Appendix: Acid Producing Materials (APM)

Acid Producing Materials (APM) are substances that generate acid when exposed to air and moisture, potentially impacting environmental and structural integrity in geotechnical projects. Predominantly found in Middle and East Tennessee, particularly in shale, sandstone, and siltstone formations, APM can cause acid drainage, leading to soil and water contamination, material degradation, and structural damage. Proper identification, testing, and management of APM are crucial for mitigating these risks and ensuring project sustainability. Please note that in the context of excavated construction material not otherwise defined by federal statute, APM is not to be considered a hazardous waste by definition. This document provides comprehensive guidance on handling APM in alignment with state and federal regulations.

Historically, the Tennessee Department of Transportation (TDOT) has significantly evolved its approach to managing APM. Since the early 2000s, TDOT has developed and refined compliance measures to address the environmental and engineering challenges posed by APM, reflecting a growing awareness of the importance of effective APM management in protecting both infrastructure and natural resources.

When APM is suspected in a construction project, the TDOT Environmental Division typically submits a set of construction plan drawings to the Tennessee Department of Environment and Conservations (TDEC) Division of Solid Waste for the approval of a Special Waste Permit. This step is crucial as it ensures that APM treatment and processing comply with environmental regulations.

APM treatment and processing is a site-specific endeavor that requires case-by-case engineering judgment. Historically, methods such as blending, full encapsulation, or relocation to an approved landfill have been employed. Regardless of the method chosen, it is essential that all parties involved collaborate to achieve an executed Special Waste Permit. This collaborative approach ensures compliance with the permit and promotes responsible environmental stewardship.

Related Documents

Key documents relevant to the handling and management of APM include the following guidelines and provisions, which outline contractual responsibilities and methodologies:

- **Special Provision 107L (SP107L):** This TDOT provision outlines the contractual responsibilities for APM samplings, testing, and handling. It ensures that APM are managed in accordance with construction plans and specifications, detailing how they should be treated and disposed of to mitigate potential environmental impacts.
- **Guideline for Acid Producing Rock Investigation, Testing, Monitoring, and Mitigation (October 2007) (APR Guidelines):** This guideline forms the basis for current APM processing methodologies.

Geology and Geographical Distribution

APM form through geological processes involving the oxidation of sulfur-bearing minerals, such as pyrite, within rocks and soil. When these minerals are exposed to oxygen and moisture, they undergo oxidation, leading to the production of ferrous sulphate ($Fe2SO4$), sulfuric acid ($H2SO4$), and sulphur dioxide ($SO2$). This oxidation process, along with the presence of water creates what is known as acid mine drainage in mining environments. The oxidation products can result in significant environmental impacts if APM are exposed during construction or excavation.

Various types of APM are commonly found in Tennessee. Pyritic shales and coal-bearing formations are among the most prevalent, containing significant amounts of pyrite that can generate acid upon oxidation. Coal seams often contain sulfur compounds that contribute to acid production when exposed to air and water. Additionally, metallic sulfide formations, which include a variety of rock types with inherent sulfur content, are significant sources of APM. Each type has unique properties that affect its potential for acid generation and environmental impact.

APM is commonly found in specific geological formations across Tennessee, particularly within the Appalachian Plateau, the Valley and Ridge, and the Blue Ridge regions. While certain counties and formations are more prone to containing APM, the presence of these materials can vary widely across the state. Understanding the regional distribution and the geological formations associated with APM is essential for effective management and mitigation in geotechnical projects. Detailed information on specific counties and formations with known APM occurrences will be provided in the accompanying chart.

Project Screening

Conduct a desktop study and project screening of historical documents, geological maps, and elevation data to assess the likelihood of encountering APM before fieldwork begins.

- **Historical Document Review:** Examine past reports, studies, and records related to the project site to identify any historical issues or findings concerning APM.
- **Geological Map Analysis:** Analyze geological maps to determine the types of bedrock, geologic formation names, and soil present in the area. Look for formations known to contain APM.
- **Elevation and Topographic Assessment:** Review elevation and topographic data to understand site characteristics and identify potential areas where APM may be present.

Sampling and Testing

Visual Inspection

Conduct a thorough visual inspection of the site, paying close attention to exposed rock faces, soil cuts, drainage areas, and excavation areas. The goal is to identify any apparent signs of APM.

- **Documentation:** Document all observations of potential APM by recording their location and condition. Photograph any areas of concern to provide visual evidence for further

investigation. This documentation will be useful for assessing the need for additional testing and developing appropriate mitigation strategies.

- **Indicators to Look For:**
    - **Color:** Yellow, orange, or reddish staining on rocks or soil, indicative of iron oxides. Solid black color may be indicative of shale or coal depending on area.
    - **Sulfide Mineralization:** Pyrite or other sulfide minerals, often appearing as metallic, brassy-yellow grains or crystals within rock formations.
    - **Odor:** Sulfurous or rotten egg smell, indicative of hydrogen sulfide gas.
    - **Water Quality:** Distinctive colors (e.g., red, yellow, white, black), low pH, or elevated conductivity.
    - **Kill Zones:** Areas devoid of vegetation.
    - **Geologic Formations:** Outcrops or formations on geological maps—especially those known to be rich in sulfides (e.g., pyrite), have a history of APM impacts, or are carbonate materials (e.g., limestone).
    - **Proximity to Coal Mines:** Nearby coal mines, road cuts, or other potential acid-producing sites.

Subsurface Investigation

Proper sampling ensures that APM are accurately identified and managed, minimizing environmental risks. Samples should be collected using conventional geotechnical drilling methods, such as Standard Penetration Test (SPT) borings and rock core sampling. The following guidelines outline key steps and considerations for effective sampling:

- **Sampling Intervals and Depth:** Conduct sample holes at intervals of approximately 150 to 250 feet. Ensure samples are taken at least 5 feet below the final grade to verify the presence of all materials. Multiple locations per cross-section may be required to determine the extent of APM across the area.
- **Vertical Profiling:** Collect samples at multiple depths ranging from ground surface to 20 feet to assess the vertical extent of APM. Carefully observe and document drill cuttings for changes in appearance, texture, odor, et cetera from the same approximate elevation across the drilling locations. Geological and engineering judgment should be applied throughout the sampling process to determine the effectiveness of the sampling plan, appropriate depths, and any additional considerations necessary to accurately assess APM presence and potential impacts.

Geophysical Methods

Geophysical methods can be utilized in identifying subsurface lithology and mapping, allowing for the detection of geological variations that may indicate APM presence. By using geophysical surveys alongside drilling data, the subsurface profile may be more accurately defined, helping to pinpoint areas of concern and reduce the need for excessive borings.

Testing Guidelines

These testing guidelines ensure that APM samples are thoroughly evaluated for their potential to produce acid, helping to mitigate risks. Ensure that materials within known geological formations

discussed in Section (?).3, which may contain APM, are thoroughly tested, even if initial visual inspections do not indicate sulfide mineralization. This will help identify hidden risks.

- **Rock Samples:**
    - **Sulfide Mineralization:** Look for signs of sulfide minerals such as pyrite, which may appear as metallic, brassy-yellow grains or crystals within rock formations.
    - **Dark Shales:** These rock types often have higher concentrations of sulfide minerals and should be tested to assess their potential for acid generation.
    - **Coal Seam Samples:** Samples from known or suspected coal seams or coal-bearing formations should be tested, as coal can contribute to acid generation when it oxidizes.
- **Soil Samples:**
    - **Soils Containing Sulfide Minerals:** Soils suspected to contain sulfide minerals based on geological mapping or visual inspection should be selected for testing. (in particular the Chattanooga Shale Formation will weather to a rust-colored silty clay and still contain measurable APM).
    - **Transition Zones:** Samples from transition zones between sulfide-bearing rock and overlying soil layers are crucial for understanding potential acid migration.
    - **Coal-Associated Soils:** Soil samples near or derived from coal deposits should be tested for potential acid-generating properties.

Testing Methods

The following testing methods are typically used by TDOT to thoroughly evaluate APM samples for their acid-producing potential. All testing must be conducted by a qualified laboratory with experience in the methods listed to ensure accurate and reliable results.

- **Neutralization Potential (NP) (EPA 600/2-78-054):** Assesses the material's ability to neutralize acidity by quantifying alkaline substances, helping to balance acid-producing and neutralizing components.
- **Acidity Potential from Total Sulfur (AP) (EPA 600/2-78-054):** Estimates the potential acidity based on total sulfur content, assuming all sulfur is in sulfide form, to predict acid production.
- **Net Neutralization Potential (NNP) (EPA 600/2-78-054):** Calculates the difference between NP and AP to determine the surplus or deficiency of neutralizing agents. A negative NNP suggests potential acid generation.
- **Total Sulfur (ASTM D4239-14):** Measures all forms of sulfur in a sample to determine potential acid formation, as sulfur contributes to acid generation.
- **Pyritic Sulfur (ASTM D2492-02 (2012)):** Measures sulfur specifically in the form of pyrite, a major contributor to acid production when oxidized.
- **Paste pH (EPA 600/2-78-054 or ASTM D4972-13):** Measures the pH of a soil-water paste to determine acidity or alkalinity, indicating potential APM.
- **Fizz Test (EPA 600/2-78-054):** A field test detecting carbonate minerals by applying dilute hydrochloric acid and observing fizzing, indicating the presence of carbonates and assessing Neutralization Potential. This field test offers a preliminary evaluation of carbonate content to decide if additional testing for acid-producing potential is needed.

Interpreting APM Test Results

- **Neutralization Potential (NP):** High NP suggests sufficient neutralizing agents to counterbalance acid-producing components, reducing the risk of acid production.
- **Acidity Potential from Total Sulfur (AP):** Higher AP values indicate greater potential for acid generation due to sulfur oxidation. Materials with high AP require mitigation to prevent acid formation.
- **Net Neutralization Potential (NNP):** NNP is a measure of the difference between the Neutralization Potential (NP) and the Acid Potential (AP). It reflects the net capacity of a material to neutralize acidity. A positive NNP indicates that the material has sufficient neutralizing agents to counteract its acid-producing potential, while a negative NNP indicates a deficiency in neutralizing agents.
    - **NNP > 0:** Material is considered non-acid-producing.
    - **NNP between -5 and 0:** Classified as Potential-APM.
    - **NNP < -5:** Indicates high risk of acid production.
- **Net Acid-Base Account Value (AP-NP):** The AP-NP value represents the difference between the Acid Potential (AP) and the Neutralization Potential (NP) of a material. It indicates the excess of acid potential over neutralizing capacity. A positive AP-NP value suggests a higher potential for acid generation, whereas a negative value suggests sufficient neutralizing capacity to balance out the acid potential.
- **Neutralization Potential Ratio (NPR):** NPR is used to determine whether a material has enough neutralizing potential to counteract its acid-producing potential. It is calculated by dividing the Neutralization Potential (NP) by the Acid Potential (AP):
    - NPR=NP/AP
    - **Interpretation of NPR Values:**
        - **NPR ≥ 4:** Material is generally considered safe and non-acid producing.
        - **NPR between 1 and 4:** Material has the potential to produce acid, particularly under certain environmental conditions.
        - **NPR < 1:** High risk of acid production.
- **Total Sulfur:** Higher sulfur content suggests a higher likelihood of acid production, making sulfur a critical indicator for APM assessment.
- **Pyritic Sulfur:** High pyritic sulfur content increases the likelihood of acid production when exposed to air and water, requiring careful handling and mitigation.
- **Paste pH:**
    - **pH < 5:** Indicates acidic material, likely to produce acid.
    - **pH ≥ 5:** Indicates neutral or basic material, but further tests are needed to confirm if it is non-acid generating.
- **Fizz Test:**
    - **Strong fizz:** High presence of carbonate minerals, suggesting good Neutralization Potential.
    - **Weak or no fizz:** Low carbonate content, requiring further assessment of AP and NP.

Treatment and Mitigation Methods

Effective management of Acid Producing Materials (APM) requires a range of treatment and mitigation methods to address their potential environmental impacts. The primary methods for managing APM include encapsulation, blending, and hauling to offsite landfills.

- **Encapsulation** involves enclosing APM to prevent their exposure to air and water, which are necessary for acid generation. Encapsulation may be constructed on TDOT Right of Way if sufficient space is available in the planned fill areas or it may be constructed at offsite locations provided and controlled by the Contractor and approved by TDOT.
    - **Full Encapsulation:** Completely encloses APM using barriers such as geomembranes or clay liners. This method is highly effective in preventing acid production but can be costly and complex to implement, making it suitable for cases with significant acid potential.
    - **Partial Encapsulation:** Encloses only the most reactive portions of APM. While it is a more cost-effective approach than full encapsulation, it still provides a degree of protection and reduces the overall potential for acid production.
- **Blending** involves mixing APM with neutralizing agents to reduce acid production. Common neutralizing agents include lime and alkaline waste products, which help neutralize the acids produced by APM, thereby reducing their environmental impact. The effectiveness of blending depends on the choice of neutralizing agent and the amount required, which should be based on the acid potential of the APM.
    - **On-Site Blending:** Performed on-site, suitable for manageable volumes of APM in fill areas of sufficient size and volume.
    - **Off-Site Blending:** Performed off-site, often used for larger quantities or when on-site blending is impractical. These sites are provided and controlled by the Contractor with TDOT approval.
- **Hauling to Offsite Landfill** is sometimes the safest and most effective method for managing APM. This approach involves transporting APM to a designated landfill specifically equipped to handle such materials. Designated landfills are designed to prevent acid release into the environment, ensuring that APM is managed in a controlled setting and minimizing environmental risks. However, this method requires careful transportation logistics and coordination with landfill facilities.

Material Classification

Material is classified into three categories based on their acid-producing potential: Non-APM, Potential-APM, and APM. Each category is defined by specific criteria and requires different handling and mitigation measures to manage their impact effectively.

- **Non-APM:** Materials that do not produce significant amounts of acid. They have a positive Net Neutralization Potential, indicating sufficient neutralizing capacity to counterbalance any potential acidity. They typically exhibit a neutral or basic paste pH and low pyritic sulfur content. No special handling or treatment is generally required.
    - **Criteria:** NNP > 0
- **Potential-APM:** Materials that have some potential to produce acid under certain conditions. They exhibit a range of NNP values indicating possible acid generation, and their paste pH is acidic. The pyritic sulfur content is moderate, suggesting some risk of acid production. Measures such as partial encapsulation, blending with neutralizing agents, or transport to an offsite landfill are recommended to manage these materials.
    - **Criteria:** NNP between -5 and 0
- **APM:** Materials that are likely to produce significant amounts of acid. They have a negative Net Neutralization Potential, indicating a deficiency in neutralizing agents compared to the acid potential. Their paste pH is acidic, and they have high pyritic sulfur content. Full

encapsulation or transport to an offsite landfill is necessary to mitigate the risk of acid production.

- **Criteria:**
  - NNP < -5
  - Paste pH < 5
  - Pyritic Sulfur > 0.1%

Classification	Net Neutralization Potential	Paste pH	Pyritic Sulfur	Recommended Action
Non-APM	NNP > 0	---	---	No special handling required.
Potential-APM	NNP between -5 and 0	---	---	Partial encapsulation, blending, or offsite landfill.
APM	NNP < -5	pH < 5	> 0.1%	Full encapsulation or offsite landfill.

Geotechnical Reports and Geotechnical Plans

Incorporating Acid Producing Materials (APM) into geotechnical reports and plans is crucial for ensuring a comprehensive evaluation, effective treatment, and proper disposal of these materials throughout the project lifecycle. Special Provision 107L (SP107L) emphasizes the requirement to treat and dispose of APM according to the construction plans. It is essential for geotechnical engineers and geologists to thoroughly review SP107L to ensure its alignment with the construction documents and to guide the APM handling process effectively.

Soils and Geology Report

The Soils and Geology Report should provide a detailed account of the site conditions, including the identification and location of any APM within the project boundaries. Key components to include are:

- **Locations of APMs:** Document the locations of APM in terms of depths, elevations, and stationing.
- **APM Testing Results:** Present all laboratory and field testing data related to APM.
- **APM Treatment and Disposal Recommendations:** Based on test results, provide clear recommendations for the handling of all APM materials.

Geotechnical Plans

The Geotechnical Plans are an essential part of the construction documentation and must clearly reflect the presence and handling of APM. These plans ensure that contractors and engineers fully understand how to manage APM during construction.

Clearly indicate APM locations on the Geotechnical Plans Sheets, accompanied by notes outlining required treatment and disposal methods. Ensure this information is also included in the Geotechnical Notes, Estimated Quantities, Boring Profile Sheets, Boring Layout Sheets, and Typical Sections.

- **Geotechnical Notes:** Specific geotechnical notes for the project should include, but are not limited to, station ranges, locations based on centerline, anticipated elevations, brief descriptions of APM materials, and references to APM G-Sheets. Additional notes as required should also be included to ensure full understanding of APM handling.
- **Estimated Quantities:** Provide initial computations of the APM volume requiring treatment or disposal. Footnote items as necessary, especially if additional clarifications on quantities are needed.
- **Boring Profile Sheets:** APM test results (AP-NP) should be plotted onto soil boring profile sticks and aligned with the proposed roadway profile. These results, in conjunction with the roadway cross-sections.
- **Boring Layout Sheets:** Areas identified to contain APM must be indicated on the boring layout sheets, ensuring clear and accurate documentation of APM locations and testing for contractors and engineers.
- **Typical Sections:** Boring profile sticks should be placed within the cross-sections of the roadway design. This visual representation aids in understanding the correlation between boring data and the roadway profile.

Standard APM Sheets (APM G-Sheets)

The APM G-Sheets are standardized engineering sheets created by GES for the specific purpose of processing and disposing of Acid Producing Materials (APM). These sheets are designed to ensure consistency and adherence to established APM handling guidelines across all projects. One of the most important considerations when preparing final bid documents is the inclusion of these standardized APM details in the G-Sheets submittal package, especially when APM is present within the project's construction limits. These details offer contractors the necessary guidance on how to properly handle and manage APM during construction.

The GES maintains a comprehensive set of standardized details, sections, notes, and specifications related to APM. It is essential that these details are incorporated into the final construction plans to ensure the accurate and effective processing of APM throughout the project. To keep up with the latest requirements, the sheets are regularly updated and made available in MicroStation or Open Roads format upon request. This ensures that all APM handling methods are up-to-date and aligned with current best practices.

APM drawings contain critical information about the treatment and disposal of APM. As such, they should not be altered or modified without careful consideration and approval from GES. Any

changes made to these drawings could affect regulatory compliance or project-specific requirements, so thorough review and approval are essential to maintaining the integrity of APM handling guidelines.

Incorporation into Project Delivery Network

Incorporating APM considerations throughout all stages of the Project Delivery Network (PDN) is crucial. Doing so ensures potential risks are communicated, allows the project team to provide input, and facilitates the development of initial APM estimates. As the project progresses through the PDN, these measures will help mitigate APM-related risks and refine cost estimates. Ultimately, this approach will lead to better construction plans and a smoother construction process.

- **0GT1 – Conduct Preliminary Geotechnical Assessment** - Identify potential APM areas through geological mapping and historical data. At this early stage, exact locations and quantities of APM may not yet be viable. The available information may only include potential APM elevations. Share this preliminary data with the project team to begin evaluating potential risks.
- **1GT1 – Develop Geotechnical Work Plan -** Review geological maps, historical data, and previous geotechnical reports, including as-builts and research papers. Based on this information, identify areas of concern and plan for a detailed subsurface investigation, including APM-specific tests.
- **2GT1 – Complete the Soils and Geology Report and 2GT2 – Complete Foundation Reports** Determine the locations of APM throughout the project site by conducting drilling and laboratory testing. Use the results to develop the Soils and Geology Report and corresponding Geotechnical Sheets (G-Sheets). Clearly document APM risks and provide detailed recommendations for treatment or disposal. Depict APM locations and testing results on the sheets and determine quantities for treatment. Integrate APM data into geotechnical plans (G-Sheets, cross-sections, and notes). During this stage, maintain continuous discussions with the project team to keep all members informed. Create a draft version of the G-Sheets that includes all required APM-specific details.
- **4GT1 – Finalize Geotechnical Plans** - Finalize the integration of detailed APM data into the G-Sheets. Ensure the plans contain clear instructions for APM treatment, disposal methods, and environmental compliance. Verify that all sheets are in compliance with TDOT standards and special provisions and finalize them for inclusion in the construction plans.

For more information on the Project Delivery Network please visit https://www.tn.gov/tdot/pm/pdn.html.