MIXING ZONES IN NORTH CAROLINA

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A mixing zone is an area downstream of a discharge point where the effluent is diluted by the receiving water and within which certain water quality standards that would otherwise be applicable may be exceeded. Under North Carolina regulations, mixing zones can be established on a case by case basis. This document summarizes North Carolina's mixing zone rule and describes how it has been used to establish mixing zones.

Standard Permitting Procedure

The following paragraphs provide a brief summary of the Division of Water Quality's standard operating procedures for determining dilution and establishing permit limits for toxicants. Further details on permitting procedures may be found in the Division's *Wasteload Allocation Standard Operating Procedures Manual* and in the *NPDES Permit Writer's Guidance Manual*.

Standard permitting practice is to use the entire critical low flow in the receiving waters to determine dilution, utilizing a simple mass balance approach. Complete and instantaneous mixing of the effluent with the receiving waters is generally assumed. Dilution is calculated as

$$D = (Q_w + Q_u)/ Q_w$$

Where:
Q_w is the maximum permitted wasteflow and
Q_u is the critical upstream streamflow, generally the summer 7Q10 flow.

Permit limits for individual toxicants are established for pollutants that have the reasonable potential to cause or contribute to an excursion above a State water quality standard. Permit limits are calculated using a mass balance approach as shown below.

$$C_a = ((Q_u + Q_w)(C_s) - (Q_u)(C_u))/Q_w$$

Where:
C_a is the allowable effluent concentration in units of mg/L or µg/L,
C_s is the North Carolina water quality standard,
C_u is the background concentration,
Q_w is the maximum permitted wasteflow and
Q_u is the critical upstream streamflow, generally the summer 7Q10 flow.

Permits for all major facilities and any facility discharging complex wastewater will contain whole effluent toxicity (WET) limits. The objective of these WET limits is to prevent discharge of toxic substances in amounts likely to cause chronic or acute toxicity to wildlife in the receiving stream. WET testing represents the only feasible method of evaluating the combined effects of constituents of complex wastestreams.

To establish a WET limit, a facility's instream waste concentration (IWC) is first calculated as follows.

$$IWC\ (\%) = [\ Q_w/(Q_w + Q_u)](100)$$

The type of WET test required is based upon the facility's IWC, as well as upon discharge and receiving water characteristics. For example, if the facility's IWC is greater than or equal to 0.25 percent, the facility will generally perform the "North Carolina *Ceriodaphnia* Chronic Effluent Bioassay Procedure". The limit is stated as "there may be no observable inhibition of reproduction or significant mortality" at the effluent concentration equivalent to the facility's IWC. The maximum permit limit is 90%.

If the facility's IWC is less than 0.25 percent, a 24 hour fathead minnow acute "No Significant Mortality" limit will be applied. The procedure employed is the "Pass/Fail Methodology For Determining Acute Toxicity In A Single Effluent Concentration".

Other limits are applicable to specific situations, such as episodic discharges or tidally influenced waters, and alternative tests may be substituted by permittees under certain circumstances. Detailed information on WET requirements is available from the Division.

General Procedure for Evaluating Mixing Zones

For the majority of discharges, permit limits are established using the approach outlined above and no explicit mixing zone is established. As provided in 15A NCAC 2B.0204 (see Appendix for the text of this rule), mixing zones for wastewater discharges can be established on a case by case basis. This rule states that mixing zones can be established in order to provide reasonable opportunity for the mixture of wastewater with the receiving waters, and specifies that these zones be established such that discharges will not:

(1) result in acute toxicity to aquatic life or prevent free passage of aquatic organisms;
(2) result in offensive conditions;
(3) produce undesirable aquatic life or result in a dominance of nuisance species;
(4) endanger the public health or welfare.

The Division evaluates the feasibility and appropriateness of mixing zones when at least one of the following conditions applies: 1) the permittee proposes to construct a diffuser; 2) the Division believes that the discharge is causing or is likely to cause water quality problems if standard practices are followed; 3) the Division receives a request for a mixing zone evaluation.

To date mixing zones have been established in only a few cases. Dilution levels at the perimeter of these zones have been used to set WET limits and permit limits for individual toxicants. Water quality standards do not apply within mixing zones, but must be met at the perimeter of chronic mixing zones. Mixing zones have not been explicitly established for BOD, fecal coliform or other pollutants.

The Division has no formal specifications for determining the size of chronic mixing zones, and EPA's *Technical Support Document for Water Quality-based Toxics Control* (EPA/505/2-90-001) provides no specific guidance on this issue. North Carolina rules provide that mixing zone dimensions be determined on a case by case basis "after consideration of the magnitude and character of the waste discharge and the size and character of the receiving waters". In practice, we have implemented this provision by taking the following factors into account: type of receiving waters (e.g. stream vs. estuary); outfall configuration; effluent characteristics; extent of mixing/dilution; specific aquatic resource concerns (e.g. sensitive areas or species, recreational use, navigation). State and federal resource agencies are consulted as appropriate.

To date the Division has established only chronic mixing zones. While no acute mixing zones have thus far been established, the Division uses the procedures described in the *Technical Support Document for Water Quality-based Toxics Control* to evaluate the dimensions of potential acute mixing zones. That document (p. 71-72) outlines four alternatives for sizing acute mixing zones to prevent lethality to passing organisms. The factors listed in the preceding paragraph are also considered.

Analytical Approach

The Division requires that the degree of mixing of the effluent with receiving waters be evaluated using either a dye study or a modeling analysis. In practice, modeling using the Cornell Mixing Zone Expert System (CORMIX) has been the method of choice. CORMIX is an analytical tool originally developed at Cornell University and now distributed by EPA's Center for Exposure Assessment Modeling. CORMIX was intended for the analysis, prediction and design of aqueous toxic or conventional pollutant discharges into diverse waterbodies. Its major emphasis is on the prediction of plume geometry and dilution characteristics within a receiving water's initial mixing zone. Plume behavior at larger distances can also be predicted. CORMIX can be used with single pipe discharges as well as with multiport diffusers.

CORMIX requires data on the discharge configuration, discharge site morphometry, ambient conditions and pollutant characteristics. Among the most important factors influencing the extent of dilution are ambient depth, ambient velocity and effluent discharge velocity. Additional information on the application of and input requirements for CORMIX may be found in *User's Manual for CORMIX: A Hydrodynamic Mixing Zone Model and Decision Support System for Pollutant Discharges into Surface Waters*, by Gerhard Jirka et al (USEPA Office of Science and Technology, September 1996).

Models are run using conservative estimates of critical conditions. Critical conditions for streams are typically defined by the velocity and cross-sectional area associated with the 7Q10 flow. Critical conditions for lakes and estuaries are established on a case by case basis and generally consider water levels, wind, lunar tides and other factors. Mixing zone analyses are generally conducted using the permitted wasteflow, although other wasteflows may also be evaluated if there is reason to believe that lower rates of mixing will occur under these conditions. In order to insure that adequate data are available to support the modeling effort, the Division requires that site-specific flow and velocity estimates be developed and that model inputs be based upon a cross-section of the receiving waterbody at the discharge site or comparable data on site morphometry.

Case Descriptions

In order to illustrate how the Division has evaluated mixing zones, two recent examples are briefly described below.

USMC-Camp Lejeune. Camp Lejeune, operated by the US Marine Corps (USMC), was designing a new centralized wastewater treatment plant to replace several older facilities. This plant, with a permitted capacity of 15 MGD, was to discharge into the estuary of the New River. The potential impact of altered salinity on estuarine biota was a major concern.

In consultation with the North Carolina Division of Marine Fisheries, the Division determined that aquatic resources would be adequately protected if at least 20:1 dilution was

attained within 50 meters of the outfall. The USMC engaged a consultant to conduct the necessary field work and to assess mixing characteristics of the proposed outfall using CORMIX.

Several alternative diffuser designs were evaluated. A design was selected which exceeded the dilution criteria described above and met the peak hydraulic requirements of the discharge. The USMC is required to conduct ambient monitoring to evaluate the extent of mixing achieved by the discharge.

City of Salisbury. The city of Salisbury was designing a new outfall on the Yadkin River to replace two discharges into small streams. While the Yadkin is a sizeable waterbody, the discharge would be located in the backwaters of a large impoundment. The Division was concerned that ambient mixing would be relatively slow in this situation and that standard procedures may not protect water quality.

An engineering firm hired by the city measured river cross-sections in the vicinity of the discharge. The firm--in conjunction with the Division--used CORMIX to evaluate the mixing characteristics of both a single pipe outfall and a multiport diffuser. After reviewing discharge and receiving water characteristics, the Division determined that the mixing zone should not exceed one third of the river width.

Using this criteria, mixing zones were developed for both the diffuser and single pipe options. Since both mixing zones provided equivalent water quality protection, requiring water quality standards to be met when the width of the plume reached one third of the river width, the Division allowed the city to choose between the two options. Salisbury elected to construct a diffuser because of the greater dilution obtained.

Further Development of Mixing Zone Policy

As noted above, the Division has established mixing zones in only a few instances. Under these circumstances working on a case by case basis has proven to be an effective approach. The number of mixing zone evaluations is likely to increase in the future, however. As this occurs it will become important for us to ensure that mixing zones are evaluated in a consistent and scientifically defensible fashion, and that our policy approach and technical requirements are clear to the public.

The Division therefore intends to review its approach to mixing zone evaluation. This review will focus on several key issues: 1) clarifying the conditions which should trigger a mixing zone evaluation and the conditions under which complete and instantaneous mixing should be assumed; 2) developing criteria for establishing the size of mixing zones; 3) developing guidelines for the data collection, technical analysis and modeling necessary to support mixing zone evaluations.

APPENDIX

NORTH CAROLINA'S MIXING ZONE RULE (15A NCAC 2B.0204)

.0204 LOCATION OF SAMPLING SITES AND MIXING ZONES

(a) Location of Sampling Sites. In conducting tests or making analytical determinations of classified waters to determine conformity or nonconformity with the established standards, samples shall be collected outside the limits of prescribed mixing zones. However, where appropriate, samples shall be collected within the mixing zone in order to ensure compliance with in-zone water quality requirements as outlined in Paragraph (b) of this Rule.

(b) Mixing Zones. A mixing zone may be established in the area of a discharge in order to provide reasonable opportunity for the mixture of the wastewater with the receiving waters. Water quality standards will not apply within regions defined as mixing zones, except that such zones will be subject to the conditions established in accordance with this Rule. The limits of such mixing zones will be defined by the division on a case-by-case basis after consideration of the magnitude and character of the waste discharge and the size and character of the receiving waters. Mixing zones will be determined such that discharges will not:

(1) result in acute toxicity to aquatic life [as defined by Rule .0202(1) of this Section] or prevent free passage of aquatic organisms around the mixing zone;
(2) result in offensive conditions;
(3) produce undesirable aquatic life or result in a dominance of nuisance species outside of the assigned mixing zone;
(4) endanger the public health or welfare.

In addition, a mixing zone will not be assigned for point source discharges of fecal coliform organisms in waters classified "WS-II," "WS-III," "B," "SB," or "SA." For the discharge of heated wastewater, compliance with federal rules and regulations pursuant to Section 316(a) of the Federal Water Pollution Control Act, as amended, shall constitute compliance with Subparagraph (b) of this Rule.

History Note: Authority G.S. 143-214.1;

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