TECHNICAL NOTES

U.S. DEPARTMENT OF AGRICULTURE NATURAL RESOURCES CONSERVATION SERVICE

ENGINEERING # 13 **SPOKANE, WASHINGTON**

January 2009

GEOLOGIC HAZARDS
LANDSLIDES

BACKGROUND
Landslides are one of a number of geologic hazards that are common throughout Washington State. This technical note provides general guidance for planning work in landslide-prone terrain and for remediating damages following slope failure.

DEFINITION
Landslides are defined as the movement of a mass of rock, debris, or earth down a slope. The type of down slope movement may be classified as: fall, topple, slide, spread, or flow. Landslides may also be defined by their degree of activity as active, reactivated, suspended, or inactive. Inactive landslides are often classified as: dormant, abandoned, stabilized or relict.

INITIATION
Landslides are initiated when driving forces exceed resisting forces. Typically, failure occurs when a triggering mechanism (e.g. intense rainfall, excavation at the base of a slope, seismic shaking, or rapid drawdown of water) increases the driving forces or decreases the resisting forces past the point of stability.

AREAS PRONE TO LANDSLIDES
- Old landslides and areas with recent or historic failures;
- On or at the base of steep slopes;
- On or at the base of slopes over steepened by cutting or filling;
- Areas of burned or cleared vegetation;
- Developed hillsides where leach field septic or irrigation systems are used;
- Along roadways where surface runoff is diverted, concentrated and discharged over the slope;

- In or at the base of minor drainage hollows;
- Areas underlain by notably soft or fractured rock.

CONSIDERATIONS FOR CONSERVATION PLANNING

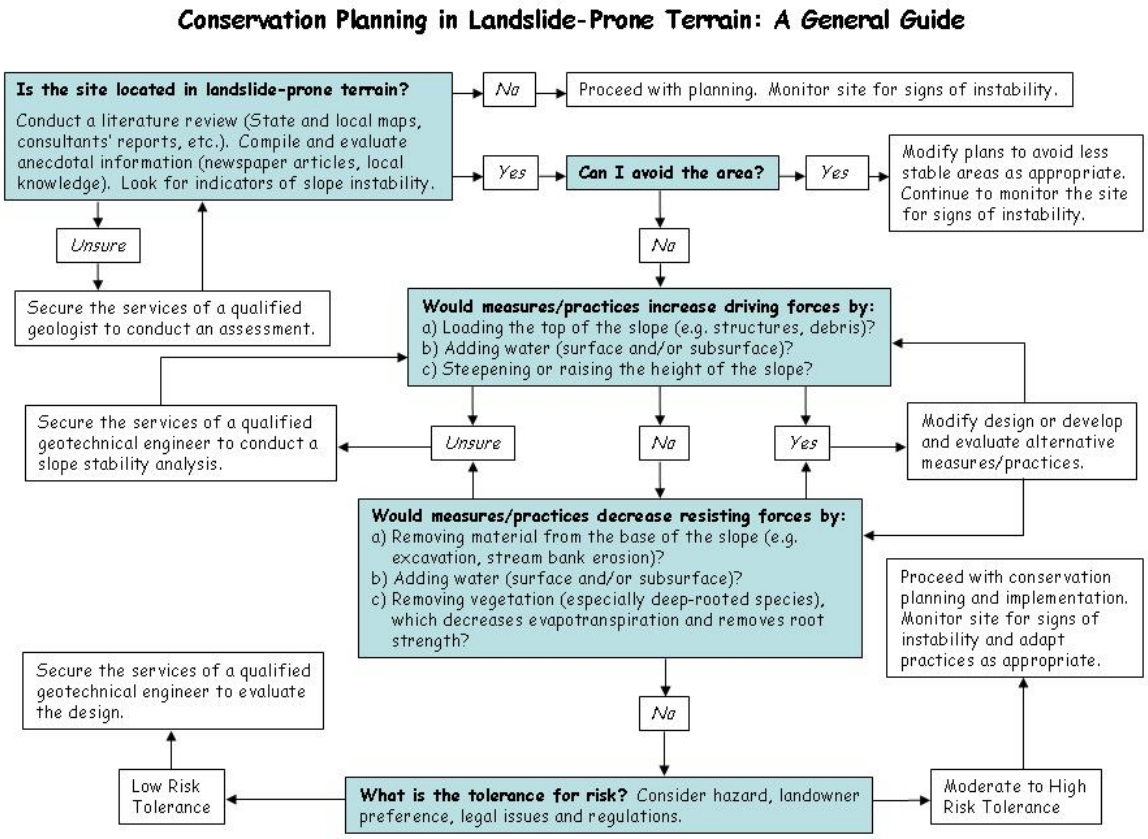
1. **Is the site located in landslide-prone terrain?** Review published and anecdotal information as an initial screen of landscape stability and history of slope failure. Complete a visual survey of the area around the project site to look for evidence of historic, recent, or impending failures. If you are unsure how to identify indicators of slope stability request assistance from a qualified geologist.

2. **Can the area be avoided?** Consider relocating project to a more stable area.

3. **Would the proposed measures/practices increase driving forces?** If you are unsure, secure the services of a qualified geotechnical engineer to conduct a slope stability analysis. Consider modifying the design or develop and evaluate alternative measures/practices.

4. **Would the proposed measures/practices decrease resisting forces?** If you are unsure, secure the services of a qualified geotechnical engineer to conduct a slope stability analysis. Consider modifying the design or develop and evaluate alternative measures/practices.

5. **What is the tolerance for risk?** Consider the severity of damage that could result from slope failure, the potential regulatory and legal issues associated with a failure and the landowner's risk tolerance. Assess whether proposed application of conservation practices would result in an unacceptably high risk of slope failure. If there is a potential risk for slope failure, consult an engineering geologist or geotechnical engineer for guidance on slope stabilization.



SOURCES OF INFORMATION

Local, state and federal units of government have various roles and responsibilities for addressing geologic hazards. Local emergency management offices often maintain emergency response plans for addressing landslides once they occur. In Washington, the state geological survey has the responsibility of conducting and maintaining an assessment of state wide landslide hazards. In addition, the federal government, through the United States Geological Survey, has the responsibility of reducing the level of hazard from landslides through the development of better identification and mitigation strategies.

1. County Government

County government often maintains information on local landslide hazards. Sometimes the information is maintained by the office of emergency services or the roads department. For example:

- Gray's Harbor County, Department of Emergency Management (http://www.co.grays-harbor.wa.us/info/dem/Planning.htm)

- King County, Office of Emergency Management (http://www.metrokc.gov/prepare/preparerespond/hazardsdisasters/landslides.aspx)

2. State Government

Washington State, through R.C.W. 43.92.025, requires the state geological survey (Washington State, Department of Natural Resources, Division of Geology and Earth Resources) to conduct and maintain an assessment of landslide hazards in Washington. The assessment must include the identification and mapping of landslide hazards, an estimation of potential consequences, the likelihood of occurrence and technical assistance to state and local government agencies on the proper interpretation and application of the results. (http://www.dnr.wa.gov/ResearchScience/Topics/GeologicHazardsMapping/Pages/geologic_hazards.aspx)

Landslide hazard maps are available through the Washington State, Department of Natural Resources, by going to the Business & Permits section from the home page and scrolling down to Topics, view all topics. It's not obvious, so here is the current link, but you may have to search for it if the DNR updates their web site and changes the link. (http://www.dnr.wa.gov/BusinessPermits/Topics/LandslideHazardZonation/Pages/Home.aspx)

3. Federal Government

The United States Geological Survey (USGS), through its geologic hazards reduction programs, has national responsibility for developing identification and mitigation strategies to reduce damages from landslides. As stated on their web site:

> *"The primary objective of the National Landslide Hazards Program (LHP) is to reduce long-term losses from landslide hazards by improving our understanding of the causes of ground failure and suggesting mitigation strategies."*

The following link to the USGS Landslide Hazards Program was available as of January 2009: (http://landslides.usgs.gov/).

REMEDIATION FOLLOWING A LANDSLIDE

Strategies for remediation of a site following slope failure are based on reducing driving forces acting on the slope and increasing resisting forces supporting the slope. In other words, the design should provide for a factor of safety sufficient to stabilize the slope.

1. Reduction of Driving Forces

Two major concerns are the mass of the material on the slope and the pore water pressure within the slope material. If the slope is overloaded with excess mass it may be subject to gravitational failure or if pore water pressures increase, the slope could fail through loss of shear strength within the slope material.

To address these concerns, the Transportation Research Board in Special Report 247 Landslides: Investigation and Mitigation (1996) suggest the following methods for reducing driving forces:

- Flatten slopes
- Bench slopes
- Reduce excavation depths
- Improve surface and subsurface drainage
- Incorporate lightweight fill

2. Increase in Resisting Forces

This approach is based on applying an external force to the toe of the landslide and/or increasing the internal strength of the soils. As with efforts to reduce driving forces, both of these approaches address concerns regarding gravitational forces acting on the mass and shear strength of the mass.

The Transportation Research Board in Special Report 247 Landslides: Investigation and Mitigation (1996) suggest the following methods for increasing resisting forces:

External force

- Buttresses
- Counterweight fills
- Toe berms
- Cantilever and gravity retaining walls
- Externally braced walls
- Walls supported by anchors or tiebacks
- Soil nailing
- Root piles
- Conventional piles
- Drilled shafts
- Reinforced-soil systems

Internal strengthening

- Subsurface drainage
- Soil reinforcement
- Vegetative and biotechnical stabilization