HILLSIDE EVALUATION AND PRELIMINARY DESIGN OLYMPIA CAPITOL CAMPUS, OLYMPIA, WASHINGTON (08-076)

REPORT

Submitted To: Washington State Department of General Administration
210 West 11th Street SE
2nd Floor, Room 206
Olympia, Washington 98504-1012

Submitted By: Golder Associates Inc.
18300 NE Union Hill Road, Suite 200
Redmond, Washington 98052

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Table of Contents

List of Figures

List of Appendices

1.0 INTRODUCTION

The purpose of the Hillside Evaluation Project (Project) was to evaluate slopes on the Capitol Campus in Olympia for stability, risk of failure, and consequences of slope failure with respect to managing the campus assets such as buildings and infrastructure. The project was planned with three phases that included research, stability assessment, and reporting.

The Project was originally defined to include slopes from the south boundary of the campus to the north legislative parking area slopes extending to (but not including) Heritage Park. During a meeting with General Administration (GA) personnel on August 6, 2009, an expansion of the study area was discussed to encompass slopes near the Greenhouse and the GA Building. The slopes of the Heritage Park Trail have been extensively evaluated by others and are not included within the Project evaluation area. However, information related to the Heritage Park Trail is discussed when applicable to other project areas.

1.1 Scope of Services

The scope of services for this project consisted of three primary phases: Research, Stability Assessment, and Reporting. A brief description of the activities performed for each phase is discussed in the following sections.

1.1.1 Research

Visits to the General Administration (GA) archives were completed on several occasions (September 10 and December 4, 2008 and January 8, February 20, and September 16, 2009) to gather information related to geotechnical studies and construction of campus buildings. Information collected included historic borings, site plans, records of slope failures, and construction plans. Approximate boring locations from the reviewed reports were added to a project database in CAD format. The working project spatial database was developed in CAD using a CAD base file provided by Blair Prigge of Parametrix in December 2008.

A qualitative evaluation of the campus slope stability was also performed. The evaluation was performed during site visits by Golder geologists. Slope conditions and key slope features were documented during these visits.

1.1.2 Stability Assessment

Services performed under the Stability Assessment phase of the campus slopes included drilling two geotechnical borings, installing inclinometers to monitor slope movements, installing vibrating wire piezometers to monitor ground water conditions, and performing slope stability analyses. One boring was advanced behind the Pritchard Building; the other boring was advanced behind the Governor's Mansion.

The slope stability analyses were performed to identify areas with the greatest likelihood of slope failure. The slope stability analyses consisted of a relative ranking of the slopes by factor of safety for the static

condition. Subsurface conditions were modeled using information from borings completed by others on the campus and information from the borings advanced by Golder for this project. The slope locations analyzed for stability included:

- Slopes west of the Pritchard Building
- Slopes west of the O'Brien Building
- Slopes west of the Governor's Mansion
- Slopes east of the Powerhouse (both south and north of the steam lines)
- Slopes north of legislative parking area (North Parking Lot)
- Slopes west the Greenhouse
- Slopes west of the GA Building

Based on the results of the slope stability analyses, potential slope stabilization projects were identified.

1.1.3 Reporting

The Final Reporting task was to provide a summary report document that incorporates project findings, evaluations, and completed technical memorandums. The final project bibliography and spatial database(s) were completed under this task. The reporting task also included preparation of a campus monitoring report.

1.2 Report Outline

This report documents the methods, results, conclusions, and recommendations of our geotechnical site investigation and slope stability analyses of the slopes on the Capitol Campus. The report is organized as follows:

- **Section 1 (Introduction)** this section.
- **Section 2 (Site Conditions)** outlines the physical setting of the project and provides a summary of our understanding of the history of the Capitol Campus slopes and nearby buildings and infrastructure.
- **Section 3 (Subsurface Explorations and Conditions)** describes the methods used to complete the field investigation, discusses the general geologic setting of the project, and summarizes the subsurface soil and groundwater conditions encountered during the field investigation; this section also describes laboratory testing and installation and monitoring.
- **Section 4 (Slope Stability and Risk Evaluation)** describes the results of our slope stability analyses and presents an overview of the risk evaluation and the results.
- **Section 5 (Conclusions and Recommendations)** summarizes conclusions about the causes of campus slope failures and presents recommendations to address stability issues.
- **Section 6 (Schematic and Final Designs)** presents an overview of the schematic designs and associated cost estimates.
- **Section 7 (Closing)** presents our closing statements.
- **Section 8 (References)** documents the outside resources referred to in performing the investigation and analyses.

The following appendices are also included with this report:

- **Appendix A (Field Explorations Procedures, Data, and Logs)** presents a summary of the various explorations completed for this project and other projects in the vicinity.
- **Appendix B (Laboratory Testing and Analysis)** presents the detailed results of the laboratory testing.
- **Appendix C (Inclinometers and Piezometers)** presents monitoring results of the inclinometers and piezometers.
- **Appendix D (Instrumentation Monitoring Program)** presents the recommended monitoring program and manuals for the instruments.
- **Appendix E (Technical Memorandums)** presents copies of memorandums submitted during previous phases of the project.
- **Appendix F (Annotated Bibliography).**

2.0 SITE CONDITIONS

The project limits include slopes extending north and northeast from state owned property near the south edge of the Pritchard Building to the slopes west of the GA Building. Down slope project limits extend to the water's edge or the railroad tracks and up slope limits extend to approximately 100 feet beyond the top edge of campus slopes. Structures of interest include the Pritchard Building, the O'Brien Building, the Governor's Mansion, the Powerhouse, the Greenhouse, the soldier pile wall, and the GA Building. This report section provides a discussion of data sources, research findings, and observations related to site conditions.

2.1 Site Basemap and LiDAR

Basic project information used for evaluations included a site basemap provided by Parametrix and topographic information from LiDAR (Light Detection and Ranging).

2.1.1 Site Basemap and Datum

An electronic site basemap showing key exploration locations and other site features was created by Parametrix based on a site utility survey and provided by Parametrix in December 2008. Golder updated the basemap to include the approximate location of selected geotechnical explorations (borings) identified during review of reports from the GA archives.

The approximate locations of the explorations are shown on the AutoCAD basemap provided as Figure 2 and Figure 3; an oversize version of Figure 2 is also provided as a foldout drawing in Appendix F at the end of this document. In the electronic basemap file, an image of the boring log is hyperlinked to the boring location; right clicking (assuming a right-hand mouse) on the boring location will open an image of the boring log. Copies of the boring logs linked in the AutoCAD file are presented in Appendix A. The basemap can serve as a resource for campus personnel to identify previous explorations on the site. The basemap can be updated to include future explorations.

Important Note: the project basemap horizontal datum is NAD1983 and the vertical datum is NAVD88. Most of the historic drawings appear to have been completed using City of Olympia Vertical Datum (COVD). The correlations between these two datums is variable – estimated to be between about 13.4 and 13.8 feet (e.g., 100 foot City Olympia Vertical Datum = approximately 113.4 to 113.8 feet NAVD88 datum). The elevations presented in this report will indicate the datum that is referenced.

2.1.2 LiDAR

LiDAR data were used in the project for multiple purposes. The LiDAR was flown in early winter 2002, and the bare earth data was downloaded from a publically accessible site in June 2008 (Puget Sound LiDAR Consortium 2008). These data were processed in GIS to produce a shaded topographic version of the data (Figure 4) as well as topographic information that was imported to the CAD basemap. The shaded topographic image was used to support geomorphic interpretations, and the topographic

information imported to CAD was used for stability evaluations and design. The LiDAR data is provided on Washington State Plane North Zone, NAD 1983 horizontal datum and NAVD88 vertical datum. It is generally not possible to determine the accuracy of public LiDAR data without a topographic survey. However, the accuracy of the data can be estimated from the return signal density and an understanding of the ground condition effect on LiDAR returns. Typically, horizontally accuracy is much greater than vertical accuracy. Based on experience with similar data, the relative accuracy of vertical data for the project should be considered no better than +/- 5 feet.

Geomorphic features identified from LiDAR interpretation, ground surface observations, and literature reviews are shown on the LiDAR image, Figure 4. The LiDAR image shows an upland area that is heavily modified, surrounded by natural and modified slopes on the west and north edges of the campus. All slopes around campus have geomorphic evidence of smaller, surficial slope failures that are usually visible on LiDAR. These smaller features are typically about 30 to 80 feet wide and about 50 to 100 feet long. Multiple west-facing scallops at the southwest edge of the campus reflect a series of very large, ancient, natural landslides that were likely initiated several thousand years ago, after the Vashon-age glaciers retreated and the Deschutes River down cut its channel. These large slides show a steeper edge or "scarp" at the top of the slope and a flatter accumulation zone near the middle to lower parts of the slope. The ancient landslide features are about 500 to 900 feet wide (north to south) and about 300 to 400 feet long (east to west, direction of movement).

Slopes west of the O'Brien and Pritchard Buildings are moderate to steeply inclined and show evidence of large-scale ancient landslides as well as artificial modification such as an apparent fill slope in the area adjacent to O'Brien and Pritchard Buildings. Very small, shallow slope failures are also visible on these slopes.

Slopes west of the Governor's Mansion, above the Powerhouse, and on the north side of campus are steep and irregularly sloped. On these slopes there are no current geomorphic features indicating large-scale post-glacial landsliding like the features that are visible west of the Pritchard and O'Brien Buildings. The steep slopes below the Governor's Mansion, Powerhouse, and north campus areas do show evidence of smaller-scale landsliding as shown on Figure 4. The slopes north and east of the Law Enforcement Memorial show a series of overlapping features possibly a combination of recent human-induced and older natural landslides. The slopes from the Powerhouse to the north part of the campus have been much more heavily modified by human activities such as historical grading, the Powerhouse construction, parking areas, the railroad embankment, Heritage Park Trail, and park construction along Capitol Lake.

2.2 Site Visits and Observations

Several site visits were performed to document campus slope conditions, observe geotechnical borings, and monitor instrumentation. The dates and purpose of site visits are summarized below:

Site Visit

Date of Visit	Purpose
7/31/08	Completed field reconnaissance to observe surface and slope conditions, document key slope features. Slopes observed included near Prichard and O'Brien Buildings, Governor's Mansion, north side of Powerhouse, and north parking area.
9/23/08	Completed field reconnaissance to observe surface and slope conditions, document key slope features; completed additional observations near north parking area and Heritage Park.
1/8/09	Observed slope conditions following a large storm event and high lake levels; focus on slopes north of parking area.
2/20/09	Met to discuss proposed activities and observe liner around the diesel tank. Also completed reconnaissance of slope above south side of the Powerhouse.
5/29/09	Drilled and installed inclinometers and piezometers, GB-1 and GB-2.
7/1/09	Completed baseline inclinometer and piezometer reading for GB-1 and GB-2.
8/27/09	Completed first reading of inclinometer and piezometer at GB-1 and GB-2. Baseline inclinometer reading for DH-1 and DH-2. Trained GA staff on inclinometer monitoring procedures.
12/2/09	Completed second reading of inclinometer and piezometer at GB-1 and GB-2. Completed first reading of inclinometer at DH-1 and DH-2. Completed initial reading of piezometers DH-7P, HC-2, HC-3, HC-5, HC-6, and HC-7. Trained GA staff on inclinometer and piezometer monitoring procedures. Observed condition of soldier pile wall.

2.2.1 Site Development

Observations of developed conditions were made during campus site visits as described in this section.

Pritchard Building

The Pritchard Building is approximately 11 feet from the slope edge at the southeast part of the building. The building is a multi-story structure, clad in sandstone panels, with a basement; no notable foundation cracking was observed. The southeast edge of the building is surrounded by concrete sidewalks and landscape areas. There is a shallow (4- to 6-inch-deep) trough visible on the outer side of the sidewalk near the southeast part of the building, extending about 40 feet. According to campus maintenance personnel, this trough could be related to installation of a storm drain system aligned with the edge of the sidewalk and trending toward the O'Brien Building. There is also some minor tilting and separation of nearby sidewalk slabs.

O'Brien Building

At the time of our initial site visits in 2008, the west side of the O'Brien Building was approximately 25 feet from the slope edge. Subsequent to those visits, a new basement addition was constructed that is located as close as approximately 6 feet from the slope edge. A lawn area is present between the

O'Brien Building and the slope edge. We understand that a below-grade soldier pile shoring wall was constructed between the new addition and the slope as part of the basement structure.

Governor's Mansion

The Governor's Mansion is an older brick structure that is located on a small hill above other campus buildings. The mansion is surrounded by landscaped areas and naturally vegetated areas. The southwest corner of the mansion is approximately 25 feet from the slope edge. No evidence of ground cracking or movement was observed near the mansion.

Powerhouse

The campus Powerhouse lies at the base of a slope on the west side of campus and provides steam heat to the campus. The Powerhouse is accessed by a stairway from the North Parking Lot and a maintenance road along Capitol Lake. The Powerhouse also includes a large (approximately 350,000 gallons) diesel oil tank south of the Powerhouse that is used for backup steam generation. The diesel oil tank is in a containment enclosure lined with a synthetic membrane. The tank may be drained in the future and used to store reclaimed water for reuse. Several utilities are present near the Powerhouse including: a sanitary sewer pump station north of the Powerhouse; a primary natural gas line feed near the top of the stairway; and multiple other utilities including several storm drain lines from the campus to the base of the slope, a steam line, a condensate line, chilled water supply and return lines, a communications line, and a potable water line.

North Parking Area

A large paved parking area is present east of the Powerhouse; this parking area extends north to near the top of the slope. Several utilities lie beneath the parking area including multiple storm drain lines, a natural gas line near the north edge of the lot; sanitary sewer; and power and communications lines. Also present are utilities associated with the Powerhouse, including the utilidor tunnel and steam, condensate, chilled water supply and return, communications, and potable water lines. The lot pavement is in generally good to fair condition; no cracks or settlement related to slope instability were observed during our visits.

Greenhouse

The Greenhouse is an "L" shaped two story structure east of the Heritage Park Trail. A second smaller shed-like structure is also present in the Greenhouse area. The Greenhouse structure is about 15 feet from the slope edge and the shed is less than 10 feet from the slope edge. The structures appear to be lightly loaded and are likely supported by shallow spread footings. Some cracking of foundations has been reported by others. The Greenhouse area includes a paved drive, parking, and storage area. No signs of ground or pavement cracking suggesting slope instability were observed during our visits.

Soldier Pile Wall

An approximately 230-foot-long soldier pile wall is located along the slope near and north of the Greenhouse. The wall supports a parking area on the north side of the Greenhouse and a lawn and parking area west of the GA building. The wall is approximately 30 feet from the paved parking area.

The soldier pile wall condition was observed during the site visit on December 2, 2009. Due to the vegetation cover (e.g., ivy extending up the wall and thick blackberry bushes on the slope below the wall), our access was limited to observations from the top of the wall and from approximately 30 feet west of the toe of the wall.

Our observations did not show any visible deterioration of the soldier pile wall. The soil loss at the toe of the wall appears to be less than 1 to 2 feet, although this observation was limited by heavy vegetation. The original wall design by GeoEngineers (1988) neglected the upper 9 feet of soil at the toe of the wall, permitting up to 9 feet of ground loss or small slope failures to occur at the toe of the wall without impacting the overall wall performance.

The condition of the wood lagging boards appears to be satisfactory. Specifically, the wood lagging boards do not exhibit signs of rotting or breaking. Portions of the wall are heavily covered with vegetation, and the condition of the boards covered by the vegetation could not be observed. Gaps between lagging boards were observed at approximately three locations (the gaps appeared to be approximately 3 to 6 inches in width). There was no evidence of soil sloughing out of the gaps between lagging boards. However, because of shadows, the presence or absence of voids could not be confirmed. No signs of ground subsidence were observed at the top of the soldier pile wall.

GA Building

The GA Building is a five-story building on the northwest edge of the Capitol Campus. A road and parking area are present west of the building. The building is approximately 40 feet from the slope edge on the northwest corner and 90 to 100 feet from the soldier pile wall on the west side of the building. Pavement on the nearby road and parking area is cracked and potholed, but there is no cracking that appears to be related to slope or wall movement.

2.2.2 Topography and Vegetation

Topography on and near the campus varies between relatively flat developed areas to steep slopes on the edge of campus above Capitol Lake. The west campus area slopes slightly downward to the north. Elevations vary from about 140 feet at the Governor's Mansion to about 20 feet at the base of slopes (NAVD88).

Pritchard and O'Brien Building Slopes

The slopes adjacent to Pritchard and O'Brien Buildings are about 110 feet high and are inclined from about 1.7H:1V in the upper part of the slope to flatter than 6H:1V at the lower part of the slope. The

upper part of the slope is very evenly inclined reflecting a zone of fill that was placed in this area as part of site development; the lower part of the slope appears to reflect the deposition zone from ancient landslide features.

Governor's Mansion Slopes

The slopes west of the mansion are about 120 feet high and generally sloped at about 1.2 to 1.3H:1V. Flatter slopes inclined at about 2.5H:1V are present near Capitol Lake reflecting a landslide run out zone potentially associated with 1996 and older landslides.

Slopes Powerhouse and Vicinity

The slopes east of the Powerhouse are about 90 feet high and vary from about 2.5 H:1V in regraded areas at the top of the slope to about 1.3H:1V in natural parts of the slope, with slopes steeper than about 1H:1V near the lower part of the slopes north and south of the Powerhouse structure. Parts of the slope north of the Powerhouse have been reconstructed as a reinforced slope inclined at about 1H:1V.

Slopes North Parking Lot (and Heritage Park)

The slopes adjacent to the North Parking Lot are about 90 feet high and inclined at about 1.25H:1V, with some steeper slopes at landslide scarps inclined at about 0.5H:1V. Slopes in the Heritage Park Trail area are inclined at about 2.5H:1V.

Slopes Greenhouse, Soldier Pile Wall, GA Building

Slopes west of the Greenhouse and GA Building are up to about 80 feet high and are inclined at about 1.25H:1V to 2.5 H:1V.

2.2.3 Surface Water

Other than Capitol Lake, there are no major surface water features on or near the campus. During site visits in late summer 2008, minor seepage (< ½ gpm) was observed near the base of the slope adjacent to the Pritchard and O'Brien Buildings. During these visits, low seepage (between about ½ and 1 gpm) was also observed at the base of slopes north of the North Parking Lot and at several slope locations near Heritage Park.

Palmer and Gerstel (1996a) noted small seeps and springs on landslide scarps near the south end of the Governor's Mansion during their field visits. Golder personnel did not observe these seeps during field visits to this area in summer 2009.

2.3 Site Data and Document Review

The project included research of the Capitol Campus development records and previous studies that could relate to campus slopes. Visits to the GA archives were completed on several occasions (September 10 and December 4, 2008 and January 8, February 20, and September 16, 2009) to gather information related to geotechnical studies for historical campus projects. Information collected included

historic borings, site plans, records of slope failures, and construction plans. Our studies and information review focused on structures, infrastructure, and other features close to the campus slopes that could be impacted by slope failure. An annotated bibliography of reviewed information is provided in Appendix F.

Over 60 geotechnical and geologic related reports and documents were reviewed for the Project. The reports were generally related to building improvements, slope failures, or other campus studies.

2.3.1 Plan Review - Campus Structures and Infrastructure

Historic design and construction plans were reviewed in the State archives to gather information about campus development that could be pertinent to the project. These plans are provided in the bibliography in Appendix F; key reviewed plans included:

- Site and foundation plans for the Pritchard Building
- Historic grading and foundation plans for the O'Brien Building
- Foundation and shoring wall plans for a 2009 addition to the O'Brien Building
- Limited plans for the Governor's Mansion
- A series of design plans for the Powerhouse including original construction, tank and containment area construction, and seismic upgrades
- Design plans for a soldier pile wall near the GA Building
- Design plans for the GA Building
- Other plans for the west campus that showed infrastructure or other features

2.3.1.1 Site Development History

Original site grades on the west campus are not fully known. Grading in parts of campus reportedly began in the late 1800s and early 1900s with construction of the Governor's Mansion and the Legislative Building. Grading occurred after approximately 1911 to fill in an old ravine west of the current location of Water Street (Palmer and Gerstel 1995; Author Unknown 1911). Additional grading appears to have occurred with construction of the Governor's Mansion in 1908 and the Powerhouse and the Temple of Justice in the early 1920s. Grading near O'Brien, Pritchard, and the Governor's Mansion occurred in 1937 – 1938, associated with O'Brien Building construction. This grading included placing fill on the slope west of O'Brien and Pritchard Buildings to create an access road and lawn area. Minor additional grading occurred in the early 1950s associated with the GA Building construction and in the late 1950s associated with Pritchard Building construction.

2.3.1.2 Buildings

Design drawings were found for the Pritchard building, O'Brien building, the Governor's Mansion, the Powerhouse, and the GA Building. Design plans were not found for the Greenhouse.

Pritchard Building

Based on a design drawing (Plot Plan by Paul Thiry Architect 1957a) showing existing site grades prior to building construction, there appears to have been relatively little grading of the slope near the Pritchard Building. This drawing shows the slope edge approximately 10 ft from building at the closest point; the current distance from the building to the slope edge is similar to that shown on the 1957 plan. Design and construction plans (Paul Thiry Architect 1957b) also showed foundations bearing at about 108 feet COVD and the basement floor at 110.8 feet (COVD). Original ground surface elevations appeared to range from about 115 feet COVD at the SW corner of Pritchard Building to about 130 feet COVD at the east side of the building (Jos H. Wohleb 1938a). Based on this information, it appears that the Pritchard foundations are likely bearing 7 to 12 feet below original site grades on the west side of the building closest to the slope.

O'Brien Building

Site plans for grading associated with O'Brien (Jos H. Wohleb 1938a) indicate that up to about 25 feet (measured vertically) of fill may have been placed on the edge of the slope to widen the area around the building. Plans show foundations extended to native soils with basement foundations at 99 to 105 feet COVD feet when the ground surface was at about 115 to 117 feet COVD (Jos H. Wohleb 1938b). The design drawings (Jos H. Wohleb 1938a) showed a distance from the original building to the slope edge varying from about 70 feet at the southern end to about 45 feet at the northern end. The current distance to the slope edge from the corner nearest the slope is approximately 25 feet, indicating that potentially 20 feet (horizontal) of the edge of the slope may have failed sometime in the past. However, no records of this failure were found during our research. The current slope configuration is very evenly inclined, potentially indicating repair or regrading of any failure that may have occurred.

In 2009, a new addition was added to the west side of O'Brien Building resulting in a building edge approximately 6 feet from the slope edge. This building addition included a basement similar to the existing structure with footings at approximately 98 to 100 feet COVD. The addition was constructed using soldier pile shoring that was left in place, and the new basement walls were cast against the shoring. The soldier piles along the northwest side of the addition (closest to the slope) extend to approximately 38 feet below the adjacent ground surface, to an elevation of approximately 90 feet NAVD88.

Governor's Mansion

Limited plans were available for the Governor's Mansion. The 1908 plans show that the south and southwest side of the mansion were originally excavated approximately 7 to 10 feet below existing grades to construct footings and a basement. A concrete retaining wall with a maximum height of approximately 13 feet was constructed around the south side of the Governor's Mansion in 1937-1938 in association with O'Brien Building construction. A new addition was added to the south and west part of the mansion in about 1974; the elevation of the footings for this addition is currently not known

(Ibsen Nelsen & Associates 1974). The garage was relocated to its current location during this renovation. There are also other smaller outbuildings, including a guard station and a soil shed, on the grounds of the Governor's Mansion.

Powerhouse

Site drawings dated 1920 (Wilder & White Architects 1920) show that the Powerhouse is founded on a combination of spread footings and piles. The spread footings were used on the east part of the building, which was excavated about 3 to 10 feet below existing grades on the adjacent slope to construct footings. The west part of the building is supported on a pile mat (number of piles, pile type, depth, and spacing unknown). Other major improvements to the Powerhouse facility included:

- The addition of an oil storage tank and containment area in about 1976 (Noel Adams PE & Associates 1976)
- Installation of a sewer pump station in 1980 (Howard Godat & Associates, 1980 a, b), placement of a synthetic liner in about 1993 (Anderson & Boone Architects 1993 a, b)
- A seismic upgrade in 1993 (ABAM Consulting Engineers 1993 a, b, c, d, e)
- Limited site repairs associated with the Nisqually Quake in 2003 and later (JWM&A 2003 a, b)

The drawings indicate that the oil storage tank and the outer containment wall are supported on piles of unknown depth (ABAM Consulting Engineers 1993). The containment wall on the east side of the tank consists of unreinforced concrete (sack grout) that has been placed against the soil slope (this part of the wall is not an engineered structure). The seismic upgrade activities included extensive soil anchors that were installed into the slope east of the building as well as a sheet pile wall driven along the west edge of the building to address liquefaction (GeoEngineers 1992 and ABAM Consulting Engineers 1993).

Greenhouse

No drawings were found in the archives for the Greenhouse. Based on the type of structure, it is likely that this building is supported on shallow footings. Review of historical drawings and exploration logs by others (Gerstel 1996) indicate that the Greenhouse is likely underlain by uncontrolled fill that was historically placed in a ravine that trended southward to the "Winged Victory" area. Settlement of the Greenhouse reportedly occurred starting in the 1960s.

Soldier Pile Wall

A soldier pile wall was constructed in about 1988 to address a slope failure that occurred west of the GA Building in 1986. The soldier pile wall extends southward to the edge of the parking area on the north side of the Greenhouse. These design drawings (Sverdrup Corporation 1988 a, b, c, d) show a soldier pile wall with piles approximately 50 feet long with up to 2 rows of tiebacks and an exposed wall face height of greater than 25 feet in some areas.

GA Building

The GA Building was constructed in the 1950s with a basement level that extends approximately one story below adjacent site grades. Based on site observations and plans review, the GA Building appears to be founded on spread footings supported by native soils.

2.3.1.3 Infrastructure

Campus infrastructure includes utilities, parking lots, sidewalks, and drive areas. Our evaluations focused on infrastructure that serves a larger part of the campus and that was located in areas that could be impacted by landsliding. Our understanding of site infrastructure is based on site maps completed by Parametrix (2008) and discussions with campus personnel. In some cases, we supplemented information provided by Parametrix with information from the archive files. Identified infrastructure includes:

- A large storm drain on the slope west of O'Brien Building that is tightlined to a discharge point downslope (near elevation 60 feet NAVD88)
- Steam lines and a gas line on the slope above the Powerhouse
- A sewer line from the pump station near the Powerhouse to the north parking area
- A gas line on the north edge of the north parking area that is within a few feet of the slope edge in some areas
- Several other storm drains with associated collection systems, including a large storm drain south of the Powerhouse

2.3.2 Report Reviews

Golder reviewed several reports and other documents directly related to campus slope stability. Key reports and documents included:

- Capitol Campus Bluff Slope Stability Analysis (Gerstel 1996a)
- Slope Stability Analysis of the Bluffs along the Washington State Capitol Campus (Gerstel 1996b)
- Capitol Campus Greenhouse Soil Stability Investigation Status Report. (Palmer and Gerstel 1995)
- Capital Campus Conservatory Soil and Slope Stability Investigation Final Report. (Palmer and Gerstel 1997)
- Design Memorandum, Geotechnical Consultation, Slide Correction, General Administrative Building (GeoEngineers 1988)

These documents provided a description of campus history and geologic and geomorphic conditions. One of the reports (Gerstel 1996b) was completed after a series of landslides in early February 1996. These reports described a history that included slope failures on most slopes around the Capitol Campus. A summary of these documented slope failures is provided below; other undocumented slides have probably occurred.

History of Slope Failures on Campus

Date	Location	Comments
1958	Slope in front of Temple of Justice	Near current Heritage Park Trail; winter 58-59
1965 – 1972	Campus-wide	Period of higher slope failure activity
1981	Campus-wide	Period of higher slope failure activity
1986/87	Slope west of GA building	Remediated by soldier pile wall in 1988
1990	Campus-wide	Period of higher slide activity
1990	Slope north of Powerhouse	Failure covered access road and RR; damaged NE corner of plant; remediated by reinforced slope
1996	Slope west of Pritchard Building	Slope failure estimated < 20 years old in 1997
1996	Slope west of Governor's Mansion	Slope failure estimated active last 30 years (as reported in 1996)
1996	Slope north of Powerhouse	Flow into lake related to heavy February rains
1996	Slope west of Governor's Mansion	Slopes west / southwest of mansion; failures extended to top of slope related to heavy February rains
1996	North slopes	Series of smaller failures related to heavy February rains
2002	Heritage Park Trail	Slope failure during construction (December)
2003	Heritage Park Trail	Slope failure during construction (October)
2009	Slope North of Parking Area	Small slope failure after heavy rain in early January

The reviewed documents provided information about subsurface explorations, slope stability analyses, and causes of slope failures. The subsurface information and data from currently existing monitoring instrument installations have been incorporated into this Capitol Campus study. Geologic conditions were similar to those observed in Golder explorations, and very little groundwater was observed. General causes of recent slope failures were identified as being related to saturation of loose/soft surface soils that mantle most campus slopes and small rotational failures initiating in the upper parts of slopes. The weak surface soils have formed through natural and human-caused processes, including remobilized soils from slope failures, soil creep, and sidecast fill or landscaping debris. The previous studies showed that stability of the surface soil mantle is very low when the layer is saturated – a condition that often occurs during and following heavy rainfall. The authors noted that the small rotational slope failures appeared to be related to small springs and seeps at the landslide headwalls.

3.0 SUBSURFACE EXPLORATIONS AND CONDITIONS

Golder personnel completed field explorations and reviewed explorations by others in order to assess the subsurface conditions that impact the campus slopes.

3.1 Field Exploration

The Golder field investigation was completed on May 26 through May 29, 2009 and consisted of advancing two geotechnical borings (GB-1 and GB-2). The approximate boring locations are shown on the Site and Exploration Plan, Figures 2 and 3. Locations are based on field measurements from existing buildings and a site survey by Parametrix (Parametrix 2008). Boring locations were selected based on existing site conditions, existing utilities, and accessibility by the drill rig. Boring logs and a summary of the field exploration procedures are provided in Appendix A.

3.1.1 Drilling

The borings were advanced using mud rotary drilling methods with a B-61, truck-mounted drill rig equipped with an autohammer. The drill rig was operated by Holocene Drilling Inc. under the full-time observation of a Golder geologist, Alison Dennison. The borings GB-1 and GB-2 were advanced to depths of approximately 103 and 104 feet below the existing ground surface (bgs), respectively. Logging and sampling of soils were performed in general accordance with Golder Associates procedures for field identification of soils, based on the Unified Soil Classification System (USCS). A summary of the soil classification terminology is presented on the Soil Classification Legend in Appendix A. The collected soil samples were returned to our Redmond, Washington laboratory for further classification; laboratory testing was performed by Soil Technology, of Bainbridge Island, Washington.

The stratigraphic contacts indicated on the boring logs represent the approximate depths to boundaries between soil units; actual transitions between soil units may be more gradual. The subsurface descriptions are based on the conditions encountered at the time of exploration. Subsurface conditions between exploration locations may vary from those encountered, and groundwater may be present during certain times of the year.

3.1.2 Installations

After completing each exploration, an inclinometer casing and vibrating wire piezometer (a type of electronic device to measure groundwater pressure) were installed in each boring. The inclinometers extend approximately 98 feet bgs in boring GB-1 and 102 feet bgs in boring GB-2. The vibrating wire piezometer was installed at 80 feet bgs in GB-1 and 50 feet bgs in GB-2. The inclinometer and vibrating wire piezometer installation details are presented in Appendix A.

3.2 Laboratory Testing

Geotechnical laboratory testing was conducted by Soil Technology on representative samples from the borings for the purpose of classification and evaluation of pertinent engineering properties. Laboratory

tests included natural moisture content determination, sieve analyses, percent fines content, and Atterberg limits. The field soil classifications were revised where applicable based on laboratory testing results. Laboratory test methods and results are provided in Appendix B.

3.3 Explorations by Others

Exploration logs were gathered from reviewed reports in the GA archives and from other sources. A summary table of explorations and copies of these explorations completed by other consultants are provided in Appendix A-2. Approximate locations of these explorations are shown on Figures 2 and 3. Please note that these explorations vary greatly in age, ranging from 1937 through 2008, and the classification system used on logs is different between consultants and over time. The approximate locations of these explorations were often determined from reproduced site plans within reports, sometimes without scales or defined site features. No exploration locations are based on surveying.

3.4 Campus Geology

The recent geologic history of the Puget Sound region has been dominated by several glacial episodes. The most recent episode, the Vashon Stade of the Fraser Glaciation (about 12,000 to 20,000 years ago), is responsible for most of the visible geologic and topographic conditions in the region. The regional Puget Sound landscape is characterized by elongated north-south oriented uplands and intervening valleys associated with this glacial advance and retreat. Older (Pre-Vashon) deposits are seen in some areas at the base of coastal bluffs; these deposits include glacial and nonglacial sediments deposited during repeated glacial and interglacial periods during the past two million years.

The Puget lobe of the Vashon Stade advanced south from British Columbia into the Puget Sound lowland reaching maximum extent south of Olympia about 17,000 years ago (Haugerud and Greenberg 2003). Sediments deposited with this glacial event typically include proglacial lacustrine silt and clay, advance outwash, and lodgment till. These sediments were overridden by thick glacial ice and are typically overconsolidated and strong. As the Puget Lobe of the Vashon Stade glacier retreated northward, it deposited a discontinuous veneer of recessional outwash and other local deposits that are normally consolidated and weaker than older glacial deposits (e.g., ice did not override these deposits). Post-glacial deposits include alluvium deposited within active stream channels, modern lacustrine (i.e., lake) deposits, marine and deltaic deposits, localized organic silt and peat deposits, landslide deposits, and volcanic deposits such as pyroclastic flows and lahars associated with post-glacial activity.

The *Geologic Map of the Tumwater 7.5-minute Quadrangle, Thurston County, Washington* (Walsh, Logan, Schasse, and Polenz 2003) covers the Capitol Campus. The geologic map shows all of the Capitol Campus mapped as Latest Vashon recessional sand and minor silt (Qgos). This unit is described as moderately well sorted, moderately- to well-rounded, fine- to medium-grained sand with minor silt. Based on boring observations, Latest Vashon fine-grained sediments (Qgof) may also be present. Qgof is less than 10 feet thick and is associated with small lakes that formed during the glacial

recession. Interpreted pre-Vashon deposits (Qps and Qpg) were observed in exposures near the base of west facing slopes and in both Golder borings; however, these units are not distinctly shown on the geologic maps. Geologic mapping describes Qps as thin- to thick-bedded to cross-bedded sand interbedded with laminated silt and minor peat and gravel. Qpg is described as gravel and sand from non-local sources, commonly tinted orange with iron oxide staining, moderately to poorly sorted, and commonly cross-bedded. The Vashon and pre-Vashon age deposits are interpreted to be underlain by bedrock at depth.

The geologic map also contains a cross-section view of units near the project. The cross-section shows a thick sequence (potentially up to 400 feet thick) of Qgos underlying the project area and most of downtown Olympia. This deposit is the result of a large outwash channel in the Olympia area that occurred as the glacier retreated. The deposits associated with this channel are laterally discontinuous and have wide-ranging grain size and characteristics.

3.5 Subsurface Conditions

Subsurface conditions were observed by Golder in limited exposures during site visits and from soil samples during drilling. Interpreted subsurface soil conditions were generally consistent with reports and exploration logs by other consultants. Soils observed in Golder explorations included late Vashon recessional deposits overlying Pre-Vashon deposits. The recessional strata were deposited in a very active fluvial environment resulting in interbedded soil units that are discontinuous between borings.

3.5.1 Observed Soil

A layer of topsoil and undocumented fill was encountered at the ground surface in both borings, GB-1 and GB-2, extending 7.5 to 4.5 feet bgs, respectively. Below the topsoil and fill, both borings encountered soil consistent with the geologic map descriptions of the Latest Vashon recessional sand and minor silt (Qgos), Pre-Vashon sandy deposits (Qps), pre-Vashon lacustrine deposits (Qpf), and Pre-Vashon gravel (Qpg). Summary information about soil units is presented in the table below; additional information is shown on the boring logs provided in Appendix A.

Topsoil/Fill (Qf)

Topsoil is a soil unit that contains a relatively high percentage of organics. The observed topsoil was relatively thin and consisted of loose, dark brown, silty fine to medium sand with little fine to coarse gravel and some organics. Fill is a soil unit placed by man; the observed fill is considered undocumented because there are no specific records that document the amount of compaction effort that was used to place the fill. The observed undocumented fill was variable in character, consisting of moist, loose to compact, yellow brown to brown gray, fine to medium sand with silt to stiff sandy silt. Fill was observed in Golder borings to depths of between 4.5 and 7.5 feet.

Latest Vashon recessional sand and minor silt (Qgos) and Latest Vashon fine-grained sediments (Qgof)

These deposits were encountered beneath fill at borings GB-1 and GB-2. The deposits included alternating layers of stratified silt, sandy silt, silty fine to medium sand, and fine to medium sand with little silt. Consistency and density of the layers ranged from very soft / loose to hard / dense. The deposits were in moist condition.

Pre-Vashon sandy deposits (Qps) and lacustrine deposits (Qpf), and gravel (Qpg)

These units were deposited in fluvial and lacustrine environments before the advance of the Vashon glacier and were subsequently over-ridden by the glacier. These soil units were over-consolidated by the weight of glacial ice; the soil units are relatively strong in comparison to the younger, overlying normally consolidated Qgos and Qgof. Both borings terminated in these Pre-Vashon deposits. At boring GB-1, an interbedded sequence of silt and sand interpreted to be Qpf and Qps was encountered at 86 feet below the ground surface (bgs). At boring GB-2, Qps was observed at 91 feet bgs. The Qpf observed in Golder borings was typically a hard, yellow brown to gray silt; the observed Qps was a very dense dark gray brown stratified fine to coarse sand with little to trace silt and some fine gravel. Pre-Vashon gravel (Qpg) was encountered in GB-1 at 91 feet bgs and was observed in an exposure near the base of the slope near the Powerhouse. At the exposure, the unit consisted of stratified, iron oxide-stained sandy fine to coarse gravel.

3.5.2 Groundwater

No free groundwater was observed by the driller during the advancement of either GB-1 or GB-2. However, based on observed soil types that are likely to hold free groundwater, vibrating wire piezometers (VWPs) were installed in both borings. The installation depths of the VWPs were based on the soil types, relative moistures, and general stratigraphy that would tend to accumulate groundwater, if present. Groundwater measurements from the VWPs in borings GB-1 and GB-2 are provided in Appendix C.

Most of the observed soil natural moisture content is close to or above optimum moisture.

4.0 SLOPE STABILITY ANALYSES AND RISK EVALUATION

The slope stability analyses performed for this study included both qualitative and quantitative evaluations of the campus slopes. The goal of the stability evaluations was to identify where specific stabilization projects should be considered and to aid in the selection of potential stabilization alternatives.

Qualitative evaluation of project area slope stability included evaluation of the landforms and underlying geology of project slopes. Quantitative slope stability evaluations included stability analyses of the existing slope configuration at nine locations with potential risk to campus infrastructure. These locations included slopes near the Pritchard and O'Brien Buildings, the Governor's Mansion, the Powerhouse (south and north slopes), the north parking lot, the Greenhouse, the soldier pile wall near GA Building, and the GA Building. At each of these locations, shallow and deep failures were evaluated.

4.1 Qualitative Slope Stability

The stability evaluations included two site visits (July 31 and September 23, 2008) by Golder geologists, Deb Ladd and Dave Findley, for field reconnaissance to observe surface conditions on the campus and nearby slopes. The project lies along former coastal bluff slopes that show geomorphic landforms evidencing ancient landslides and recent slope failures (Figure 4). These landforms are visible on LiDAR images and were observed during site visits; many smaller failures have been documented by previous campus studies and reports. Golder borings and borings by others did not show evidence of colluvium or failed soils, because the borings were located in stable areas away from the slope edge.

Indications of ancient deep-seated landslides are visible on the LiDAR image west and south of the Pritchard and O'Brien Building slopes and possibly on slopes west and north of the GA building (Figure 4). Campus slopes in these areas typically show a scarp at the top of the slope and a flatter accumulation zone near the middle to lower parts of the slope. These ancient landslide features are about 500 to 900 feet wide and about 300 to 400 feet long. These deep-seated landslides near the campus may have occurred after the retreat of the Vashon-age glacier in the south Sound and were caused by downcutting and erosion of the toe of the slope by the Deschutes River. The vegetation and geomorphology of the ancient landslide near the Pritchard and O'Brien Buildings does not show evidence of recent movement, and we did not find records of reported landsliding in this area. It is possible that these large ancient landslides are currently stable. However, changing groundwater conditions, human activities, and seismic loading have the potential to initiate movement of these types of slides. In addition, these areas may be subject to shallow surface slides even if the deep-seated landslide feature is stable. Deep-seated failures usually move at a slower rate than shallow slides.

There have been many historic smaller slope failures on the campus slopes, and these smaller slope failures will likely continue to occur. The existing small slope failures are typically about 30 to 80 feet wide and about 50 to 100 feet long. These slides are considered shallow slope failures that involve the upper 5 to 15 feet of soil and originate in natural colluvium or in fill soil and debris such as landscape cuttings

that are placed on the edge of slopes. The shallow slope failures have a factor of safety (FOS) against sliding very close to 1.0 during times when soils are saturated. An explanation of the relative likelihood of failure represented by a factor of safety is presented in Section 4.3.1.

Slopes west of the Governor's Mansion, above the Powerhouse, and on the north side of campus are steep and irregularly sloped and show evidence of many small, shallow slope failures (Figure 4). The slopes north and east of the Law Enforcement Memorial show a series of overlapping features possibly reflecting a combination of recent human-induced slope failures and older natural landslides. The slopes north and east of the Powerhouse have been heavily modified by human activities such as historical grading, including grading for the Powerhouse construction, parking areas, the railroad embankment, and the Heritage Park Trail. These modifications may have contributed to some of the shallow slope failures.

4.2 Quantitative Slope Evaluations

This section of the report summarizes the methodology and evaluation criteria for stability analyses conducted for this project. The results of the slope stability analyses are summarized in the *Stability and Risk Evaluation Update Memorandum* presented in Appendix E-2.

4.2.1 Methodology

An analysis of the stability of the existing slope conditions was carried out using the commercially available computer slope stability program, Slide version 5.043, a two-dimensional proprietary software code produced by RocScience, Inc. of Toronto, Ontario, Canada. The General Limit Equilibrium (GLE)/Morgenstern-Price method of analysis was used to compute the factors of safety for potential circular failure surfaces. Slide computes the factor of safety for different potential failure surfaces defined by the user's search criteria. The reported factor of safety for a slope is the lowest factor of safety computed for the failure surfaces within the search region.

The subsurface profiles used for stability analyses varied slightly between cross sections based on available subsurface information near each cross-section. For all stability analyses, modeled subsurface conditions included a surficial layer parallel to the slope and horizontal strata representing unconsolidated silt and sand units. At depth (approximately 66 to 91 feet deep), a stronger soil layer was modeled to represent over consolidated Pre-Vashon soil units. Soil strength parameters were determined from index property correlations, engineering judgment, and area experience. For correlation of soil data and parameters, we used Foundation Analysis and Design by Joseph E. Bowles (Bowles 1982) and the Naval Facilities Engineering Command Design Manual 7.01 (NAVFAC 1986). The slope stability cross-sections, including the soil stratigraphy and the shear strength parameters, are presented in the *Stability and Risk Evaluation Update Memorandum*, Appendix E-2.

The slope stability analyses were conducted for shallow and deep-seated failure modes at each of the areas of concern. The shallow slope failures modeled instability in a surficial soil layer that was approximately 10 to 15 feet thick. The deep slope failures modeled failure surfaces that were farther back

from the slope (e.g., 15 to 90 feet). The depth of modeled deep failures varied; the deep failures were specifically configured to intercept the structure or infrastructure.

4.2.2 Results of Stability Analyses

The results of stability analyses are summarized below for deep and shallow failures. The relative likelihood of failure associated with the factor of safety (FOS) is presented in Section 4.3.1.

Shallow Failure Results

Location of Shallow Failures	Static FOS	Comment
Pritchard Building	1.0	Failure in surficial soils, does not extend beyond edge of slope
O'Brien Building	1.1	Failure in surficial soils, does not extend beyond edge of slope
Governor's Mansion	1.0	Failure in surficial soils, does not extend beyond edge of slope
South Powerhouse (includes diesel tank)	1.0	Failure in surficial soils, does not extend beyond edge of slope
North Powerhouse	1.3	Slope reportedly reconstructed as a reinforced slope (The Portico Group 1998). Failure below reinforcing layer
North Parking Lot	1.0	Failure in surficial soils, does not extend beyond edge of slope
Greenhouse	1.0 to 1.1	Failure 15 feet from edge of slope ; the lower factor of safety (1.0) reflects localized seepage conditions
Soldier Pile and Tieback Wall west of GA Building	1.3	Assumed surficial failure of slope at toe of wall
Slope West of GA Building	1.1	Failure in surficial soils, does not extend beyond edge of slope

Deep Failure Results

Location of Deep Failures	Static FOS	Comment
Pritchard Building	1.1	Assumed failure at edge of Pritchard Building, approximately 15 feet from edge of slope.
O'Brien Building	1.3	Assumed failure at edge of O'Brien Building, approximately 25 feet from edge of slope.
Governor's Mansion	1.3	Assumed failure at edge of Governor's Mansion, approximately 25 feet from edge of slope.
South Powerhouse	1.4	Assumed failure beneath Powerhouse
North Powerhouse	1.5	Assumed failure beneath Powerhouse

Location of Deep Failures	Static FOS	Comment
North Parking Lot	1.4	Assumed failure 50 ft from top of slope
Greenhouse	1.2	Assumed failure at edge of Greenhouse, approximately 15 feet from edge of slope
Soldier Pile and Tieback Wall west of GA Building	1.6	Assumed failure at south edge of GA Building, approximately 90 feet from soldier pile wall
GA Building	1.2	Assumed failure affecting utilities near north side of GA building, approximately 20 feet from edge of slope

4.3 Slope Risk Evaluation

A slope risk evaluation was performed using the results of the slope stability analyses and the informational review of campus buildings and infrastructure. "Risk" represents the combination of the likelihood of occurrence of a slope failure and the resulting consequences of the slope failure. By combining the results of the slope stability analyses and our understanding of campus operations, a risk matrix was developed to assist the GA in prioritizing future stabilization measures and other activities. An overview of the slope risk evaluation is discussed in this section. The complete memorandum documenting the evaluation is presented as the *Stability and Risk Evaluation Update Memorandum* in Appendix E-2.

4.3.1 Likelihood of Failure

The likelihood of slope instability is commonly described by a factor of safety against failure. Slopes with lower factors of safety are at a higher likelihood for failure than slopes with higher factors of safety. For this study, the factor of safety computed from the stability analyses was used to rank existing campus slopes under the following categories for likelihood of failure:

- Less likelihood of failure - factor of safety greater than 1.1
- Moderate likelihood of failure - factor of safety between approximately 1.0 and 1.1
- High likelihood of failure - factor of safety approximately 1.0 or less

It should be noted that the factors for safety were used for relative ranking of failures and that a factor of safety of 1.1 is still relativity low.

4.3.2 Consequences

An understanding of the consequences of a slope failure is needed to evaluate the potential impacts of slope failures and assist in prioritizing slope stabilization options. For example, a slope with a high likelihood of failure that does not have any potential impacts from failure would have lower priority than a slope failure that could damage campus infrastructure. Three different categories of consequences were established to help rank the impact to the campus if a slope failure occurred:

- Low consequences of failure are limited to minor public perception and maintenance requirements; the response can likely be handled by GA personnel.
- Medium consequences of failure include damage to local infrastructure (including loss of service utilities, parking, etc), cosmetic damage to structures, and moderate maintenance activities; the response by GA may require assistance from an outside entity.
- High consequences of failure include damage to structures or damage to campus infrastructure that results in large-scale loss of service; the response by GA is likely to involve outside technical consultants and may include emergency repair or construction.

4.3.3 Risk

"Risk" is a combination of the likelihood of failure and the resulting consequence of failure if it occurs. The risk evaluation was performed to assist the GA in identifying and prioritizing potential stabilization projects. A high-risk slope is a slope with a high likelihood of failure and high consequences of failure. A low risk slope is a slope with a low likelihood of failure or low consequences of failure. A risk matrix summarizing the results of the risk evaluation of the campus slopes is presented in the *Stability and Risk Evaluation Update Memorandum* in Appendix E-2. The results of the risk evaluation indicated that high-risk failures included:

- Shallow slope failures near and south of the Powerhouse
- Shallow slope failures near the Pritchard Building
- Shallow slope failures near the Greenhouse

These high-risk failures have the potential to affect buildings such as the Pritchard Building and the Greenhouse. A failure on slopes above the Powerhouse has the potential to affect the Powerhouse and utility services to the campus; failure in this area could also affect the large diesel oil storage tank.

The results also indicated that moderate-risk failures included:

- A deep failure that intercepts the edge of the Pritchard Building
- Shallow slope failures near the Governor's Mansion
- Shallow slope failures near the North Parking Area

These high-and moderate-risk failures were then compared to potential slope stabilization alternatives to develop a short list of alternatives for schematic designs.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The Capitol Campus has a documented history of shallow slope failures as well as geomorphic evidence that much larger landslides have occurred in geologic history after the retreat of the Vashon-age glacier. Many of the failures observed on slopes near the campus occur because of natural causes. In some cases, failures have been caused by human activities, such as loading with fill or other material placed on the top of slopes and excavations made at the base of slopes.

5.1 Causes of Slope Failures

Slope failures that have affected the Capitol Campus include “shallow” slope failures and “deep-seated” landslides. Shallow slope failures refer to ground movement that typically affects the outermost 5 to 15 feet of soil on a slope. Shallow failures are relatively common in the Puget Sound area, originating in loose surface soils, natural colluvium, fill, and debris and landscaping materials. Historically, in the Puget Sound and on the Capitol Campus, these shallow failures are caused by saturation of loose / soft surface soil that typically occurs during or soon after periods of wet weather. The slope failures can affect infrastructure and structures at the top of the slope within the slide zone. Shallow failures occur relatively quickly – usually in the timeframe of a few minutes. These slides often travel down slope as a semi-fluid flow and can damage structures located at the base of the slope. Many historic slope failures at the Capitol Campus (e.g., slides documented from winter 1996 storms and others) are considered “shallow”.

The large, ancient landslides visible on campus slopes were probably caused by loss of support at the bottom of the slope caused by post-glacial downcutting of the Deschutes River. This process is no longer occurring, and as a result, these ancient landslides may be currently stable. However, changes in grade (e.g., adding fill at the top of the slope or cutting at the toe of the slope) or changes in surface and groundwater can re-activate ancient landslides. Slopes within stable ancient landslides may still be subject to shallow surface slides even if the deep-seated landslide feature is apparently stable. Because the consequences of re-activating the ancient landslides could be significant, the ongoing stability of the ancient landslides should be confirmed by the monitoring described in this report.

5.2 Slope Setbacks

Construction close to campus slopes should be avoided unless site-specific studies demonstrate that the development can be accomplished with an acceptable risk. Development is considered to include utilities, pavements (roadways, parking lots, sidewalks), and structures. The recommended setbacks have considered:

- The risk of development – whether slope failure would result in unacceptable risk because of damage to the development or safety risks related to failure
- The relative likelihood of slope failure at different distances from the slope edge
- The varying sensitivity to slope movement for different types of development

- The potential for loading the slope or creating conditions that would detrimentally affect slope stability.

Based on these considerations, we recommend the following setbacks from the slope edge for campus development:

- 0 to 30 feet – no development in this zone. In addition, vegetation should not be disturbed without an evaluation of potential effects of disturbance.
- 30 to 50 feet – non-critical development that can tolerate creep or slope movement. This includes limited development of features that would not result in an unsafe condition if the slope failed. Paved areas and some utilities could be considered in this zone. Utilities in this zone should be designed with flexible connections and automatic shutoff capabilities in case of rupture.
- Greater than 50 feet – critical structures and infrastructure could be constructed in this zone.

Infiltration facilities are an exception to the above setbacks. Infiltration facilities are features designed to allow stormwater to percolate into the subsurface. Infiltration facilities may include (but are not limited to) ponds, swales, vaults, dispersion pipes, trenches, and similar facilities. To avoid increasing groundwater levels at the slope edge and thereby reducing stability, infiltration facilities should not be allowed on the west campus except under limited circumstances, and they should not in any case be located closer than 100 feet of the slope edge. Site-specific evaluations should be performed at the location of any proposed facilities that would infiltrate more than 125% of the associated infiltration area.

Stormwater should be managed to minimize infiltration into slope areas. In particular, because stormwater pipes should not discharge on or above the campus slopes, new or existing stormwater discharge lines may need to be installed or replaced on slopes. Currently, the west campus stormwater lines are of variable pipe type and condition. Replacing these pipes or constructing new stormwater systems should include designs that:

- Use a flexible and strong material such as welded high density polyethylene (HDPE) that can withstand minor slope movements,
- Include an anchor system at the top of the slope and potentially on the slope to hold the pipe in place, and
- Discharge at the base of the slope with erosion protection to prevent slope instability caused by erosion of the slope.

5.3 Recommended Maintenance Activities

Regular maintenance activities can reduce the likelihood of slope failures. Key maintenance activities are associated with storm drains, other utilities, and landscaping and pavements. Specific maintenance activities related to the existing soldier pile wall are also important for slope stability.

5.3.1 Storm Drain Systems

The Capitol Campus has an extensive storm drain system of variable age and construction. Appropriate operation and maintenance of this system will reduce the potential for raising groundwater elevations at

locations that could increase the likelihood of slope failure. It is important that storm drain systems within about 200 feet of the slope edge be intact and not leaking or overflowing stormwater. Systems in this area should be evaluated for broken or separated pipes, and catch basins should be regularly cleaned. The existing NPDES permit requirements may provide guidelines for maintenance related to these facilities.

5.3.2 Other Utilities

Existing utilities such as water and gas may be present near slope edges (e.g., within about 20 feet). The ground surface near these utilities should be regularly inspected for signs of cracking or movement that could cause damage to these utilities. An annual inspection of the slope edge area to document conditions should be conducted for this purpose.

5.3.3 Landscaping and Pavements

Landscaping practices can contribute to slope instability. Lawn cuttings and brush piles should not be placed at the top of or on slopes, because these materials can become saturated and unstable. In addition, irrigation near slope edges should be minimized to the extent possible, and irrigation systems within about 50 feet of a slope edge should include automatic shutoff systems that would stop flow to a section of line that is broken.

Landscaping activities should also consider reduction or removal of shallow rooted species such as English Ivy and blackberries. Unlike many native shrubs and trees, shallow rooted species do not provide rooting systems that are beneficial to slope stability. In addition, ivy may harm tree health on slopes where tree root systems are improving slope stability. A discussion of these species is provided in the memorandum in Appendix E-1, and a vegetation management program is described in the memorandum presented in Appendix E-3.

Proper maintenance of pavements near slope edges (e.g., within about 20 feet) can reduce infiltration of surface water that could contribute to slope failures. Maintenance should include filling cracks with hot tar and maintaining a pavement surface that conveys surface water towards the storm drain system.

5.3.4 Soldier Pile Wall

Based on our observations, the following maintenance activities are recommended for the soldier pile wall west of the GA building:

1. Remove vegetation growing on the wall and maintain a vegetation-free wall. Trim vegetation at the toe of the wall to allow access for wall inspection.
2. Evaluate the presence of lagging board gaps and determine if voids are present behind the wall. This evaluation will require access with a ladder from the bottom of the wall or a rope/harness system from the top of the wall. A specialized consultant may be required to determine whether voids are present behind the lagging with methods such as geophysical assessment or manual removal of lagging boards.

3. If there is a gap between the lagging boards and the soil, the area should be backfilled with a granular material that does not allow water pressure to build up. Potentially suitable materials include pea gravel, sand, or controlled density fill (CDF); the use of these materials should be evaluated by a professional engineer based on the characteristics of the voids.

5.4 Recommended Monitoring

Regular observation and monitoring is recommended to identify signs of slope instability movement before large amounts of movement or damage occur.

General site observations should be completed near the slope edge on at least an annual basis and documented in maintenance logs and with photographs. Key features to observe and document include:

- Buildings and structures near slopes – observe and document condition of foundations and walls.
- Walkways and pavements – observe and document cracking and tilting. Note width and depth of cracks.
- Ground surface – observe and document the surface conditions near slope edges including any sloughing, cracking, settlement, or low spots.
- Groundwater - observe and document seepage or groundwater discharge, especially in areas where the condition had not been seen previously.

Specific monitoring with the current installed inclinometers and piezometers is recommended as described in the Monitoring Plan provided in Appendix D. Possible future monitoring could include installing additional inclinometers and piezometers and establishing new surface survey monitoring points. A schematic design with these components is described in the memorandum presented in Appendix E-3.

5.5 Potential Stabilization Alternatives

A general description of potential stabilization alternatives for addressing slope stability issues was presented in the *Stability and Risk Evaluation Update Memorandum* in Appendix E-2. Alternatives evaluated included no action; observations, instrumentation, and maintenance; dewatering; earthwork; in-situ reinforcement; a reinforced slope; and a structural (e.g., soldier pile) wall. The approximate relative costs for the stabilization alternatives as well as potential advantages and disadvantages of each are presented in the *Stability and Risk Evaluation Update Memorandum* (Appendix E-2).

From the potentially applicable stabilization alternatives, four alternatives were selected by GA personnel to be developed as schematic designs. These alternatives included:

- A campus-wide instrumentation program
- A soldier pile wall at the Pritchard Building
- A reinforced slope above the south side of the Powerhouse
- Campus vegetation management

6.0 SCHEMATIC AND FINAL DESIGNS

Based on evaluations and discussions with GA personnel, four stabilization alternatives were selected to develop further into schematic designs. From these four alternatives, one or more stabilization approaches will be selected to bring to the final design phase to support a GA project in 2010.

6.1 Schematic Design

The four stabilization alternatives were selected by the GA based on the results of the risk evaluation. The four alternatives were chosen for different purposes. The soldier pile wall near the Pritchard Building and the reinforced slope above the Powerhouse were selected to address risks to structures at these locations from slope failures with relatively high likelihood of failure. A campus-wide instrumentation program was selected as a lower cost way to monitor the long-term performance of campus slopes with particular emphasis on locations with higher risks from failure (inclinometers would be installed on slopes above the Powerhouse and near the North Parking Lot; survey points would be installed throughout campus). A vegetation management program was selected by GA as a lower cost alternative to remove vegetation that could adversely affect slope stability.

The schematic designs were prepared to assist the GA in selecting a project to plan and construct in 2010. Schematic design information will also assist the GA in future project planning. The alternatives selected for schematic design included:

- A campus-wide instrumentation program with four inclinometers, four piezometers, and multiple survey monitoring points
- A 160-foot-long soldier pile wall near the Pritchard Building
- A reinforced slope area of about 25,000 ft^2 above the south side of the Powerhouse
- A vegetation management program to remove or reduce ivy and other invasive species on campus slopes

The *Revised Schematic Design Alternatives* memorandum summarizing the schematic designs is presented in Appendix E-3. The memorandum includes a description of each alternative, the goal of the alternative, and cost estimate information. Estimated costs (estimated in 2009) for the four schematic design range from approximately $115,000 to $1,500,000.

6.2 Selected Stabilization Alternative for 2010

The campus-wide instrumentation program and the vegetation management program are being considered by GA for implementation in 2010 if budget priorities allow.

7.0 CLOSING

This report has been prepared exclusively for the use of the Washington State Department of General Administration and their consultants for specific application to slope stability assessment at the Capitol Campus in Olympia, Washington. We encourage review of this report by bidders and/or contractors as it relates to factual data only (exploration logs, laboratory results, etc.). The conclusions and recommendations presented in this report are based on the explorations and observations completed for this study and review of documents from GA archives. The conclusions and recommendations presented in this report are not intended as, nor should they be construed to represent, a warranty regarding the slope stability.

Judgment has been applied in interpreting and presenting the results. Variations in subsurface conditions are common, and actual conditions encountered may be different from those observed in the borings. If site project plans are developed based on our studies, we recommend that we be given the opportunity to review the plans and specifications to verify that they are in accordance with the conditions described in this report. It should be specifically noted that the topography shown on site plans was developed from LiDAR data and is not equivalent to survey information.

The explorations were performed in general accordance with locally accepted geotechnical engineering practice, subject to the time limits and financial and physical constraints applicable to the services for this project, to provide information for the areas explored. There are possible variations in the subsurface conditions between the test locations and variations over time.

The professional services retained for this project include only the geotechnical aspects of the subsurface conditions at the site. The presence or implication(s) of possible surface and/or subsurface contamination resulting from previous site activities or uses of the site and/or resulting from the introduction onto the site of materials from offsite sources are outside the scope of service for this report and have not been investigated or addressed.

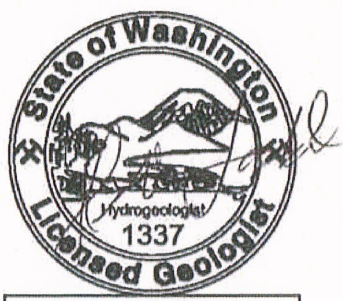
GOLDER ASSOCIATES INC.

Katy Cottingham

Katy S. Cottingham, P.E.
Project Engineer

Frank S. Shuri

Frank S. Shuri, P.E., L.G., L.E.G.
Principal and Senior Consultant



Deborah Ladd

Deborah Ladd, P.E. L.Hg.
Senior Consultant Geotechnical Engineer

Golder Associates

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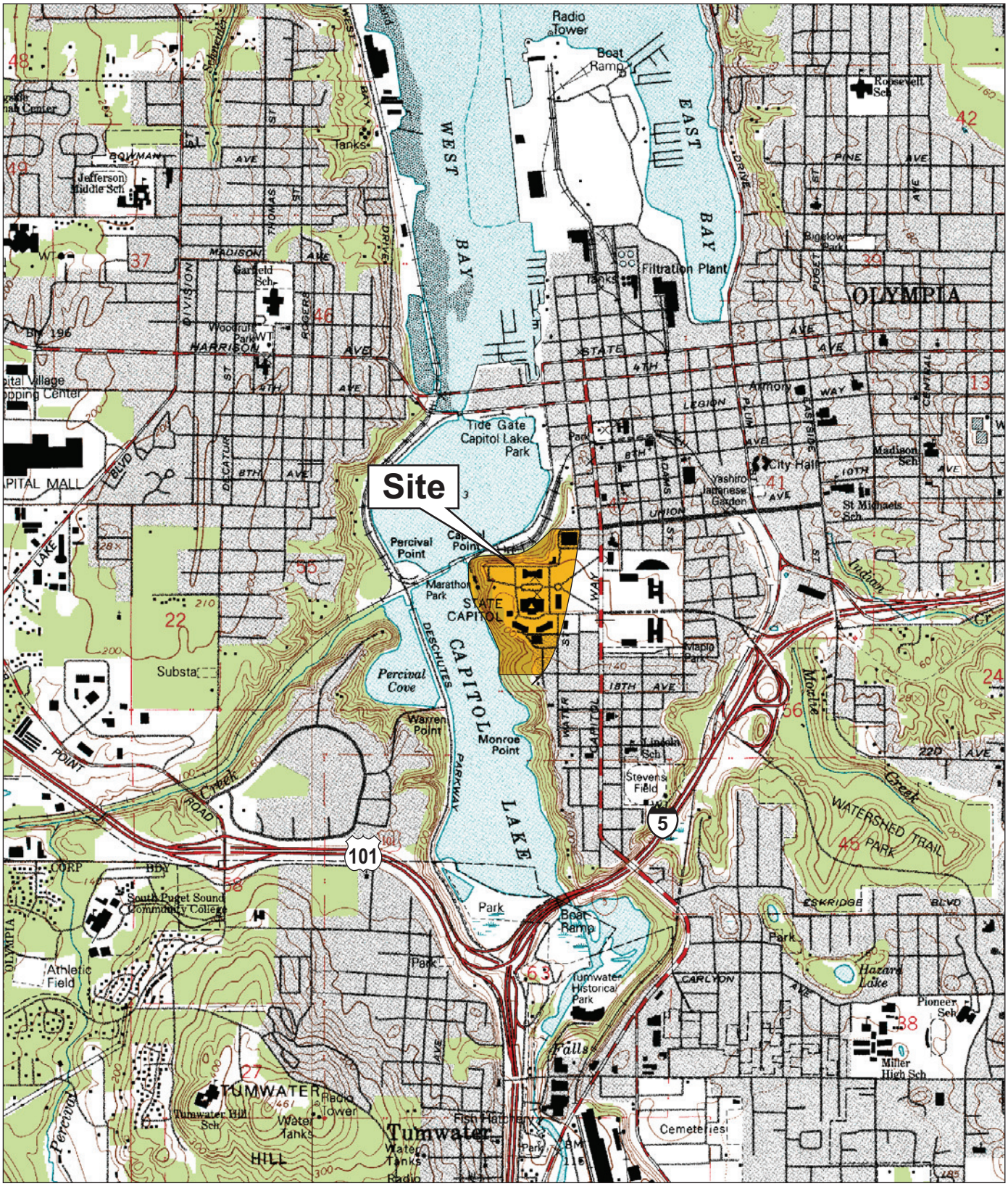
FIGURES



Source: USGS 7.5 Minute Topographic Quadrangle Map, Tumwater, WA, 1994

FIGURE **1**

VICINITY MAP

WAGA/HILLSIDE EVAL&PRELIM DESIGN/WA

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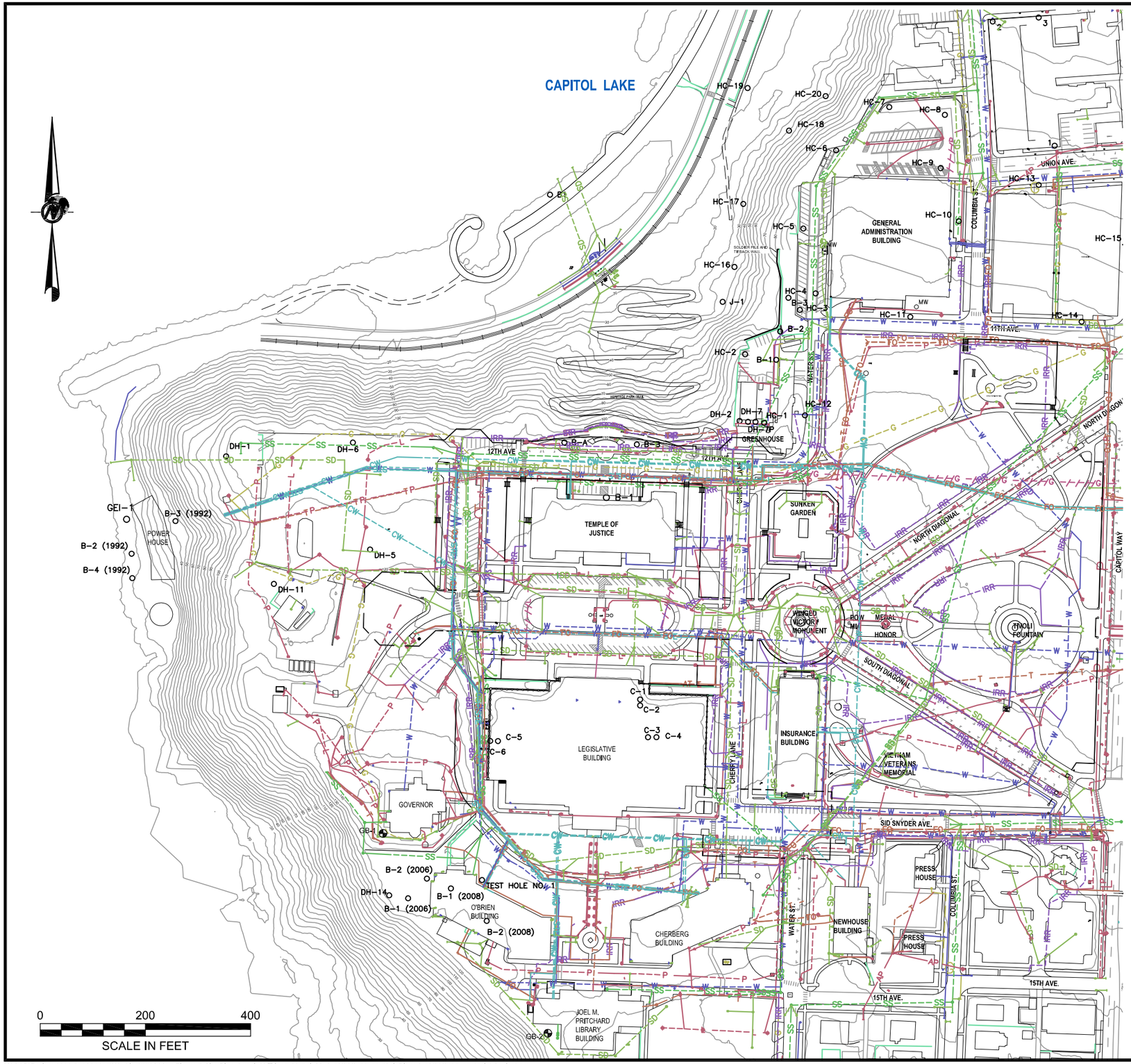


LEGEND

GB-1 ⊕ APPROXIMATE LOCATION OF GOLDER BORING AND INCLINOMETER

B-2 ○ APPROXIMATE LOCATION OF BORING BY OTHERS

SOURCE:
BASE MAP: PARAMETRIX DECEMBER 2008
TOPOGRAPHIC CONTOURS: PUGET SOUND LIDAR CONSORTIUM, DOWNLOAD 2008

DATUM:
HORIZONTAL: NAD 1983
VERTICAL: NAVD 88

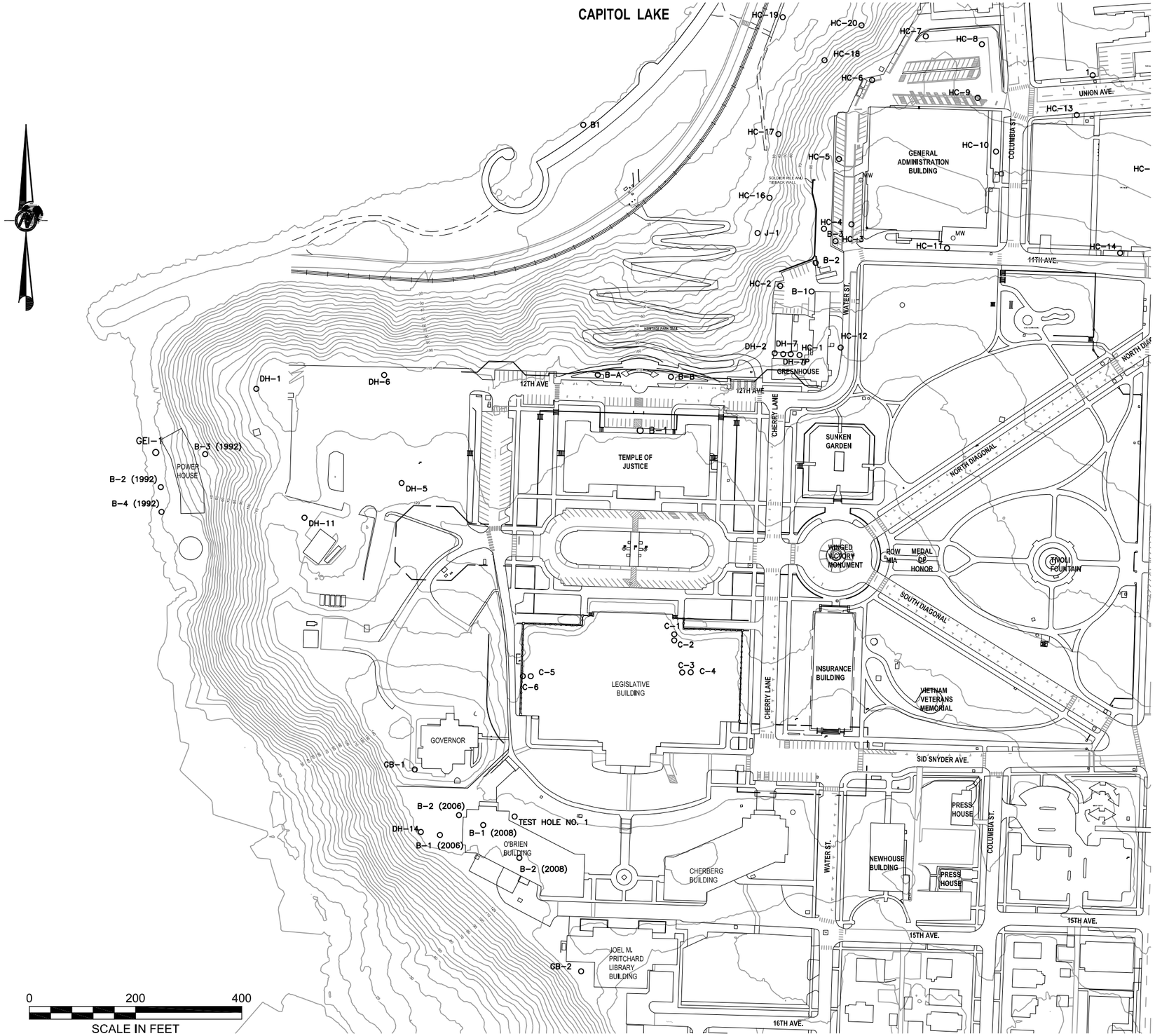
FIGURE **2**

PROJECT CAD DATABASE PLAN

WAGA/HILLSIDE EVAL&PRELIM DESIGN/WA

K:\CAD\Projects\2008\08393287\Working\08393287 Figure 2 Site Plan.dwg | Utilities11X17 | Mod: 12/22/2009, 10:19 | Plotted: 12/22/2009, 10:45 | kCottingham

Golder Associates



LEGEND

B-2 ○ APPROXIMATE LOCATION OF BORING IN DATABASE

SOURCE:
BASE MAP: PARAMETRIX DECEMBER 2008
TOPOGRAPHIC CONTOURS: PUGET SOUND LIDAR CONSORTIUM, DOWNLOAD 2008

DATUM:
HORIZONTAL: NAD 1983
VERTICAL: NAVD 88

FIGURE **3**
HISTORIC EXPLORATIONS
WAGA/HILLSIDE EVAL&PRELIM DESIGN/WA

K:\CAD\Projects\2008\08393287\Working\08393287 Figure 2 Site Plan.dwg | Historic Explorations | Mod: 12/22/2009, 10:19 | Plotted: 12/22/2009, 10:46 | kCottingham

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Capitol Lake

GA Building

Soldier Pile Wall

LEM and Heritage Park Trail

North Parking Lot

Power-house

Temple of Justice

Legislative Building

Governor's Mansion

O'Brien Building

Pritchard Building

Capitol Lake

LEGEND

- Ancient Deep-Seated Landslide (dashed and queried where inferred)
- Shallow Slide
- Soldier Pile Wall
- Modified Surface (fill, grading)
- Seepage/Spring Area
- Water

0 300

Scale in Feet

Map Projection:
Washington State Plane
North Zone NAD 1983

Source:
Gerstel (maps, 1996a and 1996b),
Puget Sound LiDAR Consortium (LiDAR data, Feb. 2002),
Golder Associates Inc. (field visits and LiDAR interpretation, 2009)

N

This figure was originally produced in color. Reproduction in black and white may result in a loss of information.

FIGURE **4**

SHADED RELIEF MAP OF CAPITAL CAMPUS

WAGA/HILLSIDE EVAL AND PRELIM DESIGN/WA

08393287F14R01_CapitolCampus_LandFeatures.mxd | 3/2/2010 | BVANG-JOHNSON

Golder Associates