DOTD GEOTECHNICAL ASSET MANAGEMENT (GAM) GUIDE

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DOTD GEOTECHNICAL ASSET MANAGEMENT (GAM) GUIDE

INTRODUCTION

The Louisiana Department of Transportation and Development (DOTD) Geotechnical Asset Management (GAM) Guide is designed to assist HQ and District users in obtaining data and performing condition assessment inspections of geotechnical assets located throughout Louisiana.

The purpose of this guide is to standardize the process in which geotechnical assets will be inventoried and inspected. This process includes creating an inventory and documenting the physical characteristics and condition of geotechnical assets. The data collected will be utilized by DOTD to aid in managing inventory and maintaining geotechnical assets to mitigate future issues, repair, and replacement of damaged assets to ensure the safety and performance of the structures.

This guidance document is based on internal DOTD documents (Bridge Inspection Manual, Inventory & Inspection Manual for Ancillary Structures, and the Tunnel Inspection Policies and Procedures Draft), work created and shared by Federal Highway Administration (FHWA), and National Cooperative Highway Research Program (NCHRP) documents. This document has been customized to meet DOTD short-term (design and construction) and long-term (asset management) mechanically stabilized earth wall (MSEW) and other geotechnical asset needs. This document is a living document and may require edits as Geotechnical Asset Management (GAM) is implemented to further match DOTD needs and potential FHWA GAM requirements.

The LTRC research project, 18-4GT, utilized MSEW as the pilot asset and populated an initial dataset through the research. Researchers created an ArcGIS database and mobile Field Maps Application to be utilized in conjunction with this guide. Additional MSEW and other assets (culverts, slopes, hazards, embankment, etc.) can be added as the database grows in the future. This GAM database is an appropriate spot for culverts that are not covered under DOTD Bridge Inspection Manual definition: *DOTD does not have an asset management program in which bridges and culverts under 20 feet in length are inspected on Off-System routes. DOTD Districts are authorized to include minor structures (less than 20 feet in length) for bridges and culverts on On-System routes and properly code Item 112 NBIS Bridge Length.*

TYPES OF GEOTECHNICAL ASSETS

Geotechnical Asset Management includes assets that are often not currently under bridge maintenance, pavement management, or the Transportation Asset Management Plan (TAMP). These elements can

vary and include slopes, culverts, cast in place (CIP) walls, mechanically stabilized earth walls (MSEW), Geosynthetic Reinforced Slopes (GRS), and other assets. MSEW are a common, complex type of geotechnical asset. LTRC research compiled these wall assets into a database as a pilot set of data, which can be utilized by HQ, and as a template for other geotechnical assets. FHWA Geotechnical Engineering Circular (GEC) No. 11 (Berg, Christopher, & Samtani, 2009) outlines the many different manufacturers, their reinforcement details, and their typical facing details in Table 1-1 of GEC 11. GEC 11 also explains many common components, applications, and the design of these wall assets.

Transportation Asset Management Plan (TAMP)

Performance-based planning and programming is a system-level, data-driven process to identify strategies and investments. DOTD released the State's official adoption of the 2019 Federal NHS Transportation Asset Management Plan on June 27, 2019, located here: http://www.tamptemplate.org/wp-content/uploads/tamps/036_louisianadotd.pdf

Geotechnical assets are not currently covered by the TAMP, but they are assets as they can affect traffic and safety, and they do need proper maintenance. Some assets like slopes and culverts may be fairly easy to repair with District forces. Other assets, like retaining walls, will need specialty contractors due to their scale, complex nature, and location in tight, urban areas. Collecting and preserving information on geotechnical assets during design and construction will help when it comes to future management and maintenance. Please see LTRC project 18-4GT report for more information.

Design Considerations

DOTD staff help ensure the longevity of assets through their initial design, construction, and oversight of the contractor and their wall-subcontractor. Table 1 through Table 3 (Berg, Christopher, & Samtani, 2009) are intended for the initial design through construction phases. These checklists guide/inform staff and inspectors of important details in contract documents (plans and specifications) and during construction. Beyond these construction stages and for the longer term, a GAM approach is preferred.

When a new structure is designed and built within Louisiana, there are design drawings. With advances in computer power, these drawings should be stored for future reference. Specific drawings from the wall manufacturer should also be included in the digital record.

Table 1. Design - Drawing Review Checklist (after FHWA NHI-08-094/095)

Drawing Review Checklist (after FHWA NHI-08-094/095)

YES	NO	NA	1.0 DOCUMENTS
			1.1 Have you thoroughly reviewed the design drawings?
			1.2 Is there a set of all project drawings in the project office?
			1.3 Has the contractor submitted shop drawings?
			1.4 Have the shop drawings been approved by the designer and/or construction division manager?
YES	**NO**	**NA**	**2.0 LAYOUT**
			2.1 Have you located the horizontal and vertical control points?
			2.2 Do you know where the MSE wall begins and ends?
			2.3 Have you identified locations of existing utilities, signs, piles, lights that affect the proposed construction?
			2.4 Have you identified the elevations/grade at top and at bottom of MSE walls?
			2.5 Have you identified the existing and finished grades?
			2.6 Do you know where the construction limits are?
			2.7 Have you identified how the site will be accessed and provisions for material storage?
			2.8 Is phased construction involved?
YES	**NO**	**NA**	**3.0 FOUNDATION PREPARATION**
			3.1 Are any special foundation treatments required?
			3.2 Is the foundation stepped?
			3.3 Is concrete leveling pad and the required elevation(s) shown on the drawings?
			3.4 Is shoring required?
YES	**NO**	**NA**	**4.0 DRAINAGE**
			4.1 Have you located the details for drainage?
			4.2 When must the drainage provisions be installed?
			4.3 Where does the drainage system outlet and does it allow for positive drainage?
			4.4 Are geotextile filters required?
			4.5 Is a drainage barrier (geomembrane) required for this project?
YES	**NO**	**NA**	**5.0 FACING**
			5.1 Have you identified the facing type, shape, size, and architectural finishing?
			5.2 Are there different types, colors, or sized facing units on the job?
			5.3 How do the facing units fit together?
			5.4 Do you understand any corner/curve details?
			5.5 Do you understand bracing, bearing pads, wedging, and shimming requirements?
			5.6 Is the facing battered?
			5.7 Are geotextile filters required for wall joints and are the placement shown on the drawings including overlaps and termination at the base and toe of the wall?
YES	**NO**	**NA**	**6.0 REINFORCING**
			6.1 What type of reinforcement is used in this project?
			6.2 Can you determine the length, location, and type of reinforcement throughout the length and height of the wall or slope?
			6.3 Do you understand how the reinforcing connects to the facing?
			6.4 Have you identified any details for avoiding obstructions when placing reinforcement?
			6.5 Are cross sections showing reinforcement location? Are cross sections shown for each stationing and major elevation change?
YES	**NO**	**NA**	**7.0 BACKFILL**

			7.1 Are different types of fill required in different locations in the wall?
YES	**NO**	**NA**	**8.0 ANCILLARY ITEMS**
			8.1 Is there any coping specified in the drawings?
			8.2 Is there any traffic barrier or guardrail specified in the drawings?
			8.3 Have you reviewed interfaces with CIP structures?
			8.4 Do you understand the details for joints at or connections to CIP structures?
			8.5 Are any of the following involved in this project?
			8.5.1 Catch basins/drop inlets
			8.5.2 Culverts/pipes?
			8.5.3 Piles/drilled shafts?
			8.5.4 Utilities and other obstructions?
			8.6 Have you reviewed any special detail to accommodate these obstructions?
			8.7 Do you know who is responsible for installation of each ancillary item?
			8.8 Are diversion ditches, collection ditches, or slope drains shown on the drawings?
			8.9 Is a permanent or temporary erosion control blanket required?
			8.10 Do you understand the erosion control details?

Table 2. Specification Compliance Checklist (after FHWA NHI-08-094/095)

Specification Compliance Checklist (after FHWA NHI-08-094/095)			
YES	**NO**	**NA**	**1.0 DOCUMENTS**
			1.1 Have you thoroughly reviewed the specifications?
			1.2 Is there a set of specifications in the field trailer?
			1.3 Are standard specifications or special provisions required in addition to the project specifications? Do you have a copy?
YES	**NO**	**NA**	**2.0 PRE-CONSTRUCTION QUALIFYING OF MATERIAL SOURCES / SUPPLIERS**
			2.1 Has the contractor submitted pre-construction qualification test results (showing that it meets the gradation, density, electrochemical, and other soil-property requirements) for:
			2.1.1 Reinforced soil
			2.1.2 Retained soil
			2.1.3 Facing soil (if applicable)
			2.1.4 Drainage aggregate
			2.1.5 Graded granular filters (if applicable)
			2.2 Has the contractor or wall supplier submitted pre-construction qualification test results and/or Certificate of Compliance demonstrating that the facing materials comply with the applicable sections of the specifications including:
			2.2.1 Facing unit and connections
			2.2.2 Horizontal facing joint bearing pads
			2.2.3 Geotextile filter for facing joint
			2.3 Has the contractor or wall supplier submitted pre-construction qualification test results and/or Certificate of Compliance demonstrating that the reinforcing materials comply with the applicable sections of the specifications?
			2.4 Has the contractor or wall supplier submitted pre-construction qualification test results and/or Certificate of Compliance demonstrating that the drainage materials comply with the applicable sections of the specifications including:
			2.2.1 Geotextile filters (e.g., type, AOS, permittivity, strength)
			2.2.2 Prefabricated Drains (i.e., geotextile filter and core)
			2.2.3 Drainage Pipe (material, type, ASTM or AASHTO designation and schedule
			2.4 Has approval of the material sources been officially granted for:

			2.4.1 Reinforced soil
			2.4.2 Retained soil
			2.4.3 Facing soil (if applicable)
			2.4.4 Drainage aggregate
			2.5 Has approval of the facing material sources been officially granted?
			2.6 Has approval of the reinforcing material sources been officially granted?
YES	**NO**	**NA**	**3.0 FOUNDATION PREPARATION**
			3.1 Has temporary shoring been designed and approved?
YES	**NO**	**NA**	**4.0 DRAINAGE**
			4.1 Is the contractor or manufacturer submitting QC test results at the specified frequency demonstrating that the drainage materials comply with the applicable sections of the specifications?
			4.2 Do the drainage materials delivered to the site correspond to the approved shop drawings?
			4.3 Do the identification labeling/markings on the geotextile filters and/or prefabricated drainage materials delivered to the site correspond to the pre-construction and QC submittals (date of manufacturing, lot number, roll numbers, etc.)?
			4.4 Have the drainage materials been inspected for damage due to transport, handling, or storage activities?
			4.5 Are the drainage materials properly stored to prevent damage, exposure to UV light, contamination?
			4.6 If any drainage materials were found damaged, have they been set aside, rejected, or repaired in accordance with the specifications?
			4.7 Has QA sampling of the drainage materials been performed at the required frequency?
			4.8 Does the QA lab know which tests to run and the required test parameters?
			4.9 Do the QA test results for the drainage materials meet the specified property values?
YES	**NO**	**NA**	**5.0 FACING**
			5.1 Is the contractor or wall supplier submitting QC test results at the specified frequency demonstrating that the facing materials comply with the applicable sections of the specifications?
			5.2 Do the facing components delivered to the site correspond to the approved shop drawings, including:
			5.2.1 Facing unit (shape, dimensions, reinforcement connections, overall quantity)
			5.2.2 Horizontal facing joint bearing pads (material type, hardness, modulus)
			5.2.3 Geotextile filter for facing joint (type, AOS, permittivity, strength)
			5.3 Do the identification labeling/markings on the facing units and components delivered to the site correspond to the pre-construction qualification and QC submittals (date of manufacturing, batch number, lot number, etc.)?
			5.4 Have the facing units and components been inspected for damage due to transport, handling, or storage activities?
			5.5 Are the facing units and components properly stored to prevent damage?
			5.6 If any facing units and components were found damaged, have they been rejected or repaired in accordance with the specifications?
			5.7 Has QA sampling of the facing units and component materials been performed at the required frequency?
			5.8 Does the QA lab know which tests to run and the required test parameters?
			5.9 Do the QA test results for the facing unit and component materials meet the specified property values?
YES	**NO**	**NA**	**6.0 REINFORCING**
			6.1 Is the contractor or wall supplier submitting QC test results at the specified frequency demonstrating that the reinforcing materials comply with the applicable sections of the specifications?
			6.2 Do the reinforcing materials delivered to the site correspond to the approved shop drawings (strength, dimensions, overall quantity)?
			6.3 Do the identification labeling/markings on the reinforcing materials delivered to the site correspond to the pre-construction and QC submittals (date of manufacturing, lot number, roll numbers, etc.)?
			6.4 Have the reinforcing materials been inspected for damage due to transport, handling, or storage activities?

			6.5 Are the reinforcing materials properly stored to prevent damage, exposure to UV light, or corrosion?
			6.6 If any reinforcing materials were found damaged, have they been set aside, rejected, or repaired in accordance with the specifications?
			6.7 Has QA sampling of the reinforcing materials been performed at the required frequency?
			6.8 Does the QA lab know which tests to run and the required test parameters?
			6.9 If pullout or interface shear testing is required, does the QA lab have enough of the applicable soil and the compaction criteria (in addition to the reinforcing materials)?
YES	**NO**	**NA**	**7.0 BACKFILL**
			7.1 Is the Contractor submitting QC test results at the specified frequency for: 7.1.1 Reinforced soil 7.1.2 Retained soil 7.1.3 Facing Soil
			7.2 Does the QA lab know which tests to run and the required test parameters?
			7.3 Do the QA test results for the various materials meet the specified property values: 7.3.1 Reinforced Soil 7.3.2 Retained Soil 7.3.3 Facing Soil
YES	**NO**	**NA**	**8.0 ANCILLARY ITEMS**
			8.1 Do any ancillary materials delivered to the site correspond to the approved shop drawings (prefabricated copings, cap blocks and attachment glue, if required, catch basins, pipe, guardrail, etc.)?
			8.2 Do the identification labeling/markings on the ancillary materials delivered to the site correspond to the QC submittals (date of manufacturing, batch number, etc.)?
			8.3 Have the ancillary materials been inspected for damage due to transport, handling, or storage activities?
			8.4 Are the ancillary materials properly stored to prevent damage?
			8.5 If any ancillary materials were found damaged, have they been set aside, rejected, or repaired in accordance with the specifications?
			8.6 Have all requirements to sample/test any aspect of the work product after assembly, installation, compaction been met?

Table 3. Construction Inspection Checklist (after FHWA NHI-08-094/095)

Construction Inspection Checklist (after FHWA NHI-08-094/095)			
YES	**NO**	**NA**	**1.0 DOCUMENTS AND PLANS**
			1.1 Has the contractor furnished a copy of the installation plans or instructions from the MSEW or RSS supplier as required by the specifications?
			1.2 Have the installation plans or instructions been approved by the designer and/or construction division manager?
			1.3 Have stockpile and staging areas been discussed and approved?
			1.4 Have access routes and temporary haul roads been discussed and approved?
YES	**NO**	**NA**	**2.0 LAYOUT**
			2.1 Has the contractor staked out sufficient horizontal and vertical control points, including points required for stepped foundations?
			2.2 Has the contractor accounted for wall batter when staking the base of the wall?
			2.3 Have drainage features and all utilities been located and marked?
			2.4 Have Erosion & Sedimentation Controls been installed?
YES	**NO**	**NA**	**3.0 FOUNDATION PREPARATION**
			3.1 Has the MSEW or RSS foundation area been excavated to the proper elevation?
			3.2 Has the foundation subgrade been inspected (e.g., proof rolled) as required by the specifications?

			3.3 Has all soft or loose material been compacted or unsuitable materials (e.g., wet soil, organics) been removed and replaced?
			3.4 Has the leveling-pad (if applicable) area been properly excavated and set to the proper vertical and horizontal alignment?
			3.5 Has the leveling pad (if applicable) cured for the specified time (typically at least 12 hours) before the contractor sets any facing panels?
YES	**NO**	**NA**	**4.0 DRAINAGE**
			4.1 Is the drainage being installed in the correct location?
			4.2 Are drainage aggregates being kept free of fine materials?
			4.3 Are all holes, rips, and punctures in geotextiles being repaired in accordance with the specifications?
			4.4 Are composite drain materials being placed with the proper side to the seepage face?
			4.5 Do all collection and outlet pipes have a positive slope?
YES	**NO**	**NA**	**5.0 FACING**
			5.1 Is the first row of facing panels (when applicable) properly placed? Do they have proper spacing, bracing, batter, and do they have the wood spacers installed?
			5.2 Is the contractor using the correct facing unit (correct size, shape, color, and with the proper number of connections) for the applicable location and elevation?
			5.3 Is a geotextile filter being properly placed over joints in the facing panels?
			5.4 Are the lower tiers of facing baskets (when applicable) properly placed? Are they setback correctly to result in the designed slope angle? Are the struts spaced correctly?
			5.5 Have secondary reinforcing layers (e.g., biaxial geogrid) and vegetated matting (where applicable) been properly placed? Are they setback correctly to result in the designed slope angle?
			5.6 Is the vertical elevation and horizontal alignment being checked periodically and adjusted as needed?
			5.7 Is the contractor removing the wooden wedges as per the specifications? (Typically removed as soon as soon as erection and backfilling the panel above the wedged panel is completed.)
			5.8 Is the spacing between individual facing units (or for RSS and wrapped face walls, overlap of reinforcement) in accordance with the specifications?
YES	**NO**	**NA**	**6.0 REINFORCING**
			6.1 Is the reinforcement being properly connected (connections tight and all of the slack in the reinforcing layers removed)
			6.2 Is the reinforcement in the proper alignment?
			6.3 Is the reinforcement the right type?
			6.4 Is the reinforcement the correct length?
			6.5 Is the reinforcement being placed at the correct spacing and location?
			6.6 Is the fill being brought up to 2” above the soil reinforcement elevation before the reinforcement is connected?
			6.7 Is construction equipment being kept from operating directly on the reinforcement (i.e., until adequate soil cover is placed over the reinforcement)
YES	**NO**	**NA**	**7.0 BACKFILL**
			7.1 At the end of each day's operation, is the contractor grading the upper surface of reinforced and retained soil to ensure runoff of storm water away from the MSEW or RSS face or provide a positive means of controlling runoff away from the construction area?
			7.2 Where applicable, has the contractor backfilled in front of the MSE wall?
			7.3 Is the contractor placing the reinforced soil in lifts that are thin enough to ensure good compaction, but thick enough not to damage the reinforcement?
			7.4 If the contractor is using water to adjust the moisture of the reinforced, retained, or facing soil, does it meet the requirements set forth in the specifications?
			7.5 Is the reinforced soil being placed to prevent damage to the reinforcement?

			7.6 Are the lifts being spread to prevent excessive tension or excess slack in the reinforcement?
			7.7 Is the fill being compacted using the correct equipment and in the correct pattern?
			7.8 Is the soil moisture content within the specified range?
			7.9 Is the soil compaction (dry density) within the specified range?
			7.10 Is large compaction equipment being kept at least 3' from the face?
YES	**NO**	**NA**	**8.0 ANCILLARY ITEMS AND FINISHED PRODUCT**
			8.1 Could installation of ancillary components (e.g., catch basins, storm-water piping, guardrail) affect the reinforcing or facing components already installed?
			8.2 Have ancillary items been installed in accordance with the drawings and specifications?
			8.3 Are ancillary items being installed at the proper locations?
			8.4 Are diversion ditches, collection ditches, or slope drains installed in accordance with the drawings and specifications?
			8.5 Is permanent or temporary erosion control blanket installed at the required locations and using the details shown on the drawings?
			8.6 Are there any visible signs of MSEW or RSS tilting, bulging, or deflecting?
			8.7 Has the vertical and horizontal alignment been confirmed by survey?
			8.8 Is there a need to confirm the vertical or horizontal alignment at a future time to evaluate whether movement is occurring?
			8.9 Are there any signs of distress to the facing components (e.g., fracturing or spalling of concrete panels, bowing of wire baskets, etc.)?

GAM INVENTORY

Collecting, organizing, and categorizing inventory information is paramount as a first step to GAM. Understandably, there is a cost effort to inventory and assess geotechnical assets. LTRC collected information on hundreds of retaining walls for the department, but an incremental approach is likely best moving forward on other remaining geotechnical assets. The walls digitized and georeferenced by LTRC are in an ArcGIS database with wall information. The verification and assessment of these and other geotechnical assets should be done by District personnel familiar with these assets and their history. As new walls are constructed/located, they can be added to the database too. Wall information includes location, wall manufacturer, wall facing and reinforcement, the Route ID, construction dates (if available), and other information. ArcGIS and ArcMaps can be utilized to document the initial placement and wall attributes, and document issues regarding performance or maintenance.

- Structural Data Inventory
- Asset Type
- Material
- Length
- Start Height
- End Height
- Blocks tall at Start
- Blocks tall at End
- Ground Elevation – Start
- Ground Elevation – End
- Construction date
- Backfill
- Anchoring
- Manufacturer
- Date Built (estimate)
- Offset (ft.) from nearest highway
- Top-Down or Bottom-Up Construction
- Retaining Backslope or Highway?
- Wall Facing & Top Cap
- Drainage (surface, weep holes, etc.)
- Rust
- Wall Base
- Erosion
- Other Items

Inventory efforts began as part of LTRC research (18-4GT), but many geotechnical assets remain undocumented (slopes, culverts, etc.). Adding assets to the database (ideally, as they are located/constructed) is necessary to put them on the map/radar, ensure maintenance needs are met, and allocate future funding.

Table 4 is also from GEC #11 and can be utilized post construction to ensure specifications are met and update the as built construction document details.

Table 4. Post Construction Inspection Checklist

1. Read the specifications and become familiar with:

___ material requirements
___ construction procedures
___ soil compaction procedures
___ alignment tolerances
___ acceptance/rejection criteria

2. Review the construction plans and become familiar with:

___ construction sequence
___ corrosion protection requirements
___ special placement to reduce damage
___ soil compaction restrictions
___ details for drainage requirements
___ details for utility construction
___ construction of slope face
___ contractor's documents

3. Review material requirements and approval submittals.

___ review construction sequence for the MSE reinforcement system.

4. Check site conditions and foundation requirements. Observe:

___ site accessibility
___ limits of excavation
___ leveling pad construction (check level and alignment)
___ drainage features; seeps, adjacent streams, lakes, etc.
___ construction dewatering
___ preparation of foundations

5. On site, check reinforcements and prefabricated units. Perform inspection of prefabricated elements (i.e. casting yard) as required. Reject precast facing elements if:

___ compressive strength < specification requirements
___ molding defects (e.g., bent molds)
___ honey-combing
___ severe cracking, chipping or spalling
___ color of finish variation
___ tolerance control
___ misaligned connections

6. Check reinforcement labels to verify whether they match certification documents.

7. Observe materials in batch of reinforcements to make sure they reinforce for flaws and non-uniformity.

8. Obtain samples according to specification requirements reinforcements.

9. Observe construction to see that the contractor complies with specification requirements for installation.

10. If possible, check reinforcements after aggregate or riprap placement for possible damage.
Either by constructing a trial installation, or aggregate or riprap and observing the reinforcement after placement and compaction of the aggregate, at the beginning of the project. If damage has occurred, contact the design engineer.

11. Check all reinforcement and prefabricated facing units against the initial approved shipment and collect additional test samples.

12. Monitor facing alignment:

___ adjacent facing panel joints ___ precast face panels ___ line and grade

OBSERVATION, INSPECTION, AND MONITORING

NCHRP Report 903 outlines a staged approach for data collection, see Figure 1 (NCHRP Report 903), in which Stage 1 efforts get the ball rolling with the initial implementation of the system to help populate the database and breakout the differences between performing and non-performing assets. These first level efforts include the initial condition and consequence assessments, which can be completed via the Field Maps app. Stage 1 gives an overview of assets and helps identify those assets that need more detailed (Stage 2, hands on) inspections. Most assets are likely functioning, vs. those that need more attention, including more detailed inspections like those shown in Stage 2 and Stage 3.

Figure 1. NCHRP Staged approach for data collection in asset management

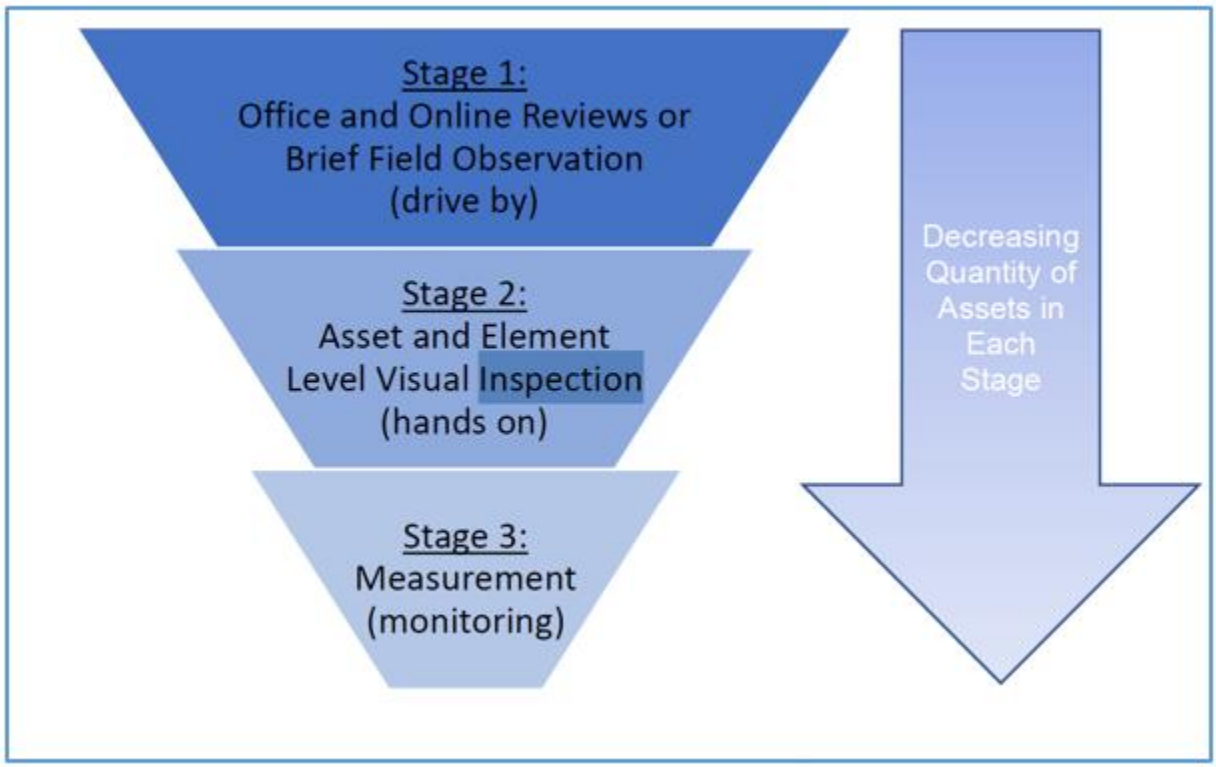

Table 5 through Table 7 and Figure 2 through Figure 5 present the National Cooperative Research Highway Program (NCHRP) Report 903 "Geotechnical Asset Management for Transportation Agencies," which serve as a guide for the overall GAM assessment and ratings. The evaluation is composed of three assessment outlined by the decision trees, where each assessment receives a rating from 1 to 5. When combined, these values create a simple evaluation of risk or level of risk (LOR). This is a simple approach with school grades (A to F) and colors (green for good, red for stop/reassess) for each asset. See Figure 5.

Table 5. Asset Operation and Maintenance Condition (O&MC)

(FHWA: Vulnerability)

Rating	Group	Description
Good Condition (Very Low)	**1**	**No work recommended or agency costs (<1% chance of adverse event in assessment year). - - NCHRP** FHWA Vulnerability: (Characteristics indicating very low likelihood (Probability < 0.001) for the wall to experience failure within 5 years of the risk assessment.)
Minor Condition (Low)	**2**	**Incidental annual maintenance, needs of a few hours of staff time or <$500 of other cost. - - NCHRP** FHWA Vulnerability: (Characteristics indicating low likelihood (Probability = 0.01) for the wall to experience failure within 5 years of the risk assessment.)
Fair Condition (Medium)	**3**	**Deterioration and repair needs evident. Agency annual costs estimated to be <5,000 or up to about 1 week of labor for asset management. - - NCHRP** FHWA Vulnerability: (Characteristics indicating moderate likelihood (Probability = 0.1) for the wall to experience failure within 5 years of the risk assessment.)
Poor Condition (High)	**4**	**Significant deterioration present. Regular agency staff involvement required and department expenses may be up to $100,000 per year for the asset.- - NCHRP** FHWA Vulnerability: (Characteristics indicating high likelihood (Probability = 0.2) for the wall to experience failure within 5 years of the risk assessment.)
Critical to Failed Condition (Very High)	**5**	**Failed or nearly failed asset causing either assets to be out of service with corrective action required or imminent. - - NCHRP** FHWA Vulnerability: (Characteristics indicating very high likelihood (Probability = 0.50) for the wall to experience failure within 5 years of the risk assessment.)

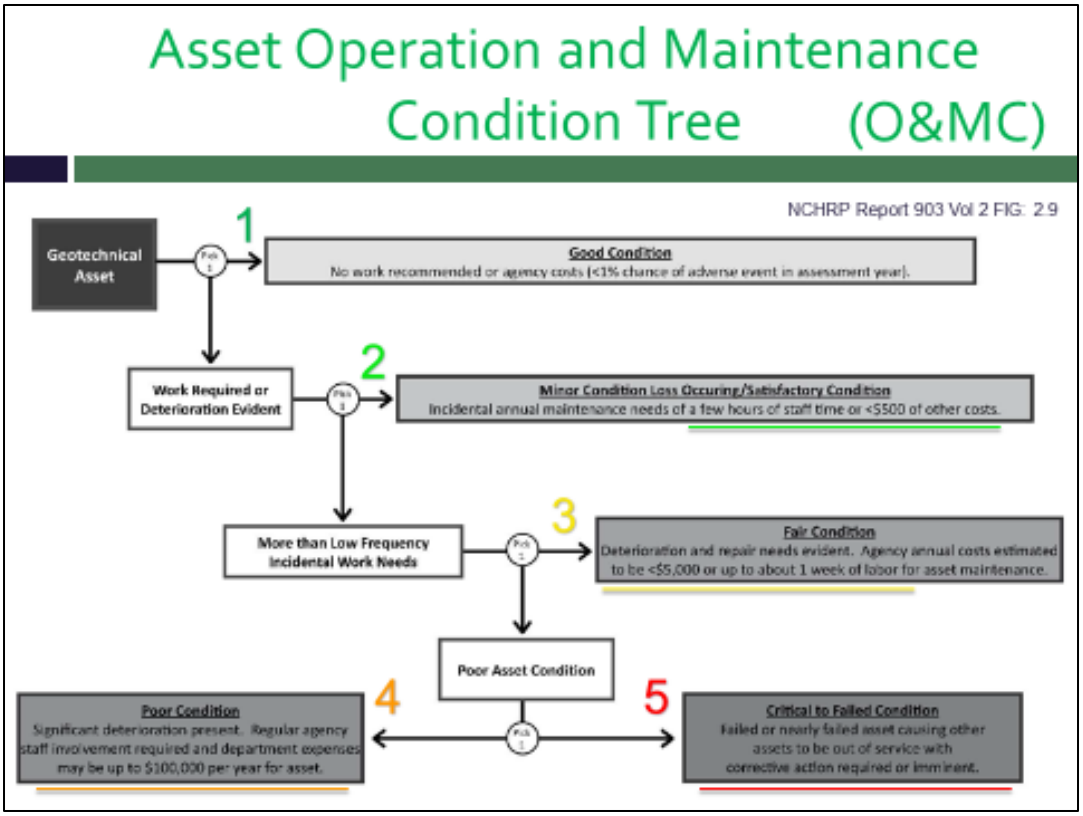

Figure 2. Asset Operation and Maintenance Condition Tree (O&MC)

Table 6. Safety Consequences

FHWA Rating	Group	Description
Insignificant	1	**No Known Crash History or Crash Event Judged to be unlikely. - - NCHRP** No injuries and discomfort or nuisance to users.- - FHWA
Minor	2	**Impact only to Shoulder and Does Not Reach Travel Lane(s) . - - NCHRP** No injuries but discomfort or nuisance to users.- - FHWA
Significant	3	**Avoidable or Limited to Driver Distraction. - - NCHRP** Injuries not requiring professional intervention.- - FHWA
Severe	4	**Vehicle Damage Possible but only Slight Injury Threat. - - NCHRP** Injuries requiring professional intervention but not leading to loss of life, long-term incapacity, or permanent disability.- - FHWA
Catastrophic	5	**Fatality or Injury Possible. - - NCHRP** Loss of life and/or injuries leading to long-term incapacity or permanent disability.- - FHWA

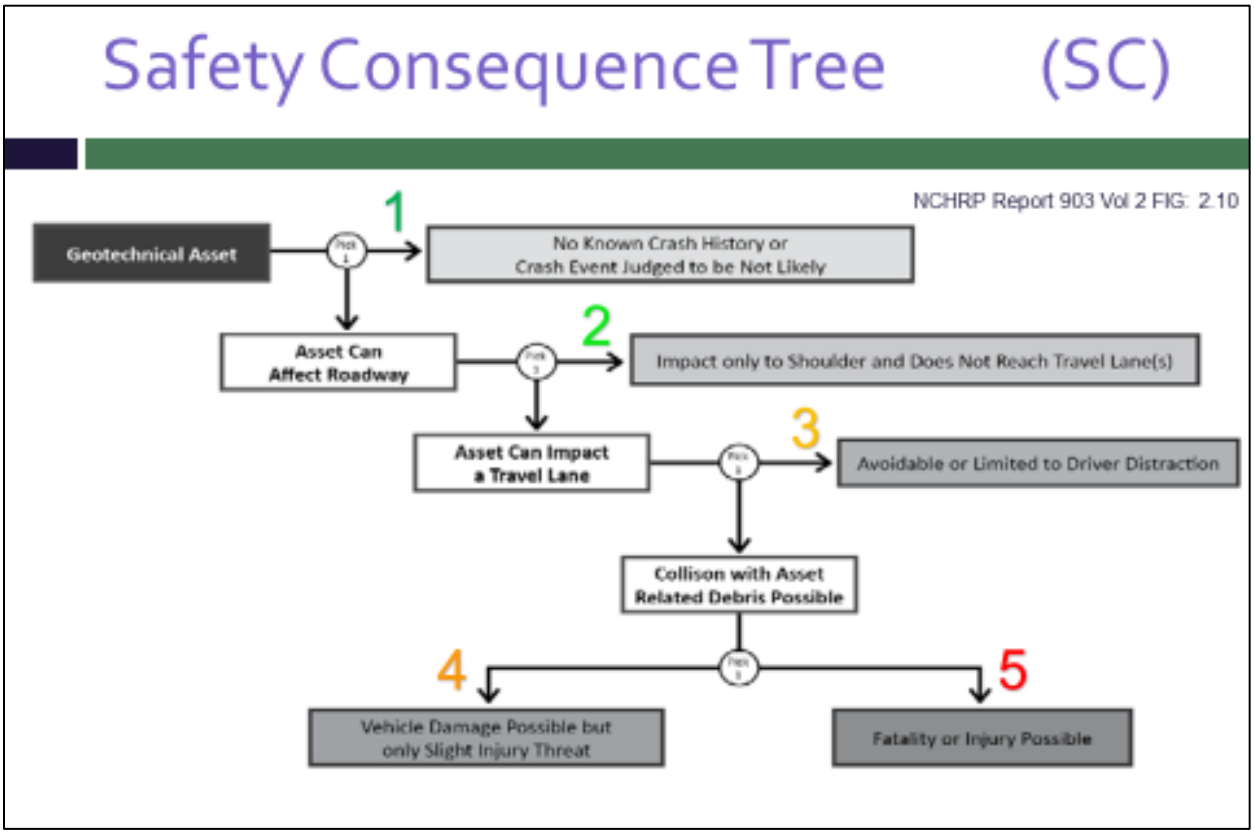

Figure 3. Safety Consequences Tree (SC)

Table 7. Mobility and Economic Consequences

Rating	Group	Description
No Impact Insignificant	1	**No Impact to Traffic Possible. - - NCHRP** Occurrence of at least one of the following: • Insignificant financial losses and no disruption to critical business functions. • Infrastructure assets and properties receive minimal damage but remain fully operational.
Event or Asset Can Impact Roadway Minor	2	**Impact only to Shoulder and Does Not Reach Travel Lane(s) . - - NCHRP** Occurrence of at least one of the following: • Minor financial losses and no disruption to critical business functions. • A number of infrastructure assets and properties are unusable or restricted but can be replaced within an acceptable timeframe.
Asset Can Impact Travel Lane Significant	3	**Avoidable or Limited to Slight Speed Reduction. - - NCHRP** Occurrence of at least one of the following: • Significant financial loss and no disruption to critical business functions. • Some assets not including significant or critical assets are unusable or restricted for weeks.
Delays Possible Severe	4	**Less than 1 Day Closure Possible or Minor Measurable Economic Impacts. - - NCHRP** Occurrence of at least one of the following: • Very significant financial loss and/or disruption to critical business functions that is recoverable within a short-term. • Non-critical infrastructure assets and properties are destroyed. Significant or critical infrastructure assets are unusable or restricted for weeks.
Delays Possible Major	5	**Delays and/or Closure for Several Days or Major Economic Impacts. - - NCHRP** Occurrence of at least one of the following: • Large unacceptable financial loss and/or failure of critical business functions resulting in long-term hardships. • Significant or critical infrastructure assets and properties are destroyed and remain unusable for months.

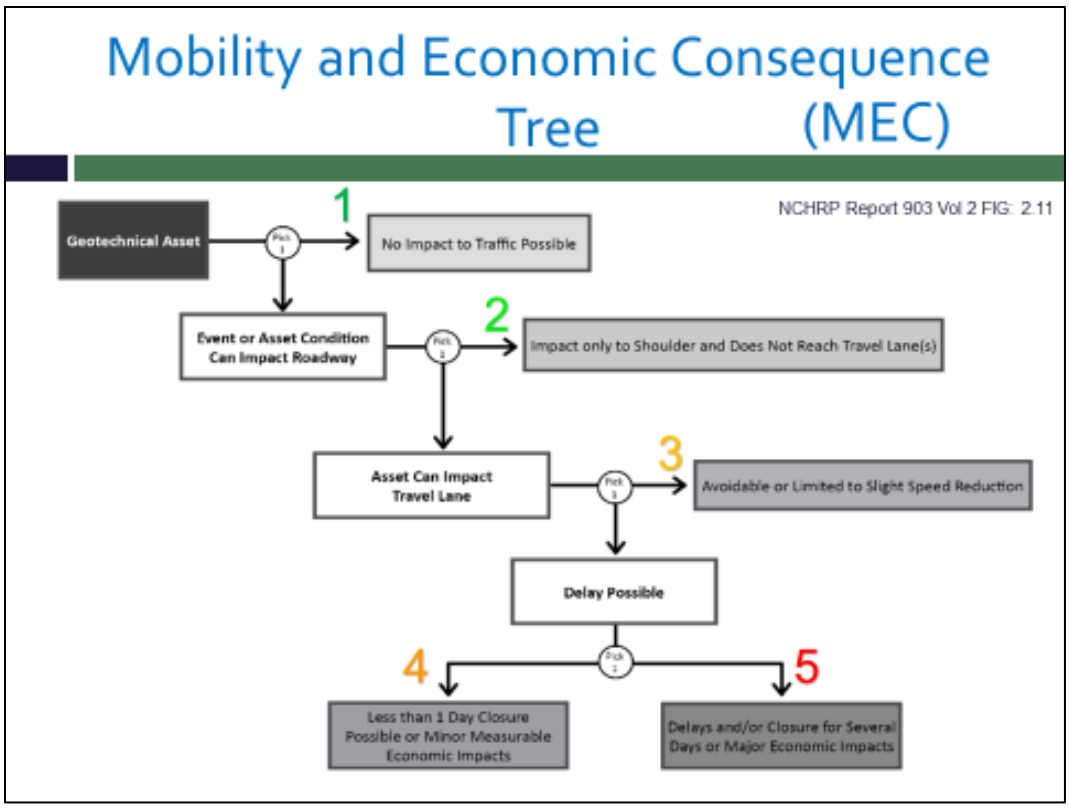

Figure 4. Mobility and Economic Consequence Tree (MEC)

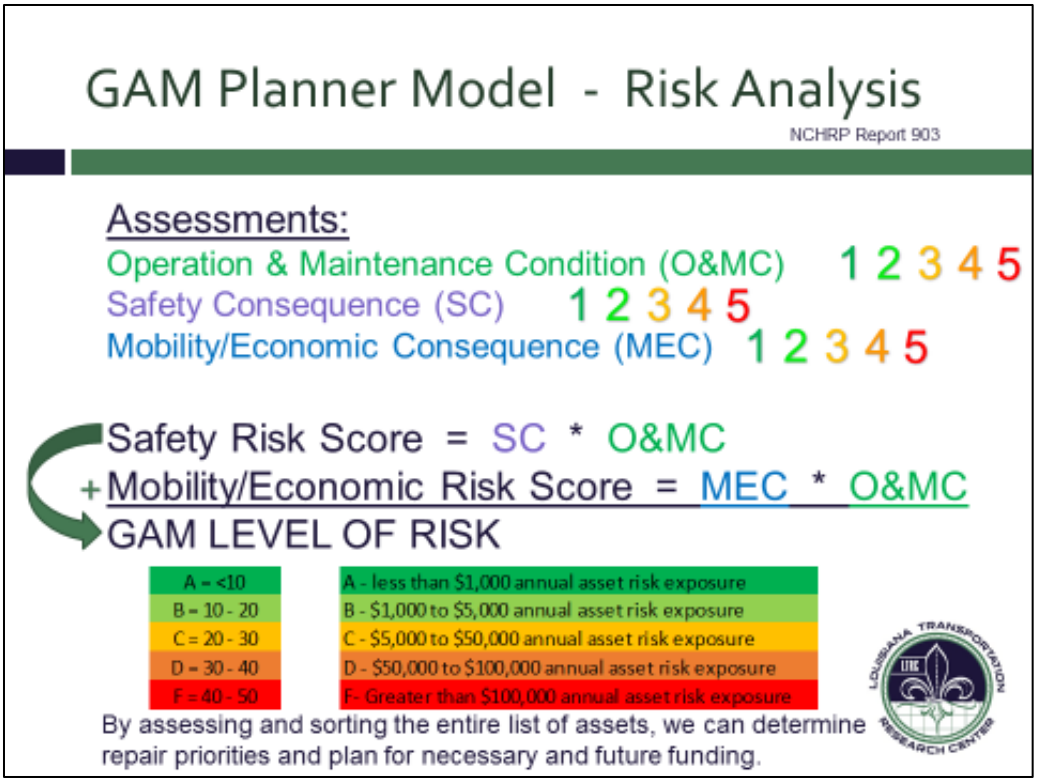

Figure 5. GAM Planner Model – Risk Analysis

The calculated level of risk (LOR) as outlined in the full LTRC report (and NCHRP 903) will help determine repair and funding priorities. For poorly performing walls and geotechnical assets, more detailed inspection checklists will provide insight to the HQ Geotechnical Section and Operation and Maintenance personnel to address these challenged assets appropriately; and allocate available funding and engineering analysis, if necessary, to those critical assets.

If the field inspector notices something wrong with a retaining wall during Stage 1 (or at any other time), damage has occurred, or a red level of risk is reached, Stage 2 inspections should be initiated. These Stage 2 inspections are more hands on than Stage 1 and likely require more-technical staff. MSE structures are to be erected in compliance with the structural and aesthetic requirements of the plans, specifications, and contract documents. The desired results can generally be achieved through the use of quality materials, correct construction/erection procedures and proper inspection.

However, there may be occasions when dimensional tolerances and/or aesthetic limits are exceeded. Corrective measures should be taken quickly to bring the work within acceptable limits. Presented below are several out-of-tolerance conditions and their possible causes.

Table 8 is included to help with preliminary diagnosis of wall issues. Depending upon the asset and its condition, the asset may require a more detailed inspection and recommendations from geotechnical

staff engineers to diagnose potential issues and remedial actions. Stage 2 should identify and document issues, then engage geotechnical specialists for additional assistance.

MSE structures are to be erected in compliance with the structural and aesthetic requirements of the plans, specifications, and contract documents. The desired results can generally be achieved through the use of quality materials, correct construction/erection procedures and proper inspection.

However, there may be occasions when dimensional tolerances and/or aesthetic limits are exceeded. Corrective measures should be taken quickly to bring the work within acceptable limits. Presented below are several out-of-tolerance conditions and their possible causes.

Table 8. Out-of-Tolerance Conditions and Possible Causes

CONDITION	**POSSIBLE CAUSE**
1. Distress in wall: a. Differential settlement or low spot in wall. (Cause 1 a & b apply) b. Overall wall leaning beyond vertical alignment tolerance. (Cause 1 a&b) c. Spalling, chipping, or cracking of facing units (Cause 1 a – e apply) (e.g., from panel to panel contact or differential movement of modular block facing units).	a. Foundation (subgrade) material too soft or wet for proper bearing. b. Fill material of poor quality or not properly compacted. c. Inadequate spacing in horizontal and vertical joints. d. Use of improper bearing pads. e. Stones or concrete pieces between facing units (e.g., units not clean or used to level face units).
2. First panel course difficult (impossible) to set and/or maintain level.	a. Leveling pad not level.
3. Wall out of vertical alignment tolerance (plumbness), or leaning out.	a. Panel not battered sufficiently. b. Oversized compaction equipment working within 3 ft. (1 m) of wall facing panels. c. Backfill material placed wet of optimum moisture content. Backfill contains excessive fine materials (beyond the specifications for percent of materials passing a No. 200 sieve). d. Backfill material pushed against back of facing panel before being placed and compacted above reinforcing elements.. e. Excessive compaction of uniform, medium-fine sand (more than 60 percent passing a No. 40 sieve). f. Backfill material dumped close to free end of reinforcing elements, then spread toward wall face, causing displacement of reinforcements and pushing panel out. g. Shoulder wedges not seated securely. h. Shoulder clamps not tight. i. Slack in reinforcement to facing connections. j. Inconsistent tensioning of geosynthetic reinforcement to facing. k. Localized over-compaction adjacent to MBW unit.
4. Wall out of vertical alignment tolerance (plumbness) or leaning in.	a. Excessive batter set in panels or offset in modular block units for select granular backfill material used. b. Inadequate compaction of backfill. c. Possible bearing capacity failure.
5. Wall out of horizontal alignment tolerance, or bulging.	a. See Causes 3c, 3d, 3e, 3j, 3k. Backfill saturated by heavy rain or improper grading of backfill after each day's operations.

6. Panels do not fit properly in their intended locations.	a. Panels are not level. Differential settlement (see Cause 1). b. Panel cast beyond tolerances. c. Backfill material not uniform. d. Backfill compaction not uniform.
7. Large variations in movement of adjacent panels.	a. Inconsistent setting of panels.

Forms 1 through Form 4 can be utilized to identify critical issues and communicate Stage 2 findings with HQ for additional assistance and resources (labor, time, funds, etc.). These checklists can help document the inspection and current condition to assist with repair or management decisions. The forms focus on high and very-high risks and are used to guide the frequency of inspections, the need for invasive investigations, the need for stabilization measures, and if appropriate, the use of more advanced methods of quantitative risk analysis and management—possibly engaging Phase 3 measurements and monitoring.

Form 1 Reinforced Backfill Performance State

This form evaluates the reinforced backfill of the asset.

1. Reinforced Backfill Performance Indicators are characteristics that collectively describe the Performance State of the backfill. These indicators should be assessed using known information. Note that not all indicators below necessarily apply to the asset.
2. In Section A, utilize the following ratings: Poor (P), Marginal (M), Good (G), or not applicable (N/A).
3. If more than three N/A boxes exist, there is insufficient information, therefore rate as Poor (P) in Section B.
4. If there are three or fewer N/A boxes, there is sufficient information, therefore assign the worst Reinforced Backfill Indicator from Section A as the Performance State in Section B.

Site Location District: _____ City:_____ Route:_____
Description:_____
GAM Wall Number:_____ GAM Segment:_____ Evaluator:_____ Date:_____

Section A – Reinforced Backfill Performance Indicator	**Rating**
<u>Backfill Saturation</u> P: Almost saturated or saturated M: Moist G: Almost dry or dry	
<u>Total Settlement</u> P: Total settlement exceeding admissible limits M: Total settlement within admissible limits G: Negligible total settlement	
<u>Differential Settlement/Tilting</u>	

Section A – Reinforced Backfill Performance Indicator	**Rating**
P: Differential settlement/tilting exceeding admissible limits M: Differential settlement/tilting within admissible limits G: Negligible differential settlement/tilting	
Localized Soil Failure P: Presence of localized shear failure in the reinforced backfill G: Absence of localized shear failure in the reinforced backfill	
Section B – Reinforced Backfill Performance State	

Form 2 Reinforcement Components Performance State

This form evaluates the structural metallic components (reinforcements, facings, facing connections, etc.) of the asset.

1. Structural metallic components indicators are characteristics that collectively describe the Performance State of the structural metallic components. These indicators should be assessed using known information. Note that not all indicators below necessarily apply to the asset.
2. In Section A, utilize the following ratings: Poor (P), Marginal (M), Good (G), or not applicable (N/A).
3. If more than three N/A boxes exist, there is insufficient information, therefore rate as Poor (P) in Section B.
4. If there are three or fewer N/A boxes, there is sufficient information, therefore assign the worst Structural Metallic Component Indicator from Section A as the Performance State in Section B.

Site Location District:_____ City:_____ Route:_____
Description:_____
GAM Wall Number:_____ GAM Segment:_____ Evaluator:_____ Date:_____

Section A – Structural Metallic Components Performance Indicator	**Rating**
<u>Reinforcement or Connection Failure</u> P: Facing connection rupture or reinforcement pullout G: No facing connection rupture nor reinforcement pull out	
<u>Reinforcement or Connection Corrosion</u> P: Severe corrosion (pitting, steel swelling, rust stains on the facing, and/or >50% rusted surface) M: Moderate corrosion (no pitting, no rust stains on the facing, and/or 10-50% rusted surface) G: Mild corrosion (no pitting no rust stains on the facing, and/or <10% rusted surface.	
<u>Facing Connection Bending</u> P: Excessive bending on the facing G: No bending on the facing	
<u>Facing</u> P: Facing displacement beyond admissible limits and/or presence of loose or detached units. M: Facing displacement within admissible limits G: Negligible facing displacement and no loose or detached units.	
Section B – Structural Metallic Components Performance State	

Form 3 Drainage Performance State

This form evaluates the drainage performance of the asset.

1. Drainage performance indicators are drainage characteristics that collectively describe the Performance State of the drainage. These indicators should be assessed using known information. Note that not all indicators below necessarily apply to the asset.
2. In Section A, utilize the following ratings: Poor (P), Marginal (M), Good (G), or not applicable (N/A).
3. If more than three N/A boxes exist, there is insufficient information, therefore rate the Drainage Performance State as Unfavorable (U) in Section B.
4. If there are two or less N/A boxes, there is sufficient information, therefore assign the worst Drainage Condition Indicator from Section A as the Drainage Performance State in Section B.

Site Location District:_____ City:_____ Route:_____
Description:_____
GAM Wall Number:_____ GAM Segment:_____ Evaluator:_____ Date:_____

Section A – Drainage Performance Indicator	**Rating**
Soil Erosion P: Soil erosion at the base of the wall or along the wingwalls G: No Erosion	
Vegetation P: Vegetation growth in facing and construction joints M: Minimal Vegetation growth in facing and construction joints G: No Vegetation growth in facing and construction joints	
Drainage System (Surface and Subsurface) P: Presence of drainage problems that cannot be addressed by routine maintenance M: Presence of drainage problems that can be addressed by routine maintenance G: No drainage problems	
Water Accumulation P: Water accumulation at the top or the base of the wall (e.g., water ponding) G: No water accumulation at the top or the base of the wall (e.g., water ponding)	
Backfill Spill-Out P: Presence of spilled-out reinforcement backfill material G: No spilled-out reinforcement backfill material	
Section B – Drainage Performance State	

Form 4 Other Wall Component Performance State

This form evaluates other factors concerning the performance of the asset.

1. Other Wall Components performance indicators are characteristics that collectively describe the Performance State of the foundation, non-metallic facing, utilities, and surroundings. These indicators should be assessed using known information. Note that not all indicators below necessarily apply to the asset.
2. In Section A, utilize the following ratings: Poor (P), Marginal (M), Good (G), or not applicable (N/A).
3. If more than three N/A boxes exist, there is insufficient information, therefore rate the Other Wall Components Performance State as Unfavorable (U) in Section B.
4. If there are three or fewer N/A boxes, there is sufficient information, therefore assign the worst Performance Indicator from Section A as the Other Wall Components Performance State in Section B.

Site Location District:_____ City:_____ Route:_____
Description:_____
GAM Wall Number:_____ GAM Segment:_____ Evaluator:_____ Date:_____

Section A – Other Wall Components Performance Indicator	**Rating**
Foundation Total or Differential Settlement P: Total or differential settlement exceeding admissible limits; and/or cracks in the leveling pad M: Total or differential settlement within admissible limits G: Negligible total or differential settlement	
Foundation Erosion and Scour P:..Berm (or embedment) erosion exposing leveling pad; or scour at the base of water-crossing walls M: Moderate erosion to berm and embedment depth that does not expose leveling pad G: Insignificant erosion to berm and wall embedment depth	
Retained Soil P. Presence of localized shear failure in the retained soil G: No localized shear failure in the retained soil	
Surroundings P: Corrosion of guardrails or presence of salt deposits near the wall; or signs of impact-related damage G: No corrosion of guardrails and no salt deposits near the wall; and no signs of impact-related damage	
Utilities P: Broken utility lines or utility pipe leakage G: No broken utility lines and no utility pipe leakage	
Facing P: Offset of units;bulging, bowing, or buckling; excessive cracks (within individual units or traversing multiple units); or popped unit corners M: Moderate facing cracks; facing scratches and chipping; moderate facing deterioration (wear and tear); lateral deformation G: No bulging, bowing, or buckling; no water staining, chipping, or wearing; negligible lateral deformation	
Coping and Parapets P: Offset of concrete coping and parapets; and/or loose or detached coping and parapets M: Admissible concrete coping and parapets displacement or cracks G: Insignificant concrete coping and parapets displacements or cracks	
Superstructure	

Section A – Other Wall Components Performance Indicator	Rating
P: Significant pavement cracks, gap between coping and roadway or abutment; or gap between approach slab and bridge deck (riding bumps) M: Moderate pavement cracks G: Insignificant pavement cracks	

Stage 3 measuring and monitoring is most often for an asset experiencing issues or problems with serviceability or risk to the public. An example of this case would be the Vicksburg Bridge and its associated active slope movements. This bridge will be monitored long into the future, in contrast to other assets addressed more easily/functioning properly. Depending upon the asset's condition, consequences, and risk, the DOTD HQ Geotechnical staff and or consultant engineers or contractors may be involved.

Inspection Frequency

There is currently no federal mandate for the inventory and inspection of retaining wall structures. However, research (NYSDOT, WisDOT, and NCDOT), common sense, and prudence lead the authors to these recommendations.

Table 9. Inspection Frequency for Wall Assets

	Type of inspection	New Assets	Interstate/ Principal Arterial	GAM Rating High Risk (F Ratings)	GAM Rating Moderate Risk (C & D Ratings)	GAM Rating Low Risk (A &B Ratings)
Stage 1	Condition Assessment	Initial	1 year	6 Months + Stage 2	3 year	5 years
	Safety Consequences	Initial	1 year	6 Months + Stage 2	3 year	5 years
	Mobility & Economic Consequences	Initial	1 year	6 Months + Stage 2	3 year	5 years
Stage 2	Detailed Inspection Checklist		After Stage 1 – Inspection frequency based on Hands On review, Damage, Risk Evaluation, and ADA and HQ O&M Recommendations			
Stage 3	Detailed with measuring and monitoring		After Stage 2 - Frequently, as needed based on damage and repair status			

GEC 11 also provides information regarding a monitoring program: if an asset is performing well, there no need for instrumentation. If there is a question regarding performance, then instrumentation can be applied to address those questions/issues. The level of risk (LOR) calculations can be utilized to determine which assets may need more detailed inspections, instrumentation, and or a monitoring program.

COMMUNICATIONS

Digital documentation, database population, and even hand sketches can convey asset status. Digitizing paper records via scanners or photo can help preserve and enhance the digital record and database. Standardization provides consistency, and consistency maintains accuracy. Staff observing or identifying deficiencies in assets should notify supervisors and ultimately the Assistant District Administrator (ADA) should be notified of any deficiencies. If District forces find a deficient geotechnical asset, needing Stage 2 inspections, notify the HQ-Geotechnical (Section 67) for further, more detailed investigations to assist with the root cause and potential repair options. When an asset is determined to be in imminent danger, notify the ADA/owner via email. The owner/ADA should immediately acknowledge receipt of the email by responding that it was received (as proof that the email was received).

To add or change a geotechnical asset in the ArcGIS database, please provide a list of assets and plan sheets showing location of the asset to LTRC for addition to the database. The information will link to the Field Maps application for initial assessments and calculation of base level of risk (LOR).

Including the final as-builts into the digital file record will also benefit the department, and future engineers that may need to enact repairs or modifications to the assets as they age. The digital record will stand the test of time and therefore be available in the future.

CONCLUSIONS AND RECOMMENDATIONS

This GAM guide is an early template to assist the Department with implementation of Geotechnical Asset Management. The ArcGIS database contains retaining walls as a pilot dataset and can be expanded to include additional assets and data about those assets. This information will benefit the department as staff retires and assets continue to age and need maintenance. Additionally, this guide could be incorporated into the TAMP as experience with GAM grows. Federal requirements may also dictate that GAM be required. This document and the associated research report (LTRC 18-4GT) and the Field Maps application plus user guide will assist with the full implementation.

REFERENCES

- LTRC Final Report, Project 18-4GT, Geotechnical Asset management for Louisiana, 2022
- LTRC Field Maps user manual, Project 18-4GT
- New York State DOT Microsoft Word - RWIIP_Ch 2_Retaining Wall Appraisals (Final) (ny.gov)
- WisDOT Structure Inspection Manual - Part 4 - Chapter 4 Retaining Walls (wisconsindot.gov)
- GEC 11 Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes - Earth Retaining Structures - Geotech - Bridges & Structures - Federal Highway Administration (dot.gov)
- Louisiana DOTD Bridge Maintenance and Inspections, Documents and Manuals (la.gov)
- Geotechnical Asset Management for Transportation Agencies, Volume 1: Research Overview | Blurbs New | Blurbs | Publications (trb.org)