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# SOIL & GEOLOGICAL HAZARD REPORT
# WHETSTONE BUSINESS PARK
# GUNNISON COUNTY, COLORADO

On August 25 and 26, 2004, Buckhorn Geotech, Inc., conducted an investigation of site and subsurface conditions at the proposed Whetstone Business Park subdivision near Crested Butte, Colorado. This work was performed at the request of Mr. John Councilman, on behalf of the owners, Whetstone Business Park, LLC. The purpose of the investigation was to evaluate any geological hazards affecting development on the property, assess the soil suitability for foundation and individual septic system design, and give pavement design recommendations for roadways. The investigation consisted of a site inspection, excavation of four test pits, logging and testing of materials encountered, percolation testing, design of pavement sections, and analysis of available data. The following report presents the findings of our investigation together with our conclusions and general engineering recommendations for planning, development, and construction within the subdivision.

## Site Description and Proposed Development

The proposed Whetstone Business Park subdivision is a 13- to 14-acre parcel located on the west side of Highway 135, approximately two miles southeast of the town of Crested Butte. The property is situated in the southeast ¼ of Section 12, Township 14 South, Range 86 West, 6th Prime Meridian. The property slopes generally to the south at grades of 0 to 10% with one area sloping up to 20%, where the property changes terrace levels. The topography of the property is shown on the attached site sketch. The property is bound on the northeast by Highway 135, on the southeast by Riverland Industrial Park, and on the west and northwest by private property. The Slate River is located to the west and south of the property. Vegetation on the property consists primarily of native grasses and sagebrush, with a small cluster of shrubs and willows located in the southwest portion of the property. What appears to be an abandoned irrigation ditch crosses the southwest corner of the property. According to the site plan provided to us by Mr. Councilman (by NCW & Associates, dated 3/23/04) the elevation of the property ranges from approximately 8,820 to 8,854 feet. The following photograph, taken looking across the property to the north-northeast towards Crested Butte Mountain, shows the vegetative cover, the local topography, and the conditions at the time of our testing.


According to Mr. Councilman, the development planned for the property is to consist of ten approximately one-acre lots and one approximately two-acre lot. The lots will be for industrial, residential, and combined industrial/residential use.

## Geology

The striking scenery of the Crested Butte region is dominated by the intersection of the Elk Mountains and the southwest-northeast trending West Elk laccolith field which terminates near Crested Butte in such well-known local features as Crested Butte, Whetstone, Axtell and Gothic Mountains. The Elk Mountains, lying directly to the northeast of Crested Butte, consist of complexly folded and faulted Mesozoic and Paleozoic sedimentary rocks and are intruded by several 30-40 million year old granitic bodies known as laccoliths. Laccoliths are small, dome shaped intrusive igneous bodies with a flat floor, looking very similar to mushrooms in shape. In the local area most laccoliths have been intruded at shallow depths into the soft, weak Mancos Shale which has later been eroded off of the top of the intrusive body forming a dome of granitic material. The Crested Butte laccolith has been dated at 29 million years old.

Much later, several episodes of glaciation, with the most recent ending approximately 10,000 years ago, carved the horns, cirques and arêtes into the mountains around the Crested Butte area. These glaciers also scoured out the inter-mountain U-shaped valleys, such as the Slate and East River Valleys. In the local area, glaciers advanced down to an elevation of approximately 8,800 feet, as seen by the major end moraines about 3 miles southeast of Crested Butte along Highway 135. Meltwater from this glacial lobe produced outwash gravels that form the terraces seen along local rivers. The effects of these glaciations are still seen in the area as over-steepened valley walls and stripped surfaces in high mountain valleys. The numerous mass-wasting features seen along both sides of the Slate River Valley and along tributary valleys are probably due to the increased moisture that was prevalent at the time the glaciers melted. Furthermore, the weak and plastic Mancos Shale formation can be seen to be failing as a complex of slides and flows along the lower flanks of the laccoliths. These failures are caused by the loading of the more dense igneous rocks and the over-steepening of the valley sides. The lower slopes of Crested Butte, Gothic and Whetstone Mountains are excellent examples of this phenomenon that are the cause of many of the construction problems in this area. Today, water and gravity are the dominant natural factors in the persistent erosional process.

According to the *Geologic Map of the Crested Butte Quadrangle* (Gaskill and others, 1986), the Slate River Valley is covered with Quaternary (Holocene) alluvial deposits of silt to boulder-size material. These deposits include river alluvial, alluvial fan, glacial, glaciofluvial, and colluvial deposits with pockets of peaty material derived from paleo pond and bog environments. On the east side of the river, where the property is located, are glacial till materials deposited as Quaternary (Pleistocene) terminal moraine landforms. The subject property is mapped predominantly as *Qg2,* with a small area at the southern tip of the property mapped as *Qg1.* Both *QG2* and *Qg1* areas are defined as mostly glacial outwash associated with the Pinedale Glaciation (Pleistocene). This glacial outwash (alluvial) material consists of moderately to well-sorted and rounded to subrounded gravels, cobbles and some boulders in a sandy gravel soil matrix. Conditions found within the test pits confirm the identification of the subsurface materials at this site as glacial in origin. No formational material was encountered in our test pits to depths of 7 to 11 feet. The geologic map shows an erosional scarp going across the property from west to east in the southern section of the property. These scarps occur at changes in the terrace levels in *Qg2* deposits.

## Geologic Hazards

A variety of geological hazards can exist in western Colorado as a result of elevation, mountainous terrain, soil and geologic conditions, and climatic effects. Geologic hazards, as defined in the Gunnison Land Use Resolution, include, but are not limited to, avalanches, landslides, rockfalls, alluvial fans, talus slopes, steep unstable, or potentially unstable slopes, Mancos shale, mudflows, and faults. Those hazards that potentially affect the proposed Whetstone Business Park subdivision are discussed below. Modern development in the valley can be considered to be only about 40 years old, with most occurring in the past 20 years. Because of this relatively short period of time, useful empirical data are limited. Some buildings and roadways throughout the local mountains and valleys have experienced negative impacts due to slope movement and groundwater problems. Logical structural engineering techniques for design and construction of buildings and roadways can be used to reduce the potential for problems related to troublesome climate and soil conditions. However, because of the overall dynamic characteristics of the area, almost every structure is subject to at least some degree of potential risk. These risks are explained below.

## Slope Instability and Erosion

According to the Colorado Geological Survey report *Geologic Hazards in the Crested Butte-Gunnison Area, Crested Butte Quadrangle* (Colorado Geological Survey Info. Series #5, by J. Soule 1976), the subject property is mapped as a stable area. These areas in the upper East River and Slate River are predominantly moraines and/or stream terraces composed of sands and gravels. However, the non-cohesive nature of the rounded to subrounded gravels, cobbles, boulders, and sandy interstitial soil, makes cut banks susceptible to erosion.

Slopes on the property range from nearly level up to twenty percent on the transition slopes between terraces. The land is currently well vegetated and shows little evidence of slope instability or recent erosion. However, slope instability can be brought on by development practices that ignore the potential for earth movements. Slope stability can be impaired by cutting into steep slopes (especially near the toe), applying new loads (especially near the crest of steep slopes), careless removal of vegetation, and introducing soil moisture or disrupting the existing pattern of surface or subsurface water flow. Providing logical landscape topography, developing an integrated grading and drainage plan, and retaining cut slopes over 3 feet high will be important in preserving slope stability. Other recommendations for enhancing slope stability are presented in the *Conclusions and Recommendations* section of this report.

Erosion is not considered a significant hazard at this site based upon our observations, provided conscientious construction practices are followed. However, careful soil and water management is recommended across the proposed subdivision to prevent erosion. It is recommended that post-construction development include careful and judicious grading and landscaping/ xeriscaping in disturbed areas.

## Shallow Groundwater

No groundwater was encountered in the four excavations on the property at the time or our investigation. However, the soils in the test pits became more moist to wet with depth. It is likely that there will be more and possibly shallower groundwater on the property during the spring and early summer snowmelt season. During that time, mountain soils are usually saturated as melting snow percolates through the subsoils, where it recharges groundwater that is flowing downhill under the force of gravity to feed the stream systems. Groundwater monitoring wells (standpipe piezometers) were installed in the excavations prior to backfilling to allow future groundwater monitoring, if deemed necessary and requested by the owners.

Seasonal high groundwater may cause movement of the near-surface soils and subsequent movement for foundations set into these soils, allow moisture penetration into crawlspaces and beneath slabs on-grade, and impede the percolation of effluent from a leach field. With proper foundation and septic design, these problems can be successfully mitigated. Specific recommendations for mitigation are given in the *Conclusions and Recommendations* section of this report.

## Wetlands

Delineation of wetlands on the property is beyond the scope of this investigation. We understand Mr. Councilman has requested wetlands delineation on the property from another party.

## Flooding

According to the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map (080078 0325B, Sept. 29, 1989) the 100-year floodplain encroaches slightly (approximately 100 feet) onto the southern portion of the property. This is an "approximate study" and we understand the owner has consulted with another party to more closely outline the actual flood plain location on the property. The majority of the property is located in Zone X, according to the FEMA mapping. These areas are determined to be outside the 500-year floodplain.

## Seismicity

According to the Colorado Geological Survey report entitled *Earthquake Potential in Colorado—A Preliminary Evaluation* (CGS Bulletin #43: Kirkham and Rogers, 1981), there are no active faults in the vicinity of the subject property. According to the Uniform Building Code, western Colorado is in Seismic Risk Zone 1 where distant earthquakes would be expected to cause only minor damage to structures with fundamental periods of vibration greater than one second. No such high-rise structures are constructed in western Colorado. It should be noted that based on recent evidence, a Seismic Risk Zone 2 designation may be more appropriate for the majority of Colorado.

## Radon Gas

Radon gas is produced by decay of radioactive minerals contained in subsurface rock and soil. The generation of radon gas is a potential hazard if ignored during design and construction. The Environmental Protection Agency (EPA) has not developed a pre-construction test that will determine levels of radioactivity on a site. However, once construction is complete, inexpensive tests can be performed to determine the accumulation of radioactivity inside the building. Recommendations for design and construction techniques found effective in the control and/or reduction of radon gas can be found in the pamphlet *Radon Resistant Techniques for New Residential Construction* (EPA/625/2-91/032) and *Radon Reduction Methods, a Homeowner's Guide* (EPA Bulletin RD-681). The Radiation Control Division can be contacted in Denver at (303) 692-3030 for more information.

No other geologic hazards are known to be present in the vicinity of the proposed Whetstone Business Park subdivision.

## Soils

Four test pits (TP#1 to TP#4) were excavated on August 25, 2004, using a backhoe at locations shown on the attached site sketch. The locations of the test pits were selected by our staff in an effort to demonstrate variability in soil, rock, and groundwater conditions across the property. The soil, rock, and groundwater conditions were visually examined and logged, and representative samples of soil encountered were brought back to our laboratory for detailed examination and testing. The stratigraphy encountered in the test pits and laboratory results are discussed below and are shown on the attached Soil Logs.

Generally, the soil conditions across the proposed subdivision can be classified into three subsoil types and a topsoil layer.

The **topsoil layer** is a brown, damp, silty loam topsoil. A 0.5-foot layer of this topsoil was found in the first three test pits. The forth test pit had a topsoil layer that was similar to soil type II (see below).

**Soil Type I** is a dry to wet, silty sand and gravel, with high rock content (ranging from 40 to 80%). This soil type was found at depths ranging from 0.5 to 8 feet in TP#1, from 0.5 to 5.5 feet in TP#2, from 0.5 to 7 feet in TP#3 and from 4 to 4.5 feet in TP#4. An Atterberg Limits test performed on a bulk sample of this soil obtained at a depth of 3 to 4 feet in TP#1 revealed that this soil is non-plastic (see Atterberg Limits results for sample "GS1"). A soil that is non-plastic has very low potential for swelling and shrinking with changes in moisture content and has little or no cohesion. A Gradation Analysis performed on the same sample indicates that the soil is composed of 7.0% fines (silt and clay), 41.4% sand, and 51.6% gravel (see Sieve Analysis results for sample "GS1"). Natural moisture content of the bulk sample was measured to be 5.9%. The Unified Classification of this soil is a sandy gravel with little silt (GW-GM).

A Modified Proctor test and a California Bearing Ratio test were performed on a sample of this soil obtained from TP#3 at a depth of 1 to 3 feet in order to assess the soil properties for a pavement section design. The results of the California Bearing Ration test showed 46.5 at 0.1-inch penetration and 47.3 at 0.2-inch penetration. The Modified Proctor test resulted in a maximum dry density of 130.7 pounds per cubic foot at optimum moisture content 8.1%.

**Soil Type II** is a damp to moist, brown, silty sand. This soil type was found from 5.5 to 9 feet in TP#2 and from 0 to 4 feet in TP#4. In TP#2 the sand was dense, but in TP#4 the sand was loose and unconsolidated. Atterberg Limits tests performed on bulk samples of this soil obtained at a depth of 6 to 7 feet in TP#2, and a depth of 2 to 3 feet in TP#4 revealed that this soil is non-plastic (see Atterberg Limits results for samples "GS2" and "GS4"). A soil that is non-plastic has very low potential for swelling and shrinking with changes in moisture content and has little or no cohesion. Gradation Analyses performed on these samples indicate that the subsoils are typically composed of 27.5 to 28.3% fines (silt and clay), 51.2 to 71.7% sand, and 0.0 to 21.3% gravel (see Sieve Analysis results for samples "GS2" and "GS4"). The moisture contents of the two samples ranged from 9.5 to 10.7%. The Unified Classification of this soil is a silty sand to a silty gravelly sand (SM). A swell/consolidation test was performed on a sample of this sand collected at a depth of 3 feet in TP#4 (see Swell/Consolidation test results for sample "GH").

Under a seating pressure of 100 pounds per square foot (psf) and left at its in-situ moisture content of 8.9%, the sample compressed 1.1%. When inundated with water, the sample consolidated another 1.1%. Upon the addition of progressively increasing pressures to 2,000 psf, the sample consolidated a total of 17.9%. The initial dry density of this sample was relatively low, measured at 71.9 pounds per cubic foot (pcf). Our field observations indicate that the in-place dry density of this soil in TP#2 is much higher than in TP#4, and therefore, less consolidation would be anticipated in this sand layer where it is dense and overlain by other soils.

**Soil Type III** is a sandy silt with little gravel. This soil type was only found in TP#4, from a depth of 4.5 to 10.5 feet. An Atterberg Limits test performed on a bulk sample of this soil obtained at a depth of 5 to 6 feet in TP#4 revealed that this soil is non-plastic (see Atterberg Limits results for sample "GS5"). A soil that is non-plastic has very low potential for swelling and shrinking with changes in moisture content and has little or no cohesion. A Gradation Analysis performed on the same sample indicates that the soil is composed of 71.2% fines (silt and clay), 24.4% sand, and 4.4% gravel (see Sieve Analysis results for sample "GS5"). Natural moisture content of the bulk sample was measured to be 18.2%. The Unified Classification of this soil is a sandy silt with little gravel (ML). A swell/consolidation test was performed on a sample of this sand collected at a depth of 5.3 feet in TP#4 (see Swell/Consolidation test results for sample "EF"). Under a seating pressure of 100 pounds per square foot (psf) and left at its in-situ moisture content of 18.1%, the sample compressed 0.2%. When inundated with water, the sample consolidated another 0.2%. Upon the addition of progressively increasing pressures to 2,000 psf, the sample consolidated a total of 1.8%. The initial dry density of this sample was moderate, measured at 107.5 pounds per cubic foot (pcf).

In Summary, Soil Type I (silty sand and gravel) is found on the majority of the property, with Soil Type II (silty sand) being found on the lower terrace, and Soil Type III (sandy silt) appears to occur in the southern section of the property. Specific recommendations for foundation types suitable for the site soils are given in the *Conclusions and Recommendations* section of this report.

## Percolation Testing

Percolation tests were performed at Test Pit #1, Test Pit #2, and Test Pit #4 which were thought to generally represent the major soil conditions within the property. The resulting percolation rates, measured in minutes per inch (mpi), are provided in the tables below.

| Test Pit | Test Hole # | Depth (inches) | Percolation Rate (mpi) | Soil Description |
|---|---|---|---|---|
| TP#1 | 1 | 40 | 10 | Type I (silty sand and gravel) |
| | 2 | 36 | 15 | Type I (silty sand and gravel) |
| | 3 | 42 | <5 | Type I (silty sand and gravel) |
| TP#2 | 4 | 36.5 | <5 | Type I (silty sand and gravel) |
| | 5 | 34 | <5 | Type I (silty sand and gravel) |
| | 6 | 34 | <5 | Type I (silty sand and gravel) |
| TP#4 | 7 | 43 | <5 | Type II (silty sand) |
| | 8 | 40.5 | <5 | Type II (silty sand) |
| | 9 | 35.5 | <5 | Type II (silty sand) |

As seen in the results above, Type I soils (silty sand and gravel) yielded percolation rates ranging from 15 minute per inch to faster than 5 minutes per inch, Type II soils (silty sand) tested yielded rates faster than 5 minutes per inch.

Gunnison County requires percolation rates between 5 and 60 minutes per inch for conventional OWS design, with a minimum of 4 feet of suitable soil without groundwater beneath the seepage bed. The fast percolation rates we encountered in our investigation indicate that OWS systems will need to be designed on a site-by-site basis according to site-specific percolation rates. It is anticipated that leachfield areas may need to import specified soil to slow percolation rates. Alternate designs may employ advanced filtration systems to pretreat effluent before disposing of it in the fast percolating native soils.

The specific types of uses for the residential and industrial lots in the subdivision have not yet been determined. Gunnison County guidelines will be required to be met for the design of each individual system at the time when individual sites are developed. Refer to the *Conclusions and Recommendations* section of this report for further information regarding OWS design.

## Asphalt Pavement

It is anticipated that Soil Type I (silty sand and gravel) comprising the upper horizon of soil in Test Pits #1 through #3 will serve as the subgrade for pavement on the property. As noted in the *Soils* section of this report, this soil is non-plastic and has a California Bearing Ratio of 46 to 47. The fact that the soil is non-plastic and is well-drained are very favorable in relation to long-term pavement performance.

A pavement design analysis has been performed to determine requirements for base and sub-base construction. We recommend a pavement section as follows:

> 3 inches asphalt concrete over
> 6 inches of compacted ¾-inch roadbase over
> compacted native silty sand and gravel

# CONCLUSIONS AND RECOMMENDATIONS

Our evaluation indicates that the subject property appears suited for the subdivision planned with careful attention to development, construction, and site-specific OWS design. Based on the site inspections and results of the laboratory soil testing, the following general recommendations are offered for foundation evaluation and for mitigation of potential geological site hazards. These recommendations are conceptual and are offered as general guidelines. ***Site-specific investigation and testing should be done to verify applicability prior to design and construction on each lot.***

## Foundation Considerations

Based upon the soil conditions encountered during our investigation, shallow spread footings should perform adequately on this property, without undue settlement or heave of the subgrade soils. However, site-specific soil investigation and testing should be conducted at the proposed building sites to determine the specific design parameters required to match the subsurface conditions to the proposed patterns and intensities of loading incurred by each structure. If any expansive soils are encountered during site specific testing, shallow spread footings may not be appropriate for that site.

The shallow spread footing or basement foundation components should rest upon uniform soil conditions (like material), usually indicated by similar color, gradation, and consistency. After excavation to foundation depth, the exposed soil surface should be compacted using vibratory or roller compaction equipment to provide a uniformly dense surface prior to placement of footing forms.

The footings, bearing pads, and retaining walls to be placed on the Type I native silty sand and gravel should be designed using an allowable bearing capacity ($q_a$) of 2,500 psf.

The footings, bearing pads, and retaining walls to be placed on the Type II native silty sand should be designed using an allowable bearing capacity ($q_a$) of 1,500 psf. This soil type was found in both dense and loose states at the site. If encountered in a loose state, the upper two feet of this sand should be removed, the exposed soil surface compacted as described above, and the removed soil replaced in 6-inch lifts with each lift being compacted to at least 90% of Modified Proctor density.

Shallow foundation systems should be extended into the subsurface a minimum depth below finished grade as prescribed by the local building official for frost heave protection.

## Slab On-Grade Considerations

Slabs on-grade may be used at the site for garage and shallow interior floor slabs, if desired, but should be verified by the results of site-specific investigation and testing. Basement floor slabs should only be used if site specific testing and groundwater monitoring confirms that they are appropriate. To provide adequate support for the slabs, topsoil and organic material should be stripped and the soil prepared as determined through site-specific investigation and testing. As noted above, in the *Foundation Considerations* Section, if expansive conditions or moist soils are encountered during site-specific geotechnical investigations, slabs on-grade may not be recommended without some form of mitigation unless the property owner is willing to accept a high-risk of post-construction movement.

Concrete floor slabs should be structurally separate from foundation, bearing walls, and interior partitions so that the slabs can float freely in response to soil volume changes without introducing distress to the structure.

Exterior concrete flatwork should be designed and constructed so that it drains freely away from the structure. Flatwork may be placed on native soil with the topsoil and organic material removed.

## Retaining Structure Considerations

Lateral loads developed against retaining walls are a function of the height of the retained soil, the backslope angle, the soil placed against the wall, the drainage conditions, and the compactive effort applied to the backfill. Design pressures should be based upon site-specific investigation and testing, and should account for any potential expansive pressures that can be exerted by the native soils.

The retaining walls should have provisions for drainage so that hydrostatic pressures are not allowed to build up. This is usually accomplished by providing free-draining granular backfill between the wall and retained soil, with a collection drain provided at the bottom of this granular zone, and/or the use of weep holes through the face of the wall. The drain system should be continuous and have a positive outfall which releases the collected water well away from the wall in a manner that minimizes the erosive energy of concentrated flow. The design engineer should ensure that drainage design is compatible with design assumptions.

## Concrete

Because of the potential sulfates in the soil and their corrosive qualities, Type I/II sulfate-resistant cement should be used in all concrete at this site.

## Drainage and Ventilation

It is important to prevent moisture from penetrating into the soil beneath or adjacent to foundations. Moisture can accumulate as a result of poor surface drainage, over-irrigation of landscaped areas, subsurface seepage, or condensation from vapor transport.

We recommend that provision be made to evacuate subsurface moisture accumulation from around foundations and under slabs. This may be accomplished using conventional footing drains in tandem with a positively-vented moisture and radon control system. Alternatively, consideration may be given to using concrete forms that facilitate both dewatering and the removal of radon gases and vapors.

Floor systems and confined areas above concrete floor slabs should be properly ventilated to allow for the release of radon gas. (See the *Radon Gas* Section of this report for EPA references for design and construction techniques.)

## Site Preparation and Grading

The site drainage plan, in tandem with the landscape and grading plans, should ensure that each lot is adequately drained and that captured runoff is discharged from the development in a manner that is compatible with the natural drainage system and pertinent local regulations. Surface water should be removed and not allowed to accumulate or stand anywhere near building sites either during or after completion of construction. This includes water from landscaped areas, patios, decks, and roofs. Drainage plans should ensure that precipitation, snowmelt, and runoff are conveyed around and away from buildings as well as driveways. This runoff should be dispersed (not concentrated) in a manner consistent with natural, pre-construction drainage patterns.

Final grading around the perimeter of foundations should slope downward with at least one foot of drop within the first 10 feet of horizontal distance. Concrete flatwork adjacent to the foundations should slope away at a rate of at least ¼-inch per foot.

Development should utilize "best practices" for design and construction so that on-site erosion is minimized. This may include construction of temporary diversion ditches, silt fencing, and/or dust suppression. If the cumulative area of disturbance at a site is greater than one acre, on-site erosion control should be planned and executed in conformance with Colorado Department of Public Health and Environment (Water Quality Control Division) stormwater discharge regulations. The local building official will be able to provide specific details regarding this requirement.

Based on our observations, excavation of the site soils can be accomplished by conventional excavating equipment. Temporary excavations should be made consistent with Occupational Safety and Health Administration (OSHA) regulations and with worker safety in mind.

Grading of all permanent cut and fill slopes should not exceed 2H:1V. All slopes greater than 2H:1V and over 3 feet in vertical height should be restrained by an engineered retaining structure/system.

## Pavement Design

We understand the development will include paved roadways consistent with the *Gunnison County Road and Bridge Standards*. We have examined soil conditions and recommended a pavement section for the soil conditions encountered in the proposed roadway alignment.

Road base and subbase sections should have sufficient width to fully extend beneath areas of curb and gutter, where used. Particular care should be given to design and construction that does not allow degradation of the asphalt edge due to trafficking on the roadside. This is usually accomplished by proper compaction of the subgrade, subbase, and base materials, and providing sufficient lateral support beyond the edge of pavement. Construction of the roadway prism should promote drainage away from the prism and subgrade. Adequate borrow ditches and culverts should be provided and, where needed, lateral and/or crossdrains should be installed to keep water away from the roadways.

Subgrade preparation, backfill gradation and placement, and asphalt and cement concrete mix designs should follow the specifications given in the *Gunnison County Road and Bridge Standards*. Topsoil should be removed and organic material grubbed prior to commencing construction of the road sections. Where subgrade is required to be reworked to meet the minimum compaction target, a minimum one foot of scarification and recompaction of the subgrade is recommended.

## On-Site Wastewater System Design and Construction

Percolation rates of less than 5 to 15 minutes per inch were measured in the soils on this property. System designs should consider the factors discussed previously in the *Percolation Testing* Section. Additional site-specific percolation tests will be required for OWS design for each lot in the subdivision. The percolation tests were conducted in accordance with Colorado State regulations and the state-of-art practice for engineering of on-site wastewater systems. However, Buckhorn Geotech takes no responsibility for OWS designs carried out by others using this information.

Water conservation devices should be used in the residential and commercial buildings to reduce the volume of water that will be passing through the OWS. Implementation of this recommendation will help to extend the working life of each system.

Care must be taken in locating each disposal area to ensure proper system operation and compliance with state and local setback criteria. The specific types of uses for the residential and industrial lots in the subdivision have not yet been determined. Gunnison County guidelines must be met for the design of each individual system.

## Closure

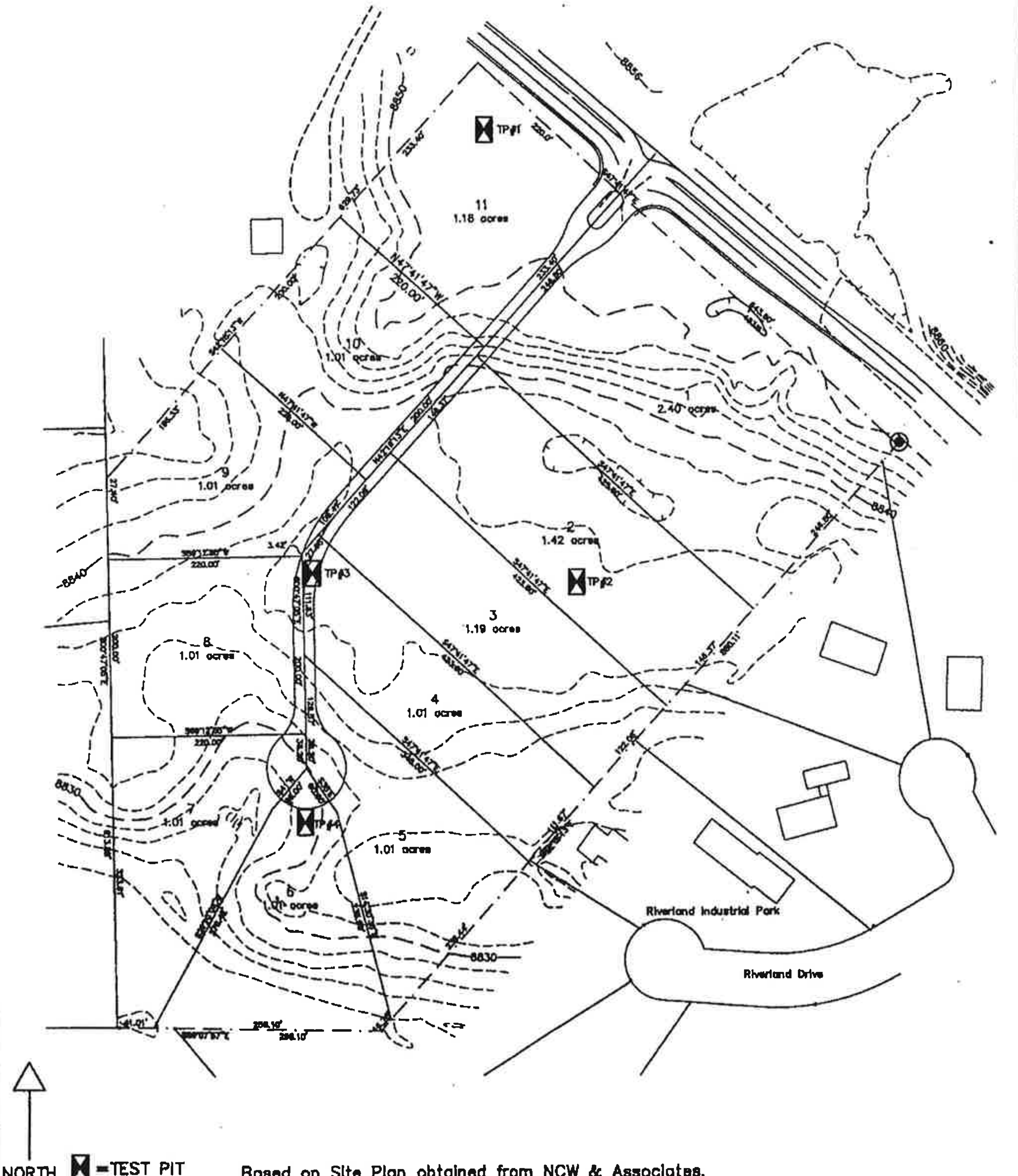
Thank you for the opportunity to perform this geologic investigation for you. Buckhorn Geotech is a full-service engineering firm providing foundation, site drainage, structural, septic system and retaining structure design services, as well as construction materials testing and inspections. Please visit our website at **www.BuckhornGeo.com** for a full description of our services. If you require any of these services or have any questions regarding this report, please do not hesitate to contact us.

Respectfully Submitted,
September 28, 2004

Thomas E. Griepentrog, P.E.
TEG/kdr

Enclosures: Site Map, Soil Log Key, Soil Logs, Sieve Analysis results, Atterberg Limits results, Swell/Consolidation graphs, CBR results, Modified Proctor results, Glossary of Engineering and Soils Terms

## SITE MAP

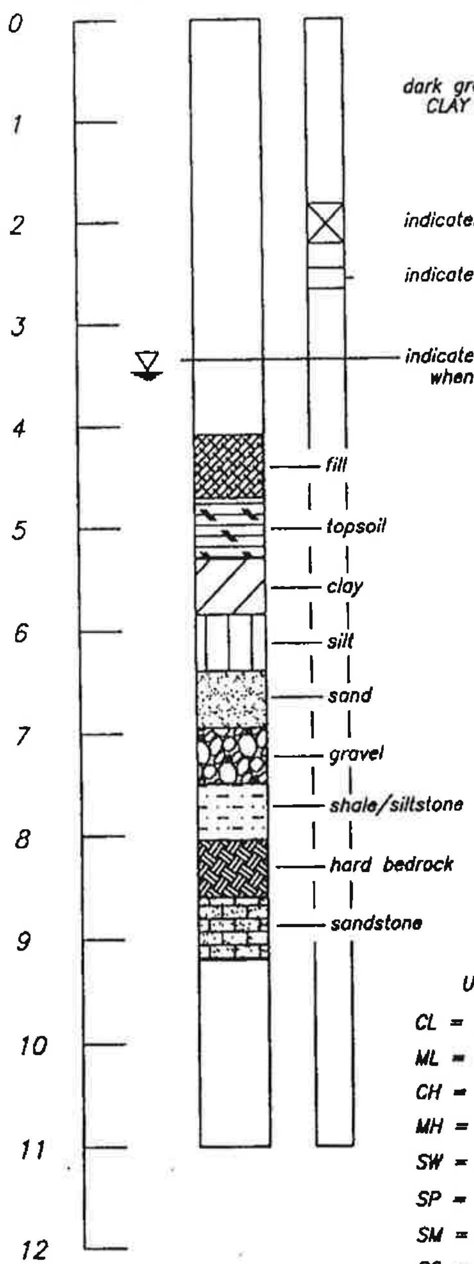



Based on Site Plan obtained from NCW & Associates.

| Drawing 1 of 1 | Field Testing K.Roberts/T.Griepentrog<br>Lab/Drafting K. Roberts<br>DATE 8/25/04<br>PROJECT # 04-078-GEO | Whetstone Business Park<br>13–14 acres<br>Gunnison County, Colorado | BUCKHORN GEOTECH<br>Civil, Structural & Geotechnical Engineers<br>222 South Park Ave. Montrose, Colorado 81401<br>970-249-6828 Fax. No. 970-249-0945 |
|---|---|---|---|

# SOIL LOG KEY

Depth (ft) | Symbol | Sample | Soil Description | Laboratory Test Results




dark gray moist firm to stiff sandy CLAY with gravel --CL (2-4')

range in depth of soil unit

Unified Soil Classification (see definitions below)

indicates bulk sample

indicates drive sample

indicates the location of free subsurface water when measured

**Constituents**

trace = 0 - 5%
little = 5 - 12%
some = 12 - 20%
-ey = 20 - 30%
and = >30%

**Laboratory Test Results**

Notes in this column indicate tests performed and test results

- DD: dry density
- MC: % moisture content
- LL: Liquid Limit
- PL: Plastic Limit
- PI: Plasticity Index
- GF: gravel fraction (%)
- SF: sand fraction (%)
- F200: silt/clay (%)
- Sh: shear resistance
- P: penetration resistance
- SP: swelling pressure
- TM: total movement under consolidation pressure
- pcf: pounds per cubic ft.
- psf: pounds per square ft.

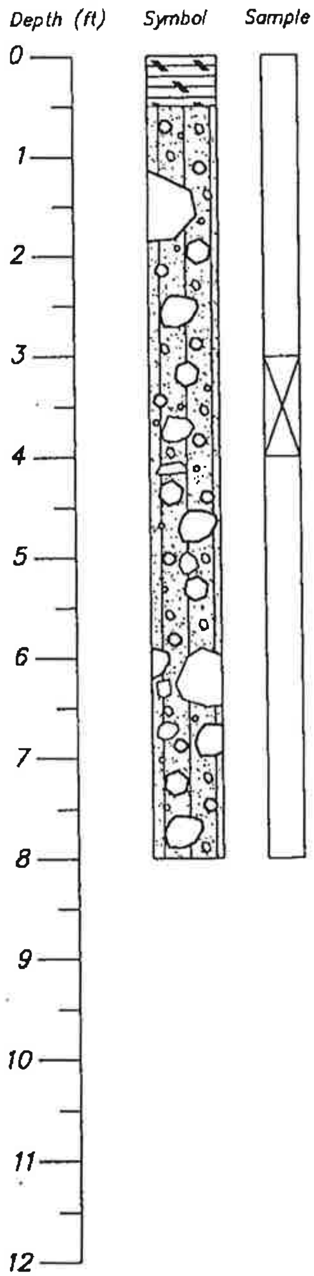
**Unified Classification System (ASTM D-2487)**

- CL = lean clay to sandy/gravelly lean clay
- ML = silt to sandy/gravelly silt
- CH = high plasticity clay to sandy/gravelly high plasticity clay
- MH = high elasticity silt to sandy/gravelly high elasticity silt
- SW = well-graded sand or well-graded sand with gravel
- SP = poorly-graded sand or poorly-graded sand with gravel
- SM = silty sand to silty sand with gravel
- SC = clayey sand to clayey sand with gravel
- GW = well-graded gravel or well-graded gravel with sand
- GP = poorly-graded gravel or poorly graded gravel with sand
- GM = silty gravel or silty gravel with sand
- GC = clayey gravel or clayey gravel with sand

| | | | |
|---|---|---|---|
| DRAWING NUMBER 1 OF 1 | INVESTIGATION<br>DRAFTING<br>DATE 12 FEB. 04<br>JOB NO. | SOIL LOG KEY | BUCKHORN GEOTECH<br>Civil, Structural, and Geotechnical Engineers, Inc.<br>222 South Park Avenue<br>Montrose, Colorado 81401<br>Phone (970) 249-6828 Fax (970) 249-0945 |

# SOIL LOG TEST PIT #1 (TP#1)

northern portion of property




**Soil Description**

damp, brown, silty TOPSOIL(0–0.5')

dry to damp, light brown, silty SAND and GRAVEL with 70–80% rounded to subrounded gravels and cobbles(0.5–8')
COMPACT to DENSE

bulk sample "GS1" @3–4'

roots extend to 4–5'

moist to wet(4–8')

end of excavation @8'
no groundwater or bedrock

**Laboratory Test Results**

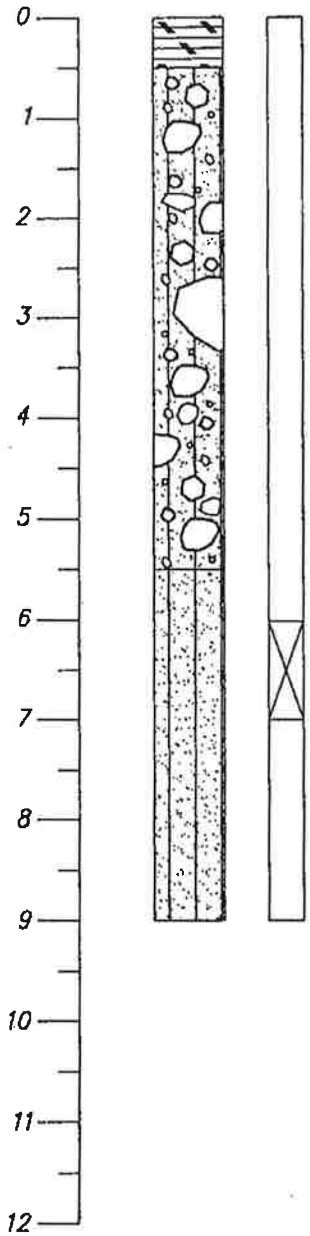
(GS1)
NON-PLASTIC
GF=51.6% SF=41.4%
F200=7.0% MC=5.9%

| DRAWING NUMBER 1 OF 4 | | Whetstone Business Park 13–acres Gunnison County, CO | BUCKHORN GEOTECH |
|---|---|---|---|
| | INVESTIGATION KR/TG | | Civil, Structural, and Geotechnical Engineers, Inc. |
| | DRAFTING KR | | 222 South Park Avenue |
| | DATE 8/25/04 | | Montrose, Colorado 81401 |
| | JOB NO. 04-078-GEO | | Phone (970) 249-6828 Fax (970) 249-0945 |

# SOIL LOG TEST PIT #2 (TP#2)

eastern central portion of property

| Depth (ft) | Symbol | Sample | Soil Description | Laboratory Test Results |
|---|---|---|---|---|




damp, brown, silty TOPSOIL(0–0.5')

dry to damp, light brown, silty SAND and GRAVEL with 70–80% rounded to subrounded gravels, cobbles, and small boulders(0.5–5.5')
DENSE

roots extend to 4–5'

bulk sample "GS2" @6–7'

moist, brown, silty SAND(5.5–9')
COMPACT

end of excavation @9'
no groundwater or bedrock

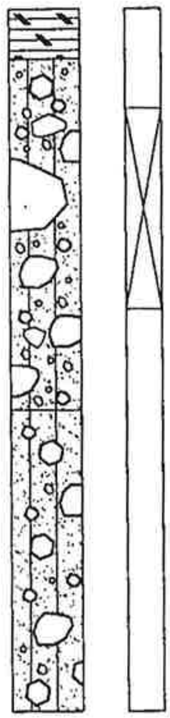
Laboratory Test Results:

(GS2)
NON-PLASTIC
GF=0.0% SF=71.7%
F200=28.3% MC=10.7%

| DRAWING NUMBER | | | | |
|---|---|---|---|---|
| 2 | INVESTIGATION | KR/TG | Whetstone Business Park | BUCKHORN GEOTECH |
| | DRAFTING | KR | 13–acres | Civil, Structural, and Geotechnical Engineers, Inc. |
| | DATE | 8/25/04 | Gunnison County, CO | 222 South Park Avenue, Montrose, Colorado 81401 |
| OF 4 | JOB NO. | 04–078–GEO | | Phone (970) 249-6828 Fax (970) 249-0945 |

# SOIL LOG TEST PIT #3 (TP#3)

western central portion of property, in proposed roadway



| Depth (ft) | Symbol | Sample | Soil Description | Laboratory Test Results |
|---|---|---|---|---|
| 0 | | | damp, brown, silty TOPSOIL(0–0.5') | |
| 1 | | | dry to damp, light brown, silty SAND and GRAVEL with 70–80% rounded to subrounded gravels, cobbles, and small boulders(0.5–4')<br>DENSE | |
| 2 | | | bulk sample "GS3" @1–3' | (GS3)<br>CBR@0.1"=46.5<br>CBR@0.2"=47.3<br>Modified Proctor<br>130.7pcf @ 8.1% |
| 3 | | | | |
| 4 | | | roots extend to 4–5' | |
| 5 | | | moist, silty SAND and GRAVEL with 40–60% rounded to subrounded gravels and cobbles(4–7')<br>DENSE<br>more coarse with depth | |
| 6 | | | | |
| 7 | | | end of excavation @7'<br>no groundwater or bedrock | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |
| 11 | | | | |
| 12 | | | | |

| DRAWING NUMBER | | | Project | |
|---|---|---|---|---|
| 3 OF 4 | INVESTIGATION | KR/TG | Whetstone Business Park<br>13–acres<br>Gunnison County, CO | BUCKHORN GEOTECH |
| | DRAFTING | KR | | |
| | DATE | 8/25/04 | | |
| | JOB NO. | 04–078–GEO | | |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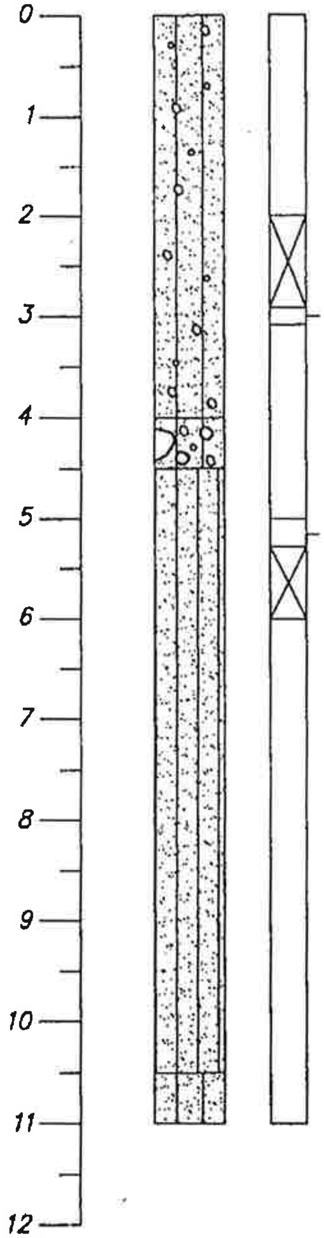
# SOIL LOG TEST PIT #4 (TP#4)
southern portion of property

| Depth (ft) | Symbol | Sample | Soil Description | Laboratory Test Results |
|---|---|---|---|---|




**Soil Description**

damp, silty gravelly SAND(0–4')
LOOSE

bulk sample "GS4" @2–3'

drive sample "GH" @3'

damp to moist, silty SAND and GRAVEL(4–4.5')

roots extend to 4–5'

drive sample "EF" @5.3'

bulk sample "GS5" @5–6'

damp to moist, brown with some mottling, sandy SILT with a trace of gravel(4.5–10.5')

wet, blue-gray, silty fine SAND(10.5–11')

end of excavation @11'
no groundwater or bedrock

**Laboratory Test Results**

(GS4)
NON-PLASTIC
GF=21.3% SF=51.2%
F200=27.5% MC=9.5%

(GH)
1.1%consolidation
@100 psf + H2O
TM=17.9% @2000 psf
DD=71.9 pcf
MC=8.9%

(EF)
0.2%consolidation
@100 psf + H2O
TM=1.8% @2000 psf
DD=107.5 pcf
MC=18.1%

(GS5)
NON-PLASTIC
GF=4.4% SF=24.4%
F200=71.2% MC=18.2%

| DRAWING NUMBER | | Project | |
|---|---|---|---|
| 4 | INVESTIGATION KR/TG | Whetstone Business Park | BUCKHORN GEOTECH |
| | DRAFTING KR | 13–acres | Civil, Structural, and Geotechnical Engineers, Inc. 222 South Park Avenue Montrose, Colorado 81401 |
| | DATE 8/25/04 | Gunnison County, CO | Phone (970) 249-6828 Fax (970) 249-0945 |
| OF 4 | JOB NO. 04–078–GEO | | |

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## Sieve Analysis

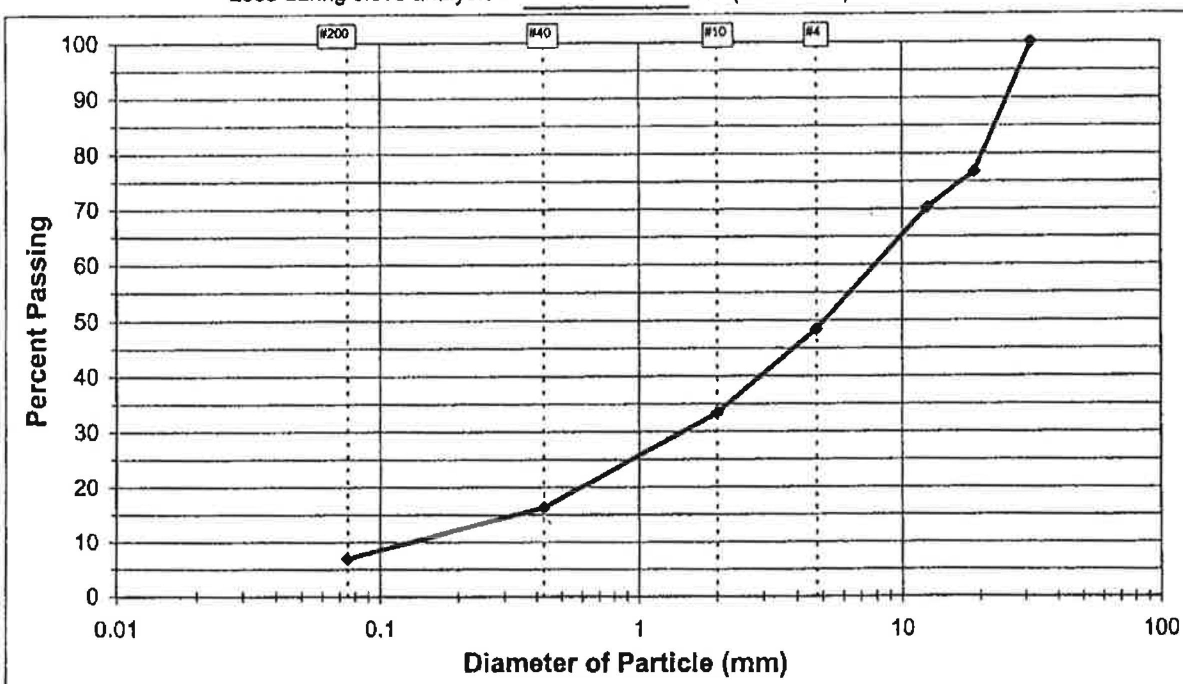
ASTM D422

| | | | |
|---|---|---|---|
| Project Name | JCI | Date | 09/16/04 |
| Location | TP#1 @3-4'; S. of CB | Project # | 04-078-GEO |
| Sample # | GS1 | Sample by | TG/KR |
| Soil Description | olive brown sandy GRAVEL with little silt (GW-GM) | Test by | SB |
| Initial mass of sample = | 1132.30 g | Test for | TG/KR |
| Initial Moisture Content = | 5.9 % | Drafting by | JG |

| Sieve # | Sieve Opening (mm) | Particle Size | Soil Mass (g) | % Weight Retained | Cumulative % Retained | % Passing |
|---|---|---|---|---|---|---|
| 3/4 | 19 | gravel | 264 | 23.3 | 23.3 | 76.7 |
| 1/2 | 12.5 | gravel | 72.6 | 6.4 | 29.8 | 70.2 |
| 4 | 4.750 | gravel | 247.4 | 21.9 | 51.6 | 48.4 |
| 10 | 2.000 | coarse sand | 170.6 | 15.1 | 66.7 | 33.3 |
| | | med sand | | | | |
| 40 | 0.425 | med sand | 192.6 | 17.0 | 83.7 | 16.3 |
| | | fine sand | | | | |
| | | fine sand | | | | |
| 200 | 0.075 | fine sand | 105.3 | 9.3 | 93.0 | 7.0 |
| pan | N/A | silt/clay | 78.9 | 7.0 | 100.0 | 0.0 |

Sum of mass = 1131.40 g

Loss during sieve analysis = 0.08 % (OK if <2%)




%Fines = 7.0% %Sand = 41.4% %Gravel = 51.6%

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## Sieve Analysis

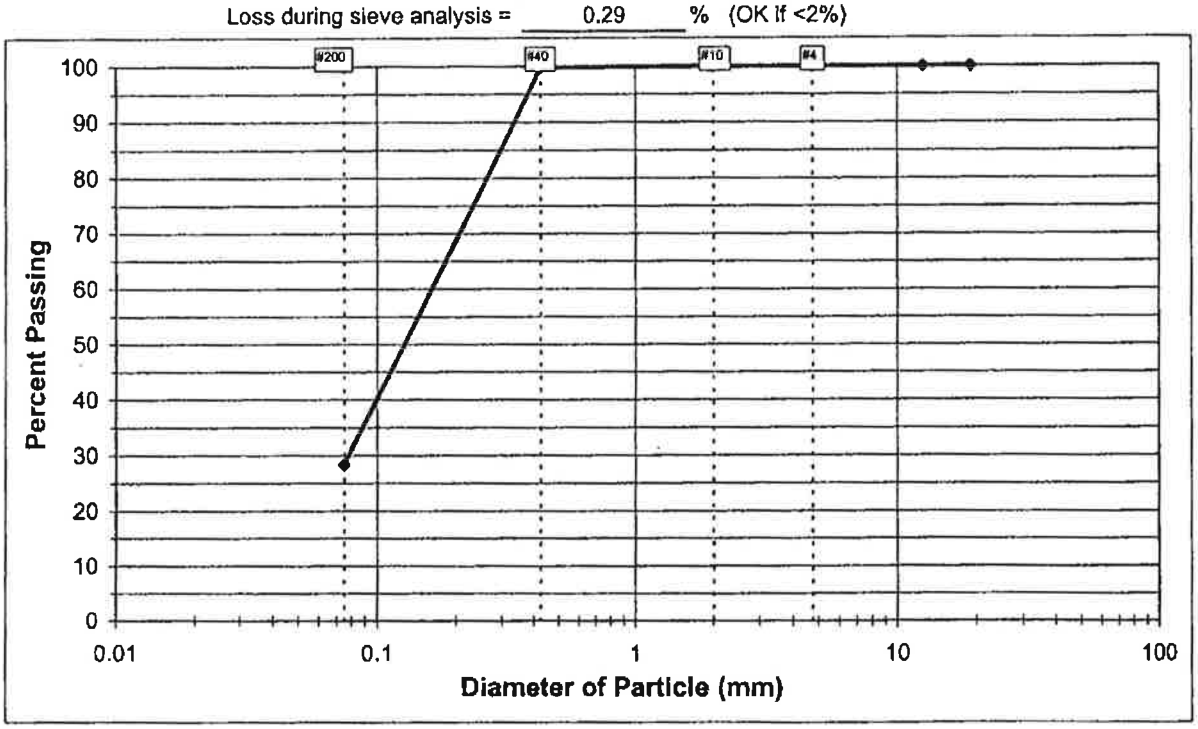
ASTM D422

| | | | |
|---|---|---|---|
| Project Name | JCI | Date | 09/16/04 |
| Location | TP#2 @6-7'; S. of CB | Project # | 04-078-GEO |
| Sample # | GS2 | Sample by | TG/KR |
| Soil Description | olive brown silty SAND (SM) | Test by | SB |
| Initial mass of sample = | 1005.60 g | Test for | TG/KR |
| Initial Moisture Content = | 10.7 % | Drafting by | JG |

| Sieve # | Sieve Opening (mm) | Particle Size | Soil Mass (g) | % Weight Retained | Cumulative % Retained | % Passing |
|---|---|---|---|---|---|---|
| 3/4 | 19 | gravel | 0 | 0.0 | 0.0 | 100.0 |
| 1/2 | 12.5 | gravel | 0.0 | 0.0 | 0.0 | 100.0 |
| 4 | 4.750 | gravel | 0.0 | 0.0 | 0.0 | 100.0 |
| 10 | 2.000 | coarse sand | 0.0 | 0.0 | 0.0 | 100.0 |
| | | med sand | | | | |
| 40 | 0.425 | med sand | 2.0 | 0.2 | 0.2 | 99.8 |
| | | fine sand | | | | |
| | | fine sand | | | | |
| 200 | 0.075 | fine sand | 716.7 | 71.5 | 71.7 | 28.3 |
| pan | N/A | silt/clay | 284.0 | 28.3 | 100.0 | 0.0 |

Sum of mass = 1002.70 g

Loss during sieve analysis = 0.29 % (OK if <2%)




%Fines = 28.3% %Sand = 71.7% %Gravel = 0.0%

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## Sieve Analysis

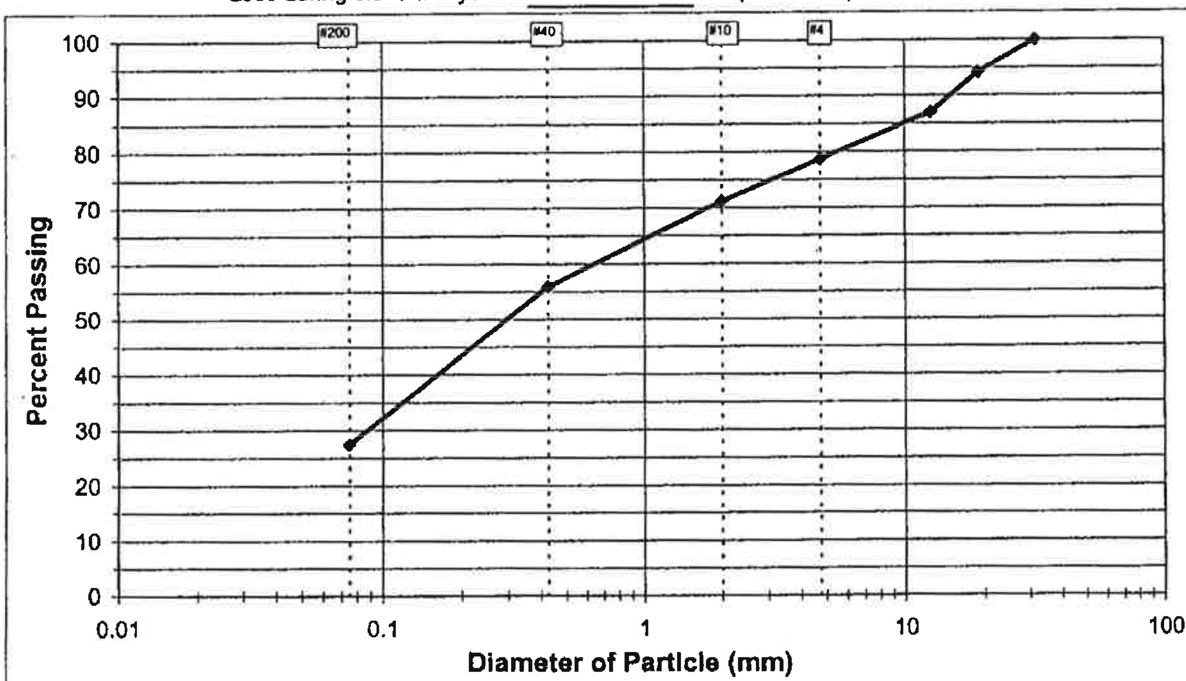
ASTM D422

| | | | |
|---|---|---|---|
| Project Name | JCI | Date | 09/15/04 |
| Location | TP#4 @2-3'; S. of CB | Project # | 04-078-GEO |
| Sample # | GS4 | Sample by | TG/KR |
| Soil Description | brown silty gravelly SAND (SM) | Test by | SB |
| Initial mass of sample = | 1002.10 g | Test for | TG/KR |
| Initial Moisture Content = | 9.5 % | Drafting by | JG |

| Sieve # | Sieve Opening (mm) | Particle Size | Soil Mass (g) | % Weight Retained | Cumulative % Retained | % Passing |
|---|---|---|---|---|---|---|
| 3/4 | 19 | gravel | 58.8 | 5.9 | 5.9 | 94.1 |
| 1/2 | 12.5 | | 71.6 | 7.2 | 13.0 | 87.0 |
| 4 | 4.750 | | 83.1 | 8.3 | 21.3 | 78.7 |
| 10 | 2.000 | coarse sand | 74.8 | 7.5 | 28.8 | 71.2 |
| | | med sand | | | | |
| 40 | 0.425 | | 152.6 | 15.2 | 44.1 | 55.9 |
| | | fine sand | | | | |
| | | | | | | |
| 200 | 0.075 | | 285.1 | 28.5 | 72.5 | 27.5 |
| pan | N/A | silt/clay | 274.7 | 27.5 | 100.0 | 0.0 |

Sum of mass = 1000.70 g

Loss during sieve analysis = 0.14 % (OK if <2%)




%Fines = 27.5% %Sand = 51.2% %Gravel = 21.3%

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# Sieve Analysis

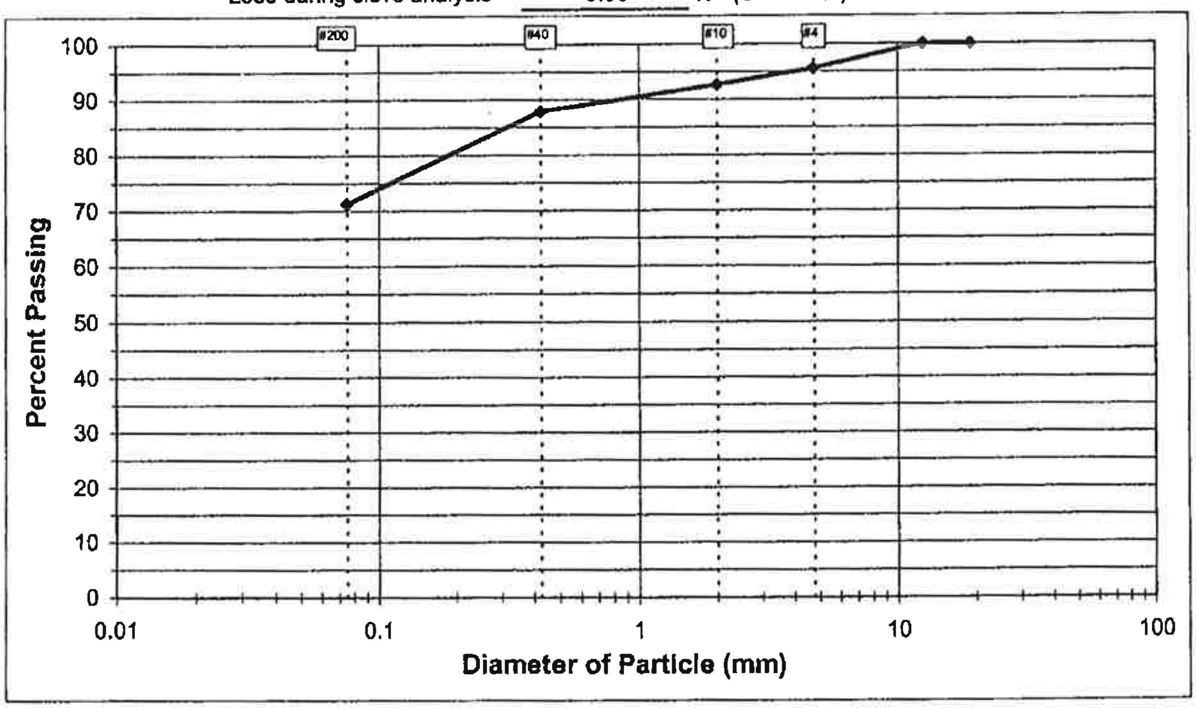
ASTM D422

| | | | |
|---|---|---|---|
| Project Name | JCI | Date | 09/16/04 |
| Location | TP#4 @5-6'; S. of CB | Project # | 04-078-GEO |
| Sample # | GS5 | Sample by | TG/KR |
| Soil Description | olive green sandy SILT with trace gravel (ML) | Test by | SB |
| Initial mass of sample = | 500.00 g | Test for | TG/KR |
| Initial Moisture Content = | 18.2 % | Drafting by | JG |

| Sieve # | Sieve Opening (mm) | Particle Size | Soil Mass (g) | % Weight Retained | Cumulative % Retained | % Passing |
|---|---|---|---|---|---|---|
| 3/4 | 19 | gravel | | 0.0 | 0.0 | 100.0 |
| 1/2 | 12.5 | gravel | | 0.0 | 0.0 | 100.0 |
| 4 | 4.750 | gravel | 22.2 | 4.4 | 4.4 | 95.6 |
| 10 | 2.000 | coarse sand | 14.5 | 2.9 | 7.3 | 92.7 |
| | | med sand | | | | |
| 40 | 0.425 | med sand | 23.9 | 4.8 | 12.1 | 87.9 |
| | | fine sand | | | | |
| | | fine sand | | | | |
| 200 | 0.075 | fine sand | 83.4 | 16.7 | 28.8 | 71.2 |
| pan | N/A | silt/clay | 356.0 | 71.2 | 100.0 | 0.0 |

Sum of mass = 500.00 g

Loss during sieve analysis = 0.00 % (OK if <2%)




%Fines = 71.2% %Sand = 24.4% %Gravel = 4.4%

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# Atterberg Limits

ASTM D4318

| | | | |
|---|---|---|---|
| Project Name | JCI | Date | 09/16/04 |
| Location | TP#1 @3-4'; S. of CB | Project # | 04-078-GEO |
| Sample # | GS1 | Sample by | TG/KR |
| Soil Description | olive brown sandy GRAVEL with little silt (GW-GM) | Test by | SB |
| Comments | NON-PLASTIC; can't roll out- too sandy/silty | Test for | TG/KR |
| | **In-situ Moisture= 5.9%** | Drafting by | JG |

## Liquid Limit

| Can # | Tare mass of can (with lid) (g) | Mass of can + wet soil (g) | Mass of can + dry soil (g) | Moisture Content (%) | Number of blows N |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |

## Plastic Limit

| Can # | Tare mass of can (with lid) (g) | Mass of can + wet soil (g) | Mass of can + dry soil (g) | PL = Moisture Content (%) |
|---|---|---|---|---|
| | | | | |

Liquid Limit = ______

Plastic Limit = ______

Plasticity Index (PI) = LL-PL = NON-PLASTIC

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# Atterberg Limits

ASTM D4318

| | | | |
|---|---|---|---|
| Project Name | JCI | Date | 09/16/04 |
| Location | TP#2 @6-7'; S. of CB | Project # | 04-078-GEO |
| Sample # | GS2 | Sample by | TG/KR |
| Soil Description | olive brown silty SAND (SM) | Test by | SB |
| Comments | NON-PLASTIC; can't roll out- too sandy | Test for | TG/KR |
| | **In-situ Moisture= 10.7%** | Drafting by | JG |

## Liquid Limit

| Can # | Tare mass of can (with lid) (g) | Mass of can + wet soil (g) | Mass of can + dry soil (g) | Moisture Content (%) | Number of blows N |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |

## Plastic Limit

| Can # | Tare mass of can (with lid) (g) | Mass of can + wet soil (g) | Mass of can + dry soil (g) | PL = Moisture Content (%) |
|---|---|---|---|---|
| | | | | |

Liquid Limit = __________

Plastic Limit = __________

Plasticity Index (PI) = LL-PL = NON-PLASTIC

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## Atterberg Limits
ASTM D4318

| | | | |
|---|---|---|---|
| Project Name | JCI | Date | 09/16/04 |
| Location | TP#4 @2-3'; S. of CB | Project # | 04-078-GEO |
| Sample # | GS4 | Sample by | TG/KR |
| Soil Description | brown silty gravelly SAND (SM) | Test by | JG |
| Comments | NON-PLASTIC; can't roll out- too sandy/silty | Test for | TG/KR |
| | **In-situ Moisture= 9.5%** | Drafting by | JG |

### Liquid Limit

| Can # | Tare mass of can (with lid) (g) | Mass of can + wet soil (g) | Mass of can + dry soil (g) | Moisture Content (%) | Number of blows N |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |

### Plastic Limit

| Can # | Tare mass of can (with lid) (g) | Mass of can + wet soil (g) | Mass of can + dry soil (g) | PL = Moisture Content (%) |
|---|---|---|---|---|
| | | | | |

Liquid Limit = ______

Plastic Limit = ______

Plasticity Index (PI) = LL-PL = NON-PLASTIC

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# Atterberg Limits
ASTM D4318

| | | | | |
|---|---|---|---|---|
| Project Name | JCI | | Date | 09/16/04 |
| Location | TP#4 @5-6'; S. of CB | | Project # | 04-078-GEO |
| Sample # | GS5 | | Sample by | TG/KR |
| Soil Description | olive green sandy SILT with trace gravel (ML) | | Test by | SB |
| Comments | NON-PLASTIC; can't roll out- too silty | | Test for | TG/KR |
| | **In-situ Moisture=** | **18.2%** | Drafting by | JG |

## Liquid Limit

| Can # | Tare mass of can (with lid) (g) | Mass of can + wet soil (g) | Mass of can + dry soil (g) | Moisture Content (%) | Number of blows N |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |

## Plastic Limit

| Can # | Tare mass of can (with lid) (g) | Mass of can + wet soil (g) | Mass of can + dry soil (g) | PL = Moisture Content (%) |
|---|---|---|---|---|
| | | | | |

Liquid Limit = ____________

Plastic Limit = ____________

Plasticity Index (PI) = LL-PL = NON-PLASTIC

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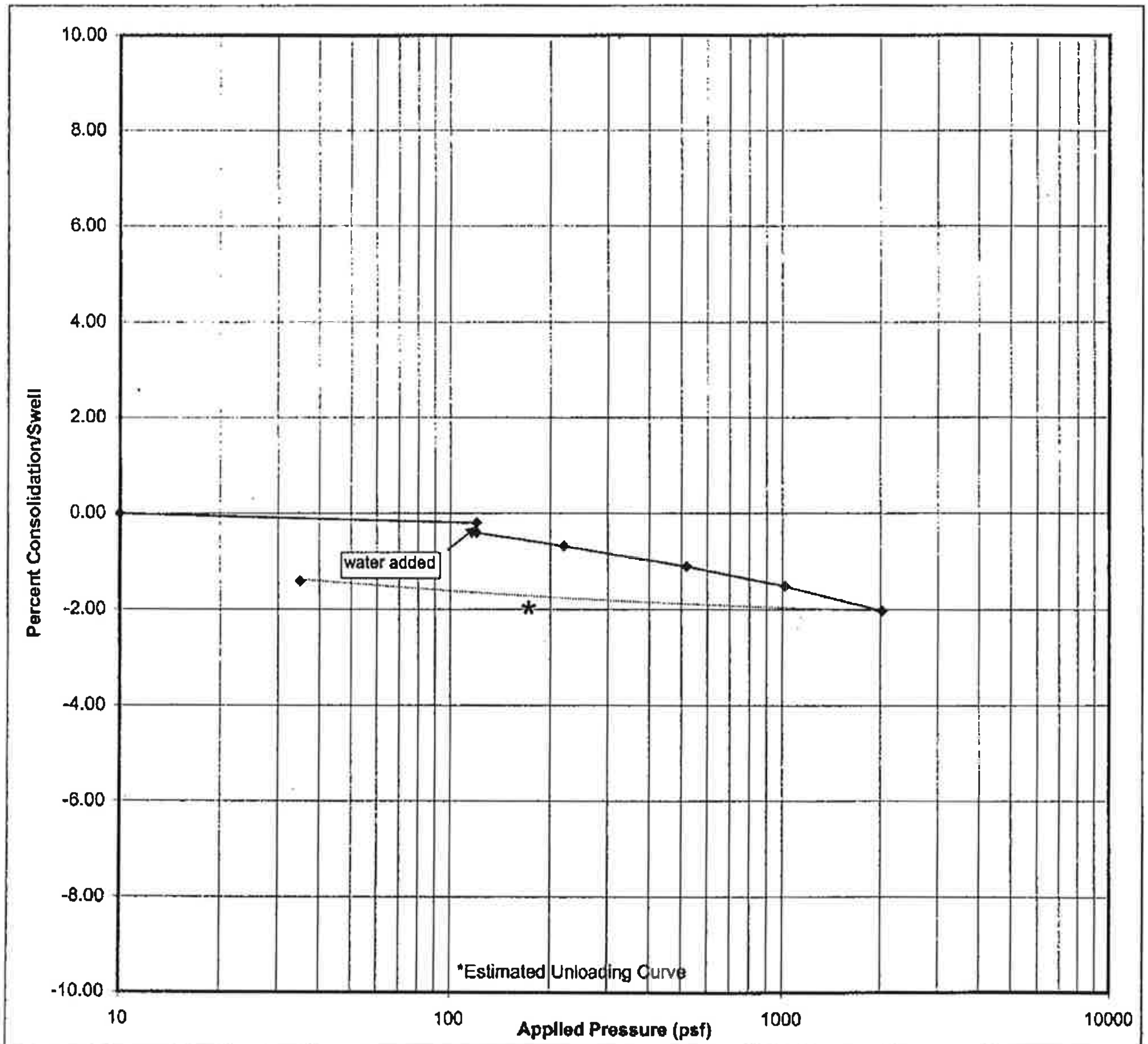
## Swell/Consolidation Test

ASTM D4546

| | | | |
|---|---|---|---|
| Project Name | JCI | Date | 08/31/04 |
| Location | TP#4 @5.3'; S. of CB | Project # | 04-078-GEO |
| Sample # | EF | Sample by | TG/KR |
| Soil Description | olive brown silty fine SAND | Test by | JG |
| Comments | | Test for | TG/KR |
| | | Drafting by | JG |

Initial compression (Due to 100 psf pressure) = 0.2 %
Initial consolidation (Due to water & 100 psf pressure) = 0.2 %
Percent total consolidation (Due to water & 2000 psf pressure) = 1.82 %

| | | | |
|---|---|---|---|
| Initial Moisture Content | 18.1 % | Final Moisture Content | 21.2 % |
| Initial Dry Density | 107.5 pcf | Final Dry Density | 107.4 pcf |
| Initial Wet Density | 126.9 pcf | Final Saturated Density | 130.1 pcf |



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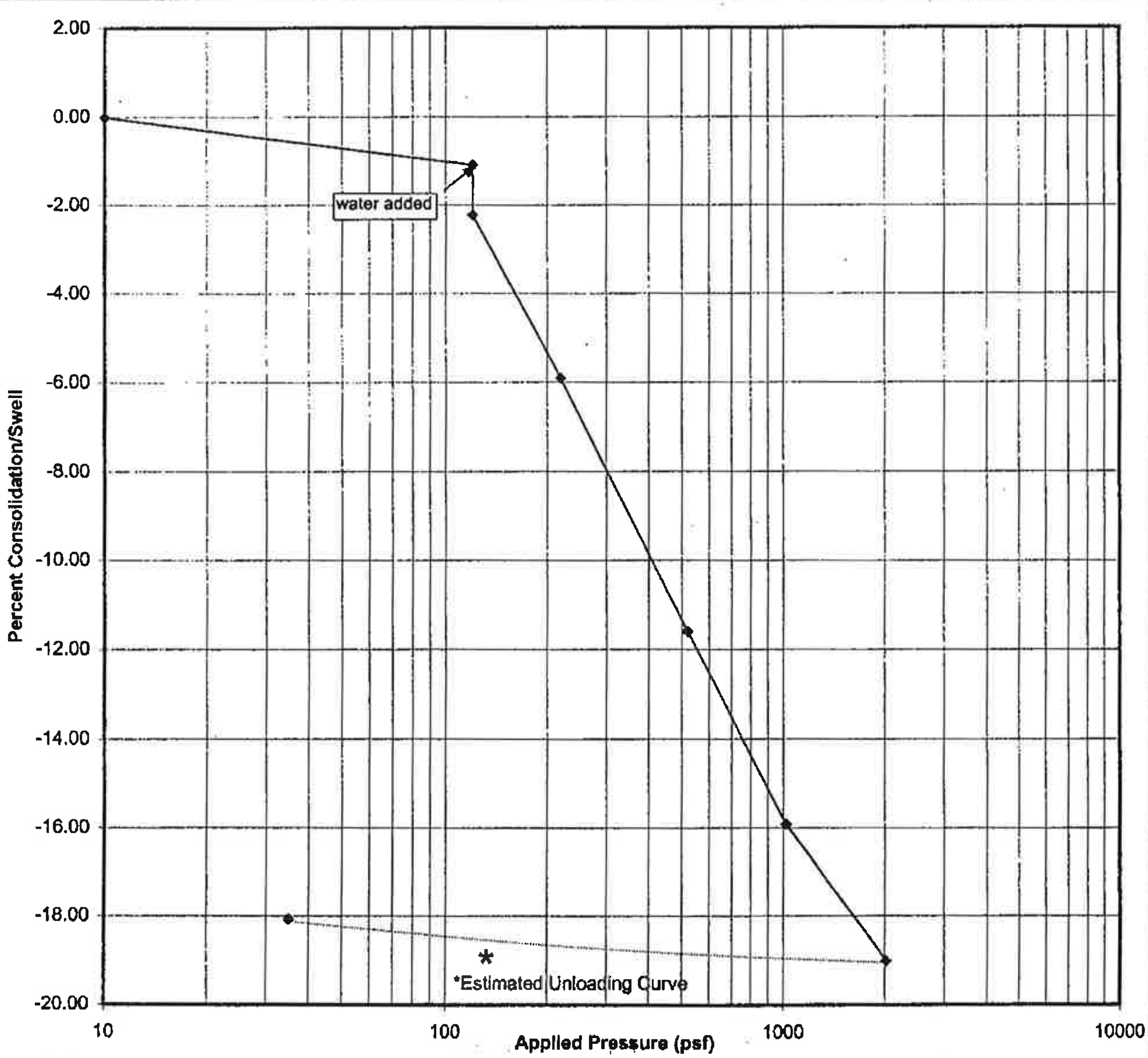
## Swell/Consolidation Test

ASTM D4546

| | | | |
|---|---|---|---|
| Project Name | JCI | Date | 08/31/04 |
| Location | TP#4 @3'; S. of CB | Project # | 04-078-GEO |
| Sample # | GH | Sample by | TG/KR |
| Soil Description | brown silty SAND | Test by | JG |
| Comments | damp, very loose & unconsolidated | Test for | TG/KR |
| | | Drafting by | JG |

Initial compression (Due to 100 psf pressure) = 1.09 %
Initial consolidation (Due to water & 100 psf pressure) = 1.13 %
Percent total consolidation (Due to water & 2000 psf pressure) = 17.92 %

| | | | |
|---|---|---|---|
| Initial Moisture Content | 8.9 % | Final Moisture Content | 32.7 % |
| Initial Dry Density | 71.9 pcf | Final Dry Density | 85.2 pcf |
| Initial Wet Density | 78.2 pcf | Final Saturated Density | 113.0 pcf |



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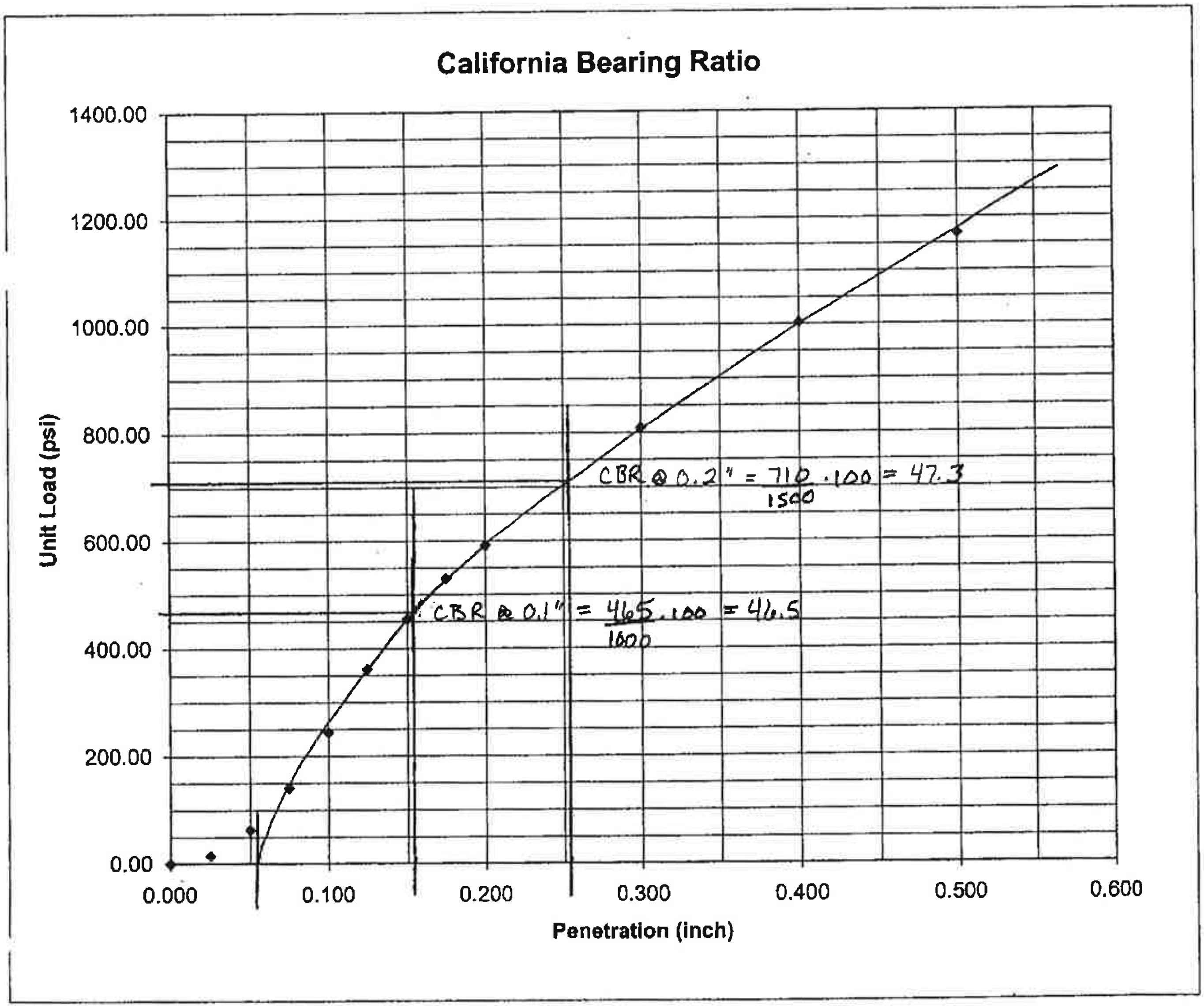
## CALIFORNIA BEARING RATIO
ASTM D1883-99

| | |
|---|---|
| Project name | JCI |
| Location | TP#3 @1-3'; S. of CB (13 acres) |
| Sample # | GS3 |
| Soil description | tan silty SAND & GRAVEL with little clay |

| | |
|---|---|
| Date | 9/16/2004 |
| Project # | 04-078-GEO |
| Sample by | KR/TG |
| Test by | JG/SB |
| Drafting by | JG |

**CBR @0.1 inch Penetration = 46.5**
**CBR @0.2 inch Penetration = 47.3**
Target Dry Density (pcf) = 124.2
Target Moisture Content (%) = 8.1%
Surcharge Weight (pounds) = 10.0

Test Dry Density (pcf) = 125.4
Test Moisture Content--Before Soaking (%) = 0
Average Moisture Content--After Soaking (%) = 8.8
Top 1 inch Moisture Content--After Soaking (%) = 10.3
Swell (%) = 0.1%



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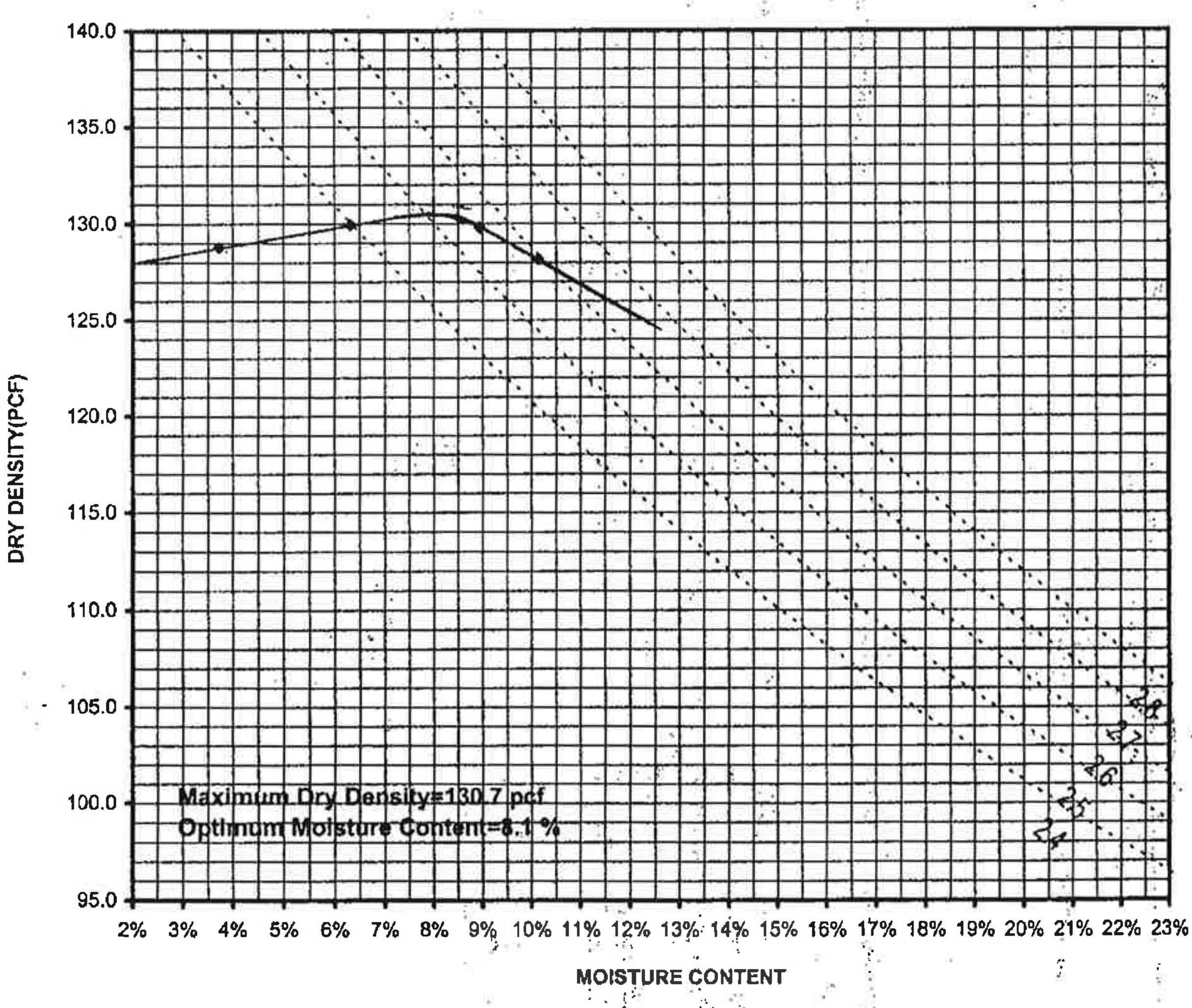
970-249-6828 Fax No. 970-249-0945

## MODIFIED PROCTOR ASTM D-1557

| | | | |
|---|---|---|---|
| Project name | JCI | Date | 09/08/04 |
| Location | TP#3 @1-3' | Project # | 04-078-GEO |
| Sample # | GS3 | Sample by | KR |
| Soil description | lt brown silty SAND & GRAVEL with little clay | Test by | SM |
| Comments | | Test for | KR |

Number of blows per layer: 56
Number of layers: 5
Size of Mold: 6 inches
Volume of Mold: 0.075 $ft^3$

Hammer Weight: 10 lb
Drop: 18 inches
Scale #: 3/4



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# Glossary of Engineering & Soils Terms

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| **Active Earth Pressure** | The pressure that a soil exerts against a vertical surface which is allowed a certain degree of flexure or rotational freedom. |
| **Allowable soil bearing capacity** | The recommended maximum contact stress developed at the interface of the foundation and the supporting soil. Given in psf (pounds per square foot). |
| **Alluvial Fan** | A cone-shaped deposit of water-transported material (alluvium). They typically form at the base of topographic features where there is a distinct decrease in gradient. Consequently, alluvial fans tend to be coarse-grained near their mouths and relatively fine-grained at their edges. |
| **Alluvium** | Rock and soil material deposited by moving water. Rocks are generally rounded and sorted by size as they are worked by water. Found in river channels or alluvial fans. |
| **ASTM** | American Society for Testing and Materials (a national non-profit organization which writes testing standards for materials, products, systems and services). |
| **At-Rest Earth Pressure** | The pressure that soil exerts upon a vertical surface which is restrained from any movement. |
| **Atterberg Limits** | Named for a Swedish scientist, Atterberg Limits are defined by the water content that produces a specified soil consistency. See *Liquid Limit* and *Plastic Limit*. |
| **Backfill** | A specified material placed and compacted in a confined area. |
| **Backslope Zone** | The area in which loads applied to the ground surface or increase in slope angle will increase the total lateral force against a retaining wall. |
| **Base Course** | A layer of specified material placed on a subgrade or subbase. |
| **Bedrock** | Sedimentary, igneous, or metamorphic rock that has not been weathered or broken down by the elements of water, ice, wind, or gravity. Also referred to as "formational" material, as bedrock is known as a particular formation for the region. |
| **Bench** | A horizontal or near-horizontal surface in a sloped deposit. |
| **Calcareous** | Containing calcium carbonate (lime). A distinct layer of calcium carbonate hardpan is called caliche. |
| **Clay** | A fine-grained soil (finer than 0.002 mm) composed of very small platy (flat) particles that are smaller than silt particles. It forms lumps or clods when dry and is plastic (Plasticity Index greater than 4) and sticky when wet. |
| **Cohesionless Soil** | Non-plastic granular soils (silt, sand, gravel) composed of bulky grains that are not attracted to each other with the addition of water. |
| **Cohesive Soil** | Soils (i.e., clays and some silts) in which adsorbed water and particle attraction work together to produce a mass which holds together and deforms plastically. |

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| **Colluvium** | Rock and soil material deposited by gravity. Rocks are generally angular to subangular, loose and not sorted. Found below steep slopes and at the mouth of canyons; talus and cliff debris are included. |
| **Compaction** | The decrease in volume of an unsaturated soil mass due to a decrease in the void spaces, usually by mechanical means. |
| **Consolidation** | The decrease in soil volume due to a release of water within a saturated soil volume. As a soil consolidates, its void ratio decreases. Loosely, the term is used to describe the result of collapse of a loose soil structure. |
| **Crawlspace** | The space beneath the house that has a raised stemwall foundation and is typically 18 to 36 inches in height. |
| **Creep** | A slow, nearly continuous movement of soil caused by changes in soil moisture and the downhill force of gravity. |
| **Dead Load** | Static loads transferred to the foundation, usually the weight of building materials, but can also be the loads imposed by retained soil or a constructed slope. |
| **Debris Flow** | Debris flows are rapid flood-like events consisting of mud, water, rock and organic debris and that have 20 to 80% particles coarser than sand sizes. Steep slopes, weak or weathered rock, a lack of vegetative cover, and abnormal precipitation contribute to debris flows. (See mud flow) |
| **Differential Settlement** | Unequal settlement between or within foundation elements of a structure. |
| **Dispersive Soils** | Fine-grained soils whose clays have been neutralized by an abundance of cations which are then susceptible to removal (dispersion) from the soil matrix. This weakens soil strength; piping and gullying are common features in this soil. |
| **Drilled Caisson** | A deep foundation system that consists of reinforced concrete piers cast into a drilled hole that extends into bedrock or other suitable material. |
| **Driven Pile** | A deep foundation system that consists of steel, concrete, or timber that is driven into bedrock or other suitable material. |
| **Existing Fill** | Materials deposited through the action of man prior to geotechnical exploration of the site. |
| **Existing Grade** | The ground surface at the time of field exploration. |
| **Expansive Soil** | A soil containing clay which expands (increases in volume) when exposed to an increase in moisture. |
| **Fine Grained Soil** | Soils composed of silt and/or clay-sized particles. |
| **Flowing Avalanche** | The turbulent cascade of slabs and blocks of relatively high-density (>25 pcf) snow and air down a slope. |
| **Fluvial** | Deposited or transported by a stream or river. |
| **Fluvioglacial** | Alluvial deposits derived from the rivers originating from the melting of glaciers. Glacial outwash is the term used to describe fluvioglacial deposits. |
| **Formational Material** | See bedrock. Also known as the "R" horizon. |
| **Grade Beam** | Typically, concrete beams that are constructed at or just below ground elevation that are used to transfer building loads to deep foundation elements. Walls and floor systems are then built upon the grade beams. |

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| **Groundwater** | Water that is resident beneath the ground surface in porous soil and rock material. This level can fluctuate due to seasonal changes and irrigation. |
| **Heave** | Upward movement of soil or foundation components. |
| **Hinge Point** | Toe of excavated wall without footing or outside edge of concrete if footing is used. |
| **Hummocky** | The bumpy or chaotic terrain on the slumped material typically resulting from a landslide or glacial deposit. The rock and soil materials are unsorted and unsystematic. |
| **Hydrocompactive Soils** | Soils that have considerable voids, thus making it susceptible to consolidation in the presence of water. |
| **Jumping Jack** | A construction machine, used to compact both cohesive and cohesionless soils, that consists of a curved shoe that tamps the soil in an up and down motion. |
| **Landslide** | The general term for the rapid downward and outward movement (flow, slide or fall) of slope-forming bedrock, rock debris and "earth" (fine-grained fragmental debris). See "slump," a type of landslide. |
| **Lifts** | Horizontal layers of fill, generally in 6 to 8-inch increments. |
| **Liquid Limit (LL)** | The water content above which a soil behaves as a liquid. |
| **Live Load** | Transient loads introduced onto a structure and its foundation due to occupancy, wind, snow and rain, earthquakes, changes in groundwater, and other environmental factors. |
| **Loam** | An mixture of sand, silt and clay. It is easily crumbled when dry and has a slightly gritty, yet fairly smooth feel, and is often slightly plastic. |
| **Monolithic Slab** | A shallow foundation system that consists of a single unit of reinforced concrete with downturned edges and may include thickened ribs on the underside of the slab. |
| **Moraine** | Deposits formed by direct glacial action. There are many forms of moraines, but they generally consist of unsorted, unstratified, subrounded to subangular materials deposited by glacial ice. Also generally known as "drift" or "till." |
| **Mottling** | The discoloration of a soil due to the reaction of water with clay minerals during prolonged periods of saturation. Red colors indicate the presence of iron oxides in an oxidized state and gray indicate the removal of free iron in reducing conditions. |
| **Mud Flow** | Mud flows are flood-like events that have 80% or more mud and sand. Over-saturation of fine-grained soils triggers mud flows, which are a rapid failure or slippage of mud and other debris entrained in the movement. (See debris flow) |
| **Native Grade** | The naturally occurring ground surface (before disturbance). |
| **Native Soil** | Naturally occurring on-site soil. |
| **Parent Material** | The formational material from which a soil is derived. |
| **Passive Earth Pressure** | The resistance of a soil against movement when a lateral force is exerted upon it. |

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| **Piping** | A feature in fine-grained soils whereby water preferentially follows root zones, animal burrows and surface soil cracks, and carries soil particles downwards through voids, leaving behind weak vertical planes, voids, and/or tunnels in the soil structure. |
| **Pistol Butting** | When the base of tree trunk is widened and bent upwards due to soil creep or slope movement. The tree continues to grow vertically despite the ground moving downslope, thus creating a shape like a "pistol butt" in the expanded trunk. |
| **Plastic Index (PI)** | The difference between Liquid and Plastic Limits (LL - PL). This represents the moisture content range that the soil is in the plastic state. The larger the PI, the more plastic a soil is. |
| **Plastic Limit (PL)** | The water content at which a soil becomes brittle after being in the plastic state. The soil breaks apart or crumbles when its moisture content is equal to or less than its PL. |
| **Plastic Soil** | A predominately silt or clay soil that exhibits plastic (deformable) behavior. |
| **Powder Avalanche** | The relatively low-density (12.5 pcf), high velocity, turbulent force of snow, air and entrained debris that precedes and extends beyond a dry-snow avalanche. The powder and air blast can travel at speeds in excess of 100 mph. |
| **Proctor Density (Standard & Modified)** | A laboratory compaction procedure to determine the maximum dry density and optimum moisture content of soil. The Standard Proctor procedure uses a 5.5-lb hammer and 3 lifts, while the Modified Proctor procedure uses a 10-lb hammer and 5 lifts. |
| **Refusal** | When very dense native material is encountered which cannot be excavated or penetrated further by whatever equipment is being used. |
| **Rock** | A natural aggregate of mineral grains connected by strong cohesive forces, usually requiring heavy equipment, drilling, wedging, blasting or other methods of extraordinary force for excavation. |
| **Scarify** | To mechanically loosen or break down existing soil structure. |
| **Settlement** | Downward movement of foundation components due to compression of a soil mass. |
| **Shale** | A thinly-bedded rock formation composed of clay or silt muds that have been solidified into rock. The Mancos Shale Formation in Colorado is of marine origin. |
| **Silt** | Fine-grained soil particles measuring 0.002 to 0.075mm, which are larger than clay but smaller than sand. Silt can exhibit plastic characteristics. |
| **Slab-on-Grade** | A concrete layer cast directly upon a base, subbase or subgrade. |
| **Slope** | The angle of a hillside, usually expressed in degrees or percent (elevation drop per given distance). |
| **Slump** | The rotational slip along a concave-up surface of rupture. A "main scarp" is the crescent shaped failure plane formed at the source of the slump. A slump is a form of landslide most common in thick, homogeneous, cohesive materials such as clay. |
| **Soil** | Any unconsolidated, excavatable earth material composed of discrete solid particles, with air or liquids between, that is the result of the chemical and mechanical weathering of rock. |
| **Soil Log** | A graphic representation of a column of soil indicating textural changes and general properties of soil or rock types encountered in a test pit or boring. |

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| **Spread Footing** | A shallow foundation system that consists of a wide (typically from 12 to 48 inches) "foot" of reinforced concrete upon which vertical wall components are built. |
| **Stemwall** | A vertical concrete foundation component, normally 6 to 12 inches wide, that rests on the spread footing and extends up to the floor level. |
| **Subbase** | A layer of specified material between the subgrade and base course. |
| **Subbase Grade** | Top of subbase elevation. |
| **Subgrade** | Prepared native soil surface. |
| **Subsoil** | The layer of soil below the topsoil and above the substratum, that has undergone pedogenesis (soil formation). The "B" horizons. |
| **Substratum** | The layer of soil below the subsoil that has not undergone soil genesis. It contains weathered parent material. The "C" horizons. |
| **Swell Potential** | The potential of a soil to expand (increase in volume) due to absorption of moisture. |
| **Tension Cracks** | Transverse cracks (linear openings) in the soil due to soil movement. |
| **Topsoil** | The surface layer of soil containing organic material and roots. The "A" horizons. |
| **Transverse** | A feature (like a crack or ridge) that is at right angles to the slope of a hillside or the general trend of a valley. |
| **Vesicular Pores** | Sponge-like openings in a fine-grained soil that are the result of the solution and dispersal of clay particles. The pores are discontinuous and vary in size. These pores are often found in soils that have been irrigated. |
| **Vibratory Roller** | A construction machine, used to compact soil and aggregate material, that consists of a heavy vibrating drum that is rolled across a surface. |
| **Void Ratio** | A ratio of the volume of voids (pore spaces) to the volume of mass of a soil. |
| **Water Table** | The relatively continuous and consistent level of groundwater below the ground surface. |
| **Weathering** | The breakdown of intact masses of rock into smaller pieces by mechanical, chemical or solution processes. |