Overview of Groundwater/Surface Water Interface Assessment and Contaminated Sediments

Michigan Bar Environmental Section Annual Program
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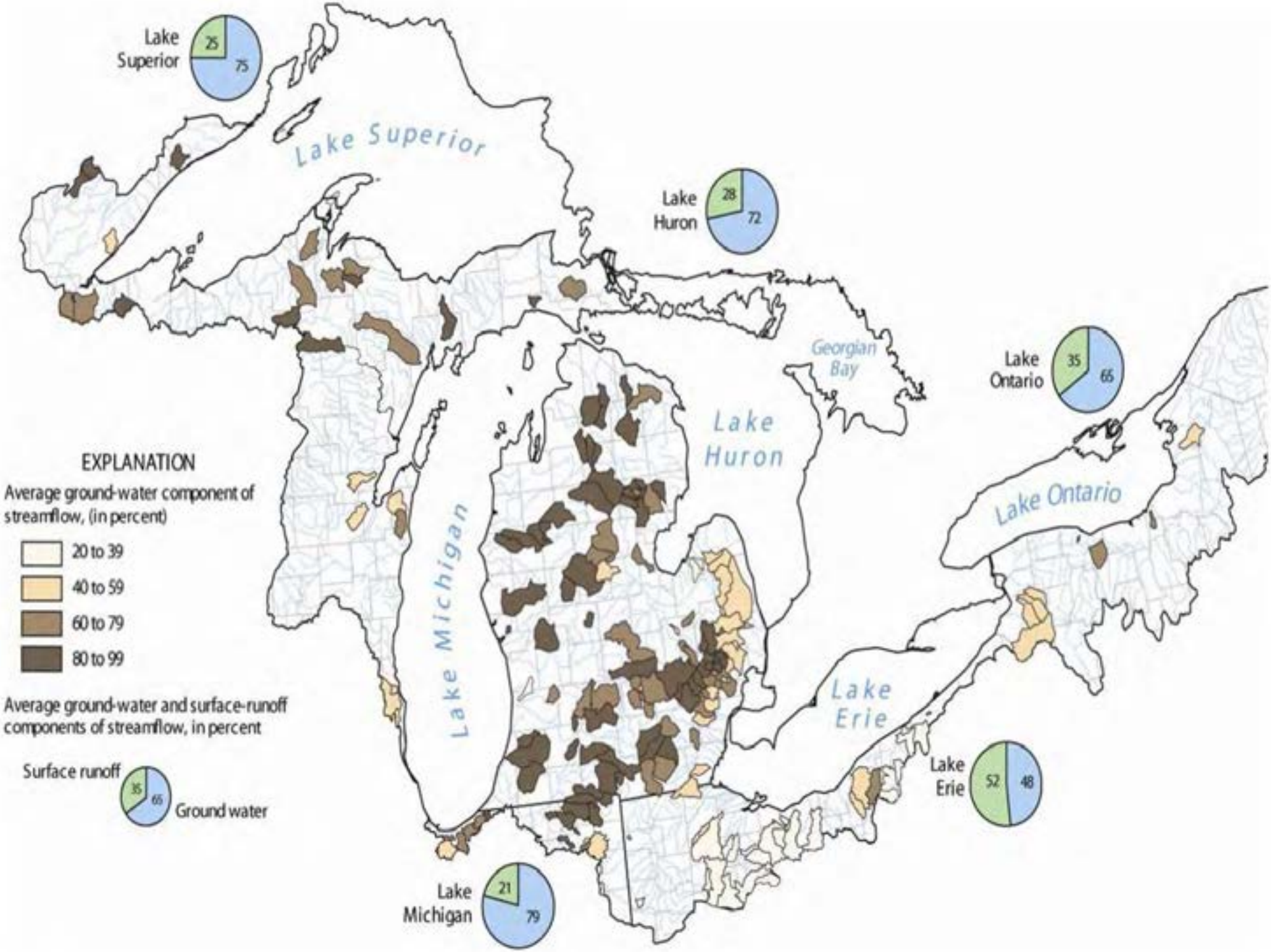
Overview

- GSI as a a remedial compliance point in Michigan
- MDEQ's development of GSI rules and guidance
- 2012 Amendments to GSI rules
- 10 ways to demonstrate compliance with GSI
- June 17, 2014 Compliance Options Resource Material
- MDEQ Emergency Dredging Plans and Contaminated Sediments
- Focus: "what's new"


Lake Superior
25
75
Lake Superior
Lake Huron
28
72
Georgian Bay
Lake Ontario
35
65
Lake Huron
Lake Ontario
EXPLANATION
Average ground-water component of streamflow, (in percent)
20 to 39
40 to 59
60 to 79
80 to 99
Lake Michigan
Lake Erie
Average ground-water and surface-runoff components of streamflow, in percent
Surface runoff
35
65
Ground water
Lake Erie
52
48
Lake Michigan
21
79

Development of GSI as a Compliance Point in Michigan

- 1990: initial identification of the groundwater surface water interface as a remedial compliance point
  - "concentration of chemicals in groundwater venting to surface water must not exceed limits that would apply if the discharge was otherwise subject to an NPDES permit, except that no mixing zone would apply"
- 1995: if a RAP was proposed to allow groundwater to vent to a surface water body above chronic GSI, the discharge must comply with Part 31 of the NREPA
  - Mixing zone must be provided for in an MDEQ approved Remedial Action Plan
  - In essence, a permit exemption to Part 31 of the NREPA

Development of GSI as a Compliance Point in Michigan

- 2004: MDEQ Operational Memorandum #5, 17-pages
  - Detailed guidance on mixing zone evaluation
  - Final: September 30, 2004 (17 pages)
- 2007: storm sewer rules
- 2010: Part 201 amendments affecting GSI
  - GSI criteria are ambient water quality criteria (Rule 57 values)
  - The appropriate monitoring point is the GSI
  - Self- implementation to demonstrate compliance w/ generic GSI criteria
- 2012: GSI rule amendments
  - Collaborative Stakeholder Initiative
  - Amendments to Part 201 (P.A. 190 of 2012; June 12, 2012)
- 2014: GSI Compliance Options Resource Material, June 17, 2014 (24 pages)

Part 201 GSI Amendments, PA 190 June 14, 2012

- 10 GSI compliance approaches, can be applied singly or in combination
- Self-implementation, liable and non-liable parties
- Identify situations where MDEQ approval is required (7)
- Clarification of the application of GSI to:
  - Sewers
  - Wetlands
- Use of Alternative Monitoring Points

10 Ways to Achieve GSI Compliance

1. Meet generic GSI criteria
2. Apply for a variance from the surface water quality standards
3. Request a mixing zone determination
4. Develop site specific criteria (including biological criteria)
5. Perform an ecological demonstration

10 Ways to Achieve GSI Compliance

6. Perform a modeling demonstration
7. Demonstrate that the pathway is not relevant
8. Demonstrate a De Minimis effect on the surface water body
9. Demonstrate technical impracticability
10. Demonstrate facility specific natural attenuation

GSI Pathway Compliance Options Resource Material

- Released: June 17, 2014
- AIPG GSI Work Shop (June 17th and 18th)
- Topics
  - GSI Pathway Relevancy
  - Conceptual Site Model
  - Water Quality Standards
  - Municipal Separate Storm Sewers

GSI Pathway Compliance Options Resource Material

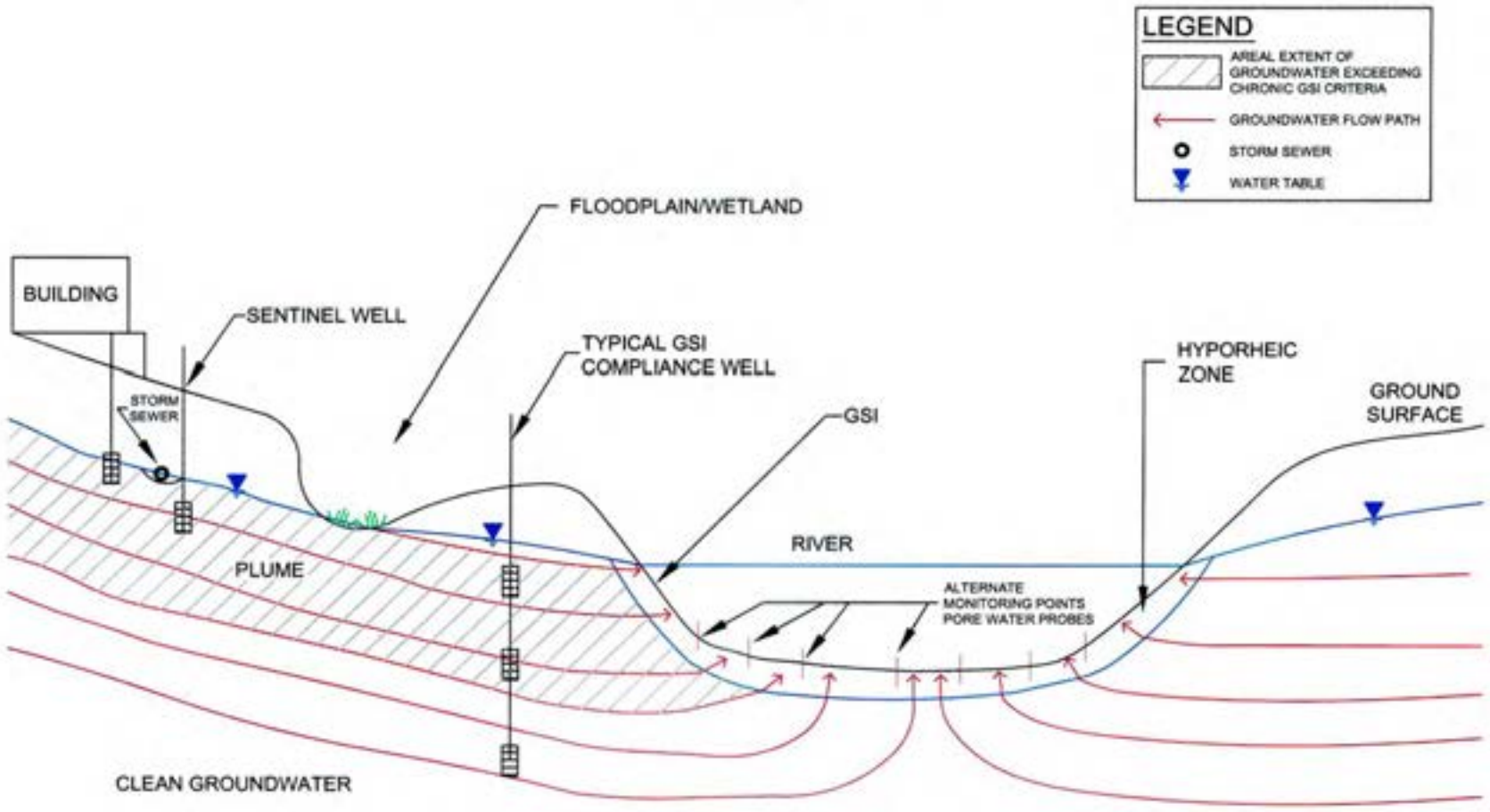
- Topics (continued)
  - GSI Compliance Options
  - Four Appendices (A-D)
    - Definitions
    - References
    - Storm Sewer Sampling Checklist
    - Self-Implementation Provisions

GSI Pathway

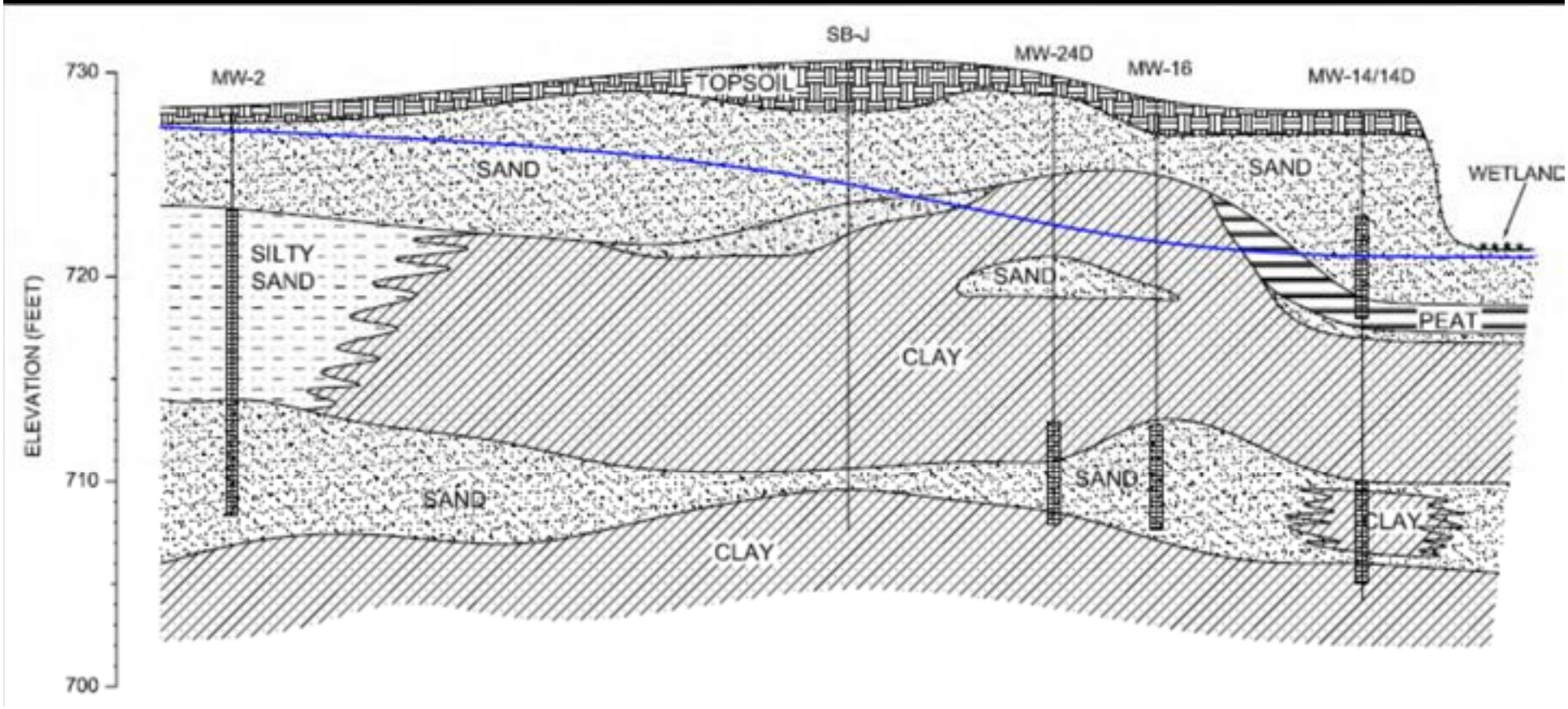
"The GSI pathway is relevant when groundwater is or is reasonably expected to vent to surface waters of the State at concentrations in excess of generic GSI criteria."

Basis: data or best professional judgment

GROUNDWATER SURFACE/WATER INTERFACE
COMPLIANCE POINTS
SIDE VIEW



Hydraulic Connection




N
0
100
200
400
600
800
Feet

Waters of the State

- The Great Lakes and their connecting waters (St. Mary's River, Keweenaw Waterway, Detroit River, St. Clair River, and Lake St. Clair),
- inland lakes, rivers, streams, impoundments, open drains, wetlands, and other surface bodies of water within the confines of the state (R 323.1044(u)).
- This includes intermittent streams, creeks, brooks, ditches, drains and wetlands.

Waters of the State

- Does not include (20120(e)(23)(g))
  - Groundwater
  - Hyporheic zone water (transition zone)
  - Water in enclosed sewers
  - Water in drainage ways and ponds used solely for wastewater or storm water conveyance, treatment or control
  - Water in sub-grade utility runs, utility lines, and the permeable sand around them

Is the GSI Pathway Relevant?

- Does groundwater vent to a water of the State?
- What is the direction of groundwater flow and the proximity of the surface water body to impacted groundwater?
- Is there a hydraulic connection between impacted groundwater and the surface water body?
- What is the mass of the hazardous substance?
- Is there documented evidence of monitored natural attenuation?
- Is there an artificial structure that could re-direct groundwater flow?
  - Highly permeable zones, utility corridors
  - Seawalls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Generic and Acute GSI Criteria

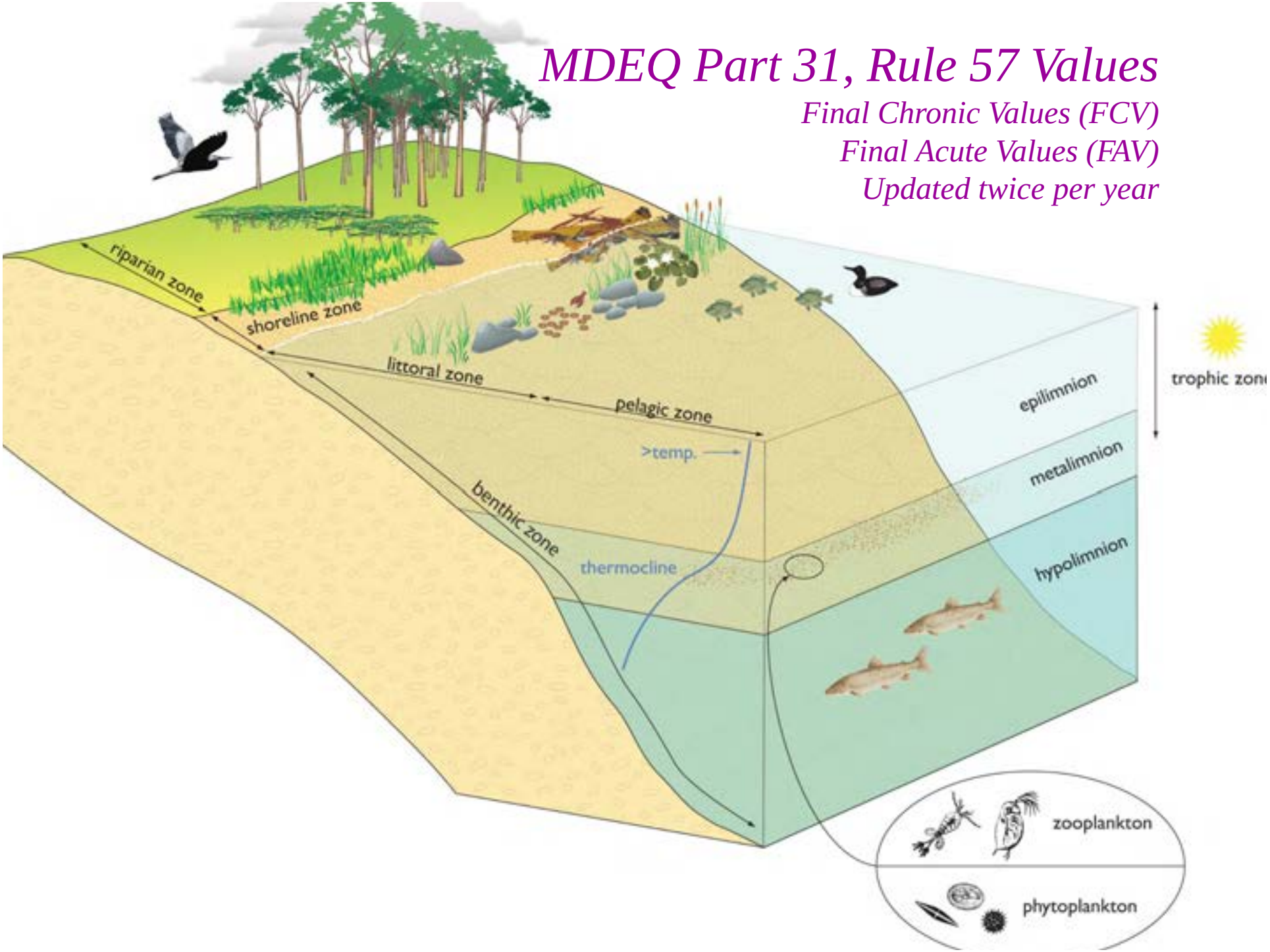
- generic GSI criteria are chronic surface water quality criteria
  1. protective of surface water used for drinking water
  2. protective of aquatic life
  3. unacceptable water quality characteristics (e.g. color, odor, sheen, taste, and odor)
  4. chloride, phosphorus, TDS, DO
- Generic GSI Criteria
- Acute GSI criteria
- Part 31, Rule 57 values: http://www.michigan.gov/deq/0,1607,7-135-3313_3686_3728-11383--,00.html

MDEQ Part 31, Rule 57 Values

Final Chronic Values (FCV)

Final Acute Values (FAV)

Updated twice per year



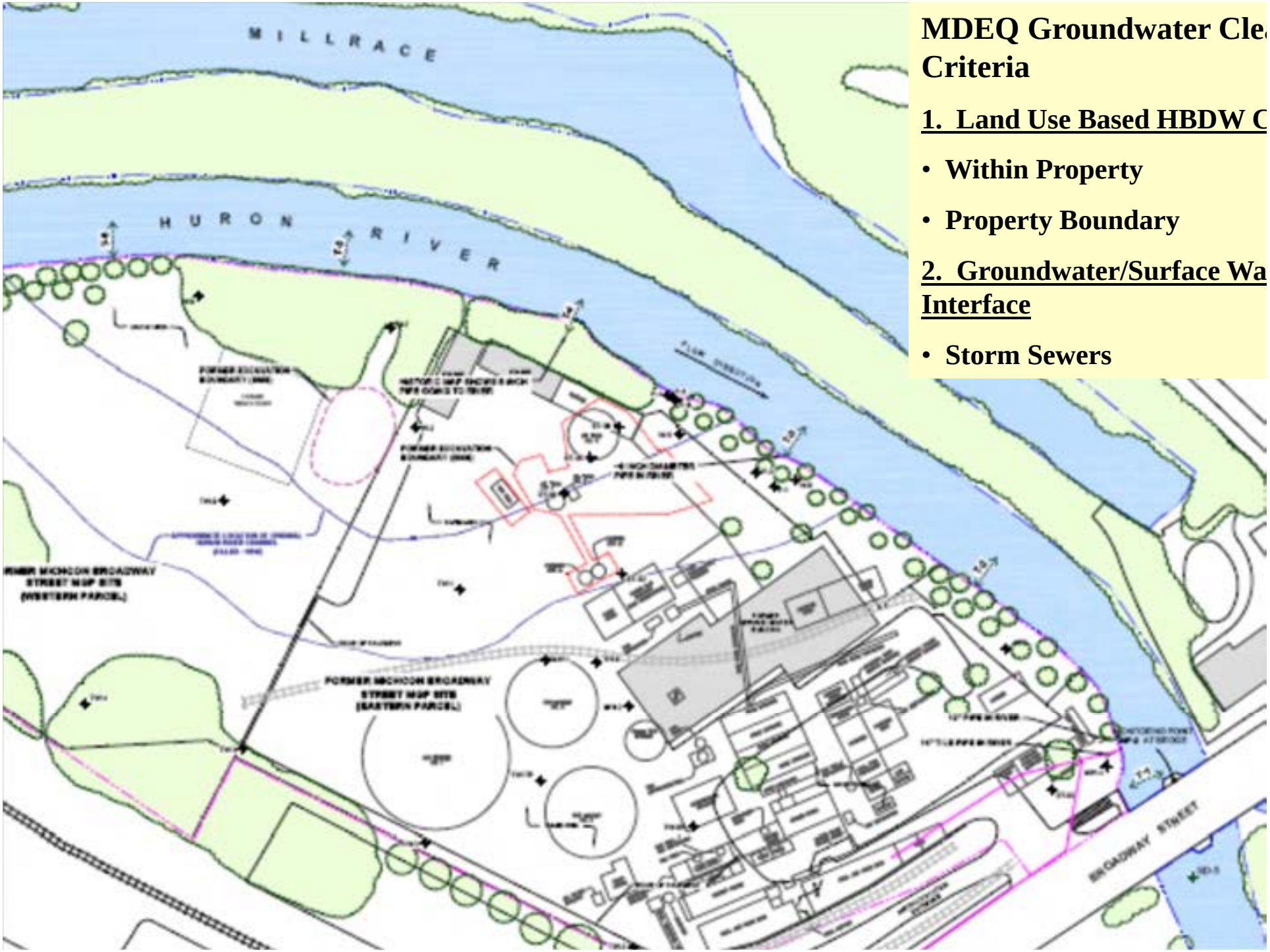
MDEQ Groundwater Cleanup Criteria and Compliance Points

- Health based drinking water criteria
  - USEPA Maximum Contaminant Levels
  - MDEQ Part 201 health based drinking water criteria
  - Apply throughout the property
  - Residential and non-residential criteria
- Groundwater/surface water interface criteria

TABLE 1. GROUNDWATER: RESIDENTIAL AND NONRESIDENTIAL
PART 201 GENERIC CLEANUP CRITERIA AND SCREENING LEVELS;
PART 213 TIER 1 RISK-BASED SCREENING LEVELS (RBSLs)
DOCUMENT RELEASE DATE: SEPTEMBER 28, 2012

All criteria, unless otherwise noted, are expressed in units of parts per billion (ppb). One ppb is equivalent to one microgram per liter (ug/L). Criteria with six or more digits are expressed in scientific notation. For example, 200,000 is presented as 2.0E+5. The lowest generic groundwater criterion for a given hazardous substance is presented in a bold box. A footnote is designated by a letter in parentheses and is explained in the footnote pages that follow the criteria tables. When the risk-based criterion is less than the target detection limit (TDL), the TDL is listed as the criterion (R 299.5707). In these cases, two numbers are present in the cell. The first number is the criterion (i.e., TDL), and the second number is the risk-based or solubility value, whichever is lower (R299.5708). Criteria were originally promulgated December 21, 2002 within the Administrative Rules for Part 201, Environmental Remediation, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended. This table reflects revisions to the criteria pursuant to the December 2010 Part 201 amendments and new criteria consistent with the provisions of R299.5706a. The effective dates of the criteria and screening levels in this table vary. Please contact the Remediation Division Toxicology Unit for additional information.

Guidesheet Number →		#1	#2	#3	#4	#5	#6	#7	#8	#9
Hazardous Substance	Chemical Abstract Service Number	Residential Drinking Water Criteria & RBSLs	Nonresidential Drinking Water Criteria & RBSLs	Groundwater Surface Water Interface Criteria & RBSLs	Residential Groundwater Volatilization to Indoor Air Inhalation Criteria & RBSLs	Nonresidential Groundwater Volatilization to Indoor Air Inhalation Criteria & RBSLs	Groundwater Contact Criteria & RBSLs	Water Solubility	Flammability and Explosivity Screening Level	Acute Inhalation Screening Level
1,1,1,2-Tetrachloroethane	630206	77	320	ID	15,000	96,000	30,000	1.10E+6	ID	ID
1,1,2,2-Tetrachloroethane	79345	8.5	35	78 (X)	12,000	77,000	4,700	2.97E+6	ID	ID
Tetrachloroethylene	127184	5.0 (A)	5.0 (A)	60 (X)	25,000	1.7E+5	12,000	2.0E+5	ID	2.0E+5 (S)
Tetrahydrofuran	109999	95	270	11,000 (X)	6.9E+6	1.6E+7	1.6E+6	1.0E+9	60,000	3.6E+6
Tetranitromethane	509148	ID	ID	NA	580	3,200	ID	85,000	ID	ID
Thallium (B)	7440280	2.0 (A)	2.0 (A)	3.7 (X)	NLV	NLV	13,000	NA	ID	ID
Toluene (I)	108883	790 (E)	790 (E)	270	5.3E+5 (S)	5.3E+5 (S)	5.3E+5 (S)	5.26E+5	61,000	ID
p-Toluidine	106490	15	62	NA	NLV	NLV	34,000	7.60E+6	NA	ID
Total dissolved solids (TDS)	NA	5.0E+5 (E)	5.0E+5 (E)	(EE)	ID	ID	ID	NA	NA	NA
Toxaphene	8001352	3.0 (A)	3.0 (A)	1.0 (M); 6.8E-5	NLV	NLV	44	740	ID	740 (S)
Triallate	2303175	95	270	NA	ID	ID	4,000 (S)	4,000	ID	ID
Tributylamine	102829	10	29	ID	14,000	32,000	2,300	75,400	ID	ID
1,2,4-Trichlorobenzene	120821	70 (A)	70 (A)	99 (X)	3.0E+5 (S)	3.0E+5 (S)	19,000	3.00E+5	NA	3.0E+5 (S)
1,1,1-Trichloroethane	71556	200 (A)	200 (A)	89	6.6E+5	1.3E+6 (S)	1.3E+6 (S)	1.33E+6	ID	1.3E+6 (S)
1,1,2-Trichloroethane	79005	5.0 (A)	5.0 (A)	330 (X)	17,000	1.1E+5	21,000	4.42E+6	NA	ID
Trichloroethylene	79016	5.0 (A)	5.0 (A)	200 (X)	2,200	4,900	22,000	1.10E+6	ID	1.1E+6 (S)
Trichlorofluoromethane	75694	2,600	7,300	NA	1.1E+6 (S)	1.1E+6 (S)	1.1E+6 (S)	1.10E+6	ID	1.1E+6 (S)
2,4,5-Trichlorophenol	95954	730	2,100	NA	NLV	NLV	1.7E+5	1.20E+6	ID	ID
2,4,6-Trichlorophenol	88062	120	470	5.0	NLV	NLV	10,000	8.00E+5	ID	ID
1,2,3-Trichloropropane	96184	42	120	NA	8,300	18,000	84,000	1.90E+6	NA	ID
1,1,2-Trichloro-1,2,2-trifluoroetha	76131	1.7E+5 (S)	1.7E+5 (S)	32	1.7E+5 (S)	1.7E+5 (S)	1.7E+5 (S)	1.70E+5	ID	1.7E+5 (S)



MDEQ Groundwater Cle Criteria

1. Land Use Based HBDW C

- **Within Property**
- **Property Boundary**

2. Groundwater/Surface Wa Interface

- **Storm Sewers**

Mixing Zone Based GSI Criteria

- Basic Concept: calculate the rate of impacted groundwater (in excess of generic GSI) venting into surface water in comparison to the rate of surface water flowing past the area of groundwater discharge
- Point of compliance: groundwater/surface water interface (GSI)

OM-5: Application of GSI Criteria to a Surface Water Body

- The rate of discharge of impacted groundwater to surface water is estimated by:

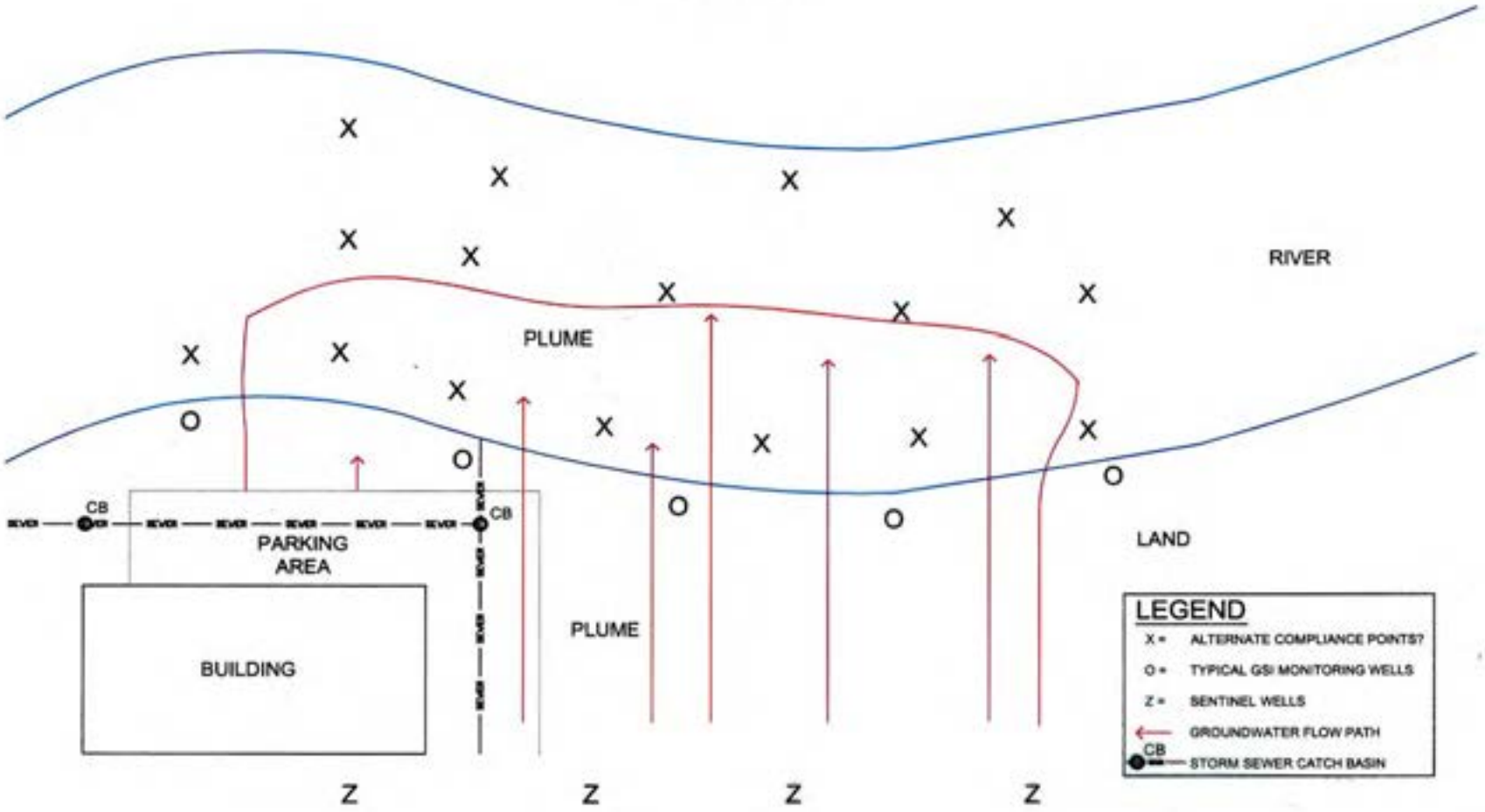
$$Q = (k)(i)(a)$$

k = hydraulic conductivity

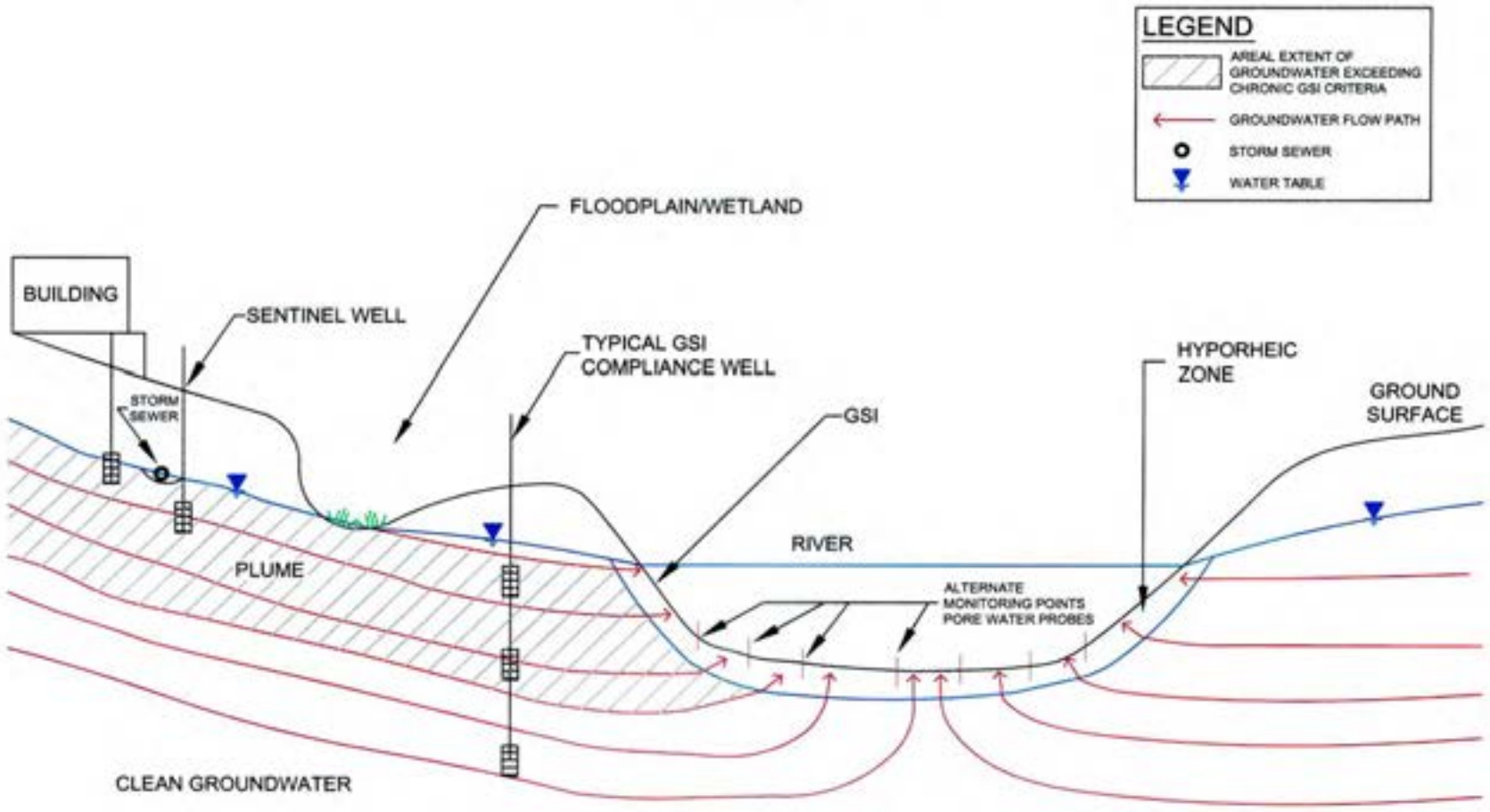
i = hydraulic gradient

a = cross-sectional area perpendicular to groundwater flow

GROUNDWATER SURFACE/WATER INTERFACE
COMPLIANCE POINTS
TOP VIEW



GROUNDWATER SURFACE/WATER INTERFACE
COMPLIANCE POINTS
SIDE VIEW



GSI Mixing Zones

- Flowing streams: calculate a dilution rate (25% of monthly low flow) versus rate of contaminated groundwater discharge to the river
- Lakes and impoundments: dilution rate of 10
- Intermittent streams and wetlands: no or limited mixing zone
- Limitation: mixing zone based GSI criterion cannot exceed acute GSI criteria
- No mixing zone for PBT chemicals (e.g., mercury)


Intermittent Stream


Wetland

Mixing Zone Based GSI Criteria

Source Sample ID Date Sampled Units	MDEQ TARGET DETECTION LIMIT 10/22/04	MDEQ HEALTH BASED DRINKING WATER 9/28/2012	MDEQ GENERIC CHRONIC GSI CRITERIA 9/7/2012	MDEQ GENERIC ACUTE GSI CRITERIA 9/7/2012
Copper	4	1,000(E)	15	48
Cyanide, Amenable	5	200 (A)	5.2	44
Cyanide, Total	NE	NE	NE	NE
cis-1,2-DCE	1	70(A)	620	11,000
trans-1,2-DCE	1	100(A)	1,500	28,000
Trichloroethene	1	5(A)	200	3,500
Vinyl Chloride	1	2(A)	13	17,000
Chromium	10	100 (A)	120	1,885
Nickel	20	100	88	1,575
Ammonia	50	10,000	29 (CC)	320 (CC)
Nitrogen, nitrate	100	10,000 (A,N)	NE	NE

Wetlands

- Use Attainability Analysis (UAA)
- Protect wetlands for all uses that apply to the wetland as specified by Part 31
- Designated uses: agriculture, navigation industrial water supply, warm water fishery, indigenous aquatic biota, partial body contact, recreation, fish consumption

Wetlands

- Venting groundwater that impairs one or more designated uses of a wetland may be allowed if:
  - the Use Attainability Analysis shows that the designated uses are not or cannot be attained
  - Example: Cedar wetland and fish consumption
  - The UAA is submitted to the MDEQ for approval
- Wetlands not regulated by Part 303 (Wetland Protection) are subject to GSI compliance

Exceedance of Acute GSI Criteria

- Exceedance of an acute GSI criterion or determination that the groundwater is acutely toxic (via whole effluent testing): 20120(e)(13)(a-c)
- "bright line"
  a. Notice to MDEQ; 7 days of obtaining knowledge
  b. Within 60 days, do one of the following:
     - implement a response activity
     - propose an alternate monitoring point
     - submit a notice of the intent to propose a site-specific criterion

Application of GSI Criteria to a Surface Water Body

- Mixing zone analysis triggered by exceedence of generic GSI criteria in groundwater
  - exceedence of an MDEQ ambient surface water quality criterion in the surface water body
  - for rivers and streams, unlikely (ft/sec v. ft/day)
- Acute GSI exceedences often lead to sediment quality assessments
  - Why?
  - Accumulation of chemicals in organic rich sediments

Groundwater Infiltration into Sewers

Storm Sewer as a GSI Compliance Point

- Contaminated groundwater (>chronic GSI) that enters a sewer that discharges to surface water, compliance options include:
  - Monitoring well adjacent to sewer
  - Sampling of water in the sewer
- Compliance point is at the sewer system outfall to surface water
- A mixing zone may applied at the point where the sewer system discharges to surface water

10 Ways to Achieve Compliance with the GSI Pathway

P.A. 190 of 2012; June 12, 2012

1. Meet generic GSI criteria (20120(e)(1)(a))
   - Self-implementable
   - Groundwater contaminants below generic GSI criteria
2. Apply for a variance from MDEQ Part 31 surface water quality standards (20120(e)(1)(b))
   - Not self-implementable
   - Requires USEPA approval
   - Example: mercury 1.3 ng/L v. variance of 10 ng/L

10 Ways to Achieve Compliance with the GSI Pathway

P.A. 190 of 2012; June 12, 2012

3. Apply for a mixing zone (20120(e)(1)(c))
   - Not self-implementable
   - Basis: chronic or acute GSI criteria
   - MDEQ Project Manager reviews the application (accuracy and completeness)
   - MDEQ Water Resource Division calculates the mixing zone based criteria

10 Ways to Achieve Compliance with the GSI Pathway

P.A. 190 of 2012; June 12, 2012

4. Develop Site Specific GSI criteria (20120(e)(1)(d))
   - Not self-implementable
   - Requires MDEQ approval
   - New provision:
     - Non-numeric or biological criteria (e.g. tissue based criteria)

10 Ways to Achieve Compliance with the GSI Pathway

P.A. 190 of 2012; June 12, 2012

5. Conduct an ecological demonstration (20120(e)(1)(e))
   - ecological demonstration evaluation is self-implementable
   - Liable party may request Department approval for no additional response activities if the evaluation shows venting groundwater is not an issue
   - Response Activity Plan is required for activities that rely on ecological demonstration
   - Non-liable parties can self-implement

10 Ways to Achieve Compliance with the GSI Pathway

P.A. 190 of 2012; June 12, 2012

6. Conduct a Modeling Demonstration
   - Calibrated model
   - Verified with site-specific field measured data
   - Demonstrate compliance with GSI criteria
   - Non-liable parties can self-implement
   - MDEQ Groundwater Modeling Resource Material, February 3, 2014

10 Ways to Achieve Compliance with the GSI Pathway

P.A. 190 of 2012; June 12, 2012

7. Evaluate pathway relevancy (20120(e)(3)(a-h))
   - Does a hydraulic connection exist?
   - Proximity to surface water body?
   - Does the surface water meet the definition of “waters of the state?”
   - Direction of groundwater flow?
   - Mass of chemical that may affect groundwater?
   - Can the sewer be demonstrated to be sufficiently tight?

10 Ways to Achieve Compliance with the GSI Pathway

P.A. 190 of 2012; June 12, 2012

8. De Minimis Determination (20120(e)(14))
   - New provision
   - Not self-implementable
   - Does the mass of chemical really have an effect on surface water quality?
   - Mass flow and rate of groundwater movement may be lines of evidence used in the determination
   - MDEQ: automatically approved after 90-days if the determination is not reviewed

10 Ways to Achieve Compliance with the GSI Pathway

P.A. 190 of 2012; June 12, 2012

9. Technical Impracticability Waiver (20120(e)(15))
   - Not self-implementable
   - Can be requested from the MDEQ if:
     - Source of contamination is controlled
     - Compliance with GSI criteria is unachievable
   - MDEQ: 180 days to respond
     - Approval
     - Request for additional information
     - Denial with detailed explanation

10 Ways to Achieve Compliance with the GSI Pathway

P.A. 190 of 2012; June 12, 2012

10. Facility Specific Evidence of Natural Attenuation (20120(e)(16))
    - Natural attenuation of hazardous substances in groundwater up-gradient of the GSI may be relied upon in lieu of any active remediation of groundwater
    - Multiple lines of evidence

Conditions where Self-Implementation Does Not Apply

- Response Activity Plans must be submitted to the MDEQ for the following (20120(e)(6)
  - Use of alternative monitoring points
  - Ecological demonstration
  - Modeling demonstration
- And, one or more the following conditions apply
  - Criterion is based on acute toxicity endpoints
  - Bioaccumulative chemicals of concern are present
  - Discharge to a protected coldwater fishery
  - Outstanding state resource

Ecological Demonstration

- "Evaluating GSI Transition Zones in Ecological Risk Assessments" (ECO Update/Ground Water Forum Issue Paper; USEPA, 2008)
- "multiple lines of evidence"
  - Chemistry
  - Toxicity (groundwater, surface water, and sediment)
  - Biological evaluation (macroinvertebrates)
  - Bioaccumulation (PCBs, dioxins, pesticide/herbicides)

Ryder Creek

Ecological Assessment to Demonstrate GSI Compliance

- "Multiple lines of evidence"
- Chemistry: groundwater, surface water, sediments
- Toxicity: groundwater, surface water, sediments
- Biological impacts
  - Fish
  - Macroinvertebrates
  - Habitat
- Bioaccumulation

Toxicity Testing

- Test organisms are exposed directly to either the groundwater, surface water or sediment
- The response of the test organism is examined in relation to a specific endpoint
  - acute toxicity:
    - Groundwater, surface water: survival
    - sediment: survival and growth
- Powerful tool:
  - Dave Mount, USEPA-Duluth “you avoid the lamplight approach;” … “you only know what you know”

Selection of Samples for Toxicity Testing

- Representative samples…
- Inside of the plume, select samples based on groundwater chemistry results
  - Select samples between chronic GSI and acute water quality criteria (Rule 57 FAV)
  - Select samples above acute water quality criteria
  - Surface water samples: upstream, downstream, where groundwater vents to the surface water body
- bioavailability…


GSI Monitoring Wells

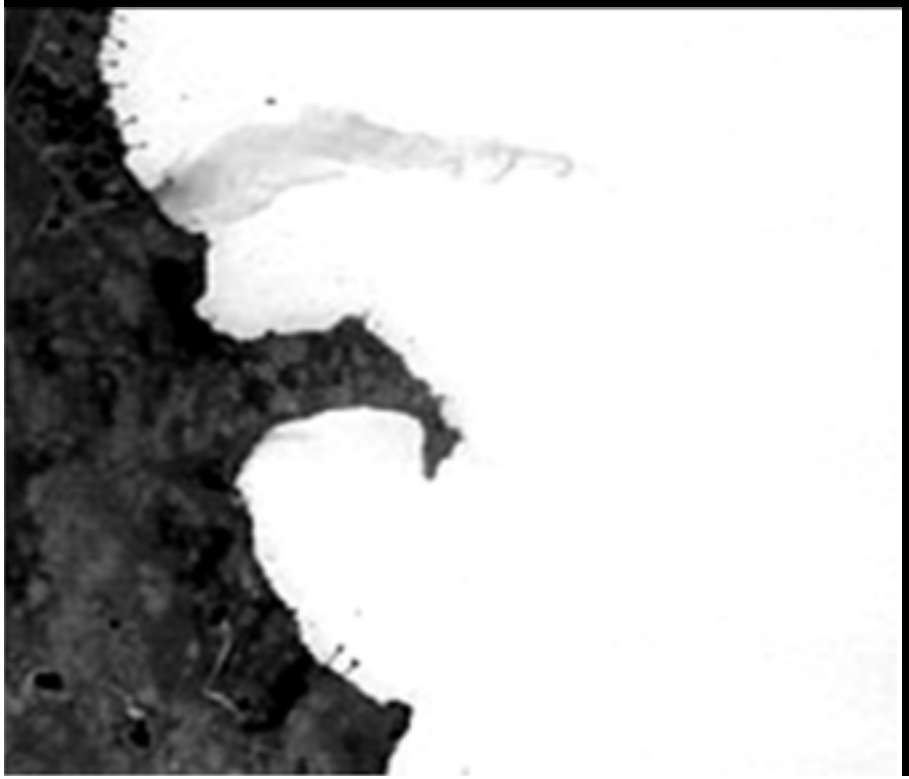
Ryder Creek Positive Head in Monometer

Alternate GSI Monitoring Points

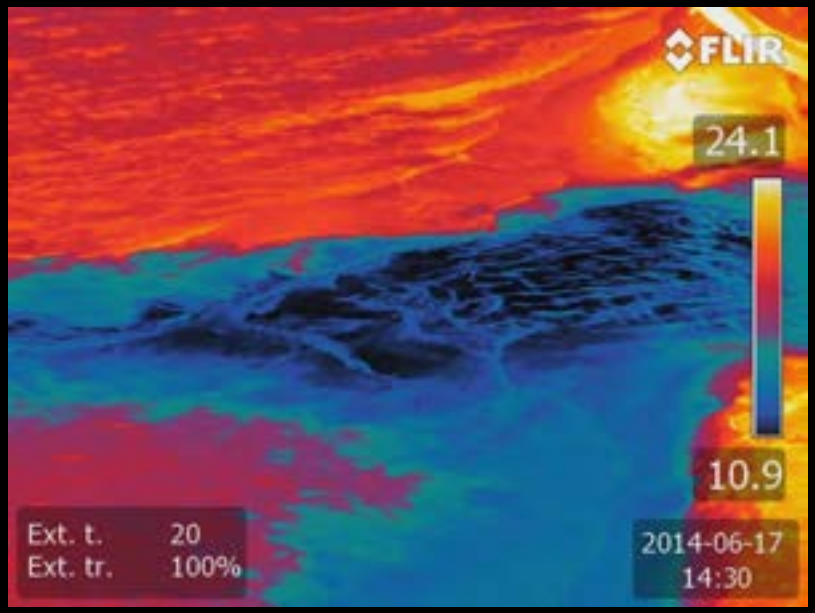
- Alternate monitoring points (20120(e)(8))
  - Alternate monitoring points are located where groundwater is venting
    - Beyond waters edge
    - Pore water within sediments, at the GSI
  - Document approximated boundaries of venting groundwater, substrate and geology
  - Document that the venting area and alternative monitoring points are reasonably representative of higher concentrations
- subject to 30-day MDEQ notice and approval prior to relying on them for compliance
- Sentinel wells and contingency plan

OM-5: Application of GSI Criteria to a Surface Water Body

- non-uniform groundwater discharge
  - Thermal images: Woods Hole Oceanographic Institute, 2002



FLIR Camera to Map Groundwater Discharge Zones



FLIR Camera

Seepage Meters and Porewater Samplers

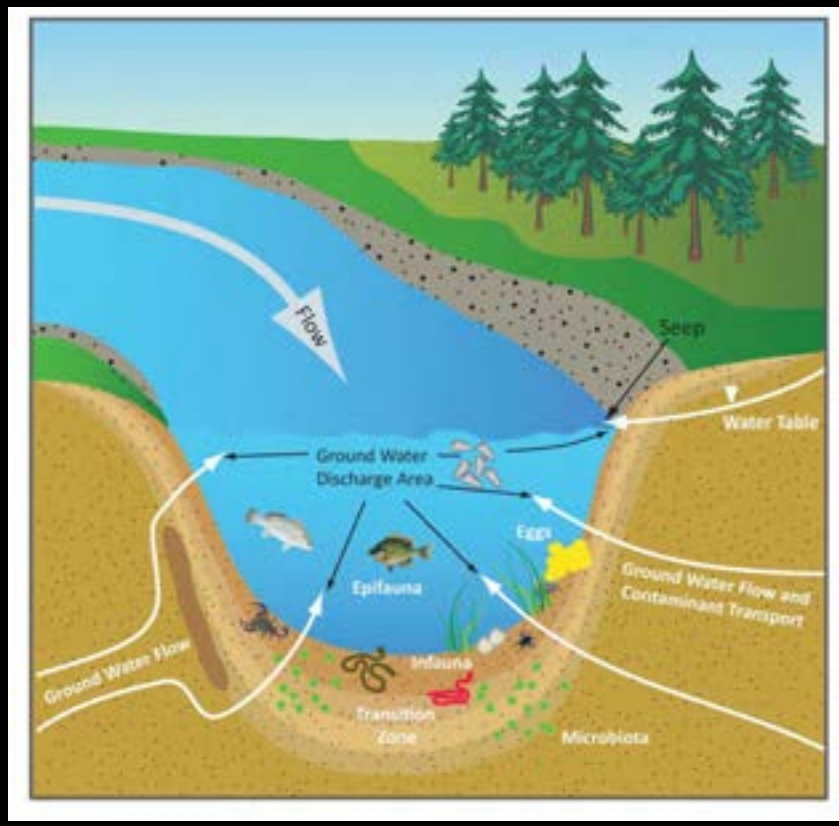
Surface Water Toxicity Testing

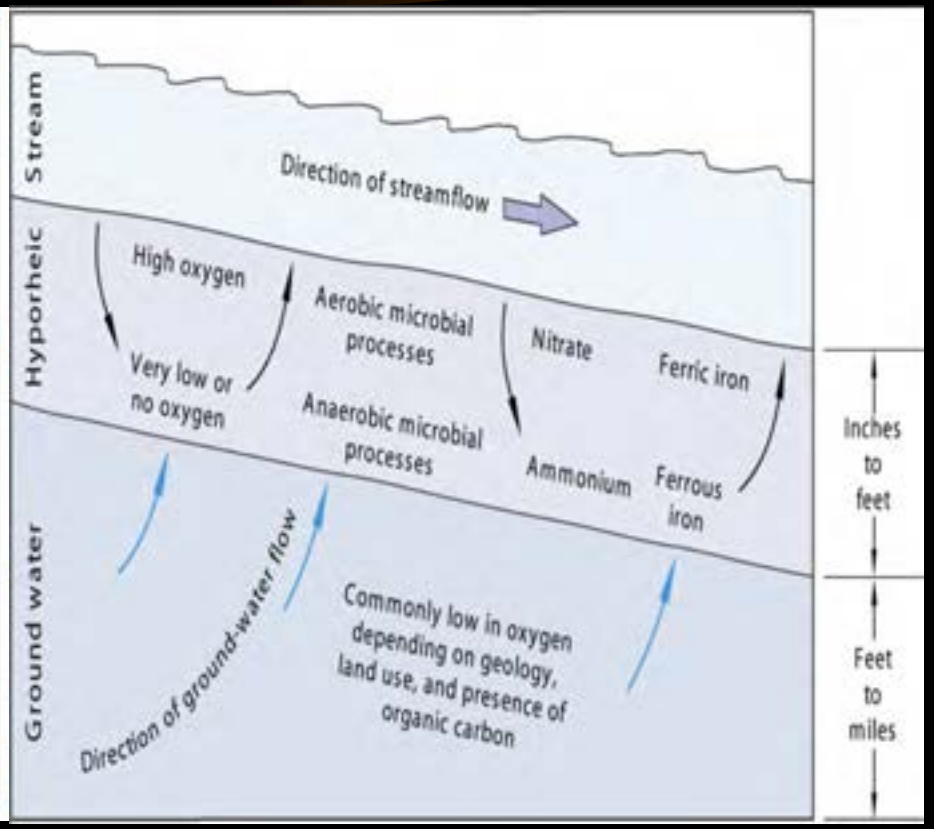
- Standardized Tests
  - Five dilutions
  - DO >4 mg/L
  - pH 6 -9
  - Ammonia >3 mg/L, pH control
- *Ceriodaphnia dubia*
  - 48-hour test, survival endpoint
  - 4 test chambers
  - 5 *C. Dubia*
- *Pimephales promelas*
  - 96-hour test, survival endpoint
  - 2 test chambers
  - 10 fish

Surface Water Toxicity Testing

- Chronic toxicity tests…
  - ***Ceriodaphnia dubia***, endpoint survival and reproduction
    - 7-day test
    - 10 test chambers per test concentration
    - 1 *C. Dubia*
  - ***Pimephales promelas****:* endpoint survival and growth
    - 7-day test
    - 4 test chambers per test concentration
    - 10 fish
- Acute toxicity test: 1-gallon
- Chronic toxicity test: 2-gallons, 2-gallons, 3-gallons
- Toxicity test setup: 36-hours from sample collection

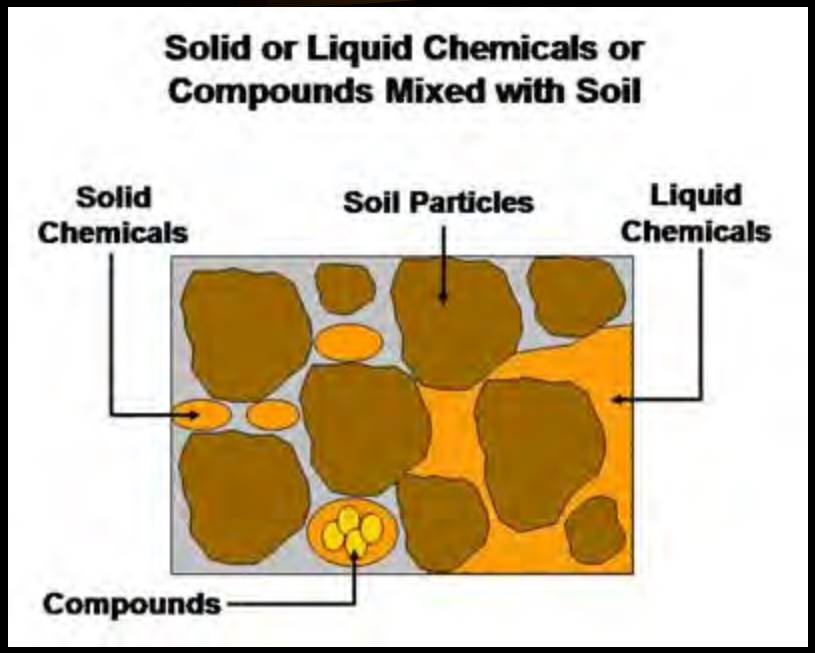
Groundwater Transition Zone and Bioavailablity





Attenuation Mechanisms

- microbial processes
  - anaerobic to
  - aerobic
- precipitation reactions
  - DO, pH, ORP
- adsorption
  - total organic carbon (TOC)
- surface water v. sediment chemistry



Bioavailability

- Total v. bioavailable concentration
  - Chemical form: Cu^{+2}, Cr^{+6}
- Common attenuation factors:
  - Dissolved organic carbon
  - Hardness
  - Biotic ligands
- Mixtures

Biological Evaluation

- Evaluate in-stream impacts
  - Fish population (number, species diversity, % salmonids, DELT anomalies)
  - Macroinvertebrate population
  - Habitat
- in Michigan, use GLEAS Procedure 51(wadeable streams)
- Similar procedures for lakes and large rivers

GLEAS Procedure 51, Fish Population Assessment

- field season: June 1 to September 30th
- Stable stream discharge, low to moderate flow
- Permit required: 3 wks
- 1% trout, cold water stream designation
- 2% DELT anomalies, poor designation
- “Fish swim”


18
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RESEARCH

DELT Anomalies

Table X. Fish Community Summary, Percent (%) Salmonids, and Coldwater Habitat Attainment

Family Name	Common Name	Scientific Name	2007 Reach A	2007 Reach D-1
Petromyzontidae (lampreys)	Chestnut lamprey	*Ichthyomyzon castaneus*	4	1
	Lamprey ammocetes	*Lampetra appendix*	4	
Salmonidae (salmon and trout)	Brown trout	*Salmo trutta*	25	
	Brook Trout	*Salvelinus fontinalis*		
Catostomidae (suckers)	White sucker	*Catostomus commersoni*	1	1
Cyprinidae (minnows and carp)	Creek chub	*Semotilus atromaculatus*	1	
Umbridae (mudminnows)	Central mudminnow	*Umbri limi*	1	2
Gasterosteidae	Brook stickleback	*Culeca inconstans*	1	1
Centrarchidae (sunfish)	Rock bass	*Ambloplites rupestris*	1	
	Smallmouth bass	*Micropterus dolomieu*	1	
Percidae (perch)	Johnny darter	*Etheostoma nigrum*		
Cottidae (sculpins)	Slimy sculpin	*Cottus cognatus*	79	16
		Total Number of Species	10	5
		Total Number of Individuals	118	21
		Approximate Length Sampled (ft)	270	50
		Approximate Stream Width (ft)	30	10
		Time Sampled (sec)	2097	365
		Number DELT Anomalies	0	0
		% Salmonids	**21.2**	**0.0**
		Site Characterization Summary	**Coldwater Habitat**	**Poor**

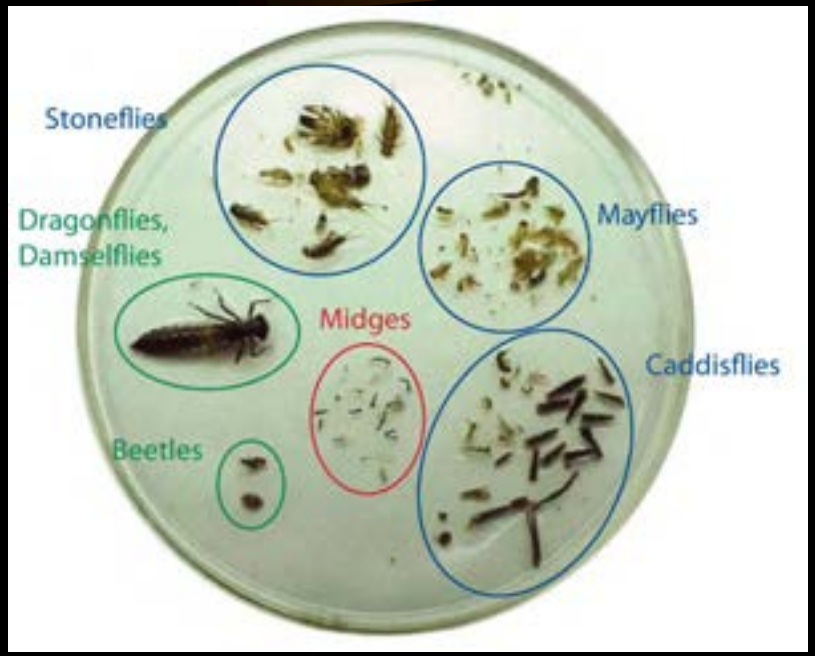
NOTES: Greater than 1% salmonids (brown trout) indicate coldwater habitat designation is achieved.

Macroinvertebrate Evaluation

Macroinvertebrate Evaluation

Macroinvertebrate Evaluation

- Field sorting and identification (GLEAS Procedure)
- Laboratory identification
- Is venting groundwater an issue?
- “just ask the bugs”



Habitat Evaluation

- Substrate
- Channel flow
- Available cover
  - Large wood debris
  - Vegetative cover
- Bank Stability
- Riparian zone
- Sediment Deposition

GLEAS Procedure 51 Scoring Metrics

Table X. Habitat Scores, GLEAS Procedure 51

Habitat Parameter		Reach A	Reach D
1) Epifaunal Substrate/ Available Cover		15	6
2) Pool Substrate Characterization		16	12
3) Pool Variability		16	7
4) Sediment Deposition		11	4
5a) Channel Flow Status - Maintained Flow Volume		10	10
5b) Channel Flow Status - Flashiness		9	10
6) Channel Alteration		16	16
7) Channel Sinuosity		10	11
8) Bank Stability	(LB)	9	10
	(RB)	9	10
9) Vegetative Protection	(LB)	10	10
	(RB)	10	10
10) Riparian Zone Width	(LB)	10	10
	(RB)	10	10
Total Score		161	136
Site Characterization Summary		Excellent	Good

Habitat Characterization Total Point Score (metrics 1-10)

1. Excellent >154
2. Good 105 – 154
3. Marginal 56 – 104
4. Poor <56

Table 1. Macroinvertebrate Community Summary and IBI Scores, Reaches A to E

IBI Metrics		2007 Reach A	2007 Reach D
	Total Number of Taxa	18	
	Total Mayfly Taxa	2	
	Total Caddisfly Taxa	5	
	Total Stonefly Taxa	1	
	% Mayfly Composition	3	
	% Caddisfly Composition	30	
	% Dominant Taxa	28	
	% Isopoda, Leeches, Snails	5	
	% Surface Dependent	1	
	Total Number of Individuals	100	1
	Time Sampled (min)	30	
IBI Scores	Total Number of Taxa	0	
	Total Mayfly Taxa	-1	
	Total Caddisfly Taxa	0	
	Total Stonefly Taxa	0	
	% Mayfly Composition	0	
	% Caddisfly Composition	1	
	% Dominant Taxa	-1	
	% Isopoda, Leeches, Snails	0	
	% Surface Dependent	1	
	Total Score	0	
	Site Characterization Summary	Acceptable, neutral	Poor

THE USE OF ECOLOGICAL ASSESSMENT TOOLS TO ACHIEVE GSI COMPLIANCE: OVERVIEW OF THE TOOL BOX

- 10 Ways to Demonstrate Compliance with GSI
- 3 of the 10 Utilize Ecological Assessment in achieve GSI compliance
  - Chemistry (groundwater and surface water)
  - Toxicity (sediment and surface water)
  - Biological Evaluation
    - Fish population (number, species diversity, % salmonids, DELT anomalies)
    - Macroinvertebrate population
    - Habitat and wetland evaluation
    - Standard procedures and metrics for wadeable streams, large rivers and lakes

Contaminated Sediment Assessment

- USEPA Superfund, RCRA Corrective Action
- USACE: navigational servitude
- Part 201: MDEQ OM-4, Att. 3 (8-2-2006)
  - Site Characterization
  - Evaluate Remedial Options
    - Removal
    - Capping
    - Monitored natural recovery
    - Combination of the above

USEPA and USACE Sediment Sampling Guidance

- MDEQ guidance (Part 201)
  - Lateral and vertical extent
  - Lines of evidence: primarily bulk sediment chemistry, toxicity
- USEPA guidance (Superfund, RCRA Corrective Action)
  - lateral and vertical extent
  - Multiple lines of evidence: chemistry, toxicity, bioavailabity, biological impacts
  - Removal, capping, monitored natural recovery
- USACE and MDEQ guidance
  - collection of representative sediment samples of the "dredge cut"
  - support decisions regarding sediment disposal/placement options

MDEQ OM-4, Attachment 3, Sediments

- Phased approach
- First sample sediments for bulk chemistry
  - Compare data to USEPA (2002c and 2003) sediment quality guidelines
  - If less than SQG, first off ramp
- If greater than SQG, than conduct whole sediment toxicity testing
- If sediment is not acutely toxic, second off ramp
- If the sediment is toxic, then
  - Presumptive remedy, or
  - Site specific cleanup criteria development

MDEQ OM-4, Attachment 3, Sediments

- compare bulk sediment chemistry to:
  a. USEPA Region 5 Ecologic Screening Levels (8-22-2003)
  b. “Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems” (USEPA, 2002; McDonald et al, 2000)
     1. threshold effects concentrations (TECs)
     2. probable effects concentrations (PECs)
     3. 29 compounds, metals, PNAs, PCBs, organochlorine pesticides

MDEQ OM-4, Attachment 3, Sediments

- threshold effects concentration (TECs): "harmful affects to sediment dwelling organisms are not expected to occur"
- probable effects concentration (PECs): "harmful affects…are expected to occur frequently"

Compare Sediment Quality Data to TECs, ESLs, PECs

Site Designation Transect Number Sample Depth Date Sampled	UNITS	THRESHOLD EFFECT CONCENTRATION (US EPA 2002)	PROBABLE EFFECT CONCENTRATION (US EPA 2002)	ECOLOGICAL SCREENING LEVELS (US EPA 2003)	SED 1 Tran 1 0-6" 10/09/07	SED 1A Tran 1 0-6" SUP 10/10/07	S2D 1B Tran 2 6-12" 10/09/07	SED 1B2 Tran 2 6-12" SUP 10/10/07	SED 3A Tran 3 0-6" 10/09/07	SED 4A Tran 4 0-6" 10/24/07
METALS, TOTAL										
Arsenic	mg/Kg	9.79	33	9.79	3.5	2.7	5.8	3.9	6.8	0.4
Cadmium	mg/Kg	0.99	4.98	0.99	1.3	0.6	1.3	1.5	0.9	0.4
Chromium	mg/Kg	43.4	111	43.4	35	15	27	22	15	9
Copper	mg/Kg	31.6	149	31.6	455	277	55	3,700	45	19
Lead	mg/Kg	35.8	128	35.8	197	99	189	581	97	32
Mercury	mg/Kg	0.18	1.06	0.174	0.55	0.053	0.28	0.59	0.54	<0.05
Silver	mg/Kg	na	na	0.5	4.8	0.4	3.3	6.2	5	0.4
Zinc	mg/Kg	121	459	121	289	291	314	787	277	37
SEMI-VOLATILE ORGANIC COMPOUNDS										
Acenaphthene	µg/Kg	na	na	6.71	311	<330	<330	<330	<330	457
Acenaphthylene	µg/Kg	na	na	5.87	<330	811	<330	441	<330	<330
Benzo(a)anthracene	µg/Kg	108	1,050	108	477	3,220	684	1,850	887	877
Benzo(a)pyrene	µg/Kg	150	1,450	150	1810	1,610	727	1,610	639	1418
Benzo(g,h,i)perylene	µg/Kg	na	na	170	674	1,320	831	1,450	711	897
Chrysene	µg/Kg	166	1,290	166	1,110	2,080	477	2,310	564	845
Dibenzo(a,h)anthracene	µg/Kg	33	na	33	<330	<330	<330	<330	<330	<330
Fluoranthene	µg/Kg	423	2,230	423	1,450	5,010	1,210	3,610	1,870	1,310
Naphthalene	µg/Kg	176	561	176	<330	<330	<330	<330	<330	<330
Phenanthrene	µg/Kg	204	1,170	204	771	1,710	<330	1,450	554	637
Pyrene	µg/Kg	195	1,520	195	2,110	4,300	831	3,820	1,310	1,410
TOTAL PAHs	µg/Kg	1,610	22,800	na	7,913	20,061	4,680	16,781	6,535	7,843
METALS, SEM										
Cadmium	µmoles/gram	na	na	na	na	0.027	na	0.027	0.054	na
Copper	µmoles/gram	na	na	na	na	7.50	na	9.11	0.57	na
Mercury	µmoles/gram	na	na	na	na	0.0000526	na	0.000035	<0.00021	na
Lead	µmoles/gram	na	na	na	na	0.81	na	0.77	0.47	na
Zinc	µmoles/gram	na	na	na	na	12.6	na	7.1	2.1	na
Nickel	µmoles/gram	na	na	na	na	0.21	na	0.27	0.19	na
Acid Volatile Sulfide	umoles/gram	na	na	na	na	6.5	na	27.7	54.5	na
SEM/AVS Ratio	unitless	na	na	na	na	3.25	na	0.62	0.06	na
TOC, Walkley Black	%	na	na	na	na	0.60	na	2.57	3.26	na

MDEQ OM-4, Attachment 3, Sediments

- if the sediment quality data does not exceed USEPA SQGs, first off ramp
- Otherwise, submit a work plan to the MDEQ to determine extent of sediment impacts and conduct whole sediment toxicity testing and/or evaluation of bioaccumulation
- 10-day whole sediment acute toxicity testing, two species:
  - the freshwater insect *Chironomus dilutus (previously known as C. tentans)*
  - benthic amphipod *Hyalella azteca*.

USEPA Contaminated Sediment Assessment

- "Multiple lines of evidence"
  - Bulk sediment chemistry
  - Whole sediment toxicity (acute and/or chronic)
  - Biological impacts
    - Fish
    - Macroinvertebrates
    - Habitat assessment
  - Bioavailablity

Whole Sediment Toxicity Testing

- Test organisms are exposed directly to sediment samples
- The response of the test organism is examined in relation to a specific endpoint (acute toxicity: survival and growth)

Whole Sediment Toxicity Testing

Freshwater insect: *Chironomus dilutus*

Benthic amphipod: *Hyalella azteca*

Selection of Samples for Toxicity Testing

- Typically 6-10 samples are selected for 10-day, whole sediment toxicity testing
- select samples based on bulk sediment chemistry results
  - Select samples between USEPA TEC/ESLs and PEC
  - Select samples above PECs
- bioavailability…

Core Sampling

Sediment Sampling Equipment
Ponar and Eckman Samplers

Sediment Sampling Equipment
Standard Ponar Sampler

Whole Sediment Toxicity Testing Considerations

- The mean and variance of the survival and growth data (8-replicates) are compared to:
  - GLEC laboratory control
    - Sediment collected from the Boardman River, a local river that has a primarily forested watershed in the Pere Marquette State Forest
  - site reference sediment sample (background)

Comparison of Average[1] Dry Weight (mg), Biomass[2] (mg) and Percent Survival Between Reference Sediments (GLC 9100) and Investig
Sediment Samples

Hyalella azteca 10-Day Whole Sediment Toxicity Tests

:ATE #	GLEC Laboratory Control		Site Reference		Sample 1		Sample 2		Sample 3		GLEC Sec Contr	
	CS104		GLC#: 9100		GLC#: 9101		GLC#: 9102		GLC#: 9103		Water C	
	Average[1] Weight (mg)	Biomass[2] Weight (mg)	Average[1] Weight (mg)	Biomass[2] Weight (mg)	Average[1] Weight (mg)	Biomass[2] Weight (mg)	Average[1] Weight (mg)	Biomass[2] Weight (mg)	Average[1] Weight (mg)	Biomass[2] Weight (mg)	Average[1] Weight (mg)	
	0.09300	0.09300	0.07112	0.07332	0.09234	0.09237	0.09234	0.07342	0.05423	0.03278	0.02167	
	0.10200	0.10200	0.12797	0.12384	0.09157	0.09115	0.08457	0.08553	0.05342	0.03467	0.05222	
	0.10700	0.10700	0.15130	0.14117	0.09950	0.07463	0.09132	0.08034	0.08321	0.07324	0.01400	
	0.09778	0.08800	0.12997	0.11583	0.08996	0.08992	0.09422	_0756	0.07654	0.06123	0.06300	
	0.08700	0.08700	0.09830	0.09854	0.11230	0.11345	0.09134	0.07443	0.07278	0.05578	0.03900	
	0.09200	0.09200	0.08112	0.08113	0.08764	0.08763	0.07345	0.07562	0.08552	0.06523	0.02750	
	0.09400	0.09400	0.12114	0.11787	0.04223	0.04112	0.06223	0.05116	0.03472	0.02317	0.02400	
	0.08700	0.08700	0.10115	0.13420	0.08112	0.08313	0.07231	0.07378	0.11782	0.09821	0.04500	
age[1] ght (mg)	0.09497		0.11026		0.08708[a]		0.08272[a]		0.07228[a]		0.03580	
age Weight g)		0.09375		0.11074		0.08418[a]		0.07347[a]		0.05554[a]		
Percent ival	98.8		97.5		100.0		93.8		72.5[a]		91.3	

Dry Weight is the **total dry weight of surviving organisms**
weight is the total Dry Weight of surviving organisms divided by the initial number of organisms
ntly different ($p < 0.05$) from reference sediment SETC0000C206 (GLC Number: 9100)

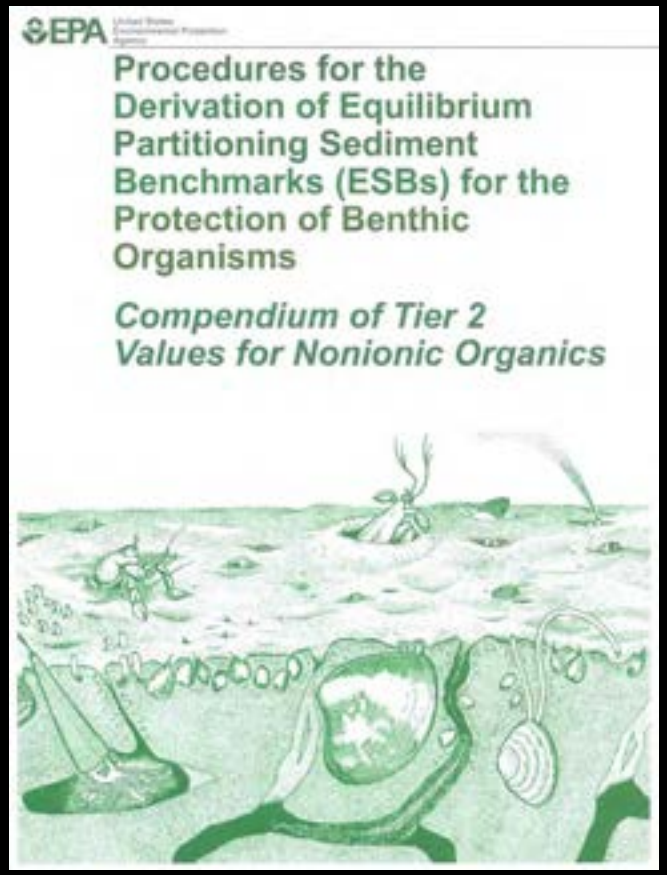
Whole Sediment Toxicity Testing Considerations

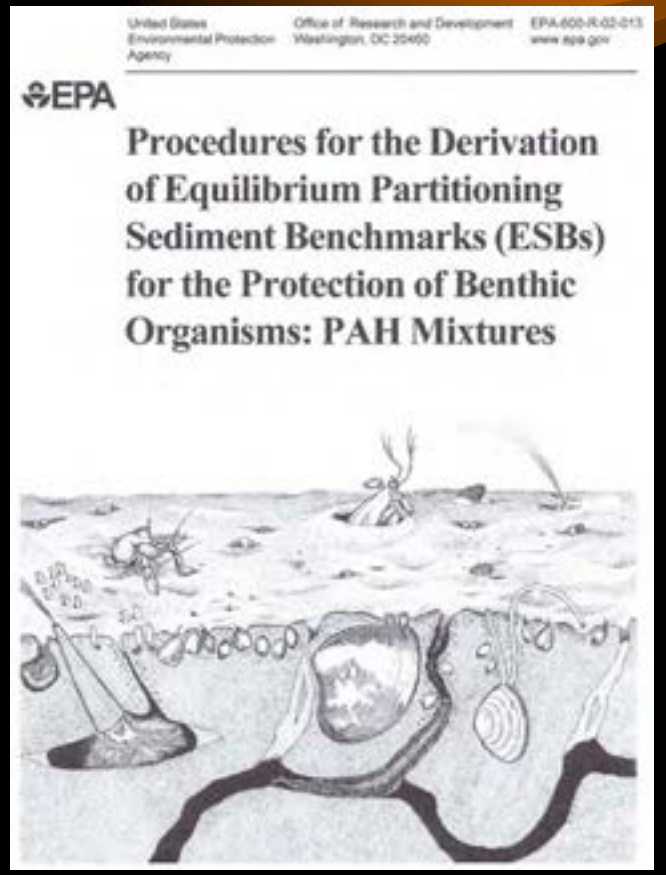
- MDEQ: acute toxicity
  - 10-day *Chironomus* (survival and growth)
  - 10-day *Hyalella* (survival and growth)
  - 8 replicates
- USEPA: acute and chronic toxicity
  - 20-day *Chironomus* (survival and growth)
  - 28-day *Hyalella* (survival and growth)
  - 8 replicates
- USACE: acute toxicity
  - Open lake reference area and open lake disposal area
  - 10-day *Chironomus* (survival and growth)
  - 10-day *Hyalella* (survival)
  - 5 replicates

Bioavailability

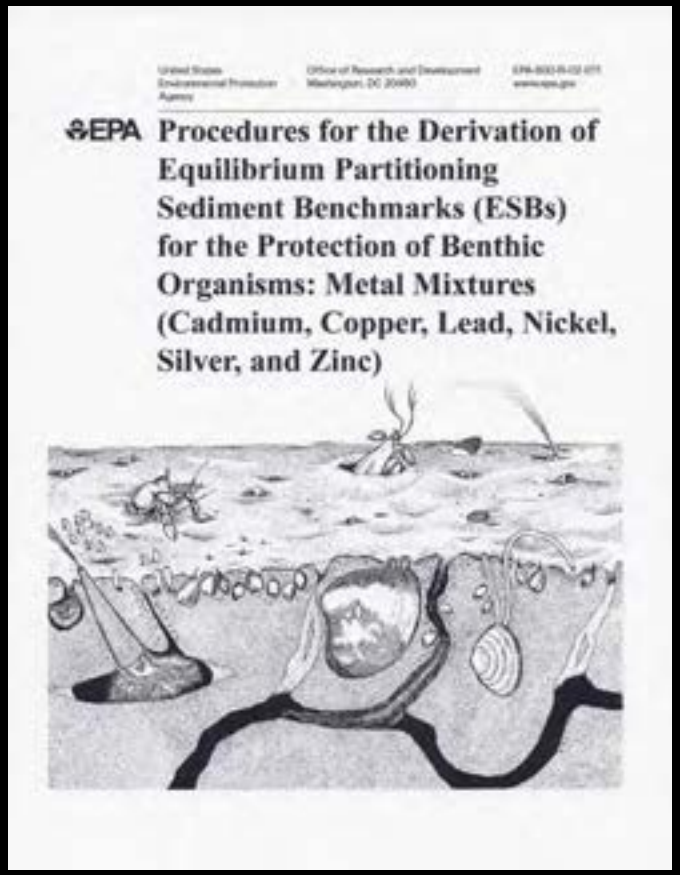
- USEPA (2005 and 2008), EQP for PAHs and nonionic compounds (VOCs)
  - Fraction organic carbon
- USEPA (2003) equilibrium partitioning (EQP) guidance for metal mixtures (Cd, Cu, Pb, Hg, Ni, and Zn)
  - Acid volatile sulfide/sequentially extracted metals
  - Fraction organic carbon

USEPA Guidance

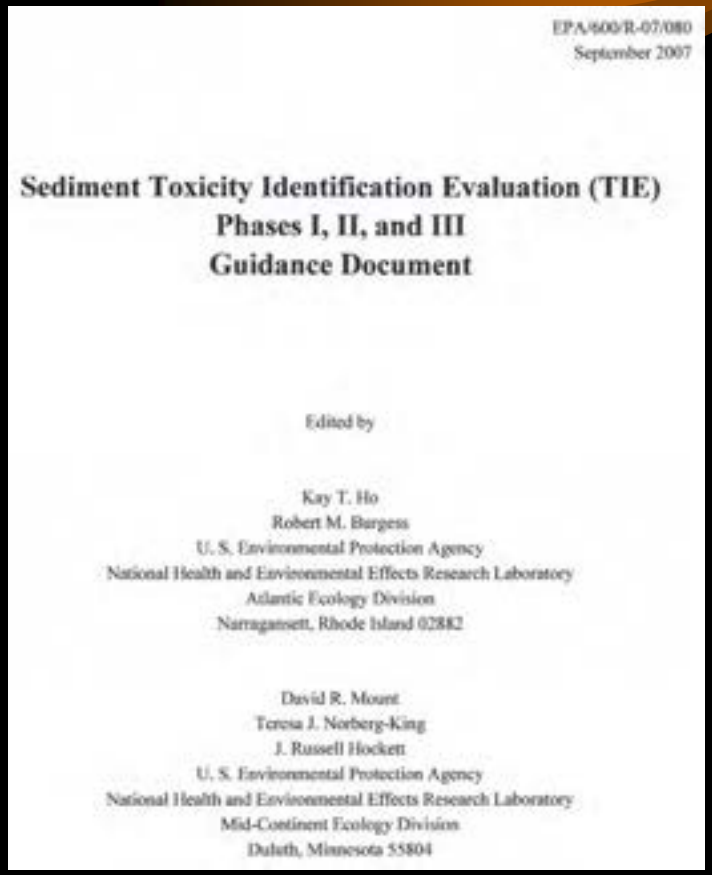




Bioavailability



EPA **Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: Metal Mixtures (Cadmium, Copper, Lead, Nickel, Silver, and Zinc)**



EPA/600/R-07/080
September 2007

Sediment Toxicity Identification Evaluation (TIE) Phases I, II, and III Guidance Document

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Bioavailability Depends on Many Factors

- pH
- Redox (ORP)
- Acid volatile sulfide (AVS)
- Total Organic Carbon (TOC)
- Focus: the toxicity of porewater on aquatic organisms

Application of Bioavailability, Copper in Sediment

Copper TEC: 32 mg/kg
Copper PEC: 149 mg/kg

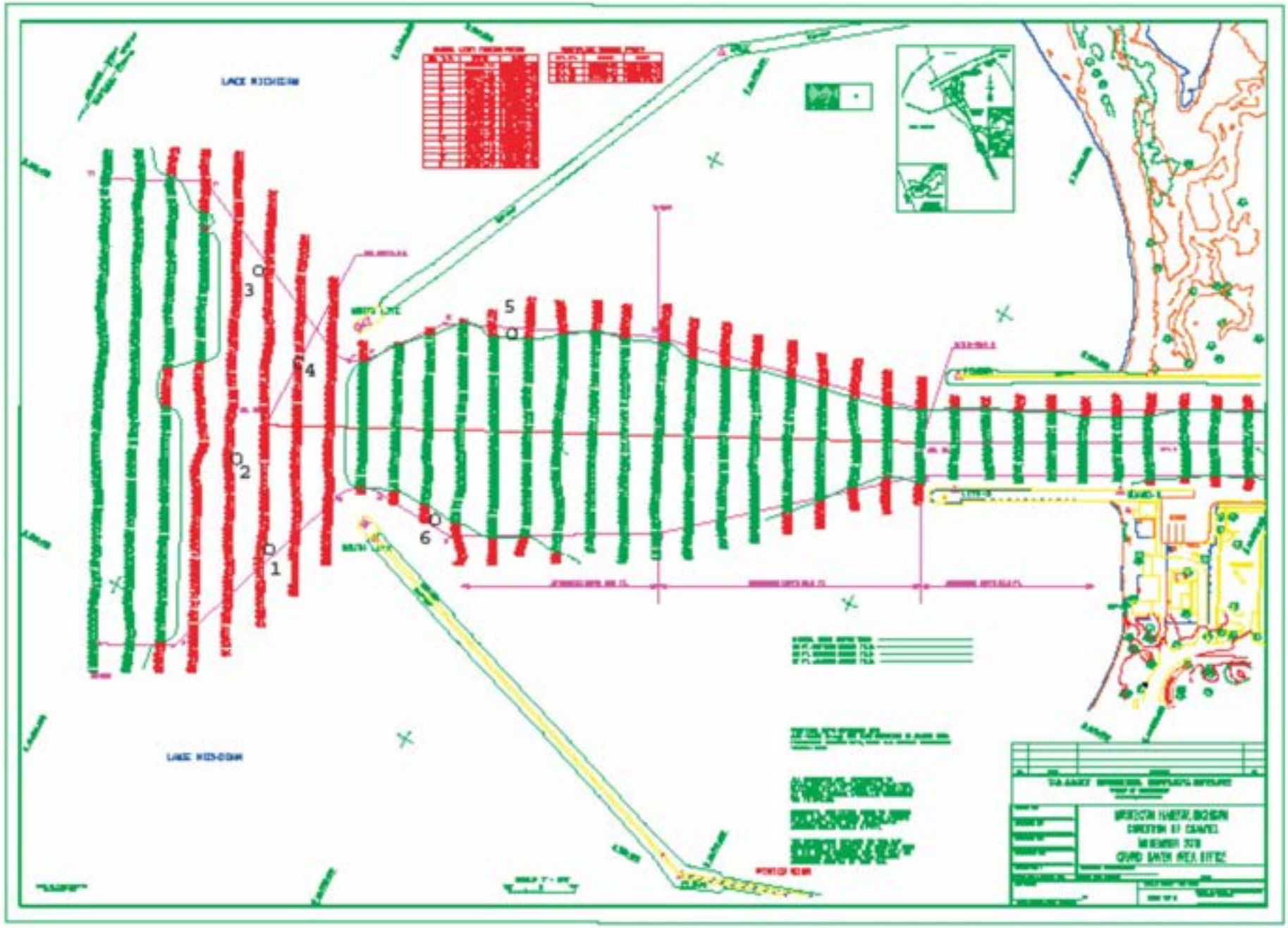
Sample ID	Copper Conc. (mg/kg)	AVS (μmoles/gram$_{oc}$)	Foc (%)	SEM (μmoles/gram$_{oc}$)	Sum (SEM-AVS)/f_{oc} (μmoles/g_{oc})	*Chironomus dilutus* (10-day)	*Hyalella azteca* (10-day)
1	11,100	<2.2	4.48	124.414	2,728	fail	fail
2	5,110	0.94	4.69	32.763	678	pass	fail
3	1,660	9.1	9.13	11.118	22.1	fail	pass
4	513	1.9	2.20	12.660	489	fail	pass
5	448	1.1	1.90	4.190	163	pass	pass
6	257	6.4	1.75	1.182	-298	pass	pass
7	32	7.0	2.20	0.569	-292	pass	pass

Application of EQP

- equilibrium partitioning (EQP) can be used as a tool to select samples for toxicity testing
  - most commonly used to explain sediment toxicity
  - not in lieu of toxicity testing
- USEPA EQP concerns…
  - chemical mixtures
  - Sediment pore water versus ingested dose ("bugs eat dirt")
  - Variability in attenuation mechanisms with time (AVS, pH, ORP, etc.)

USACE Contaminated Sediment Assessment

- USACE:
  - Maintain navigation channels:
    - "Navigational servitude"
  - Public benefit v. public trust (bottom lands of the Great Lakes and connecting channels)
  - Confined disposal facilities (CDFs), dredged material disposal facilities (DMDFs), open water disposal
- 1998 Great Lakes Dredged Material Testing and Evaluation Manual, see Appendix D



MDEQ 2013 Emergency Dredging Program

- Water levels in Lake Michigan and Lake Huron are at an all time low
- Water levels in Lake Michigan, Lake Huron, and Lake St. Clair are 16 inches lower than last year
- Lake Erie is 21 inches lower than last year

MDEQ 2013 Emergency Dredging Program

- Feb. 25, 2013: Expedited Permit Program
- March 19, 2013: MDEQ Procedural Changes
- $20.96 million made available by the State of Michigan for emergency dredging
- 49 harbors received funds (State or municipal owned marinas and boat launches)
- why? Boating has a very significant impact on Michigan's economy, $3.9 billion in trip/craft spending

MDEQ Procedural Changes

- Metals testing reduced from 12 metals to 7 metals (arsenic, cadmium, lead, mercury, selenium, and zinc)
- PNAS and PCBs: only if dredging will occur within the: Detroit River, Rouge River, Raisin River, Kalamazoo River, Saginaw River, Saginaw Bay, Manistique Harbor.

Sediment Criteria

- Uncontaminated if…
  - Below Statewide Default Background Levels (metals)
  - Below Target Method Detection Limit (TMDL)
  - If one or more samples above TMDL/Background, calculate 95% Upper Confidence Limit
    - If UCL < TMDL/Background, uncontaminated
    - If UCL > TMDL/Background, leachate testing (TCLP or SPLP) and compare results to groundwater criteria
    - Uncontaminated if leachate testing is less than groundwater criteria and total concentrations are below soil criteria

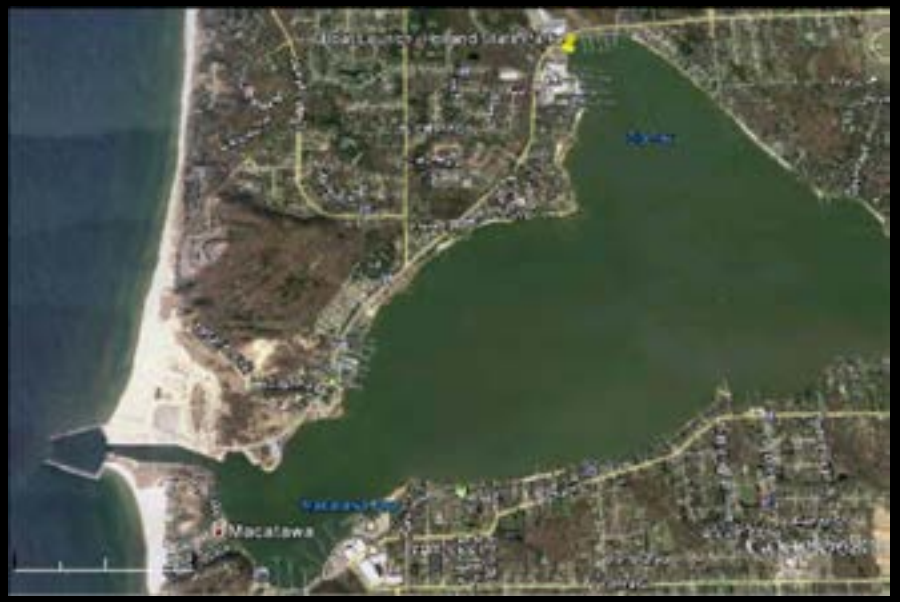
Sediment Criteria

- Statewide Default Background
  - Type A Cleanup Criteria, September 30, 1993
- Groundwater and Soil Criteria
  - Type B Cleanup Criteria, February 4, 1994
    - Op Memo 8, Revision 3
- Issue: the Dredging criteria are very stringent in comparison to Part 201 or USEPA sediment cleanup criteria

Sediment Criteria Comparison

Chemical	Threshhold Effect Concentration (TEC)[4] µg/Kg	Probable Effect Concentration (PEC)[5] µg/Kg	Ecological Screening Level (ESL)[6] µg/Kg	Statewide Default Background Value, ug/kg (Type A: 9-30-1993)	Groundwater Criteria, ug/L (Type B: Op Memo 4, Rev 3, 2-4-94)	Target Method Detection Limit in Water, ug/L (Type B: Op Memo 4, Rev. 3, 2-4-94)	Soil Criteria, ug/kg (Type B: Op Memo 4, Rev. 3, 2-4-94)	Target Method Detection Limit in Soilr, ug/kg (Type B: Op Memo 4, Rev. 3, 2-4-94)
Anthracene	57.2	845	57.2		1,200	5	46,000,000	330
Arsenic	9,790	33,000	9790	5,800	0	1	720	100
Benzo(a)pyrene (Q)	150	1450	150		NLL	5	180	330
Cadmium (B)	990	4,980	990	1,200	1	0	130,000	50
Chromium (III) (B,H)	43,400	111,000	43,400	18,000				
Chrysene (Q)	166	1,290	166		NLL	5	180,000	330
Copper (B)	31,600	149,000	31,600	32,000	16	25	9,800,000	1,000
Fluoranthene	423	2,230	423		370	5	31,000,000	330
Lead (B)	35,800	128,000	35,800	21,000	4	3	400,000	1,000
Mercury (B,Z)	180	1,060	174	130	0.0013	0.02	78,000	100
Naphthalene	176	561	176		29	5	9,300,000	330
Nickel (B)	22,700	48,600	22,700					
Phenanthrene	204	1,170	204		5	5	930,000	330
PCBs	59.8	676	59.8		NLL	0.2	1,000	330
Pyrene	195	1,520	195		520	5	19,000,000	330
Zinc (B)	121,000	459,000	121,000	47,000	81	20	86,000,000	1,000

Emergency Dredging Projects



Overview

- GSI as a a remedial compliance point in Michigan
- MDEQ's development of GSI rules and guidance
- 2012 Amendments to GSI rules
- 10 ways to demonstrate compliance with GSI
- June 17, 2014 Compliance Options Resource Material
- MDEQ Emergency Dredging Plans and Contaminated Sediments
- Focus: "what's new"

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