

APPENDIX C SOILS INVESTIGATION REPORTS AND MITIGATION

C.1 PURPOSE

This appendix provides the minimum requirements for soils investigations associated with new and improved County infrastructure. In addition, it provides guidelines for the documentation to be developed for summarizing the results of these investigations.

C.2 GEOLOGIC HAZARDS REPORT

C.2.1 General Requirements

These guidelines outline the minimum information that shall be presented and evaluated in a Geologic Hazard Report. These guidelines are not intended to be a rigid framework of requirements, nor a specific format for each report submitted for County review. The level of detail and emphasis may vary due to unique or particular geologic conditions or due to the type of project.

C.2.2 Report Guidelines

A. Overall Project Information

A general project description shall be included with each report and in a clear manner present at a minimum the following list of items:

- Size and location of the project;
- Existing site land uses;
- Proposed site land uses; and,
- Identification of the person who prepared the study and his/her qualifications for conducting the study.

B. Study Overview

A general overview of the report objectives, contents, methods, level of investigation, and findings should be provided:

- State the objective(s) and level of investigation for the study;
- Cite the previous publicly available geologic reports which were reviewed or referenced in the course of preparing the geologic hazard study and indicate the author(s), firm, and date of each report;
- List the methods of investigation as well as professional firm(s) who participated;
- If the level of investigation varies within the subject area, describe in the text and show on the maps areas of concentration or exclusion;
- Describe the general physiographic setting of the project and its relationship to local topographic features;
- Describe the general geologic setting of the project and indicate any lithologic, tectonic, geomorphic, or soils problems specific to the area; and,
- Describe the general surface and groundwater conditions.

C. Site Evaluation Techniques

The most appropriate site evaluation techniques shall be determined by the geologist/geotechnical engineer based on site conditions and the activities being proposed for the site. However, the list below presents typical methodologies and techniques used to evaluate the potential geological hazards of a site. Based on their applicability to the site being investigated, the information listed under each technique shall be included with the submitted report unless otherwise indicated to not be required. A detailed explanation is necessary for exclusion of minimum requirements listed.

1. Extent

State the extent and method of surface and subsurface geologic studies.

2. Geologic Mapping

The geologic mapping shall:

- Show important details corresponding to the size, extent and degree of the investigation on the project topographic map;
- Show the abundance of distributions of earth materials and structural elements exposed or inferred in the subject area. Observed and inferred features or relationships should be so designated on the geologic map;
- Portray all geologic information at a scale that is appropriate for readability and interpretation. When different sources are used. "Tie-points" between the sources shall be presented, and,
- Indicate the geologic base map use, date, and significant additions and modifications to previous work.

3. Aerial Photographs and Remote-Sensing Imagery

When aerial photographs or imagery are used, the report shall:

- Present the source(s) of photographs or images, if available;
- Indicate data and scale of photographs or imagery; and,
- Highlight critical points and their relationship to the project.

4. Geophysical Investigations

Geophysical investigation information shall:

- Indicate the type and objectives of the geophysical investigation(s) (if any), quality of the data, and limitations of geophysical techniques;
- Describe the information used to correlate the geophysical data and geologic conditions; and,
- Display the geophysical data on the topographic/geologic maps and cross section.

5. Drill-Hole Data

Drill-hole data information shall:

- Describe the specific investigative methods, tests conducted, drilling, and date of investigation;
- Show the location of all borings on the topographic or geologic map; and,
- Show boring logs, geophysical logs, or profiles obtained in the investigation.

6. Test Pits and Trenches

The test pit and trench information shall:

- Describe the location and dimensions of all pits and trenches and date of investigation;
- Indicate the location of all excavations on the topographic/geologic map and profiles;
- Provide a large scale descriptive log with sufficient detail; and,
- Show sample location if supplemental laboratory tests were conducted.

7. Field and Laboratory Tests

The field and laboratory tests information shall:

- Describe the type of any tests conducted in the field or laboratory;
- Describe the sample method and test procedures; and,
- Show the test results on the data work sheets or on summary tables.

8. Monitoring Programs

The monitoring program information shall:

- Describe the type, objectives, and location of all monitoring programs in the subject area; and,
- State the monitoring period, the firm(s) or individuals responsible for the care and disposal of the installations.

D. Geologic Descriptions

As appropriate for site conditions, the report should provide the following general geologic description information.

1. Bedrock Units

- Rock type and bedding attitude or foliation;
- Age of and correlation with recognized formations;
- Dimensional characteristics such as thickness and extent;
- Distribution and extent of the weathered zone;

- Physical characteristics; and,
- Response of bedrock materials to natural processes.

2. Surficial Deposits

- Distribution, occurrence, and age;
- Identification of material types and sources;
- Dimensional characteristics such as thickness and extent;
- Surface expression and relationships with present topography;
- Physical and chemical characteristics; and,
- Distributions and extent of altered zones.

3. Geomorphic Features

Geomorphic features resulting from landslides, earthflows, debris flows, mudflows, rockfalls, debris avalanches, fault scarps, soil creep, erosion scarps, avalanched paths, and subsidence phenomenon.

- Locations and distribution;
- Dimensional characteristics;
- Age of feature and history of activity;
- Recurrence interval for geomorphic process; and,
- Physical characteristics.

4. Structural Features

Structural features include joints, faults, shear zones, folds, schistosity, and foliation.

- Occurrence, distribution, and proximity to site;
- Dimensional and displacement characteristics of faults;
- Orientation and changes in orientation;
- Physical characteristics such as brecciation, slickensides, gouge zones, sand boils, sag ponds, springs alignment;
- Disrupted drainages, or ground-water barriers;
- Nature of offset(s) and timing of movement(s); and,
- Absolute or relative age of latest movement.

5. Surface Drainage

- Distributions;
- Relation to topography (drainage patterns);
- Relation to areas of vegetations;
- Relation to geologic features;
- Source permanence, and variation in amount of surface water;
- Evidence of earlier occurrence of water localities now dry;
- Estimated peak flows an physiographic flood plain of drainages;

- Probable maximum or 100-year flood limits, including flash and debris floods; and,
- Outfall.

6. Ground Water

- Distributions and occurrence;
- Hydraulic gradients;
- Relation to topography;
- Relations to geologic features; and,
- Seasonal variations.

E. Geologic Interpretation

The report shall include interpretations and detailed descriptions of the following:

1. Geologic Hazards

Geologic hazards include landslides, avalanche, rockfall, mudflows, debris flows, radioactivity, etc.

- Geomorphic and structural features/processes present in the area;
- Man-induced features/processes;
- Age and activity of the features/processes;
- Natural contentions affecting the features/processes;
- Susceptibility to man-induced changes;
- Potential impact of hazard(s) and risk to project;
- Amenability of adverse conditions for adequate mitigation;
- Long-term lateral and vertical stability of earth materials; and,
- Impact of project on materials stability.

2. Geologic Constraints

Geologic constraints include expansive soil or rock, potentially unstable slopes, high groundwater levels, soil creep, hydrocompaction, shallow bedrock, erosion, etc.

- Soil, surface and ground water, and geomorphic conditions;
- Man-induced conditions;
- Activity of conditions
- Effect of natural or man-induced changes;
- Potential impact of conditions and risk to project;
- Amenability of adverse conditions for adequate mitigation; and,
- Impact of project on long-term project stability.

F. Relationship of Geologic Factors on the Proposed Action

This topic normally constitutes the principal contribution of the report. It involves both the affects of geologic features upon the proposed grading, construction,

and land use; and the effects of these proposed modifications upon future geological processes in the area. The following checklist includes the topics that ordinarily should be considered as part of the findings, conclusions, and recommendations of the geologic reports:

1. Compatibility

General compatibility of natural features with proposed action that should be discussed includes:

- Topography;
- Lateral stability of earth materials;
- Problems of flood inundation, erosion, and deposition;
- Problems caused by features or conditions in adjacent properties; and,
- Other general problems.

2. Proposed Cuts

A description of proposed cuts and the relationship to the activities being proposed including:

- Prediction of what materials and structural features will be encountered;
- Prediction of stability based on geologic factors;
- Problems of excavation (e.g. unusually hard or massive rock, excessive flow of groundwater); and,
- Recommendations for reorientation or repositioning of cuts, reductions of cut slopes, development of compound cut slopes, special stripping above daylight lines, buttressing, protections against erosion, handling of seepage water, setbacks for structures above cuts, etc.

3. Proposed Fill

A description of proposed fill and the relationship to the action including:

- General evaluation of planning with respect of canyon-filling and sidehill masses of fill; and
- Comment on suitability of existing natural materials for fill.

4. Recommendations for Fill

Recommendations concerning the positioning of fill masses, provision for underdrainage, buttressing, special protection against erosion including:

- Recommendations for subsurface testing and exploration; and
- Cuts and test holed needed for additional geologic information.

5. Special Recommendations:

Details concerning any unique or unusual recommendations concerning the action including recommendations about:

- Areas to be left as natural ground;
- Removal or buttressing of existing slide masses;
- Flood protection;
- Problem of groundwater level fluctuation;
- Position of structures, with respect to active faults;
- Problems associated with radon gas and soil radioactivity; and,
- Problems caused by natural gases, such as methane and hydrogen sulfide, radon, and,
- Protection of existing and proposed utility facilities.

G. Conclusions

The report shall provide detailed conclusions of the analysis including:

1. Land Compatibility

State generally whether the intended use of the land is compatible with the investigated site conditions; and if mitigation measures are necessary. In addition, depict those areas where "no building" is recommended.

2. Construction Planning

Discuss critical construction planning aspects that may need further consideration by the contractor including the stability of earth materials, grading plans and the need for selective location of project facilities.

3. Geologic Basis

The report shall clearly state the geologic basis for all conclusions.

H. Recommendations

The report shall provide recommendations to be used in later stages of the project based on this preliminary analysis of the project site including:

1. Mitigation Procedures

Discuss the development of mitigation procedures or design changes necessary to minimize or abate any hazardous condition requires a recommendation.

2. Long-term Project Objectives

Recommendations should focus upon the long-term stability and safety of the proposed project.

C.3 GEOTECHNICAL REPORT

C.3.1 General Requirements

These guidelines outline the minimum information that shall be presented and evaluated in a Geotechnical Report. These guidelines are not intended to be a rigid framework of requirements, nor a specific format for all reports. The level of detail and emphasis may

vary due to unique or particular conditions or due to the type of project. The Geotechnical Report shall generally show results from the applicable testing. The report shall also include a description of site characteristics, e.g., topography, drainage features, etc.

C.3.2 Detailed Report Requirements

A. Required Items

The following items are required to be included in all Geotechnical Reports:

- Site location and description
- Boring location diagram
- Laboratory test reports with evaluations (classification tests) (See Table C-1)

Table C-1. Applicable Geotechnical Laboratory Tests

Applicable Laboratory Tests
Visual classification
Liquid limit - AASHTO T89 or ASTM D4318
Plastic limit - AASHTO T90 or ASTM D4318
Plasticity Index
In-situ moisture content
Percent passing No. 200 sieve - AASHTO T11 or ASTM C117-90
Gradation of granular (sand & gravel) materials - AASHTO T27, ASTM D422 or ASTM C136
AASHTO classification and group index - AASHTO M145
Standard Penetrations Test
Swell Potential Evaluation - ASTM D4546-96

- Boring logs, to include but not limited to the following: (1) Date, Strata Elevation, Depth of Boring; (2) Natural moisture content, blow count and dry density of each undisturbed sample; and (3) Water table elevation
- Seasonal variations in soil and groundwater conditions to include the expected seasonal groundwater elevation variation shall be summarized.
- Shallow bedrock depth and description including mitigation requirements if bedrock is within 3 feet of subgrade.
- Percentage of soluble sulfates.
- Backfill and fill evaluation including any additional tests required for trench backfill evaluation, fill evaluation, etc.
- Groundwater evaluation including the elevation of groundwater encountered in each boring at time of drilling and at 24 to 48 hours after drilling. If deemed necessary, the boring may remain open for up to 7 days if required for further assessment.

B. Recommendations and Mitigation Plans

The report shall include recommendations and mitigation concerning but not limited to the following:

- Allowable soil pressure
- Foundation types
- Groundwater
- Maximum stable slopes (cut, fill, and natural)
- Retaining wall information (if applicable)
- Detention pond design and construction (if applicable)
- Cut and fill criteria (such as compaction, moisture content, benching)

C. Engineer Seal

All Geotechnical Reports shall be signed and seal by a professional engineer registered or authorized to practice in the State of Colorado.

C.3.3 Boring Standards

The following represent the minimum boring standards and guidelines for conducting borings for Geotechnical Reports.

A. Timing of Soil Borings

1. Initial Borings

The information from the initial soil borings shall be summarized in the Geotechnical Report. The entire site shall be sampled for initial testing. This is required to evaluate soil and groundwater conditions and for evaluating roadway locations that may not yet be determined or may change.

2. Structures

Soil borings for design of transportation structures shall be taken prior to the design of the structure.

3. Fill for Right-of-Way Grading

Testing shall be provided for all proposed fill material. All proposed fill material shall be approved by The ECM Administrator prior to placement. The material shall meet minimum requirements and be equal to or better than existing conditions. No fill material with a liquid limit greater than 40 and plasticity index greater than 20 shall be used in the upper 2-feet of the pavement subbase without implementing proper mitigation techniques.

B. Frequency of Borings

The following represent the minimum number of borings that are required based on a typical improvements project. The number of borings may be increased based on the geotechnical engineer's recommendations or at the request of the ECM Administrator.

- A minimum of 2 borings for each project with public improvements shall be performed.

- A minimum 1 boring for each SCS (NRCS) soil type within a development shall be performed.
- A minimum of 1 boring shall be performed for each 10 acres of development up to 100 acres. One additional boring shall be performed for every 25 acres of development above the 100 acres.

C. Borings for Structures

The boring frequency for transportation structures shall satisfy AASHTO Bridge Design requirements and CDOT Materials Testing requirements.

D. Depth of Borings

Borings shall be performed to a minimum depth of 20 feet. In areas where the cut depths are expected to exceed 8 feet, borings shall be extended to a minimum of 15 feet below proposed finished grade. Borings shall extend deeper if needed to determine if bedrock or high groundwater levels are design concerns. Samples for structures shall be taken to a minimum depth of 10 feet below the footing elevation. Additional depth may be required for piers or piles.

It should be noted that boring depths will ultimately be determined by the geotechnical engineer based on site conditions. However, when depths different than those presented is performed, documentation as to the difference must be presented in the submitted report.

C.3.4 Testing

The following represent a listing of the minimum testing requirements and procedures for Geotechnical Reports. The actual numbers and types of tests will be based on the site and the activities being proposed.

A. Applicable Tests

- Visual Classification
- Liquid Limit
- Plastic Limit
- Plasticity Index
- Moisture Content
- Percent Passing 200
- Gradation (Granular Soils)
- AASHTO Classification
- Swell Potential Evaluation
- Percentage of Soluble Sulfates
- Standard Penetration/California Test
- Corrosion Potential Resistivity

B. Classification Testing

Soils shall be classified visually and representative samples tested to determine the soil properties. Sands and gravel samples shall be analyzed for gradation where needed to comply with classification requirements.

C.3.5 Soil Mitigation

Mitigation measures for soil problems revealed by the soils investigation shall be included in the Geotechnical Report. The following specific factors shall be addressed:

A. Mitigation Measures and Approval

All special problems found in soils investigation (e.g., expansion, frost, soluble sulfates, shallow bedrock, heave, groundwater, soil instability, utility backfill, etc.) shall be addressed in the mitigation plans. All proposed mitigation shall be approved by the ECM Administrator.

B. Swell Criteria

If the average swell is 2.0 percent or greater, the pavement design report must provide mitigation measures. The mitigation measures shall reduce destructive swell potential under the public improvements, including landscaping, to an acceptable level of less than 2.0 percent. The swell test report shall specify sample conditions, surcharge pressures, and other key testing factors.

C. Swell Mitigation Measures

Some commonly accepted mitigation measures for swell include: (1) over excavation; (2) chemical treatment; and (3) moisture treatments. Other procedures may be proposed for approval by the ECM Administrator. The selected method must work for the full life expectancy of the improvements.

D. Mitigation of Unstable Subgrade

Some commonly accepted mitigation measures for unstable subgrade include: (1) over-excavation; and (2) chemical treatment. Other procedures may be proposed for approval by The ECM Administrator. The selected method of mitigation must work for the full life expectancy of the improvements.

E. Mitigation Recommendations

1. Extent of Mitigation

Soil treatment shall extend to the back of curb, or to the back of walk for attached or monolithic walk. For detached walk, separate mitigation procedures may be required. A combination of mitigation methods may be required to sufficiently mitigate a soil problem.

2. Approval of Chemical Treatment

Mitigation procedures that alter existing soil conditions (such as lime, fly ash, or cement treatment) shall follow an approved mix design process.

Additional testing is required to verify that no swell is introduced in the chemical treatment.

C.4 PAVEMENT DESIGN REPORT

The Pavement Design Report must be submitted and approved prior to any nonstructural concrete or paving installation. See Appendix D for specific requirements for the Pavement Design Report information.

C.5 INSPECTION AND TESTING REPORTS

All tests and inspection results performed by the sponsor's testing firm shall be submitted directly from the testing agency to the ECM Administrator at the time of field tests, and within ten (10) working days after the testing or retesting date of laboratory test (See Chapter 5 and Appendix J, Roadway and Ancillary Facility Inspections and Testing, for more detailed information).

C.6 SUBSURFACE WATER INVESTIGATION REPORT

C.6.1 When Required

If groundwater is encountered within 5 feet of the original ground surface, a Subsurface Water Investigation Report shall be submitted for approval by the ECM Administrator. This report is required to ensure mitigation of high groundwater effects upon public improvements within the right-of-way. This information may be a separate report or may be included in the Geotechnical Report. This report is not required for temporary dewatering activity needed to facilitate construction of buried utilities. However, all applicable state and federal requirements shall be followed.

C.6.2 Report Requirements

The subsurface water investigation report shall include the following information.

A. Site Location

Site location and description including locations of any irrigation ditches and wetlands.

B. Groundwater

Elevation of water table and seasonal high water level shall be presented within the report and critical issues pertaining to groundwater highlighted.

C. Additional Subsurface Information

Other relevant subsurface information such as water ownership (water rights), groundwater quality (contamination or other undesirable characteristics).

D. Subsurface Drainage

Subsurface drainage recommendations, including its effects on all conditions, including sensitive habitat.

E. Control Measures and Designs

1. Subsurface Drains

Should subsurface drains be recommended, the drains must have a gravity discharge without any possibility of back flow or blockage of the outlet. Any subsurface drain system shall be owned and maintained by the Applicant or the Applicant's assigned successor(s). These drains may discharge into the ECM Administrator's storm drainage system, including inlets or detention ponds, upon appropriate submitted design and approval by the ECM Administrator. Anticipated impacts to the groundwater table on adjacent properties must be quantified.

2. Drain Lines

Drain lines may be installed in the sanitary sewer trench, at an elevation of one sewer diameter lower than the sanitary sewer line.

3. Drain Line Separation from Sewer

Drain line separation from sewer shall be marked to specifically distinguish the drain from the sanitary sewer line.

4. Pipe Materials

Pipe Materials shall be an approved material pipe, for long-term 100 years minimum design life, with appropriate cleanouts.

5. Drain Outlet

Drain Outlet into an inlet structure or detention pond shall be designed to prevent any possibility of backflow and blockage of the drain line.

F. Engineer Seal

All Subsurface Water Investigation Reports shall be signed and seal by a professional engineer registered or authorized to practice in the State of Colorado.

Appendix C Soils Investigation Reports and Mitigation
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REVISION 2
Section C.6.2-C.6.2