

11. Indications and Alerts

Indications are factors that, when observed, help confirm or deny models about the current threat from landslides. Note that landslides usually do not provide clear indications before they happen. Usually the best expectation is to determine that overall conditions have worsened for landslides in the area. Rock falls are even more difficult to foresee. In Hennepin County, sensors continuously monitor for some factors favorable for landslides. Alerts are notices regarding elevated threat conditions and are a call for added vigilance and precautionary measures to decrease short-term vulnerability. Warnings are an urgent notice of site-specific danger that is imminent or in progress and that requires immediate action to save lives, infrastructure or property. A warning normally requires site-based monitoring.

Indications in Structures

Structures do not always provide indications before a landslide happens. The occurrence of any of the following situations does not always mean that landslide activity is the cause. Sometimes these indications accompany slow-moving creeping slides, which can be destructive but not often dangerous. Rapid onset slides, on the other hand, can be violent and life threatening. When multiple indications happen in a relatively short amount of time, especially when recent weather has produced extreme rainfall and high soil moisture, evacuate the structure. An investigation by a registered or licensed geologist or engineer is needed to assure

safety. Indications include:

- cracks appear in pavement, foundation, supporting walls or sidewalks
- chimneys crack or begin to lean or tilt
- doors or windows suddenly start to stick or jam
- outside walls, walkways or stairs pull away from a house or building
- soil begins to detach from the foundation leaving a gap
- sudden plumbing or gas line leaks.

Indications on Properties

Nature does not always provide indications before a landslide happens. The following situations do not necessarily mean that potential landslide activity is imminent. Some of these indications can reflect a slow, creeping landslide. Creeping slides can be destructive but are not usually life threatening. Rapid onset slides on the other hand, can be violent and life threatening. When multiple indications happen in a relatively short amount of time, or when recent weather has produced extreme rainfall and high soil moisture and these indications happen, an investigation by a registered or licensed geologist or engineer is advisable.

Indications include:

- newly bulging ground at the bottom of a slope
- appearance of springs, seeps or saturated soils in areas that have typically been dry
- recent appearance of cracks or holes in the ground
- utility poles are installed vertically but begin to lean over time
- fence posts that lean or retaining walls that begin to bulge
- trees on slopes grow curved trunks to compensate for slope creep.

Area Monitoring

Area monitoring tracks the changing environmental conditions over a wide area to detect factors generally favorable for the triggering of landslides. These factors include rainfall, soil moisture and others. A high degree of sensor granularity is required to be able to detect small-scale differences within the area of concern. In some cases, the sensor reporting frequency is an important consideration to provide timely advisory and alerting services.

Surface-based monitoring.

- 1) **Hennepin West Mesonet** (hennepinwestmesonet.org) provides accurate and near real-time reporting of many environmental factors, including rainfall, soil moisture to a depth of 48 inches (1.2 m), and soil frost profile to a depth of 10 feet (3 m). Planned network density in Hennepin County is based on a five-mile separation. Over 20 stations operate in and adjacent to Hennepin County.
- 2) **Airport weather stations** (ASOS/AWOS) are located at three airports in Hennepin County (Minneapolis-Saint Paul International (MSP); Crystal (MIC); and Flying Cloud (FCM) in Eden Prairie). Airport stations are located in the eastern and southern extremes of Hennepin County. Sensors are oriented to aviation weather and do not have soil data. Observations are publicly available hourly, unless conditions warrant a special observation.
- 3) **The Minnesota Department of Transportation Roadway Weather Information System** (RWIS) stations are located along Interstates, freeways and principal arterial highways. There are three RWIS stations located in Hennepin County. Soil depth and moisture sensors extend to a depth of 17 inches (43 cm). Reports are updated at five-minute intervals.
- 4) **Human weather observers in the Community Collaborative Rain, Hail and Snow Network** (CoCoRaHs), as well as Cooperative Observers with the Minnesota State Climatology Office, take daily total rainfall measurements at various sites across the county and report them once daily. Sometimes additional observations are taken and reported.

Radar and satellite monitoring.

- 1) **Radar.** The National Weather Service WSR-88D dual-polarity Doppler weather radar located at Chanhassen, Minnesota is able to estimate rainfall and provide an estimated storm-total rain accumulation projection graphic of the surface. This is a good tool for estimating rainfall in places between surface observation stations.
- 2) **Satellite.** There are also satellite-based soil moisture observation tools (GOES/SMAP) that can help augment surface measurements. Satellite tools are helpful, but suffer from coarse resolution (3 kilometers is best) and long data latency (12 hours is best) that limit their ability to aid timely and accurate alerting.

Site Monitoring

Specific sites that are susceptible to landslides and that also have significant vulnerabilities from human activity or infrastructure are ideal for landslide monitoring. Monitoring may consist of trip wires, tensiometers or inclinometers to anticipate and measure motion. These can be used along roads and trails to detect changes prior to slope failure and enable timely warning to avert injuries to those exposed.

Some infrastructure must be located at the top of slopes in order to function. In these cases, setbacks and other zoning measures are not effective. Infrastructure such as bridges at the top of slopes may be monitored as well for structural stresses and changes that might indicate slope or structural failure. Deep-seated landslide features are also not well-served by building setbacks. On slopes where springs are present, or where there are identified slope failure deposits or scars, monitoring for motion using tensiometers or inclinometers may be very useful.

Monitoring change on steep or near-vertical slopes requires low-angle or side-looking views, preferably under leaf-off conditions or, using a method that can “see through” vegetation, such as Light Detection and Ranging (LIDAR). Structure-from-motion photography (*Westoby et al., 2012*) taken from the ground or using drones could create elevation models of bluff faces to record changes where slope

is not obscured by the vegetation. Side-scan LIDAR (e.g., Day et al., 2013) can be used to look through vegetation to map portions of the bluff faces.

Careful placement of stormwater infrastructure is important so as not to induce erosion, especially in the St. Peter Sandstone. For example, under the Highway 5 Bridge abutment (Figures 7.8a and 7.8b) erosion-control measures put in place have varying levels of permanence.

As of publication of the Hennepin County Landslide Hazard Atlas (2020), only one monitoring site was known at river mile 19.2 on the Minnesota River where it has meandered adjacent to the north valley wall. Significant bluff erosion has occurred due to a combination of localized erosive velocities as the river flows around the bend and the permanent soil saturation that occurs near the springs that has accelerated bluff erosion, low in-situ shear strength, steep slopes and the removal of vegetation. In 2010, the Lower Minnesota River Watershed District installed inclinometers in the bluff to monitor movement in the slope. Data are collected annually. While significant erosion has occurred at the toe of the bluff, no movement has been documented in the bluff. Hennepin County Emergency Management encourages research into slope monitoring and welcomes researchers to contact Hennepin County Emergency Management to discuss their projects.

Advisories and Alerts

Together with its partners, Hennepin County Emergency Management would like to be able to provide advisories to the emergency response community (fire, police, emergency medical and public works) when environmental conditions are nearing those needed for landslides in the local environment. When environmental conditions exist that are understood to have reached those needed to produce landslides in the local area, Hennepin County Emergency Management will provide alerts to the public via social media, and special statements to the media.

- 1) **Landslide Advisory.** An advisory means that environmental conditions are nearing those that are needed to produce landslides in the local area. Advisories are provided to the Hennepin County emergency response community through standard Hennepin Watch distribution and externally via social media.
- 2) **Landslide Alert.** An alert means that environmental conditions have reached a point favorable for the triggering of landslides in Hennepin County. This is roughly analogous to a severe weather watch criteria. However, unlike the case for severe weather, a landslide warning is not possible. Thus, this product is essentially the final call to action so it is termed an alert rather than a watch. Alerts are issued to the public through Emergency Management social media and via special statements to local media outlets.

CAUTION: It is important to realize that Landslide Advisories and Alerts cannot account for human-induced landslides. Human activities may trigger landslides at more unexpected times or much earlier than possible under natural environmental conditions. Leaky pipes, watering slopes, excavating on hillsides and other ill-advised activities are not factored into landslide advisories and alerts.

Warning

In ideal circumstances, a landslide warning is issued when a slide is determined to be imminent at a particular site and a warning message is used to ensure that people in the area have adequate time to escape the danger. **Currently, landslide warning capabilities do not exist in Hennepin County. The technical capability to detect landslides before they happen is still largely in the research phase.**

It is only effective on slopes where an extensive network of sensors have been placed. Current technology means that only very high-risk slopes can justify the large expense of the extensive sensor network needed to warn for slides. At this point, only one monitoring location is known in Hennepin County.

Research

Hennepin County Emergency Management is seeking opportunities to host such academic landslide prediction and warning research. Researchers are encouraged to contact Hennepin County Emergency Management to discuss their projects.