Brickyard Area of Lilydale Regional Park
Stormwater Management and Slope-Stability Study

BARR

Executive Summary

The Brickyard Area of Lilydale Regional Park is an area of both historic and recreational significance for the City of St. Paul. From the 1890s to the 1970s this area was used as a clay-mining and brick-making site. Evidence of that history remains in the three quarry areas (East, Middle, and West Clay Pits) and the ruins of a brick oven. Adjacent to the brick oven is Echo Cave, a man-made feature carved into the white Cambrian sandstone rock. In the early 1900s this rock was mined for its high silica content (used to make glass), supporting the demand for glass bottles from nearby breweries. Four fossil beds near the clay pits offer clues to an even earlier history and are popular with fossil hunters. Recreational features of the Brickyard Area include the popular Brickyard Trail, the Bruce Vento Scenic Overlook, several water falls, and the Middle Clay Pit bluffs which are often used for ice climbing.

The Brickyard Area is characterized by steep slopes, intermittent streams and seeps, and trails and ravines that convey stormwater from the direct and upland tributary areas. Erosion of the ravines and clay pits has led to decreased water quality in downstream Pickerel Lake (an important feature of Lilydale Regional Park) and slope instability. These concerns prompted the City of St. Paul to hire Barr Engineering Co. (Barr) to study erosion and slope-stability issues in the area. The primary objective of this study was to develop concept-level stormwater management, erosion-control, and slope-stability recommendations for City use. Specifically, the study was designed to:

- Help the City and its partners gain a better overall understanding of slope-stability issues in the Brickyard Area, particularly as they relate to proposed park structures and restricted active-use areas.
- Identify and evaluate erosion issues along the Brickyard Trail and in other area ravines.
- Identify and prioritize stormwater management techniques to reduce erosion while maintaining an aesthetic that is compatible with the unique, natural geologic setting of the park.

To formulate recommendations, Barr made two site visits to the Brickyard Area to gather information and document conditions. Geotechnical and stormwater analyses were also performed. A summary of these efforts is provided in the following pages.

Site observations

Barr staff and City personnel performed a field review of site conditions on May 15 and July 2, 2014. The focus of the first visit was to observe and generally inventory the existing ravines, trails, ravine/trail crossings, park amenities, storm sewer inflows, and slope-stability areas of concern. The Figure 1 on the following page shows features of the study area.

The second site visit was prompted by heavy precipitation in June that revealed additional slope-stability issues. The primary focus of this visit was a large slope failure toward the north end of the study area. Additional slope failures and material loss along the Brickyard Trail between the Middle and West Clay Pits and a sinkhole near the intersection of Annapolis Street and Cherokee Heights Boulevard were also examined.

Cherokee Heights Culvert and Ravine

Photo: Ravine slope failure. Significant erosion was observed along the ravine side slopes; there are several active slope failures in the ravine.

Northwest Slope Failure Area and Lower North Stream Channel

Photo: Large slope failure from above. Evidence of historic slope failures was observed. One failure was "reactivated" during a wet period in June 2014; this failure had enough force to topple mature trees along the lower section of the Brickyard Trail.

East, Middle, and West Clay Pits

Photo: Middle Clay Pit wall with fresh soil scarp in upper-right corner. The slopes above the pits are fairly steep with former scarps evident at numerous locations. Soil slopes at the corners of the clay pits seem prone to instability and failure.

Brickyard Trail, Including Bruce Vento Spur

Photo: Erosion on the Brickyard Trail–Fossil/Brick Oven Section. Moderate-to-severe erosion from concentrated stormwater runoff along the straight and steep sections of the Brickyard Trail was observed. A steep slope adjacent to the trail showed evidence of slope failure that was reactivated during a wet period in June 2014.

Bruce Vento Scenic Overlook

Photo: Soil overhang, from above, at Bruce Vento Scenic Overlook. A mass of overhanging soil, supported by vegetation/root zones was observed. There is potential for this area to fail when the roots eventually give way.

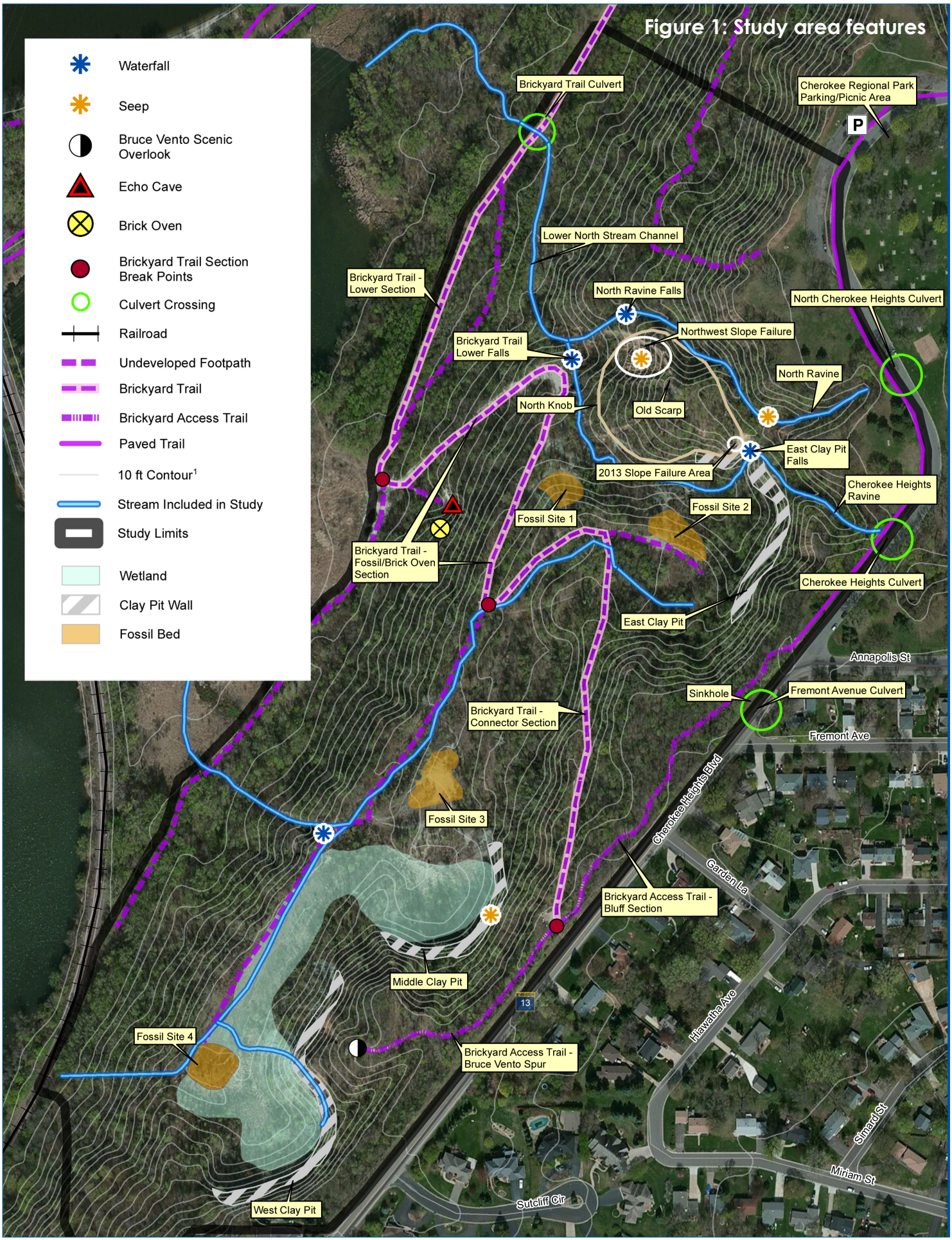
Figure 1: Study area features
Waterfall
Seep
Bruce Vento Scenic Overlook
Echo Cave
Brick Oven
Brickyard Trail Section Break Points
Culvert Crossing
Railroad
Undeveloped Footpath
Brickyard Trail
Brickyard Access Trail
Paved Trail
10 ft Contour[1]
Stream Included in Study
Study Limits
Wetland
Clay Pit Wall
Fossil Bed
Brickyard Trail Culvert
Cherokee Regional Park Parking/Picnic Area
P
Lower North Stream Channel
Brickyard Trail - Lower Section
North Ravine Falls
North Cherokee Heights Culvert
Northwest Slope Failure
Brickyard Trail Lower Falls
North Ravine
North Knob
Old Scarp
East Clay Pit Falls
2013 Slope Failure Area
Cherokee Heights Ravine
Fossil Site 1
Fossil Site 2
Brickyard Trail - Fossil/Brick Oven Section
Cherokee Heights Culvert
East Clay Pit
Annapolis St
Sinkhole
Fremont Avenue Culvert
Brickyard Trail - Connector Section
Fremont Ave
Cherokee Heights Blvd
Fossil Site 3
Garden La
Brickyard Access Trail - Bluff Section
Middle Clay Pit
13
Hiawatha Ave
Fossil Site 4
Brickyard Access Trail - Bruce Vento Spur
Sinard St
Miriam St
Sutcliff Cir
West Clay Pit

Geotechnical analysis

To evaluate the stability of the existing slopes in the Brickyard Area and the effects of water content/saturation, the physical properties of the soil and rock were examined. Samples from five boring locations were analyzed to identify the following soil/rock characteristics: stratigraphy, natural moisture content, unit weight, plasticity, grain size, strength, and permeability. Slope-stability simulation modeling was also performed to evaluate the influence of topography, soil strength, and seepage/saturation on area slope stability and to calculate "factors of safety" (the ratio of resisting forces in the soil to the driving forces that cause slope movement).

Stormwater analysis

To gain a better understanding of drainage patterns within the Brickyard Area and their influence on erosion a stormwater analysis was done. An XP-SWMM hydrologic and hydraulic model was developed to estimate stormwater depths and corresponding flows and velocities in the storm sewer system, channels, and ravines throughout the study area.

More information about hydrology in the Brickyard Area and its impact on slope stability can be found on page 8.

Potential for slope failure

Based on May and July site observations, the results of geotechnical and stormwater analyses, as well as Barr's experience, conditions in the area (at the time of the study) were categorized as low-risk, moderate-risk, or high-risk (see Figure 2). These rating categories are specific to this project and not based on industry standards. The primary factors influencing risk assessment were likelihood for large-volume landslides, likelihood of soils falling from significant heights, likelihood of persons being caught in a slide from above the failure surface, and a history of previous landslides. No area of the park was considered "no-risk." The uncertainties of weather, soil type and strength, and human activity always pose some risk of unexpected soil movement. It is also important to note that this is a constantly changing landscape (as evidenced by site changes between May and July site visits). It is impossible to state, with any degree of certainty, that these slopes will or will not fail over time.

One solution for managing high-risk areas is to limit public access. There are two areas in the park where we recommend that restricted access be considered (see Figure 3, page 7). These areas include only one of the four popular fossil sites identified by the City and do not include the Brickyard Trail.

HIGH RISK

Areas categorized as *high-risk* have the following features or characteristics:

- Likelihood for large volume circular-failure or block-failure landslides
- Likelihood for soils to fall from significant heights
- Likelihood for persons to be caught in a slide from above the failure surface
- History of previous large-volume slides

MODERATE RISK

Areas categorized as *moderate-risk* have the following features or characteristics:

- Likelihood for lesser-volume circular-failure or surficial translational-failure landslides
- Likelihood for soils to fall from lower heights
- History of previous lesser-volume slides

LOW RISK

Areas categorized as *low-risk* have the following features or characteristics:

- Generally flatter grades and minimal likelihood for landslides
- Likelihood for soils to fall from lower heights
- No apparent history or evidence of landslides
- Areas that were not observed during the May and July 2014 site visits, but generally have similar characteristics to other low-risk areas within the study area

No area of the park was considered *no-risk*. The uncertainty of weather; soil type, strength, and stratigraphy; and human activity always pose some risk due to unexpected movement of soils.

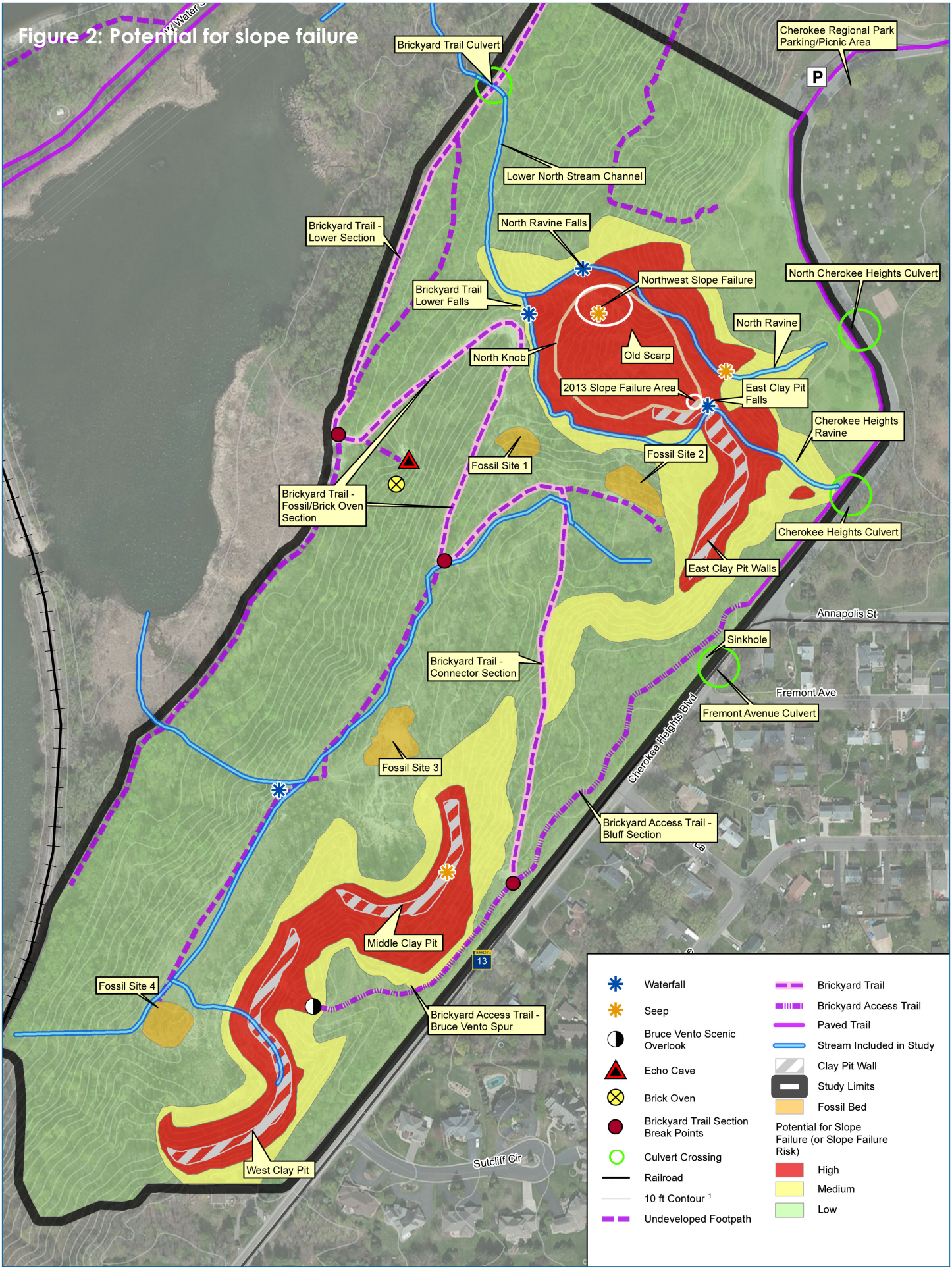
Figure 2: Potential for slope failure
Brickyard Trail Culvert
Cherokee Regional Park Parking/Picnic Area
P
Lower North Stream Channel
Brickyard Trail - Lower Section
North Ravine Falls
Northwest Slope Failure
North Cherokee Heights Culvert
Brickyard Trail Lower Falls
North Ravine
North Knob
Old Scarp
2013 Slope Failure Area
East Clay Pit Falls
Cherokee Heights Ravine
Fossil Site 1
Fossil Site 2
Brickyard Trail - Fossil/Brick Oven Section
Cherokee Heights Culvert
East Clay Pit Walls
Annapolis St
Sinkhole
Brickyard Trail - Connector Section
Fremont Ave
Fremont Avenue Culvert
Cherokee Heights Blvd
Fossil Site 3
Brickyard Access Trail - Bluff Section
Middle Clay Pit
13
Fossil Site 4
Brickyard Access Trail - Bruce Vento Spur
West Clay Pit
Sutcliff Cir
Waterfall
Seep
Bruce Vento Scenic Overlook
Echo Cave
Brick Oven
Brickyard Trail Section Break Points
Culvert Crossing
Railroad
10 ft Contour 1
Undeveloped Footpath
Brickyard Trail
Brickyard Access Trail
Paved Trail
Stream Included in Study
Clay Pit Wall
Study Limits
Fossil Bed
Potential for Slope Failure (or Slope Failure Risk)
High
Medium
Low

Recommendations

General recommendations for the Brickyard Area of Lilydale Regional Park are listed below. More specific recommendations related to (1) ravine stabilization/ stormwater management, (2) steep-slope stabilization, and (3) erosion along the Brickyard Trail are outlined in the column at right.

- **Restrict access to high-risk areas of the park—** including Cherokee Heights Ravine, North Ravine, and a portion of the Lower North Stream Channel; the East, Middle, and West Clay Pit areas; and the Bruce Vento Scenic Overlook. These areas are indicated on Figure 3 by a red-dashed line. Only one of four fossil sites is included in these proposed restricted areas.
- **Conduct additional research on industry-accepted best practices for managing risk in park settings.**
- **Stabilize and re-vegetate slopes, where feasible—** including the steep slopes in the northern Brickyard Area and the slopes in the "connector" section of the Brickyard Trail. The Bruce Vento Scenic Overlook and Bruce Vento Spur of the Brickyard Trail could also be mechanically stabilized.
- **Perform inspections—**annually and after significant precipitation events, with subsequent adjustments to access areas. In addition, the Cherokee Heights Ravine, North Ravine, and Lower North Stream Channel should be routinely monitored and inspected for new erosion that could impact downstream areas, including Pickerel Lake.
- **Place barriers and/or signage at access points to restricted areas—**as well as general park access points to alert visitors.
- **Consider monitoring changing conditions in the park with equipment such as tilt meters, inclinometers, piezometers, etc.**

Planning-level opinions of construction costs for alternatives are included in the complete *Brickyard Area of Lilydale Regional Park Stormwater Management and Slope-Stability Study* report. These estimates are included to assist in evaluating and comparing options; they do not represent absolute values for given alternatives.

Regardless of any selected alternative(s), additional site visits, geotechnical investigation, borings, and soils testing must be performed to refine the recommendations for specific park areas and address potential changes to conditions.

Ravine stabilization/stormwater management for Northern Brickyard Area

1. Restrict access to the Cherokee Heights Ravine, North Ravine, and Lower North Stream Channel (area outlined by red-dashed line, Figure 3). Restricting this area includes closing Fossil Site 2.
2. Stabilize the steep slopes in the North Knob.
3. Re-establish and stabilize the Lower North Stream Channel using river-rock riprap. Boulder riffles could potentially be added for aesthetics and to help reduce flow velocities.
4. Once the stream channel is re-established and stabilized, replace the Brickyard Trail culvert with a small span bridge.

Steep-slope stabilization

1. Restrict access to the Middle and West Clay Pit areas and the Bruce Vento Scenic Overlook (area outlined by red-dashed line, Figure 3)
2. Relocate or mechanically stabilize the Bruce Vento Scenic Overlook.
3. Stabilize the section of the Bruce Vento Spur of the Brickyard Trail highlighted on Figure 3.
4. Stabilize a portion of the "connector section" of the Brickyard Trail using vegetated, reinforced soil slopes—assuming the canopy cover does not prevent sunlight penetration. In the interim, remove (or relocate) the park bench downslope of this area. Alternatively, this area could be graded to a stable slope.
5. Stabilize the North Knob by grading to a stable slope.

Brickyard trail erosion

Implement one (or a combination) of the three following erosion-control measures:

1. Install Geoweb to stabilize and reinforce the trail.
2. Repair the trail and install waterbars to deflect water off the trail and reduce future erosion.
3. Install a "side channel" (reinforced ditching) along the side of the trail and resurface this area.

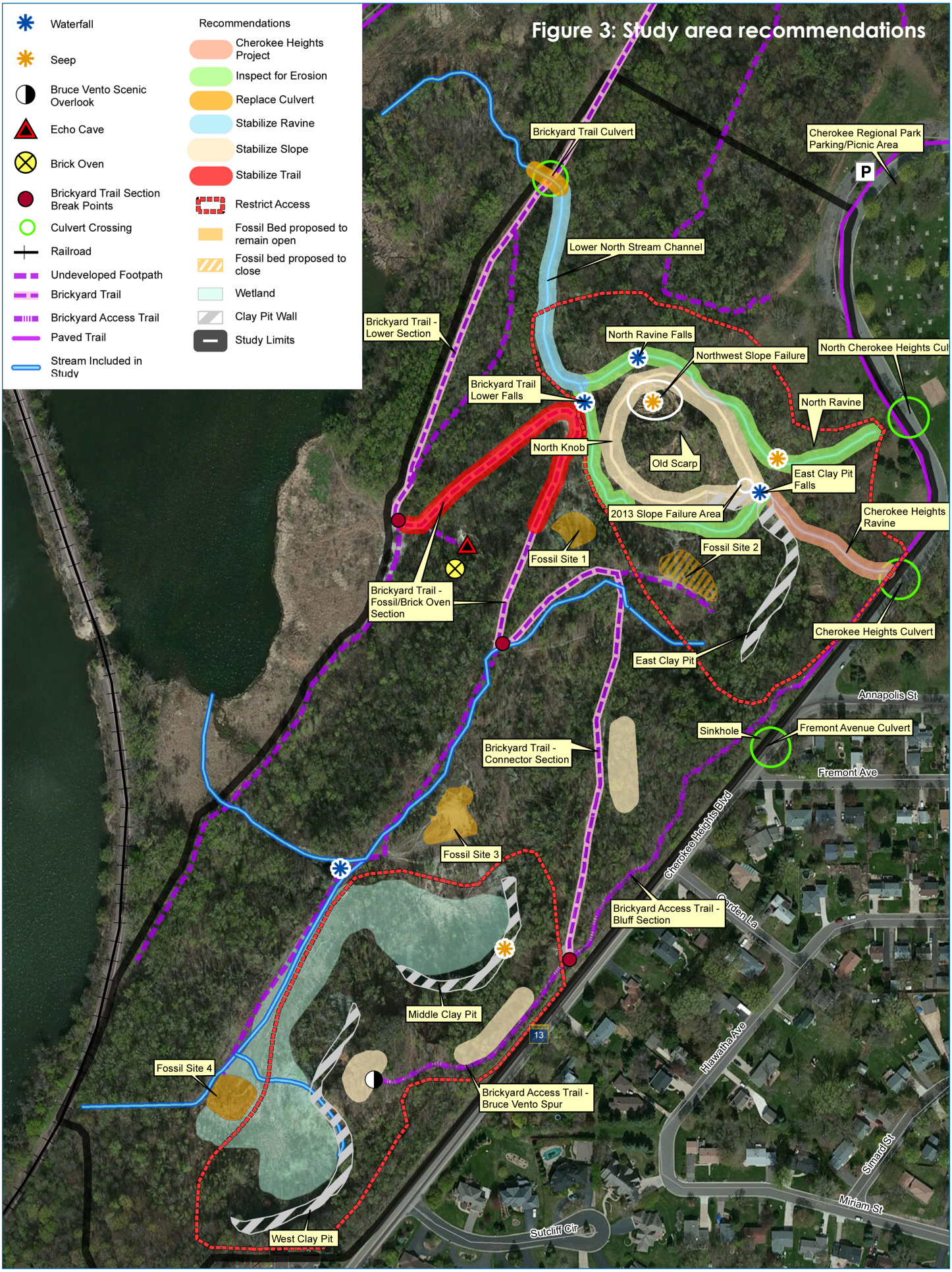
Figure 3: Study area recommendations
Waterfall
Seep
Bruce Vento Scenic Overlook
Echo Cave
Brick Oven
Brickyard Trail Section Break Points
Culvert Crossing
Railroad
Undeveloped Footpath
Brickyard Trail
Brickyard Access Trail
Paved Trail
Stream Included in Study
Recommendations
Cherokee Heights Project
Inspect for Erosion
Replace Culvert
Stabilize Ravine
Stabilize Slope
Stabilize Trail
Restrict Access
Fossil Bed proposed to remain open
Fossil bed proposed to close
Wetland
Clay Pit Wall
Study Limits
Brickyard Trail Culvert
Cherokee Regional Park Parking/Picnic Area
P
Lower North Stream Channel
Brickyard Trail - Lower Section
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Fossil Site 4
Brickyard Access Trail - Bruce Vento Spur
Simard St
Miriam St
Sutcliff Cir
West Clay Pit

Hydrology and the Brickyard Area

Figure 4, below, developed by the US Geological Service, shows the earth's water (hydrologic) cycle. Surface runoff, infiltration, seepage, and groundwater (circled in red) all contribute to unstable slopes in the Brickyard Area of Lilydale Regional Park.

- **Surface runoff—**Precipitation that does not infiltrate and contributes to erosion at the toe of the slope (Figure 5)
- **Channelized surface water—**Surface runoff that channelizes in the ravines
- **Groundwater (seepage)—**Precipitation that infiltrates but "seeps" back out when it reaches an impermeable rock layer

Some of the ways this water impacts slope stability are described at right.

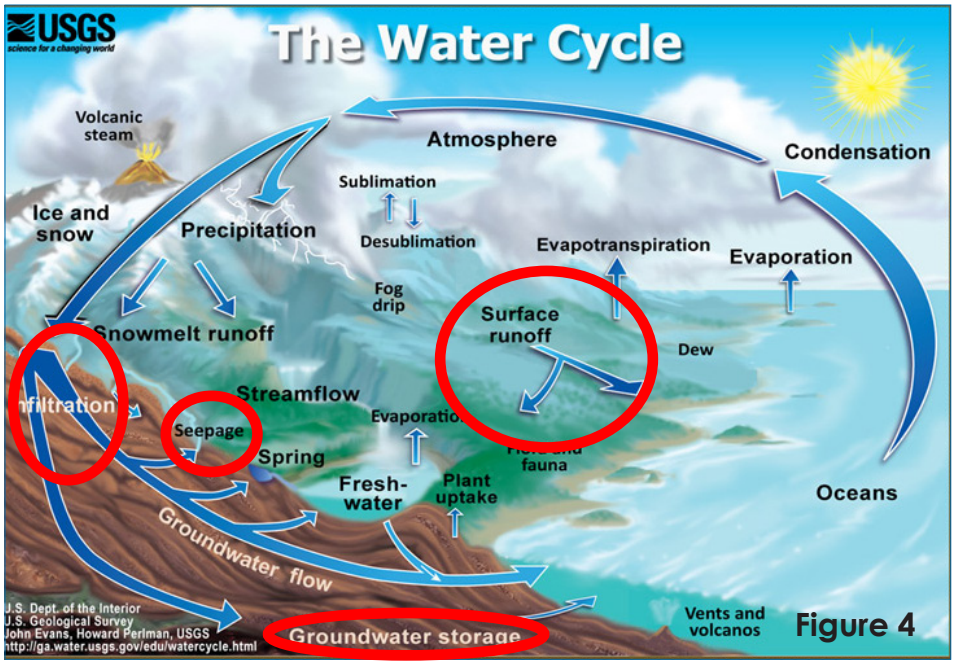


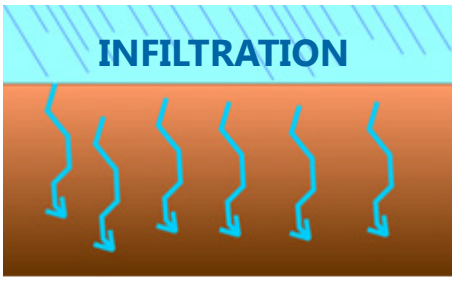
Figure 4

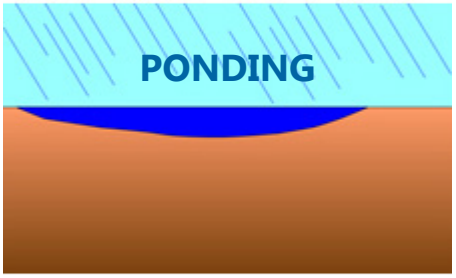
Water and slope stability

Filling the void—When precipitation infiltrates the soil it fills the void spaces between the soil grains (Figure 6). Too much water in these void spaces reduces or eliminates the suction and cohesive forces that hold the grains together.

Changing geometry—Runoff that erodes the toe of the slope may cause unstable conditions by changing the slope's geometry.

Creating pressure—Water adds weight to the soil. If 2 inches of rain infiltrate a 100- x 200-foot slope, the slope weight increases by 200 tons (source: "The Role of Water in Slope Stability," Lecture, Western Washington University).





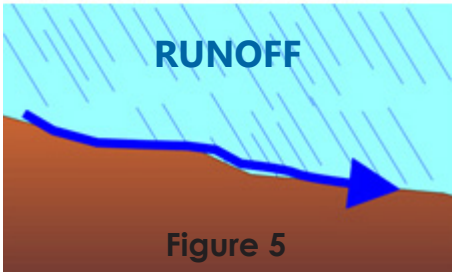


Figure 5

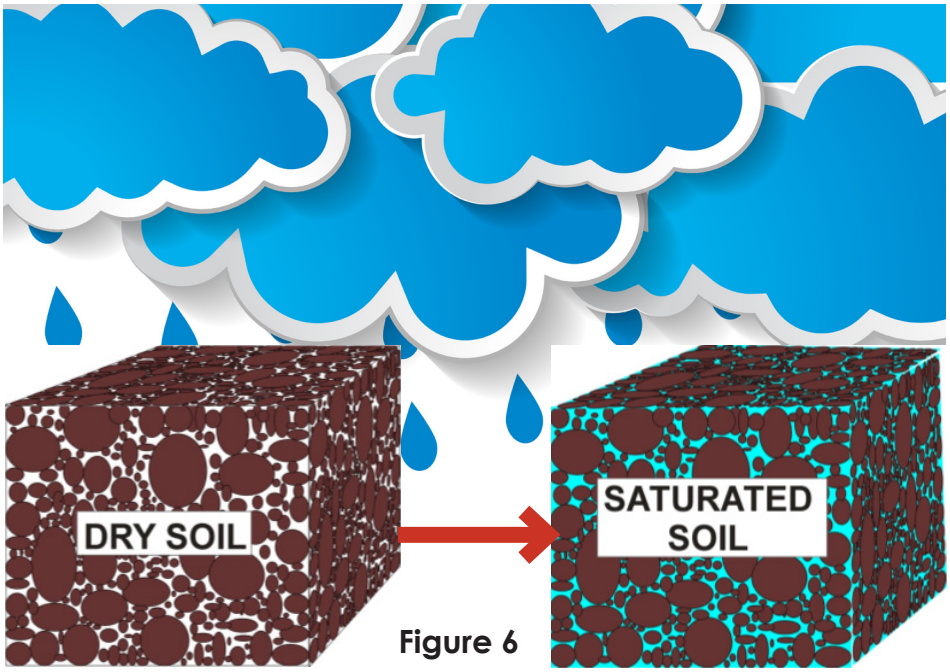


Figure 6