom or near valley bottom "inner gorge (an incised feature with steep sides but gradients less than 10 to 20 percent or a steep, valley-floor stream escarpment.
- Gullied escarpment – **eg** - as for escarpment, but the landslide appears to initiate in a gully incised into the escarpment.
- Gully headwall – **gh**.
- Gully sidewall – **gs**.
- Gully channel – **gc**

Terminus "Landform" or Runout Zones

- Connected gully channel – **cg** – landslide stops in a gully channel that appears to have a direct connection to either a main stem river channel or to a connected tributary
- Gully channel – **gc** - landslide appears to stop in a gully channel but there is no clear connection or lack of connection to a river channel or a connected tributary. For example there may be a fan at the base of the gully but it is not clear if a stream crosses the fan to the valley-floor stream. In some cases forest cover may obscure the true terminus of the landslide in gully channels or areas downslope of a gully.
- Gully channel fan – **gcf** – landside stops in bottom of gully channel and top of fan.
- Concave headwater drainage – **ch** – landslide stops in a headwater drainage basin
- Connected tributary – **ct** – landslide stops in a tributary stream (or occasionally in a gully channel leading directly into a tributary stream, that is, it is not entirely clear where the landslide stopped) that is connected to a river

- Unconnected tributary – **ut** - landslide stops in a tributary stream (or occasionally in a gully channel leading directly into a tributary stream, that is, it is not entirely clear where the landslide stopped) that is not connected to a river
- Connected tributary/floodplain –**ctfl** – landslide stops in part on a floodplain adjacent to the tributary channel
- Fan – **f** – landslide appears to stop on a fan surface and may or may not be linked by a stream channel to a valley-floor stream
- Fan/connected tributary –**fct** - landslide stops in part on fan and in part in the channel of a connected tributary (may be on the fan) or occasionally a river. It is often not possible to determine with certainty that the landslide reached the stream or that there was post-event downstream transport of sediment and debris to the valley-floor stream, or that the stream channel on the fan has destabilized following logging and/or the landslide event.
- Fan and main channel – **fmc** – the landslide appears to stop both on a fan surface and in the channel of a valley-floor river channel.
- Floodplain, glaciofluvial terrace or valley flat – **flt**– the landslide appears to stop on a floodplain, glaciofluvial terrace or valley flat.
- Inner gorge – **ig** – landslide stops in an inner gorge.
- Lake – **lk** – landslide stops in a lake.
- Upper slope – **us** – the landslide appears to stop on an upper slope.
- Mid slope –**ms** – the landslide appears to stop on a mid slope.
- Toe slope – **ts** – the landslide appears to stop on a lower or toe slope.
- Toe slope/main channel - **tsmc** – the landslide appears to stop both on an toe slope and in a main stream/river channel
- Main channel – **mc** – landslide stops in the main channel of a valley-floor stream or river. The channel may or may not be confined in an inner gorge.
- Road – **rd** – landslide stops on a road.

Landslide Classification

- Debris flows – **df**
- Debris slide/debris flow – **dsdf**
- Debris avalanche/debris flow – **dadf**
- Debris side/debris avalanche – **dsda**
- Rockslide – **rs**
- Rockslide-debris avalanche – **rsda**
- Slump – **u**
- Rockslide/debris slide/debris flow **– rsdsdf**

Generalized Landslide Path Classification

Initiation Zone	Transport Zone	Runout Zone	Letter Code	Class #
Open Slope	Open Slope (not channelized)	Upper Slope	os-us	1
		Mid Slope	os-ms	2
		Toe of Slope	os-ts	3
		Fan/cone	os-f	4
		Valley Flat	os-flt	5
		Tributary Channel	os – tc	6
		Mainstem Channel	os – mc	7
	Channelized	Mid Slope	os-gc-ms	8
		Toe of Slope	Os-gc-ts	9
		Fan/cone	Os-gc-f	10
		Valley Flat	Os-gc-flt	11
		Tributary Channel	os-gc-tc	12
		Mainstem Channel	os-gc-mc	13
		Gully channel	os-gc	21
Escarpment	Escarpment	Main / tributary Channel	es – mc/tc	24
		escarpment	es-es	20
		Toe of slope/ Fan/ Valley Flat	es-ts/f/flt	22
Gully Head	Gully	Gully Channel/ Tributary Channel	gh-gc / tc	14
		Fan/cone/Valley Flat	gh-f / c / flt	15
		Mainstem Channel	gh-mc	16
Gully Sidewall	Gully	Gully Channel	gs-gc	17
		Fan/cone/valley flat	gs-gc-flt	18
		Mainstem Channel	gs-mc	19
Gully Channel	Gully	Gully channel/ Main Channel/ Tributary Channel/ fan/ Lake	gc-gc/mc/c/f/lk	23

Landslide Size Classification

Minimum Size	Maximum Size	Size Class
≅ 500 m^2	≅ 1,000 m^2	1
≅ 1,000 m^2	≅ 2,500 m^2	2
≅ 2,500 m^2	≅ 5,000 m^2	3
≅ 5,000 m^2	≅ 10,000 m^2	4
≅ 10,000 m^2	unlimited	5

Vegetated 2001 Air Photo Classification

Vegetated	**y** - yes
Not vegetated	**n** - no
Partially vegetated	**p** - partially

Notes:

In general a conservative judgments are made with respect to the air photo interpretation of the terminus of the landslide if a certain determination can not be made.

In some cases, particularly in gullies, a landslide may have been interpreted as a debris slide that stopped in the gully channel because the lower reaches of the landslide scar were vegetated or obscured by forest cover along the gully sides.

Appendix D
Historical Landslide Inventory Air Photo Summary

Year	Flight Line	Photo Numbers	Missing Photos
1961/1962	HI	7001-7054	
		8254-8283	
		8285-8350	
		8388-8402	
		8413-8741	
		9105-9223	9173-9174
		9229-9247	
		9257-9395	
1979	MB208C	24258-24283	
		24300-24321	
		24390-24411	24392-24395
	MB209C	24737-24757	
		24815-24837	
		24855-24875	
		24905-24926	
		24946-24968	24953
		24983-25005	
		25032-25056	
		25073-25089	
	MB210C	25120-25142	
		25295-25321	
		25446-25467	
		25491-25502	
	MB211C	25966-25993	25977
		26038-26062	
		26088-26114	
1988	MB88012	004-015	
		019-027	
		030-045	
		050-082	
		093-180	
		185-205	
		209-231	
		245-288	
		300-324	
	MB88011	244-272	
		274-335	312
		345-395	
		405-430	
1995	MB95005	003-026	

Year	Flight Line	Photo Numbers	Missing Photos
		031-054	
		087-107	
		109-128	
		137-160	
		180-199	
		212-225	
		234-255	241-247
		261-277	
		280-297	
		300-360	
		364-380	
		384-397	
		402-411	
		415-421	
2001	WY01004	001-016	
		081-151	
		172-204	