MONITORED NATURAL ATTENUATION FOR INORGANIC CONTAMINANTS IN GROUNDWATER: GUIDANCE FOR DEVELOPING CORRECTIVE ACTION PLANS PURSUANT TO NCAC 15A .0106 (l)

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1.0 BACKGROUND, PURPOSE, AND SCOPE

Monitored natural attenuation (MNA) has been proposed as a corrective action remedy for inorganics in groundwater at numerous facilities across the State, including coal ash sites. 15A NCAC 02L .0106 (l) allows for the use of MNA for the remediation of groundwater contamination and states that any person required to implement an approved corrective action plan "*may request that the Director approve such a plan based on natural processes of degradation and attenuation of contaminants.*" A contaminant is defined here as a constituent (or constituent of interest (COI) that exceeds the 02L .0202 standards or Interim Maximum Allowable Concentrations (IMACs), and is above background concentrations.

The Division of Environmental Management produced a 15A NCAC 2L Implementation Guidance in December 1995 (1995 Guidance), that provided direction on the implementation of selected sections of 02L, including 02L .0106 (l) (MNA). However, the 1995 Guidance focused on *organic* contaminants that attenuate primarily through biodegradation to less toxic daughter constituents rather than inorganic contaminants that attenuate primarily through other mechanisms such as dispersion, sorption, and, in some cases precipitation or co-precipitation. Unlike organic attenuation that is permanent and irreversible, the attenuation of inorganics by sorption and (or) (co)precipitation may, in some cases, be *reversible* if subsurface conditions change. An inorganic contaminant that was otherwise immobilized within aquifer solids may re-mobilize and re-enter the groundwater system if geochemical conditions change. This possibility is assessed within an MNA Corrective Action Plan (CAP) for inorganics. It is recognized also that inorganics occur naturally in soils, bedrock, and groundwater which may affect the cleanup levels to which the MNA remedy must ultimately achieve.

The purpose of this document - 'MNA for Inorganic Contaminants in Groundwater: Guidance for Developing Corrective Action Plans' – is to outline Division of Water Resource expectations for an approvable MNA CAP for *inorganic* contaminants. This document augments the 1995 Guidance and acknowledges that both documents are relevant to the implementation of MNA under 02L .0106 (l). It is the expectation that an approvable MNA CAP demonstrate adherence to the criteria set forth in 02L .0106 (l) for each source area and that the contaminants in question can be remediated to 02L/IMAC standards within an acceptable period-of-time. Hybrid remediation strategies (for example, MNA, coupled with a passive reactive barrier) may also be presented under a 02L .0106 (l) CAP. The decision to approve the use of MNA rests with the Division Director.

This document describes the expectations for the use of MNA. While MNA shares some elements of risk based remediation, the two are separate and distinct, and this guidance is not intended to address risk based remediation[1].

[1] Legislation (SL 2015-286) prohibits the use of risk-based remediation for coal ash sites.

2.0 CONDITIONS FOR MNA APPROVAL UNDER NCAC 15A 02L .0106 (l)

Pursuant to 02L .0106 (l), the use of MNA may be a viable corrective action alternative when certain criteria are met. These criteria are discussed below.

02L .0106 (l)(1). All sources must be controlled or removed. The 1995 Guidance discusses source control on p. 12 (paragraph 1) and on p. 17. In some cases, the responsible party (RP) may satisfy this requirement by being in the active process of source control or source removal. If an RP can remediate to the 02L standards/IMACs, source material may, under certain conditions, remain in place. For purposes of this guidance, capping a source in place may, in some instances, constitute "control". In such a case a de-watered source may be essentially stabilized and prevented from contributing additional mass to a plume[2]. For source areas that are capped in place and contain inorganic waste below the seasonal high water table, robust evidence must be provided, using a method pre-approved by the Division, that demonstrates adequate source control of the submerged waste. In some cases, it may not be possible to effectively control a source with only a cap in place closure.

While 02L .0106 (l) does not preclude the use of MNA at sites where a plume is migrating or changing shape, it does require that the source has been controlled and that contaminant mass is not being added to the existing plume at quantities that would result in a contravention of the rule. In most cases this will mean that the source has been removed or capped and de-watered.

02L .0106 (l) (2). The contaminant must have the capacity to attenuate under site conditions. The 1995 Guidance discusses the attenuation of organic, but not *inorganic* contaminants. The use of MNA under 02L .0106 (l) (2) does not require that a contaminant plume be fixed in space, if the plume characteristics are well understood and documented. However, attenuation should be occurring, sufficient for 02L .0106 (l) compliance, and persistent over time. The dominant attenuation mechanisms for inorganics often include some combination of dilution, dispersion, sorption, precipitation/co-precipitation, and (or) phyto-attenuation.

The case for natural attenuation is evaluated by the Division using, as a guideline, the EPA four tier framework (EPA, 2007) (Appendix C). In this framework, the emphasis is on characterizing what is causing attenuation to occur and determining that this cause (or causes) is (are) persistent over time. EPA Tier 1 states that active COI removal be shown[3]. EPA Tier 2 states that the dominant attenuation mechanism(s) and their rate(s) be determined. EPA Tier 3 states that the long-term stability of attenuation be shown. And Tier 4 describes performance monitoring to show that attenuation is occurring as expected and proposed.

Demonstrating that natural attenuation is sufficient and appropriate is the responsibility of the RP. The degree of demonstration that is expected by the Division is based on site conditions

[2] Plume, as used in this document, refers to either a mass of dissolved inorganic constituent spreading from a source (boron, for example), or to a distribution of a dissolved inorganic constituent whose presence and concentration is dependent on local geochemical conditions (iron, for example).

[3] While EPA Tier 1 requires that "plume stability" be shown, 02L rules do not preclude plume migration in an MNA remedy. For example, 02L .0114 (a) provides notification requirements and states that, "*under 2L .0106(k), (l), or (m), the RP shall notify the Health Director and Chief AO of the political jurisdictions in which the plume occurs and all property and owners and occupants within or contiguous to the area underlain by the contaminant plume, and under the areas where it is expected to migrate*".

such as the location and behavior of the plume and the attenuation capacity of the unit through which the plume flows. For example, a stable plume that is distant from the nearest receptor and whose leading edge is flowing through highly sorptive soils would typically require less attenuation demonstration than a moving or expanding plume whose leading edge is in close proximity to a receptor and whose leading edge is flowing through open, poorly sorptive bedrock fractures.

The RP may use a combination of methods to demonstrate sufficient COI removal, attenuation rates, and persistence of the observed attenuation. Any modeling in support of these demonstrations should, in most cases, use conservative assumptions and include sensitivity analyses that evaluate end member conditions. Section 4.0 of this Guidance discusses expectations for data collection in support of the MNA CAP, and Section 5.6 discusses expectations for demonstration of natural attenuation.

02L .0106 (l) (3). The time and direction of contaminant travel must be predicted with reasonable certainty. The 1995 Guidance discusses contaminant modeling and travel predictions on p. 12 (paragraph 3) and on p. 23-24. Predictions may be carried out using an analytical or numerical model whose construction, assumptions, and performance are acceptable to the Division. It is noted that contaminants travel at different rates based on their sorptive characteristics and the subsurface geochemistry and sorptive hosts. The chosen model should be able to account for this or the modeler should assume worst case travel predictions (fastest, farthest) of the most highly mobile, lead edge contaminant (boron or sulfate, for example at coal ash sites) and apply this assumption to all contaminants.

02L .0106 (l) (4). Contaminant migration has not and will not result in any 02L standards/IMACs violations to a receptor or foreseeable receptor. The 1995 Guidance discusses migration to receptors on p. 11, 12 (paragraph 4) and on p. 25-26. As used in 02L .0106 (l) (4), "receptor" is defined as a supply well, and "foreseeable receptor" refers to a future groundwater use area defined in the 1995 Guidance (page 25) as "*property where the groundwater resources have a potential use, public water is not available, and the permission of the area property owners allowing contamination to migrate onto their land has not been obtained, including locations for which formal plans exist to use groundwater for public or private use; locations for which property owner(s) has expressed an anticipated or possible future use of groundwater resources; rural locations for which public water supplies will most likely not be available for future residential, agricultural or industrial development and the owner(s) has expressed a future anticipated use; and locations where the land ownership cannot be determined at present".* A foreseeable receptor (i.e. future use area) shall include all potentially affected properties near the contamination site for which a public water supply is not available or legally promised by the RP.

Surface water receptors are addressed by 02L .0106 (l) (6). An understanding of plume characteristics in space and time is necessary to properly assess contaminant migration and its potential impact on receptors or foreseeable receptors.

02L .0106 (l) (5). Contaminants have not and will not migrate onto adjacent properties unless (a) a public water supply sourced by surface water or unaffected groundwater is available, or (b) owner approval has been granted in writing. The 1995 Guidance discusses migration onto adjacent properties on p. 12 (paragraph 5). An understanding of plume characteristics in space and time is necessary to properly assess contaminant migration onto adjacent properties.

02L .0106 (l) (6). Contaminated groundwater discharge from the source area is not currently causing and will not in the future cause violations to surface water standards. The 1995 Guidance discusses surface water standard violations on p. 13. Understanding the plume characteristics in space and time is needed to properly select the surface water sample locations for assessing potential current violations and to model or sample for potential future violations.

02L .0106 (l) (7). Performance monitoring well(s) will be no farther than 5 years travel time downgradient from the plume front, and no closer to the nearest supply well or future use area than 1-year travel time from the plume front. The 1995 Guidance discusses performance monitoring on p. 13 and p. 27.

02L .0106 (l) (8), (9), (10). All pertinent access agreements, public notice, and adherence to all other environmental laws must be demonstrated. The 1995 Guidance discusses access agreements and public notice on p. 13, p. 27-28, and p. 30.

02L .0106 (i). 02L .0106 (i) states that "*In the evaluation of corrective action plans, the Director, or his designee shall consider the extent of any violations, the extent of any threat to human health or safety, the extent of damage or potential adverse impact to the environment, technology available to accomplish restoration, the potential for degradation of the contaminants in the environment, the time and costs estimated to achieve groundwater quality restoration, and the public and economic benefits to be derived from groundwater quality restoration*." It is the expectation that the RP provide information that is needed to evaluate these considerations as discussed further in Section 6 of this guidance.

3.0 DEFINING SOURCE AREAS

The requirements of 02L .0106 (l) must be met for *each COI*[4] and *each source area* at a facility. Some facilities may be represented by a single source area. Other facilities may contain several source areas.

Large waste areas (e.g. coal ash basins) may need to be divided into separate smaller source areas if, for example, contaminant transport is toward different sets of receptors[5]. Where appropriate, some source areas may be strategically combined based on geographic proximity (for example, conjoining or overlapping source areas), common source characteristics and impacts, common receptors, and a shared proposed remedy. The Regional Office should be consulted when identifying source areas for

[4] A COI is defined as a constituent that occurs above 02L standards/IMACs and background levels at or beyond a compliance boundary, or a constituent that occurs above 02L standards/IMACs and background levels in bedrock *within* a compliance boundary in an area with vulnerable downgradient receptors.

[5] Cliffside (Rogers Energy Complex) active ash basin is an example of a site with a large waste area (an active, unlined ash basin) that was divided into two source areas. This basin has two dammed outfalls over a half mile apart (one into Suck Creek and the other into the Broad River). Contaminated groundwater discharge moves toward two different areas and sets of receptors. Dividing this large waste area into two source areas is appropriate.

purposes of CAP development. It is also the expectation that a separate CAP, as deemed appropriate by the Regional Office, be developed for each source area (or each combined source area).

4.0 COLLECTING DATA IN SUPPORT OF MNA CAP

It is the Division's responsibility to approve or disapprove CAPs submitted by the RP. The decision whether to approve or disapprove a CAP is dependent upon the technical merits of the submittal. The need for appropriate data used to assess and document natural attenuation cannot be overstated. The following sections discuss the data collection and analysis that are needed to properly evaluate and review the appropriateness of MNA.

4.1 Sample Location and Data Needed to Evaluate Plume Characteristics and Natural Attenuation

To allow a proper review of natural attenuation and receptor risk, (a) the characteristics of a plume in time and space should be assessed, and (b) the mechanisms of attenuation should be understood. The amount of data needed to adequately assess the plume characteristics and attenuation is dependent on the complexity of site conditions and its potential risk to receptors. More extensive data collection is usually required at sites with complex subsurface conditions (e.g. fractured rock settings). An understanding of the horizontal and vertical movement of contaminants from source to receptor is expected. Data typically are needed, at a minimum, along the longitudinal plume centerline from a location at the source to a location beyond the downgradient plume boundary. In some cases, wells positioned along a lateral transect (perpendicular to groundwater flow) may be used to augment, but not replace, the longitudinal plume centerline wells. Such wells would be used, for example, for plume mass balance, lateral plume spread, or related computations. *Poorly connected bedrock wells and wells located on the side perimeter of a plume are generally inappropriate for demonstrating contaminant attenuation.* Instead, an emphasis on longitudinal plume centerline wells is expected, and those plume centerline wells should be screened across the vertical interval of the flow system that contains the maximum contaminant concentrations at that location.

Useful references for analyzing plume attenuation include:

- EPA, 2002, 'Calculation and Use of First-Order Rate Constants for Monitored Natural Attenuation Studies', EPA/540/S-02/500;
- EPA, 2007, Monitored Natural Attenuation of Inorganic Contaminants in Groundwater, Volume 1, Technical Basis for Assessment, EPA/600/R-07/139;
- Farhat, Newell, and Nichols, 2006, Mass Flux Toolkit to Evaluate Groundwater Impacts, Attenuation, and Remedial Alternatives; and/or
- ITRC, 2010, A Decision Framework for Applying MNA Processes to Metals and Radionuclides in Groundwater; and others.

Understanding the dominant attenuation mechanisms - dilution, dispersion, sorption, precipitation/co-precipitation, and (or) phyto-attenuation - and their relative importance requires adequate sampling of subsurface reactants (e.g. iron and aluminum hydrous oxides), solid and water phase contaminant concentrations, and geochemical conditions, and these data should be collected at properly located and screened wells (discussed above). The following table lists selected parameters, measures, and constituents that are often useful in understanding and documenting natural attenuation. This list is not intended to be comprehensive.

Selected parameters, measures, and constituents that are often useful in understanding and documenting natural attenuation of inorganics

Alkalinity	pH
Aluminum hydroxides	Selenium species, as applicable
Anion exchange capacity	Soil-water pair chemistry
Arsenic species, as applicable	Specific conductance
Cation exchange capacity	Sulfate
Chromium species, as applicable	Sulfide
Eh	Total dissolved solids
Iron hydroxides	Total organic carbon
Iron species	Turbidity
Manganese species	Others as identified based on site conditions

4.2 Iterative Nature of Data Collection in Support of an MNA CAP

Data collection in support of an MNA CAP is normally an iterative process. Results of one phase are used to determine where and how to collect data in a subsequent phase. In this way, data collection is progressively focused and leads to a refined understanding of site conditions, plume conditions, and attenuation. The RP should install and sample a sufficient number of monitoring points to define the extent of groundwater contamination both horizontally and vertically, to understand contaminant movement and attenuation with distance and depth (within hydrostratigraphic flow units), and to understand contaminant trends over time.

Wells installed to assess horizontal and vertical extent may or may not be useful in assessing the capacity of the subsurface to attenuate, via dilution, dispersion, sorption, precipitation, or other mechanism, contaminants along a plume centerline. If required timeframes preclude an iterative approach (e.g. Coal Ash Management Act of 2014 (CAMA)), data collection should be particularly robust in the early phase of investigation to ensure that adequate and representative data will be available within the timeframes needed to demonstrate the appropriateness of MNA to the satisfaction of the Director. It is the responsibility of the RP to ensure that the necessary number of monitor wells are installed in the appropriate locations and at appropriately screened/open intervals to allow the development of an acceptable and approvable MNA CAP. The Division will support the RP in this effort through written and verbal input during assessment and corrective action planning based on the information and data available at the time of the input, but the responsibility for ensuring that monitor well placement and screened/open intervals are sufficient to develop a defensible MNA CAP rests with the RP.

4.3 Data Inventory

Monitor wells installed to assess horizontal and vertical plume extent (which includes most CSA wells) and many compliance boundary wells may or may not be properly positioned or screened to assess plume characteristics, attenuation, and MNA viability that are needed for an MNA CAP. To ensure that adequate data are available for MNA CAP development, the RP should inventory the available monitor wells for each source area and provide the Regional Office responses to the following questions *prior to* assembling the evidence needed to demonstrate adherence to 02L .0106 (l).

(a) have background concentrations been formally established for all COIs in soil and groundwater?

(b) for each source area, how many wells within each flow system are located along the contaminant plume centerline? Along a transect that is perpendicular to the plume centerline?

(c) how many wells in (b) above are screened across the most contaminated vertical interval of a given flow unit or are screened across the full thickness of the flow unit?

(d) what is the length of record and how many valid sample events are available for wells listed in (b) and (c)?

(e) does turbidity, well construction (for example, grout contamination, etc.), or well “break in” issues preclude the use of data in (b), (c), and (or) (d)?

(f) for each source area and within each flow unit, how many spatial locations were sampled for solid phase chemistry and were these locations associated with "end member" (maximum and minimum) groundwater concentrations for each contaminant[6]? How many of these spatial locations are associated with (b) or (c) above?

(g) given that iron hydroxide (HFO) content is a good indicator of retention capacity for most metal contaminants, how many locations in (f) was HFO measured?

Results of this inventory will help the review team evaluate whether the existing dataset is adequate for assessing plume characteristics, attenuation, and attenuation mechanisms (e.g. the capacity for solid phases to retain contaminant mass over time) with reasonable certainty. If available at the time of the data inventory, the review team would also benefit from model results described in Section 7.5.2. If data for (f) and (g) from *other (different)* source areas on site are used to augment the existing dataset, an explanation is expected for why this is appropriate (for example, an RP may show using lithology data from both areas that the subsurface geology and sorptive properties are similar in both source areas).

Approximately 14 days after the Division's receipt of this information, the RP should meet with the Regional Office to review the amount and location of existing data and discuss its adequacy for MNA CAP development. If the existing dataset is determined to be adequate, then the RP should proceed with the development of the MNA CAP. If not, the RP should reach agreement with the Regional Office on any additional well and solid phase samples (locations and depths) needed to adequately assess plume characteristics and (or) attenuation capacity.

5.0 MINIMUM CONTENTS EXPECTED IN AN MNA CAP FOR INORGANICS

An MNA CAP should provide, at a minimum, data and information required by 15A NCAC 02L .0106 (h) and (l) and, if applicable, CAMA and (or) other regulations. The following sections discuss the minimum contents expected in an MNA CAP.

5.1 Site Background and Regulatory Basis for Corrective Action. This section should describe the site, its history, ownership, operations, relevant permits (NPDES, e.g.) and a summary of their requirements, and a list of environmental reports prepared for the site to date. This section should include the relevant regulatory requirements incumbent upon the RP, as well as the *specific portions* of 2L .0106, CAMA, and (or) other regulations that are being addressed by the MNA CAP.

5.2 Conceptual Model of Groundwater Flow and Contaminant Transport. This section should succinctly describe the site setting, regional geology and its effect on groundwater flow and quality, areas of recharge and discharge, hydrologic boundaries, hydrostratigraphic units, and heterogeneities and their effect on groundwater flow, quality, and contaminant transport. Heterogeneities may include: flow units that pinch out; flow properties

[6] Understanding the solid phase contaminant concentrations in locations of both low and high groundwater COI concentrations are important in understanding the sorptive capacity of the system. This is particularly true in the case of non-linear isotherm adsorption models that describe most metals. That is, a soil has a limited ability to sorb contaminant mass due, for example, to limited sorption sites, so a soil can become less efficient at removing mass at higher dissolved concentrations.

that vary with hydrostratigraphic unit; artificial areas (filled and (or) re-worked) of the site; different geologic formations across the site and their *demonstrated* effect on groundwater quality; faults, dikes, or other geologic anomalies and their effect on flow and transport; spatially varying subsurface sorption capacities (e.g. iron or aluminum hydrous oxides, partition coefficients (Kd)); and (or) others. If portions of the conceptual model rely on inferences or assumptions rather than field data, this should be clearly stated along with a technically defensible rationale for the inference or assumption. For example, if a hydrologic boundary is inferred by topography but was not measured, this should be stated and rationale provided. Rather than referencing content from an earlier report submittal, it is preferred that the content for this section be included in the MNA CAP.

5.3 Potentiometric Maps. The following potentiometric contour maps should be provided:

5.3.1 Potentiometric contour map of shallow system

5.3.2 Potentiometric contour map of bedrock system (as applicable)

5.3.3 Vertical gradient map showing observed head differences (shallow minus bedrock, based on a representative shallow layer and a representative bedrock layer) contoured at 2 foot intervals.

For sites at which flow modeling has been conducted, the following additional maps are expected:

5.3.4 Potentiometric contour map of simulated shallow system once steady state conditions have been reached after basin or waste area closure (excavation, engineered cap, or other alterations to the subsurface arising from corrective actions), as applicable

5.3.5 Potentiometric contour map of simulated bedrock system once steady state conditions have been reached after basin closure (excavation, engineered cap, or other alterations to the subsurface arising from corrective actions), as applicable

5.3.6 Simulated vertical gradient map showing head differences (shallow minus bedrock, based on a representative shallow layer and a representative bedrock layer) once steady state conditions have been reached after basin or waste area closure (excavation, engineered cap, or other alterations to the subsurface arising from corrective actions), contoured at 2 foot intervals.

Each of the above maps should be superimposed on an orhtophoto base map showing source areas and waste and compliance boundaries, 2-ft contours, and all monitor wells, identified receptor supply wells, and jurisdictional surface waters. If figure clarity is compromised by the amount of information being presented, please contact the Regional Office prior to the CAP submittal.

5.4 Background Concentrations. Inorganic constituents occur naturally in subsurface soils and groundwater, and for purposes of 02L implementation, only those concentrations that occur above background levels are relevant to remediation and attenuation. The MNA CAP should include a table showing all COIs and their representative background value in soil and groundwater.

5.5 Characterization of Source Areas. This section discusses the information needed to understand the source, its impact on soil and groundwater, associated receptors, risks, and remedial alternatives. It is expected that this information be provided separately for ***each*** source area that is proposed to be addressed by an MNA remedy.

5.5.1 Source history, volume, and characteristics. History of waste placement, list of waste materials and volumes emplaced, characteristics (behavior, leachability, etc.) of waste materials, and chemistry of source area pore water and underlying groundwater.

5.5.2 Horizontal and vertical extent of source material. A plan view map (showing source area and all jurisdictional waters and supply wells within a ½ mile radius) and a cross section map (showing seasonal high water level and depth of material and any associated liners or caps), along with an estimated volume of source material.

5.5.3 Horizontal and vertical extent of saturated source material. A plan view map and a cross section map (showing seasonal high water level and depth of material and any associated liners or caps), along with an estimated volume of saturated source material.

5.5.4 Source control and stability. Describe how the source has been controlled (excavation, engineered cap, de-watering, and (or) other) and the permanence or impermanence of the control strategy. Describe the stability of the source area, including (i) any dams or other structures associated with the source area and their hazard rating, (ii) the type, condition, and designed lifespan of any engineered liner or cap, if applicable, (iii) proximity to 100-year flood zone, (iv) type, age, and health of tree cover, if applicable, and (v) any hazards to the public health, safety, or welfare resulting from the source area that is not covered above.

5.5.5 COI(s) associated with source area. List the COIs that have been are associated with the source area. For each COI listed, state whether it occurs as a continuous plume or as a constituent whose dissolved concentrations are controlled largely by geochemical conditions along a flow path.

5.5.6 Base and iso-concentration maps showing horizontal and vertical extent of COI(s) in groundwater and soil at and downgradient of source area. A separate plan view base map should be provided *for each source area*. The base map should be large scale (often 1 inch = 100 to 200 feet will be appropriate) and show the contents listed in Appendix C. A plan view map and a cross section map should be provided *for each COI* within the source area in question depicting the horizontal and vertical extent of the COI. Areas with sparse concentration data should be indicated (e.g. dashed iso-concentration lines).

5.5.7 Identification of receptors associated with the source area.

5.5.7.1 Surface waters, to include all jurisdictional wetlands, streams, ponds, lakes, rivers, etc.

5.5.7.2 Supply wells within a ½ mile radius (or other distance as defined by the Division) of source area waste or, if applicable, compliance boundary.

5.5.7.3 Future groundwater use areas.

5.5.8 Evaluation of human and ecological risks associated with the source area.

5.5.9 Evaluation of alternative corrective actions (e.g. pump and treat, reactive barriers, in-situ stabilization, phytoremediation, MNA, etc.) with consideration of the following factors: degree of protection of human health and the environment; regulatory compliance; time required to accomplish restoration; cost required to accomplish restoration; reduction of toxicity, mobility, or volume of contamination; permanence of the remedy; implementability; stakeholder acceptance; and others, as appropriate.

5.6 Demonstration of Natural Attenuation. This section should provide documentation of plume characteristics and a demonstration that MNA will fulfill the requirements of 02L .0106 (l) (i.e. protect human health and the environment, etc.) and any other applicable regulations. Hybrid remediation strategies (for example, MNA, coupled with a passive reactive barrier) may also be presented under a 02L .0106 (l) CAP. Documentation of adequate attenuation should include maps, graphs, models, and (or) attenuation equations and slope factors, and the data used to construct these should be from technically defensible well locations/depths (see Section 4 of this Guidance). Contaminant attenuation must be demonstrated separately ***<u>for each source area proposed for MNA</u>*** and to the satisfaction of the Director. The following sections discuss the expectations for natural attenuation demonstration for each separate source area.

5.6.1 Understanding plume characteristics in space and time

Understanding and documenting plume characteristics in space and time are necessary components of an MNA CAP. This documentation is used by the Division to help understand otherwise un-identified risks to receptors, the quality of any attenuation or predictive models, and the appropriateness of the proposed MNA remedy for the source area under consideration.

As discussed in Sections 4.1 and 4.2, the number of spatial and temporal monitoring points that are needed for plume assessment is dependent on the degree of source and subsurface complexity and the degree of uncertainty about potential contaminant transport to receptors. Highly variable COI concentrations in space or time observed in an extremely heterogeneous subsurface (fractured bedrock, for example) flow system near receptors would necessitate a higher number of monitoring points than a site that is mostly isolated from receptors and is associated with relatively uniform subsurface and groundwater quality conditions. There should be enough monitoring points to define the extent of groundwater contamination both horizontally and vertically, to understand contaminant trends with distance toward receptors, and to understand contaminant trends over time.

The monitor well network for most sites typically will include an upgradient well, at least one set of wells screened across the transverse axis of the plume, one set of wells screened along the longitudinal axis of the plume, and sentinel wells. If more than one flow unit exists, the well network should be constructed to measure maximum concentrations in the flow units as contamination moves horizontally and vertically from source to receptors. Monitoring frequency should be designed to detect any variability in plume concentrations and extent due to seasonal water table fluctuations, tidal influence, source removal and (or) groundwater remediation efforts, or other effects. Where formal statistical methods are needed to demonstrate increasing or decreasing trends in a well or wells, eight to ten sample events may be needed.

The documentation of plume characteristics should include some combination of the following qualitative and quantitative methods, including contaminant concentration contour maps, concentration versus time graphs for selected monitoring wells along a plume centerline (including well(s) closest to receptors), and concentration versus distance graphs showing concentrations along the plume centerline at a selected timepoint.

- Graphical methods (qualitative evaluation)
    - Concentration vs. time plots, concentration vs. distance plots, and concentration isopleths maps
- Quantitative methods
    - Statistical methods that analyze single-well trends (for example, Mann-Kendall, Theil-Sen, linear regression)
    - Plume-based methods (plume area, plume mass, plume center of mass, and mass flux analyses)

Wells selected for use in a given analysis must be appropriate to that method and be representative of the conditions being analyzed. For example, a side gradient well may not be used to analyze plume centerline conditions. See the report titled 'Calculation and Use of First-Order Rate Constants for Monitored Natural Attenuation Studies' (EPA/540/S-02/500, November 2002) as an example of proper plume analysis.

5.6.2 COI migration predictions

Pursuant to 02L .0106 (l) (2), each COI must have the capacity to attenuate under current and future site conditions as demonstrated by adherence to criteria 02L .0106 (l) (4), (5), and (6). Criteria 02L .0106 (l) (4), (5), and (6)[7] require predictive modeling of travel time, direction, and distance, and according to 02L .0106 (l) (3), there should be "reasonable certainty" in the model results.

Various predictive modeling approaches are acceptable. It is recommended that the RP work with the Regional office to better assure that the selected approach is appropriate and sufficient for use in the MNA CAP. In some cases, the RP will choose to use a three-dimensional flow and transport numerical model. The model approach should be

[7] 02L .0106 (l) (4) requires a demonstration that contaminated groundwater will not result in any 02L standards/IMACs violations to a receptor or foreseeable receptor. 02L .0106 (l) (5) requires a demonstration that contaminated groundwater will not migrate onto adjacent properties unless (a) a public water supply sourced by surface water or unaffected groundwater is available, or (b) owner approval has been granted in writing. 02L .0106 requires that contaminated groundwater discharge not cause a surface water violation.

dependent upon the quality and amount of data available for its construction and calibration. To meet the expectation of "reasonable certainty", it is recommended that basic elements of model construction be pre-approved by the Division. For 3-D models these will often include the selected grid spacing, boundary locations, boundary conditions, flow zone layering strategy, target well selection, particularly important input data (hydraulic conductivities, sorption coefficients, monitor well adequacy for modeled source areas, supply well pumping inclusion, and others), and strategy for sensitivity analyses and reporting. Failure to include the Division in model selection and development often will result in the need for multiple revisions requiring model re-development and re-calibration. It is recommended that the RP discuss this step with the Regional Office prior to model development or at the earliest opportunity if model development is already underway and regional approval has not yet been obtained.

5.6.2.1 Predictions based on existing conditions.

The predictive modeling of time, direction, and distance of contaminant travel should be carried out based on existing conditions. The following figures are expected:

(a) a concentration-time plot for each COI corresponding to the following locations: (i) nearest supply well, (ii) nearest future groundwater use area, and (iii) nearest surface water.

The following information should also be provided: the time it takes for the COI to reach (i), (ii), and (iii), the time it takes for the COI to reach (i), (ii), and (iii) at its 2L/IMAC concentration, the time it takes for the COI to reach (i), (ii), and (iii) at its maximum concentration, and the time it takes for the COI to reach (i), (ii), and (iii) at a concentration that is back below the 2L/IMAC concentration. It is recommended that this information be included in the plot margin.

(b) a map (superimposed on the requested base map) showing the maximum predicted migration distance, at any detectable concentration, of each COI.

(c) a map (superimposed on the requested base map) showing the maximum predicted migration distance, at the 2L/IMAC standard concentration, of each COI.

5.6.2.2 Predictions based on source control and corrective actions.

The predictive modeling of time, direction, and distance of contaminant travel should be carried out for ***each of three*** source control options (excavation, engineered cap, and (or) a hybrid of partial excavation and cap). The modeling for each option should also account for any proposed corrective action alterations to the subsurface (e.g. permeable reactive barrier, slurry wall, groundwater removal, etc). The figures listed in 5.6.2.1 (a), (b), and (c) are expected for each scenario.

5.6.3 Conceptual model of natural attenuation.

The natural attenuation of ***each COI*** should be described in terms of the following mechanisms, the relative strength of which may vary by source area:

5.6.3.1 Dilution and dispersion. These mechanisms may be considered together and are typically evaluated using conservative, mostly non-reactive constituents (e.g. boron or chloride).

5.6.3.2 Sorption, if applicable. Sorption should be documented. The subsurface reactants responsible for sorption should be identified along with their sorptive capacity. Evidence should be provided demonstrating that reactant mass is sufficient and conditions are conducive to continuous long term sorption.

5.6.3.3 Precipitation, if applicable. Precipitation or co-precipitation should be documented, along with the conditions and timeframes under which the precipitation reaction occurs. Evidence should be provided demonstrating that the precipitation or co-precipitation reaction is irreversible or will otherwise persist indefinitely.

5.6.3.4 Phyto-attenuation, if applicable. Phyto-attenuation should be documented. Tree or plant species responsible for phyto-attenuation should be identified along with the conditions under which phyto-attenuation occurs. Evidence should be provided demonstrating that phyto-attenuation is irreversible or will otherwise persist indefinitely.

5.6.3.5 Other mechanisms, if applicable. Other attenuation mechanisms should be documented, as applicable, along with the conditions under which they occur and evidence showing their long term persistence.

5.6.4 Demonstration that contaminated groundwater discharge to surface water will not result in violations of surface water standards contained in 02B .022.

Pursuant to 02L .0106 (l) (6), contaminated groundwater intercepting surface waters may not, now or in the future, possess contaminant concentrations that would result in violations of standards for surface water contained in 15A NCAC 2B .0200. Adherence to this requirement should be demonstrated in the MNA CAP as follows:

5.6.4.1 Existing conditions

Surface water samples should be collected at strategic near bank locations where maximum groundwater contaminant concentrations are expected to discharge to waters of the state. Results should document, for each MNA CAP source area, that discharge of contaminated groundwater to surface waters does not result in violations of 02B surface water standards (2017, DWR 2L-2B Sampling Guidance Memorandum). Generally, surface water samples should be collected in locations expected to intercept maximum plume concentrations (e.g. near bank samples collected during low flow conditions and in a location where the plume centerline is expected to discharge to the surface water of concern). The Regional Office should be consulted to determine locations and methods of surface water sampling.

5.6.4.2 Future conditions

The MNA CAP should propose locations and frequency of future surface water sampling that will document, over time, whether the discharge of contaminated groundwater to surface waters results in violations of 02B surface water standards. The locations and frequency of sampling will be dependent upon site conditions and documented plume behavior.

5.7 MNA schedule, performance monitoring plans, and contingency plans

The CAP should include a schedule for implementation of the proposed MNA CAP.

Requirements for performance monitoring and contingency corrective action plans are discussed in 02L .0106 (l) (7), in the 1995 Guidance (p. 13 and p. 27), and in Section 2.0 and Appendix C of this Guidance.

Performance monitoring must include monitor wells and surface water sample locations, and the MNA CAP should include a map and table of proposed locations. It is recommended that performance monitoring sampling be conducted quarterly during the two years following CAP approval, followed by semi-annually for the next three years. Sample parameters should be discussed with the Regional Office. The sampling locations, frequency, and parameters should be reviewed periodically. It is the RP's responsibility to document and request where reduced sampling is appropriate.

Alternative corrective action plans should be provided for each source area as a contingency for a case in which performance monitoring shows that contamination is not being attenuated as expected. At the approval of the Division, the Contingency Plans may be provided under a separate cover within 120 days of the MNA CAP submittal; in such case, the Division will review and approve the Contingency Plans separately from the MNA CAP.

5.8 Access agreements, public and other notices, and adherence to other laws

The MNA CAP should include documentation showing all necessary access agreements, public notice announcements, and (or) adherence to other relevant environmental laws. These requirements are discussed in 02L .0106 (l) (8), (9), and (10), and in the 1995 Implementation Guidance (p. 13, p. 27-28, and p. 30), and in NCAC 15A 02L .0106 (k)(6), (l)(9), and (m)(D), and NCAC 15A 02L .0114.

5.9 Completed checklist for MNA CAP for Inorganics

The RP should refer to Appendix A for a checklist that should be completed and submitted as part of the MNA CAP for inorganic contaminants.

6.0 REFERENCES

EPA, 2007, Monitored Natural Attenuation of Inorganic Contaminants in Groundwater, Volume 1, Technical Basis for Assessment, EPA/600/R-07/139. https://nepis.epa.gov/Exe/ZyNET.exe/60000N4K.TXT?ZyActionD=ZyDocument&Client=EPA&Index=2006+Thru+2010&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A\\zyfiles\\Index%20Data\\06thru10\\Txt\\00000002\\60000N4K.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h|-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL

EPA, 2002, Calculation and Use of First-Order Rate Constants for Monitored Natural Attenuation Studies, EPA/540/S-02/500, November 2002. https://nepis.epa.gov/Exe/ZyNET.exe/10004674.TXT?ZyActionD=ZyDocument&Client=EPA&Index=2000+Thru+2005&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C00thru05%5CTxt%5C00000005%5C10004674.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL#

Farhat, Newell, and Nichols, 2006, Mass Flux Toolkit to Evaluate Groundwater Impacts, Attenuation, and Remedial Alternatives, User's Manual. https://clu-in.org/download/contaminantfocus/ER-0430-MassFluxToolkit.pdf

ITRC (Interstate Technology & Regulatory Council), 2010. *A Decision Framework for Applying Monitored Natural Attenuation Processes to Metals and Radionuclides in Groundwater*. APMR-1. Washington, DC: Interstate Technology & Regulatory Council, Attenuation Processes for Metals and Radionuclides Team. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwi766CYtKfUAhVKeyYKHbkBDkwQFggmMAA&url=http%3A%2F%2Fwww.itrcweb.org%2FGuidanceDocuments%2FAPMR1.pdf&usg=AFQjCNGKvOjhv48c4DQYa0OAz-lLvOfNdw&cad=rja

NCDWQ, 2012, Evaluating Metals in Groundwater at DWQ Permitted Facilities: A Technical Assistance Document for DWQ Staff http://digital.ncdcr.gov/cdm/ref/collection/p16062coll9/id/251181

Smith and Gardner, 2016, Final Draft Monitored Natural Attenuation and No Further Action Evaluation Study, Prepared for N.C. Coal Ash Management Commission.

7.0 APPENDICES

APPENDIX A – CHECKLIST FOR MNA CAP FOR INORGANICS

The following checklist should be completed for each source area and included as part of the MNA for Inorganics CAP.

For each source area,

Y/N	Consideration
	1.a. Has the source of contamination been removed or controlled in accordance with 02L .0106 (l)(1)?
	1.b. Has this been properly documented?
	2.a. Will submerged ash (or other waste) remain on site?
	2b. If so, will this result in additional mass loading to the existing plume?
	2.c. If additional mass loading does not occur, why not?
	3. Have provisional background threshold values (PBTVs) been formally established for all COIs in soil and groundwater?
	4.a. Has downgradient surface water been tested for adherence to 2B standards?
	4.b. Were any surface water locations impacted by the discharge of a contaminated plume?
	5.a. Has downgradient surface water been modeled for future (predicted) adherence to 2B standards?
	5.b. Were any modeled surface water locations impacted at any point in the future?
	5.c. Has downgradient surface water been modeled for future (predicted) adherence to 2B standards?
	5.d. Have long-term surface water sample locations been proposed in the performance monitoring plan to address future adherence to 2B standards?
	5.e. Were any modeled surface water locations impacted at any point in the future?
	5.f. Was a predictive groundwater-surface water mixing model developed for the source area and, if so, what are the most significant limitations that affect the model's reliability?
	6. Are any of the surface water receptors used as a water supply and, if so, how far away are the Intakes?
	7. Has a "data inventory" been conducted and shared with the Division (see 'Data Inventory' Section)?
	8. Are contaminants in bedrock groundwater above 02L standards/IMACs at any location inside or outside the compliance boundary? If yes, what source area is implicated and is it predicted that the plume in fractured bedrock will reach a supply well in the future? What model was used to predict contaminant migration in bedrock? What are the most significant limitations affecting the reliability of the model?
	9. Have all supply wells within ½ mile radius of the source area waste boundary or, if applicable, compliance boundary been abandoned? List any wells that have not been abandoned or for which this information has not been obtained. Have the owners of these supply wells all converted to an alternative permanent source of clean drinking water? List all properties that have not been converted to an alternative, permanent clean drinking source or for which this information has not been obtained.

Y/N	Consideration
	10. If contaminated groundwater has migrated (or is predicted to migrate) off site onto surrounding properties, are all those properties served by a potable surface water or non-impacted groundwater supply or have those property owners allowed in writing the trespass of the contaminated groundwater?
	11. For each COI within the source area, 11.a. Does the constituent behave as a plume (for example, boron, sulfate, TDS, etc.)? If so,
	i. has the plume been defined in space (horizontally and vertically)?
	ii. has the downgradient edge of the plume been measured or is this not possible/practical due to the location of a major surface water or other access issues?
	iii. is a well located and screened to measure the maximum ("hot spot") plume concentrations at or near the source? Is a well located and screened to measure the maximum contamination along the plume longitudinal centerline at a point on the downgradient plume edge? If not, why not? iv. are concentrations within the plume boundary increasing? decreasing? stable?
	iv. is the plume expanding? shrinking?
	v. Is the plume migrating?
	vi. has the plume migrated to any supply wells? to any future groundwater use areas?
	vii. is the plume expected to migrate to any supply wells? to any future groundwater use areas?
	viii. have plume characteristics been properly assessed and documented (see #5 of the Section titled 'Minimum Contents Expected in MNA CAP for Inorganics')?
	ix. has attenuation been properly assessed along plume centerline and documented (see #8 of the Section titled 'Minimum Contents Expected in MNA CAP for Inorganics')?
	x. is attenuation expected to be persistent over the long term and has this been demonstrated in the MNA CAP?
	11.b. What is the predicted maximum distance the plume will travel? Has this been shown on a base map that contains all surface water receptors, supply well receptors, property boundaries, and future groundwater use areas? What concentration-distance model was used for the prediction and what are the most significant limitations that affect the model's reliability?
	11.c. What is the predicted length of time it will take to reduce concentrations to below 02L standards/IMACs at the nearest surface water receptor and at the compliance boundary? What concentration-time model was used for the prediction and what are the most significant limitations that affect the model's reliability?
	11.d. Does the COI occur not as a contiguous, identifiable "plume", but as discontiguous areas of concentrations whose values are controlled by local geochemical conditions (for example, iron, manganese, and others)? If so,
	i. are the geochemical controls on the COI concentration understood?
	ii. have the geochemical controls been measured in wells associated with checklist #11 (a) (I, ii, and iii) above?

Y/N	Consideration
	iii. does the COI occur or is the COI predicted to occur in the future above 02L standards/IMACs in any supply wells? future groundwater use areas? if so, has rationale been prepared that explains whether or not the source area is responsible for the COI occurrence?
	iv. has the COI been properly mapped, assessed, and documented (see #5 of the Section titled 'Minimum Contents Expected in MNA CAP for Inorganics')?
	v. has attenuation been assessed and documented for areas of maximum concentrations (see #7 of the Section titled 'Minimum Contents Expected in MNA CAP for Inorganics')?
	vi. is attenuation expected to be persistent over the long term and has this been demonstrated in the MNA CAP?
	11.e. How does cap-in-place compare to excavation (or, if proposed, partial excavation), for purposes of checklist items #11 (a), (b), (c) and (d) above?
	11.f. If presented, are soil-water pairs collected in horizontal and vertical locations representative of high and low COI concentrations?
	11.g. If Kd lab tests were conducted using site soils, how much variation was observed across the source area? across flow units? across the site? across lab methods (for example, batch versus column tests)? Were lab-derived Kd's used as the calibrated values in any transport modeling, and if not, why not?
	12. Are performance monitoring wells able to be positioned no farther than 5 years travel time downgradient from the plume front, and no closer to the nearest supply well or future use area than 1-year travel time from the plume front.
	13. Have all pertinent access agreements been obtained, public notices provided, and adherence to all other environmental laws been demonstrated?
	14. Has a description of the proposed MNA remedy been provided, along with the reasons for its selection and a proposed schedule?
	15. Has all relevant information needed to assess the MNA CAP been provided, including information on risk associated with the source area, the cost and benefits of cleanup, and the technology available to accomplish cleanup?
	16. Has the CAP and any other associated reports and (or) appendices been sealed by a professional engineer and (or) geologist?

APPENDIX B. EPA FOUR TIER MNA EVALUATION.

This appendix summarizes the four tiers used in the EPA MNA evaluation process, along with data/analyses that, in some cases, are used to support such an evaluation.

TIER 1. Demonstrate COI removal. COI removal is separate from and in addition to any "source" removal or control that is proposed. For purposes of this Guidance, active COI removal may be via dispersion[8], sorption on/in a solid phase, precipitation/co-precipitation, phyto-attenuation, or other

[8] Dispersion as used here is intended to mean both dispersion (from mechanical mixing due to longitudinal and transverse variations in the 3-dimensional velocity field) and dilution (from added recharge along a flow path). Degradation or phase change is another removal mechanism that typically is not relevant for the MNA of metals.

mechanisms. While dispersion does not actually "remove" COI mass from the groundwater system, it does displace and thereby dilute the mass by transferring it to areas of the groundwater system where the concentrations are below the groundwater standards. In most cases, some combination of dispersion and (or) sorption will be the dominant mechanisms removing inorganic contaminants from the groundwater system. Often, precipitation involves (mainly) iron or manganese which in turn could serve as sorption hosts for other COIs. Precipitation should thus be considered as a potential mechanism for selected constituents such as iron, manganese, sulfate, and, in some cases, other highly concentrated COIs. Various methods may be used for Tier 1 demonstration and may include the following:

Water-solid pairs. For contaminants susceptible to sorption, Tier 1 may be demonstrated by comparing COI concentrations of water-solid pairs at representative locations within the area of the plume. If used, pair data generally should comprise at least three locations and be representative of the flow zone(s) (shallow, deep, or bedrock) through which that COI occurs above the 02L standards/IMACs. The locations of the pair data should be mapped (with water-solid pair location labels for identification) to show the proximity of the pair data to the source area and to areas of low and high groundwater concentrations. The pair data should show an increasing trend in sorbed mass from locations with low dissolved concentrations to locations with high dissolved concentrations. If these criteria are not met, the evidence would be considered inconclusive, and additional line(s) of COI removal evidence would be expected.

Partition coefficient (Kd) lab tests. For contaminants susceptible to sorption, COI removal by sorption may be shown with Kd lab test results. Kd is defined as the ratio of the contaminant concentration associated with the solid to the contaminant concentration in the surrounding aqueous solution when the system is at equilibrium. Depending on the number and location of test samples, this may not produce a quantitative estimate of mass removal from the system nor is it an indication of the long term sorptive capacity, but it is strong evidence that COI mass is being removed from groundwater.

Concentration-time and concentration-distance analyses. See Sections 4.1, 4.2, and 5.6.1 and EPA, 2002, 'Calculation and Use of First-Order Rate Constants for Monitored Natural Attenuation Studies'.

<u>TIER 2</u>. Identify the dominant attenuation mechanism(s) and estimated rate(s) of attenuation. It is necessary to understand the dominant attenuation mechanism(s) in order to evaluate the long-term persistence of that (those) mechanism(s). An estimate of attenuation *rates* (that is, the rate at which contaminant mass is reduced (dispersion) and (or) transferred to solids via sorption or (co)precipitation) helps assess the length of time it will take to reach cleanup goals. Data needed for Tier 2 typically include stratigraphy, seepage velocities, contaminant concentrations in groundwater and solids, groundwater geochemistry (pH, Eh, etc), and a certain amount of subsurface mineralogy and contaminant speciation in groundwater and solids. Understanding and documenting heterogeneities at the scale of concern is also expected.

To determine the dominant attenuation mechanism, a comparison should be made between the mass that is decreased due to dispersion versus the mass that is removed (transferred) from the aqueous phase to the solid phase due to sorption or due to precipitation. To estimate the rate of dispersion, contaminants shown to be relatively conservative (non-sorbing) may be used to estimate concentrations along a groundwater flow path. If it is assumed that the contaminant will be conserved as it moves downgradient, then any reduction in concentration is due to dispersion. The dispersion attenuation rate is valid and defensible only if the same flow path is being measured. Otherwise, the dispersion estimate would be meaningless, as in the case of an upgradient concentration that is measured in a shallow flow unit within the heart of a contaminant plume and a downgradient concentration that is measured in a side gradient well screened across a disconnected lower flow unit.

To estimate the rate of mass transfer via sorption, results from Kd lab tests or geochemical modeling may be used. Lab results that produce extreme Kd variability, for a given COI, between methods (batch versus column), replicated tests, locations, or depths would carry a fair amount of uncertainty, and additional line(s) of evidence usually would be expected in the MNA CAP to document the rate of attenuation by sorption. The greater the degree of sorption variability either between tests or between locations, the greater the degree of uncertainty in contaminant migration predictions obtained from flow and transport modeling that uses a single sorption coefficient per COI.

To estimate precipitation, solubility diagrams may be used qualitatively and geochemical modeling may be used quantitatively.

Assuming properly positioned and screened wells exist and have been sampled during a sufficient number of events, concentration-time and concentration-distance methods may be used to estimate the attenuation rate that results from any or all mechanisms (dispersion, sorption, precipitation). A useful reference for evaluating plume characteristics, demonstrating contaminant removal, and estimating attenuation rates is EPA, 2002, 'Calculation and Use of First-Order Rate Constants for Monitored Natural Attenuation Studies'.

Another robust and quantitative line of evidence (mass balance) is the demonstration of mass attenuation as measured across a planar transect perpendicular to the plume migration centerline. This method accounts for all COI mass that passes a 2-D plume face and its concentration flux over time. This method assumes that the plume centerline is known and that monitor wells are located along a transect perpendicular to the centerline flow and that these wells are sufficient to estimate representative flow rates and COI concentrations. This method further assumes relatively isotropic conditions with little vertical variation in the plume's flow field. A decreasing trend through this planar transect would be strong evidence of COI removal and would allow an attenuation rate to be estimated.

<u>TIER 3</u>. Demonstrate that the attenuation capacity is stable over the long term. Once the dominant attenuation mechanism(s) is (are) understood, the long-term stability of that (those) mechanism(s) should be evaluated. Tier 3 should answer the question, "will current attenuation rates continue indefinitely?" Factors that could affect the attenuation capacity and stability include (a) changes in groundwater geochemistry (pH, Eh, etc), (b) insufficient mass flux of groundwater constituents that participate in the attenuation reaction, and (c) insufficient mass of solids that participate in the attenuation reaction. Long-term stability may be demonstrated by assessing differences between "end member" conditions (pH, Eh, ion loading, etc) using lab testing of site solids, geochemical modeling, and, in some cases, flow and transport modeling under a range of sorption coefficient values. Other methods may be considered and should be discussed with the Regional Office prior to their use.

<u>TIER 4</u>. Conduct performance monitoring. Performance monitoring should be used to demonstrate, over time, that attenuation is occurring as originally demonstrated and proposed in the MNA CAP. Performance monitoring under Tier 4 is, for purposes of this document, the same as the performance monitoring required under 02L .0106 (l) (7). 02L .0106 (l) (7) states that performance monitoring wells should be installed (a) no farther than 5 years travel time downgradient from the plume front, and (b) no closer to the nearest supply well or future use area than 1-year travel time from the plume front. The Regional Office should be consulted if the performance monitoring wells cannot be located

according to these criteria either due to property access issues, plume discharge to a major surface water feature, or supply well locations. Performance monitoring wells should be screened and (or) open to the flow unit with the greatest likelihood for contamination and should be sampled for the same list of constituents and geochemical parameters (pH, Eh, etc.) that were monitored during the contaminant assessment phase.

APPENDIX C. CONTENTS EXPECTED IN BASE MAPS.

Characterization maps (i.e. base maps and COI iso-concentration maps) generally should be orthophoto renderings (semi-transparent) that include the following information. Generally, one characterization map is expected for each source area proposed for an MNA remedy.

(1) property boundary, waste boundary and, if applicable, compliance boundary

(2) 2-foot topographic contours (semi-transparent). In some cases, 5- or 10-foot contours may be acceptable based on consultation with the Regional Office.

(3) all jurisdictional surface waters, permitted (or proposed permitted) outfalls, and seeps. Indicate either "permitted" or "proposed for permitting"; perennial streams should be shown with a blue line that extends unbroken from its headwaters to its point of discharge; a dotted line should be shown for portions of a stream that are piped underground; all wetland areas should be clearly indicated.

(4) all supply wells (referred to as receptors in 2L .0106 (l)(4)) and their associated property boundaries within the predicted maximum plume extent or half mile radius of the compliance boundary, whichever is a longer distance as defined by the most mobile COI.

(5) all shallow monitor wells (different color for each flow unit).

(6) all deep monitor wells (different color for each flow unit).

(7) all bedrock monitor wells (different color for each flow unit).

(8) all abandoned wells (use a gray color).

(9) all wells used only as a water level piezometer due to water production issues (use a different symbol).

(10) all surface water/seep/outfall sample locations.

(11) transect lines associated with any geologic cross sections, attenuation computations, or vertical COI concentrations.

(12) for each sample location in (4) through (10) above, use a line of small font to show the following data in the following order:

Monitor well:

Well identifier (include stratigraphic unit abbreviation in parentheses, followed by screened or open interval in feet below land surface). Ex: MW-3 (BR) 40-75.

most recent leading edge indicator constituent concentration (e.g. boron for coal ash basins), in ug/L, with "up", "down", "stable", or "?" for increasing, decreasing, stable, or uncertain boron trend with time

most recent pH/Eh value

list of abbreviated constituents above 2L/IMAC, along with most recent concentration (ug/L) depth to bottom of ash/waste

depth to top of transition zone (TZ)

depth to top of bedrock

solid phase HFO content; if unknown, state “NM” for not measured.

geomean Kd (show both batch and column geomeans computed for that location) of a sorptive constituent of interest (e.g. arsenic)(e.g. Kd COI (batch geomean)/(column geomean)

geomean Kd (show both batch and column geomeans computed for that location) of a mostly conservative constituent of interest (e.g. boron for coal ash sites) (e.g. Kd COI (batch geomean)/(column geomean)

indication of whether solid phase was analyzed for the list of constituents (if yes, indicate with “COIs*”; if no, indicate with “—“)

depth to seasonal mean high water level (WL)….in parentheses elevation of seasonal mean high WL (ft above mean sea level). Show WL = “dry” as applicable.

geomean of slug test hydraulic conductivity (k) values (ft/day)

Note: For all parameters, use “NM” for not measured.

EXAMPLE: GW-2 (BR, 24-29) B=3200 up, pH=6/Eh=105…B=3200, Co=6.9, Fe=2900, Mn=280…..ash=41, TZ=45, BR=50…HFO=2200, Kd As=3/2900, Kd B=0.1/1, COIs*..…WL=25 (2428)….k=3.2

SW, seep, outfall:

Location identifier (in parentheses include type of SW location….seep, outfall, permitted, etc)

most recent leading edge indicator constituent concentration (e.g. boron for coal ash basins), in ug/L, with “up”, “down”, “stable”, or “?” for increasing, decreasing, stable, or uncertain boron trend with time

list of constituents above 2L/IMAC (seep), 2B (SW), or permit limit (outfall)

indication of whether sediment phase was analyzed for constituents (if yes, indicate with “COIs*”; if no, indicate with “—“).

EXAMPLE: SW-14 (SW) B=200 down, Al, --

Supply well:

well identifier

total depth

casing depth

most recent leading edge indicator constituent concentration (e.g. boron for coal ash basins), in ug/L, with “up”, “down”, “stable”, or “?” for increasing, decreasing, stable, or uncertain boron trend with time

most recent pH/Eh value

list of abbreviated constituents above 2L/IMAC, along with most recent concentration (ug/L)

APPENDIX D – 1995 15A NCAC 2L IMPLEMENTATION GUIDANCE

15A NCAC 2L IMPLEMENTATION GUIDANCE

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November 4, 1993 - Requirements for .0103(e)
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DIVISION OF ENVIRONMENTAL MANAGEMENT

15A NCAC 2L IMPLEMENTATION GUIDANCE

.0103 POLICY GUIDANCE

Purpose of Rule

The Rule defines the general policy of the Environmental Management Commission (EMC) with regard to groundwater protection and use. The Rule also restricts site characterizations and corrective actions to persons licensed by appropriate professional licensing boards.

(a) This is a statement of general policy. The term 'significant' found in the third sentence has no regulatory meaning. The Paragraph is considered to be a statement of fact given to make the reader aware of groundwater conditions in the state and is for informational purposes. The statement does not require any regulatory action or activity toward any person or entity and as a result is not considered regulatory.

(b) Considered to be self-explanatory.

(c) Considered to be self-explanatory.

(d) Considered to be self-explanatory.

(e) Any investigation, assessment, interpretation, characterization, or corrective action plan will require appropriate licensing as specified in .0103(e). Monitoring plans required in .0110 and .0106, and monitoring reports required in .0106 which contain the interpretation of monitoring data likewise require appropriate licensing. Excluded from these requirements are emergency response reports, initial response reports, 24-hour reports, and reports which serve only to transmit information and do not contain data interpretation. Examples of reports and forms submitted to the Division which must be signed and sealed by an individual properly licensed by the state include, but are not limited to:

1) UST Closure Reports (the site assessment portions only)
2) Initial Abatement and Site Check (20-day report)
3) Initial Site Characterization (45-day report)
4) CSA - Comprehensive Site Assessment
5) CAP - Corrective Action Plan
6) Monitoring and Free Product Reports (those which include the interpretation of data)
7) Design of vapor and groundwater monitoring systems
8) RS Designation Applications (15A NCAC 2L .0104)
9) Variance Applications (15A NCAC 2L .0113)

UST Closure reports, Initial Site Characterization Reports, Initial Abatement and Site Check Reports, CSAs, Design of Groundwater or Vapor Monitoring Systems, Monitoring Reports, and CAPs that do not contain plans or designs for active groundwater remediation systems may be prepared and sealed by either a North Carolina Professional Engineer or Licensed Geologist. Active groundwater remediation is defined to mean any remediation method which employs the use of pumps to move liquids and/or gases at a site. All plans and specifications required under .0106 and intended for use in construction of, or for obtaining regulatory authorization to construct an active remediation system must be prepared under responsible charge of a Professional Engineer and must bear the seal of the same. However, preliminary or conceptual site restoration plans which are not intended for use in construction or for obtaining regulatory approval may be prepared by either a Professional Engineer or a Licensed Geologist.

.0104 RESTRICTED DESIGNATION (RS) POLICY GUIDANCE

Purpose of Rule

The Rule establishes a temporary groundwater designation (RS) that is intended to warn the public that groundwater so designated may not be suitable for use as a source of drinking water without treatment. If the groundwater remediation effort is successful, the groundwater will be restored to its original classification. If remedial efforts are unsuccessful, the groundwater may be reclassified as GC.

When groundwater has been contaminated as a result of man's activities, the Director may designate an area of groundwater as RS under any of the following conditions:

-the Director has approved a corrective action plan, or termination of corrective action, and it is evident that the approved plan will not result in restoration of the resource without an extended period of time; or

-a statutory variance to the groundwater standards specified in 15A NCAC .0202 has been granted in accordance with 15A NCAC 2L .0113.

Additionally, any groundwater occurring in an area previously defined within a Compliance Boundary associated with a waste disposal permit is automatically designated RS.

It has been noted that .0104(c), (d), and (e) could be interpreted to conflict with the Compliance Boundary requirements found in 15A NCAC 2L .0107. In all cases the requirements of .0107 will take precedence over those specified in .0104(c), (d), and (e).

(a) Considered to be self-explanatory.

(b) Considered to be self-explanatory.

(c) The determination of the RS boundary must be performed using predictive calculations or computer modeling of environmental contaminant fate and transport. A description of the methodology used, assumptions made and a discussion of the applicability of the modeling to the site are required. All supporting technical data and modeling results must be included with the request. Please refer to Modeling of Contaminant Fate and Transport in the General Information section for further guidance on computer modeling and requisite documentation.

(d) The monitoring program must comply with .0103(e) and must be sufficient to:

-determine the quality of the groundwater within the contaminant plume,
-determine the movement of the plume, and
-ensure that the conditions established for the approved RS area are maintained.

The State may require the installation of additional monitoring wells as conditions change in the RS area.

The term 'increase' refers to an escalation of any chemical parameter concentration above the level determined for the plume at the time the RS designation was approved. An increase in contaminant levels will be reviewed by the Director or his designee. Additional monitoring or remedial action may be required if it is determined or suspected that the increase represents:

-another release which may or may not be associated with the original contaminant release,
-degradation or transformation of the original contaminant into new or related chemical compounds, or
-unknown conditions or circumstances.

(e) The individual responsible for the contamination is considered the 'applicant' for the purposes of this Rule. If a responsible party cannot be identified and the Division initiates the RS designation for an area of groundwater, then the Division shall ensure that all public notification requirements have been met.

(f) The individual responsible for the contamination must submit to the Division any information specified in .0104(f)(2) necessary to complete the required public notice.

(1) The Chief Administrative Officer is considered to be the Mayor, Chairman of the County Commissioners, the County Manager, the City Manager or other individual of equal or similar position as appropriate.
(2) Considered to be self-explanatory.
(3) Considered to be self-explanatory.
(4) Considered to be self-explanatory.

.0106 CORRECTIVE ACTION GUIDANCE

Purpose of Rule

The Rule defines the following:

1) notification and corrective action requirements for permitted and non-permitted facilities;
2) the kinds of data required for approval of alternate cleanup levels, natural remediation, or termination of corrective actions;
3) the conditions in which contaminated groundwater may be designated RS or reclassified as GC; and
4) the conditions in which current remedial activities shall be abandoned in favor of new technologies.

(a) Considered to be self-explanatory.

(b) This Paragraph refers to the discovery of a sudden and unexpected release of a contaminant into the environment. The term 'immediate' is defined as being within a 24 hour period unless there are extenuating circumstances. If the release occurs at a time when it is not possible to report the release to the Division within 24 hours due to weekends or holidays, the morning of the next business day is acceptable. The Paragraph also defines the reporting requirements to the Division of Environmental Management. It has no bearing upon, nor does it affect any rule or regulation defining additional reporting requirements by North Carolina General Statute, the Division of Emergency Management or any federal agency.

(c) This Paragraph is applicable to all contamination incidents resulting from activities which have not been permitted by the Division, including all non-permitted facilities. The term 'immediate' is defined as being within a 24-hour period unless there are extenuating circumstances. If the release occurs at a time when it is not possible to report the release to the Division within 24 hours due to weekends or holidays, the morning of the next business day is acceptable. The Paragraph also defines the reporting requirements to the Division of Environmental Management. It has no bearing upon, nor does it affect any rule or regulation defining additional reporting requirements by North Carolina Statute, the Division of Emergency Management or any federal agency.

(1) Considered to be self-explanatory.
(2) Non-aqueous phase liquids (free product) must be recovered and controlled to the maximum extent feasible. Corrective actions must be initiated as soon as possible following discovery of free product.
(3) Reports must be prepared in accordance with .0103(e).

(4) Corrective action plans must be prepared in accordance with .0103(e). In addition, each CAP must have a properly executed GW-100(c) form, entitled Certification for the Submittal of a Corrective Action Plan Under 15A NCAC 2L .0106(c), attached to the front. Either an original or a legible photocopy of an original form must be used; a CAP will not be accepted if a retyped version of the GW-100(c) form is used. The GW-100(c) forms have been revised since the original November 1993 printing. Copies of current forms are available from the Groundwater Section's regional offices or Pollution Control Branch. Each item on the GW-100(c) certification form must be initialed by hand and the form must bear the seal and signature of the certifying North Carolina-licensed professional [see Section .0103(e) for clarification on the professional jurisdictions of Professional Engineers and Licensed Geologists]. In addition, the CAP must display the seal and signature of the certifying licensed professional.

The term 'prepared' as used on the GW-100(c) form should be construed to mean that the CAP has been prepared under the responsible charge of the certifying licensed professional pursuant to North Carolina Statutes. The term is included on the form because Professional Engineers and Licensed Geologists are prohibited from certifying plans prepared by individuals not working under their direct control and supervision.

The responsible party must report the cause and extent of the release and the corrective actions taken and intended to be taken to mitigate threats to human health and the environment to the local Health Director and the chief administrative officer of the local political jurisdictions [see Section .0114(a)].

(d) This Paragraph is applicable to violations resulting from an activity performed under authority of a permit issued by the Division. Reports and corrective action plans must be prepared in accordance with .0103(e).

(e) Considered to be self-explanatory.

(f)

(1) Considered to be self-explanatory.

(2) Considered to be self-explanatory.

(3) All primary sources of contamination (e.g., leaking storage containers, waste stockpiles, etc.) must be removed, or remediated and controlled. Here 'control' means demonstrating the physical ability to direct restrain or dominantly influence the contaminated media and free product (non-aqueous phase liquid). If needed, initial abatement actions taken to remove, remediate or control primary source(s) of contamination must be initiated prior to, or concurrent with the site assessment activities required under .0106(c) and (d). The goal of free product recovery efforts must be recovery to the maximum extent feasible. Please refer to Source Control in the General Information section for further guidance on the meaning of control.

(4) All secondary sources of contamination (e.g., non-aqueous phase liquids and contaminated soil) must be either remediated (removed or treated), or controlled. Here, 'controlled' means demonstrating the physical ability to direct, restrain or dominantly influence the contaminated media and free product (non-aqueous phase liquid). If needed, initial abatement actions taken to remediate or control secondary source(s) of contamination must be initiated prior to, or concurrent with the site assessment activities required under .0106(c) and (d). The goal of free product recovery efforts must be to recover product to the maximum extent feasible. Please refer to Source Control in the General Information section of this document for further guidance on the meaning of control.

(g) Reporting must be done in accordance with the provisions of .0103(e).

(h) All corrective action plans are submitted pursuant to Paragraph (c) or (d) of this Rule and must meet the requirements of .0103(e) and .0106(j). Please refer to Monitoring in the General Information section for guidance and policy related to monitoring of corrective actions.

(i) Considered to be self-explanatory.

(j) All corrective action plans are submitted pursuant to Paragraph (c) or (d) of this Rule. This Paragraph: (1) reiterates the general Rule that cleanup must restore groundwater to prerelease conditions; and (2) adds the requirement that plans submitted under Paragraphs (c) and (d) must use the best available technology. Best Available Technology (BAT) is considered to be that technology which achieves the specified cleanup goals within a reasonable time frame at the most economical cost per unit of cleanup. For example, a remedial technology which has the capacity to clean up a site in nine months at a cost of $1,000,000 would not be considered the BAT if an alternative technology existed which would accomplish the same goals in twelve months at a cost of $10,000. For those sites at which BAT is required, the Director, or his designee, will review the CAPs to determine if the requested time frames for remedial activities are appropriate and if the technologies proposed can be considered to be the BAT for the site in question.

The Paragraph also recognizes the exceptions to these two general requirements as set out in Paragraphs (k), (l), and (m). Paragraph (l) does not require the use of BAT, but requires restoration to the standards specified in .0202 by the natural processes of degradation and attenuation of contaminants.

Paragraphs (k) and (m) allow for termination of active cleanup prior to achieving the standards in .0202, but contain no exception to the requirement to use BAT. For sites being remediated under Paragraphs (k) and (m), site monitoring will be required until the standards have been achieved by natural attenuation processes.

ALTERNATIVE CORRECTIVE ACTION STRATEGIES

.0106(k), (l) and (m)

(k) The purpose of this Paragraph is to provide a means by which a responsible party may seek approval to actively remediate groundwater to a level other than the standards specified in .0202. Approval of a corrective action plan (CAP) under this Paragraph will be considered only for non-permitted sites for which active groundwater remediation, other than by natural processes, has already been or is proposed to be implemented. Responsible parties will be required to use the Best Available Technology until the alternate standards established under Paragraph (k) are achieved. Please refer to Paragraph (j) for the definition of Best Available Technology.

Requests for approval of remediation to alternate standards will be made as part of the proposed CAP submitted pursuant to Paragraph (c) of this Rule. The request must be based on current site data. A description of site conditions must be included with the CAP; however, previously submitted CAPs, site assessment reports, and monitoring report(s) should be referenced. All critical data should be summarized in figures and tables. The items enumerated in .0106(k) are considered the minimum information needed to consider such a request and should be submitted with the CAP in the order presented in the Rule. The Director may request additional information. In determining whether to approve a CAP submitted under .0106(k), the Director will apply the standard for approval of all corrective action plans set out in Paragraph (i).

The CAP must include a list of all contaminants detected at the site in concentrations which exceed the standards specified in .0202 and their respective proposed cleanup levels. Justification must be provided that the recommended cleanup levels are protective of human health and the environment.

The active remediation phase will be followed by a period of natural attenuation and monitoring until the standards have been achieved. Therefore, it should be understood that .0106(k)(4) and .0106(k)(5) define the minimum degree to which contaminants must attenuate in order for the site to be considered eligible for the provisions of .0106(k), and that monitoring will be required to verify that natural attenuation is occurring. In addition, the proponent must demonstrate to the satisfaction of the Director that the remaining contamination will be remediated to the standards by natural processes within an acceptable period of time. The period of time considered acceptable for remediation will depend on a number of site-specific parameters; therefore, it will vary between sites. Please refer to <u>Natural Attenuation of Groundwater</u> and <u>Monitoring</u> in the General Information section for guidance and policy on demonstrating natural attenuation.

Documentation that groundwater in the area of the plume has not been identified for future use or development by a state or local government planning process must be included in the CAP. This information may be available from the local county or municipal planning offices, local utility commissions, or from the Department of Environment, Health and Natural Resources, Division of Water Resources. An example of documentation which would be satisfactory to meet this requirement is a signed letter from the appropriate governing body stating that no plans are on record for the development of groundwater resources in the area. Alternatively, the CAP proponent may write a letter for the appropriate government representative to sign which confirms that there are no plans for groundwater development in the vicinity of the site. Another option may be to peruse the appropriate government files and planning documents and copy the appropriate portions which serve as evidence that groundwater in the area of the plume will not be developed because another type of development is planned for the area (e.g., a large shopping mall is slated for construction over the contamination area and will be served by municipal water).

Determining Alternate Standards

The CAP must present a listing of proposed alternate cleanup levels for all contaminants detected above 2L standards. Once these levels are achieved, active remedial actions may terminate. One approach to determining appropriate alternate standards for a site is to recognize that the contamination will not be permitted to adversely impact any receptor. First, determine acceptable contaminant concentrations for groundwater at all potentially impacted receptor(s). Then, use contaminant fate and transport calculations or modeling to "back calculate" the cleanup goals for the source area of the plume that will allow natural attenuation processes to reduce the concentrations to acceptable levels by the time the groundwater reaches the receptor(s).

Another method of determining alternate standards which may be acceptable is to base the target concentrations on the projected effectiveness of the most cost-effective remediation technique that is applicable to the site. Target cleanup levels derived in this manner would have to be justified to be protective of human health and the environment.

(1) All sources of contamination and free product have been removed or controlled pursuant to 15A NCAC 2L .0106 (f), and 15A NCAC 2N .0703 and .0705, if applicable.

Demonstrating complete delineation of the soil contamination and non-aqueous phase liquid (secondary sources of contamination) in accordance with Groundwater Section Guidelines for the Investigation and Remediation of Soils and Groundwater and providing an acceptable plan for the remediation or control of all sources may satisfy the meaning of 'controlled' as it pertains to this Rule. Please refer to Section .0106(f)(4) and Source Control in the General Information section for further guidance on control of contamination sources.

(2) Time and direction of contaminant travel can be predicted with reasonable certainty.

The technical basis for the determination of rate and direction of groundwater flow used in modeling and/or calculations must be provided. The direction of contaminant transport should be predicted based on groundwater hydraulic head measurements and should take all nearby pumping, recharge and discharge influences into account. The rate of contaminant transport should be estimated directly from empirical site data or predicted through the use of an appropriate model. Please see Modeling of Contaminant Fate and Transport and Estimating Aquifier Parameters in the General Information section for additional information.

Site monitoring will be required to determine if natural attenuation is occurring, and to test the validity of the conceptual model for the site. Please refer to Monitoring in the General Information section of this document and Rule .0110 for additional information regarding monitoring plans and reports.

(3) Migration of contaminants onto adjacent properties.

In order to be considered for approval, the CAP must demonstrate that at least one of the three conditions described in subsection (k)(3) is true. The term 'served' in (k)(3)(A) means connected to an approved public water supply. Suitable water supplies must meet the regulatory definition of a public water supply and be approved by the Public Water Supply Section of the Division of Health Resources. Documentation, preferably a letter from the utility company, should be provided indicating which households are on public water supply. The CAP must certify that the public water supply is dependent on surface waters or hydraulically isolated groundwater, as applicable.

A map must be provided that shows the current plume boundary as well as all adjacent properties and those down gradient properties where the plume is predicted to migrate. A tax map of the area would be ideal for this purpose. Any supply wells on those properties must be located on the map. An indication of which properties are predicted to be impacted and the technical basis for this determination must also be provided. In addition, a map must be provided which shows the predicted maximum extent of the plume. When applicable under .0106(k)(3)(B), the CAP must include documentation of the property owner's written consent allowing contamination to migrate onto their property. Please see Public Notification in the General Information Section and Section .0114 (b) for additional information.

(4) The groundwater standards specified in 2L.0202 will be met at a location no closer than one year time of travel up gradient of an existing or foreseeable receptor.

All existing and foreseeable receptors must be identified on the base map. Receptors may include but are not limited to utility lines, basements, elevator shafts, public and domestic supply wells, surface waters, and regions of groundwater that have been identified for planned resource development by state or local governments. If a property is to be developed in the future and is served by a public water supply, then planned domestic supply wells might not be considered receptors. Please refer to Identifying Potential Receptors in the General Information section for information on the definition of receptors.

(5) Groundwater discharge will not result in the violation of a surface water quality standard specified in 15A NCAC 2B .0200.

If the groundwater plume is predicted to discharge to surface waters, the CAP must document the technical basis for predicting that such discharge will not result in the violation of a surface water quality standard or criteria, as applicable. The DEM classification of the surface water body (as specified in 15A NCAC 2B) must be included in the CAP. The DEM's Water Quality Section staff may be contacted for information pertaining to surface water classifications, standards and criteria.

If the plume is already discharging to surface waters, the CAP should include recent laboratory analytical results from that water body. Samples should be collected from upstream and downstream of the discharge area, if applicable. All surface water quality data should be provided in table format with lab reports, sample locations and chain of custody forms provided.

(6) Public notice provided in accordance with 15A NCAC 2L .0114(b).

Please refer to Public Notification in the General Information section for policy regarding public notification requirements.

(l) The purpose of this Paragraph is to allow for natural remediation of contaminated groundwater until such time as the affected groundwater conforms with the standards specified in .0202. This Paragraph applies only to sites where the contamination resulted from a non-permitted activity, and does not apply if the site requires any type of ongoing active groundwater remediation. However, for sites which have already undergone active groundwater remediation and which meet the criteria specified in .0106(l), approval may be requested to remediate remaining contamination by natural attenuation processes.

Documentation that groundwater in the area of the plume has not been identified for future use or development by a state or local government planning process must be included in the CAP. This information may be available from the local county or municipal planning offices, local utility commissions, or from the Department of Environment, Health and Natural Resources, Division of Water Resources. An example of documentation which would be satisfactory to meet this requirement is a signed letter from the appropriate governing body stating that no plans are on record for the development of groundwater resources in the area. Alternatively, the CAP proponent may write a letter for the appropriate government representative to sign which confirms that there are no plans for groundwater development in the vicinity of the site. Another option may be to peruse the appropriate government files and planning documents and copy the appropriate portions which serve as evidence that groundwater in the area of the plume will not be developed because another type of development is planned for the area (e.g., a large shopping mall is slated for construction over the contamination area and will be served by municipal water).

In order to be granted approval to remediate any site by natural attenuation processes, it must be demonstrated to the satisfaction of the Director that the contaminant(s) in question can be remediated to .0202 standards within an acceptable period of time. The period of time considered acceptable for remediation will depend on a number of site-specific parameters; therefore, it will vary between sites. Please refer to Natural Attenuation of Groundwater in the General Information section for additional information and guidance. In determining whether to approve a CAP, the Director will apply the standard for approval of all corrective action plans set out in Paragraph (i).

(1) All sources of contamination and free product have been removed or controlled pursuant to 15A NCAC 2L .0106 (f), and 15A NCAC 2N .0703 and .0705, if applicable.

Demonstrating complete delineation of the soil contamination and non-aqueous phase liquid (secondary sources of contamination) in accordance with Groundwater Section Guidelines for the Investigation and Remediation of Soils and Groundwater and providing an acceptable plan for the remediation of those sources may satisfy the meaning of 'controlled' as it pertains to this Rule. Please refer to Section .0106(f)(4) and Source Control in the General Information section for further discussion on control of contamination sources.

(2) The contaminant has the capacity to degrade or attenuate under site-specific conditions.

Please refer to the Natural Attenuation of Groundwater, Natural Attenuation of Soil, and Natural Attenuation of Bedrock Contamination in the General Information section for further information.

(3) Time and direction of contaminant travel can be predicted with reasonable certainty.

The direction of contaminant transport should be predicted based on groundwater hydraulic head measurements and should take all nearby pumping, recharge and discharge influences into account. The technical basis for determining values for aquifer parameters used in modeling of contaminant transport must be provided in the CAP. The rate of contaminant transport should be estimated directly from empirical site data or predicted through the use of an appropriate model. Please see Modeling of Contaminant Fate and Transport and Estimating Aquifer Parameters in the General Information section for additional guidance.

(4) Contaminant migration will not result in any violation of groundwater standards at any existing or foreseeable receptor.

All existing and foreseeable receptors must be identified on the base map. Receptors may include but are not limited to utility lines, basements, elevator shafts, public and domestic supply wells, surface waters, and regions of groundwater that have been identified for planned resource development by state or local governments. If a property is to be developed in the future but is served by a public water supply, then planned domestic supply wells might not be considered receptors. Please refer to Identifying Potential Receptors in the General Information section for information on the definition of receptors.

(5) Migration of contaminants onto adjacent properties.

In order to be considered for approval, the CAP must demonstrate that at least one of the three conditions described in subsection (l)(5) is true. The term 'served' in (l)(5)(A) means connected to an approved public water supply. Suitable water supplies must meet the regulatory definition of a public water supply and be approved by the Public Water Supply Section of the Division of Health Resources. Documentation, preferably a letter from the utility company, should be provided indicating which households are on public water supply. The CAP must certify that the public water supply is dependent on surface waters or hydraulically isolated groundwater, as applicable.

A map must be provided that shows the current plume boundary as well as all adjacent properties and those down gradient properties where the plume is predicted to migrate. A tax map of the area would be ideal for this purpose. Any supply wells on those properties must be located on the map. An indication of which properties are predicted to be impacted and the technical basis for this determination must also be provided. In addition, a map must be provided which shows the predicted maximum extent of the plume. When applicable under .0106 (l)(5)(B), the CAP must include documentation of the property owner's written consent allowing contamination to migrate onto their property.

(6) Groundwater discharge may not result in the violation of a surface water quality specified in 15A NCAC 2B.0200.

If the groundwater plume is predicted to discharge to surface waters, the CAP must document the technical basis for predicting that such discharge will not result in the violation of a surface water quality standard or criteria, as applicable. The DEM classification of the surface water body pursuant to 15A NCAC 2B must be specified in the CAP. The DEM's Water Quality Section staff may be contacted for information pertaining to surface water classifications, standards and criteria.

If the plume is already discharging to surface waters, the CAP should include recent laboratory analytical results from that water body. Samples should be collected from upstream and downstream of the discharge area, if applicable. All surface water quality data should be provided in table format with lab reports and chain of custody forms provided.

(7) Groundwater monitoring program.

A groundwater monitoring program sufficient to track the migration, degradation and attenuation of contaminants and contaminant byproducts must be included in the CAP. Rule .0110 specifies the requirements of monitoring plans and reports. Proposed monitoring wells must include one or more well(s) placed in the zone defined to be:

-at least one year of groundwater travel time up gradient of the closest, down gradient existing or foreseeable receptor; and
-no further down gradient from the current leading edge of the plume than the distance groundwater is predicted to travel in five years.

Please refer to Natural Attenuation of Groundwater and Monitoring in the General Information section for additional information on site monitoring.

(8) Access agreements.

Documents must be included with the CAP documenting that all necessary access agreements needed to monitor groundwater quality have been or can be obtained.

If access necessary for monitoring natural attenuation cannot be obtained, the site will not be considered approvable under .0106(l).

(9) Public notice provided in accordance with 15A NCAC 2L .0114(b).

Please refer to Public Notification in the General Information section for information regarding public notification.

(m) The purpose of this Paragraph is to provide a mechanism whereby a responsible party may seek approval to terminate active remediation prior to achieving the groundwater standards. A corrective action plan submitted pursuant to this Paragraph must demonstrate that continued operation of the remediation system will not result in a significant decrease in dissolved contaminant concentrations. The items enumerated in .0106(m) are considered the minimum information needed to consider such a request and should be submitted with the CAP in the order presented in the Rule. The Director may request additional information. In determining whether to approve a CAP, the Director will apply the standard for approval of all corrective action plans set out in Paragraph (i).

It should be understood that .0106(m)(4) defines the minimum degree to which a contaminant must degrade or attenuate in order for termination of corrective action to be approved. If a contaminant plume does not have the capacity to achieve compliance within the defined time of travel, the site is not eligible for the provisions specified in .0106(m). Please refer to Natural Attenuation of Groundwater in the General Information section for additional guidance.

(1) Considered to be self-explanatory.

(2)(A) Continued corrective action will not significantly reduce contaminant concentrations.

The asymptotic slope described in this Paragraph is used as a means of determining the rate at which remediation is progressing. In order to qualify for the provisions in .0106(m), a showing must be made that current remedial efforts have produced their maximum result in terms of lowering the concentration of contaminant compounds in groundwater. The slope is determined from the curve representing the concentration of the dissolved contaminants over time. The contaminant concentrations must be in milligrams per liter and the time scale must be months. The absolute value of the slope of the curve of decontamination (which is a negative slope) must be less than or equal to one unit of chemical contamination remediated during the course of 40 months, and greater than or equal to zero. Therefore, if the absolute value of the slope is calculated to be equal to or less than a ratio of 1:40, then the stipulations of .0106(m)(2)(A) have been met. Please note that the slope of the curve must be calculated mathematically and may not be determined by measuring directly from a graph. However, a graphical representation of the data must be included with the CAP.

A minimum of four quarters of monitoring data must be used to graph and evaluate the curve of decontamination. Using the ratio of one milligram per liter over 40 months, the decrease in the concentration of a contaminant in groundwater cannot exceed 300 micrograms per liter in the previous 12 month period to be eligible for approval under .0106(m). If a "best fit" curve is used to fit the data, the CAP must include an explanation of the type of statistical analysis performed.

The demonstration of asymptotic slope must be made for each contaminant detected in concentrations exceeding the groundwater standards listed in .0202. The demonstration cannot be based on total organic compounds, total BTEX, total petroleum hydrocarbons, etc. Additionally, the slope determination must be made for data from all existing monitoring wells which have had contaminants detected in concentrations exceeding the standards. Groundwater samples used for determining the slope of decontamination must be collected from properly constructed monitoring wells; data collected from remediation wells cannot be used. Please note that improperly designed, constructed or operated remediation systems may render a site ineligible for the provisions of Paragraph (m).

(2)(B) Migration of contaminants onto adjacent properties.

In order to be considered for approval, the CAP must demonstrate that at least one of the three conditions described in subsection (m)(2) is true. The term 'served' in (m)(2)(B) means connected to an approved public water supply. Suitable water supplies must meet the regulatory definition of a public water supply and be approved by the Public Water Supply Section of the Division of Health Resources. Documentation, preferably a letter from the utility company, should be provided indicating which households are on public water supply. The CAP must certify that the public water supply is dependent on surface waters or hydraulically isolated groundwater, as applicable.

A map must be provided that shows the current plume boundary as well as all adjacent properties and those down gradient properties within and contiguous to the area where the plume is predicted to migrate. A tax map of the area would be ideal for this purpose. Any supply wells on those properties must be located on the map. An indication of which properties are predicted to be impacted and the technical basis for this determination must also be provided. In addition, a map must be provided which shows the predicted maximum extent of the plume. When applicable under .0106(m)(2)(B)(ii), the CAP must include documentation of the property owner's written consent allowing contamination to migrate onto their property.

(2)(C) Groundwater discharge will not result in the violation of a surface water quality standard specified in 15A NCAC 2B .0200.

If the groundwater plume is predicted to discharge to surface waters, the CAP must document the technical basis for predicting that such discharge will not result in the violation of a surface water quality standard. The DEM classification of the surface water body pursuant to 15A NCAC 2B must be specified in the CAP. The DEM's Water Quality Section staff may be contacted for information pertaining to surface water classifications, standards, and criteria.

If the plume is already discharging to surface waters, the CAP should include laboratory analytical results of recent sampling of that water body. Analyses should include samples from upstream and downstream of the discharge area, if applicable. All surface water quality data should be provided in table format with a description of sampling locations, lab reports and chain of custody forms also included.

(2)(D) Public notice provided in accordance with 15A NCAC 2L .0114(b).

Please refer to Public Notification in the General Information section for policy regarding public notification requirements.

(3) Groundwater development not planned.

Documentation that groundwater in the area of the plume has not been identified for future use or development by a state or local government planning process must be included in the CAP. This information may be available from the local county or municipal planning offices, local utility commissions, or from the Department of Environment, Health and Natural Resources, Division of Water Resources. An example of documentation which would be satisfactory to meet this requirement is a signed letter from the appropriate governing body stating that no plans are on record for the development of groundwater resources in the area. Alternatively, the CAP proponent may write a letter for the appropriate government representative to sign which confirms that there are no plans for groundwater development in the vicinity of the site. Another option may be to peruse the appropriate government files and planning documents and copy the appropriate portions which serve as evidence that groundwater in the area of the plume will not be developed because another type of development is planned for the area (e.g., a large shopping mall is slated for construction over the contamination area and will be served by municipal water).

(4) Groundwater monitoring program.

A groundwater monitoring plan sufficient to track the migration, degradation and attenuation of contaminants and contaminant byproducts at a location at least one year time of travel up gradient of any existing of foreseeable receptor must be provided in the CAP. The monitoring requirement should be construed to mean that the migration of the contaminant plume must be restricted. More specifically, the contaminant plume must conform to the groundwater standards specified in .0202 at the location one year's predicted time of travel up gradient of any receptor. Please refer to Monitoring in the General Information section for further policy and guidance related to monitoring. Additionally, Natural Attenuation of Groundwater in the General Information section provides guidance on monitoring sites undergoing natural attenuation.

General Information

Source Control

Primary and secondary sources of contamination are required by .0106(f) to be removed or controlled. 'Control' is defined to mean the physical ability to direct, restrain or dominantly influence non-aqueous phase liquid (free product) and other source(s) of contamination. Demonstrating complete delineation of all soil contamination and providing an acceptable plan for its remediation may satisfy the meaning of 'control' as it pertains to .0106. Similarly, providing continued delineation of non-aqueous phase liquid and providing an acceptable plan for its continued recovery and containment may satisfy the meaning of control of free product.

Contamination that is trapped in the capillary fringe and saturated zone may continue to leach to groundwater, resulting in unreasonably long remediation and monitoring periods. The effect of residual contamination is especially critical if natural attenuation processes will be relied on for remediation. Therefore, **the assessment of contaminant sources should include the delineation of any significant soil contamination and free product existing in the capillary fringe or saturated zones** near the source area or "hot spot" of the plume. If trapped or residual soil contamination is discovered in or near the saturated zone, the CAP should include a discussion of options for its remediation. A cost-benefit analysis which takes long-term monitoring into consideration should be provided for viable remedial options.

It is important to note that soil contamination which occurs down gradient of the source area in a relatively narrow, horizontal zone at or near the water table surface (i.e., in the capillary fringe) may have resulted from the adsorption of dissolved contaminants to the soil. This soil contamination is considered to be the result of the migration of the groundwater contamination; therefore, it is not generally considered a source of contamination.

In general, the use of impermeable barriers (caps) will not be approved as a method for exerting control over contamination source areas. However, in some cases where site conditions preclude the possibility of source remediation and an impermeable barrier exists, the impermeable barrier may be considered to provide control of the secondary contamination sources. However, it must be demonstrated that that the CAP will prevent water from leaching contaminants from the source area and causing groundwater contamination in excess of the standards specified in .0202. The CAP must include a discussion on the expected effectiveness, integrity and cost of the barrier over an extended period of time. A discussion of the projected future uses of the site, including potential exposure pathways, must also be provided in the CAP. Additionally, the proponent should be aware that a low permeability cap may limit the availability of terminal electron acceptors and nutrients necessary for effective in situ biodegradation.

One example where a barrier or cap may be approved to control secondary soil contamination is a situation where a No. 6 fuel oil release has occurred in clayey soil under a manufacturing facility. In this example, the fuel does not contain enough volatile constituents to effectively strip using a vacuum extraction technique. Furthermore, due to the nature of the soil and the contamination, the rate of natural attenuation will be slow. Demolition of the building in order to excavate the soil may be cost-prohibitive, and leaving the building in place could serve as a barrier to prevent leaching of contaminants to the groundwater. If it can be demonstrated that leachate will not cause a groundwater standards violation, then the soil contamination may be considered to be controlled by the presence of the low permeability cap.

Natural attenuation may be an approved method of remediation or control for soil contamination under some circumstances. Please refer to <u>Natural Attenuation of Soil</u> for policy guidance on the applicability of natural attenuation to soil contamination.

<u>Natural Attenuation of Groundwater</u>

The CAP should reference the publication(s) which indicate that the contaminants have the capacity to attenuate under appropriate conditions. For example, research has shown that the BTEX compounds (benzene, toluene, ethyl benzene, xylenes) can readily biodegrade under aerobic conditions, and may degrade at lower rates in some anaerobic environments. In contrast, trichloroethylene (TCE) has not been demonstrated to readily degrade under aerobic conditions but may degrade in some anaerobic settings. Further, many dissolved organic and inorganic compounds attenuate due to adsorption to aquifer material, especially when it contains a relatively high percentage of organic carbon.

The CAP must document that conditions at the subject site are conducive to natural remediation processes and should present any evidence that natural attenuation is occurring at the site. A demonstration of natural attenuation may be based on direct evidence such as monitoring data which shows the plume decreasing in volume and concentration. Indirect evidence may also demonstrate that natural attenuation is occurring at the site. Such a demonstration may include, but is not limited to, showing: decreases in terminal electron acceptors, increases in the byproducts of microbial respiration, and the presence of a significant population of bacteria capable of degrading the contaminants. In addition, the CAP should indicate which site-specific parameters are predicted to limit the rate of biodegradation and natural attenuation.

If groundwater remediation by natural attenuation is proposed for a site where trapped contamination exists in the capillary fringe and saturated zone, the CAP should contain a discussion on the effect the residual contamination will have on the timing and success of remedial efforts. This discussion should generally include estimates of leachate concentrations for the contaminants of concern based on their concentrations in the soil or aquifer matrix and other site-specific parameters. Please refer to <u>Selecting Contaminants of Concern</u> in the General Information section for further guidance.

The CAP should also include a discussion of the relative toxicity and environmental fate of potential chemical compounds which may result from incomplete degradation of contaminants, if applicable. This information may be available in the literature or may be determined from site data. For example, TCE has been demonstrated to degrade to vinyl chloride under anaerobic conditions. Vinyl chloride is more toxic and presents more potential risk than the parent compound from which it was produced. Potential breakdown products should be also be considered in monitoring plans.

Adsorption is another natural attenuation process that can be considered in the CAP. Soil and aquifer matrices with high organic carbon content have greater adsorption potential for hydrophobic contaminants and, therefore, tend to retard contaminant transport. Total organic carbon (TOC) values are used to determine fraction organic carbon (f_{oc}). When the contaminants are organic chemicals, soil and aquifer matrix samples collected for TOC analysis must be collected from an uncontaminated area. If the samples were collected from zones containing organic compounds, the measured TOC fraction would be too great and estimates of retardation rates due to adsorption to organic carbon would be too high. Furthermore, samples collected for TOC analysis should come from the zone(s) within the aquifer that contain the contamination. This is because dissolved contamination is commonly demonstrated to migrate preferentially through more transmissive zones within an aquifer.

TOC values will generally range from 0.1% to 1% for aquifer matrix, and from 1% to 3.4% for surficial soils. If higher values are used for predictive calculations or modeling, they must be based on lab analyses for samples collected as indicated above. All estimated values must be justified to be conservative for the soil type(s) present at the site. It is important to note that organic compounds may adsorb to mineral surfaces if the TOC in the sediment is low. This process is particularly important in fine-grained sediments which have a high surface area to volume ratio.

Research has provided a general understanding of site conditions which are amenable to natural attenuation of dissolved phase contamination. The aquifer matrix must be sufficiently permeable to allow for the diffusion and advection of nutrients and terminal electron acceptors. Sites with saturated hydraulic conductivity (K) values greater than 10^{-4} cm/sec are usually considered good candidates. The pH of the groundwater, which affects microbial viability and the availability of nutrients, should be between 6 and 8 for optimal microbial growth. Natural attenuation may be marginally effective at sites with a pH slightly outside of this range. Aquifer temperatures in North Carolina are generally within the acceptable range (5 to 45 degrees Celsius) for bioremediation. Ideally, the carbon:nitrogen:phosphorous (C:N:P) ratio in the aquifer should be between 100:10:1 and 100:1:0.5. Both organic nitrogen (measured as total organic nitrogen) and inorganic nitrogen (measured as ammonia, nitrate and nitrite) may be available to organisms.

A well-aerated aquifer could contain dissolved oxygen concentrations near 8 milligrams per liter. Background dissolved oxygen levels greater than 2 milligrams per liter are generally considered adequate to support aerobic biodegradation. However, because oxygenated water intersects the contaminant plume at its periphery, most aerobic biodegradation occurs at the plume margins. Therefore, the core of the plume will generally be anaerobic.

Groundwater parameters that may be appropriate for analysis at potential natural remediation sites include: contaminant concentrations, concentrations of intermediate compounds formed by degradation of contaminants, nutrient concentrations, pH, redox potential (Eh), terminal electron acceptors (e.g., oxygen, nitrate, sulfate, Fe^{3+}, Mn^{4+},Mn^{3+},etc.), and byproducts of respiration (e.g., carbon dioxide, methane, Fe^{2+} , Mn^{2+}, etc.). Eh measures a solution's ability to accept or transfer electrons, and provides indirect information on the oxygen content of the plume. Not all of the parameters listed above are required to be measured at every site; in some cases an adequate evaluation can be done based on some of these indicator parameters. However, if natural attenuation is proposed for marginal sites, the proponent will want to provide as many lines of evidence as is reasonable to support the claim that natural processes will remediate the plume.

All parameters analyzed for and the values obtained must be reported in the CAP. A description of the methods used for all analyses and site measurements, and justification of their applicability to the site, must also be provided. For field measurements, the instrument type and calibration method should also be provided. Any parameter values that were not measured directly but were calculated or estimated by other means must be justified and conservative. Conservative values will result in the prediction of worst-case scenarios for contaminant transport and remedial progress.

Direct measurement of natural attenuation involves analyzing for contaminant concentrations periodically and comparing these values to historic values. If the plume is no longer expanding and the contaminant concentrations are diminishing [which generally occurs only if the contaminant sources have been remediated, or if the groundwater plume has achieved a steady-state (equilibrium) with residual contamination] then natural attenuation may be assumed to be occurring at the site. For sites where the plume is still expanding, natural attenuation may be demonstrated if it can be shown that the rate of contaminant transport is significantly less than the estimated rate of linear groundwater velocity. For some sites, the rate of natural attenuation may be estimated by comparing concentration decreases along the longitudinal axis of the plume for contaminants that readily attenuate with contaminants that are known to be recalcitrant to attenuation (Wiedemeier et al., 1995; McAllister and Chiang, 1994; see the attached reference list).

Indirect indicators of natural attenuation may include a decrease in the concentrations of dissolved oxygen and other terminal electron acceptors relative to levels in uncontaminated background wells. Similarly, an increase in concentration of the products of redox reactions may provide evidence for natural attenuation. For example, an increase in dissolved Fe^{3+} in the plume, as compared to up gradient wells, may indicate that anaerobic biodegradation is occurring (Wiedemeier et al., 1995; McAllister and Chiang, 1994; see the attached reference list).

Natural Attenuation of Bedrock Contamination

Natural attenuation will generally not be approved for sites where contamination occurs in bedrock (e.g., fractured rock, permeable carbonate rock). This policy is based on two considerations: 1) dispersion may be the principal attenuation mechanism causing the plume to attenuate in bedrock, and 2) a reasonable estimate of the rate and direction of contaminant transport will be difficult or impossible to obtain.

However, approval may be granted for some sites where no potential receptors are identified, and contaminant concentrations are low enough to allow for the designation of a compliance boundary (radius) beyond which it can be certified that contaminants will not exceed the standards. **Approval may be granted on a case-by-case basis if all of the following conditions are met:**

- -the CAP certifies that contamination exceeding the standards is not predicted to migrate beyond the compliance boundary specified in the CAP,
- -implementation of the CAP will not result in impacts to receptors or surface water,
- -the assessment demonstrates a knowledge of where the contamination is located in the subsurface,
- -the CAP proposes a monitoring plan sufficient to track the migration of the plume and to serve as a warning system to protect potential receptors, and
- -public notification has been made to all owners and occupants of properties that could be impacted by the migration of the plume.

It is important to recognize that the primary attenuation process that is likely to occur in bedrock environments is dispersion. Therefore, CAPs submitted pursuant to this Paragraph may not be approved if contaminant levels are so high that a large volume of the aquifer would be required to effectively disperse the plume. Additionally, a detailed assessment of contaminant migration pathways and a more elaborate monitoring well network, including nested wells screened at discreet intervals, may be required. Approval of CAPs for bedrock contamination sites will not be granted on the basis of a lack of knowledge of site conditions.

Natural Attenuation of Soils

Natural attenuation of contamination in the unsaturated (vadose) zone primarily involves the processes of biodegradation, dissolution, and adsorption to soil matrix. **Natural attenuation may be approved for remediation of contaminated soil if all of the following conditions apply:**

- -petroleum hydrocarbon contamination concentrations exceed the cleanup levels derived from the Site Sensitivity Evaluation (SSE),
- -the soil contamination has not caused groundwater contaminant concentrations to exceed the standards specified in .0202,
- -leachate from the contaminated soil is not predicted to create a groundwater violation at any time in the future,
- -the contaminant has the capacity to degrade or attenuate under site specific conditions,
- -soil remediation by other methods is not economically or technically reasonable due to site conditions and /or the nature of the contaminant, and
- -the contaminated soil will not pose a threat to human health due to soil ingestion, inhalation or absorption through skin contact.

Scientific literature provides various analytical methods for calculating leachate concentrations. A reference for a peer-reviewed formula is provided in the list of selected references which accompanies this document (see Menatti, 1994). In addition, several computer models which calculate soil leachate concentrations are commercially available (e.g., SESOIL, JURY). All estimated parameters must be conservative and predict worst-case scenerios.

The following rules of thumb for natural attenuation of petroleum-contaminated soil should be considered when developing a CAP for natural attenuation of soil. The soil pH, which affects both the viability of organisms and the availability of nutrients, should be between 5.5 and 8.5, with 6.5 to 8 considered optimal. Seasonal average soil temperature should be between 15 and 45 degrees Celsius. Average soil temperatures for sites in North Carolina are within this range. The optimal carbon:nitrogen:phosphorous (C:N:P) ratio in the soil is between 100:10:1 to 100:1:0.5. Both organic nitrogen (measured as total organic nitrogen) and inorganic nitrogen (measured as ammonia, nitrate and nitrite) may be available to organisms. Soil moisture should be within the range of 25% to 85% of its water-holding (field) capacity; 50% to 80% is optimal. Too little moisture in the soil can limit the presence of microbes; too much moisture may occlude pore space, thereby limiting the rate of air flow through the soil. The air filled porosity should be at least 10% of the total porosity in order to allow for adequate replenishment of oxygen in the soil. In general, the intrinsic permeability of the contaminated soil should be $>10^{-10}$ cm^2. Intrinsic permeability is a measure of the permeability of the matrix to fluid and is independent of the fluid type. Saturated hydraulic conductivity for the soil should be greater than 10^{-5} cm/sec. Clays and very clay-rich sediments generally do not have sufficient air permeability to allow oxygen to be supplied at a rate adequate to support biodegradation. However, soil structures, if present, may increase soil permeability above that expected on the basis of sediment grain size analysis only.

In addition to the above parameters, several soil analyses and measurements can be done which may provide evidence that natural attenuation is occurring in the soil. Measurements made on soil from the zones of contamination must be compared with measurements from uncontaminated background areas. Reduced concentrations of oxygen (soil gas or dissolved in pore water), nitrogen, phosphorous, oxidized iron (Fe^{3+}), oxidized manganese (Mn^{4+}, Mn^{3+}), or sulfate (SO_4^{2-}) may indicate that biodegradation is occurring at the site. An increase in reduced iron (Fe^{2+}) or reduced manganese (Mn^{2+}) may indicate anoxic conditions, which can be the result of biodegradation. An increase in carbon dioxide (CO_2) or methane (CH_4) in the soil gas can indicate anaerobic respiration. However, methanogenic organisms are sensitive to pH and generally do not thrive in soil with a pH below 6.0 (i.e., acidic soil). Because the majority of soils in North Carolina are acidic, anaerobic degradation of contamination by methanogenic bacteria is not typically a major attenuation process.

Please note that not all of the parameters listed above are required to be measured at every site; in some cases an adequate evaluation can be accomplished based on some of these parameters. However, if natural attenuation is proposed for a marginal site, then the proponent will want to provide as many lines of evidence as is reasonable to support the claim that natural processes will remediate the plume.

Because they represent actual field conditions, field measurements for natural attenuation indicators are generally preferable to laboratory plate count studies or bench-scale tests. Soil gas respirometry studies are commonly used to measure indications of in situ biodegradation. These studies involve field measurements of soil oxygen depletion and the production of carbon dioxide (or methane) as byproducts of microbial respiration. Soil gas measurements made in the zone of contamination must be compared with measurements made in uncontaminated background areas to determine if biodegradation is occurring at the site. In general, laboratory microcosm studies (bench tests) do not duplicate field conditions and are not necessary for demonstrating the applicability of natural attenuation to a particular site.

If, due to the nature and/or concentration of contaminants, toxicity to microbes is suspected, then plate counts of aerobic or anaerobic heterotrophs [measured in colony forming units (CFU)] should be measured in the lab. These tests are necessary only when there is reason to suspect that toxic or marginal conditions may exist at the site. Values below 1000 CFU/gram may indicate either a toxicity problem or the lack of nutrients necessary to support microbial metabolism. Plate counts specific for petroleum degrading bacteria can also be done. Soil samples for microbial plate counts must be collected aseptically using sterile sampling equipment and must be maintained at approximately four degrees Celsius. Samples must not be frozen.

Monitoring natural attenuation of soil contamination must include analyzing soil samples for the contaminants of concern. In addition, the monitoring plan should include periodic soil gas respirometry tests or other indirect measurements of natural attenuation. A monitoring well will be required to verify that groundwater is not impacted. If possible, this well should be installed just outside of the soil contamination in a down gradient location. A well installed through the contaminated soil has the potential to create an artificial pathway for contaminant migration which could result in groundwater contamination. The monitoring frequency for natual attenuation of soil contamination may vary between sites, but in general will be required less often than for groundwater remediation sites. The Director will consider all reasonable proposed monitoring plans.

Selecting Contaminants of Concern

Contaminants of concern must be chosen so that the behavior of the entire plume can be modeled conservatively based on those compounds. The selection criteria must be explained in the CAP. For complex chemical mixtures such as petroleum fuels, the contaminants of concern will generally be those chemicals which:

-have the highest solubility in water,
-are the most toxic,
-form toxic chemicals as a result of incomplete degradation, and/or
-are least susceptible to environmental attenuation processes.

Residual soil and/or free product with the potential to leach to groundwater should be analyzed for the concentrations of contaminants of concern. These values may be used to calculate leachate concentrations and to predict contaminant fate and transport using analytical or computer models.

Estimating Aquifer Parameters

For sites with potentially impacted receptors (i.e., situations where the most accurate data possible is necessary due to a potential threat to human health or the environment) and sites where the data are needed to properly design remediation systems, aquifer pumping tests may be required to estimate values of aquifer parameters. However, for sites where potential receptors have not been identified, an aquifer pumping test may not be required to obtain estimated values for hydraulic conductivity (K) and transmissivity (t). In these cases, an alternative means of estimating aquifer characteristics may be adequate.

For example, it may be acceptable at some sites to perform textural analysis on soil samples collected from the zone(s) of contamination and to base conservative estimates of aquifer characteristics on published values for K corresponding to the soil types present. Any observed soil or relict rock structures should be considered for potential affects on contaminant transport. In addition, the scientific literature provides methodologies for estimating K from grain size distribution data [Hazan, 1911; Masch and Denny, 1966; Sherard, Dunningan and Talbot, 1984].

Alternatively, or in addition to soil data, the use of slug test data may be used to estimate K. It is important to recognize for assessment and monitoring purposes that dissolved contamination generally migrates in the most transmissive media. Therefore, slug tests should be conducted in the zones through which contamination is migrating. Further, for aquifers with significant heterogeneity, several slug tests should be performed in order to obtain a range of values for contaminant transport rates. Please refer to the Groundwater Section's policy statement on the use of slug tests, dated October 6, 1995. Copies of this policy may be obtained from the regional offices or from the Pollution Control Branch.

Another method which may be used to estimate contaminant transport rates is to utilize the site monitoring history in cases where the approximate release date is known or where monitoring has tracked the migration of the plume over time. If site data demonstrate the approximate time elapsed for contaminants to migrate from one down gradient monitoring well to another, an estimate of the transport rate may be calculated. By comparing this empirically-derived contaminant transport rate with the estimated linear (seepage) velocity for groundwater flow, a rate for natural attenuation may be estimated for the site.

Regardless of how the groundwater linear velocities and contaminant transport rates are estimated, the values should always be conservative. In order to predict a worst-case scenario, it should be generally assumed that there will be no contaminant losses from volatilization. Further, unless significant organic carbon is documented to be present in the zone(s) through which the contamination is migrating, adsorption to aquifer material should be assumed to be a minor component of natural attenuation. Please note that the soil samples for total organic carbon (TOC) analysis should be collected from an uncontaminated area representative of the contaminant-bearing zones of the aquifer. If the sample is collected from an area containing significant contamination by organic compounds the value for TOC could be artificially high causing estimates of retardation due to adsorption to be too high.

A potentiometric surface map (superimposed on the base map) which identifies the location of the current plume and all potential receptors must be included in the CAP. The location of one year of groundwater travel time up gradient of the existing or foreseeable receptor closest to the leading edge of the plume must be indicated on the map, if applicable. All current and proposed monitoring wells must also be located on the base map. Isoconcentration maps based on the most recent analytical data should also be included.

Modeling of Contaminant Fate and Transport

Contaminant fate and transport calculations or computer modeling will often be necessary to predict the maximum extent to which the plume is expected to migrate. This is particularly important if it cannot be demonstrated that the rate at which contaminants are entering the dissolved phase has reached a steady-state equilibrium with natural attenuation processes and that the plume is not expanding. Predictive calculations or modeling will be used to provide assurance that potential receptors will not be impacted and that monitoring plans are adequate to track plume migration. In addition, they will ensure that all parties required under .0114(b) to be notified have been identified.

In order to model contaminant transport, the distribution and concentrations or mass fraction of the contaminants of concern for any residual contaminated soil, aquifer material, or free product present at the site must be identified. The contaminants of concern must be chosen so that the behavior of the entire plume can be modeled conservatively based on those compounds. Please refer to Selecting Contaminants of Concern in the General Information section for additional guidance.

The concentrations of the contaminants of concern may be used to calculate leachate concentrations and to predict contaminant fate and transport using analytical or numerical (computer) models. A decaying source may be used in numerical models to simulate a source area which is undergoing remediation.

A tiered approach should be used for contaminant fate and transport modeling. The first step in evaluating plume migration is to develop an appropriate conceptual model of contaminant distribution and the hydrogeologic framework of the site. Then, the available site monitoring history should be reviewed to see if it can be determined empirically that the plume has reached a steady state (equilibrium) configuration or is shrinking in size and concentration. If the data are insufficient to make this determination, simple analytical calculations may be used to predict retardation factors and contaminant transport rates (Wiedemeier et al., 1995; McAllister and Chiang, 1994). The use of simple, one-dimensional computer models may also be considered.

Two- and three-dimensional models should not be utilized unless the amount and quality of site data warrants their use. If these complex models are run using many estimated input values, the model output may not be worth the effort and expense. Furthermore, several years of monitoring data are often needed to properly calibrate a numerical model. If these data are available, it might be sufficient to base predictions of transport and attenuation rates on site history alone, thereby eliminating the need to run a computer model.

Because all models are based on severely simplifying assumptions about the site, implementation of CAPs based on modeling will rely heavily on site monitoring. The monitoring network will provide an early warning system and will provide data necessary to reevaluate predictions. **Computer modeling efforts must be well documented in order to be considered acceptable. At a minimum, this documentation must include:**

-the name, version, and developer of the model,
-the type of sites for which the model was designed and/or is applicable,
-critical assumptions inherent to the model,
-critical conceptual assumptions and estimates of input values made by the modeler,
-a description of the calibration process used by the modeler,
-a description of the range of values used and the results of sensitivity analyses on critical data inputs to the model, and
-a graphical representation and narrative explanation of the modeling results.

Please note that all assumptions and estimated values must be documented in the CAP to be conservative. Conservative estimates are values that predict worst-case scenarios.

<u>Identifying Potential Receptors</u>

The meaning of 'foreseeable receptor' as used in .0106 is defined to include any receptor listed in Rule .0102 (19). Additionally, a foreseeable receptor may be any property where the groundwater resources have a potential use, public water is not available, and the permission of the area property owners allowing contamination to migrate onto their land has not been obtained, including:

-locations for which formal plans exist to use groundwater for public or private use;
-locations for which the property owner(s) has expressed an anticipated or possible future use of groundwater resources;
-rural locations for which public water supplies will most likely not be available for future residential, agricultural or industrial development and the owner(s) has expressed a future anticipated use; and
-locations where the land ownership cannot be determined at present.

Utilities will not be considered receptors unless they are predicted to be adversely impacted. If the plume is predicted to intercept utilities, the CAP must contain a discussion on the physical integrity of the construction materials (e.g., PVC, polyethylene, glues, gaskets, seals, etc.) in contact with the contamination. The discussion of material integrity must be presented by a North Carolina Professional Engineer.

Drainage ditches and surface impoundments of water are considered surface water bodies, and as such are subject to the standards and criteria set forth in 15A NCAC 2B. The Water Quality Section of the Division of Environmental Management may be contacted for information related to surface water classification and standards.

The site, and adjacent properties on to which the plume is predicted to migrate, should be evaluated for the existence of any of the environmentally sensitive areas listed below. Knowledge of the presence of sensitive environments will facilitate the determination of special sampling requirements and the evaluaton of risk to the environment.

1) National Parks and State Parks; Designated and Proposed Federal and State Wilderness and Natural Areas; Sensitive Areas Identified Under the Natural Estuary Program or the Near Coastal Waters Program; Critical Areas Identified Under the Clean Lakes Program; Criticial Habitats or Habitats Known to be Used by State or Federally Designated or Proposed Endangered or Threatened Species or Species Under Review as to Their Endangered or Threatened Status; National and State Preserves and Forests; National or State Wildlife Refuges; Federal Land Designated for Protection of Natural Ecosystems; Terrestrial Areas Utilized for Breeding by Large or Dense Aggregations of Animals; Areas Important to Maintenance of Unique Biotic Communities; State-Designated Areas for Protecton or Maintenance of Aquatic Life - contact NC Division of Parks and Recreation - Natural Heritage Program at (919) 733- 7701.
2) Marine Sanctuaries - contact NOAA at 202-606-4126.
3) National Monuments - contact U.S. Park Service at 202-343-7014.
4) National and State Historical Sites - contact NC Department of Cultural Resources at (919) 733-5722.
5) National and State Seashore, Lakeshore and River Recreational Areas; State or Federal Designated Scenic or Wild Rivers - contact NC Division of Parks and Recreation - Planning and Development Section at (919) 846-9991.
6) Areas Identified Under Coastal Protecton Legislation; Coastal Barriers or Units of a Coastal Barrier Resources System - contact NC Division of Coastal Management at (919) 733-2293.
7) Spawning Areas Critical for the Maintenance of Fish/Shellfish Species within River, Lake or Coastal Tidal Waters; Migratory Pathways and Feeding Areas Critical for Maintenance of Anadromous Fish Species within River Reaches or Areas in Lakes or Coastal Tidal Waters in which such Fish Spend Extended Periods of Time; State Lands Designated for Wildlife or Game Managment; State-Designated Areas for Protection or Maintenance of Aquatic Life - contact NC Wildlife Resources Commission at (919) 288-5738.
8) Wetlands - (On site or adjacent to site) - contact US Army Corps of Engineers at (919) 847-1707.

Monitoring

Monitoring plans for alternative corrective action sites must include sufficient monitoring points to track the horizontal and vertical migration of the plume and to create a warning system of wells up gradient of potentially impacted receptors as specified in .0106(l)(7). In addition to tracking migration, the progress of the remediation must be monitored. This may be done by both direct and indirect methods. In accordance with 15A NCAC 2L .0110, a North Carolina Professional Engineer or North Carolina Licensed Geologist is required to report any indication that the implementation of a CAP pursuant to .0106(k), (l) or (m) is not performing according to predictions.

Monitoring of natural attenuation may be based on direct evidence such as monitoring data which shows the plume decreasing in volume and concentration. Indirect evidence may also demonstrate that natural attenuation is occurring at the site. Such a demonstration may include, but is not limited to, showing: decreases in terminal electron acceptors, increases in the byproducts of microbial respiration, and the presence of a significant population of bacteria capable of degrading the contaminants. In addition, the CAP should indicate which site-specific parameters are predicted to limit the rate of biodegradation and natural attenuation.

Specific groundwater parameters that may be appropriate to monitor at natural remediation sites include: contaminant concentrations, concentrations of intermediate compounds formed by incomplete degradation of contaminants, nutrient concentrations, pH, redox potential (Eh), terminal electron acceptors (e.g., oxygen, nitrate, sulfate, Fe^{3+}, Mn^{4+}, Mn^{3+}, etc.), and byproducts of respiration (e.g., carbon dioxide, methane, Fe^{2+} , Mn^{2+} , etc.). **Not all of the parameters listed above are required to be monitored at every site; in some cases an adequate evaluation of the progress of remediation can be made based on some of these parameters.** For example, if the plume can be shown to be steadily decreasing in concentration, it may not be necessary to monitor any parameters other than the concentrations of the contaminants of concern. In addition, if the plume is, or is predicted to discharge to surface water, then water samples must be collected and analyzed periodically to monitor for impacts to the surface water body. A description of the methods used for all analyses and field measurements, and justification of their applicability to the site, must also be provided. For field measurements, the instrument type and calibration method should also be provided.

Alternative corrective action sites will generally be monitored quarterly for the first year followed by less frequent monitoring. The Director will consider all reasonable, site-specific monitoring proposals. The predicted rate of contaminant transport and proximaty to potential receptors should be considered when proposing a monitoring schedule.

Public Notification

All potentially affected parties [as specified in .0114(b)] are required to be notified of proposed corrective actions. A list of individuals notified, along with copies of the notification letters and the certified mail receipts (the receipts retained by the sender after mailing), must be included with the CAP. If the signed return receipts (green cards) are submitted to the Groundwater Section (Section) at a later date, they should be clearly labeled with the site name, county and Groundwater Incident Number (PIRF number) so that they can be matched with the CAP. Please note that renotification will be required if subsequent CAPs or CAP addendums are submitted which contain significant changes to proposed site actions.

The Section has developed a standard letter format to assist the regulated community in preparing the notification letters required in .0106 (k), (l) and (m) and .0114 (b). The standard letter contains key elements which must be included in any notification letter in order to satisfy the requirements of the Rule. In addition, the Section has prepared a standard format for placing public notice in newspapers. Copies of these shell documents are available from the regional offices and from the Pollution Control Branch. The shell documents state that the CAP proponent is required to provide these parties with a copy of the CAP upon request.

A public (newspaper) notice may be substituted for individual notices only under the following conditions:

-the plume has not migrated, and is not predicted to migrate, onto the properties owned or occupied by the parties for whom the public notice is replacing individual notification, and
-approval to substitute the public notice for individual notification has been obtained from the appropriate Regional Office.

Newspaper notices may not be substituted for individual notification of the following parties: the local Health Director; the chief administrative officer of the local political jurisdiction containing the plume; and all owners and occupants of properties within the area where the plume is, or is predicted to migrate.

For sites where the plume is on, or is predicted to migrate onto, property with roads or highways, the North Carolina Department of Transportation or appropriate local government authority maintaining ownership or easement should be notified. Similarily, if roads or highways are located adjacent to the property containing the plume, the DOT or local government authority maintaining ownership or easement is considered the adjacent property owner and/or occupant and must be notified pursuant to .0114(b).

In situations where the contamination resulted from the release of petroleum fuel hydrocarbons from regulated underground storage tanks, the Division may need to fulfill additional public notice requirements. For sites where public notice of corrective action was placed in local newspapers prior to implementation of active remediation, the Division shall place a similar notice prior to approving a CAP under .0106(k), (l) or (m).

If approval of a CAP submitted under this paragraph is granted, the CAP proponent is required by .0114(c) to notify all parties specified under .0114(b) of the decision. This notification must be done via certified mail within 30 days of receipt of the approval letter from the Director.

Corrective Action Plan Preparation and Submittal

Each CAP must be submitted to the appropriate regional office on the same day the letters for public notice are mailed. Each CAP must have a properly executed GW-100 certification form attached to the front. Either an original or a legible photocopy of an original form must be used; a CAP will not be accepted if a retyped version of the GW-100 form is used. The GW-100 forms have been revised since the original November 1993 printing. Copies are available from the Groundwa Section's regional offices and from the Pollution Control Branch. Each item on the GW certification form must be initialed in ink by hand and the form must bear the seal and signature certifying North Carolina-licensed professional [see section .0103(e) for clarification on the professional jurisdictions of Professional Engineers and Licensed Geologists]. In addition, the CAP must display the seal and signature of the certifying licensed professional.

The term 'prepared' as used on the GW-100 certification form should be construed to mean that the CAP has been prepared under the responsible charge of the certifying licensed professional pursuant to North Carolina Statutes. The term is included on the form because Professional Engineers and Licensed Geologists are prohibited from certifying plans prepared by individuals not working under their direct control and supervision.

Reimbursement: State Underground Storage Tank Trust Funds

Reasonable and necessary costs associated with the preparation and implementation of a CAP will be reimbursed by the State UST Trust Fund for eligible sites under .0106(k), (l) or (m). Costs associated with the preparation of a CAP will not be reimbursable if data existed prior to CAP preparation which clearly indicated that site conditions do not meet the requirements specified in .0106(k), (l) or (m). Situations where reimbursment will not be made include:

-the plume has migrated (or is predicted to migrate) offsite, public water is not available, and the permission of offsite property owners allowing the plume onto their property has not been granted;
-the plume is currently causing, or is predicted to cause a violation of surface water standards or criteria (15A NCAC 2B);
-the time and direction of contaminant transport cannot be predicted with reasonable certainty;
-contaminated groundwater has or is expected to reach a receptor and resultant adverse impacts will not be mitigated (see Identifying Potential Receptors in the General Information section);
-access agreements required for site monitoring and/or remediation cannot be obtained, and the need for such access should have been anticipated;
-another regulatory agency has authority over any portion of the plume and requires active remediation; and
-the area in the vicinity of the plume was identified for groundwater resource development prior to CAP preparation.

In addition to the above, other conditions where reimbursement for the development of a CAP pursuant to .0106(m) will not be made include:

-sites for which it has not been demonstrated that further groundwater remediation will not result in significant reductions in contaminant concentrations, and
-sites where the remediation system was improperly designed and/or operated.

Costs associated with the preparation of a "soil only" CAP under .0106(l) will not be reimbursable if the Site Sensitivity Evaluation (SSE) is applicable to the site and soil contaminant concentrations did not exceed the cleanup levels derived from the SSE at the time of CAP preparation.

For sites where a CAP has previously been received by the DEM, only those costs associated with the preparation of new text, calculations, figures, and tables not previously submitted in either the CSA or the first CAP will be reimbursable. Costs for the purchase of computer equipment, modeling software, and staff training are not reimbursable. Additionally, costs for performing toxicological exposure assessments or health risk evaluations are not reimbursable.

(n) Considered to be self-explanatory.

(o) Considered to be self-explanatory.

(p) Considered to be self-explanatory.

(q) Considered to be self-explanatory.

.0114 NOTIFICATION REQUIREMENTS

Purpose of Rule

The Rule defines the notification requirements for contamination incidents not related to permitted facilities. Although not specified in the Rule, the notice requirements contained in 15A NCAC .0114 have, as part of their authority, North Carolina General Statute 143.215.2.

(a) The Chief Administrative Officer is considered to be the Mayor, Chairman of the County Commissioners, the County Manager, the City Manager or other individual of equal or similar position as appropriate. Notification must be made by certified mail. These requirements apply to CAPs submitted pursuant to .0106(c) only. Please be aware that renotification will be required if subsequent CAPs or CAP addendums are submitted which contain significant changes to proposed site actions.

(b) These requirements apply to CAPs submitted pursuant to .0106(k), (l) and (m). The Chief Administrative Officer is considered to be the Mayor, Chairman of the County Commissioners, the County Manager, the City Manager or other individual of equal or similar position as appropriate. It is important to note that both the property owners and the occupants of those properties specified must be notified. The Groundwater Section of the DEM has developed a standard format to be used by the regulated community when preparing the notification letters as required under this subsection. It contains several key elements which must be included in any notification letter if it is to satisfy the requirements of the Rule. Copies of this shell document are available from the regional offices or from the Pollution Control Branch. Please be aware that renotification will be required if subsequent CAPs or CAP addendums are submitted which contain significant changes to proposed site actions.

(c) If the Director grants approval of the CAP, the proponent is required to re-notify all parties specified in .0114(b) of the approval. This requirement pertains to all CAPs approved under .0106(k), (l) and (m).

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