Applied Geotechnical Engineering Consultants, Inc.

August 4, 1998

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Attention: Jim Aland
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Subject: Supplemental Geotechnical Investigation
Green Hill Country Estates Phase VI
Part of Sections 4 and 9, T6N, R2E, SLB&M
Weber County, Utah
Project No. 66095

Gentlemen:

Applied Geotechnical Engineering Consultants, Inc. conducted a geotechnical investigation and landslide study for the Green Hill Country Estates Phase VI and presented our findings and recommendations in a report dated June 5, 1996 under Project No. 66095. The approximate area of the proposed subdivision is shown on Figure 1.

## SCOPE

AGEC was requested to conduct additional investigation of a new slide area and to observe the condition of the previously studied slide areas in May 1998. We were also requested to further evaluate the extent and severity of expansive soils at the site.

This letter presents the results of the supplementary investigation and provides additional recommendations addressing the conditions encountered and evaluated during this study.

## ADDITIONAL FIELD STUDY

Nine test pits were excavated with a rubber-tired backhoe in the Phase VI area on May 29, 1998. The test pits were excavated at the approximate locations indicated on Figure 2.

The test pits were logged and soil samples obtained by a geologist from AGEC. The new and previously studied slide areas were also observed. Logs of the subsurface conditions encountered in the test pits are graphically presented on Figure 3 with Legend and Notes on Figure 4.

**SITE CONDITIONS**

The site was visited on May 29 and July 16, 1998. At the time of our site visits the site conditions were the same as were described in the above referenced report.

One additional slide area was observed at the approximate location shown on Figure 2. The slide appears to be a relatively shallow failure and appears to have occurred as a result of the existing road cut. The soil in the new slide area is very moist to wet and relatively soft, similar to previous slide areas studied. There is a natural spring up-slope from the new slide area.

The approximate locations of the previously studied slide areas are also shown on Figure 2. These areas were observed at the time of our site visits. The slide areas were measured to extend further up the slope and wider than they were at the time of our previous study.

Based on our discussion with the developer, we understand that soil was removed from the slide areas following our previous study and prior to the time of our subsequent site visits. It appears that the removal of soil from the slide areas has allowed the slope above the previous slide area to move as a result of removal of the resisting soil mass.

**SUBSURFACE CONDITIONS**

Subsurface conditions encountered in the test pits consist of approximately ½ to 1 foot of topsoil (if present) overlying low and high plastic clay and some clayey gravel layers.

The upper several feet of soil in the area of TP-5A, TP-6A and TP-7A was observed to be disturbed from the new slide.

The following is a description of the subsurface conditions encountered in the test pits.

<u>Topsoil</u> - The topsoil consists of sandy clay which is moist, dark brown and contains roots.

<u>Clay</u> - The clay consists of low and high plastic clay with occasional gravel and cobbles. It is soft to very stiff, slightly moist to wet and reddish brown to gray in color.

Laboratory tests conducted on samples of the clay indicate natural moisture contents of 21 to 34 percent and natural dry densities of 81 to 104 pounds per cubic foot. Samples of the clay were found to have Liquid Limits of 60 to 80 percent and plasticity indexes of 42 to 57 percent.

Consolidation tests conducted on samples of the clay (conducted on samples with their in-situ moisture content) indicate that the clay will swell slightly and compress a small amount with the addition of light to moderate loads. When the samples were air-dried prior to testing, the soil was observed to be moderately to highly expansive when wetted. Results of the consolidation tests are presented on Figures 5, 6 and 7.

Gravel - The gravel is clayey and contains cobbles and occasional boulders. The gravel is dense, moist to very moist and reddish brown to grayish brown in color.

Results of the laboratory tests are summarized on Table I and are included on the logs of the test pits.

**SUBSURFACE WATER**

Free water was measured at a depth of approximately 6 feet below the ground surface in TP-9A when measured 48 days after the test pit was excavated. No free water was observed in the other test pits at the time of excavating.

Due to the location of the site, we anticipate that the subsurface water encountered is the result of perched groundwater conditions. With the relatively impervious nature of the natural soil and the slope of the site, water may be transmitted through permeable layers.

Slotted PVC pipe was installed in Test Pit TP-9A to facilitate future measurement of the subsurface water level. Fluctuations on the water level area anticipated with time. Evaluation of the water level fluctuations is beyond the scope of this letter.

**SUPPLEMENTAL RECOMMENDATIONS**

A. Slope Stability

The area of the proposed development includes an area which is mapped as a historic landslide. The site is prone to slope movement unless site grading, slope retention and drainage is carefully planned. The following recommendations are given.

1. Existing slide areas, including the new slide area, should be repaired to protect road cuts and the stability of the adjacent hillside. Recommendations for repairing the slide areas are presented in the above referenced report.

2. Site grading should be carefully planned for the proposed residences. Lot specific geotechnical investigations should be conducted to evaluate stability of proposed and existing cuts, fills and retaining systems.

3. Recommendations given in the above referenced geotechnical report should be followed.

B. Expansive Soil Areas

Shallow foundations and flat concrete or pavement placed on expansive soil similar to that encountered at the site can experience movement causing structural distress if the soil is subjected to changes in moisture content.

1. Lot specific geotechnical investigations should be conducted to identify expansive soil areas and to give specific foundation recommendations.

2. As a minimum, the foundation recommendations given in the above referenced report including drainage precautions and protecting the foundation soils from changes in moisture should be followed.

3. Based on the data obtained during the field and laboratory studies, straight shaft drilled piers drilled into the natural soil or bedrock are considered to be a positive foundation system to support the proposed residences in areas where highly expansive soils are encountered.

   A drilled pier foundation is intended to transfer the support of the structure down to a zone of relatively stable moisture content and to load the piers sufficiently to resist uplift pressure.

   Using this type of foundation, each column is supported on a single drilled pier and the building walls are placed on grade beams supported by a series of piers. Loads applied to the piers are transmitted to the soil partially through peripheral shear stresses which develop on the sides of the pier and partially through end bearing pressure.

   In addition to their ability to reduce differential movements caused by expansive materials, straight-shaft piers have the advantage of providing high supporting capacity with a relatively small amount of movement.

   Pier capacity and depth to bearing stratum should be determined during lot specific investigations. Alternative pier foundations systems including helical piers or driven piles could also be considered.

4. Floor slabs present a very difficult problem where highly expansive materials are present near the floor slab elevation because sufficient dead load cannot be imposed on them to resist uplift pressure generated when the materials are wetted and expand. Based on the moisture-volume change of some of the soils present at the site, some lots may require the use of structural floors above a well ventilated crawl space to prevent damage from floor slab movement. The floor slab should be supported on grade beams and piers the same as the main structure.

**LIMITATIONS**

This letter has been prepared in accordance with generally accepted soil and foundation engineering practices in the area for the use of the client for design purposes. The conclusions and recommendations included in the letter are based on the information obtained from the test pits excavated at the locations indicated on the site plan and the data obtained from laboratory testing. Variations in the subsurface conditions may not become evident until excavation or additional exploration is conducted. If the subsurface conditions or groundwater level are found to be significantly different from those described above, we should be notified to re-evaluate our recommendations.

Sincerely,

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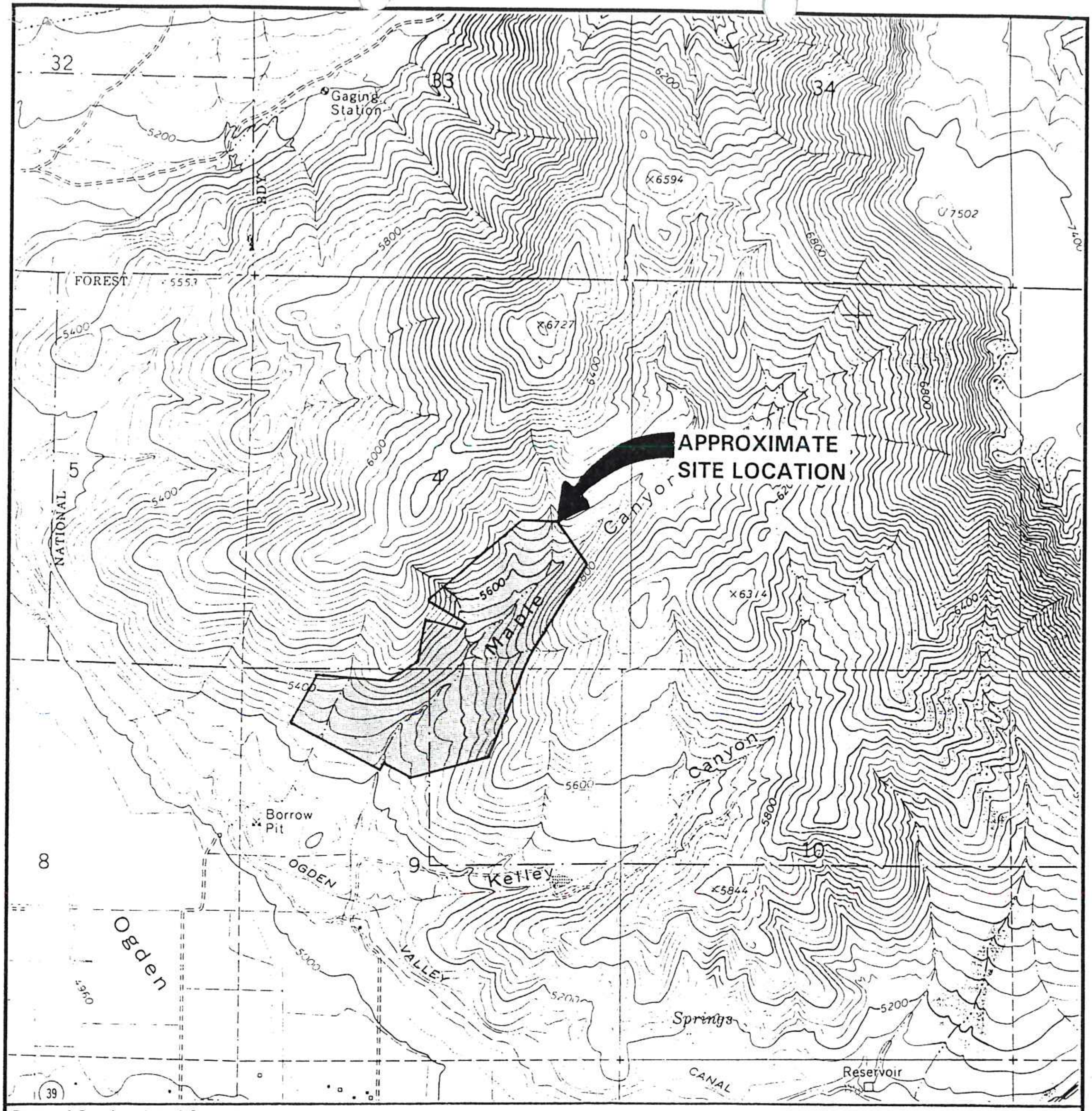


Parts of Section 4 and 9
T6N, R2E, SLB & M

From USGS Quadrangle
Browns Hole, Utah

North

Approximate Scale

1" = 2,000

**GREENHILL COUNTRY ESTATES - PHASE 6**
**PART OF SECTIONS 4 AND 9, T6N, R2E, SLB&M**
**WEBER COUNTY, UTAH**

| 66095 | AGEC | Site Location Map | Figure 1 |
|---|---|---|---|

Applied Geotechnical Engineering Consultants, Inc.

# GEOTECHNICAL AND LANDSLIDE STUDY

## GREEN HILL COUNTRY ESTATES PHASE VI
## PART OF SECTIONS 4 AND 9
## T6N, R2E SLB&M

## WEBER COUNTY, UTAH

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PROJECT NO. 66095 JUNE 5, 1996

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## CONCLUSIONS

1. The subsurface soils encountered in existing landslide areas of the site consist of low to high plastic clay. Clayey gravel was encountered below the clay in the landslide area in the western portion of the site. The clay extended to the maximum depth investigated in the landslide areas in the eastern portion of the site.

2. Subsurface materials encountered in areas adjacent to the landslides, where no apparent movement of the ground has occurred, consist of approximately 1 to 1½ feet of topsoil overlying layers of clayey gravel and clay with gravel.

3. No free water was encountered in our exploration at the site to the maximum depth investigated, which was approximately 7 feet below the ground surface.

4. The natural clay soil exhibit moisture sensitive characteristics. If the soil is allowed to dry and is wetted, it may expand. It is important to maintain little or no moisture change in the soil under the proposed buildings in areas where moisture sensitive soils are encountered. Recommendations relating to expansive soils encountered at the site are included in the report.

5. The proposed residences may be supported on spread footings bearing on the undisturbed natural soil or on compacted structural fill extending down to the undisturbed natural soil. An allowable net bearing pressure of 1,500 pounds per square foot (psf) may be used for footings bearing on natural clay soils. Footings bearing on a minimum of 2 feet of the natural gravel soil or a compacted structural fill may be designed for an allowable net bearing pressure of 2,500 psf.

6. Landslide areas were observed in the road cut areas of the site. The existing landslides should be stabilized. Recommendations for stabilizing the landslide areas are included in the report.

7. To maintain stability in cut and fill areas, cut and fill slopes in the natural clay soils should be no steeper than 4:1 (horizontal to vertical). Cut and fill slopes in the natural gravel soils should be no steeper than 2:1 (horizontal to vertical). Proper retaining systems should be provided if steeper slopes are required and careful attention should be given to proper drainage of any cut and fill slopes.

8. A significant amount of fill has been placed in the roadway areas, particularly over the areas of two creek crossings, where culverts have been installed. Moisture and density tests conducted on the fill indicate that the areas tested have been compacted between 78 and 92 percent of the maximum dry density as determined by ASTM D-698. Fill to support roadways should typically be compacted to at least 95 percent of the maximum dry density as determined by ASTM D-698.

9. Geotechnical information related to foundations, subgrade preparation, pavement design and materials are included in the report.

## SCOPE

This report presents the results of a Geotechnical Investigation and Landslide Study for the proposed Green Hills County Estates, Phase VI Subdivision, located in portions of Sections 4 and 9 of Township 6 North, Range 2 East of the Salt Lake Base and Meridian in Weber County, Utah. The report presents the subsurface conditions encountered, laboratory test results, and recommendations for foundations, pavement and landslide repair. The site location is shown on Figure 1.

Six trenches and 2 test pits were excavated to obtain information on the subsurface conditions and to obtain samples for laboratory testing. Eight locations were excavated to conduct in-place moisture and density tests on the existing fill in and adjacent to roadways. Information obtained from the field and laboratory was used to define conditions at the site and to develop recommendations for the proposed foundations and pavement. The information was also used to analyze the stability of the existing landslide areas, determine the probable causes of the failures and provide recommendations for stabilization of the landslides.

This report has been prepared to summarize the data obtained during the study and to present our conclusions and recommendations based on the proposed construction and the subsurface conditions encountered. Design parameters and a discussion of geotechnical engineering considerations related to construction are included in the report.

## SITE CONDITIONS

The site includes hillsides on both sides of Maple Canyon in the area northeast of Ogden Valley. The topography includes moderately steep hillsides which extend down in both directions towards the central portion of the property towards the creek. The creek through Maple Canyon flows in a southwesterly direction. Several small drainages extend through the site to the creek from the north and south. Another small drainage extends through the western portion of the property from the north to south.

Considerable cuts and fills were observed for the proposed roads. Fill was observed in the roadways at the locations of the creek crossings. We understand that most of the road has been cut into the natural hillside and fill has been placed adjacent to the road on the downhill sides.

The surface of the site is covered mostly with the natural vegetation of the area which includes sagebrush, grass, weeds and sparse scrub oak.

The area surrounding the site includes hillsides similar to the property in all directions. There has been some residential development south of the western portion of the site. We understand that some landslides have been observed in the adjacent residential development, where hillsides have been cut steeper than their natural slopes.

## FIELD STUDY

The field study was conducted on November 15, 1995. Six trenches and two test pits were excavated through the landslide areas and adjacent to the landslides. Test Pits TP-1 through TP-8 were excavated up to 4 feet in depth to conduct in-place moisture and density tests. The trenches and test pits were excavated with a rubber-tired tractor mounted back hoe. The trenches and test pits were logged, soil samples obtained and in-place moisture and density tests conducted by an engineer from AGEC. The location on in-place moisture and density tests and approximate location of landslide areas are shown Figure 2. The locations of trenches and test pits are shown on Figures 3, 4 and 5. Logs of the subsurface conditions encountered in the trenches and test pits are shown on Figures 6, 7 and 8. A profile of the central landslide area is shown on Figure 9. No trenches were excavated in the area of the central landslide area.

## SUBSURFACE CONDITIONS

The subsurface soils exposed in the trenches, which were excavated in the existing landslide areas consist of low to high plastic clay. Clayey gravel was observed below the clay in the western landslide area.

Subsurface soils observed in the test pits excavated adjacent to the landslide areas consist of layers of clayey gravel and low to high plastic clay with gravel.

Fill which was observed on and adjacent to the roadway areas consists of clayey sand with a small to moderate amount of gravel and clayey gravel with sand.

A description of the soil encountered in the test pits follows:

Topsoil - The topsoil consists of sandy clay which is moist, brown in color and contains roots.

Fill - The fill encountered in the roadway area and areas adjacent to the roadways consists of clayey sand with a small to moderate amount of gravel to clayey gravel with sand. The fill was observed to be slightly moist to moist and reddish brown to brown in color.

Three moisture/density relationship (Proctor) and gradation tests were conducted on samples of the fill. Results of the Proctor and gradation tests are presented on Figures 11, 12 and 13. Two California Bearing Ratio (CBR) tests were also conducted on remolded samples of the fill. Results of the CBR tests are present on Figure 14 and 15.

In-place moisture and density tests were conducted on the fill at the approximate locations indicated on Figure 1.

The following are results of the in-place moisture and density tests.

| Test | Depth | Dry Density, (pcf) | Moisture Content, (%) | Description of Fill |
|---|---|---|---|---|
| T-1 | SG | 98.7 | 17.8 | Clayey Sand with Gravel |
| T-2 | 3' BSG | 114.0 | 14.0 | Clayey Gravel with Sand |
| T-3 | SG | 121.5 | 13.6 | Clayey Gravel with Sand |
| T-4 | 3' BSG | 95.5 | 10.5 | Clayey Sand |
| T-5 | 4' BSG | 102.2 | 7.3 | Clayey Sand |
| T-6 | 3½' BSG | 91.4 | 19.5 | Clayey Sand |
| T-7 | 2½' BSG | 112.0 | 14.4 | Clayey Gravel with Sand |
| T-8 | 3' BSG | 116.6 | 16.6 | Clayey Gravel with Sand |

Note: SG indicates the existing subgrade level and BSG indicates below the existing subgrade level. A trench correction was applied to moisture test results taken below grade.

The test results were compared to the laboratory maximum dry densities and indicate that the areas tested are compacted from 78 to 92, with an average of 86 percent, of the maximum dry density as determined by ASTM D-698. Fill to support pavement should typically be compacted to at least 95 percent of the maximum dry density as determined by ASTM D-698. Fill to support pavement should typically be compacted to at least 95 percent of the maximum dry density as determined by ASTM D-698.

Clay - The clay contains layers of low to high plastic clay. It is medium stiff to very stiff, slightly moist to very moist, and contains occasional gravel. The clay is reddish brown to gray in color.

Laboratory tests conducted on samples of the clay indicate natural moisture contents range from 16 to 29 percent and natural dry densities range from 95 to 112 pounds per cubic foot (pcf). A sample of the clay was found to have an unconfined compressive strength of 3,560 psf. Additional strength testing was conducted, including triaxial and direct shear tests. Tests were conducted on samples of the clay with and without water. Tests were also conducted to determine residual strength. Test results indicate a cohesion value of 1,385 psf and a friction angle of 45.8 degrees on a sample which was not wet. Tests conducted on wet samples indicate cohesion values range from 200 to 985 psf and friction angles range from 6 to 21.5 degrees. Testing indicates residual cohesion values range from 162 to 165 psf and residual friction angles range from 4 to 12.2 degrees. A residual cohesion of 50 psf and residual friction angle of 21.5 degrees were obtained on a sample which was not wetted. The results of the strength tests are summarized on Table II and are presented on Figures 16 through 23.

Test results indicate that the strength of the soil is significantly reduced when the material is wetted. Residual strengths were also found to be significantly lower.

Consolidation tests were conducted on samples of the clay. The results of the consolidation tests indicate that the clay will compress a small amount with the addition of light to moderate loads. One of the samples tested was observed to swell when wetted at a constant pressure after it had been air dried. Results of the consolidation tests are presented on Figure 24.

Clayey Gravel - The clayey gravel contains cobbles and boulders. It is dense, slightly moist to moist and brown to reddish brown in color.

A Summary of the Laboratory Test Results are presented on Table I and II and are include on the Trench Logs.

## SUBSURFACE WATER

No free water was encountered in the trenches or test pits at the time of excavating to the maximum depth investigated which was approximately 7 feet.

## PROPOSED CONSTRUCTION

We understand that the area is to be subdivided into approximately 36 residential lots which range in size from approximately 1½ to 5 acres.

We anticipate that houses will be one to two-story, wood frame structures with basements.

Roads will be constructed through the subdivision. We have assumed traffic for roads consisting of 500 cars and 1 delivery truck per day and 2 garbage trucks per week.

If the building loads or traffic are significantly different from those described above, we should be notified to re-evaluate our recommendations.

## PROBABLE CAUSES OF LANDSLIDES

We understand from our discussion with the property owner that the landslides occurred during the spring of 1995. All of the slope failures appear to have occurred in road cut areas.

Based on the measurements obtained in the landslide areas, the conditions observed in the trenches, the results of laboratory testing and our engineering analysis the following items likely contributed to the slope failures in the road cut areas.

1. Soil Strength - The slope failures appear to have occurred in areas where the subsurface materials are primarily high plastic clay. The laboratory testing indicated that there is a significant loss of soil strength when the soils become wet. Slope failures were not observed in areas where the upper soil consists of clayey gravel.

2. Water Conditions - Based on our analysis and discussion with the property owner, the slope failures likely occurred at a time when the soils in the landslide areas were very moist. We anticipate that drainage from up-slope of the landslide areas may have seeped into the

ground near the top of the road cut areas. The increased weight of the very moist to wet soil and the reduction of strength of the material allowed the soil to slide.

3. Road Cuts - All of the landslides were observed to be in road cut areas. The cut slopes ranged from approximately 3½:1 to 2½:1 (horizontal:vertical). Some areas of the road cuts were not at a constant slope and none of the areas had been revegetated. The road cutting process may have contributed to the infiltration of water, as well as increasing the slope.

## RECOMMENDATIONS

Based on the subsurface conditions encountered, laboratory test results, and the proposed construction, the following recommendations are given:

A. Site Grading

Cut and fill will be required to accomplish the proposed development. Much of the cut and fill for roadways has already been completed.

1. Slopes

In order to maintain stability similar to the natural slopes, permanent unretained cut slopes of up to 15 feet should be designed no steeper than 4 horizontal to 1 vertical in the natural clay soils. Larger cuts should be considered on an individual basis. Permanent unretained slopes in the natural gravel soils should be designed no steeper than 2 horizontal to 1 vertical. The risk of slope instability will be significantly increased if seepage is encountered. If seepage is encountered in permanent excavations, a specific stability investigation should be conducted to determine if seepage will adversely effect the cut.

Fill slopes up to 10 feet high may be constructed on 4 horizontal to 1 vertical, if clay soils are used and 2 horizontal to 1 vertical if granular soils are used. All fill for slopes compacted to at least 95 percent of the maximum dry density as determined by ASTM D-698 near optimum moisture content. The ground surface underlying the fill should be carefully prepared by removing significant organic material, scarifying to a depth of 8 inches and recompacting to 95 percent of the maximum standard Proctor density prior to fill placement. Fill should be keyed into hillsides exceeding 5 horizontal to 1 vertical.

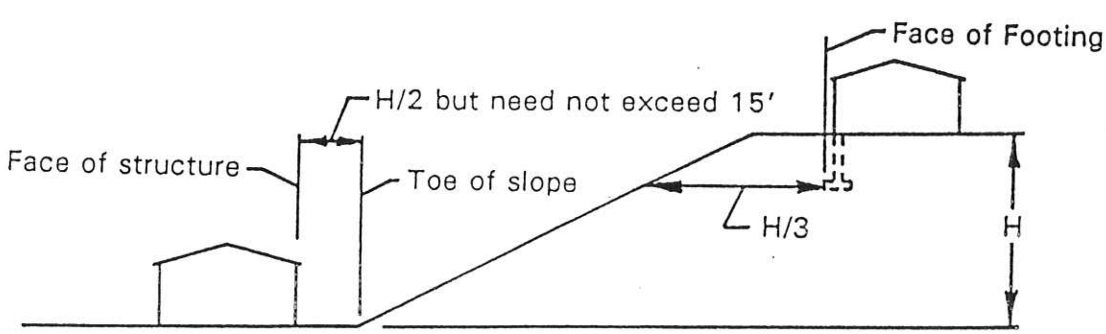
The natural slope in portions of the site is 4:1 (horizontal to vertical) or steeper. Lot specific geotechnical investigations should be conducted to determine if steeper cut/fill slopes are possible. Site grading should be carefully planned for each lot to provide proper slope retention.

Good surface drainage should be provided upslope of cut and fill slopes to direct surface runoff away from the cut or fill face. Slopes should be protected from erosion by revegetation or other methods.

Landscaping maintenance and surface protection may determine the most desirable slopes.

2. <u>Building Setbacks from Slopes</u>

Buildings constructed near slopes steeper than 3 horizontal to 1 vertical should be set back at least the minimum distances indicated below.



3. Existing Fill

A significant amount of existing fill was observed in the proposed roadway area and adjacent to the roads. The fill density was found to be erratic and below the recommended values. Any fill that is encountered below footing and floor slab areas that has not been properly compacted should be removed and replaced with properly compacted structural fill.

If the owner is willing to accept some risk of building and/or pavement distress due to differential settlement of the fill, consideration may be given to leaving a portion of the existing fill in the areas of the pavement. This is discussed later in the Subgrade Preparation and Foundation sections of the report.

The stability of the existing road fills is dependant upon the type of materials which were used to construct the fills. We did not observe signs of instability in the fill areas and the fill material observed near the surface is primarily granular fill. However, the stability of existing fills was not evaluated in this study.

4. Excavation

We anticipate that excavation at the site can be accomplished with typical excavation equipment. Gravel with sand and cobble was observed in excavations at the site. We anticipate that excavation can be accomplished with conventional heavy-duty excavation equipment. Cobbles and boulders may be particularly troublesome in confined excavations such as utility trenches.

5. Subgrade Preparation

Prior to placing grading fill or base course, all organic material, existing fill and other deleterious material should be removed.

The subgrade should be scarified to a depth of approximately 8 inches and compacted to at least 95 percent of the maximum dry density as determined by

ASTM D-698. The subgrade should then be proof-rolled to identify any soft areas. Soft areas should be removed and replaced with compacted fill.

Ideally, all unsuitable fill would be removed from below pavement areas. Consideration may be given to only removing a portion of the fill from below pavement areas, if the owner is willing to accept some risk of pavement distress caused by differential settlement of the fill. We suggest that at least 2 feet of properly compacted fill be placed below the pavement if this option is used. If clay was used to construct road fills, consideration should be given to evaluating the stability of the road fills.

6. Drainage

With the moisture sensitive soil present at the site, it is important that the following drainage precautions be observed during construction and maintained at all times after the residences have been completed.

a. Excessive wetting or drying of soils in foundation excavations should be avoided.

b. The ground surface surrounding the exterior of the residences should be sloped to drain away from the structures in all directions, maintaining a slope of at least 6 inches in the first 10 feet.

c. The upper 2 feet of foundation wall backfill should be low permeable clay or silt soil.

d. Roof down spouts and drains should discharge well beyond the limits of backfill.

e. Sprinkler lines and sprinkler heads should not be placed within 10 feet of the foundation walls.

The collection and diversion of drainage away from the pavement surface is important to the satisfactory performance of the pavement section. Proper drainage should be provided.

7. Compaction

Compaction of materials placed at the site should equal or exceed the minimum densities as indicated below when compared to the maximum dry density as determined by ASTM D-1557.

| Fill to Support | Compaction |
|---|---|
| Foundations | ≥ 100% |
| Concrete flatwork and pavement | ≥ 95% |
| Landscaping | ≥ 90% |
| Retaining Wall Backfill | 90 - 95% |

To facilitate the compaction process, the fill should be compacted at a moisture content within 2 percent of the optimum moisture content as determined by ASTM D-698.

The base course should be compacted to at least 95 percent of the maximum dry density as determined by ASTM D-1557 at a moisture content within 2 percent of the optimum.

8. Materials

Listed below are materials recommended for structural fill.

| Fill to Support | Recommendation |
|---|---|
| Footings and Floor Slabs | Low permeable granular soil<br>-200 = 30 to 50%, LL <30%<br>Maximum size 4 inches |

| Fill to Support | Recommendation |
|---|---|
| Floor Slabs (Upper 4 inches) | Sand and Gravel<br>-200 <5%<br>Maximum size 2 inches |
| Slab Support | Non-expansive granular soil<br>-200 = 30 to 50%, LL <30%<br>Maximum size 6 inches |

The on-site non-expansive granular soil may be suitable for use as fill, if it meets the above requirements. Most of the on-site soils are not suitable for use as fill below buildings, but may be used in pavement and landscaping areas or as utility trench backfill. The natural soils will require proper moisture conditioning prior to use as fill. Topsoil, organics and other deleterious materials should be removed prior to using the material for fill. All of the on-site soils are suitable for use as fill in landscaping areas. Use of fine-grained soil as backfill behind retaining walls will result in higher lateral pressures than granular soil. This is discussed in the Lateral Earth Pressure section of the report.

B. Foundations

1. Bearing Material

With the proposed construction and the subsurface conditions encountered, we recommend that the residences be supported on the natural undisturbed soil or on compacted structural fill.

All organic topsoil, uncompacted fill or other deleterious material should be removed from below foundation areas. Structural fill placed below foundations should extend out and away from the edge of the footings a distance equal to the depth of fill beneath footings.

2. Bearing Pressure

Spread footings bearing on the undisturbed natural clay soil may be designed for an allowable net bearing pressure of 1,500 psf. Footings bearing on the undisturbed natural clayey gravel or on compacted structural fill may be designed for a net allowable bearing pressure of 2,000 psf. Footings should have a minimum width of 1½ feet and a minimum depth of embedment of 1 foot.

3. Temporary Loading Conditions

The allowable bearing pressure may be increased by one-half for temporary loading conditions such as wind or seismic loads.

4. Settlement

We estimate that settlement will be less than 1 inch for footings bearing on the undisturbed natural clay soil. We estimate that settlement will be less than ½ inch for footings bearing on the natural gravel soil or on a minimum of 2 feet of compacted structural fill. Care should be taken not to disturb the natural soil at the base of footing excavations, so that settlements can be maintained within tolerable limits.

5. Frost Depth

Exterior footings and footings beneath unheated areas should be placed at least 40 inches below grade for frost protection.

6. Foundation Base

The base of all excavations should be cleared of loose or deleterious material prior to fill or concrete placement.

7. Moisture Sensitivity

The on-site clay soils are sensitive to changes in moisture. If the soils are allowed to dry and are wetted, they may expand. It is important to maintain little or no moisture change in the soils under and surrounding the foundations during the life of the buildings. Exterior grading should promote drainage of runoff water from the areas surround the structures. Irrigation in the areas surrounding the structures should be minimized.

8. Construction Observation

A representative of the geotechnical engineer should observe all footing excavations prior to structural fill or concrete placement. This is particularly important with the potential for moisture sensitive soil in the area.

C. Concrete Slab-on-Grade

1. Slab Support

Floor slabs may be supported on the undisturbed natural soil or on compacted structural fill.

2. Underslab Gravel

A 4-inch layer of free draining gravel (less than 5 percent passing the No. 200 sieve) should be placed below the floor slabs for ease of construction and to promote even curing of the slab concrete.

3. Moisture Sensitivity

Clay soils located within the site are sensitive to changes in moisture and may expand when wetted. Lightly loaded portions of the structure, like the floor slabs, will be most susceptible to movement if the supporting clay soil expands. Ideally, all moisture sensitive soils would be removed from below the floor slab areas. Due to the cost of removal and the uncertainty of where the clay layers might be, we recommend that the following items be followed.

a. Positive joints should be provided between the floor slab and bearing walls so that the slabs may undergo unrestrained vertical movement independent of the bearing walls.

b. A positive drainage system should be provided around the exterior of the building.

D. Subsurface Drains

No free water was encountered at the site at the time of the investigation, however, the clay may result in perched water conditions or highly permeable layers may transmit water to the subgrade portion of the buildings during times of rainfall or snow melt. Consideration should be given to installing a permanent under drain system for subgrade construction.

The under drain system should consist of peripheral drains on the below grade portion of the structures leading to a sump where water can be removed by pumping or gravity flow. The drain line should consist of a perforated pipe surrounded by free-draining gravel. The drain line should be placed at least 18 inches below the floor level to provide free drainage of the water. Three-quarter inch washed rock or similar material would be satisfactory drainage gravel. Drains should be connected to the gravel backfill and underslab gravel.

The upper 2 feet of backfill above the drains should be low permeable clay soil to reduce the potential that the drainage water from around the house exterior would be transmitted through the drain to the foundation soils.

E. Lateral Earth Pressures

1. <u>Lateral Resistance for Footings</u>

Lateral resistance for footings placed on the natural soil or on compacted structural fill is controlled by sliding resistance between the footing and the foundation soils. A friction value of 0.3 may be used in design for ultimate lateral resistance.

2. <u>Subgrade Walls and Retaining Structures</u>

The following equivalent fluid weights are given for design of subgrade walls and retaining structures. The active condition is where the wall moves away from the soil. The passive condition is where the wall moves into the soil and the at-rest condition is where the wall does not move. The values listed assume a horizontal surface adjacent the wall.

| Soil Type | Active | At-Rest | Passive |
|---|---|---|---|
| Clay | 50 pcf | 65 pcf | 250 pcf |
| Sand and Gravel | 40 pcf | 55 pcf | 300 pcf |

3. Seismic Conditions

Under seismic conditions, the equivalent fluid weight should be increased by 27 pcf for active and at-rest conditions and decreased by 27 pcf for the passive condition. This assumes a horizontal ground acceleration of 0.3g which represents a 10 percent probability of exceedance in a 50 year period.

4. Safety Factors

The values recommended above assume mobilization of the soil to achieve ultimate soil strength. Conventional safety factors used for structural analysis for such items as overturning and sliding resistance should be used in design.

F. Seismicity

The site is located in Seismic Zone 3 based on the Uniform Building Code seismic zone map of the United States. The residences should be designed and constructed in accordance with Zone 3 requirements using a soil profile type "S-2".

G. Pavement

Based on the subsoil conditions encountered, laboratory test results and the assumed traffic the following pavement support recommendations are given.

1. Subgrade Support

The near surface soil observed in the roadway areas consists of sandy clay with gravel to clayey gravel with sand. Much of the subgrade area consists of fill. Two California Bearing Ratio (CBR) test were conducted on subgrade materials, as presented on Figure 13 and 14.

2. Pavement Thickness

Based on the subsoil conditions and assumed traffic, a design life of 20 years and methods presented by the Utah Department of Transportation, a pavement section consisting of 3 inches of asphaltic concrete overlying 8 inches of high quality base course is calculated.

3. Pavement Material

Pavement materials should meet the Utah Department of Transportation Specifications for gradation and quality. The pavement thickness indicated above assumes the base course is high quality material with a CBR of at least 80 percent. Other materials may be considered for use in the pavement section. The use of other materials may result in different pavement material thicknesses.

I. Stabilization of Landslide Areas

The following options are given for stabilization of the existing landslide areas.

1. Removal of Material and Replacement with Granular Fill

Due to the isolated and small areas included by slides, we recommend that the disturbed material be removed from the landslide area. The disturbed soil should be replaced with compacted granular fill. The on-site granular soils are suitable for this used. The fill should be compacted to at least 95 percent of the maximum dry density as determined by ASTM D-698.

If this option is used, proper surface drainage should be provided in the areas surrounding the landslides to provide surface runoff from ponding or seeping into the ground, particularly uphill from landslide areas.

2. <u>Regrade to Flatten Slopes</u>

The landslide areas could be regraded to flatten the slope to no steeper than 4 horizontal to 1 vertical. Disturbed soil within the landslide areas should be recompacted in conjunction with the regrading of the area.

Proper surface drainage should be provided as indicated above.

3. <u>Subsurface Drain</u>

The landslide areas could be regraded to match the existing cut slopes. A drain system would need to be provided above the landslide areas to intercept drainage and carry it away from landslide areas. The drain would consist of a trench approximately 10 to 15 feet in depth above the landslide area, extending the width of the landslide. A perforated pipe would be placed at the bottom of the trench and the trench backfilled with washed gravel. A filter fabric should be placed between the gravel and the natural soil. The perforated pipe would then be tied into drain lines which would carry intercepted water down to the shoulder of the road or to the storm sewer system.

## LIMITATIONS

This report has been prepared in accordance with generally accepted soil and foundation engineering practices in the area for the use of the client for design purposes. The conclusions and recommendations included within the report are based on the information obtained from the test pits excavated at the locations indicated on the site plan and the data obtained from laboratory testing. Variations in the subsurface conditions may not become evident until excavation is conducted. If the subsurface conditions or groundwater level are found to be significantly different from those described above, we should be notified to re-evaluate our recommendations.

APPLIED GEOTECHNICAL ENGINEERING CONSULTANTS, INC.

LICENSED PROFESSIONAL ENGINEER
6/5/96
No. 177892
JAY R.
McQUIVEY
STATE OF UTAH

Jay R. McQuivey, P.E.

Reviewed by James E. Nordquist, P.E.

JRM/cs

State of Utah
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mark Babbit

September 3, 1998

Jim Gentry
Planner
Weber County Planning Commission
2380 Washington Boulevard
Ogden, Utah 84401

Dear Mr. Gentry,

Enclosed is my review of the supplemental geotechnical investigation for Green Hill Country Estates Phase VI by Applied Geotechnical Engineering Consultants. If you have any questions, feel free to call me at 801-537-3381.

Sincerely,

Bill D. Black

Bill D. Black
Project Geologist

| Project: Review of "Supplemental geotechnical investigation--Green Hill Country Estates Phase VI, part of sections 4 and 9, T6N, R2E SLB&M, Weber County, Utah." | | | Requesting Agency: Weber County Planning |
|---|---|---|---|
| By: Bill D. Black | Date: 09-03-98 | County: Weber | Job No: 98-32 |
| USGS Quadrangle: Browns Hole (1368) | | Number of attachments: 0 | |

## INTRODUCTION

This report is a review of a supplemental geotechnical investigation for Green Hill Country Estates Phase VI by Applied Geotechnical Engineering Consultants (AGEC) (1998). The subdivision is located in the S1/2 section 4 and N1/2 section 9, T. 6 N., R. 2 E., Salt Lake Base Line and Meridian. Jim Gentry, Weber County Planning Commission requested the review. I received the report on August 7, 1998. Previous reports for this subdivision include an AGEC (1996) geotechnical and landslide report, a Utah Geological Survey review of AGEC's report (Ashland, 1996), and a report regarding a new landslide in the subdivision and its implications regarding AGEC's (1996) recommendations (Black, 1998). The purpose of this review is to assess if AGEC (1998) adequately addresses potential expansive-soil problems and slope-stability concerns in the subdivision. The scope of work consisted of a literature review.

## DISCUSSION

Landsliding is a potential hazard at the property. AGEC (1996) observed four existing landslides in permanent 3:1 (horizontal:vertical) road cuts in the subdivision, and speculated these failures were triggered by a reduction in strength when soils became wet during infiltration of spring runoff. To maintain stability of road cuts and other cut slopes at the site, AGEC (1996) recommended final cut-slope angles in the natural clay soils at the subdivision be lower (4:1), existing landslides be stabilized, and surface drainage be directed away from the cut slopes. AGEC (1996) provided several options to stabilize the road-cut failures: (1) excavation and replacement, (2) regrading to flatter slopes, or (3) regrading to natural slope angles in combination with subsurface interceptor drains. Ashland (1996) believed these recommendations were adequate if construction was carefully monitored, and he also believed AGEC's (1996) assessment of the landslide hazard at the property appeared thorough, well documented, and supported by data.

A new slope failure occurred in 1998 in a 4:1 road cut in the eastern part of the property due to infiltration of spring runoff (Black, 1998), which suggested that cuts conforming to AGEC's (1996) recommendations may fail. Therefore, Black (1998) advised that slope-stability recommendations in AGEC (1996) be reviewed and revised. AGEC (1998) indicates existing slides at the property also enlarged this spring, and all of these slides probably resulted from

Green Hill Country Estates Phase VI, Weber County, Utah, *in* Mayes, B.H, compiler, Technical reports for 1996, Applied Geology Program: Utah Geological Survey Report of Investigation 231, p. 109-111.

Applied Geotechnical Engineering Consultants, Inc., 1996, Geotechnical and landslide study--Green Hill Country Estates Phase VI, part of sections 4 and 9, T6N, R2E SLB&M, Weber County, Utah: Midvale, Utah, unpublished consultant's report, 21 p.

----1998, Supplemental geotechnical investigation--Green Hill Country Estates Phase VI, part of sections 4 and 9, T6N, R2E SLB&M, Weber County, Utah: Sandy, Utah, unpublished consultant's report, 4 p.

Black, B.D., 1998, Investigation of a recent cut-slope failure and implications for geotechnical slope-stability recommendations at Green Hill Country Estates Phase VI, Ogden Valley, Weber County, Utah: unpublished Utah Geological Survey Technical Report, Job No. 98-18, 2 p.

Livn


# State of Utah
DEPARTMENT OF NATURAL RESOURCES
UTAH GEOLOGICAL SURVEY

Michael O. Leavitt
Governor
Ted Stewart
Executive Director
M. Lee Allison
State Geologist

2363 South Foothill Drive
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801-467-7970
801-467-4070 (Fax)


December 20, 1994

Curtis Christensen
Public Works Director
Weber County
2510 Washington Blvd.
Ogden, Utah 84401

Dear Curtis:

This letter responds to your request for written confirmation of my comments regarding slope stability of the Greenhill Country Estates Subdivision, Ogden Valley, which we visited on Friday, December 16, 1994.

The subdivision lies on two large landslides mapped by Mike Lowe of the Utah Geological Survey (formerly Weber County Geologist). Although the potential for renewed movement of the entire mass of these landslides is probably small, there is a much greater potential for localized reactivation of parts of these landslides. The existing landslide debris is permeable and clayey, and may be susceptible to local failure due to loading, grading, or the addition of water. Such localized failure has evidently happened at the subdivision in the past, as documented by Kimm Harty of the UGS during a site inspection in the fall of 1992. Similar slope failures may reasonably be expected if prudent precautions are not exercised during future development.

During our visit, we first inspected a cut slope on a lot at the southern, downslope portion of the subdivision, and then traversed the northern, upslope portion of the subdivision. These two sites illustrate design considerations that should be evaluated by a qualified professional prior to additional development at the subdivision. On the individual lot downslope, the developer apparently excavated without first submitting a geotechnical report to the county. I recommend that a geotechnical report be reviewed prior to approval of building permits, and excavations not be allowed prior to such approval. The report should include information on the design of the foundation, cut slopes, and retaining structures meant to minimize the potential landslide hazard. Conformance of these factors with approved plans would help ensure safe design.

Satisfactory planning and incorporation of hazard-reduction techniques on a single lot, however, may impact development on neighboring lots. This was your concern for development of upslope properties, and I agree. Loading the landslide head, introducing water from landscaping upslope, or improper grading may cause problems for downslope properties. Therefore, it is best to perform a comprehensive study for the entire subdivision to address all geotechnical issues, including slope stability, prior to looking at individual lots. This comprehensive study should include requirements for proper drainage and grading, and should recommend hazard-reduction measures if needed. As with a lot-specific plan, the subdivision plan should be reviewed by a qualified professional and approved by the county prior to additional development. Such a comprehensive plan may eliminate the need for individual lot-by-lot studies and lower the ultimate cost of planning for individual lot owners.

If I can be of further assistance, please feel free to call me at 467-7970. We can help perform the recommended reviews for Weber County on request. I have also enclosed a copy of our statewide map of the radon-hazard potential, as you requested. John Hultquist of the Utah Division of Radiation Control has additional radon-related material on measurement and hazard-reduction techniques, and will provide you with copies if you call him at 536-4250. Be sure you specifically ask him for the booklet on radon-reduction techniques for new construction, and mention that you are interested in incorporating such techniques in a county ordinance. He appreciates any interest in promoting awareness of the indoor-radon hazard, and can assist you in building-code development related to radon.

Sincerely,

Barry J. Solomon
Geologist, Applied Geology Section

Encl.

State of Utah
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June 22, 1998

Craig Barker
Director
Weber County Planning Department
2380 Washington Boulevard
Ogden, Utah 84401

Dear Mr. Barker,

Enclosed is the report on my investigation of the cut-slope failure at Green Hill Country Estates and implications for geotechnical slope-stability recommendations. If you have any questions, feel free to call me at (801) 537-3381.

Sincerely,

Bill D. Black
Project Geologist

cc: Jim Gentry, Weber County Planning Department

Utah Geological Survey

| Project: | | | Requesting Agency: |
|---|---|---|---|
| Investigation of a recent cut-slope failure and implications for geotechnical slope-stability recommendations at Green Hill Country Estates Phase VI, Ogden Valley, Weber County, Utah. | | | Weber County Planning Department |
| By: Bill D. Black | Date: 06-22-98 | County: Weber | Job No: 98-18 |
| USGS Quadrangle: Browns Hole (1368) | | Number of attachments: 0 | |

## INTRODUCTION

At the request of Craig Barker, Weber County Planning Department, I conducted a reconnaissance of a recent cut-slope failure in an undeveloped portion of Green Hill Country Estates Phase VI east of Huntsville, Utah, in the NW1/4NE1/4 section 9, T. 6 N., R. 2 E., Salt Lake Base Line and Meridian. Applied Geotechnical Engineering Consultants (AGEC) previously conducted a geotechnical and landslide study for the development (AGEC, 1996), which was reviewed by Francis Ashland (Utah Geological Survey) at the request of the Weber County Planning Department and found to be thorough and adequate (Ashland, 1996). The purpose of my reconnaissance was to evaluate whether the slope of the failed cut met AGEC's (1996) recommendations and, if so, whether future slope-stability problems may be anticipated in spite of their recommendations being followed. The scope of work included a literature review and a site visit on May 29, 1998. Rob Edgar (AGEC) and Curtis Christensen (Weber County Engineer) were present during the site visit to conduct a follow-up investigation for possible expansive soils. I inspected only one area undergoing cut-slope failure; other cuts in the development may also be failing.

## DISCUSSION

The 1998 slope failure is in a west-facing 4:1 (horizontal:vertical) road-cut slope about 15 feet (4.6 m) high on the east side of Maple Canyon in the eastern part of the Green Hill Country Estates development. The surface of rupture appears to be shallow (about 3 feet [0.9 m] deep) and is between an upper high-plasticity clay layer and an underlying clayey gravel deposit. I observed water seeping from the toe of the failure during my reconnaissance, which suggests the slope is saturated. AGEC (1996) previously noted four similar landslides that occurred during spring 1995 in 3.5:1 cut slopes in the development. The 1998 failure is not in an area of pre-existing landslides (AGEC, 1996). AGEC (1996) speculated the 1995 failures were triggered by a reduction in strength when clay soils became wet during infiltration of spring runoff. No failures were found in areas where the upper soil consists of clayey gravel (AGEC, 1996).

To maintain stability of road cuts and other cut slopes at the site, AGEC (1996) recommended no cuts steeper than 4:1 in natural clay soils. Although AGEC (1996) observed no evidence of shallow ground water during their subsurface investigation, they indicate the risk from slope instability is higher if shallow water is present. The 1998 failure is in a 4:1 cut slope saturated by spring runoff, and the slope of the cut is slightly steeper than the natural slope. This suggests disturbance of the natural slope may cause even shallow cuts in the clay soils to fail when wet.

## RECOMMENDATIONS

Cut slopes in the clay soils at the site conform to AGEC's (1996) recommendations but are still failing. Thus, I recommend that:

- AGEC review and revise their recommendations as needed for maintaining cut-slope stability,
- Weber County devise a means to ensure that AGEC's recommendations are followed and that no unplanned cuts are made (such as for landscaping),
- AGEC's (1996) recommendation to maintain good surface drainage upslope of the cut slopes and to direct water away from the cut faces be followed, and
- as a precaution, landowners minimize landscape irrigation. Although spring runoff is the principal cause of both the 1995 and 1998 failures, landscape irrigation may cause further slope instability.

## REFERENCES

Applied Geotechnical Engineering Consultants, Inc., 1996, Geotechnical and landslide study--Green Hill Country Estates Phase VI, part of sections 4 and 9, T6N, R2E, SLB&M, Weber County, Utah: Midvale, Utah, unpublished consultant's report, 21 p.

Ashland, Francis, 1996, Review of a geotechnical and landslide-hazard report for the proposed Green Hill Country Estates Phase VI, Weber County, Utah, *in* Mayes, B.H., compiler, Technical reports for 1996 Applied Geology Program: Utah Geological Survey Report of Investigation 231, p. 109-111.