Texas Commission on Environmental Quality

Guidance for Requesting a Water Balance Alternative Final Cover for a Municipal Solid Waste Landfill (Revised January 27, 2011)

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1.0 Introduction

The purpose of this guidance is to provide information for owners and operators of municipal solid waste (MSW) landfills who are considering a water balance (WB) / evapotranspiration (ET) alternative final cover system. This guidance is only applicable to a landfill which has a geomembrane/compacted clay composite liner required in the facility's existing permit. A landfill that does not have a geomembrane/compacted clay composite liner required in the facility's existing permit may utilize this guidance as written, or may seek an alternative maximum percolation rate for equivalency demonstration purposes. Any requests for alternative maximum percolation rates will be evaluated on a case by case basis.

Pursuant to Title 30 Texas Administrative Code (30 TAC) Section (§) 330.457(d), an alternative final cover design may be approved if it meets the following two criteria or performance standards:

- The final cover achieves an equivalent reduction in infiltration as the clay-rich soil cover layer specified in §330.457(a)(1) or (2)
- The final cover provides equivalent protection from wind and water erosion as the erosion layer specified in §330.457(a)(3).

These requirements are intended to ensure compliance with federal criteria in 40 CFR §258.60(b).

A WB final cover is one type of alternative final cover design. WB final covers are also commonly referred to as ET covers or unsaturated soil covers. In general, WB final covers rely on finer textured soils to store water and sustain vegetation until the water is removed by evapotranspiration. In contrast, a conventional final cover system consists of a layer of compacted clay-rich soil, a geomembrane layer, a drainage layer, and a layer of top soil designed to minimize percolation of water into the waste. A WB final cover requires healthy vegetation, and soil properties that will provide adequate unsaturated hydraulic properties, plant nutrients, water holding capacity, and slope stability over the long term. The design of a WB final cover should take into account site-specific conditions including climax plant community, climate, and the properties of the soil proposed for constructing the cover system.

WB covers are generally designed by one of two methods. One approach is to model and design the cover system without reliance on vegetation for moisture transpiration, relying solely on evaporation and storage in the soil layer(s). The second method is to rely on vegetation to aid in the removal of moisture from the soil layer(s). The values selected for percentage vegetative cover, root penetration, and root density in the modeling effort directly affect the conservativeness of the designed WB cover.

1.1 Climatological Partitioning of the State

Texas is a large State with widely varying climatological characteristics ranging from arid in the west to humid in the east. The MSW Permitting Program has used the 25-inch average annual precipitation line as defined by 30 TAC §330.5(b)(1)(D) to delineate areas of the State defined as arid. This approach originated from federal provisions adopted as part of the Subtitle D requirements. Those parts of the State west of the 25-inch average annual precipitation line have been deemed arid for the purpose of allowing alternative landfill designs (i.e. arid exempt landfills). Consistent with this approach, the level of information needed to support the design and modeling of WB final covers for landfill sites in the State will depend on their average annual precipitation. Data from the closest weather station to the facility with at least the most recent 30 years of precipitation reporting should be acquired and used to determine the average annual precipitation for the period.

1.2 Overview of Equivalency Demonstration

The selected computer model input parameters and their values that are used in the WB final cover design and equivalency demonstration should represent site specific conditions (including climate, vegetation, and soil conditions). Construction quality assurance and control specifications should ensure that the WB cover is constructed and maintained as designed and modeled, including the soil conditions and the vegetation conditions.

A recognized approach would be for a WB cover modeling and design process to demonstrate that the percolation at the bottom of the WB final cover is ≤4 mm for each of the years during the 30-year period of record. During cover performance verification testing, ≤8 mm in a year of measured percolation is recognized as satisfactory cover performance. Measured percolation of >8 mm and ≤12 mm in a year may require additional modeling and a revised cover design for the remainder of the landfill. Measured percolation above 12 mm in a year likewise, may require additional modeling and a revised cover design for the remainder of the landfill. Additionally, these facilities may require retesting for percolation and soil moisture profiles.

To meet the soil erosion criterion in 30 TAC §330.457(d)(2), it is recognized as reasonable to demonstrate that soil loss is ≤3 tons/acre/year, as calculated using the Universal Soil Loss Equation (TNRCC October 1993).

1.3 Options for WB Final Cover Authorization

A landfill site with 25 inches or less average annual precipitation would be expected to use site specific parameters including soil properties, vegetation, and climate/weather data for use in the design and modeling of the WB final cover. However, the design and modeling of the WB final cover for such sites may be based solely on numerical modeling without calibration of the model provided the model is an approved and proven numerical unsaturated flow model. To authorize this WB final cover, the facility should submit to the MSW Permits Section for review and approval a permit modification application under 30 TAC §305.70(k)(10) containing the WB final cover design, WB final cover construction quality control plan (CQCP), and a satisfactory demonstration of equivalency utilizing site-specific soil, vegetation, and weather conditions as discussed in detail in later sections of this document.

A landfill site that receives greater than 25 inches of average annual precipitation, likewise, will be expected to provide site specific soil, vegetation, and climate/weather data for use in the design and modeling of the WB final cover system. In addition, such sites would be expected to employ one of the following two options for demonstrating the designed cover system's performance: (1) a pre-construction design option (Model Calibration Option); or (2) a post-construction design verification option (Cover Performance Verification Option).

Under the Model Calibration Option, a facility will design a WB cover and then construct one or more test plots (Calibration Test Plots) in order to obtain site-specific field-collected data with which to calibrate the model. The test plot(s) shall be of an approved design, including size, location, and monitoring instrumentation for collection of model calibration data. Details of the Model Calibration Option are provided in Section 2.0, and the Calibration Test Plot is discussed in Section 2.1.

Under the Cover Performance Verification Option, a facility will design a WB cover and then verify the constructed WB final cover design and performance through the use of site-specific field-scale testing (Cover Verification Test Plot). A preferred method of field testing for verifying the WB final cover performance is the incorporation and monitoring of field-scale lysimetry coupled with in-situ soil instrumentation and laboratory testing of soil samples within the constructed WB cover system. Lysimeter test plots have been proven effective in measuring the amount of percolation through cover soils. Design aspects and construction considerations of lysimeter test plots have been documented by Benson, et.al. (1999) and Albright, et.al. (2010). Details of the Cover Verification Option are provided in Section 3.0, and the Cover Verification Test Plot is discussed in Section 3.1.

Both the Calibration Test Plot and the Cover Verification Test Plot should include instrumentation capable of continuous data collection. Test plots proposed to be monitored solely with discrete sampling have not been considered adequate. Test plots should be configured so as to represent the area of the landfill cover with the greatest water storage demand.

2.0 Model Calibration Option

A facility proposing model calibration should coordinate with the MSW Permits Section in designing and establishing the field calibration test plots(s), monitoring parameters, and data gathering procedures to ensure that the calibration study sufficiently addresses the recommendations in this guidance. If a test plot is to be located on property covered by an MSW permit, then the permittee should submit a permit modification request containing a detailed workplan for agency approval prior to constructing the test plot(s). If a test plot is to be located on property not covered by an MSW permit, a detailed workplan should be submitted for agency review and comment to ensure agreement on the data acquisition requirements and methods.

For a site opting for a calibrated WB cover model utilizing a test plot located at a permitted landfill facility, two permit modifications would typically be required. In the first permit modification, the information for a field-scale WB test plot at the facility should include:

- Detailed design plans

- Construction quality assurance procedures
- Operating procedures.

The purpose of the test plot is to provide data with which to calibrate the model used in the initial WB cover design process. Test plots should be operated for at least three years after vegetation has been established to design parameters in order to minimize the impact of the initial moisture of the cover soils and to incorporate weather conditions with a variety of patterns at the site. The length of time between test plot construction and initiation of data collection could possibly be shortened somewhat if the modeled cover design does not rely on vegetation. Using the data collected from the test plot, the applicant would re-run the analyses to predict the performance of the proposed WB cover model and prepare a revised cover design. General informational and operational requirements for model calibration test plots are detailed in Section 2.1 below.

In order to calibrate the water balance model, the model input parameters should be adjusted within an appropriate range until the model predicted soil water contents and soil water storages closely match the field data for the duration of the monitoring period. All of the following criterion should be met for a model to be considered calibrated.

- The model-predicted soil water contents and soil water storages should not show a consistent bias (the bias here refers to over-prediction or under-prediction of the parameter throughout the modeling period)
- The maximum and minimum soil water storages predicted by the model should be within five percent of the field values
- The timings associated with the increases and decreases in soil water storage predicted by the model should be within one week of the timings observed in the field.

In order to assess the model calibration results, the sensitivity of the input parameters on the predicted soil water storages, water contents, surface runoff, evapotranspiration, and cumulative percolation should be reported in the form of time series plots.

Provided the data collected from the test plot can be successfully used to calibrate the model, the applicant should submit a permit modification request for the WB final cover to be installed at the facility. The submittal should include:

- A detailed report of the construction and operation of the test area
- Data derived from the testing
- Modeling procedures and input/output information
- Discussion of changes made to the WB cover
- Final cover design
- WB final cover CQCP.

It is possible that calibration test plot data may be able to be utilized at other facilities with similar climatological and soil conditions. Persons intending to utilize calibration test plot data at multiple sites should discuss this proposal with the TCEQ in advance in order to ensure agreement on the applicability of the data.

It is also likely that initial calibration efforts will yield valuable information as to proper monitoring methods, monitoring instrument types and numbers, size of test plots, and length of monitoring period. The agency encourages the use of this information in the development of subsequent focused calibration projects.

2.1 Calibration Test Plot

For model calibration, a calibration test plot should be installed, maintained, and monitored to allow for the collection of data with which the WB final cover model may be properly calibrated. This test plot should be able to generate, at a minimum, the following information in order to define the adequacy of site specific parameters used in the model to predict the performance of the WB cover:

- Continuous moisture content with depth
- Soil temperature
- Percolation.

The site specific parameters to be evaluated should include, but are not limited to:

- Root depth/density
- Leaf area index (LAI)
- Plant water intake
- Initial moisture content
- In-situ soil geotechnical and hydraulic properties (density, porosity, saturated and unsaturated hydraulic conductivity, water retention curves).
- Moisture content
- Moisture retention profiles
- Adequate number of moisture sensor nests should be used
- Adequate vertical spacing of the moisture sensors (not greater than one foot) within each nest should be used
- Duplicate moisture sensors at each depth within each nest should be used
- Parameters or criteria for run-off.

In addition to the collection of site specific field data, the following meteorological parameters should be collected onsite contemporaneously with test plot monitoring:

- Precipitation
- Pan evaporation (can be obtained from local weather reporting station)
- Air temperature
- Solar radiation (can be obtained from local weather reporting station)
- Wind speed
- Relative humidity
- Cloud cover
- Dew point (calculated).

All candidate borrow materials should be evaluated with a test plot prior to model calibration. A field-scale lysimeter may be included in the calibration test plot to better understand potential percolation from the WB cover.

3.0 Cover Performance Verification Option

For a site proposing to verify the performance of the WB final cover system design using a cover performance verification test plot, typically one permit modification will be required. The permit modification application would be expected to include a final cover design that has been modeled to allow ≤4 mm percolation in a year through the cover using site-specific soil, vegetation, and weather data. The application would also contain a WB final cover CQCP which includes the method(s) proposed for field-verifying that the final cover is performing as designed. After TCEQ approval of the WB final cover, the applicant will construct a cover verification test plot in concert with the installation of the initial section of the landfill's final cover. Monitoring equipment for the test plot should include at least one lysimeter and three clusters of soil moisture probes. Alternative monitoring equipment and methods will be considered in the future should such equipment and test methods become available. General informational and operational requirements for cover performance verification test plots are detailed in Section 3.1 below.

The cover verification test plot should be monitored for a minimum of three years after vegetation is fully established to design standards. An objective of the cover performance verification procedure should be to demonstrate the WB cover's performance under the precipitation conditions derived from the 30-year historical records which resulted in the maximum modeled percolation or storage. It is recommended that the application contain a contingency plan for artificial moisture loading to be implemented in year three of the test period, in the event the natural weather patterns in years one and two do not produce the necessary conditions. The length of time between test plot construction and initiation of data collection could possibly be shortened somewhat if the modeled cover design does not rely on vegetation. For a site proposing the Cover Performance Verification Option, the permit modification authorization will contain a condition specifying that the WB final cover would be required to be revised in some manner to reduce percolation should the results of the verification testing indicate that the WB final cover is failing to perform as designed after establishment of vegetation. Additionally, sites with approved alternative final cover(s) will be required to maintain financial assurance for the cost of closure of the clay/geomembrane composite cover in the permit until the WB final cover has been successfully demonstrated. The financial assurance should continue to reflect the cost of the clay/geomembrane cover, and any reduction in the amount of required financial assurance would be based on a reduced amount of landfill area requiring closure.

It is possible that cover performance verification test plot data may be able to be utilized at other facilities with similar climatological and soil conditions. Persons intending to utilize cover performance verification test plot data at multiple sites should discuss this proposal with the TCEQ in advance in order to ensure agreement on the applicability of the data.

3.1 Cover Performance Verification Test Plot

For WB final cover performance verification, a cover performance verification test plot should be installed, maintained, and monitored to allow for collection of data to determine whether the actual performance (e.g. moisture patterns and percolation through the cover) is adequate. The test plot for final cover performance verification should be designed to assess compliance with the ≤4 mm percolation limit. The permit modification application should detail the soil monitoring equipment and methods to be used and how those methods will confirm the function of the WB final cover system. Care should be taken to select monitoring equipment and methods so as to reduce the uncertainty in modeled estimates which might be larger than required cover performance. At a minimum, the monitoring system should provide the following data:

- Continuous moisture content
- Basal percolation
- Soil temperature
- Weather data.

Soil moisture and basal percolation should be collected using automatic data acquisition systems to provide essentially continuous records.

The cover verification test plot should be operated, maintained, and monitored for a minimum of three years after vegetation is established. For WB cover designs that do not depend on vegetation for meeting the ≤4 mm percolation criterion, the test period may begin with the installation of the test plot. In all cases, data gathering from the test plot should begin no later than six months after construction.

The cover verification test plot should be constructed concurrent with the construction of the initial section of landfill final cover during closure or partial closure. The initial section of landfill cover containing the test plot should be limited to not greater than 10 acres. At least one lysimeter should be installed within the test plot, and each lysimeter should have dimensions of not less than 30 feet by 30 feet. At least three clusters of soil probes should be installed with the lysimeter, with one of the clusters upslope, one within, and one downslope of the lysimeter. Each probe cluster should consist of at least three probes with duplicate sensors located in the upper, middle, and lower portions of the cover soil with vertical spacing of not greater than one foot. The probes should be capable of continuous measurement of soil moisture. The actual design aspects of the lysimeter and soil probes should be determined site specifically and should be developed by engineers with experience in lysimeter design, construction, and monitoring.

During the cover evaluation period, the applicant should prepare and submit an annual report documenting the results of all monitoring performed and demonstrating that the cover system is functioning as designed. The report should document the following:

- Soil data
- Vegetation data
- Weather data
- Soil moisture retention curves

- Basal percolation
- Observations and recommendations of the project engineer.

The TCEQ will review and evaluate the annual reports to determine if the WB final cover is meeting performance equivalency requirements and providing adequate protection from wind and water erosion.

Generally, if the measurements and results of the lysimeter and the soil moisture sensors indicate that the cover is allowing ≤8 mm percolation in a year, the cover would be viewed as successful and the remainder of the WB final cover can be installed pursuant to the WB final cover CQCP. If >8 and ≤12 mm percolation in a year is measured, then the remaining WB final cover would be redesigned using data from the test plot, and the new design would be submitted to the TCEQ for permit modification. Upon approval, the remainder of the cover can be installed pursuant to the approved WB final cover CQCP. If >12 mm percolation in a year is measured, then the remaining WB final cover would be redesigned, and the new design submitted to the TCEQ for permit modification. Upon approval, an initial phase of cover may be constructed, which would include a new test plot for cover performance verification in the same manner as the original test plot. Additional WB final cover beyond the initial maximum of 10 acres that includes the test plot should not be constructed until the TCEQ has determined that the initial phase of WB cover has been successfully demonstrated.

4.0 Modeling and Model Calibration

The UNSAT-H model has been the primary model used in WB cover equivalency demonstration applications received by the TCEQ to date. This model, and other unsaturated flow models, may be considered effective in the design process for these cover systems provided that the input data (e.g. soil properties, weather patterns) are representative of actual physical conditions.

The selected computer program should integrate soil, plant, and climate variables, and their effect on hydrology and soil water balance to predict the performance of the proposed WB final cover system. The program should:

- Simulate unsaturated flow
- Include a surface boundary simulating soil-atmosphere interactions (precipitation, infiltration, evaporation, and runoff)
- Include adequate models for saturated and unsaturated hydraulic behavior
- Model root water uptake (transpiration)
- Integrate climatic data.

Various computer programs for alternative cover modeling are described in ITRC (2003). The basis for selecting the computer program (including the version of the program and how it is appropriate for the WB final cover) should be explained as well as which specific options in the program were selected.

All model assumptions, options, and input data should be identified in the application and justified with respect to the site-specific conditions. Input data should be explained in relation to:

- General options
- Hysteresis options
- Heat flow options (if selected)
- Vapor flow options (if selected)
- Soil hydraulic properties
- Surface node bounding values
- Initial conditions
- Plant parameters
- Potential evapotranspiration (PET) partitioning (if selected)

For each of the input data, the permittee needs to indicate available range of values and justify the validity of value(s) chosen. Soil borrow source laboratory-derived parameters should be used.

The model default values should not be used unless they are representative of site-specific conditions. For example, values used in the UNSAT-H model for a, b, and c in the root-growth equation should be site-specific values. The permittee should document how each parameter input into the model is determined and how it is representative of site-specific conditions. For models other than UNSAT-H, applicants should make a copy of the user's guide available.

The model should be run to simulate the performance of the proposed WB cover system as designed over the 30-year period represented by the meteorological data set. The lower flux boundary should be the bottom surface of the WB cover. Sensitivity analyses should be provided on any variables for which a site specific value cannot be determined.

Summarize the results of each model run in a table which lists the quantities for each year of the run for the following parameters:

- Precipitation (P)
- PET
- P/PET ratio
- Model estimated "actual" evaporation and transpiration
- Runoff as a percent of total precipitation
- Storage
- Percolation through the WB cover
- Total mass balance error for the year.

The mass balance error should be added proportionately to the percolation, surface runoff, and evapotranspiration. The results should also be illustrated graphically, showing the model estimated storage requirement plotted by year, and the calculated available storage capacity for the ET cover. The model input and output files should also be provided.

The effective water storage capacity of the cover soil should not be less than the modeled capacity. The annual percentage runoff generated by the model is expected to be less than 10 percent of total water applied (precipitation and irrigation). Higher modeled runoff amounts may be acceptable if hourly rainfall data have been shown to support rainfall application rates and the hydraulic properties of the surface soil layer are representative of in-situ soils. If use of irrigation is proposed to establish and sustain plant growth or to simulate precipitation, the water impingement due to irrigation should be accounted for in the model. If the site receives snow or ice, the model input needs to be adjusted to account for moisture from snow and ice melt.

A narrative should be provided which describes the modeler's understanding of the model and the results for the scenarios modeled. The narrative should also include a discussion of the sensitivity analyses and identify the worst-case scenario and how it was determined.

For sites where model calibration is indicated, site specific soil parameters and field-study generated empirical data should be used. A detailed discussion of the calibration process, input values and output results should be provided. Model calibration should include considerations for hysteresis. Care should be taken to model only representative conditions and any model input data that is not based on field monitoring results and parameters should be identified and the rationale for its use discussed.

5.0 Description of Proposed Final Cover Design

The WB final cover design must be fully described, including the number of layers, the thickness, function, and properties of each layer, and the vegetation. Summarize the results of the model and the calculations used to determine that the WB final cover design meets the two criteria in 30 TAC §330.457(d), and discuss how the proposed WB cover meets the two criteria. Drawings should be provided that illustrate the proposed WB final cover system. The drawings should include details for the proposed WB final cover system, along with details of the standard cover system or any other alternative cover system(s) approved for the facility, and details of tie-ins between each of the cover systems.

Evaluate and discuss the potential for a WB cover system to function successfully at the site. The following site conditions should be characterized:

- Climate
- Existing and proposed vegetation
- Growing seasons
- Distribution of precipitation through the year
- Types of soils available
- Moisture retention curves of the candidate soils
- Compaction characteristics
- Capability of the soils to sustain native and non-native plants.

Soils used in the evaluation must be demonstrated to be locally available. Laboratory tests should be performed on the local soil to determine its suitability. Details of the recommended soil tests are discussed in Section 6.0 below. Before commencing construction, field and laboratory tests should be performed on the materials that will be used to ensure that the material properties conform to the design specifications. If the properties differ from those modeled, then a revised demonstration should be submitted for review and approval.

6.0 Soil

The WB cover soils should be modeled using input data that represent the properties and characteristics of the soil that will be used in the WB cover throughout the soil profile. The soil must be compatible with and support the growth of the plants proposed for use in the WB cover, which includes achieving the required root depth, root density, and plant surface coverage so the percolation and erosion are adequately controlled. The engineering, hydraulic, and agronomic properties of the soils to be used in the WB final cover should be characterized by sampling and laboratory testing. The laboratory testing should be performed on undisturbed in-situ soil and reconstructed, recompacted soil samples. At a minimum, the following tests should be performed and reported for candidate soils:

- Unified Soil Classification System (USCS) classification
- Bulk density
- Maximum dry density obtained according to Standard Proctor Tests
- Compaction percentage
- Soil water retention curve
- Saturated hydraulic conductivity at proposed soil placement conditions
- Nutrients (nitrogen, phosphorus, potassium, micronutrients)
- Other characteristics (e.g., organic matter, sodium adsorption ratio).

Using this information, it should be determined if the soils will need to be amended before use in the WB cover. Generally, at least the upper foot of the soil profile should be conducive to plant growth. If soil amendments are necessary, then the soil amendment process needs to be fully described and addressed in the WB final cover CQCP and the amended soil should be tested for the properties described above. A map should be provided showing the soil borrow sources and the test sample locations.

The soil water retention curves should be defined using experimental data obtained for a wide range of suction values. The trend of the moisture retention curve, as defined using well established models (e.g. Van Genutchen), should be presented indicating in this trend the actual data points obtained in the laboratory testing program. The hydraulic conductivity function predicted using the moisture retention curve information and the measured saturated hydraulic conductivity should also be provided.

7.0 Vegetation

If the WB cover is designed with reliance on vegetation for moisture transpiration, sufficient information should be provided explaining which plants are suitable for the site-specific soil types, root depths, root densities, percent coverage, and climatic conditions. The vegetation selections should include a site-specific analysis and recommendation by a vegetation expert (such as an agricultural extension service agent, range scientist, or a botanist) with supporting documentation from peer-reviewed published sources that are readily available. The documentation should describe each plant type, with data on seasonality, succession, rooting characteristics (depth, density, and spread), leaf area index, and suitability for the soil types proposed to be used and for the location of the site. If the WB cover is designed without reliance on vegetation for moisture transpiration, information should be provided specifying which plants are proposed for erosion control and the target percent coverage. The United States Department of Agriculture's publications on local and county soil and vegetation types are excellent starting points for such information.

The modeled root depth and root density should be consistent with the climate and the selected vegetation. The cover soil thickness should be sufficient for the design root depth and density. Model inputs should reflect a percent bare ground of at least 15 percent, and use a low estimate of the maximum leaf area index for the selected vegetation. The use of a percent bare ground of greater than 15 percent would add conservatism in the cover design and would better account for periods when vegetation establishment proves difficult. The maximum leaf area index should be determined for the plant community that will develop on the cover assuming fair vegetation quality.

The vegetation analysis should take into account that the soil may not have all the properties of a natural or in-situ soil, and the WB final cover CQCP should include a program of amending the soil (organic matter, fertilizer, etc.) to meet the conditions assumed in the vegetation analysis. Sufficient documentation should be presented to demonstrate that the specific plants chosen will grow in site-specific climate and soil conditions proposed for the WB cover. A range of vegetation scenarios (e.g., near term - what is seeded by design; long term - an established plant community that may differ from what was seeded) should be modeled. For example, it is not sufficient to list 15 different plant types without correlating them to the site-specific climate and soil conditions for the WB cover. Some plants cannot survive and grow as predicted by the model in all areas.

The plant species chosen should have a root depth that is expected to develop within the soil layers of the WB final cover. If the root depth and density of the selected vegetation cannot be verified, the root depth used in the model should be based on the minimum root depth to compensate for the uncertainty of actual rooting depth that may be accomplished at the site.

8.0 Climate/Weather

Precipitation and other climate data needed to define the site’s potential evapotranspiration should be characterized using a 30-year daily meteorological data set that includes daily precipitation, humidity, air temperature, solar radiation, and wind speed. Data should be obtained from a location that is representative of the site. If more than one weather station’s data is to be used in determining precipitation values for the site, then provide a discussion of the rationale for the use of data from multiple weather stations and the process by which site precipitation values were determined. The locations of all weather stations from which meteorological data were obtained in relation to the location of the landfill site should be provided on a scaled map.

Ensure that the model does not produce runoff on days with no precipitation. Surface runoff should not begin until the rainfall or snowmelt rate exceeds the soil infiltration rate or the surface soil becomes saturated.

9.0 Final Cover Construction Quality Control Plan

Construction quality assurance and quality control (QA/QC) requirements should verify that the WB cover is constructed consistent with the conditions, parameters, and assumptions used in the modeling and design effort. The parameters, conditions, and assumptions used to demonstrate equivalency of the WB final cover system should be translated into material specifications, construction QA/QC testing specifications and procedures, and documented in the WB final cover CQCP. The WB final cover CQCP should include all construction quality control and assurance requirements and specifications proposed to ensure that the WB cover is constructed and maintained as designed. For a facility employing a final cover performance verification test plot in the first section of WB cover installed, the CQCP should contain detailed QA/QC procedures for constructing and monitoring the test plot as well as QA/QC for the rest of the WB cover to be installed. Specifications should be provided for:

- Soil density and hydraulic conductivity
- Construction methods to achieve the design density and hydraulic conductivity
- Moisture content
- Soil type(s) (USCS tests)
- Vegetation utilized and how it will be established, evaluated, and maintained
- Provisions for initial irrigation, fertilization, and seeding as needed to establish and maintain good condition, and desired root density and depth
- Tests and test frequencies for verifying design conditions.

Borrow source testing should be performed for USCS classification at a frequency of at least one test per 1,000 cubic yards. Hydraulic conductivity testing should be performed using large block samples at a minimum frequency of one test per lift and one test per 10,000 cubic yards of placed material.

Slope stability evaluations should be provided. The WB final cover CQCP should specify how soils will be evaluated for agronomic properties, how soils will be amended, and if vegetation will be fertilized or irrigated and under what circumstances. Methods and procedures should be specified for assessing the vegetation and for determining whether the vegetation has been established in accordance with the design specifications. The CQCP should include test procedures and frequencies for assessing the viability of the vegetation and quantifying the percent vegetation, including root depth, root density, and plant coverage. Standard or widely accepted vegetation measurement methods for the plant types proposed, which are approved/accepted by the USDA or similar government entities, should be acceptable.

WB cover construction methods must ensure that the soil in-situ density is adequate to provide adequate vegetation growth, maintain low unsaturated hydraulic conductivity values, and minimize the development of cracks, macro features and differential settlement. The CQCP should include instructions to limit equipment weight and traffic on the cover, and procedures for identifying and correcting over-compaction and other out-of-specification situations or damage.

10.0 Final Cover System Evaluation Report and Certification

The WB final cover CQCP should specify that a final cover system evaluation report (FCSER) and certification will be submitted for each section of WB cover that is constructed, and identify the information to be reported, including:

- Completed report forms required by TCEQ
- Summary of construction activities
- Drawings showing sample and test locations
- Field and laboratory test results
- “As-built” drawings (including cover elevation and thickness of the soil layers)
- Vegetation details (plant mix, method of planting)
- Description of construction problems and how they were resolved
- Statement of compliance with the MSW rules and the WB final cover CQCP.

The FCSER should be signed and sealed by a professional engineer licensed in the state of Texas.

11.0 Vegetation Establishment Report

The WB final cover CQCP should specify that a vegetation establishment report will be submitted semi-annually during the cover vegetation start-up period, indicating the type and quantity of vegetation that has become established, the percent vegetative cover, and vegetative root structure (depth and density). If the type or quantity of vegetation or root structure does not meet specifications, then corrective action must be taken to improve the vegetation and be consistent with the WB final cover as designed for the equivalency demonstration.

12.0 Closure Plan and Post-Closure Plan

The facility’s closure plan should describe each type of final cover system, including the proposed WB alternative final cover system, and which parts of the landfill may be covered with each type (for example, Subtitle D areas, pre-Subtitle D areas, side slopes, and top surfaces). The closure plan should include the WB final cover CQCP.

The post-closure care plan for the facility must document the post-closure care inspection, maintenance, and reporting requirements associated with the alternative design. Post-closure care cost estimates should include the cost of long term maintenance of vegetation, which may include reseeding, fertilizing, and irrigating, and restoring cover that has been eroded or damaged (for example, by burrowing of animals).

13.0 References

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