Contaminant Pathways Evaluations for Upland Confined Placement:

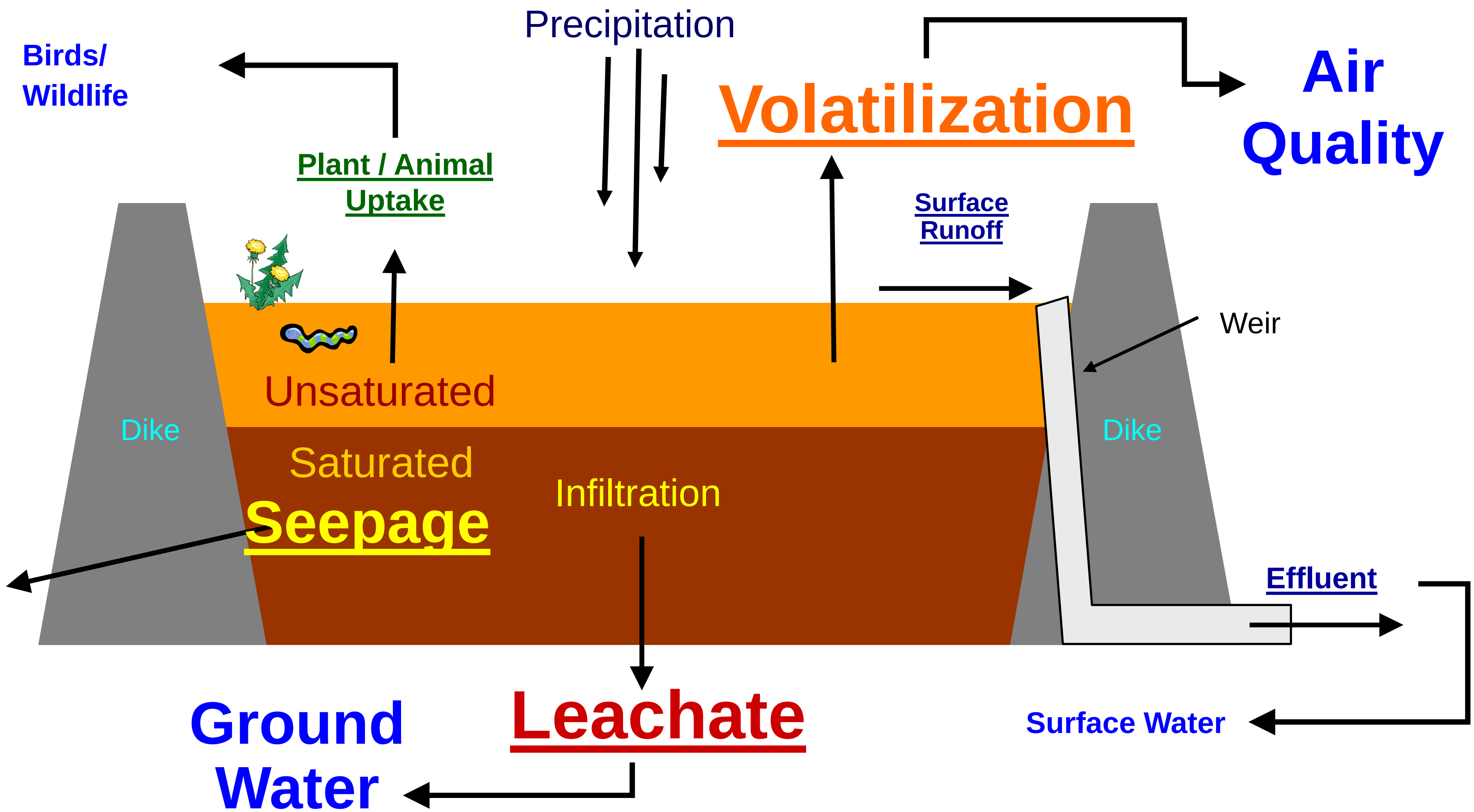
Leachate and Volatilization

Dr. Paul R. Schroeder

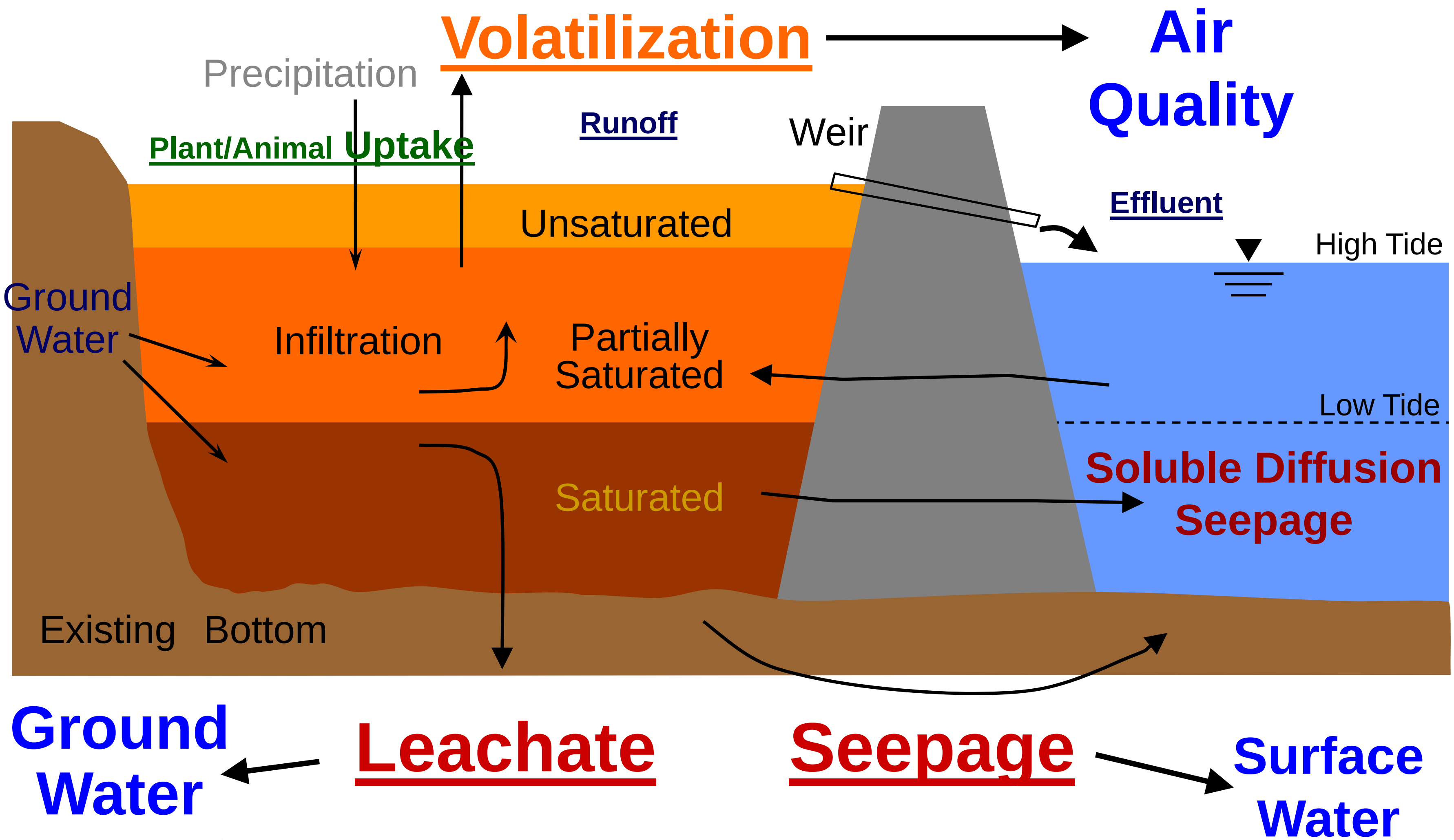
Keywords: CDFs, Contaminant Pathways, Testing, Leachate

Dredged Material Assessment and Management Seminar
24-26 May 2011, Jacksonville, FL

Conceptual Model - Contaminant Pathways



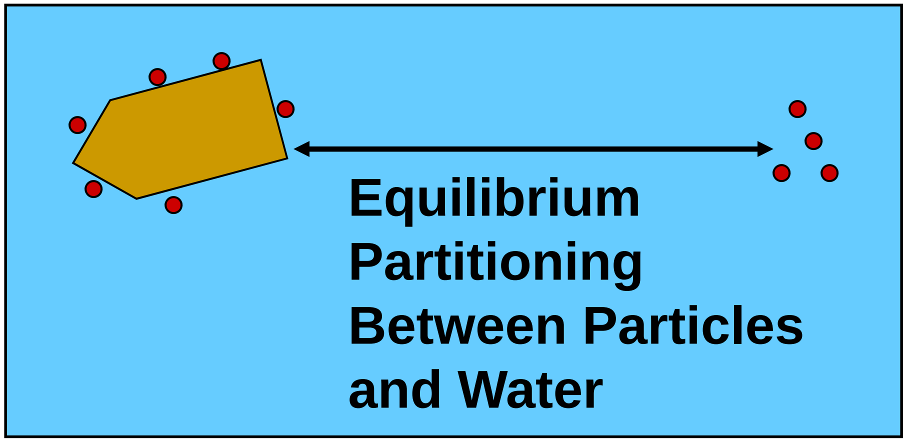
Nearshore CDF Contaminant Migration Pathways



CDF Pathway End Points

- **Leachate**
  - Applicable GW Standards for freshwater sediments after factoring in attenuation
  - Applicable Surface Water Standards for marine sediments after factoring in attenuation
- **Volatiles**
  - OSHA Human Exposure Standards after factoring in dispersion
  - Health-Based Air Concentrations for acceptable level of risk after factoring in dispersion

Tier II - Screening



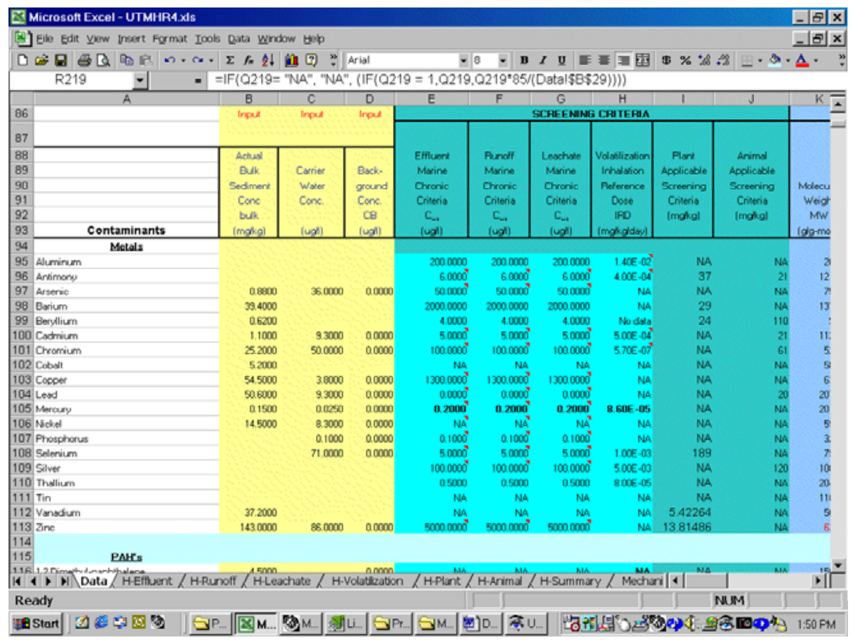
Volatile Emissions (Henry's Law)

Mixing, Attenuation and Dispersion

Leaching from saturated, reduced geochemical environment

Volatilization from Flooded and Exposed dredged material for On-site and Off-site exposures

Spreadsheet developed to support the UTM proposed screening



Microsoft Excel - UTMHR4.xls

R219 =IF(Q219= "NA", "NA", (IF(Q219 = 1,Q219,Q219*85/(Data!B29))))

	A	B	C	D	E	F	G	H	I	J	K
86		Input	Input	Input	SCREENING CRITERIA						
87											
88–93	Contaminants	Actual Bulk Sediment Conc bulk (mg/kg)	Carrier Water Conc. (ug/l)	Back-ground Conc. CB (ug/l)	Effluent Marine Chronic Criteria C (ug/l)	Runoff Marine Chronic Criteria C (ug/l)	Leachate Marine Chronic Criteria C (ug/l)	Volatilization Inhalation Reference Dose IRD (mg/kg/day)	Plant Applicable Screening Criteria (mg/kg)	Animal Applicable Screening Criteria (mg/kg)	Molecu Weigh MW (g/g-mo
94	**Metals**										
95	Aluminum				200.0000	200.0000	200.0000	1.40E-02	NA	NA	2
96	Antimony				6.0000	6.0000	6.0000	4.00E-04	37	21	12
97	Arsenic	0.8800	36.0000	0.0000	50.0000	50.0000	50.0000	NA	NA	NA	7
98	Barium	39.4000			2000.0000	2000.0000	2000.0000	NA	29	NA	13
99	Beryllium	0.6200			4.0000	4.0000	4.0000	No data	24	110	[illegible]
100	Cadmium	1.1000	9.3000	0.0000	5.0000	5.0000	5.0000	5.00E-04	NA	21	11
101	Chromium	25.2000	50.0000	0.0000	100.0000	100.0000	100.0000	5.70E-07	NA	61	5
102	Cobalt	5.2000			NA	NA	NA	NA	NA	NA	5
103	Copper	54.5000	3.8000	0.0000	1300.0000	1300.0000	1300.0000	NA	NA	NA	6
104	Lead	50.6000	9.3000	0.0000	0.0000	0.0000	0.0000	NA	NA	20	20
105	Mercury	0.1500	0.0250	0.0000	**0.2000**	**0.2000**	**0.2000**	**8.60E-05**	NA	NA	20
106	Nickel	14.5000	8.3000	0.0000	NA	NA	NA	NA	NA	NA	5
107	Phosphorus		0.1000	0.0000	0.1000	0.1000	0.1000	NA	NA	NA	3
108	Selenium		71.0000	0.0000	5.0000	5.0000	5.0000	1.00E-03	189	NA	7
109	Silver				100.0000	100.0000	100.0000	5.00E-03	NA	120	10
110	Thallium				0.5000	0.5000	0.5000	8.00E-05	NA	NA	20
111	Tin				NA	NA	NA	NA	NA	NA	11
112	Vanadium	37.2000			NA	NA	NA	NA	5.42264	NA	5
113	Zinc	143.0000	86.0000	0.0000	5000.0000	5000.0000	5000.0000	NA	13.81486	NA	6
114											
115	**PAH's**										

Data / H-Effluent / H-Runoff / H-Leachate / H-Volatilization / H-Plant / H-Animal / H-Summary / Mechani

Ready NUM

Start 1:50 PM

Leachate Tier III

- **Sediment-Specific Exposure Testing and Evaluations**
- **Laboratory Determination of Sediment Chemical Properties for Contaminant Transport**
  - Partitioning coefficient as a function of salinity
  - Leachable fraction
  - Clay and organic fractions of foundation soils
  - Hard carbon analysis
  - Attenuation
- **Models for Mixing, Attenuation and Dispersion**
- **Comparisons with End Points**
- **Tier III results can be used in Risk Assessments**

Leachate to Groundwater

Sequential Batch Leach Test (SBLT) for Freshwater Sediments

"Pancake" Column Leach Test (PCLT) for Marine/Brackish Sediments

Selection of Test Procedure

- **Freshwater Dredged Material: Batch Testing**

  Generally yields well-behaved contaminant desorption isotherm or single point K_D if clustered concentration data result.

- **Saline Dredged Material: Column Testing**

  Salt elution from saline dredged materials results in colloid release to leachate that cannot be quantitatively described by batch test results because of the effects of leachate shear velocity.

Batch Test Procedures

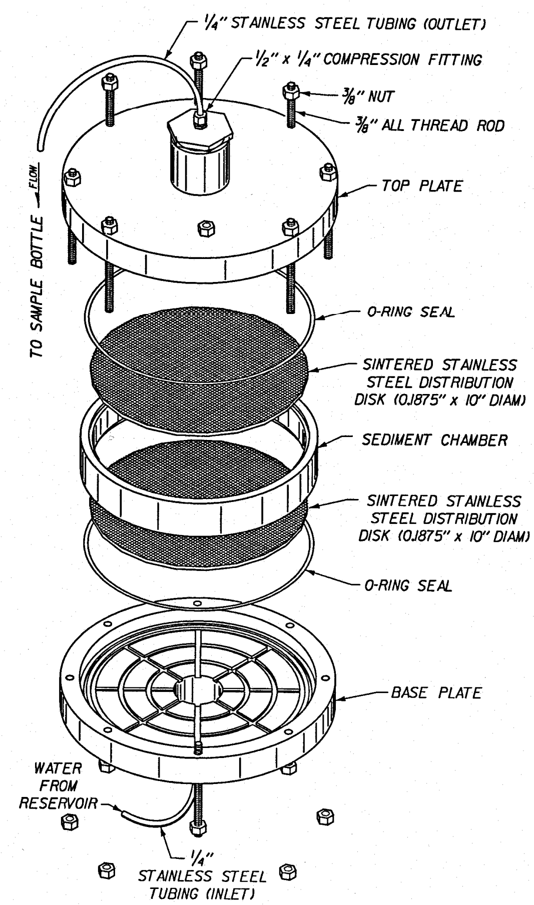
1. Load sediment in a 4:1 water-to-sediment ratio under anaerobic (nitrogen atmosphere) conditions (for unoxidized dredged materials).
2. Shake for 24 hours, centrifuge, and filter leachate.
3. Add water to sediment to make up that removed. Repeat steps 1 and 2.
4. Repeat procedure for at least four cycles.

Column Test Procedures

- Laboratory-scale physical model of contaminant elution from dredged material
- Thin layer column to maximize the number of pore volumes eluted
- Testing conducted in up-flow mode
- Pore water velocity limited to 1×10^{-5} cm/sec
- Elution of 30 pore volumes recommended

Column Test Apparatus

- Thin layer column for maximizing number of pore volumes eluted
- Improved flow control and delivery
- Column is 25.4 cm in diameter
- Details on column design and operation available in guidance documents



Leachate Pathway Assessment

- **Quality**
  - Partitioning
  - Leachable Fraction
- **Quantity**
  - Consolidation Analysis
  - Permeability
  - Pore Pressure Gradient
- **Dilution Attenuation Factor**
  - Diffusion
  - Degradation
  - Volatilization
  - Irreversible exchange with solids
- **Receptor**
  - Groundwater Supply for Freshwater
  - Benthic Zone Receptor for Saline Waters
- **Transport**
  - Advection
  - Diffusion
- **Groundwater Modeling**
  - Vadose Zone TN
  - Saturated Zone TN
  - MultiMed / IWEM
  - GMS

Vadose Zone Transport Considerations

- **Vadose Zone Properties**
  - Quantity of fine-grained materials, oxides, sulfides, and organic matter
  - Thickness
  - Porosity
  - Partitioning relationship
- **CDF Design**
  - Thickness
  - Permeability
  - Climate
  - Dredged material characteristics

Saturated Zone Transport Considerations

- **Groundwater Velocity**
  - Increases diffusion and dilution
  - Decreases the time to reach receptor
- **Receptor Locations**
  - Upgradient or off-center limits exposure
  - Distance increases diffusion and dilution
- **Aquifer Thickness increases diffusion and dilution**

Saturated Zone Transport Considerations

- **Aquifer Heterogeneity**
  - Increases short-circuiting
  - Decreases diffusion and dilution
- **Retardation Capacity**
  - Function of the quantity of fine-grained materials, oxides, sulfides, and organic matter in the aquifer
  - Reduces the long-term exposure

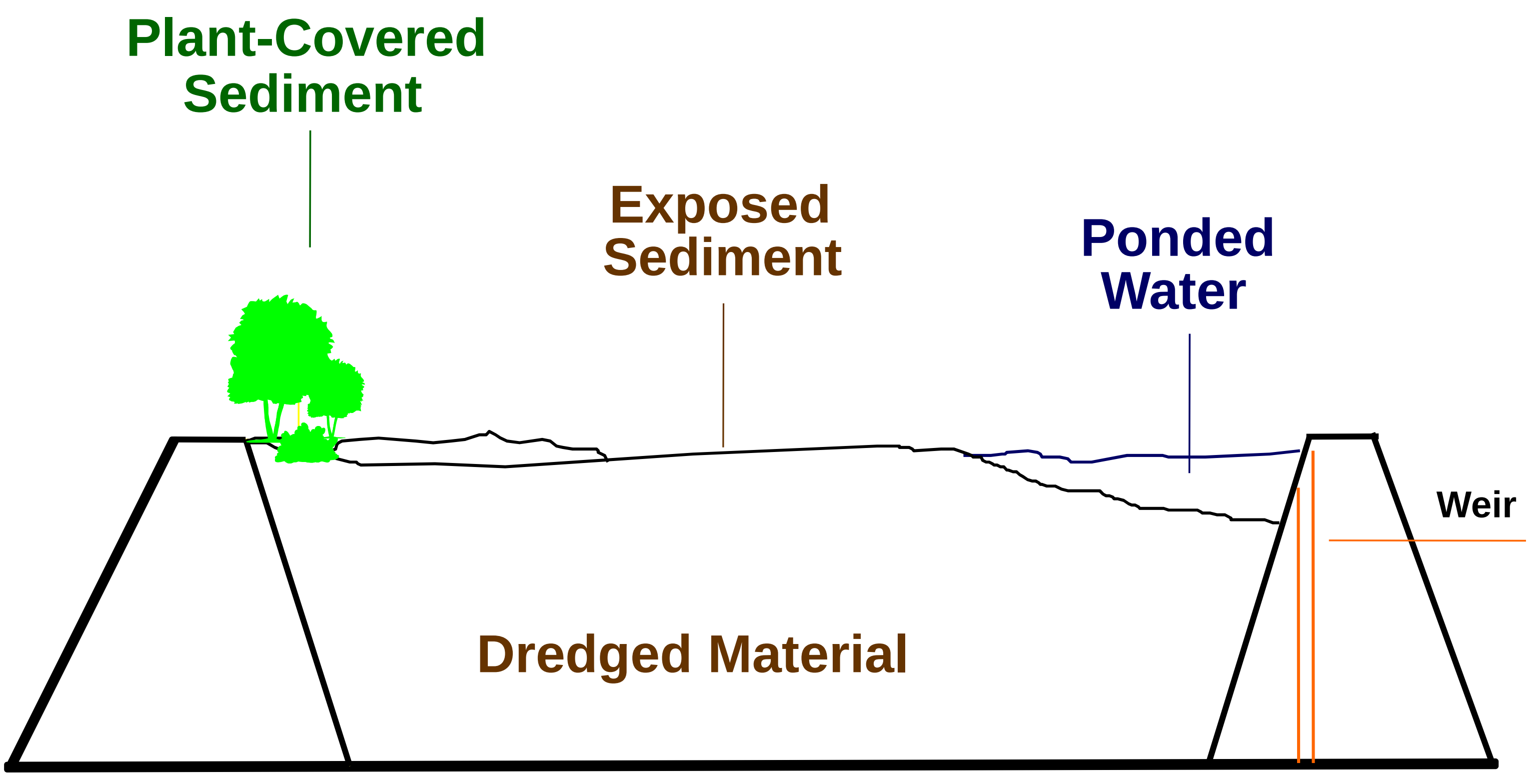
Leachate Controls

- **Liners and Drains**
  - Geomembranes
  - Clay for coarse-grained materials
- **Amendments**
  - Stabilizing agents
  - Adsorbing or precipitating agents such as activated carbon to control organics or apatite to control certain metals

Volatilization Tier III

- **Sediment-Specific Exposure Testing and Evaluations**
- **Laboratory Determination of Sediment Chemical Properties for Contaminant Transport**
  - Partitioning coefficient
  - Henry's law constant
  - Diffusivity in air
  - Air and water side mass transfer coefficients
- **Models for Dispersion**
- **Comparisons with End Points**
- **Tier III results can be used in Risk Assessments**

Volatile Emission Regimes



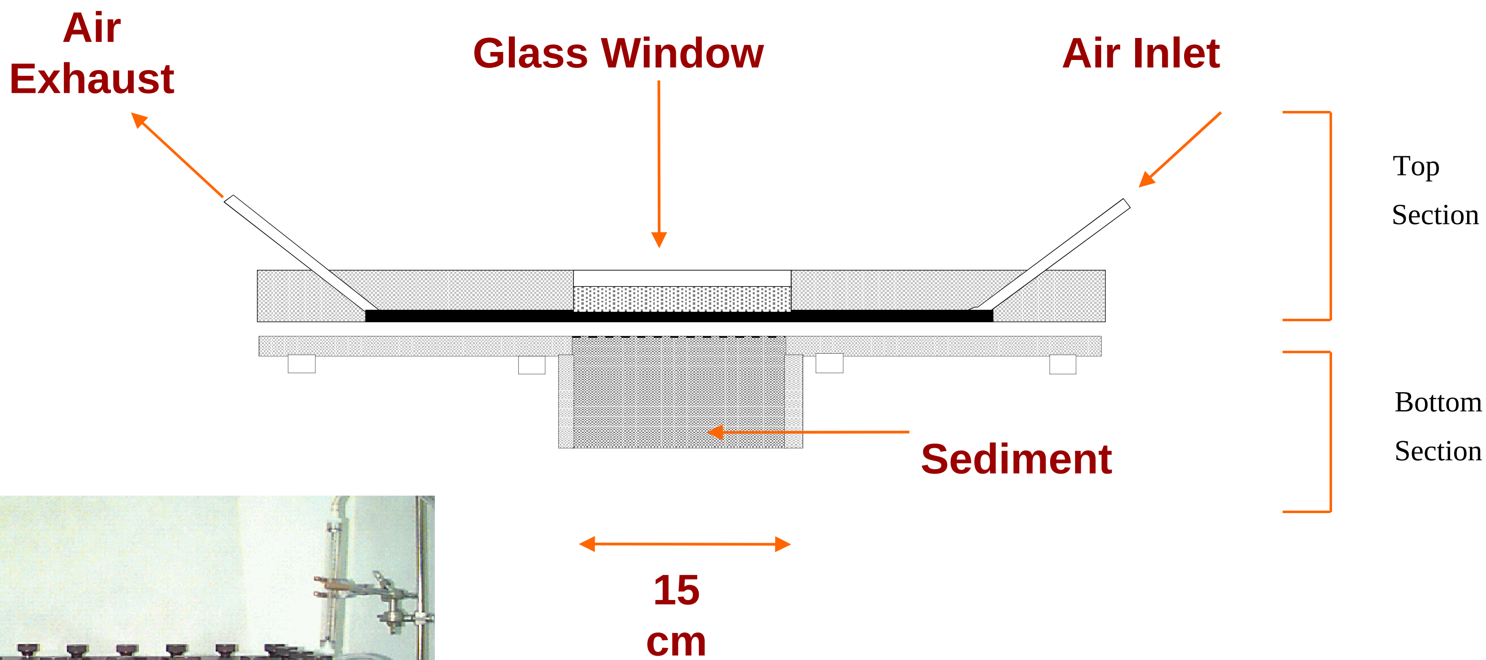
Evaluation of Volatile Losses

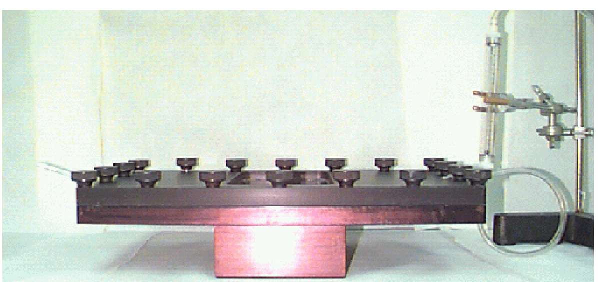
- **Laboratory Procedures to Quantify Volatile Losses in the Field**
  - ➢ Determine partitioning characteristics
  - ➢ Determine mass transfer coefficients
- **Predictive Models to Describe the Loss of Volatile Organic Compounds from Dredging and Disposal Sites**

Volatilization Parameters

- **Sediment Physical Characteristics**
  - Moisture content, porosity, aging, oil and grease concentration
- **Contaminant Chemical Properties**
  - Henry's Law constant, diffusion coefficient, partitioning coefficient, vapor pressure, sediment contaminant concentrations
- **Environmental Variables**
  - Relative air humidity, temperature, wind
  - Mechanical movement (mixing) of the sediment

Flux Chamber Used for Quantifying Volatile Emissions in a Laboratory Setting



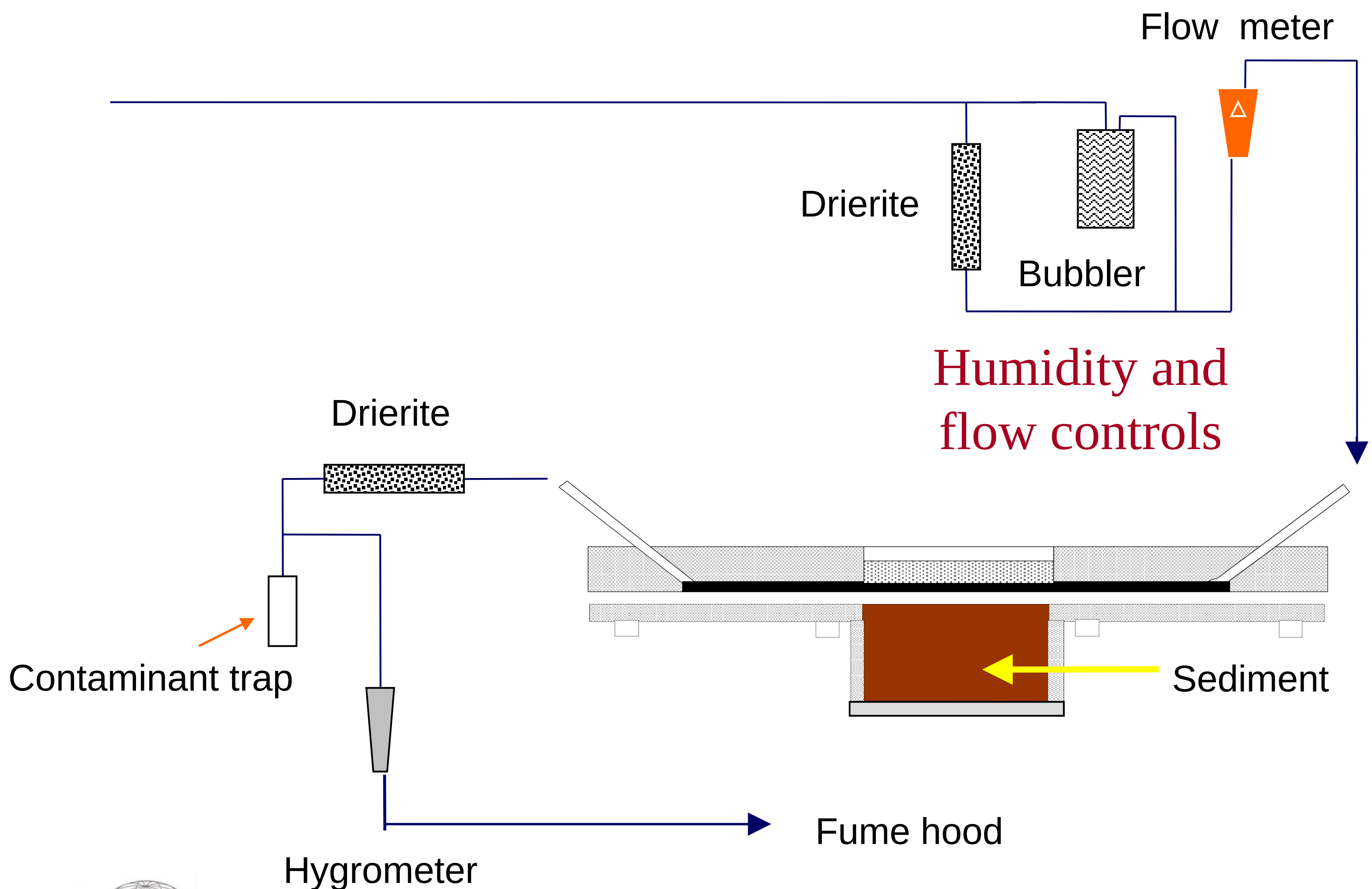


Equipment

VOC Flux Chamber (Description)

- **Two-piece construction of anodized aluminum**
- **Bottom section**
  - Sediment chamber-25 cm x 15 cm x 10 cm deep
- **Top portion**
  - Designed with channels to distribute airflow uniformly across sediment surface
  - Fitted with glass window to allow visual monitoring of sediment surface
- **Chamber is sealed with an O-ring and threaded fasteners to produce an airtight fit**

Laboratory Experimental Design



Equipment

- Air Supply – laboratory “house” air or compressed gas cylinder; vacuum pump
- Sampling Traps - contaminant-specific

  air sampling tubes (Supelco, Inc.)
- Flow Meter (able to handle flows > 1 L/min)
- Tygon tubing
- *Humidity Meter (for in-line monitoring)
- *Water Bubbler (air humidity adjustment)

  * optional (dependent upon sampling conditions)

Sediment Preparation

- Core or grab samples should completely fill storage containers (cores not removed need to be immediately sealed)
  - Volume of sample is dependent upon compounds of interest
- Refrigerate samples
- Thoroughly homogenize samples prior to sediment analysis and volatile emissions testing

Test Protocol (Laboratory)

- Carrier Air – “house” air; compressed gas of sufficient purity, or vacuum pump
- Flow rate - 1.7 L/min
- Trapping Material - dependent upon contaminants of interest
- Humidity - controlled via water bubbler
- Sampling Regime - dependent upon contaminant concentrations, trapping material and retention capacity, experimental conditions (i.e., soil moisture)

Example Sampling Protocol

- **Sampling times / intervals:**
  - **6, 24, 48, 72 hours, 5, 7, 10, and 14 days**
    - Sample continuously (replace trap at each sample interval making sample intervals anywhere from 6 to 96 hours each)
    - Sampling length dependent on contaminant concentrations and analytical detection limits

Engineer Research and Development Center

Example Sampling Protocol

- **Experimental conditions:**
  - Initiate experiment with field moist sediment and apply dry air over sediment surface (14-day experiment)
  - Apply humid air over sediment surface for 7 days
  - Rework sediment and repeat with dry air

Field Apparatus

Field Measurements

Flux Calculations

- **Contaminant flux is calculated by determining the total mass of material captured in a given time interval using the equation:**

$$N_A(t) = \Delta m / \Delta t / A_c$$

Δm = mass (mg) of compound collected on the trap in time Δt(hr)

A_c = area the sediment-air interface, m^2 (0.0375)

$N_A(t)$ is expressed in $mg/m^2/hr$

Air Quality Models

Gaussian Models --

Computes contaminant concentration at a point (X, Y, Z) downwind from a source at an elevation H above the ground by simple dispersion equation. Web Models, SCREEN3 or CTSCREEN

Suite of More Sophisticated Models Available for Complex Terrains from EPA --

AERMOD or ISCLT3

http://www.epa.gov/scram001/dispersionindex.htm

Volatilization Controls

- **Activated Carbon Applications**
  - CDF pond
  - Slurry
- **Capping**
  - Prevent exposed condition by maintaining pond
  - Cover dredged material with clean material

Questions?