

Introduction to Mixing Zones

Ben Cope
Office of Environmental Assessment
EPA Region 10

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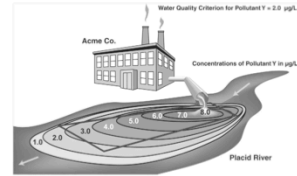


Disclaimer

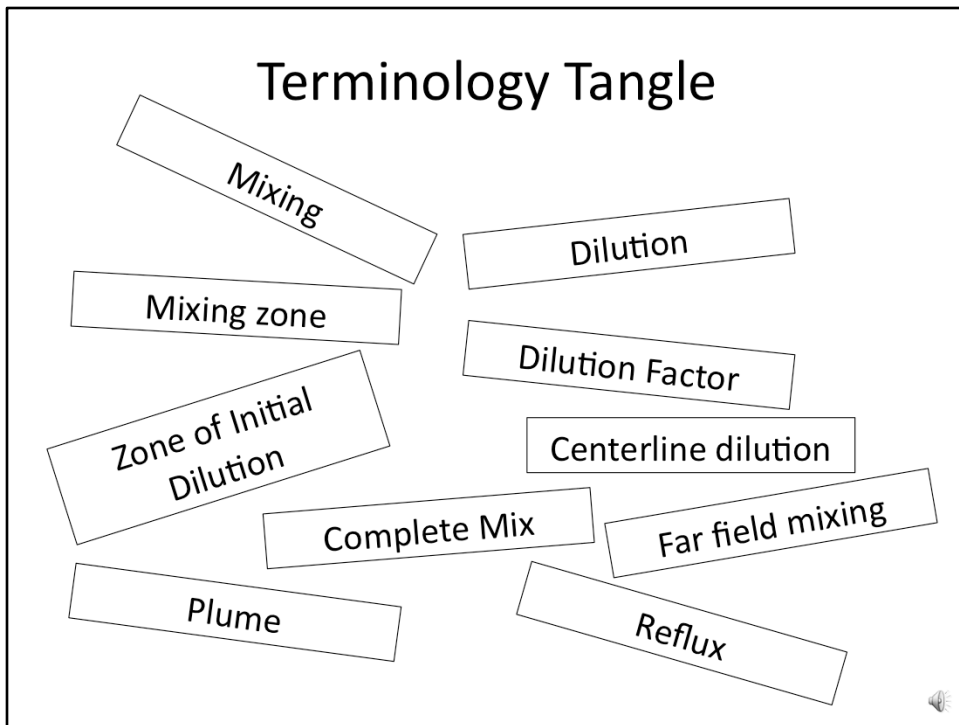
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Topics of this Intro

- What is a Mixing Zone?
- Basic concepts and terminology
- Varied state mixing zone restrictions
- Range of complexity in problems and tools
- Simplest analyses...and when they don't work
- Setting the MZ - forward or backward, or both
- Fortitude and environmental protection

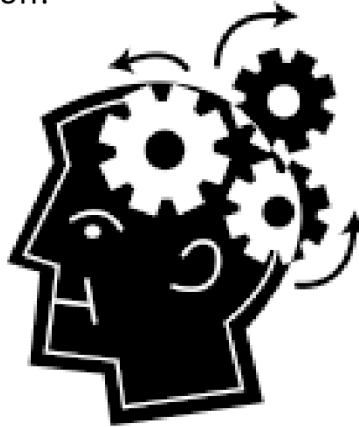


Terminology Tangle



Making sense of it

- Concepts can be difficult – e.g., mixing in 1D, 2D, 3D
- Some tricky and inconsistent language out there
- Ask for clarification!



What is a Mixing Zone?

EPA's TSD for Water Quality-based Toxics Control:

“A mixing zone is an area where an effluent discharge undergoes initial dilution and is extended to cover the secondary mixing in the ambient waterbody. A mixing zone is an allocated impact zone where water quality criteria can be exceeded as long as acutely toxic conditions are prevented.”

State of Washington

- “Mixing Zone” means that portion of a water body adjacent to an effluent outfall where mixing results in the dilution of the effluent with the receiving water. Water quality criteria may be exceeded in a mixing zone as conditioned and provided for in WAC 173-201A-400.

Ultra-concise definition

- “Mixing Zone” – portion of a waterbody where a discharge is allowed to exceed water quality criteria by certification under the Clean Water Act (section 401).
- NOT a term describing the mixing process or where mixing occurs

What is “Dilution”?

- Webster's: “Dilute” – 1. to thin or reduce the concentration of.
- EPA Dilution Modeling Guidance (1994, 2003):
 - “Dilution” – ratio of parts ambient to parts effluent at a given location in a waste plume (volumetric).
 - *Think Physical Mixing.*
 - “Effective Dilution” - ratio of the effluent concentration to the plume concentration.
 - *Think Chemical Thinning.*

Other word problems

- “Mixing Zone” vs “Zone of Initial Dilution” (301h)
- “Complete” vs “Incomplete Mix”
 - In what sense? Virtually all mixing takes time/space
- “Model assumptions”
 - Built into the selection of the model
 - User defined
- Again, ask for clarification often!

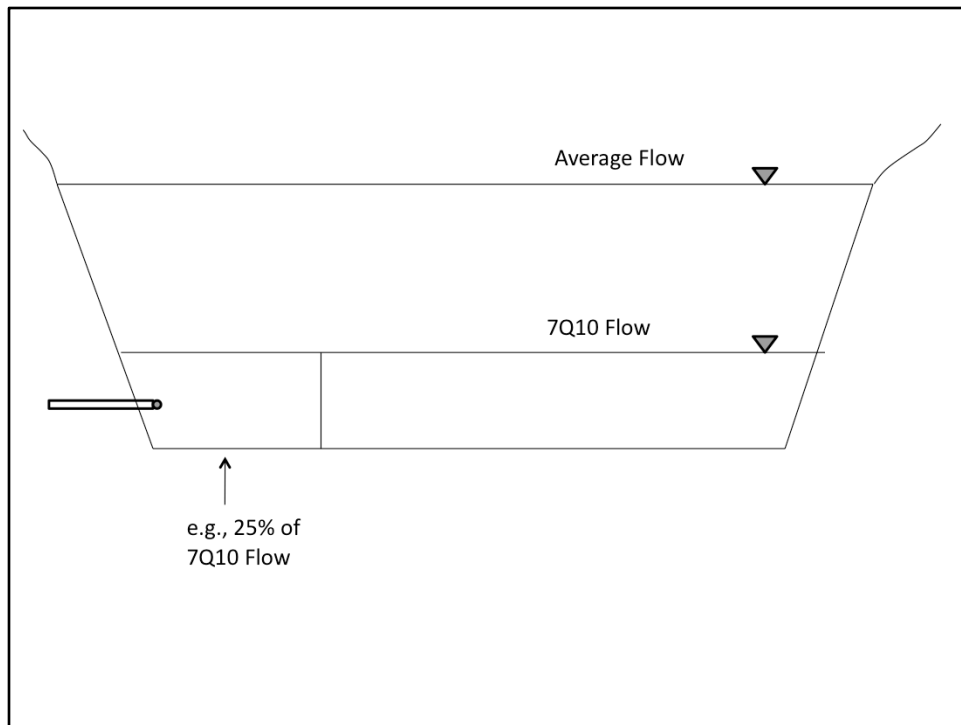


Mixing zone rules vary

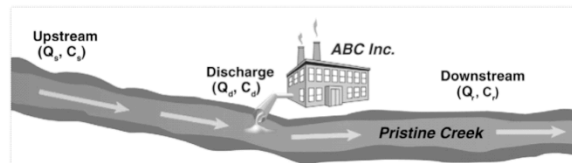
- Examples: Numeric rules or guidelines for rivers across EPA Region 10
- Alaska
 - No numeric guidelines
- Idaho
 - 25% of the flow volume and width
- Oregon
 - 25% of the flow volume and width
 - 60-200 ft length depending on size of stream
- Washington
 - 25% of flow volume and width
 - 300 feet + depth of water downstream
 - Acute: 10% of chronic zone, 2.5% of flow volume, 25% of width
- Numerous, important narrative rules that may affect sizing
 - e.g., critical habitat, municipal water intakes, overlapping mixing zones, etc.

Simplest example

- State allows 25% of 7Q10 flow for chronic mz and 25% of river width
- Proposed discharge meets acute criterion
- Single port discharge in a shallow river
- Background is zero
- Shallow – OK to assume vertical complete mix
- $WLA = ((0.25 \times Q_{riv})/Q_{eff}) \times \text{criterion}$
- Done!



Mass Balance



$$Q_{up} \cdot C_{up} + Q_{eff} \cdot C_{eff} = (Q_{up} + Q_{eff}) \cdot C_{down}$$

Reduce Q_{up} to allowable flow in mixing zone regs

Replace C_{down} with water quality criterion (C_{wqc})

Re-arrange the equation

$$C_{eff} = \frac{[(Q_{up} + Q_{eff}) \cdot C_{wqc} - (Q_{up} \cdot C_{up})]}{[Q_{eff}]}$$

Conservative values needed!

$Q_{up} \Rightarrow$ low (e.g., 25% of 7Q10)

$Q_{eff} \Rightarrow$ high (e.g., design flow)

$C_{up} \Rightarrow$ high (e.g., 95th percentile)

Assumptions of a mass balance approach

- Instantaneous mixing of effluent and receiving water (or fraction of it)
 - Specific plume conditions near outfall not a major concern
- No settling, uptake, transformation of pollutant
 - Common assumption in mixing zones and permit limit derivation

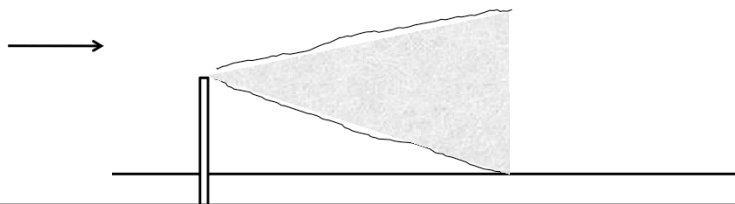
Complications

- Need for more detail – even in simple situation
 - More complicated mixing zone standards
- Deep river, reservoir...not 1D
- Estuary...salinity, bouyancy, currents, etc.
- Multi-port diffuser, not simple pipe
- Situations that don't fit the mold
 - Unknown or unusual diffuser features
 - Above surface discharges
 - Intermittent discharges
 - Banks and other structures near outfall

Rivers - One step up in complexity

Lateral mixing analysis (2D)

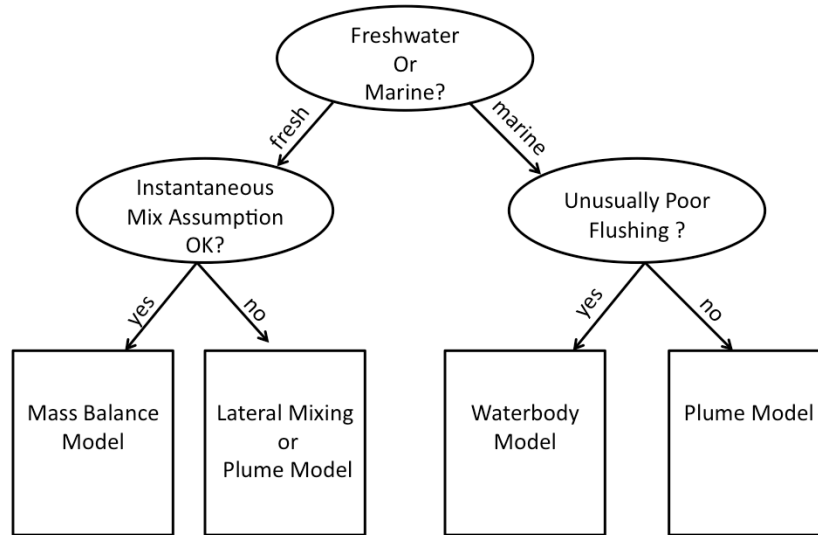
- Issue: MZ length in addition to width/volume
 - Spreadsheet tools (e.g., WA's rivplum6)
 - Estimate rate of lateral mixing based on Manning's equation and shear velocity
-

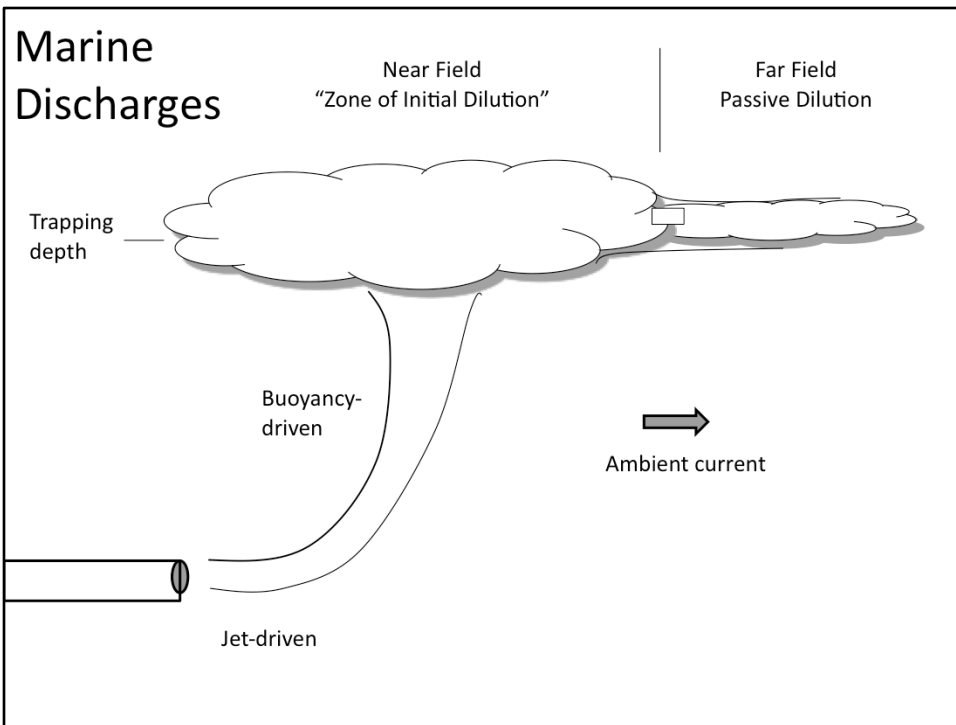


Levels of Difficulty - Rivers

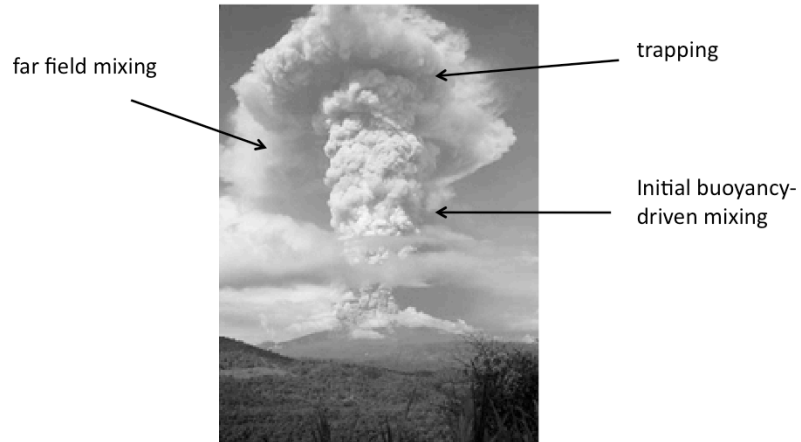
- 1 – mass balance approach, % of low flow, no background, single pollutant
- 2 - multiple pollutants, measurable background levels
- 3 – need plume info, aka dilution modeling
- 4 – dilution modeling is “non-standard”
 - e.g., workarounds, expert advice needed

Model Selection



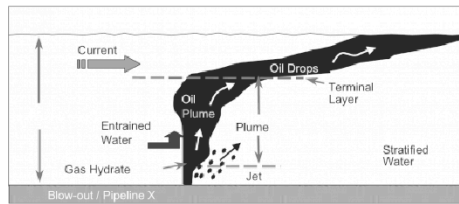


It's a Bird, It's a Plume...



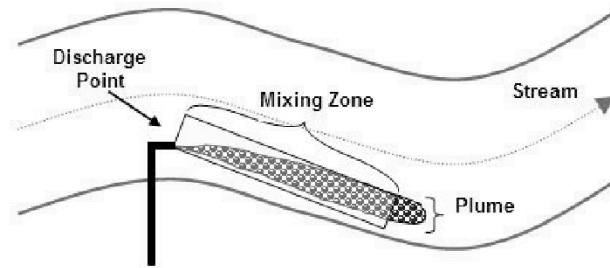
http://www.noaa.gov/features/protecting_0808/volcanoes.html

A highly publicized and disastrous plume



2003 Nat'l Academies,
"Oil in the Sea III"

Plumes in rivers

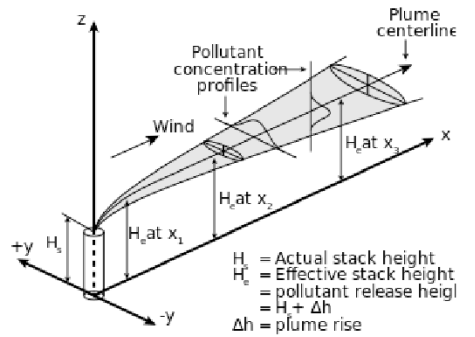


<http://www.deq.state.or.us/wq/wqpermit/mixingzones.htm>

2 Workhorse Dilution Models

- VISUAL PLUMES
- CORMIX

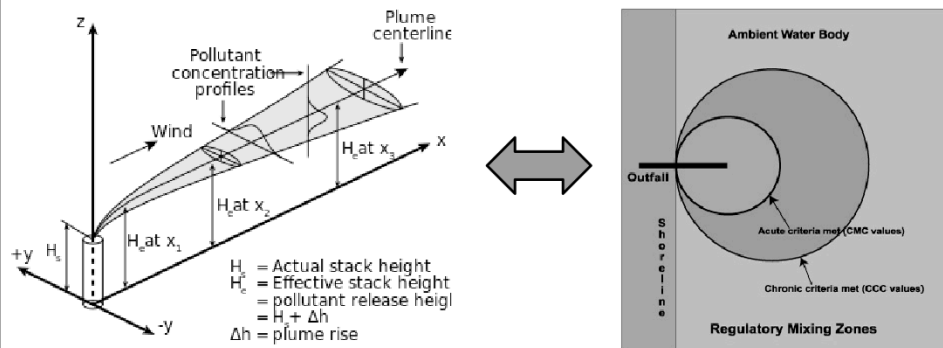
Provide anatomy
of the plume



[http://en.wikipedia.org/wiki/File:Gaussian_Plume_\(SVG\).svg](http://en.wikipedia.org/wiki/File:Gaussian_Plume_(SVG).svg)

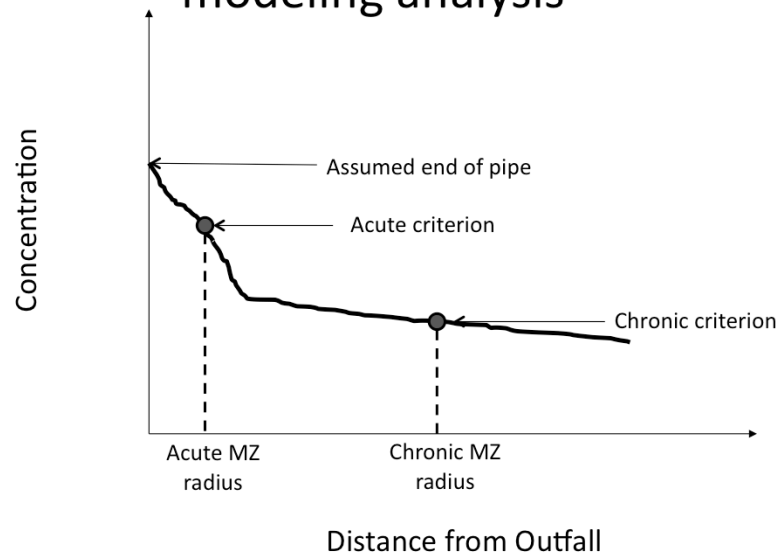
- Key metric – dilution with distance

Technical meets Regulatory



[http://en.wikipedia.org/wiki/File:Gaussian_Plume_\(SVG\).svg](http://en.wikipedia.org/wiki/File:Gaussian_Plume_(SVG).svg)

The “answer” provided by a dilution modeling analysis



What is a dilution factor?

- Same potential confusion
 - Physical mixing vs chemical thinning
- Simple case is not confusing
 - Example: River = 99 cfs, Effluent = 1 cfs, complete mix
 - Dilution Factor (volumetric) is 100:1
 - **If Background=0**, Effective Dilution Factor (chemical) is also 100:1
 - They can discharge 100x the criterion and the mixture will match the criterion.

“Dilution factor”...continued

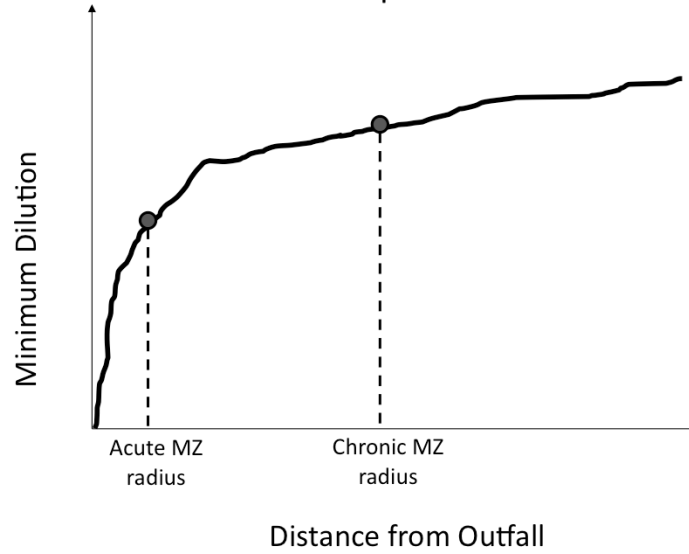
- But if background > 0, not so simple
 - Example: River = 99 cfs, Effluent = 1 cfs
 - Dilution Factor (volumetric) is still 100:1
 - **If background is half the criterion level**, the Dilution Factor (chemical) is 50:1
 - They can only discharge 50x the criterion
 - Some call the 50:1 factor above the “effective dilution factor”

Less terminology, more stepwise process

- Always distinguish between volumetric dilution and chemical dilution
- First, get **volumetric dilution vs distance**
- Next, decide the mixing zone size allowable
- Find the volumetric dilution at that distance
- Analyze chemicals of concern separately
 - Different background concentration for each

Volumetric Dilution vs Distance

Useful core info from plume model



In math speak, focus on finding S

$$C_p = C_a + (C_e - C_a) / S$$

Where,

S = dilution (volumetric)

C_p = concentration in the waste plume

C_a = ambient concentration

C_e = effluent concentration

Rearranging into a back-calculator

$$C_p = C_{req}$$

$$C_e = C_a + (C_{req} - C_a) \cdot S$$

Where,

C_p = concentration in the waste plume

C_a = ambient concentration

C_e = effluent concentration

S = dilution (volumetric)

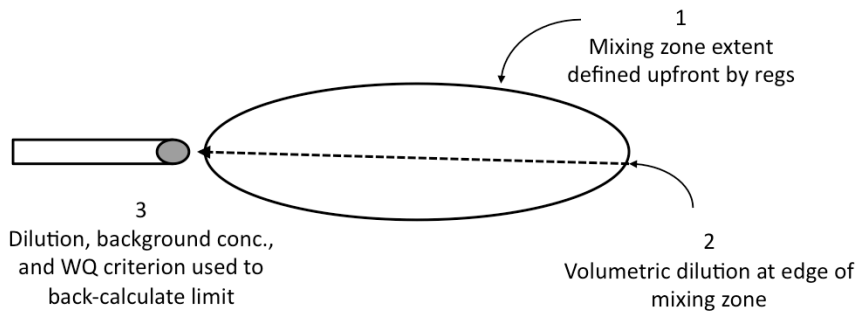
Levels of Difficulty – Estuary/Ocean

- 1 – dilution model required, no background, single pollutant
- 2 - multiple pollutants, measurable background levels
- 3 - modeling is “non-standard”
- 4 - very poor flushing area, waterbody model needed.

Two directions of analysis

Direction 1:

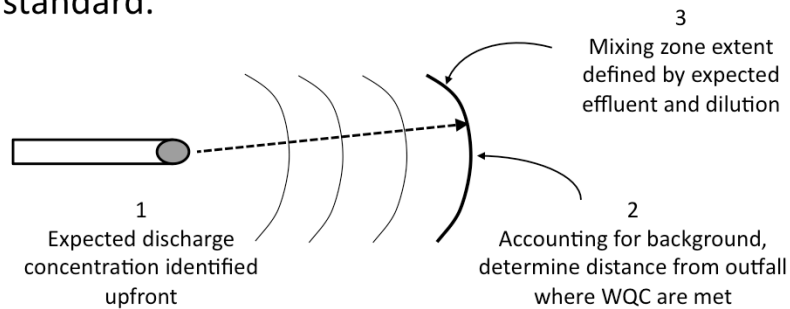
Start with allowable size based on state rules, determine dilution with distance using mass balance or model, and back-calculate the allowable effluent concentration.



...The other direction...

Direction 2

Start with the expected effluent concentration, determine dilution with distance using mass balance or model, and estimate the distance to point where the waste field is diluted to the standard.



Iterative process

- One option: Run calculations in both directions, then ask questions:
 - Is past maximum effluent concentration particularly high, leading to a large mixing zone size?
 - Could/should add'l treatment be required (and/or a better outfall location or design)?
 - Do state mixing zone restrictions drive the need for improvement (direction 1) or a treatment inadequacy at the facility (direction 2), or both?
 - Iterate until a good mixing zone decision is made

Science + Mission

MISSION: *Protect human health and environment*

Permit writers often have authority/duty to:

- Require a discharge to be submerged and re-located off the bank
- Require a major discharge to have a diffuser
- Require treatment upgrades to minimize mixing zone size

All provide faster mixing and/or smaller mixing zones

➔ less biota exposure





Science + Mission



Continued...

- By definition, no mixing zone if impaired
 - criteria at end-of-pipe until a TMDL is developed
- Rules/circumstances may warrant denial of mixing zones
 - e.g., bioaccumulative pollutants, endangered species concerns
- Mixing zone studies must be well-documented
 - All relevant info, assumptions, model inputs, etc.
 - If not, return to sender
- State must explicitly authorize the mixing zone in state certification
 - If no state authorization, all limits are criteria at end-of-pipe

The End...Questions?

