Introduction to Mixing

Learning Objectives

- Explain the concepts of mixing and dilution
- Define “mixing zone”
- Introduce steady state and dynamic models

Is Dilution Allowed?

Do water quality standards allow consideration of dilution?

No

Criteria apply at end of pipe

Yes

Determine level of dilution allowed by water quality standards

Continue to next step

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Is Dilution Allowed? (Continued)

- Clean Water Act does not require attaining water quality criteria at the point of discharge
- States have discretion to allow dilution
- States should specify any conditions on dilution allowances as part of their water quality standards
- 122.44(d)(2) states that when establishing WQBELs "should account for dilution of the effluent in the receiving water (where appropriate)"

Allowable Dilution

Water Quality Standards often allow dilution …

- up to 100% of critical flow (e.g., 7Q10 low flow) if there is *rapid and complete mixing*
- within a limited mixing zone at the critical flow if there is *incomplete mixing*

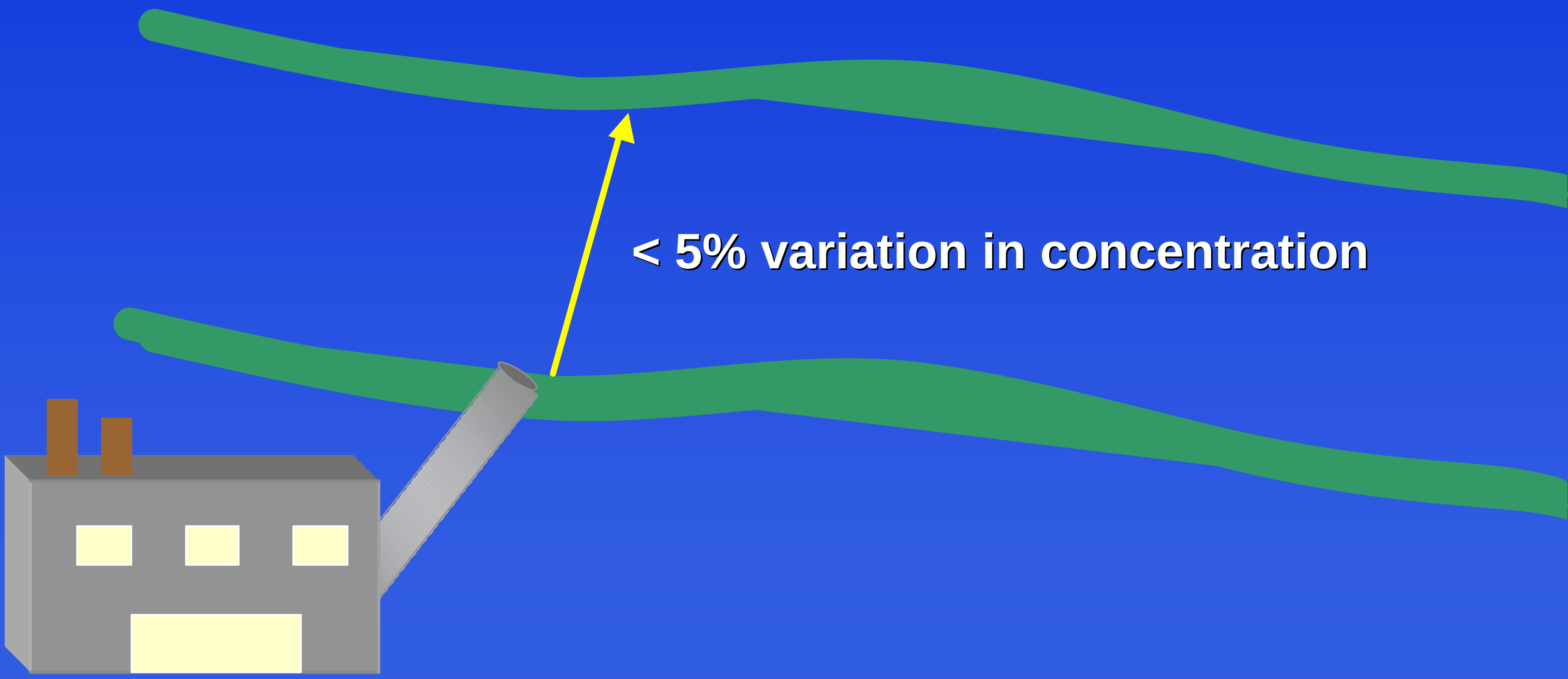
Mixing Considerations

Is there rapid and complete mixing?

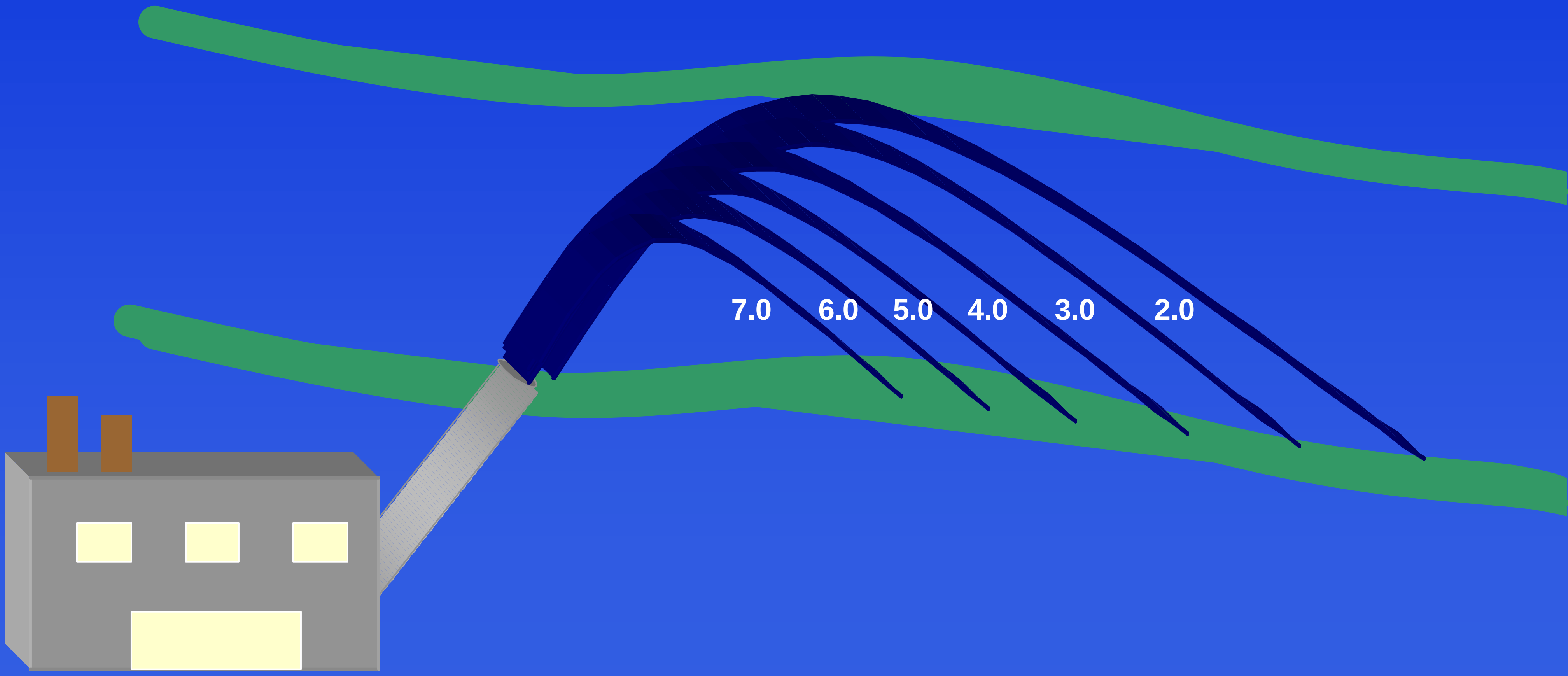
What is Rapid and Complete Mixing?

- Rapid and complete mixing occurs when lateral variation in concentration in the direct vicinity of the outfall is small (e.g., less than 5%)
- Potential occurrences include:
  - Effluent dominated systems (effluent flow greater than stream flow)
  - Diffuser located across entire stream width

Rapid and Complete Mixing



Incomplete Mixing



Mixing Considerations (Continued)

Is there rapid and complete mixing?

Yes

Complete mix assessment

Examples of Allowable Dilution in Rapid and Complete Mix Situations

- 100% of 1Q10 or 7Q10 low flow
- 50% of 1Q10 or 7Q10 low flow
- 25% of 7Q2 low flow or 1 cfs, whichever is greater

Mixing Considerations (Continued)

Is there rapid and complete mixing?

Yes → Complete mix assessment

No → Incomplete mix assessment

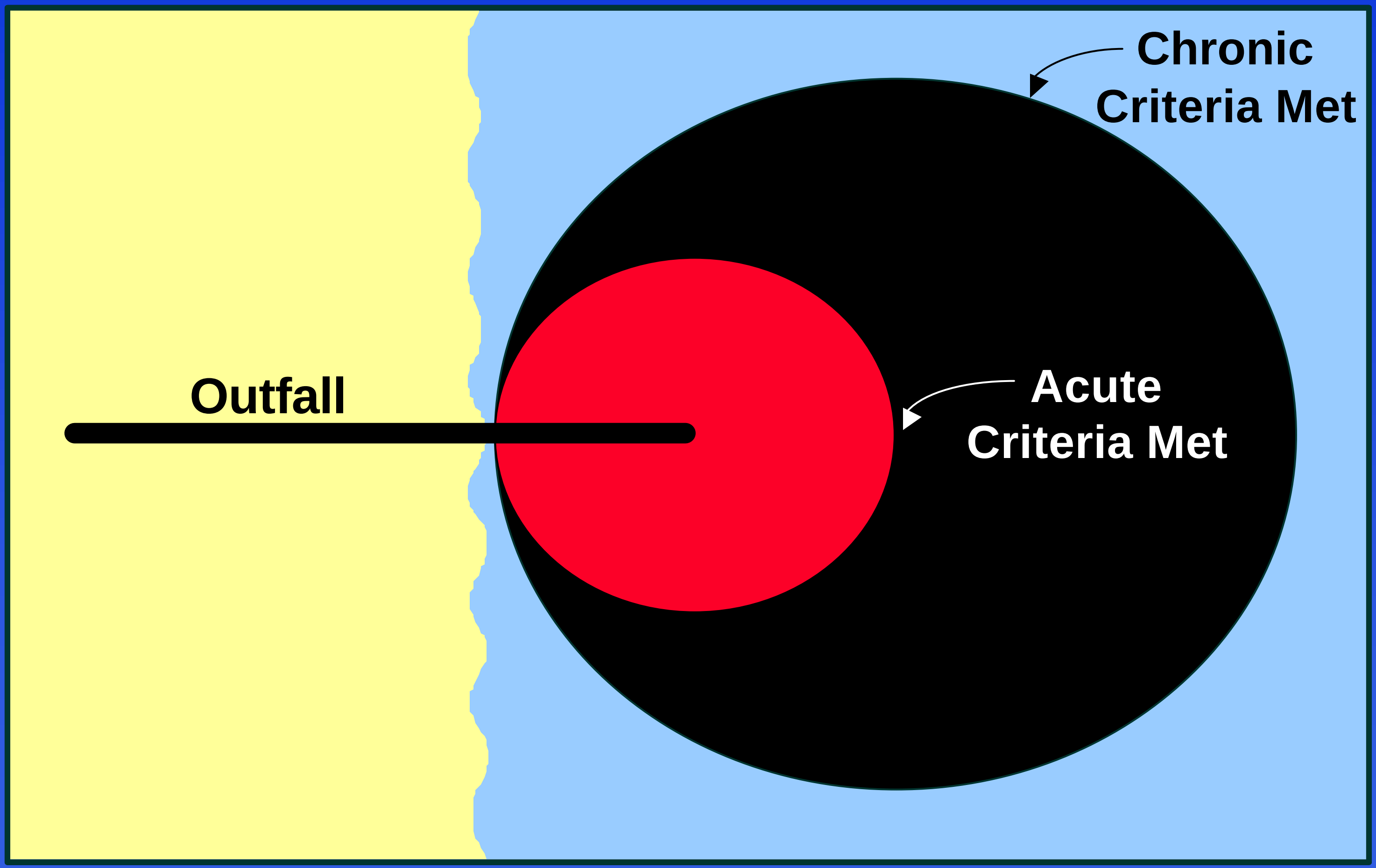
Incomplete Mix Assessment

- **Field Studies**
  - Actual measurement of instream contaminant concentrations
  - Dye studies
- **Modeling**
  - Calibrated to actual observations
  - Simulate critical conditions

Regulatory Mixing Zones

- **Definition**
  - A limited area or volume of water where initial dilution of a discharge takes place and where water quality criteria can be exceeded
- **Constraints**
  - Cannot impair integrity of the waterbody
  - No significant health risks
  - No lethality to passing organisms

Regulatory Mixing Zones (Continued)



Examples of Regulatory Mixing Zones

- < 1/4 of stream width and 1/4 mile downstream
- <1/2 stream width and longitudinal limit of 5 X stream width
- Default dilution of no more than 10% of critical flow
- No more than 5% of the lake surface
- Default of no more than 4:1 dilution for lake discharges

Mixing Considerations (Continued)

Is there rapid and complete mixing?

Yes

Complete mix assessment

No

Incomplete mix assessment

Are resources available
for dynamic modeling and is
a dynamic model desirable?

No

Steady state
model

Steady State Model

- Predicts the magnitude of pollutant concentration for a single set of environmental conditions
- Used when complete data are not available

Steady State Model (Continued)

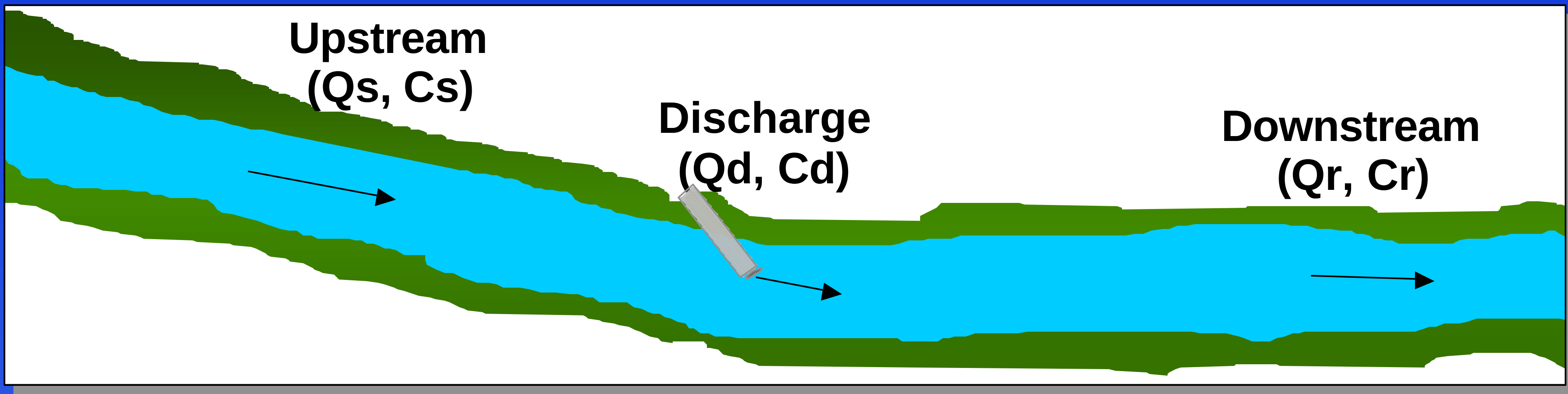
- Assume "critical conditions" for flow, pollutant concentrations and environmental effects
- Choose conditions that reflect the duration and frequency concerns for the applicable criteria

Steady State Model (Continued)

Example Critical Condition:
Dilution Flow

Acute Toxicity:	1Q10 low flow
Chronic Toxicity:	7Q10 low flow
Human Health:	Harmonic mean flow, 30Q5 low flow

Steady State Complete Mix Assessment



Mass-Balance Equation: QdCd + QsCs = QrCr

- Q = Flow (mgd or cfs)
- C = Pollutant concentration (mg/l)
- Mass = [Concentration] [Flow]

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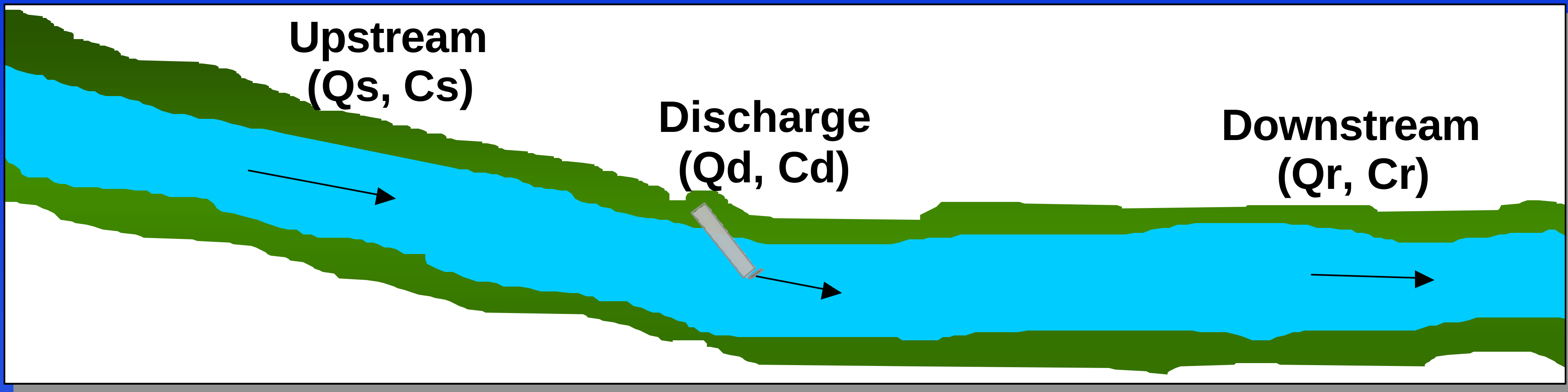
Mass-Balance Equation
QdCd + QsCs = QrCr

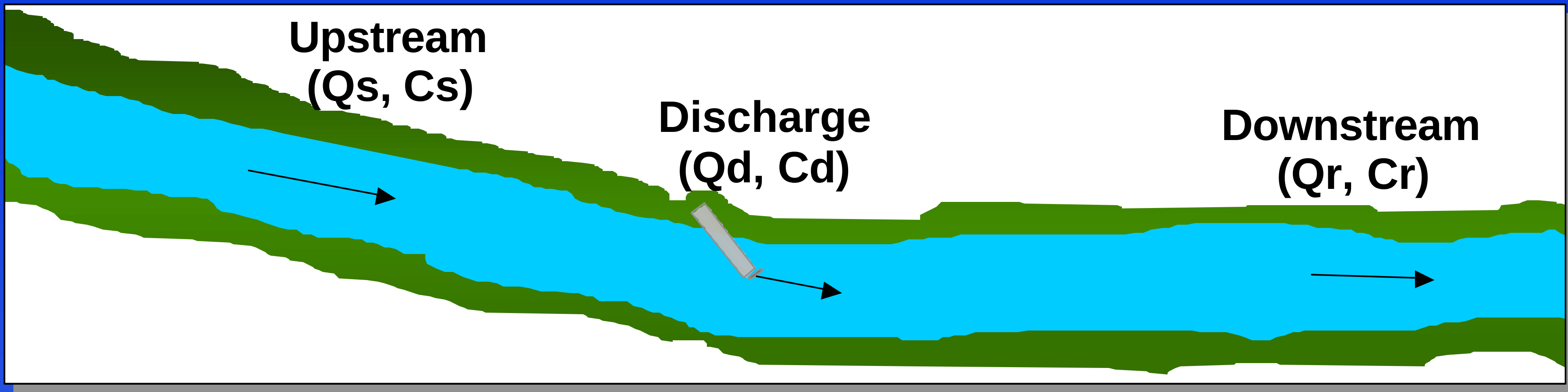


$$Cr = \frac{QdCd + QsCs}{Qr}$$

Cr = downstream concentration

Qs = receiving water flow available for dilution as specified in water quality standards (e.g., 100% of 7Q10 low flow for rapid and complete mixing)

Mass-Balance Equation
QdCd + QsCs = QrCr



$$Cd = \frac{QrCr - QsCs}{Qd}$$

Cd = allowable discharge concentration (Waste Load Allocation)
Cr = applicable water quality criterion
Qs = receiving water flow available for dilution as specified in water quality standards (e.g., 100% of 7Q10 low flow for rapid and complete mixing)

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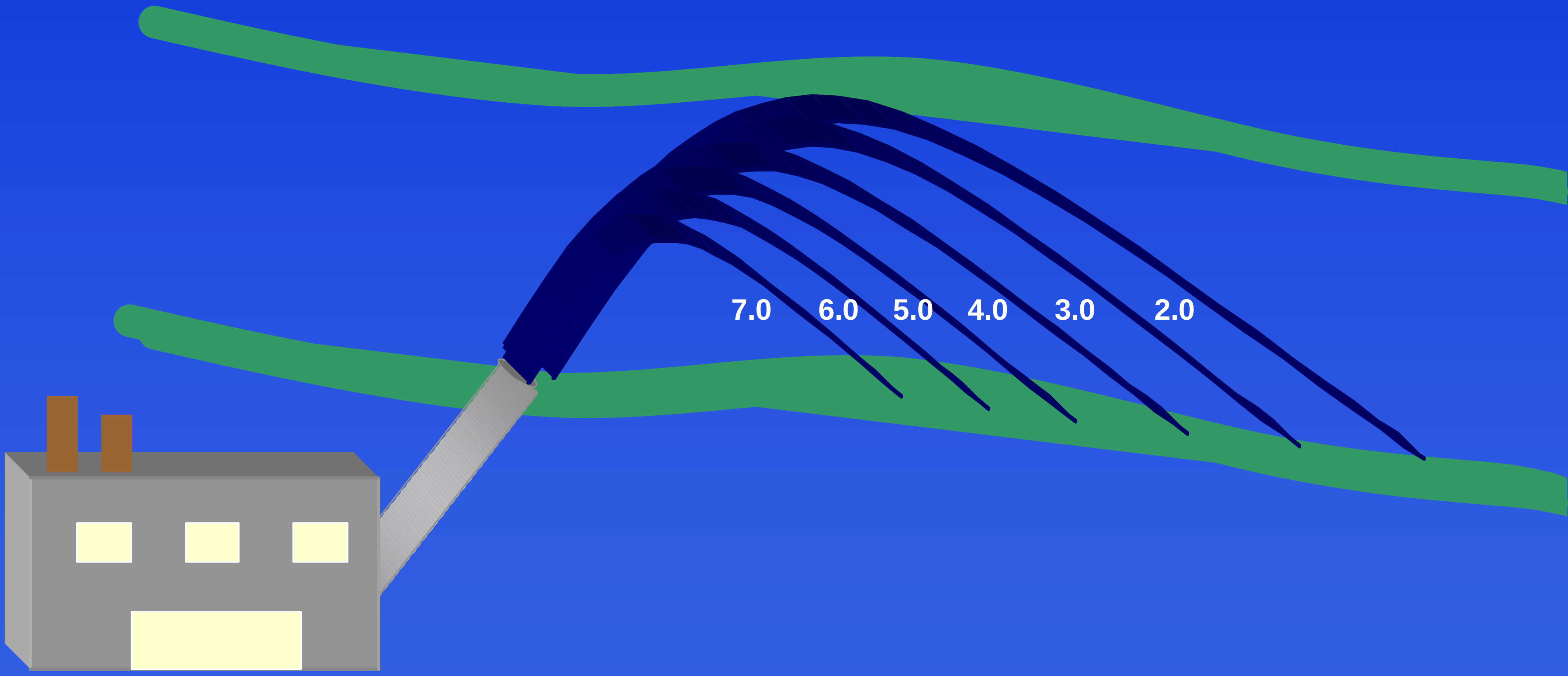
Steady-State
Incomplete Mix Assessment

What if the applicable water quality criterion = 4.0 μg/l?



Steady-State Incomplete Mix Assessment

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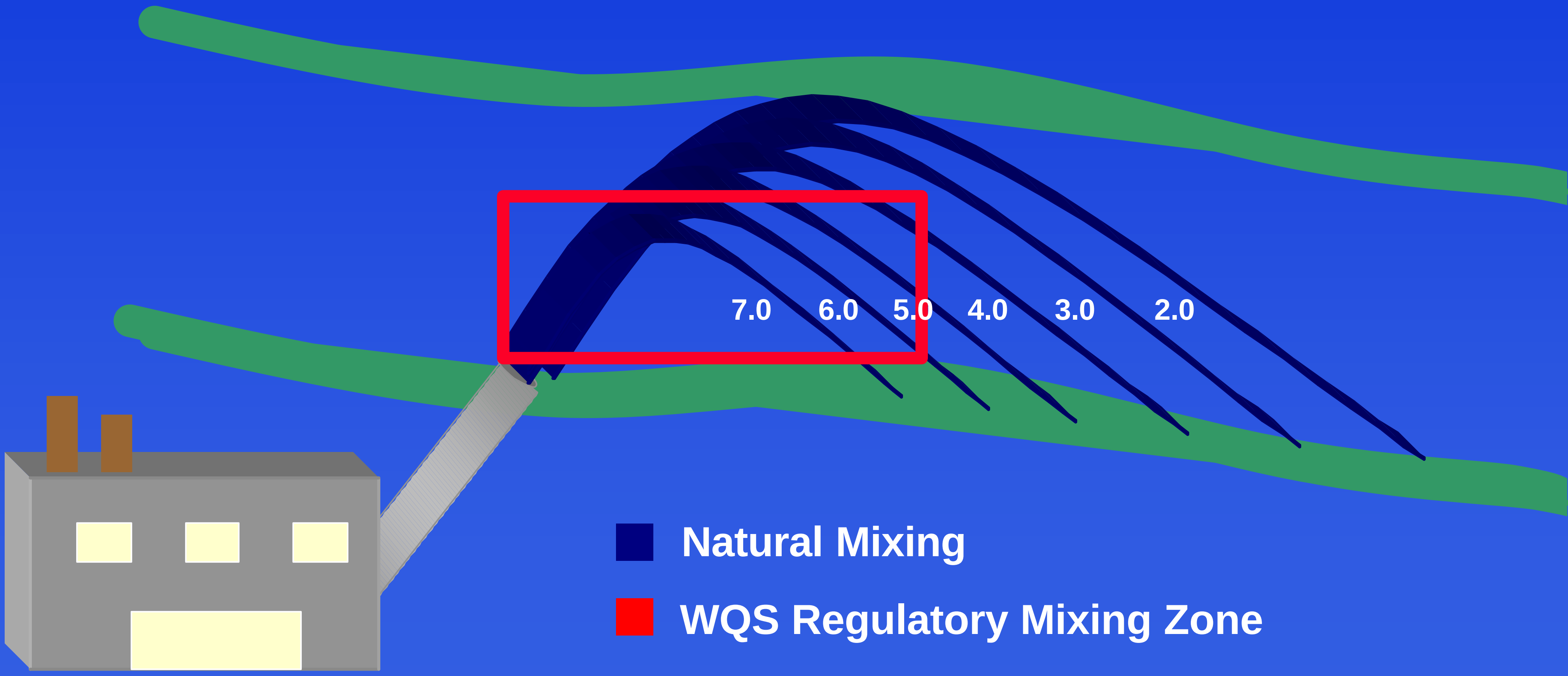

Steady-State Incomplete Mix Assessment

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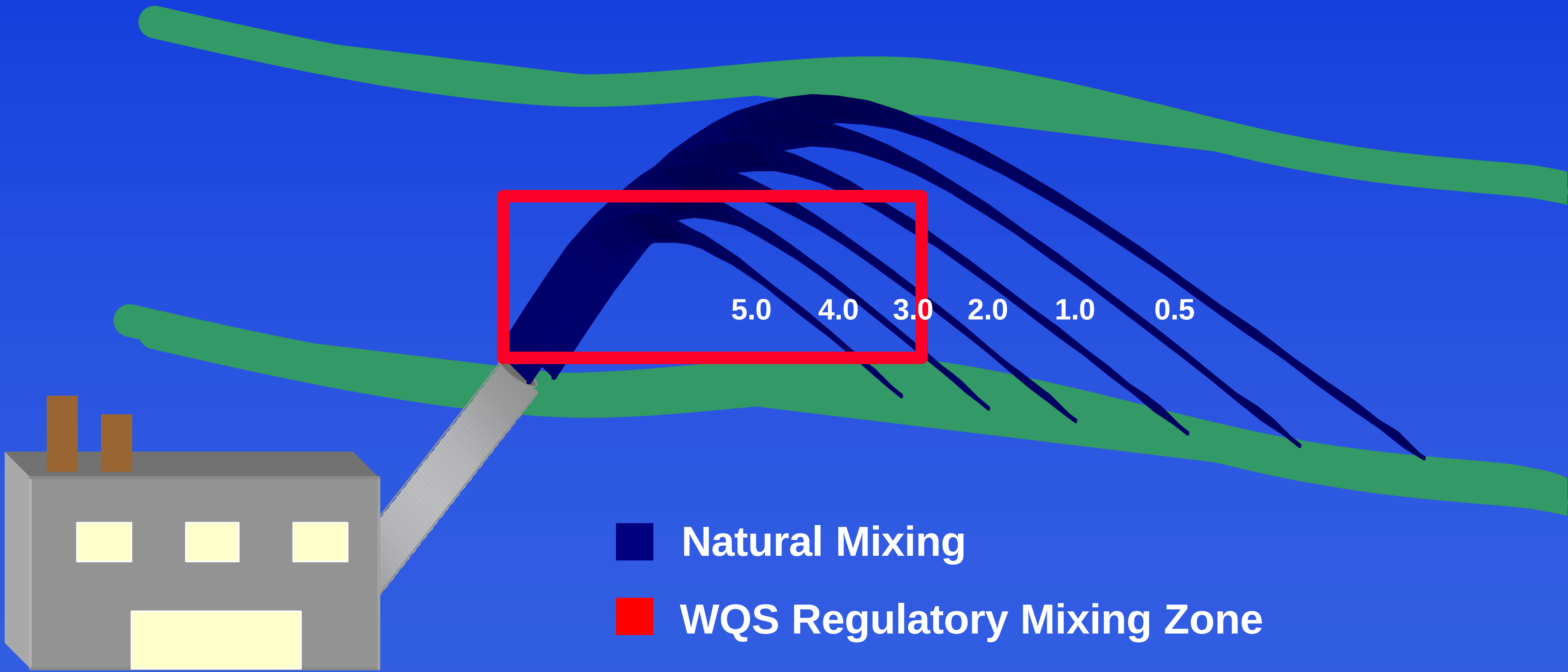
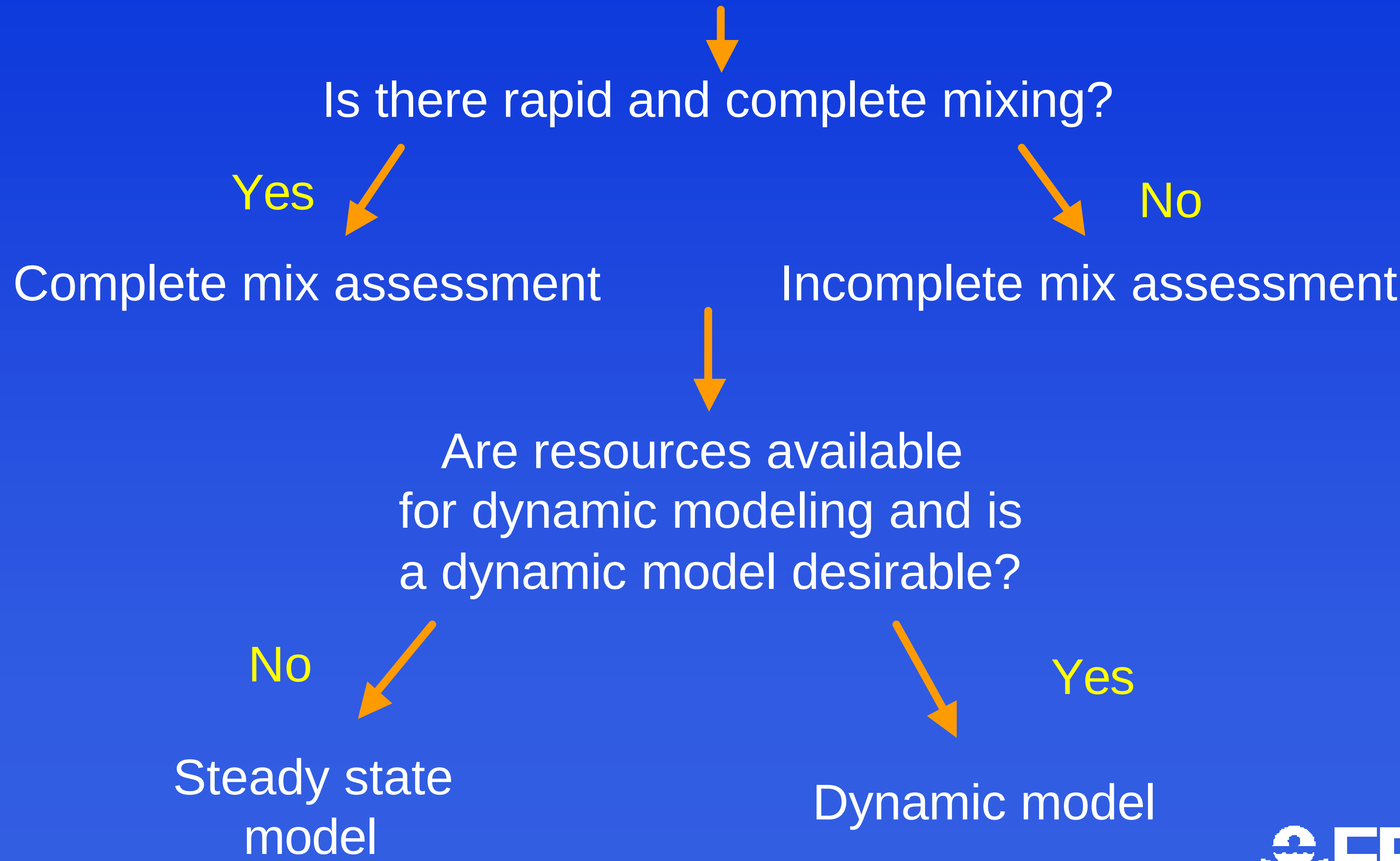


Mixing Considerations (Continued)



Dynamic Model

- Used when adequate data are available to estimate frequency distribution of effluent quality
- Accounts for daily variations of and relationships between effluent, receiving water, and environmental conditions

Dynamic Model (Continued)

- Variability in model inputs
- Results are expressed as a probability of exceeding criteria instead of a single value
  - Continuous simulation
  - Monte Carlo simulation
  - Log-normal analysis

Information Needed to Perform a Water Quality Assessment

- Applicable water quality standards and implementation procedures
  - Criteria and designated uses
  - Critical receiving water flows or volumes
  - Allowable dilution
- Discharge characteristics
  - Flow rate
  - Pollutant concentrations

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Information Needed to Perform a Water Quality Assessment (cont.)

- Receiving water characteristics
  - Pollutant concentrations (i.e., background)
  - Stream flow
- Pollutant characteristics
  - Type of pollutant
    - Non-conservative: mitigated by both natural stream dilution and degradation in the receiving stream (e.g., ammonia, bacteria)
    - Conservative: mitigated only by natural stream dilution (e.g., heavy metals)
  - Reaction rates

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Why Use Models?