SECTION 6

6.0 GEOTECHNICAL

6.1 INTRODUCTION

The purpose of this section of the Manual is to provide guidance on geotechnical components related to the design of City infrastructure and to provide appropriate references to applicable standards and regulations that are located in other publications. The City Standard Specifications provides information related to geotechnical topics such as subsurface investigations, laboratory testing requirements for soil and construction materials, rock excavation, and field testing and inspections. The City Standard Specifications shall cover the minimum requirements for testing involved in the construction of embankments, streets, concrete structures, sanitary sewer systems, storm sewer systems, and water mains and appurtenances.

A geotechnical investigation is generally not required for proposed streets that will be dedicated to the City. However, when a geotechnical investigation is required it shall be performed in accordance with the City Standard Specifications.

Street projects that are initiated by the City shall require a geotechnical investigation to be performed in accordance with the City Standard Specifications.

Generally, retaining walls will not be constructed within the City right-of-way. However, in some situations existing conditions make it impracticable to keep the retaining wall out of the right-of-way. Retaining walls that will be located within the City right-of-way, and have a height of six (6) feet or greater, shall require a geotechnical investigation. Guidance related to the geotechnical investigation for retaining walls is located in Section 6.2 "Retaining Walls".

The City Standard Specifications shall apply to any earthwork being performed as part of a City project or as part of a project that will be dedicated to, or maintained by, the City. This will typically include earthwork (excavation and filling) associated with streets, utilities, public detention ponds, public parks, public parking lots, and other public facilities.

Embankments, or other earth slopes, that will be on City property, including right-of-way, shall be designed to be no steeper than 3:1. See the City Standard Specifications , Section 9, for construction and testing criteria.

6.2 RETAINING WALLS

6.2.1 General Overview

This section provides design standards and guidelines for performing geotechnical analyses for retaining walls that will be located on the City property including the right-of-way. At this time the only type of retaining walls that will be accepted by the City are cantilevered retaining walls constructed of reinforced concrete and Mechanically Stabilized Earth (MSE) walls utilizing geosynthetic reinforcement and a modular block face.

All retaining walls proposed to be constructed within the City right-of-way shall have the design approved by the City prior to beginning construction of the wall. Retaining walls that will be six (6) feet or greater in height, from the bottom of the footing or the bottom of the lowest block – to the top of the wall face, shall require a geotechnical investigation to verify design parameters. See Section 6.2.3 "Geotechnical Investigation" for the geotechnical investigation requirements.

Any retaining wall, public or private, greater than six (6) feet shall be inspected by the Public Safety Department - Codes Enforcement Division at the time of construction.

6.2.2 Internal and External Wall Stability

The internal and external stability of all retaining walls shall be evaluated by a licensed professional engineer in the State of Alabama. For walls greater than six (6) feet in height the following analyses should be submitted to the City:

Reinforced concrete retaining walls

- Factor of safety against overturning
- Factor of safety against sliding
- Factor of safety against bearing capacity failure
- Settlement calculations
- Global stability analysis

MSE retaining walls

- Factor of safety against sliding
- Factor of safety against bearing capacity failure
- Settlement calculations
- Factor of safety against reinforcement failure
- Global stability analysis

The submittal should include all hand calculations or all input parameters if computer software was used. All assumptions should be clearly stated. Assumptions about in-situ soil conditions and backfill material shall be verified by an appropriate geotechnical investigation.

6.2.3 Geotechnical Investigation

Geotechnical investigations for retaining walls shall be performed in accordance with this section of the Manual. Soil test borings shall be drilled at each end of a proposed retaining

wall and on fifty (50) foot centers along the length of the wall. The depth of each soil boring should be two (2) times the retaining wall height, rounded up to the nearest five (5) foot interval. If the soil boring(s) encounter unsuitable foundation materials, then the boring(s) should be extended an additional five (5) feet into firm soil layers or to auger refusal, whichever is less. For MSE walls, the boring location should be approximately at the midpoint between the face of the wall and the back of the reinforcement. For reinforced concrete walls, the boring location should be approximately beneath the centerline of the wall.

The geotechnical investigation should include appropriate field and laboratory testing necessary to verify the soil parameters used in designing the retaining wall. Typically, this shall include testing to estimate the following soil parameters and/or properties:

- Soil strength parameters of the foundation soils
- Consolidation properties of the foundation soils
- Soil strength parameters of backfill soils
- Soil properties associated with compaction of backfill materials
- Classification of backfill material
- Stabilized groundwater elevation

Additional testing may be specified by the engineer of record for the retaining wall. The City requires that a minimum compaction criteria of ninety-five (95%) percent of the maximum dry density, as determined by AASHTO T-99, be achieved on all backfill soils. The engineer of record for the retaining wall may specify more stringent compaction criteria.

6.2.4 Global Stability

A global stability analysis shall be performed on any retaining wall equal to or greater than six (6) feet high which will be constructed on a slope that is equal to or steeper than 4:1. The analysis may be performed using computer software but shall utilize Bishop's Method (or Bishop's Simplified Method). Effective stress parameters are to be used when analyzing for the long term stability of the embankment. The slope, when analyzed with the retaining wall in place, shall have a factor of safety of no less than one and three tenths (1.3). The analysis must be submitted to the City for review and approval prior to construction of the retaining wall.

6.2.5 Sliding, Overturning, Bearing Capacity, and Settlement

The following factors of safety shall be used in the retaining wall stability analysis:

- Factor of Safety against sliding: 1.5
- Factor of Safety against overturning: 2.0
- Factor of safety against bearing capacity failure: 2.0

Total settlement shall be limited to one and one-half (1.5) inches for MSE walls and one (1) inch for cantilevered retaining walls. Differential settlements shall be limited to one half (0.5) inches for all walls.

6.2.6 Backfill Drainage behind Retaining Walls

Adequate drainage is very important to the stability of a retaining wall. The use of granular backfill material, such as No. 57 stone, offers the benefits of good drainage, easy compaction, and increased sliding resistance.

Retaining wall drainage systems typically utilize weepholes and perforated pipe. Weepholes penetrate the retaining wall and drain the area immediately behind the wall. Weepholes should have a minimum diameter two (2) inches so as to permit free drainage; for large walls, four (4) inch weepholes are common. The spacing between weepholes should be approximately thirty-six (36) to forty-eight (48) inches to allow uniform drainage from behind the wall. A geotextile filter fabric, such as the Mirafi N-series or equivalent, should be used between the backfill soils and the weephole opening.

Excess groundwater should be discharged at the ends of the retaining wall or tied into a stormwater conveyance system. Water discharged at the ends of the retaining wall should be directed away from the toe of the wall and configured such that the potential for erosion is limited.

A geotextile filter fabric, such as the Mirafi N-Series or equivalent, should be used to separate the granular backfill material from the select backfill material, and allow groundwater to flow through it.

6.3 DAM DESIGN GUIDELINES

6.3.1 General Overview

The technical guidance for dam design and dam safety has been taken primarily from the Earth Dams and Reservoirs Technical Release (TR)-60, Natural Resources Conservation Service (NRCS); and Federal Guidelines for Dam Safety: Emergency Action Planning for Dam Owners (FEMA 64). The intent of this Section is to provide technical guidelines and requirements for the design and construction of dams within the City.

6.3.2 Dam Classification

A dam shall mean any artificial barrier, including appurtenant works, which impounds or diverts water, wastewater, or liquid borne materials. A dam meeting any of the following criteria shall be under the jurisdiction of the City:

a. Has an impounding capacity at a maximum water storage elevation of at least twenty (20) acre-feet; or
b. Is fifteen (15) feet or more in height; or
c. Will create a probable loss of human life in the event of failure or improper operation, regardless of height or storage capacity; or
d. Will create a probable loss of critical infrastructure in the event of failure or improper operation, regardless of height or storage capacity.

Items "c" and "d" shall be determined by the City Engineer. If a dam meets any of those criteria, the City shall then ask the engineer of record to assign a hazard category. The City shall use the NRCS TR-60 hazard category definitions. Typically, a dam breach analysis must be performed to determine the hazard classification. The City will not have purview over any dams less than six (6) feet in height or less than ten (10) acre-feet of impoundment.

The City shall review all jurisdictional dams through the DRT process. It is strongly encouraged that a pre-submittal meeting be setup with the City Engineer to discuss the design requirements for a particular proposed dam.

The engineer of record shall be required to determine the hazard classification of the proposed dam and provide the City with the engineering analysis that supports the hazard classification. The analysis and calculations shall be included in a written report that is required to be prepared by a licensed professional engineer in the State of Alabama. The engineer shall be competent in areas related to dam investigation, design, construction, and operation for the type of dam being investigated, designed, constructed or operated; and understands adverse dam incidents, failures and the potential causes and consequences of failures.

6.3.3 Classes of Dams

NRCS has established the following classifications of dams which include:

- Low Hazard Class,
- Significant Hazard Class, and
- High Hazard Class.

Low Hazard Dams are those dams which failure would at the most result in damage to agricultural land, farm buildings or minor roads.

Significant Hazard dams are those dams located in predominantly rural or agricultural areas where failure may damage isolated homes, main highways or minor railroads, or cause interruption of use or service of relatively important public utilities.

High Hazard dams are those dams in which failure may cause loss of life, serious damage to residential, industrial, or commercial buildings; or damage to, or disruption of, important public utilities or transportation facilities such as major highways or railroads. Dams proposed for construction in established or proposed residential, commercial, or industrial areas shall be given a *High Hazard* classification, unless the Applicant provides convincing evidence to the contrary.

6.3.4 Design and Safety Requirements

The TR-60 describes design procedures and provides minimum requirements for planning and designing earth dams and associated spillways. It is required that the design of High Hazard and Significant Hazard dams follow the procedures that are set forth in TR-60.

High Hazard dams must be capable of safely passing one hundred (100%) percent of the Probable Maximum Precipitation (PMP) through the principal spillway and emergency spillway without overtopping the dam. The PMP for Lee County, Alabama is approximately forty-four (44) inches for a twenty-four (24) hour period. The PMP data that was interpolated or extracted from Figure 20 of the Hydrometeorological Report No. 51, Probable Maximum Precipitation Estimates, United States East of the 105th Meridian, Office of Hydrology, National Weather Service, U.S. Department of Commerce, NOAA, June 1978.

Within thirty (30) days after completion of a High Hazard dam, the owner shall submit one (1) complete set of as-built plans and specifications to the Public Works Department. The submittal shall also include a letter signed by the engineer of record for the project, certifying that the dam was constructed in accordance with the approved plans and specifications.

Significant Hazard dams shall be designed to control the contributory watershed runoff from one hundred (100%) percent of the PMP without overtopping the dam. Within thirty (30) days after completion of a Significant Hazard dam, the owner shall submit one (1) complete set of as-built plans and specifications to the Public Works Department accompanied by a letter signed by the engineer of record for the project, certifying that the dam was constructed in accordance with the approved plans and specifications.

Low Hazard dams should be designed according to NRCS Conservation Practice Standard No. 378 "Pond". This publication is used for Low Hazard dams where the effective dam height times the storage is less than three thousand (3,000). If the criteria of a dam are greater than the above specified condition then the engineer must revert to TR-60.

The Applicant shall provide written notification of completion of any jurisdictional dam to the City, within thirty (30) days after the dam has been constructed. Also, the Applicant

shall certify that the dam was constructed as shown in the drawings previously submitted or submit new as-built drawings. If the dam was constructed to accommodate stormwater attenuation, the dam certification shall be included with the certification of the stormwater storage facility discussed in Section 7.4.4 "Stormwater Storage Facility Certification".

Because the size and type of structure used for the principal spillway is one of the most critical elements in the design of High Hazard and Significant Hazard dams, the engineer of record responsible for the project shall provide the Public Works Department with detailed hydraulic, hydrologic, and structural computations supporting the selection of the apparatus to be used. Detailed drawings and specifications relating to the apparatus shall be submitted to the Public Works Department for their review.

6.3.5 Hydrologic/Hydraulic Analysis

For a dam break analysis, the US Army Corps of Engineers (USACE) computer model HEC-RAS should be used. This program simulates a breach, its resulting flood peak, and uses unsteady flow principles to route the flood through the downstream valley.

The top-of-dam elevation should be used for the water-surface elevation at the beginning of the dam break for a "wet-weather" case. The results of the downstream flood routing should be used to establish the limits and plot the inundated areas for emergency conditions associated with the dam break discharge. An inundation map should be created to depict the area that could be flooded should the hypothetical emergency occur. The inundation mapping should be extended downstream to the point at which it falls within the FEMA regulatory floodplain.

Additionally, the NRCS program SITES should be used to route the PMP hydrograph through the dam.

6.3.6 Inspection Guidelines

The inspection guidelines are designed to assist the dam owner to better understand the requirements, responsibilities, and duties inherent with dam ownership and to assist the engineer of record by providing a consistent approach to dam inspection and in-service evaluation. The Public Works Department has created inspection forms, which are located in Appendix Q, to assist the engineer of record in the inspection. The engineer of record will recognize that major portions of the guidelines will not apply to smaller dams, and will use professional judgment in identifying applicable portions of the guidelines to be used in producing a site-specific inspection report. The City shall perform annual, regular inspections on all jurisdictional dams in conjunction with their annual detention pond inspections.

The owner and the operator of a dam shall be responsible for the proper operation and maintenance as well as the structural integrity of the dam. In order to fulfill this responsibility, it is recommended that the owner and/or operator perform a visual inspection of the dam at least every sixty (60) days and after every major rainfall event over the watershed. Any symptoms of dam failure observed during such visual inspections shall be immediately reported to the City and engineer of record.

6.3.7 Types of Inspections

Several different types of dam inspections can be performed including an Informal Inspection, a Regular Inspection, a Formal Inspection and an Emergency Inspection. Dams and appurtenances should be inspected regularly to identify conditions that may adversely affect the safety of a dam and its ability to perform intended functions. An inspection may include the periodic evaluation of the as-built dam to insure conformity with current design and construction practices. Inspection reports resulting from Formal Inspections of High Hazard and Significant Hazard dams should be submitted to the City within sixty (60) days of the completion of the inspection.

Informal Inspection – The visual inspection of the dam by the dam owner or operator to detect apparent signs of deterioration or other deficiencies of the dam structure or function is recommended to be performed at least every sixty (60) days and after every major rainfall event over the watershed. Informal Inspections require that personnel conducting the inspection be knowledgeable about the dam and it appurtenances. The dam owner or operator can use portions of the inspection form as a guide when inspecting the dam.

Regular Inspection – The City shall perform an annual courtesy inspection on all High and Significant Hazard dams. This inspection will typically coincide with the City's Annual Detention Pond Inspection. During the inspection the City will visually look for any obvious signs of structural weakness, instability or maintenance issues. If a critical item is discovered during the Regular Inspection, a Formal Inspection will likely be required.

Formal Inspection – It is recommended that a Formal Inspection be performed every two (2) to three (3) years. However, if a critical issue is discovered during the City's Regular Inspection, a Formal Inspection will likely be required. The Formal Inspection and performance evaluation of High Hazard and Significant Hazard dams shall be paid for by the owner. The owner shall hire a consultant who is a licensed professional engineer in the State of Alabama to review and determine the safety and integrity of the dam and appurtenant structures. Formal Inspections require a detailed field examination and include a thorough review of the records on project design, construction, and performance. Detailed underwater inspections should be included as needed. The owner shall submit the Formal Inspection to the City for review and final approval. A City approved Emergency Action Plan (EAP) and Operation and Maintenance Manual should be confirmed and their adequacy determined by the dam owner. All addresses and telephone numbers contained within the EAP must be verified and current. Inspection reports shall be deemed incomplete without this information. Technical experts and specialists may be required to evaluate individual features and conditions; however, a licensed professional engineer in the State of Alabama must make the final coordinated evaluation. A review of prior Regular and Formal Inspection reports should be undertaken to evaluate trends in performance.

Emergency Inspection – An Emergency Inspection is an unscheduled inspection of a dam and its appurtenances necessitated by a potentially natural event such as a large flood or earthquake, or when a condition develops that appear to immediately threaten the safety of the dam. An Emergency Inspection is applicable to any hazard classification and requires immediate attention. An Emergency Inspection may trigger a Formal Inspection as deemed necessary by the City's Dam Inspector.

6.3.8 Emergency Action Plan

The owner of a High Hazard Potential Dam shall develop an EAP that must be approved by the Public Works Department. The following publication should be used as a guideline for developing an EAP:

> FEMA 64 - "Federal Guidelines for Dam Safety: Emergency Action Planning for Dam Owners" April 2004.

An EAP should be formulated for each High Hazard dam. The plan should be to the level of detail warranted by the size and location of the dam and reservoir. It should evaluate downstream inundation hazards resulting from floods or dam failure, and upstream conditions that might result from major land displacements or increased flood flows, including the effects from failure of upstream dams.

The plan should include inundation maps for the flows resulting from design floods and from possible failure of the dam. The complete EAP should be transmitted to the Public Works Department. A review of the plan should be performed concurrent with Formal Inspections and updates made to the plan as recommended by FEMA 64.