

Mounding Analysis Guidelines for Subsurface Wastewater Systems in North Carolina

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I. Introduction

Groundwater mounding beneath a subsurface wastewater system is important to evaluate during the site assessment process to assure a sufficient unsaturated zone shall be maintained between the soil/wastewater dispersal system interface (e.g., trench bottom) and any underlying soil wetness conditions. The relative importance in any given project is a function of system size, the site's soil and geologic properties, and proximity to other inputs (current and proposed for future). Size alone is often not the most important determinant. For example, mounding on a high dune beneath a 10,000 gallons per day (gpd) system may be minimal, while mounding under a 600 gpd system located over a shallow restrictive horizon may be severe.

A mounding analysis typically requires the collection of appropriate site-specific hydraulic data, and the proper application of a modeling technique. Special training is prerequisite for the soils scientist, geologist, engineer and environmental health specialist to be capable of making meaningful predictions.

This paper/presentation reviews the On-Site Water Protection Section's current policies and procedures for groundwater mounding analysis in conjunction with subsurface wastewater projects permitted by local Health Departments under Public Health Commission Rules. While an effort is made to set forth the "state of practice" applicable to projects subject to On-Site Section review, it is recognized that this is an evolving field, and university scientists, consultants, and health departments are encouraged to research and present alternative approaches which would be reviewed on a case-by-case basis.

The same information and models which are part of a mounding analysis are also typically required to produce a pollutant migration analysis from a subsurface system (e.g., nitrogen migration analysis). Such an analysis, though not discussed further herein, must often also be considered by the project consultant/designer and presented for review prior to approval of a proposed subsurface system site.

II. Regulatory Requirement for Mounding Analysis

A. "Large" Systems:

State wastewater rules require a groundwater mounding analysis for all systems with design flows in excess of 3000 gpd, with individual fields designed for over 1500 gpd [15A NCAC 18A .1946(4)]. The exception for systems which include multiple fields, each designed for less than 1500 gpd, is not applicable when the multiple fields are considered to be "hydraulically" interactive. The projected absence of an "hydraulic interaction" may be

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required to be proven on a case-by-case basis. However, typical scenarios where hydraulic assessment shall not be required are as follows:

- On sloping lots, when no portion of a < 1500 gpd field drains or is upslope of any portion on another adjoining <1500 gpd field based upon site topography.
- On level lots, when separate <1500 gpd fields are at least 50 feet apart.
- On level lots, when separate < 1500 gpd fields are at least 20 feet but less than 50 feet apart, but the areal loading is also less than 1500 gpd/acre (measured by using smallest polygon which includes any combination of the multiple fields).

The above exceptions do not apply, however, if the individual systems otherwise are required to have an hydraulic assessment in conjunction with the use on an advanced pretreatment system pursuant to Rule .1970.

B. Sites Where Depth to a Soil Wetness Condition is Determined by Modeling:

Rule .1942(g) and (h) allow for the site to be monitored and modeled, or just modeled to predict depth to a soil wetness condition, using the computer program DRAINMOD. These Rules require that the DRAINMOD analysis consider mounding due to wastewater application whenever the sites are to receive over 1500 gpd [monitoring and modeling procedure, Rule .1942(g)] or over 600 gpd [modeling only procedure, Rule .1942(h)].

C. As part of “Special Evaluation” For an Advanced Pretreatment System:

This evaluation, which should include a mounding analysis, is generally required (Rule .1970) in conjunction with any proposed vertical separation reduction, or for LTAR increases (Group III or IV soils, or Group II or III soils proposed to be drained). A “Special evaluation” is also required for advanced pretreatment systems when drainage is proposed with Group III soils, a groundwater lowering system is to be used in conjunction with a fill system, when sandy clay loam saprolite is to be used, and whenever LTAR increases are proposed for systems designed for greater than 1000 gpd.

D. Off-site or remote systems:

These are becoming increasingly popular. Despite being comprised of smaller individual systems, mounding analysis may still be required for contiguous “off-site:” areas. These conditions include:

- “Net” design flow to the contiguous off-site area exceeds 3000 gpd or 1500 gpd/acre.
- Individual off-site systems otherwise require a “Special Evaluation” or hydraulic assessment.

III. Field Data Collection

A. General Requirements:

The mounding analysis is only as good as the quality of data used for the assessment. For sites requiring mounding analysis, site-specific data are required. These Data include:

- Site Information:
 - Topography
 - System footprint
 - Locations of adjacent drainage features and surface waters (including elevations)
 - Adjacent impacting features (including associated quantitative information).
 - Storm water detention basins
 - Other on-site wastewater systems (subsurface/surface irrigation).
- Soil Information:
 - Soil boring locations, profile descriptions
 - Depth to soil wetness condition (also relative elevation)
 - Depth to any restrictive horizons
 - KSAT of effective saturated zone/zones (see below; note: additional KSATs may be required to support proposed LTAR).
 - Other soil/aquifer parameters required for mounding model to be used, e.g.,
 - Storativity
 - Transmissivity
- Hydrogeologic Information:
 - Deep boring locations/logs
 - Continuous split-spoon sampling data
 - Blows/inch data
 - Observed water level
 - Regional geologic/aquifer description and control/boundaries
 - Groundwater Gradient (with supporting data)

B. Saturated Conductivity Measurement:

This is the most important parameter necessary to measure on a site-specific basis for the mounding analysis to be tenable. The field data collection method selected must be site and system appropriate. Common errors include measurements in a deeper aquifer only, which

doesn't adequately account for the probable impacts on mounding of shallower more slowly conductive zones that control the "mound" height during wet-weather periods. Conversely, it is also incorrect to measure only the conductivity of the shallow (often unsaturated) zones, and not obtain data from deeper zones which contain the saturated aquifer. Common methods used, their applicability and limitations are summarized in Table 1:

Table 1: Field Measurement Techniques for Saturated Conductivity		
Method	Applicability	Limitations
Constant Head Permeameter ("Amoozemeter")	-LTAR Assessment (B,C horizons) -Effective conductivity for some mounding models -Obtain data from shallower zones when water table is seasonally deep	-Must be above "capillary fringe" (2-feet or more, depending on soil type). -"Point" measurement only
Augur Hole Pump-Out (Slug)	-Drainage analysis (DRAINMOD) -Allows for analysis of multiple layer KSATs when water table is high -Systems <10,000 gpd	-Water table must extend up into zones of interest -"Point" measurement only. -Analysis technique critical
True Aquifer Test	-Provides "Area" results for system >10,000 gpd	-Requires drilled wells -Must apply "art" of curve fitting -Usually results for single area only (too costly to replicate elsewhere)

Appropriate decisions must be made about the number of measurements necessary to adequately characterize the site. The deeper conductive zones for aquifer testing often show less variability across a site than shallower layers where quantitative testing to verify LTAR is typically required. For point measurements (constant head permeameter, augur hole pump-out), a minimum of three replicates per site (or three per acre of drainfield/repair area, whichever is greater) is typically recommended. When analyses are made to support a drainage system design, measurements should also typically be taken from at least three different depths vertically at each test location (shallow horizon, most restrictive horizon, and underlying conductive horizon).

For true aquifer (pump) testing, a minimum of one test, comprised of one representatively located pumping well and at least two recovery wells should be considered for systems designed for 10,000 to 25,000 gpd. For systems >25,000 gpd, at least one additional pumping and recovery well set should be considered, or more as needed to adequately represent the entire site.

Methodology used for any field measurement is critical, and practitioner (and reviewer) should be "book"-trained and "field" trained by individuals with demonstrated experience. Some key references are included below. Critical decisions needed for success are the selection of augur hole diameter and depth, depth of any well screening, pre-test preparations (e.g, soaking hole), length of data collection time, pumping rate (e.g., during 24-hour aquifer test), and method of data analysis. For aquifer testing, it is important that the wells used are "fully penetrating" of the aquifer of interest, with screening encompassing the full range of expected water level variations.

Reporting of data should include locations of all monitoring and test borings on a site plan (including relative elevations of ground surface, well casing and measured water levels); field data collection logs; calculations including formulas used for all KSAT estimates (with depiction of all input parameter values).

IV. Groundwater Mounding Modeling

A number of models can be utilized for performing the groundwater mounding analysis. Which model is most appropriate to use is a project-specific determination, dependent on site conditions, system size, and the relative importance of adjacent contributing systems. Each model incorporates its own set of unique assumptions, which if violated could render results obtained either meaningless or certainly subject to question. The modeler should carefully evaluate whether the underlying assumptions of the model selected are met, and assess how any excursions could affect results presented.

The three models most commonly used, applicability and use limitations, are shown in Table 2.

Table 2: Models for Groundwater Mounding Analysis		
Model	Applicability	Limitations
Colorado State University (CSU)	<ul style="list-style-type: none"> -Typically homogenous, level, coastal plain -Rectangular basin (“field”) -One-side “line sink” -Easy to use, available -Can predict mound decay with distance -Can evaluate impacts of variable application periods 	<ul style="list-style-type: none"> -Not “calibrated” -Special handling of variable KSAT layers -Not “Windows” available
DRAINMOD	<ul style="list-style-type: none"> -Typically eastern NC, level sites, especially with drains -Amenable to horizon variability -Yields time-distribution of wetness levels -Can calibrate with short-term water level monitoring data 	<ul style="list-style-type: none"> -Needs extensive soils and site-specific data to predict modification impacts -Single “point” prediction only. -Limited ability to handle variably shaped drainage networks -Must predict mounding by converting to irrigation rate -Requires considerable training to fully understand and use correctly
MODFLOW	<ul style="list-style-type: none"> -Larger projects, statewide applicability -Can incorporate multiple conditions in both vertical and horizontal direction -Can incorporate multiple simultaneous inputs -Variably-shaped drainage features, constant head boundaries -Can calibrate to ambient conditions 	<ul style="list-style-type: none"> -Requires extensive site and surrounding area delineation -generally yields “steady state” results only -Requires practitioner highly trained and skilled in hydrogeology and in Modflow modeling procedure.

The Colorado State University (CSU) model is an analytical model and frequently the first choice for the “typical” large system in Coastal North Carolina. It has also proven useful for Piedmont projects where groundwater mounding could be an issue, in addition to a lateral flow analysis. This includes sites with slopes typically less than 10-percent or where the initial water table may be up to 30 feet deep but the project is large enough that mounding could still be a concern. When system design flow exceeds 25,000 gpd, a more comprehensive numerical model is typically warranted. The CSU model is also a good method to initially screen possible interactions of other adjoining wastewater or stormwater systems, by viewing the distance/mound decay feature (shows drop in mound height with distance away from the application area. A common error made when using the CSU model for a large system is to model the mound beneath a single drainfield only, even though the system may be comprised of two or more fields. The appropriate approach would be to model both conditions: the groundwater mound beneath each individual field, and the projected mound under the smallest rectangle that encompasses all active drainfields. In the latter case, the inputted “Recharge” rate is computed to be the total system design flow rate divided by the area of this rectangle.

DRAINMOD is the model of choice for sites requiring parallel drains to “work” (also, typically sites in Eastern North Carolina). No other readily available model allows for the time distribution of projected water levels to be so comprehensively projected. For the most accurate results, site-specific input parameters will be obtained, and model parameters verified using measured water level data during a wet-weather season or at least during multiple storm events (requires site-specific monitoring of water levels and rainfall). Wastewater input cannot be perfectly simulated, because the model “assumes” any irrigation input is to the entire area between parallel drains. If the actual loading rate is used, the total assumed volume of wastewater added would be too high, but if the rate is reduced by spreading the total volume over the entire area between the drains, the “peak” mound predicted could be underestimated. It is typically recommended to “run” the model both ways, and average the results to approximate the “peak” projected mound height. When DRAINMOD is used to determine soil wetness level, North Carolina Wastewater Rules require it be considered the highest level projected to occur between January 1st and April 30th for at least 14 consecutive days, with a 30 percent recurrence frequency, based on at least a 30-year simulation.

MODFLOW, a numerical model, is the most commonly used model for mounding analyses of larger (typically >25,000 gpd) systems, in Coastal areas as well as elsewhere in North Carolina. The hydrogeologic regime surrounding the project site (both horizontally and vertically) must be fully characterized, including location and elevation of adjoining surface waters, drainage features, topography, rainfall and evapotranspiration inputs, soils and water level information. Unlike the CSU model, multiple horizontal layers can be included (with varying horizontal and vertical KSATs), and the initial water table gradient can be sloped. Multiple simultaneous inputs (e.g., from adjoining wastewater projects or stormwater basins) can be simulated, and the model can also serve as the basis for performing nutrient migration analyses. Successful running of the model requires a good deal of sophistication, training and art.

Reporting of model results must clearly delineate input parameters and all assumptions incorporated into the model. Input and output files must be provided when submitted for review,

with electronic copies of computer input files often requested so results can be verified or re-evaluated under varying conditions.

V. Stormwater Impacts on Groundwater Mounding Analysis

As the State's stormwater quantity and quality management program has become more widely implemented, the opportunity for interaction between on-site stormwater retention devices (infiltration galleries, retention basins, etc.) and subsurface wastewater drainfields has become more prevalent. The same groundwater regime locally receiving beneath drainfields 200 to 800 inches of wastewater effluent annually is now also being asked to assimilate the "capture" of at least the one or more inches of rainfall-induced runoff from all of the project's "impervious" surfaces during each storm event, which could be a substantial additional hydrologic input. The potential impacts of these stormwater basins on the groundwater mound beneath the wastewater system must be assessed on a project-specific basis.

Modeling the impact of the stormwater basin on the wastewater system can be a challenge. The time period of interest is generally different for the two sources. The wastewater system is typically assessed over a long time frame under steady-state conditions, with wastewater input normally assumed to be the "design" flow continuously applied over a six-month to multi-year period. The stormwater basin is designed to receive diverted surface runoff which occurs during rainfall events, providing large transient flows periodically distributed to the site during any given year.

Unfortunately, it cannot yet be definitively stated either every circumstance when a stormwater management system's impacts must be evaluated, or how to best do so. The presence of any stormwater retention devices within 500 feet of a subsurface system requiring State review should be indicated on the site plan. An assessment of stormwater impacts can be expected to be provided when such devices are within 200 feet of any drainfield or designated repair area, and may also be requested on a case-by-case basis when further away, whenever a mounding analysis beneath the wastewater system is required.

The expected quantities of stormwater added to an adjacent basin will need to be provided by the stormwater system designer. An approximation could be made based on the total impervious surface area draining to the basin multiplied by the projected rainfall during a "design" storm of a certain duration and recurrence frequency. The mounding impacts could be assessed multiple ways, with the sensitivity to varying inputs evaluated. Two such inputs could include:

- i. Annual input during the year with a 30-percent exceedence probability (assuming all of the rain falling during the year on an impervious surface infiltrates in the stormwater basin).
- ii. 14-day input of the highest monthly rainfall with 30-percent exceedence probability.

The annual and monthly rainfall values with a 30-percent exceedence probability can be obtained from the WETS tables published on the NRCS Website:
www.wcc.nrcs.usda.gov/climate/wetlands.html

These data may also be found in the Monthly Station Climate Summaries, 1971-2000, from NOAA's National Climatic Data Center (data available for 100 NC weather stations). For example, the annual and monthly peak 30-percent exceedence rainfall values for Morehead City are 62.69 and 8.98 inches, respectively. The groundwater mounding model (e.g., CSU or MODFLOW) could assess these impacts by i) applying 62.69/365 to the impervious surfaces draining to the basin daily for 365 days; and ii) applying 8.98/14 to the impervious surfaces daily for 14 days. When the CSU model is being applied, the stormwater basin would be modeled independently, with the mounding impact on the edge and center of the closest drainfield determined at the end of the application period (365 days and 14 days, respectively). When MODFLOW is used, the input of the stormwater and wastewater can be determined simultaneously. When the CSU model is run, if the impacts of stormwater on the wastewater application area appear significant (e.g., greater than 6-inches), a more sophisticated modeling effort may be needed.

VI. References

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ASTM Groundwater Assessment/Modeling Standards:

D 5447. Standard Guide for Application of a Ground-Water Flow Model to a Site-Specific Problem.

D 5609. Standard Guide for Defining Boundary Conditions in Ground-Water Flow Modeling.

D 5126. Standard Guide for Comparison of Field Methods for Determining Hydraulic Conductivity in the Vadose Zone.

D 4043. Standard Guide for Selection of Aquifer-Test Method in Determining of Hydraulic Properties by Well Techniques.

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D. Groundwater Mounding Models:

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Drainmod: Dr. Wayne Skaggs, NC State University. Available at: http://www.bae.ncsu.edu/soil_water/drainmod/

ModFlow: Waterloo Hydrogeologic (now part of Schlumberger Water Services). (Visual Modflow): Available at:

http://www.swstechnology.com/software_category.php?CatID=3
<http://www.groundwatersoftware.com/software.htm>

A great deal of free MODFLOW information and basic versions are also available from the USGS, at: <http://water.usgs.gov/nrp/gwsoftware/modflow2005/modflow2005.html>