Mixing Zone Modeling Webinar Workshop Series
January 22- 24 2013

CORMIX Mixing Zone Modeling

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CORMIX Mixing Zone Modeling - Outline

- Part 1
  - Types & Scale of mixing models
  - CORMIX Description, Access, Input data requirements, specification, schematization
  - Single port & Multiport diffuser specification
  - Q & A

Break (10 minutes)

- CORMIX GUI Overview – Demo
- Part 2
  - Flow Classification Process
  - CORMIX Output
  - Q & A

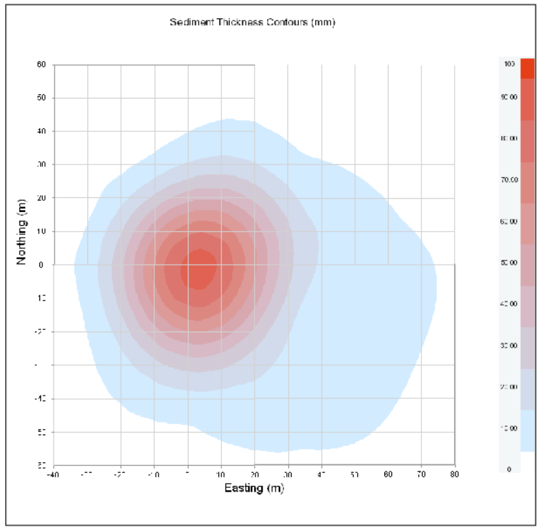
Break (10 minutes)

- Part 3
  - Case Study – Single Port and Multiport Diffuser - Demo
  - Q & A

Break (10 minutes)

- Part 4
  - Advanced CORMIX, Validation, QA/QC
  - Q & A
  - Wrap Up

Models for Mixing Processes: Part1



CorPlot visualization of sediment bottom deposition contours of a offshore WBM discharge study – modeled using CORMIX

Predictive Models for Mixing Processes – Types & Scale

Complete Models:

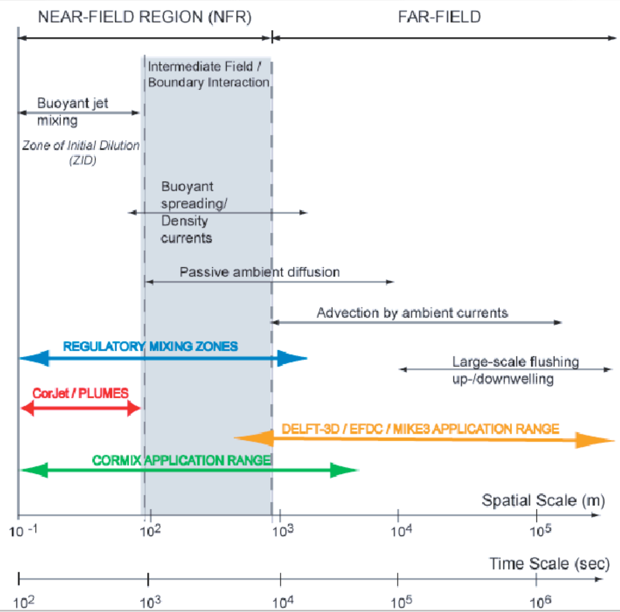
- Single *domain* with *one set* of governing *equations*
  - Drawbacks
    - Numerical limitations
    - Turbulence Models
    - Boundary Conditions
- Fluent, Flow3D, STAR3D

Zone Models:

- Divide domain into sub-regions with specific mixing processes
  - Allows use of simplified equations
- Jet Integral Models
- Mixing Zone Expert System – CORMIX

Model	Scale	Typical Grid Resolution
Ocean Circulation	Ocean wide	10 - 100 of km
Coastal Circulation (Far-field)	Coastal Zones, Estuaries	0,1 - 1km
Discharge Mixing Models (Near-field)	Local (scale of outfall)	no grid; predictions up to 10m - 5km

Physical Mixing Processes



Modeling Approaches

Hydrodynamic Models for Mixing Zone Analysis

(shaded) **Denotes CORMIX problem domain**

Near Field Region Models	Far-field Region Models
A) General Case - high/low momentum flux - high/low buoyancy flux - arbitrary discharge alignment geometry - deep/shallow conditions (stable & unstable) - arbitratry ambient stratification - boundary interaction/dynamic attachments Applicable Models: **CORMIX - Mixing Zone Model Expert System**	A) General Case - complex coastal topography & bathymetry - complex current structure (tidal, wind driven) - arbitrary ambient stratfiication Applicable 3D Circulation and Transport Models: **Delft3D (hydrostatic)** **Mike3 (non-hydrostatic)** **POM/ECOM (hydrostatic)** **Telemac3 (hydrostatic)**
B) Restricted Case - combination of weak momentum & high buoyancy flux - deep conditions (stable) - typical for coastal sewage discharge Applicable Models: **CorJet - (included in CORMIX)** **PLUMES**	B) Restricted Case - open coastal areas - simple current patterns - rivers Applicable Models: **CORMIX** **- Tidal Data Option** **- Far Field Locator (FFL post-processor)**

Shaded (CORMIX problem domain): Near Field A) General Case; Far-field B) Restricted Case.

Near-field Models

- Jet Integral Models (CORJET)
  - Integrate dynamic terms along trajectory, across cross-sectional plane
    - Simple ordinary differential equations
  - Empirical equations for turbulence closure: rate of entrainment, ambient drag force, and frontal spreading velocity
  - fast & easy
    - *BUT*: infinite, steady ambient waters (no boundary interactions)

- Mixing Zone Models (CORMIX)
  - Amplifications for boundary interaction, unstable near-field, buoyant spreading, passive diffusion
  - Full range of discharge geometries and ambient conditions
  - Boundary interaction, buoyant spreading and passive diffusion
  - Few parameters
    - Easy input, fast calculations, no calibration
  - ***Limits*:** only simple reversals, 1st order decay, single source

Far-field Models

- **Eulerian hydrodynamics and transport models**
  - Solve unsteady, baroclinic, shallow water equations in 3D (hydrostatic)
  - Orthogonal curvilinear co-ordinates
  - Terrain-following, sigma - coordinate system
  - k-ε turbulence closure
  - Water quality module: Mancini model for coliform inactivation
- **Limits**
  - Ignores dominant NF processes or treats them superficially
  - Spatial and temporal resolution limited by calculation power
  - Difficult to match boundary / initial conditions, shear turbulence
  - **Not particularly useful for <u>Outfall Design</u>**

CORMIX – Introduction and History

- Simulation and decision support system
  - Environmental impact assessment of mixing zones from continuous point source discharges
- Focus on role of boundary interaction to predict mixing behavior and plume geometry
- Mixing Zone Modeling & Outfall Design
  - single-port, multiport diffuser discharges and surface shoreline discharge sources
  - Submerged, Near-Surface, Above Surface Discharges
- Effluents
  - conservative, non-conservative, heated, dense brine discharges suspended sediments (dredge and drilling muds and cuttings)
- > 25 years of R&D
  - USEPA - ORD, Office of Water, OST
  - MEDRC
  - USBR
  - Sates of MD and DE
  - Cornell, OGI, PSU
- **CORMIX Support, Licensing, Distribution**
  - **MixZon Inc. (Small Business in Portland, OR)**

Portland, Oregon youth of 1938 join the mayor in protest of Willamette River pollution. Photo: Oregon Historical Society.

CORMIX - Access

- **USEPA Federal, State, Local & Tribal Regulators**
  - **Licensing to CORMIX General Release – CORMIX v8.0G @ NO CHARGE**
  - Discounted Site Licensing and Technical Support to other versions
  - Contact **support@mixzon.com**
- Web Resources
  - **www.mixzon.com**
    - User Registration and Access to CORMIX Evaluation version downloads
    - User Manuals
    - CORMIX Technical Reports
    - Licensing and Support
  - **www.cormix.info**
    - CORMIX Information
    - Applications
    - Methodology
    - References
    - Validations
    - FAQ

CORMIX - Cornell Mixing Zone Expert System

CORMIX1: Single Port Discharges (Doneker & Jirka, 1989)

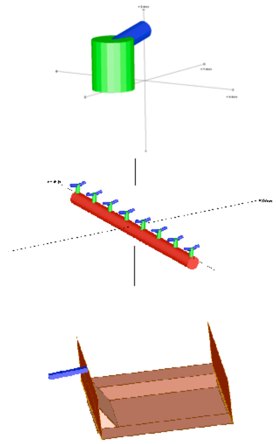
- ***Bounded & Unbounded*** channels
  - rivers, estuaries, coastal, lakes
- ***Crossflows*** or ***stagnant***
- ***Buoyant*** (positively, negatively, or neutral)
- ***Uniform*** or ***Stratified*** Ambient (up to 3 density layers)
- Submerged, Near & Above Surface Discharges
- Brine, Sediment (Drill Cuttings and Muds)
- Covers **> 95 %** of cases

CORMIX2: Multiport Diffusers (Akar & Jirka, 1990)

- Similar conditions as CORMIX1
- 3 Major Diffuser Types
  - ***Alternating, Unidirectional, Staged***
- Covers **> 80 %** of cases

CORMIX3: Surface Discharges (Jones & Jirka, 1990)

- Similar conditions as CORMIX1
- Covers **> 90 %** of cases



CorSpy visualizations of single port, multiport & surface discharge

CORMIX1, 2, 3 ?

- **All versions of CORMIX 8.0 include CORMIX1, CORMIX2 and CORMIX3 modules**

CORMIX

CORMIX1
Single Port Discharges

CORMIX2
Multiport Discharges

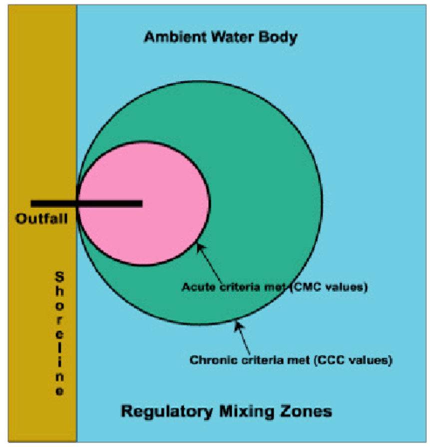
CORMIX3
Surface Discharges

Why An ”Expert” or ”Rule Based” System?

- Data Driven System – specify data, system selects the model
- Proper model **choice; Correct** model application
- **Guides** in data acquisition
- Addresses CREM guidelines - *http://www.epa.gov/crem/index.html*
- ***Flexible:***
  - **Screening** of alternatives
  - **Switch** to other models
- Continuous update of **knowledge base**
- **Documented** analysis - **Not** a ***”black box”***
- **Design** System
- Advanced ***CAD 3-D Graphics*** tools (CorVue, CorSpy, CorPlot)
- Advanced tools (CorHyd, CorTime, Far-field model linkage)
- **Common Framework**
  - ***Regulator***
  - ***Applicant***
- **Teaching** environment
  - ***Adapts*** to user

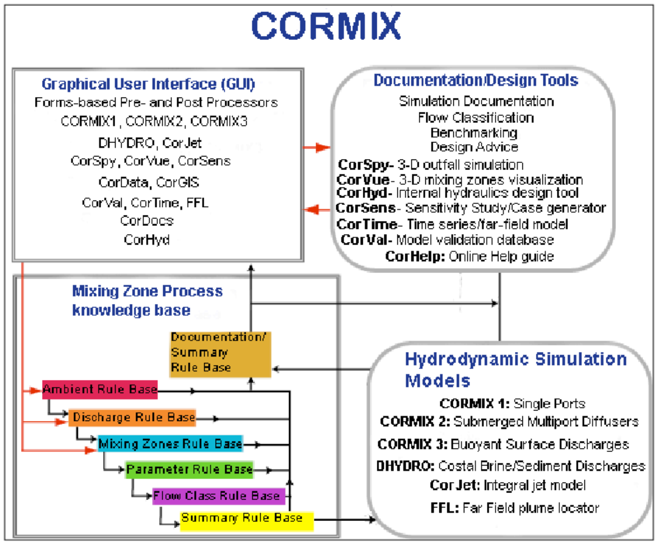
General Features of CORMIX

- ***Data screening***
- Predicts ***quantitative & qualitative*** features of mixing process
- Covers NPDES ***regulatory*** concerns for ***conventional*** & ***toxic*** discharges
- Provides ***guidance*** to ***improve designs*** and associated dilutions
- Flags ***undesirable designs***
- Provides ***descriptions*** of mixing processes



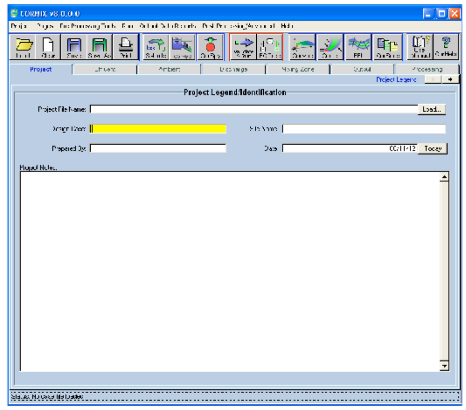
Chronic and acute Regulatory Mixing Zones for conventional and toxic discharges, respectively

CORMIX System Components



CORMIX GUI

- Intuitive windows based GUI
- Tab data input forms
  - -Project
  - -Effluent
  - -Ambient
  - -Discharge
  - -Mixing Zones
  - -Output
  - -Processing
- Data screening
- Validation
- Extensive built in user help and advice



CORMIX Graphical User Interface (GUI)

CORMIX Rule Base

- Input data ***automatically screened*** for ***logic, data type, data range and validation errors***
- Rule Base
  - Ambient , Discharge, Zone
  - Parameter
    - Automatically computes all flow ***parameters,*** L***ength scales, fluxes,*** other ***values***
    - Describes ***near -field*** flow ***properties***
  - Classification & Summary

A) Discharge Quantities

Discharge Volume Flux: $Q_0 = u_0 A_0$ [L^3/T]

Discharge Momentum Flux: $M_0 = u_0 Q_0$ [L^4/T^2]

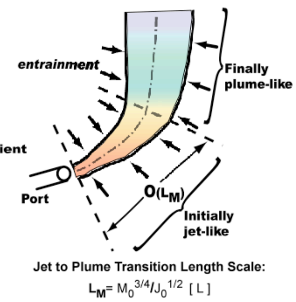
Discharge Buoyancy Flux: $J_0 = g'_0 Q_0$ [L^4/T^3]

Discharge Buoyancy: $g'_0 = g(\rho_a - \rho_0)/\rho_a$ [L/T^2]

B) Buoyant Jet In Stagnant Uniform Ambient

Uniform Ambient Density: $\varepsilon = 0$

Stagnant ambient: $u_a = 0$

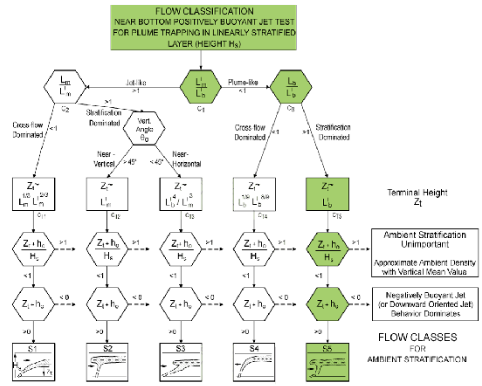


Parameter Calculations for buoyant jet mixing

CORMIX Rule Base

Flow CLASSIFICATION Rule Base

- Determines correct ***flow classification*** for given ***discharge/environment*** interaction
- Develops a generic ***qualitative description*** of flow patterns
- Specifies flow ***protocol*** for ***hydrodynamic simulation***
- Flow class description gives a ***qualitative description*** of the ***physical processes*** of near-field and far-field mixing
- Heart of CORMIX ***"knowledge base"***
- Compilation of 200 years of hydraulic research



CORMIX1 Classification system for plumes trapped by ambient density stratification.

CORMIX HYDRODYNAMIC SIMULATION Modules

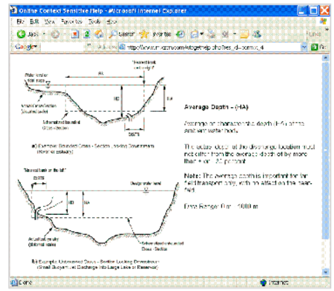
- FORTRAN hydrodynamic simulation program for selected flow classification
- Singe Port Discharge - CORMIX1
- Submerged Multiport Diffusers - CORMIX2
- Shoreline/Surface Discharges - CORMIX3
- Coastal Brine/Sediments/Drilling Effluents - DHYDRO
- CorJet - Stable Near-field model for detailed CORMIX1 & CORMIX2
- FFL - Far-Field Plume Locater
- CorSens - Sensitivity Study Post-processor
- CorTime - Time series analysis, far-field model linkage
- Contains about 400k + lines of code
- 25 + years R&D

CORMIX Documentation User Help

- Multiple-levels of help in GUI
  - Yellow ***Tool Tip***/hint
  - ***CORMIX Help popup (right click)***
  - Context Sensitive Help
  - "User Manual" button

  - CorHelp – Online UI Help
  - "Help -> CorHelp-Online User Guide" menu

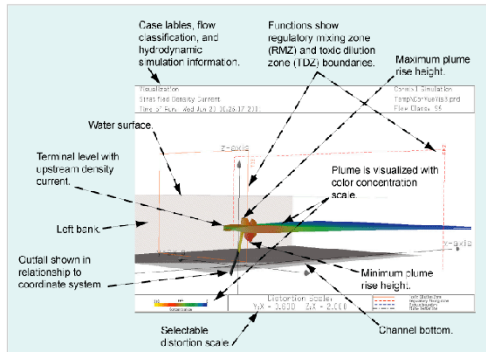
  - "Help -> CorDocs-Online Tech. Docs" menu
    - Online CORMIX1/2/3 Tech. Reports
- Download Manuals, Reports, FAQs, Support, QA/ QC - http://www.mixzon.com
- Information, Validations, References, FAQ's , Glossary, Search Tool - http://www.cormix.info
- Support Ticketing System
  - E-mail to: **support@mixzon.com**



Online Context Sensitive Help

CORMIX Advanced Analysis & Design Tools

- HYDRO ***simulation results summary***
- Specifies concentrations at ***regulatory mixing zones***
- E***xpert advice*** for design iteration
- Data visualization & design
  - CorVue (Plume Visualization)
  - CorSpy (Outfall Visualization)
  - CorHyd (Hydraulics & Design)
  - CorPlot
    - 2d plots
    - S & C Isolines
    - Deposition Contours
  - CorTime
    - Time Series Modeling and Analysis
    - Far-Field Model Linkage



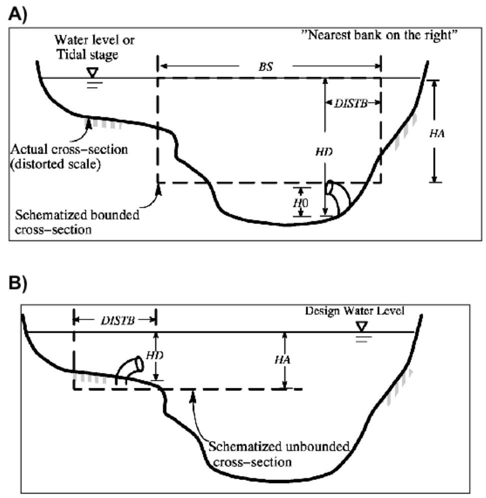
CorVue 3D Mixing Zone Visualization

CORMIX Data INPUT – General

- All data input segments have similar features
- Current data entry box is highlighted in yellow
- Double-click clears entry
- ***Open format:*** decimals not required for numerical input
- Systems checks for data ***inconsistencies*** and ***errors***
- If error occurs during validation - user will be prompted to check and re-enter values
- **Units of Measure**
  - CORMIX uses ***metric SI*** units (MKS) in all internal calculations
  - Automatically converts English/Mixed input units to metric SI equivalents
  - Force all inputs to SI - "Convert to SI Units" button
  - CORMIX reports only in SI units
  - **3 - 4 significant digits** is sufficient; Densities – up to **5** ***significant digits***

Ambient Cross-Section "Schematization"

- **Ambient environments** always have ***boundaries***
  - Vertical
  - Lateral
- One must enter boundary information into CORMIX
  - Process called ***Schematization***
- Assemble ***cross-section plots*** at several downstream locations
- Determine "Equivalent rectangular Cross-sectional area" or ***schematization*** to account for plume boundary interaction
- ***Negatively Buoyant Discharge***
  - Will sink downwards

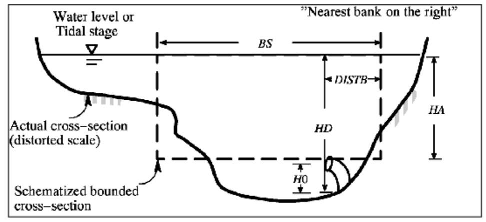


Cross-Section Schematization

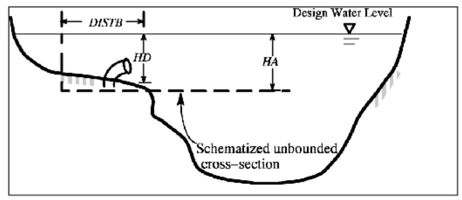
Ambient Cross-Section "Schematization"

- ***Positively Buoyant Discharge***
  - Will rise upwards
    - Deeper areas irrelevant
  - **Neglect** very shallow bank areas/shallow floodways
- For **highly non-uniform** conditions:
  - HD usually strongly influences **near -field** mixing
  - HA usually strongly influences **far -field** mixing
- **Iterative process**

A)



B)



Schematizations for positively buoyant discharge

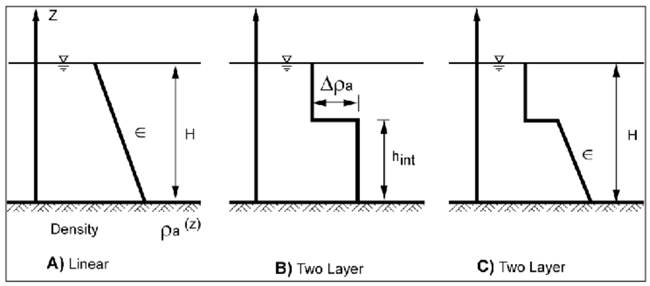
Ambient Density Specification

- Specified as **fresh water** or **non-fresh**
- Important dynamic parameter is **density** not temperature
- If **fresh water and above 10 deg C**, ambient temperature can be specified
- Ambient density can be **uniform** or **non-uniform**
  - Neutral, Positive or Negatively buoyant discharges
    - Up to 2 layer density profiles (CORMIX1 & 2)
  - Brine/Sediment discharges
    - Up to 3 layer density profiles (Brine & Sediment)
  - CorJet allows any arbitrary density profile
    - Up to 10 layers

Ambient Density Specification

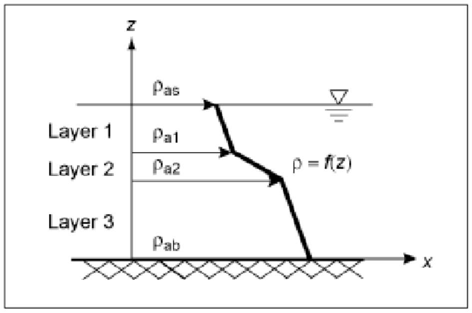
Neutrally, Negatively or Positively buoyant discharge density profiles:

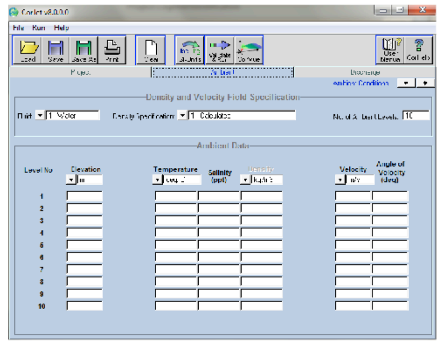
- If vertical variation of density < 1°C or 0.1 kg/m^3
  - Specify as ***uniform***
  - Specify **average ambient density** or **average ambient temperature**
- CORMIX1 and 2 allow for the stratification types shown in figure below
- CORMIX3 (Surface Discharge) assumes positive or neutral discharge and uniform surface layer



Possible Approximations of Ambient Density Profiles

Ambient Density Specification





Brine or Sediment discharges

- ***Up to 3 density levels***

CorJet

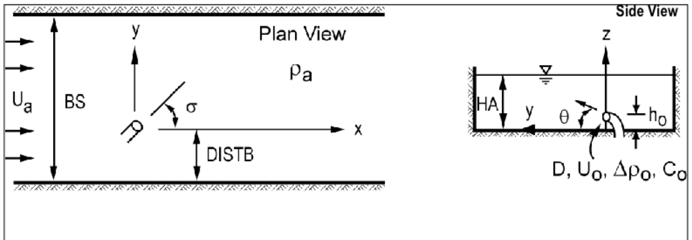
- ***Up to 10 density levels***

Wind Speed

- ***Wind speed*** *(*U_w)
- Effects far-field mixing, for ***heated discharges***
- Wind is ***non-directional*** in CORMIX
  - However wind direction may affect surface velocity field
  - Surface currents should be captured by **schematization**
- **Wind direction can be captured in CorJet**

CorVue visualization of a CorJet simulation

CORMIX1- Single Port Discharge - Data Input

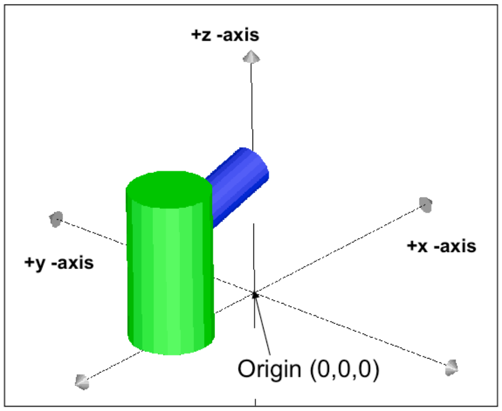


a) Definition Diagram CORMIX1 (Special case: HA = HD)

- Submerged, Near Surface, Above Surface
- Ambient Data
  - Distance from nearest bank (DISTB), Bounded Section Width (BS), Ambient Velocity (U_A), Ambient Density (RHO_A), Ambient Depth (HA)
- Port Configuration/Geometry
  - Port Diameter (D_0), Vertical Angle (THETA), Horizontal Angle (SIGMA), Port Height Above Channel Bottom (h_0)
- Discharge Data
  - Effluent Flow (Q_0) or Velocity (U_0), Effluent Density (RHO_0),
  - Effluent Concentration – **Excess above background** (C_0)
    - **Tip**: Enter as % for simplicity

CORMIX1 - Coordinate System

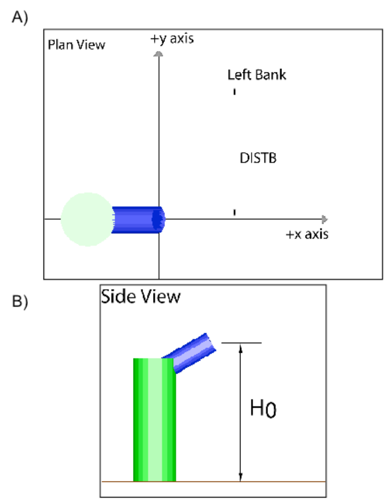
- ***Right hand*** coordinate system
- ***Origin***: (0,0,0) on bottom directly ***below port***
  - Index finger
    - **+x direction** of ***ambient flow,*** u_a
  - Middle finger:
    - +***y lateral*** direction
  - Thumb:
    - +***z direction*** upwards
  - Always specified in PRD file



Coordinate System shown in CorSpy for co-flow discharge. +x is the direction of the ambient velocity u_a

CORMIX1- Discharge Location

- ***Nearest bank***
  - **Left** or **Right** as seen by observing facing downstream
- **DISTB**
  - lateral ***distance to nearest bank***
- ***Port diameter (D_0), or cross-sectional area (A_0)***
- ***Height of port above bottom (H_0)***

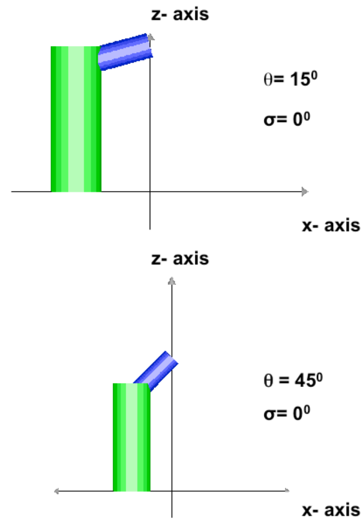


A) Distance to bank DISTB, and
B) Port height H0 in CorSpy

Port Orientation - Vertical Angle of Discharge θ

Vertical angle of discharge **THETA**

- Angle between **port centerline** and **horizontal** plane
- Near Bottom Discharges
  - -45 <= θ <= 90°
- Near Surface Discharges
  - -90 <= θ <= 90°

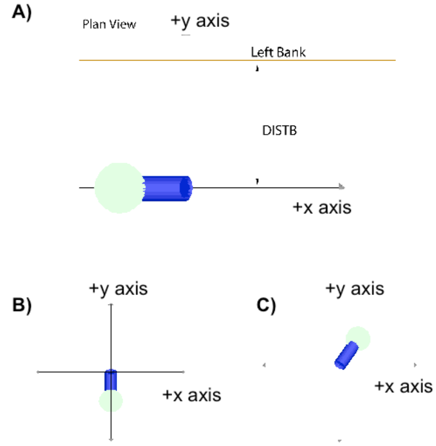


Side views of single port discharge showing the discharge angle θ, in CorSpy

Port Orientation - Horizontal Angle of Discharge σ

***Horizontal angle of discharge* SIGMA**

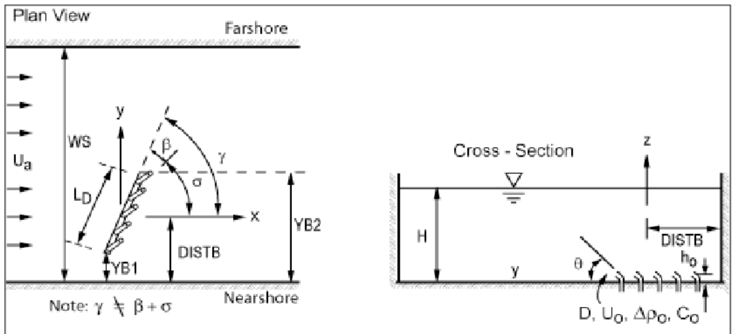
- Angle between **ambient current** and **plan projection** of **port centerline** measured **counterclockwise**
- 0º ≤ σ ≤ 360º
  - σ = 0º or 360º : **Co-flow**
  - σ = 90º : **Crossflow** to left
  - σ = 180º : **Counter-flow**



Plan Views of A) σ = 0º,
B) σ = 90º, and,
C) σ = 235º in CorSpy

CORMIX2 - Multiport Diffuser Data Entry

- Generalized definition sketch appears below
- Many parameters similar to single port definitions

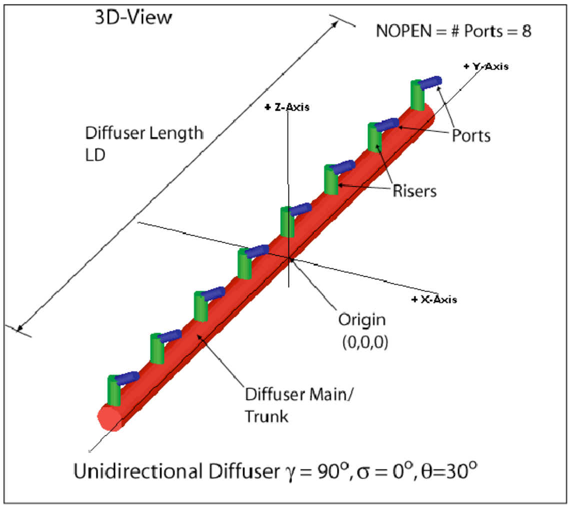


a) Definition Diagram CORMIX2

Definition Diagram for CORMIX2 (special case HA= HD)

CORMIX2 - Basic Diffuser Definitions

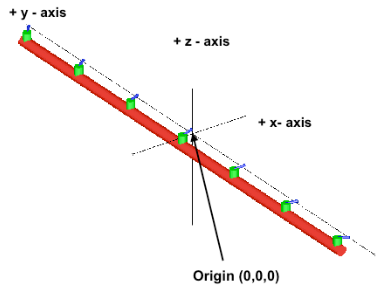
- ***Multiport diffuser:***
  - Linear structure w/ many port/nozzles discharging w/ high velocity
- ***Diffuser line/main/trunk:***
  - Line connecting first port to last port
- **Ports/Nozzles** may be connected to ***vertical risers***
- Simple pipe openings
- CORMIX2 assumes a **straight diffuser line**
  - If NOT, Approximate by straight line

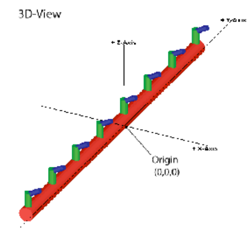


Multiport Diffuser Specification & Visualization In CorSpy

CORMIX2 - Coordinate System

- Similar Ambient and Effluent Discharge data as Single Port
- **Right hand coordinate system:**
  - Index finger: +*x* direction of ***ambient flow*** UA
  - Middle finger: +*y* ***lateral*** direction
  - Thumb : +*z* direction ***upwards***
- Origin: (0,0,0) on bottom, at depth HD below water surface
- Origin (0,0,0) located at ***diffuser mid –point***
- If diffuser starts on shoreline, ***origin on shoreline***





Unidirectional Diffuser $\gamma = 90^{\circ}$, $\sigma = 0^{\circ}$, $\theta=30^{\circ}$

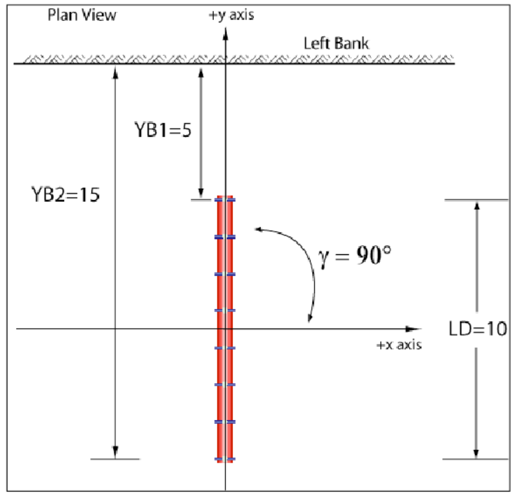
CORMIX2 - Diffuser Geometry

- CORMIX2 assumes **uniform discharge conditions** along diffuser line
- ***Local ambient depth at discharge*** **HD**
  - Offshore slopes should be approximated by ***mean depth***
  - w/ possible bias to ***shallow near-shore*** conditions
- ***Mean values*** should be specified for ***variable diffuser*** geometry
- ***Average diameter*** D_0 of discharge ports/nozzles
- ***Number*** of ports or risers and number of ports per riser
- Jet contraction coefficient value
  - Set = 1.0 for conservative design

CORMIX2 - Diffuser Geometry – Alignment Angle γ

Average alignment angle **GAMMA**

- Measured counterclockwise from ***ambient current*** (x-axis) to ***diffuser axis***
  - $0^o <= \gamma <= 180^o$
- Distance from the shore to the ***first*** and ***last*** port/riser YB1, YB2
- Figure shows an ***alternating perpendicular diffuser***
  - Length LD = 10m
  - $\gamma = 90^o$

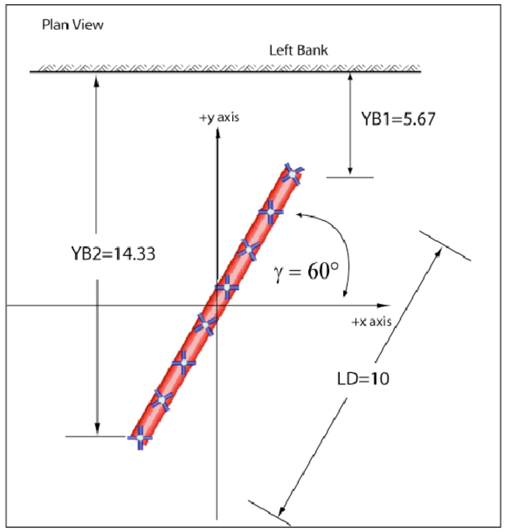


Multiport diffuser geometry example for typical alternating diffuser.

CORMIX2 - Diffuser Geometry – Alignment Angle γ

Average alignment angle **GAMMA**

- Measured counterclockwise from ***ambient current*** (x-axis) to ***diffuser axis***
  - $0^o <= \gamma <= 180^o$
- Distance from the shore to the ***first*** and ***last*** port/riser YB1, YB2
- Figure shows an ***alternating rosette diffuser***
  - $\gamma = 60^o$

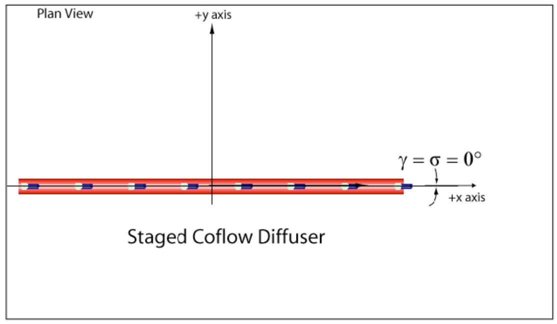


Multiport diffuser geometry example for oblique rosette alternating diffuser.

CORMIX2 - Diffuser Geometry – Alignment Angle γ

Average alignment angle **GAMMA**

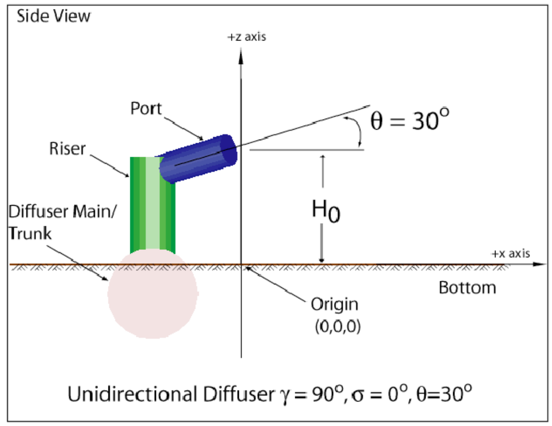
- Measured counterclockwise from ambient current (x-axis) to diffuser axis
  - $0^o \leq \gamma \leq 180^o$
- Figure shows an ***staged diffuser***
  - $\gamma = 0^o$



Multiport diffuser geometry example for co-flowing staged diffuser.

CORMIX2 - Diffuser Geometry - Vertical Angle θ, Port Height H_0

- Average ***Vertical angle of discharge*** **THETA (θ)**
  - Angle between port centerline and horizontal plane
  - $-45^o \leq \theta \leq 90^o$
  - Horizontal discharges θ = 0°
  - Vertical discharges θ = 90°
- ***Average height of port centers* H_0** above bottom



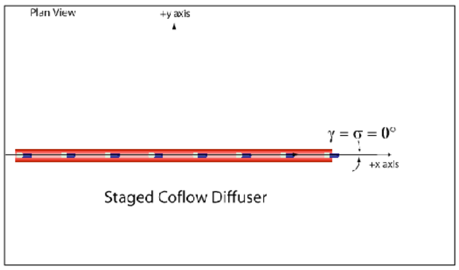
Example of local port geometry for multiport diffuser

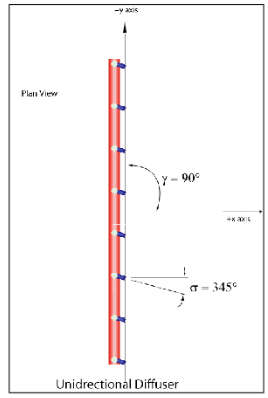
CORMIX2 - Diffuser Geometry – Horizontal Angle σ

For **<u>unidirectional and staged diffusers</u>** only:

- ***Horizontal angle of discharge*** **SIGMA (σ)**

- Angle between ambient current and plan projection of port centerline measured counterclockwise
  - $0^o \le \sigma \le 360^o$
  - **Coflow:** $\sigma = 0^o$ or 360^o :
  - **Crossflow:** $\sigma = 90^o$

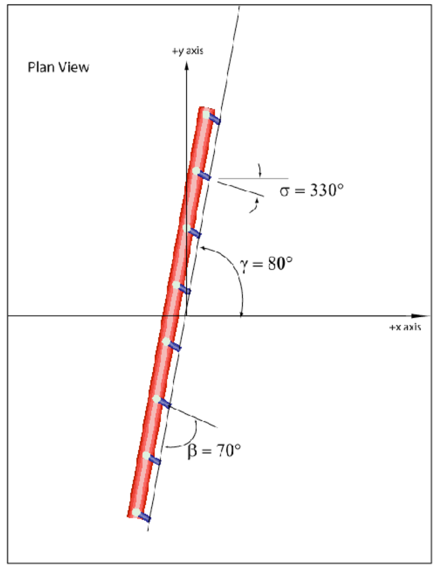




CORMIX2 - Diffuser Geometry – Relative Orientation β

For **unidirectional and staged diffusers** only:

- ***Relative orientation angle*** **BETA β**
  - Measured from average plan projections of port centerlines to nearest diffuser axis (clockwise or counterclockwise)
  - 0º<= β <=360º
- Unidirectional diffuser
  - β [?] 90º
- Staged diffuser
  - β [?] 0º

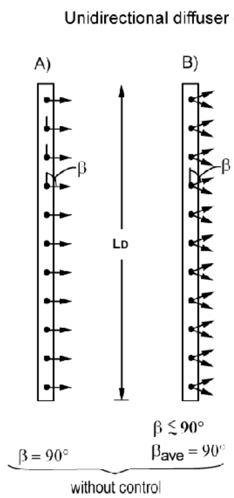


CORMIX2 Multiport Diffuser Types

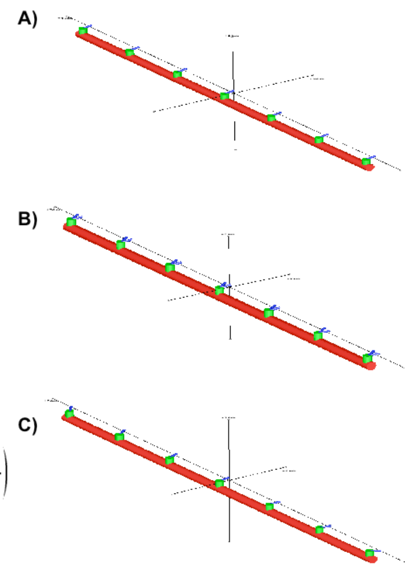
3 Major CORMIX2 Diffuser Types

- ***Unidirectional diffuser:*** all ports point to one side of diffuser line, more or less horizontally
  - Imparts **net *horizontal momentum* perpendicular** to diffuser line
- ***Staged diffuser:*** all ports point in one direction along diffuser line, more or less horizontally
  - Imparts **net *horizontal momentum* along** diffuser line
- ***Alternating diffuser:*** ports do not point in single horizontal direction
  - Imparts ***no net horizontal momentum***
  - May point more or less ***horizontally*** in ***alternating directions***
  - May point ***vertically upwards***
- CORMIX always assumes ***uniform spacing*** and ***round*** port cross-sections

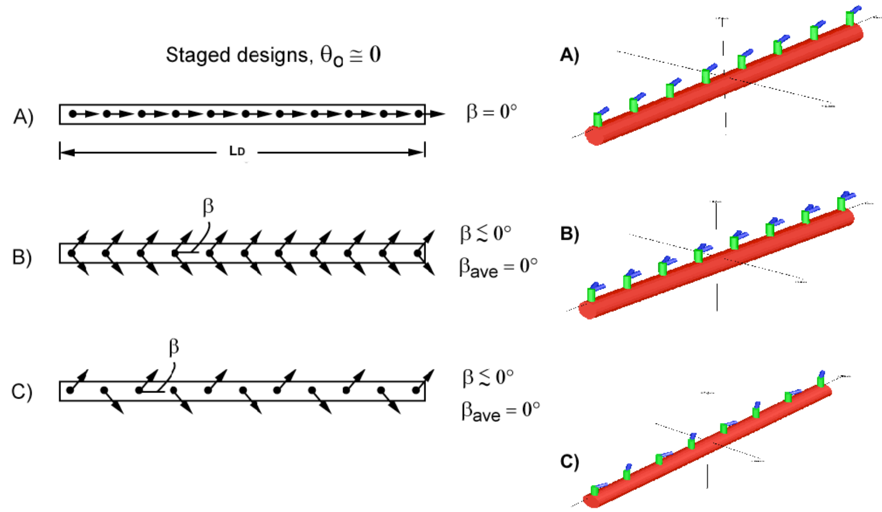
Unidirectional Diffusers



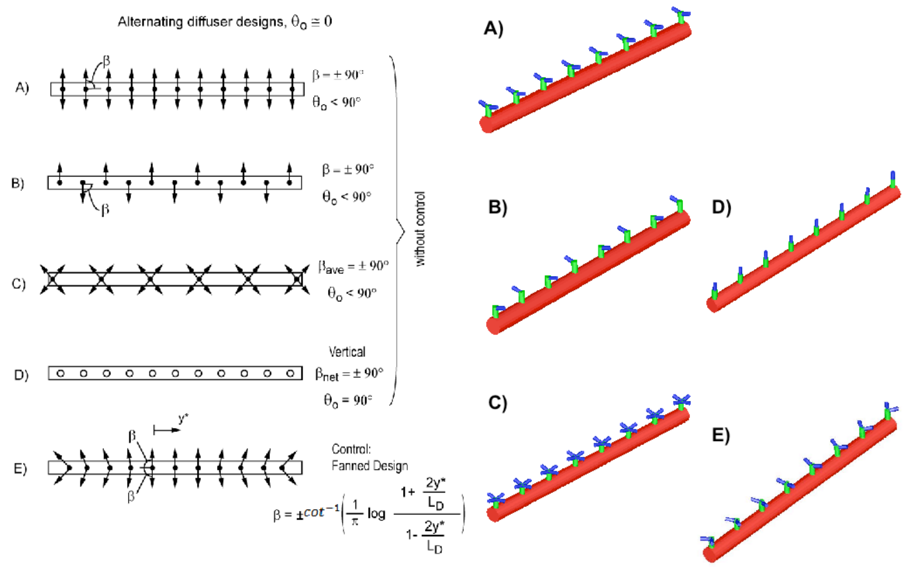
$$\beta = \cot^{-1}\left(\frac{1}{\pi}\log\frac{1+\frac{2y^*}{L_D}}{1-\frac{2y^*}{L_D}}\right)$$



Staged Diffusers



Alternating Diffusers



Models for Mixing Processes: Part 1 Summary

- Types & Scale of mixing models
- CORMIX Model
  - CORMIX Input Specification

Q & A

Break

10 minute break

CORMIX – GUI Demo

- GUI Components
  - Menu & Tool bars
  - Input Tab Pages
- Levels of Help
  - Tool Tips
  - Help Windows
  - Online Context sensitive help
  - CORMIX User Manual
  - CorHelp – Online User Interface Help
  - Flow class tree – FC-DTree Button
- CORMIX Files
  - Input file (*.cmx)
  - Prediction File (*.prd)
  - Sessions Report (*.ses)
  - Processing Journal (*.jrn)
- Brief Overview of CORMIX Pre-Post Processing and Advanced Tools
  - CorVue, CorSpy
  - CorSens
  - CorPlot
  - CorHyd
  - CorTime

Models for Mixing Processes: Part 2

- Flow Classification Procedure
  - Flow Classification - *Basic Parameters*
  - Basic Flux quantities – *Source Properties*
  - Length Scales – *Measures of Influence*
- CORMIX Output
  - Hydrodynamic Simulation Module
  - Prediction File
  - Processing Journal
  - Session Report

CORMIX Flow Classification – Basic Parameters

- u_a = ambient velocity
- u_o = discharge velocity
- A_0 = port area
- H = water depth
- h_{int}= pycnocline height
- W = width of channel
- g'_0 = discharge buoyancy
  - Reduced gravitational acceleration due to density difference

$$g_0' = \frac{g(\rho_a - \rho_o)}{\rho_a}$$

- ε = ambient buoyancy gradient

$$\varepsilon = (-\frac{g}{\rho_a}\frac{\partial \rho_a}{\partial z})$$

Basic Discharge Flux Quantities – *Source Properties*

- **Discharge Volume Flux Q_0** - *Source Strength*

  $Q_0 = U_0 A_0$ *[L^3/T]*

- **Discharge Momentum Flux M_0** - *Source Kinetic Energy*

  $M_0 = Q_0 U_0$ *[L^4/T^2]*

- **Discharge Buoyancy Flux J_0** - *Source Gravitational Energy*

$$J_0 = \frac{\rho_a - \rho_0}{\rho_a} g Q_0 = g_0^{'} \cdot Q_0$$

[L^4/T^3]

Length Scales – Discharge Length Scale L_Q

- **NOT *precise measurements*** for influence of different processes
- Only ***scale estimates, .i.e. "on the order of"***
- **Discharge (volume, geometric)** length scale $\mathbf{L_Q}$

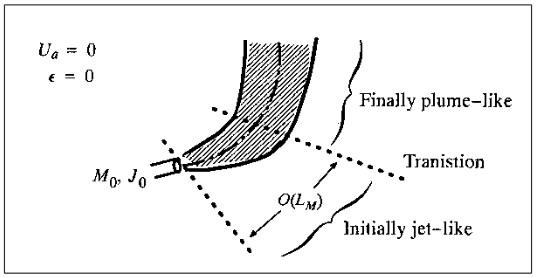
$$L_Q = \frac{Q_0}{M_0^{1/2}} = \frac{Q_0}{\left(Q_0 * u_0\right)^{1/2}} \quad \sim \quad D \quad [L]$$

- Measures Length of ***Zone of Flow Establishment (ZOFE)***
  - Change in velocity profile from logarithmic to free jet

Length Scales - Jet/Plume Transition Length Scale L_M

- For ***combined buoyant*** *jet* flow, the distance at which the transition from jet to plume behavior occurs in stagnant uniform ambient

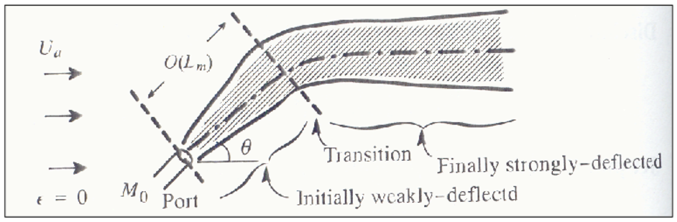
$$L_M = \frac{M_0^{3/4}}{J_0^{1/2}} \qquad [L] = \frac{[\frac{L^4}{t^2}]^{3/4}}{[\frac{L^4}{t^3}]^{1/2}}$$



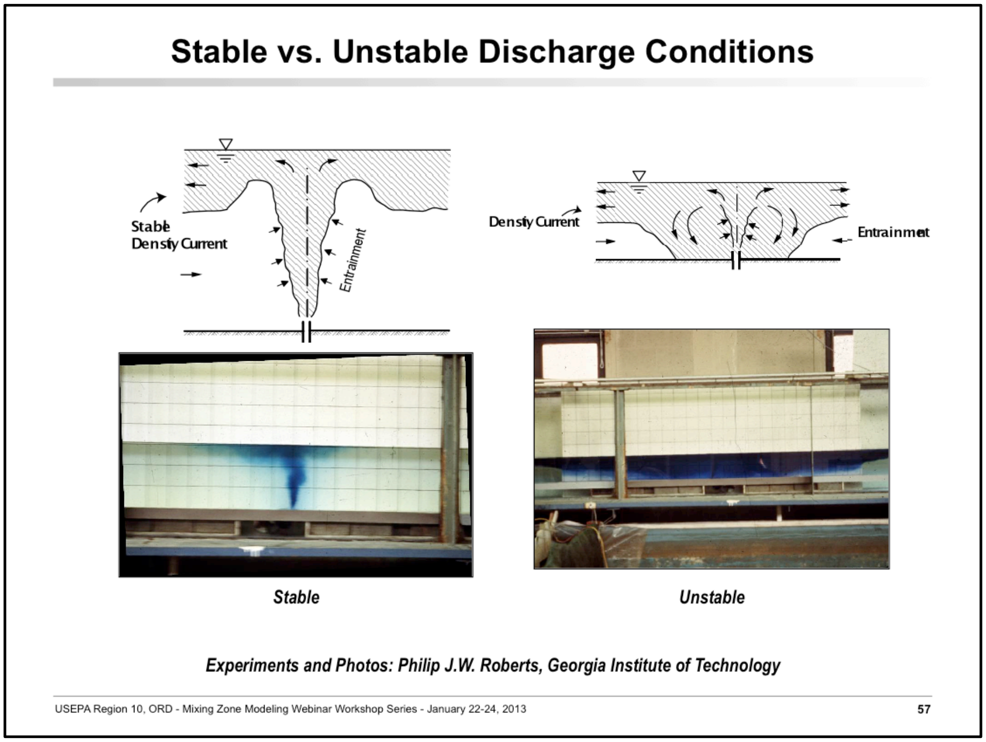
Length Scales - Jet/Crossflow Transition Length Scale L_m

- In the presence of ***crossflow,*** the **distance** of **jet penetration** before jet is **strongly deflected** by ambient flow

$$L_m = \frac{M_0^{1/2}}{u_a} \qquad [L]$$



- Several length scales defined for various transitions, interactions
- **Similar length scales defined for CORMIX2 and CORMIX3**
  - User Manual
  - Technical Reports
  - CORMIX Workshops, Online Training


Stable vs. Unstable Discharge Conditions
Stable
Density Current
Entrainment
Density Current
Entrainment
Stable
Unstable
Experiments and Photos: Philip J.W. Roberts, Georgia Institute of Technology
USEPA Region 10, ORD - Mixing Zone Modeling Webinar Workshop Series - January 22-24, 2013
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General CORMIX Flow Classification Procedure

- CORMIX analyzes the ***dynamic interaction*** of the ***plume*** with the ***ambient environment***
- Plume ***momentum*** and ***buoyancy*** at ***boundary interaction*** control ***mixing*** hydrodynamics and flow ***classification***
- Example for CORMIX1 Flow Classification:
  1. Is stratification **dynamically important?**
     - Does jet/plume **get trapped?**
     - Yes: Stratified flow classes **S** (e.g. S1, S2, etc)
  2. **Negatively** buoyant?
     - Yes: Negatively buoyant flow classes **N** (e.g. NV1, NH3, etc.)
  3. **Positively** buoyant or neutral?
     - Yes: Buoyant flow classes **V,H** (e.g. V1, H4-0, etc)
  4. **Bottom attachment** effects?
     - Yes: Attached flow classes **..A** (e.g. V1A2, S3A3, etc)

CORMIX Flow Class

CORMIX1 (126 flow classes)

Classes **S**	Flows trapped within **linear stratification**
Classes **V,H**	**Positively** buoyant flows in **uniform** density layer
Classes **NV,NH**	**Negatively** buoyant flows in **uniform** density layer
Classes A	Flows affected by **dynamic bottom attachments**
Classes **I**	Images of S,V,H,A e.g.: IS, IV1, IH2, IPV3, IPH4 (**Near Surface**)

CORMIX2 (64 flow classes)

Classes **MS**	Flows **trapped** within linear **stratification**
Classes **MU**	**Positively** buoyant flows in **uniform** density layer
Classes **MNU**	**Negatively** buoyant flows in **uniform** density layer
Classes **I**	Images of MS,MU,MNU e.g.: IMS, IMU, IMPU (**Near Surface**)

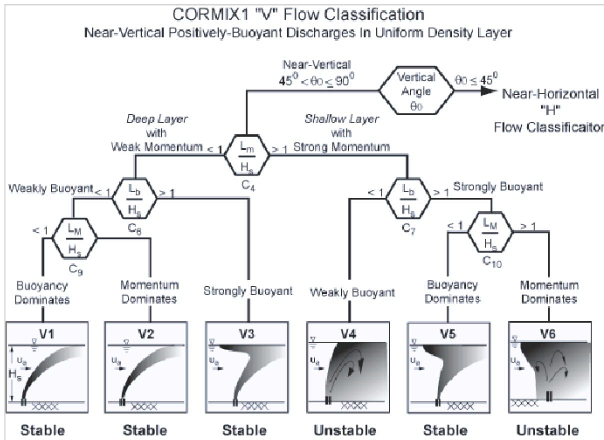
CORMIX3 (9 flow classes)

Classes **FJ**	**Free jet** flows w/o near-field **shoreline interaction**
Classes **SA**	**Shoreline attached** discharges in crossflow
Classes **WJ**	**Wall jets/plumes** from discharges **parallel** to shoreline
Classes **PL**	**Upstream** intruding

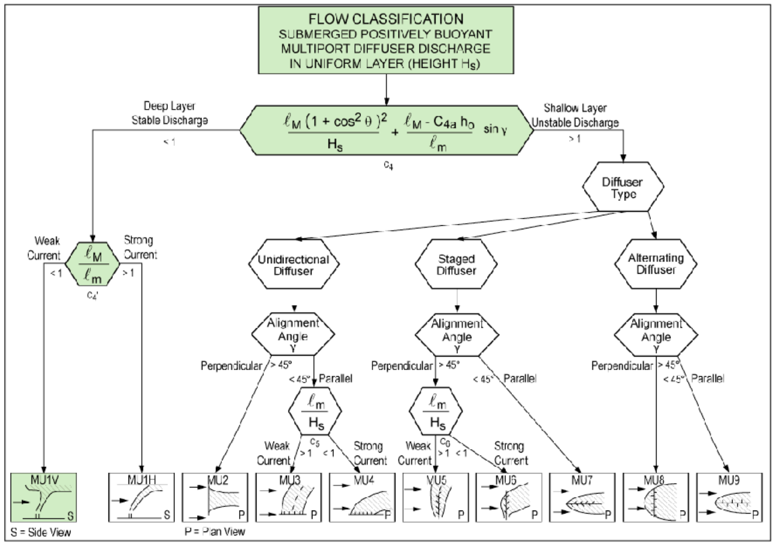
Flow Class Categories and Descriptions

CORMIX1 Flow Classification Example

- Example for deeply submerged near-vertical single port discharge (V*x*)
- CORMIX User Manual - Appendix A – complete set of flow classifications
- For a particular input case - “FC-Tree” button in CORMIX UI



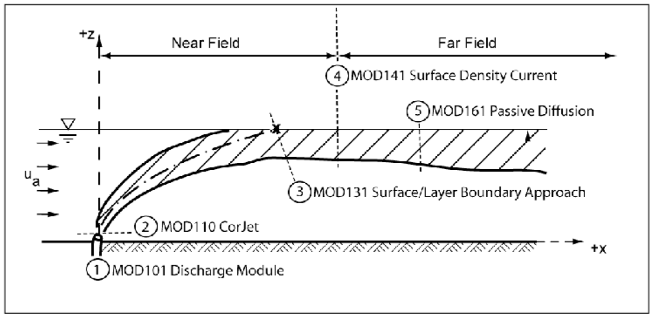
CORMIX2 Flow Classification Example



MU flow classes: Positively buoyant multiport flows in uniform density layer

Hydrodynamic Simulation Modules

- CORMIX uses regional flow models
- Distinct Series of ***"hydrodynamic modules"*** are **executed sequentially** to simulate entire flow field for a given flow classification
- Flow class descriptions give qualitative description of physical mixing processes likely to be present for flow



Illustrative example of a sequence of CORMIX hydrodynamic flow modules executed for plume simulation for flow classification V1

CORMIX Hydrodynamic Simulation & Prediction File

CORMIX Hydrodynamic Simulation and Flow Modules

- The FORTRAN tabular simulation output is available as ***filename*.prd**
- **x, y, z trajectory** of plume centerline
- **Concentration c** of pollutant
- **Dilution S** = c_0/c
- **Plume width (B, BH,** or **BV)**

Continuous modules

- Most ***subsurface modules*** based on **CORJET or CorSurf**
- Some ***buoyant spreading modules*** are ***integral***

Control volume modules

- Used when no mechanistically based mathematical description is available
- Based on ***conservation of mass, momentum***

Transitions from module to modules

- Continuous, satisfying ***conservation of mass, momentum, energy***
- ***Occasional mismatches in plume width will result***
- Most ***mismatches are small***

CORMIX Hydrodynamic Simulation & Prediction File

Maximum Centerline vs. Flux Average Dilution

- To obtain ***flux average*** or ***bulk dilution (***S_f***)***
- For single port discharges: $S_f/S = 1.7$
- For multiport discharges or surface discharges: $S_f/S = 1.3$

Dilution vs. Concentration

- CORMIX gives ***minimum centerline dilution*** S
  - ***maximum concentration*** C
- Dilution S is ratio of initial concentration C_0 to concentration C at given location

$$S = \frac{C_0}{C}$$

- Dilution neglects any **decay** or **growt**h for **non-conservative** pollutants
- Dilution S will **NOT** include 1st order effects; while Concentration C **does!**

Hydrodynamic Display

- Plume centerline shift to bank after attachment more gradual than predicted

CORMIX Output - CORMIX1 Prediction File - Header

```
CASE DESCRIPTION
..........
```

Project Tab Information: Case description, date, time, site name, etc.

```
ENVIRONMENT PARAMETERS (metric units)
 Unbounded section
 HA   =   35.00  HD   =    30.50
 UA   =    0.015 F    =     0.010 USTAR =0.5197E-03
 UW   =    2.000 UWSTAR=0.2198E-02
 Density stratified environment
 STRCND=  C        RHOAM =  997.6240
 RHOAS =  996.2053  RHOAB =  999.6072  RHOAH0=  999.5599  E    =0.7725E-03
 DRHOJ =   2.1813  HINT  =    15.50  ES    =0.2153E-02

DISCHARGE PARAMETERS (metric units)
 BANK  =  RIGHT    DISTB =    46.00
 D0   =    0.254 A0   =    0.051 H0   =    0.60  SUB0 =    29.90
 THETA =    10.00  SIGMA =    90.00
 U0   =    3.019 Q0   =    0.153      =0.1530E+00
 RHO0  =  998.2051  DRHO0 =0.1355E+01  GP0   =0.1329E-01
 C0   =0.3500E+04  CUNITS=  ppb
 IPOLL =  1       KS   =0.0000E+00  KD   =0.0000E+00
```

Effluent & Ambient Tab Information:
Summary input ambient and discharge data, Densities, currents, flow rates, channel data.

```
FLUX VARIABLES (metric units)
 Q0   =0.1530E+00  M0   =0.4620E+00  J0   =0.2034E-02  SIGNJ0=    1.0
 Associated length scales (meters)
 LQ   =    0.23  LM   =   12.43  Lm   =   45.31  Lb   =   602.58
                        Lmp  =    4.95  Lbp  =    3.12
```

Computed Flux Variables and Length Scales - based on input data

```
NON-DIMENSIONAL PARAMETERS
 FR0  =    51.97  R    =   201.30
```

Computed Froude number and cross flow ratio – based on input data

```
FLOW CLASSIFICATION
 11111111111111111111111111111111111111111
 1  Flow class (CORMIX1)     =   S3                       1
 1  Applicable layer depth HS =   15.50                   1
 11111111111111111111111111111111111111111
```

Predicted Flow Class and layer depth

```
MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0   =0.3500E+04  CUNITS=  ppb
 NTOX  =  1       CMC   =0.1200E+04  CCC   =  CSTD
 NSTD  =  1       CSTD  =0.6000E+03
 REGMZ =  1
 REGSPC=  2       XREG  =    0.00  WREG  =   120.00  AREG  =    0.00
 XINT  =  3500.00  XMAX  =  3500.00
```

Mixing Zone Tab: Summary mixing zone input data

CORMIX Output - CORMIX1 Prediction File - Near-field

```
X-Y-Z COORDINATE SYSTEM:
   ORIGIN is located at the bottom and below the center of the port:
      46.00 m  from the RIGHT bank/shore.
   X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP =  10 display intervals per module
```

Explanation of coordinate system

```
-----------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE
     X      Y      Z      S      C      B      Uc      TT
    0.00   0.00   0.60   1.0 0.350E+04  0.13   3.019  .00000E+00
END OF MOD101: DISCHARGE MODULE
-----------------------------------------------------------------------------------
```

Every module has a description, BEGIN and END

```
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION
 Jet-like motion in linear stratification with weak crossflow.

 Zone of flow establishment:       THETAE=    10.00  SIGMAE=    89.88
  LE   =     1.25  XE   =     0.00  YE   =     1.23  ZE   =     0.82

 Profile definitions:
  B = Gaussian 1/e (37%) half-width, normal to trajectory
  S = hydrodynamic centerline dilution
  C = centerline concentration (includes reaction effects, if any)
 Uc = Local centerline excess velocity (above ambient)
 TT = Cumulative travel time
```

Each module will include a description of the Plume Profile.
Eg: Gaussian profiles, top-hat profiles, etc.

```
     X      Y      Z      S      C      B      Uc      TT
    0.00   0.00   0.60   1.0 0.350E+04  0.13   3.019  .00000E+00
```

x, y, z value of plume centerline trajectory, Centerline Dilution - S , Concentration - C, Width - B, Excess Velocity - Uc, Travel Time - TT

```
.................................
** CMC HAS BEEN FOUND **
 The pollutant concentration in the plume falls below CMC value of 0.120E+04   in the current prediction interval.
This is the extent of the TOXIC DILUTION ZONE.
    0.08    5.86   1.70    4.4 0.804E+03  0.66   0.824  .35600E+01
**WATER QUALITY STANDARD OR CCC HAS BEEN FOUND**
```

CMC (TDZ) and CCC (WQS) alert messages.

```
 The pollutant concentration in the plume falls below water quality standard  or CCC value of 0.600E+03
in the current prediction interval.  This is the spatial extent of concentrations exceeding the water quality standard or CCC value.
    0.18    8.22   2.22    6.1 0.571E+03  0.93   0.587  .71119E+01
    0.32   10.68   2.82    8.0 0.436E+03  1.21   0.450  .12113E+02
 Level of buoyancy reversal in stratified ambient.
```

Buoyant Jet reversal

```
    0.51   13.02   3.39    9.8 0.356E+03  1.48   0.367  .18106E+02
.................................
 Maximum jet height has been reached.
```

Maximum buoyant jet trajectory height

```
    1.31   20.03   4.27   15.2 0.231E+03  2.30   0.231  .43204E+02
.................................
Terminal level in stratified ambient has been reached.
 Cumulative travel time =        66.3937 sec  (    0.02 hrs)
END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION
```

Cumulative plume travel time and end of module

CORMIX Output: CORMIX1 Prediction File - Boundary Interaction

```
BEGIN MOD137: TERMINAL LAYER INJECTION/UPSTREAM SPREADING
 UPSTREAM INTRUSION PROPERTIES:
    Maximum elevation of jet/plume rise   =    7.62 m
    Layer thickness in impingement region =    1.30 m
    Upstream intrusion length             =   94.44 m
    X-position of upstream stagnation point =  -92.35 m
    Thickness in intrusion region         =    1.30 m
    Half-width at downstream end          =  197.08 m
    Thickness at downstream end           =    0.93 m
```

Boundary approach module with Upstream Intrusion (BEGIN MOD137 … UPSTREAM INTRUSION PROPERTIES)

Upstream stagnation point (X-position of upstream stagnation point = -92.35 m)

```
 Control volume inflow:
   X      Y      Z      S     C        B     TT
  2.09  24.72   3.42  19.2 0.182E+03  2.87 .66394E+02
```

Control volume inflow boundary conditions

```
Profile definitions:
 BV = top-hat thickness, measured vertically
 BH = top-hat half-width, measured horizontally in Y-direction
 ZU = upper plume boundary (Z-coordinate)
 ZL = lower plume boundary (Z-coordinate)
 S  = hydrodynamic average (bulk) dilution
 C  = average (bulk) concentration (includes reaction effects, if any)
 TT = Cumulative travel time
```

Plume profile definition – 2 dimensional profile

```
   X      Y      Z      S      C        BV     BH     ZU     ZL     TT
 -92.35  24.72   3.42 9999.9 0.000E+00  0.00   0.00   3.42   3.42 .66359E+04
 -88.49  24.72   3.42  75.9 0.461E+02  0.33  27.87   3.58   3.25 .66394E+02
```

-x values – upstream intrusion points.
S at stagnation point is undefined so S = 9999.9

```
................................
** REGULATORY MIXING ZONE BOUNDARY is within the Near-Field Region **
In this prediction interval the TOTAL plume width meets or exceeds  the regulatory value =  120.00 m.
This is the extent of the REGULATORY MIXING ZONE.
   6.07  24.72   3.42  19.3 0.181E+03  1.29  140.75   4.06   2.77 .33181E+03
  24.98  24.72   3.42  22.5 0.155E+03  1.23  153.68   4.03   2.81 .15926E+04
```

Extent of Regulatory Mixing Zone
(within NFR in this case)

```
................................
  100.63  24.72   3.42  36.1 0.970E+02  0.93  197.08   3.89   2.95 .66359E+04
 Cumulative travel time =      6635.8916 sec  (   1.84 hrs)
END OF MOD137: TERMINAL LAYER INJECTION/UPSTREAM SPREADING
------------------------------------------------------------------------------------------
** End of NEAR-FIELD REGION (NFR) **
```

Control volume outflow boundary conditions

End of Near Field Region

```
In this design case, the discharge is located CLOSE TO BANK/SHORE. Some boundary interaction occurs at end of near-field.
This may be related to a design case with a very LOW AMBIENT VELOCITY.
The dilution values in one or more of the preceding zones may be too high.
Carefully evaluate results in near-field and check degree of interaction.
```

Shore interaction & low Ua warnings

```
Consider locating outfall further away from bank or shore. In the next prediction module, the plume centerline will be set to follow the bank/shore.
```

Design Advice

CORMIX Output: CORMIX2 Prediction File - Far-field Density Current

BEGIN MOD241: BUOYANT AMBIENT SPREADING

→ Buoyant Ambient Spreading Module Start

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)
TT = Cumulative travel time

→ Plume profile definition – 2 dimensional rectangular profile

Plume Stage 1 (not bank attached):

→ Plume has NOT yet contact lateral bank

X	Y	Z	S	C	BV	BH	ZU	ZL	TT	
32.26	0.00	0.00	8.7	0.115E+02	0.49	62.07	0.49	0.00	.15603E+04	
39.94	0.00	0.00	8.8	0.113E+02	0.48	63.76	0.48	0.00	.19443E+04	
47.62	0.00	0.00	8.9	0.112E+02	0.48	65.40	0.48	0.00	.23282E+04	
55.30	0.00	0.00	9.0	0.111E+02	0.47	67.00	0.47	0.00	.27122E+04	
62.98	0.00	0.00	9.1	0.110E+02	0.46	68.54	0.46	0.00	.30962E+04	
70.66	0.00	0.00	9.2	0.109E+02	0.46	70.05	0.46	0.00	.34802E+04	

Cumulative travel time = 3480.2034 sec (0.97 hrs)

Plume is ATTACHED to RIGHT bank/shore.
Plume width is now determined from RIGHT bank/shore.

→ Plume contact with RIGHT bank (looking downstream); Hence "–ve" Y values

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL	TT	
70.66	-70.00	0.00	9.2	0.109E+02	0.46	140.00	0.46	0.00	.34802E+04	
356.53	-70.00	0.00	11.6	0.865E+01	0.47	171.25	0.47	0.00	.17774E+05	
642.40	-70.00	0.00	14.7	0.682E+01	0.52	198.45	0.52	0.00	.32067E+05	
928.26	-70.00	0.00	18.6	0.538E+01	0.58	223.58	0.58	0.00	.46360E+05	
1214.13	-70.00	0.00	23.4	0.428E+01	0.66	247.53	0.66	0.00	.60654E+05	
1500.00	-70.00	0.00	29.1	0.344E+01	0.75	270.74	0.75	0.00	.74947E+05	

→ Y coordinate shifts to right bank after shoreline contact

Cumulative travel time = 74947.1719 sec (20.82 hrs)

Simulation limit based on maximum specified distance = 1500.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD241: BUOYANT AMBIENT SPREADING

→ Simulation limit/ROI and end of module

CORMIX2: Multiport Diffuser Discharges End of Prediction File

22222222222222222222222222222222222222222222222222222222222222222222222222222222222222

CORMIX Output: CORMIX3 Prediction File - Far-field Passive Diffusion

```
BEGIN MOD361: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT
```

Far-Field passive diffusion – Begin Module

```
Vertical diffusivity (initial value)   = 0.179E+00 m^2/s
Horizontal diffusivity (initial value) = 0.224E+00 m^2/s
```

Ambient diffusivity values

```
Profile definitions:
 BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
   = or equal to water depth, if fully mixed
 BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
    measured horizontally in Y-direction
 S  = hydrodynamic centerline dilution
 C  = centerline concentration (includes reaction efects, if any)
 TT = Cumulative travel time
```

Plume profile definition

```
Plume Stage 2 (bank attached):
    X        Y       Z     S        C        BV      BH     TT
  292.93  -10.00   0.00  119.6 0.836E+00  4.13   36.19 .39545E+03
```

Plume has contacted lateral RIGHT bank
Y coordinate shifts to RIGHT bank after shoreline contact

```
Plume interacts with BOTTOM.
The passive diffusion plume becomes VERTICALLY FULLY MIXED within this
 prediction interval.
```

Plume contacts BOTTOM and VERTICALLY Fully Mixed
BV = HS

```
  663.64  -10.00   0.00  323.9 0.309E+00 10.00   40.43 .85826E+03
 1034.34  -10.00   0.00  354.6 0.282E+00 10.00   44.27 .13211E+04
** REGULATORY MIXING ZONE BOUNDARY **
In this prediction interval the plume DOWNSTREAM distance meets or exceeds
the regulatory value =  1200.00 m.
This is the extent of the REGULATORY MIXING ZONE.
```

Extent of Regulatory Mixing Zone Boundary

```
 1405.05  -10.00   0.00  382.9 0.261E+00 10.00   47.80 .17839E+04
 1775.76  -10.00   0.00  409.2 0.244E+00 10.00   51.09 .22467E+04
 2146.47  -10.00   0.00  434.0 0.230E+00 10.00   54.18 .27095E+04
 2517.17  -10.00   0.00  457.4 0.219E+00 10.00   57.10 .31723E+04
 2887.88  -10.00   0.00  479.7 0.208E+00 10.00   59.88 .36351E+04
 3258.59  -10.00   0.00  500.9 0.200E+00 10.00   62.54 .40979E+04
 3629.29  -10.00   0.00  521.3 0.192E+00 10.00   65.09 .45607E+04
 4000.00  -10.00   0.00  541.0 0.185E+00 10.00   67.54 .50235E+04
Cumulative travel time =       5023.5024 sec (    1.40 hrs)
```

Cumulative plume travel time

```
Simulation limit based on maximum specified distance =   4000.00 m.
 This is the REGION OF INTEREST limitation.

END OF MOD361: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT
-----------------------------------------------------------------------------
```

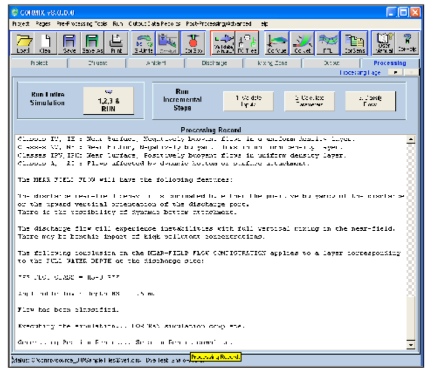
Simulation limit/ROI and end of module

```
-----------------------------------------------------------------------------
CORMIX3: Buoyant Surface Discharges             End of Prediction File
3333333333333333333333333333333333333333333333333333333333333333333333
```

End of Prediction File

CORMIX Output: Processing Record

- Basic ***information*** on mixing processes using ***careful terminology***
- ***Logic*** and parameter ***range errors encountered during automatic data screening***
- Additional checks for data consistency with modeling assumptions
- ***Computed length scales and dynamic parameters***
- Describes key ***calculations & assumptions***
- Subsequent tests **<u>may alter or amplify</u>** initial results
  - Ambient density profiles may not be stable
    - Stability is checked with a ***flux Richardson number***
  - Dynamic bottom attachments
  - Near-field ***instabilities*** may prevent sinking plume
- Collects information for ***Flow Classification***
- ***Logic*** of ***flow classification***
- Alerts user to ***FLOW CLASSIFICATION***
  - Alerts user if simulation is available for the assigned flow class
- ****.jrn file extension***



Processing record

CORMIX Output: Processing Record Messages

Some Examples:

- "The effluent density (1000.45 kg/m^3) ***is greater*** that the surrounding water density at the discharge level (997.2 kg/m^3). Therefore, the effluent is ***negatively buoyant*** and will tend to ***sink towards*** the bottom"
- ***"STRONG BANK INTERACTION*** will occur for this perpendicular diffuser type due to its ***proximity to the bank*** (shoreline). The shoreline will act as a symmetry line for the diffuser flow field. The diffuser length and total flow variables are doubled (or approximately doubled, depending on the vicinity to the shoreline). All of the following length scales are computed on that basis"
- "The specified ***two layer*** ambient density stratification is ***dynamically important***. The discharge near field flow will be confined to the lower layer by the ambient density stratification. Furthermore, it ***may be trapped*** below the ambient density jump at the pycnocline."
- "The discharge port or nozzle points towards the nearest bank/shoreline. Since this is an unusual design, make sure you have specified the discharge horizontal angle (SIGMA) correctly."

CORMIX Output: Session Report

- Contains ***concise summary*** of simulations **(*.ses file extension)**
- ***Interprets prediction*** results in relationship to ***regulatory criteria***
- ***Alerts*** user to special plume characteristics
- Session Report:
  - **Date** and **Time** of analysis
  - Complete echo of **data input**
  - Calculated **flux, length scale** and **non-dimensional parameter** values
  - The CORMIX **flow classification** assigned
  - The **coordinate system** used in analysis
  - Summary of near-field **hydrodynamic mixing zone (HMZ)** conditions
  - Far-field locations where plume becomes **fully mixed vertically** and **horizontally**
  - Summary of **toxic dilution zone (TDZ)** conditions
  - Summary of **regulatory mixing zone (RMZ)** conditions
  - Describes **bottom attachments, bank interaction, upstream intrusions**

Models for Mixing Processes: Part 2 Summary

- CORMIX Flow Classification
- Output

Q & A

Break

10 minute break

Models for Mixing Processes: Part 3

- Case Study - Demo
  - Single Port Discharge
  - Dye study comparison with CORMIX Predictions
  - Multiport Discharge
  - Exercise, Demo and Review
  - Q & A

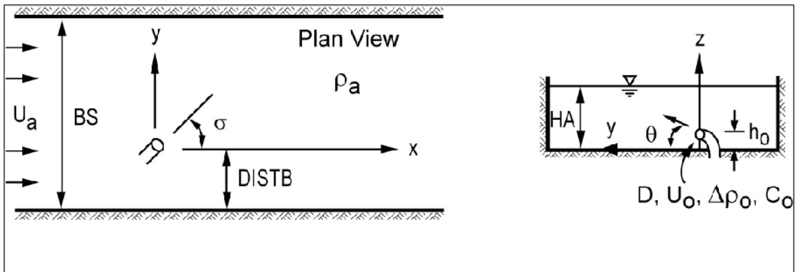
Case Study: Single Port Mixing Dye Study & Multiport Diffuser Design

Case Study Objectives

- **Case Study 2 – Submerged Single Port Discharge, Multiport Diffuser Design**
  - **(Appendix C CORMIX User Manual – pg. 149 onwards)**

- **Objectives:**
  - Read through the complete example description
  - Simulate existing single port discharge in a shallow river
  - Reconcile Dye study data and CORMIX Predictions
    - Use FFL (far-field locator)
  - Specify and Simulate new multiport diffuser design

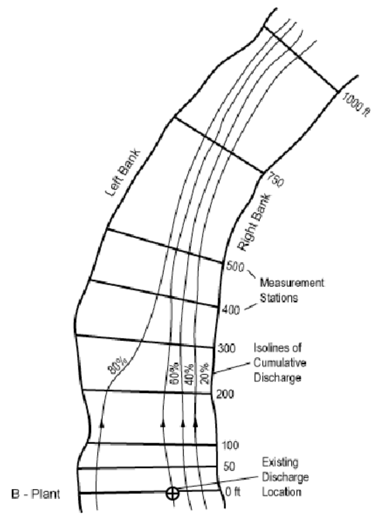
CORMIX1 – Single Port Data



a) Definition Diagram CORMIX1 (Special case: HA = HD)

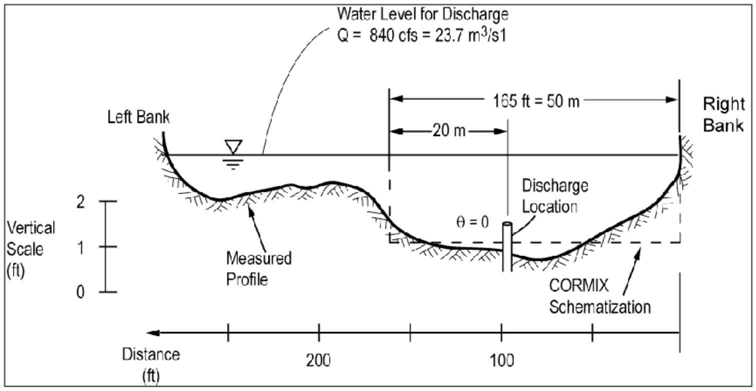
Case Study: Ambient Data

- Q_A = 840 cfs (23.7 m^3/s) during dye test
- Figure shows cross-section of discharge reach
- Data can be used with FFL to plot plume results
- Discharge ***appears geographically nearer*** to ***right*** bank
- However, discharge is located on ***60% isoline*** of Q_{AC}
  - Hence, discharge ***hydraulically closer*** to ***left*** bank
  - Reflected in ambient schematization



Plan view of single port discharge location and cumulative discharge

Case Study: Ambient Data



Ambient Schematization of discharge location

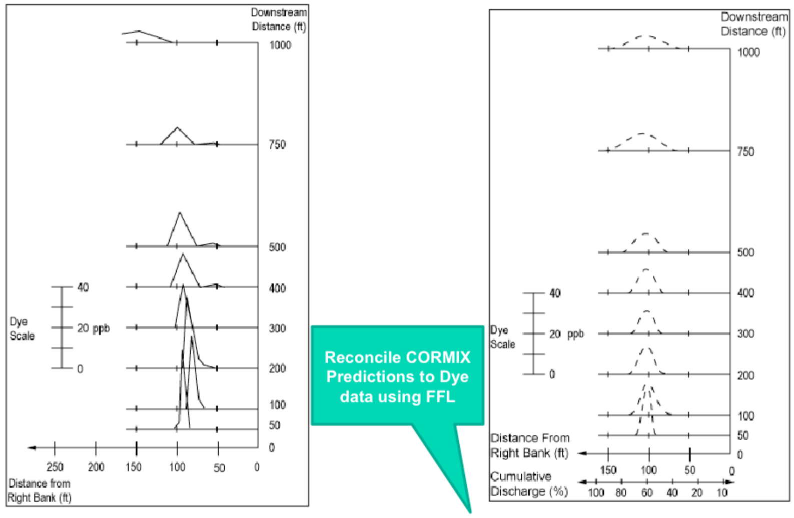
- Average depth of H_A = 0.6 m in near/far field for given Q_A
- Average Temperature, T_A = 20 ^oC
- Discharge is 165 ft. (50m) wide channel, located 20 m from left bank
  - Schematization based on location of discharge on 60% Q_{AC}

Case Study: Discharge Data

Existing Single Port Discharge:

- Port Diameter D_0 = 8" = 0.2 m
- Port Angles (Pointing downstream, parallel to bottom)
  - Vertical Angle THETA = 0^o
  - Horizontal Angle SIGMA = 0^o
- 95 ft. (28.9 meters) from right bank – physically
  - Remember ***hydraulically closer*** to ***left*** bank
- Discharge port elevation H_0 = 0.15 m
- Discharge flow is Q_0 = 0.092 m^3/s
- Discharge (density), temperature is T_0 = 22^oC
- Discharge Concentration (dye) is C_0 = 560 ppb

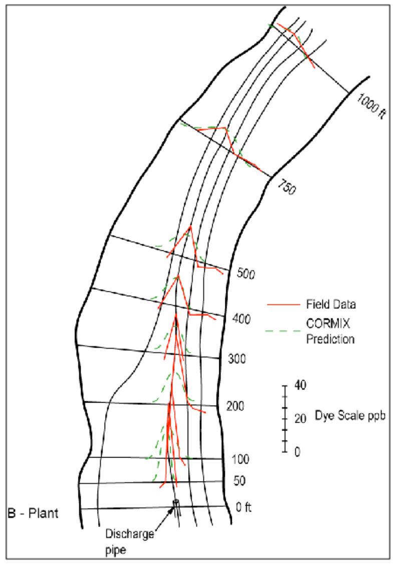
Case Study: Dye Study vs. Single Port Predictions



Measured dye concentrations plotted as a function of distance from right bank

Dye concentrations predicted by CORMIX1 plotted as a function of distance from right bank in schematized channel

Case Study: Reconciliation of Dye Data & Prediction



Dye Data and FFL predictions

Case Study: CORMIX1 – Single Port Data - Demo

- Overview of Single Port Data & Description
- Load Case File
- Review Input Data
- Run Simulation
- Review Processing Record, Prediction File, Session Report, FC-DTree
- Brief Demo of CorVue, CorSpy
- Describe and Demo FFL

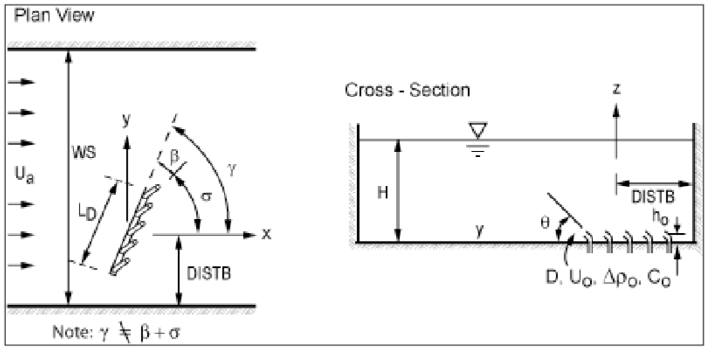
Case Study: CORMIX2 - Multiport Diffuser Design

Strategy to Improve Near-Field Mixing of Single Port:

- **Multiport Diffuser Discharge**
  - **Improves Initial Dilution by using line source**
- Use ambient Q_{7-10} = 285 cfs (8.06 m^3/s)
- Ambient depth H_A at Q_{7-10} = 0.3 m
- Investigate Multiple diffuser configurations and locations
- Consider 15-m long unidirectional diffuser
  - 7 ports each 0.0635 m diameter
  - Perpendicular to shoreline
  - Move closer to right bank to delay contact with left shoreline
  - Proposed Port Height H_0 = 0.09m
  - Fanned and un-fanned designs

Multiport diffuser under construction

CORMIX2 - Multiport Diffuser Data



Case Study: CORMIX2 – Multiport Data - Demo

- Overview of Multiport Data & Description
- Load Case File
- Review Input Data
- Run Simulation
- Review Processing Record, Prediction File, Session Report, FC-DTree
- Brief Demo of CorVue, CorSpy

Case Study - Questions

1. What is the single port flow class, dilution S at the end of the near-field and at 1000 ft.?
2. For the single port, how far downstream is the end of the near-field and what is the travel time?
3. What is the multiport diffuser flow class, dilution at the end of the near-field and at 1000 ft.?
4. For the multiport diffuser, how far downstream is the end of the near-field and what is the travel time?
5. What happens to plume dimensions within the near-field for the multiport diffuser?
6. How does a “fanned” diffuser design affect dilution S at the end of the near-field and at 1000 ft.?
7. What happens to dilution S if the number of ports N is decreased from 7 to 5 or increased from 7 to 9?
8. What happens to dilution S if the diffuser length LD is changed ±10% from 15 m to 13.5 m or 16.5 m?
9. What is the maximum dilution S possible at the site?
10. What information does the far-field locator (FFL) give?

Models for Mixing Processes: Part 3 Summary

- Case Study Demo
  - Single Port Discharge
  - Reconcile Dye Study and CORMIX Predictions
  - Multiport diffuser discharge design and analysis

Q & A

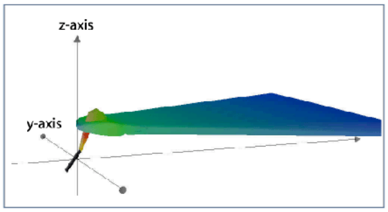
Break

10 minute break

Models for Mixing Processes: Part 4

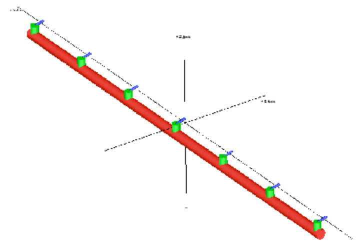
- Advanced CORMIX
  - Introduction
- Validation, QA/QC
- Field Data Collection
  - Integrated Remote Sensing System
- Summary of Topics Covered
- Q & A
- Wrap Up

CORMIX Advanced Design Tools: CorVue & CorSpy



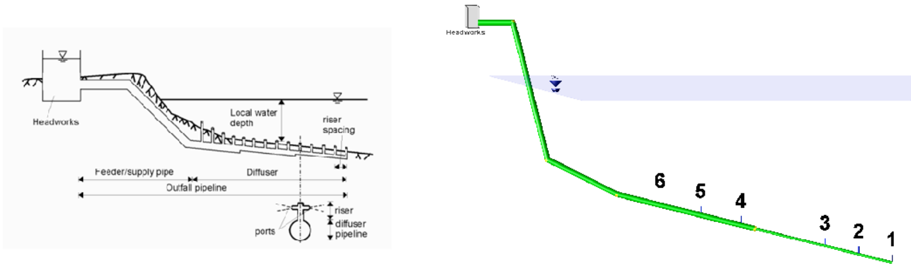
CorVue 3D visualization of a CORMIX simulation

CorVue visualization of CorJet simulation of atmospheric plume mixing



CorSpy visualization of an Unidirectional Multiport Diffuser

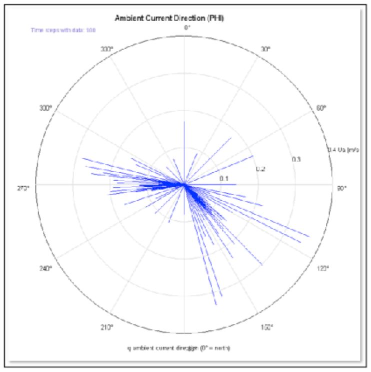
CORMIX Advanced Design Tools: CorHyd



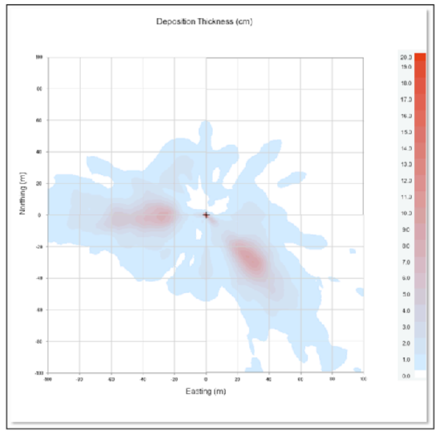
Schematic sketch (above) and CorHyd visualization (right) of a multiport diffuser outfall

- CorHyd - Multiport Diffuser ***hydraulic design and specification tool.***
- Internal diffuser head loss and flow distribution calculation
- A properly designed diffuser will have a constant mass flux along the diffuser line with high port velocity.
- Originally developed by Dr. Tobias Bleninger and Dr. Gerhard H. Jirka at KIT, Germany.

CORMIX Advanced Design Tools: CorPlot

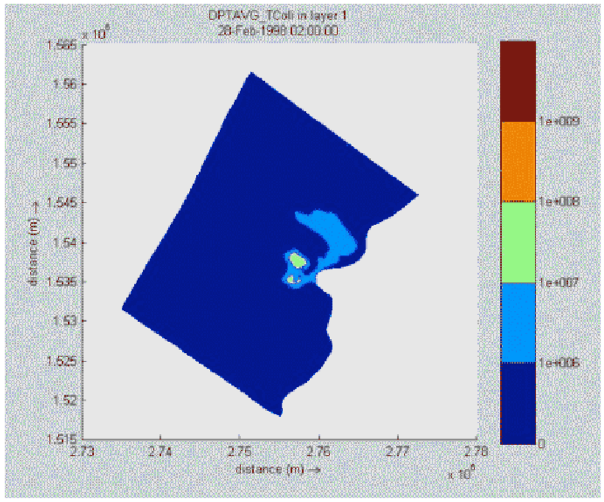


CorPlot - ambient current time series data



CorPlot– Sediment Bottom Deposition Contour plot for offshore oil and gas drilling muds and cuttings discharge

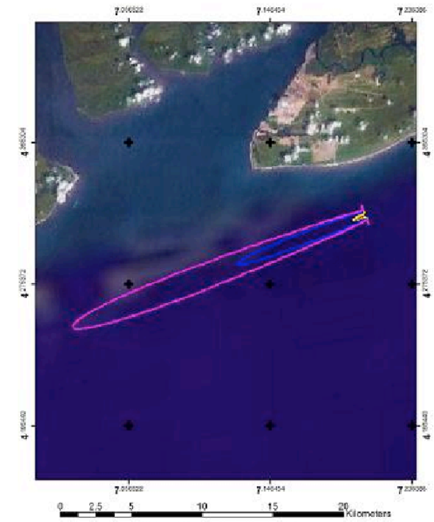
CORMIX Advanced Design Tools: CorTime



CorTime: CORMIX – Far Field Model (Delft3D) linkage.

Time series analysis and visualization of depth averaged concentration [MPN / m³] of total coliforms from offshore multiport discharge
Ref: "Coupling hydrodynamic models for multiport diffusers: design and siting of the Cartagena outfall"
Dr. Tobias Bleninger, IFH – University of Karlsruhe

CORMIX Advanced Design Tools: CorUCS

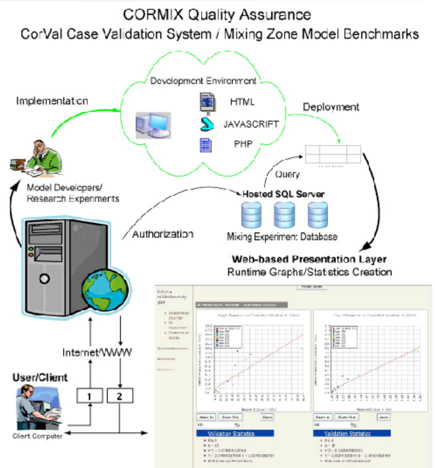


Yellow Contour dilution S= 1596
Blue Contour dilution S = 5255
Pink Contour dilution S = 11517

Along shore, Unstratified case
GAMMA = 90
Current speed = 0.3 m/s

CORMIX - QA/QC & Validation

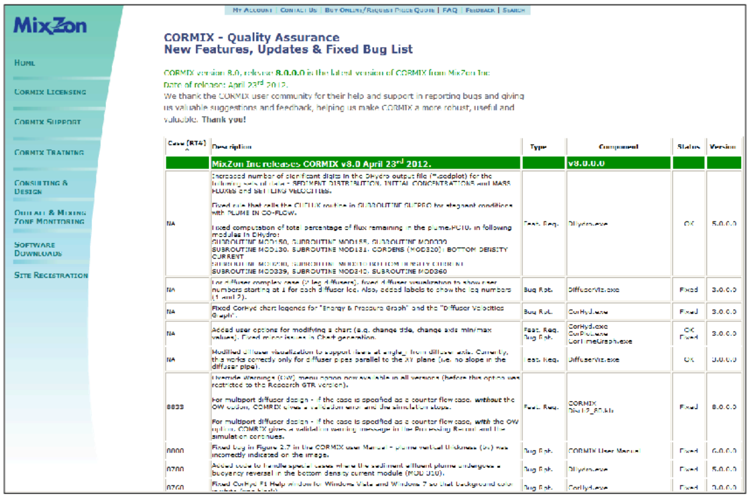
- Independent Validations
- Extensive documentation and validations
  - http://www.cormix.info
- **CorVal**
  - Validation database
  - Model development
- **Benchmarks**
  - Test cases
- **Support Tickets**
  - Stalled cases
  - Bug fix queue
  - Documented revision
  - Update/Upgrade cycles



1. Via web browser, user selects CorJet Benchmark case to inspect or upload CORMIX case simulation files for database validation.
2. Benchmark or validation database results are returned to user in a web page.
3. Qaulity assurance- facilitated by user feedback, bug reports, suggestions for improvement. Documented by support ticket system, email to: support@mixzon.com
4. Quality assurance information available at:http://www.mixzon.com/quality_assurance.php

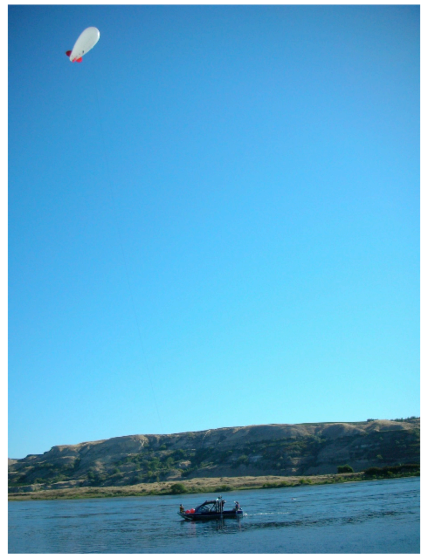
CORMIX - QA/QC & Validation – Support Tickets

- Support Ticketing E-mail: **support@mixzon.com**
- Documented Revisions/Updates: **http://www.mixzon.com/quality_assurance.php**

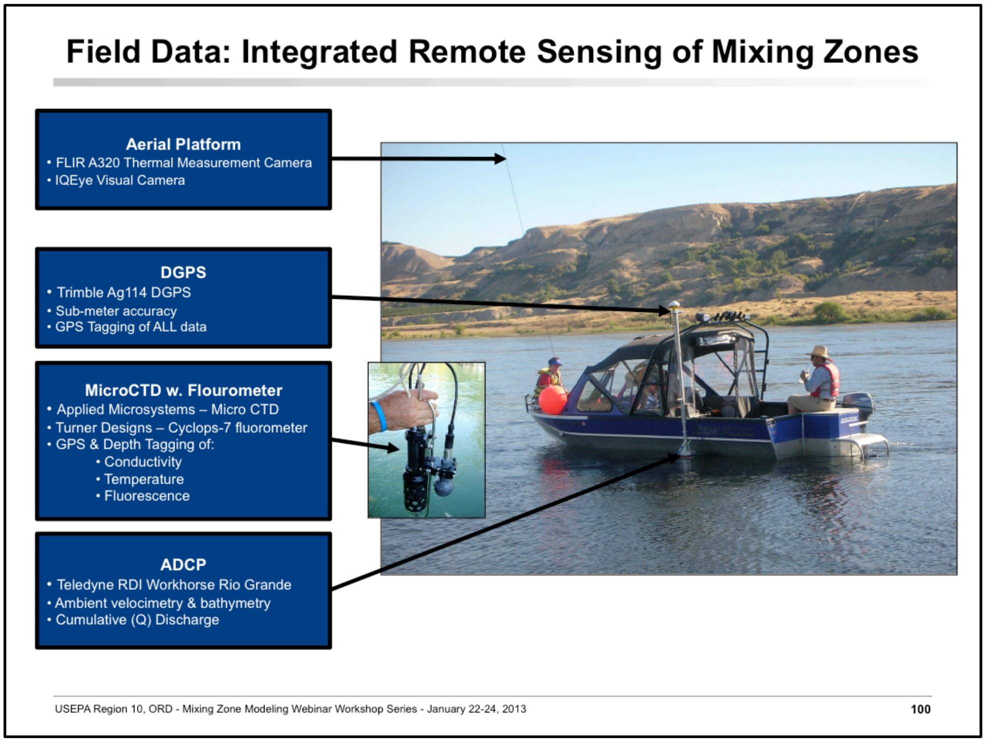


Field Data: Integrated Remote Sensing of Mixing Zones

- **EPA SBIR Program**
  - **Phase 1: EP-D-06-049**
  - **Phase 2: EP-D-07-086**
- Aerial Remote Sensing System
  - Helium Balloon Platform
  - Temperature as a dilution tracer



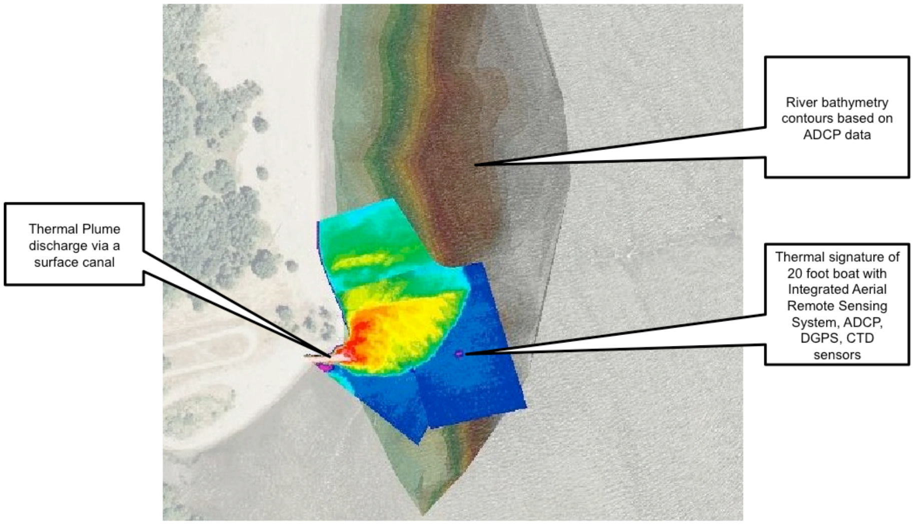
USEPA Region 10, ORD - Mixing Zone Modeling Webinar Workshop Series - January 22-24, 2013 **99**



• **M**ixZon **D**ata **A**cquisition **S**ystem
- Integrates data from land, air, and water based sensors for WQ monitoring and measurement

• Aerial Platform
- FLIR A320 Thermal Camera
- IQEye Visual Camera
- Range Finder
- Temperature & Humidity Sensors
- Digital Compass & GPS
- Pan Tilt Control
- Tethered Helium Balloon
- 802.11 wireless communication
- Near-real time aerial images
- Custom Integration Software developed in-house
- Developed w. USEPA SBIR awards
- **Assists boat crew w. sample collection**

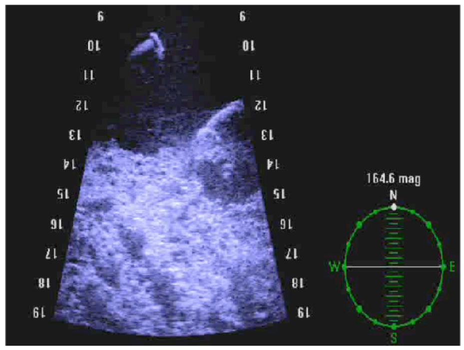
Field Data: Integrated Remote Sensing of Mixing Zones



Geo-rectified aerial thermal IR image of a Cooling Water Discharge Mixing Zone into the Columbia River, OR. Bathymetry data collected using a boat mounted ADCP and presented using false coloring.

Field Data: Integrated Remote Sensing of Mixing Zones

- Acoustic Video Camera - DIDSON
  - Outfall condition survey
  - Discharge Geometry
- Safer, Cheaper than manned diver inspection
- Useful in turbid conditions



Acoustic camera inspection of a Unidirectional Multiport WWTP Diffuser

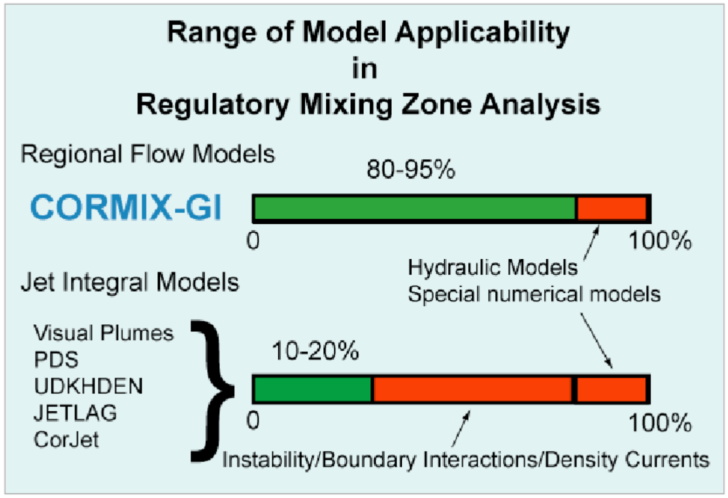
Wrap up: CORMIX - Topics Covered in 3 Hours!

CORMIX Functionality/Feature	Topics covered in this presentation
CORMIX Basics	50%
CorSpy – Outfall Visualization Tool	20%
CorVue – Plume Visualization Tool	20%
CorSens – Sensitivity Analysis Tool	
Length Scales	30%
CORMIX1 – Single Port Discharges	50%
CORMIX2 – Multiport Discharges	30%
CORMIX3 – Surface Shoreline Discharges	
CorJet – Near-Field Jet Integral Model	10%
CorGis – ArcView/Basins Data Extension	
FFL – Far-Field Locator	40%
Brine & Sediment Discharge Modeling	10%
Tidal Cases	10%
CorHyd – Diffuser Hydraulics and Design	10%
CorPlot – 2d and 3d plots	10%
CorUCS – Universal Coordinate System Converter	10%
CorTime/Far-Field Linkage	10%
CorVal – Validation Database	10%
CorHelp – Online UI Help	90%
CorDocs – Online Hypertext Technical Reports	80%

Wrap Up: CORMIX - Resources, Support & Training

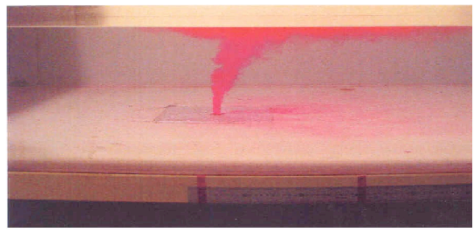
- Evaluation Version, Licensing, Websites, Manuals, Technical Reports, Validations, Applications, References & Documentation
  - **www.mixzon.com**
  - **www.cormix.info**
- Support
  - **support@mixzon.com**
- Training
  - **CORMIX Online Training for Regulators**
    - **April 02nd - April 25th 2013**
    - **8, 1-hour online training classes**
  - CORMIX 2 Day Training Workshops in Portland OR.
    - **June 17th - 18th 2013**
    - 2 day workshop
  - **http://www.mixzon.com/training/**

Wrap Up: CORMIX Model Applicability



Wrap Up: Unique CORMIX Features

- Data-driven Model Selection
- Boundary Interaction
- Discharge Stability
- Near-field dynamic plume attachments
- Density Current Mixing
- Upstream Spreading
- Variable current speed and directions (CorJet)
- Visualization Tools
- Advanced Analysis Tools
- Design Tools
- Benchmarking/Validation Tools
- Extensive Validations
- QA/QC



Models for Mixing Processes: Part 4 Summary

- Advanced CORMIX – Intro
- Validations, QA/QC
- Field Data Collection
- Wrap - UP

Q & A

Acknowledgements

- USEPA Region10, Catherine Gockel
- USEPA TISFD, Jean Balent
- USEPA ORD
- Environmental Management Support, Inc.
- University of Karlsruhe
  - Prof. G.H.Jirka
  - Dr. Tobias Bleninger
- USEPA
  - Hira Biswas, Lauren Wisniewski
- USBR
  - Ken Yokoyama
- Portland State University
- MixZon Inc
  - Brenda S McCoy, Ruta Stabina
  - Kent Thompson, Adi S. Ramachandran

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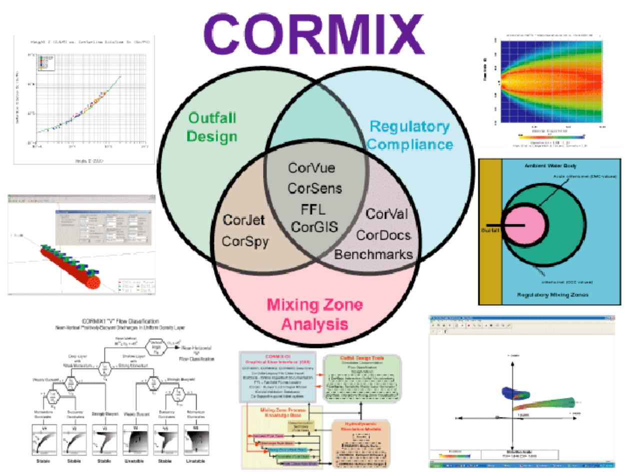

Good Luck & Good Mixing!