Reactive Sediment Cap at East Branch Grand Calumet River

Evaluation and Confirmation of As-Placed Design Characteristics of Materials

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AquaBlok®
Composite Particle System

Grand Calumet River
Great Lakes Legacy Act (GLLA) Clean-up
Grand Calumet River Area of Concern

East Branch (Zone B) of the Grand Calumet River:

- **1.8-mile stretch of the river from Indianapolis Boulevard to Holhman Avenue**
- **350,000 cubic yards of sediment were removed**
- **A cap was placed over the dredged sediment.**
- **Near shore habitats were restored with native plants**
- **Completed in 2015.**

AquaBlok
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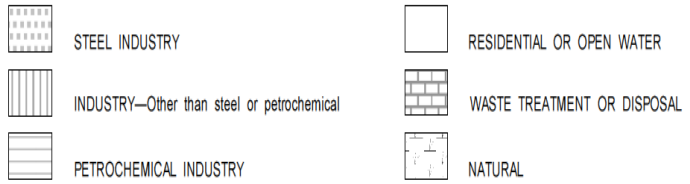
Mix of Historic Industrial Use Drives Target Contaminants & Remedy

- PAHs primary driver of remediation
- Remedy - Cap Objectives



Total PAH Bulk Sediment Concentration in bioturbation zone	**27.0 mg/kg – dw (3.4 mg/kg-dw 1 %OC)**
Cap Design Life	**100 yrs**

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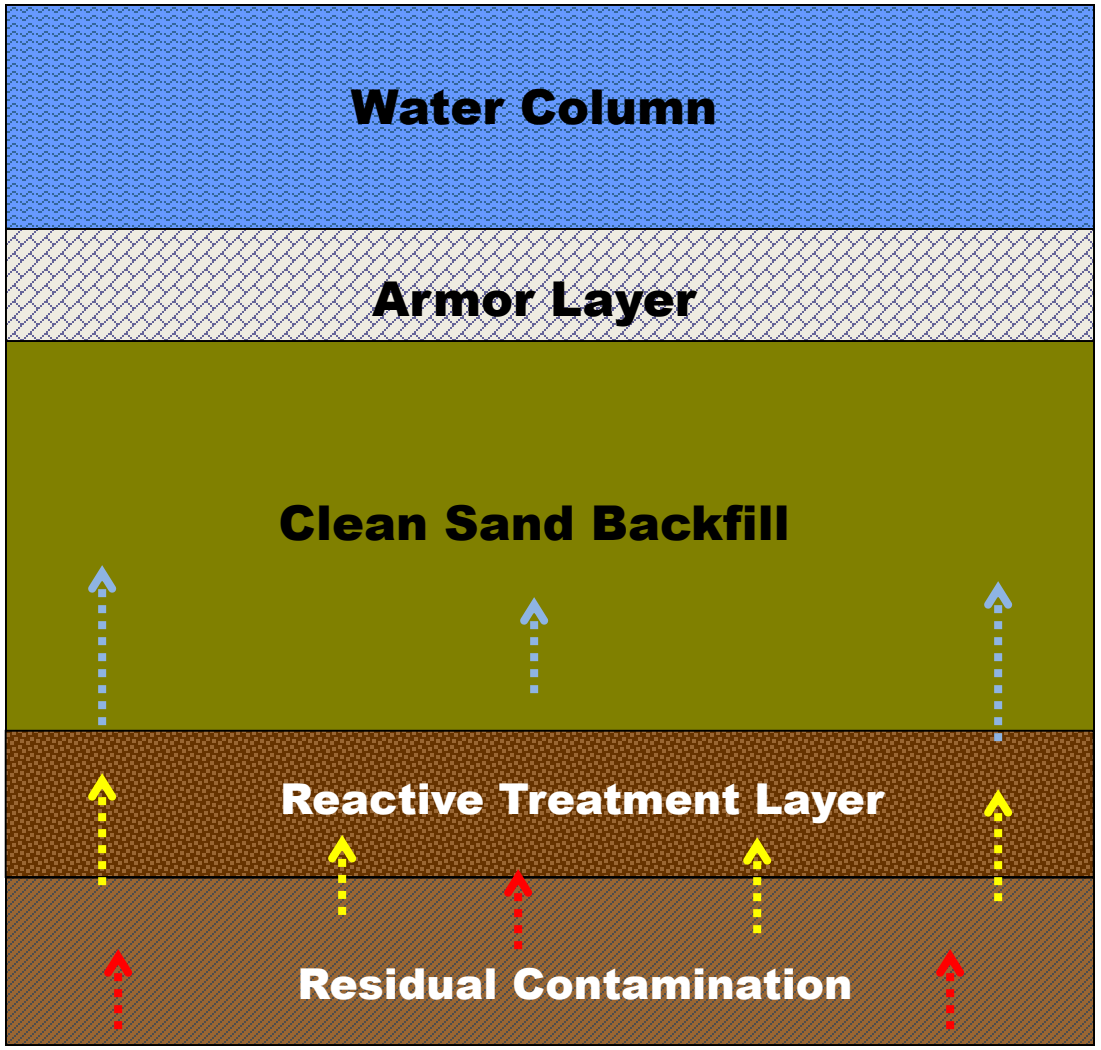
Reactive Cap Model & Design Considerations

- Model Assumes *Uniform Distribution* of Organoclay within Layer
- Thickness = *Residence Time* for Adsorption (Hydrologic Conditions)
- Adsorption Capacity of Organoclay *Expressed by Partition Coefficient*
- Adsorption Capacity Must Protect from Possible *Isolated Seep Zones*
- Material Approach Must Allow for *Reduction in Permeability* Due to Swell of Organoclay



not to scale

Data to Develop & Run Cap Model

- Contaminant characteristics
  - Site specific data
- Sediment characteristics
  - Site specific data
- Active layer characteristics
  - Material characteristics (study/literature based data)
- Conventional cap characteristics

TABLE 1B
DESIGN SPECIFIC MODEL INPUTS

Material Property	Value	Unit
Effective adsorption partition coefficient (K_d)*		
Area A (STA 5+54 to STA 55+00)	19,950	L/Kg
Area B (STA 55+00 to STA 95+15)	39,810	L/Kg
Active layer thickness		
Area A (STA 5+54 to STA 55+00)	10.14	cm
Area B (STA 55+00 to STA 95+15)	10.14	cm
Active adsorbent loading		
Area A (STA 5+54 to STA 55+00)	4.1	kg/m2/cm
Area B (STA 55+00 to STA 95+15)	1.37	kg/m2/cm

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Initial Model Output Results

Case	Media	For model (kg/m2/cm	Reactive layer Loading lb Oclay/cf	% Oclay by wt	thickness (cm)	Sand thickness (cm)	Log Koc	Initial Porewater conc(C0)(ug/L)	Surface sediment (0-10 cm) Average bulk concentration (Conc at 100 yrs	Conc at 200 yrs	Conc at 300 yrs	Conc at 400 yrs
Area A:												
Extent of removal ranges from approx 1 feet to potentially 6 feet of sediment to reach a target elevation of 573 feet												
Porewater concentrations range from 1.6 ug/L to 958.2 ug/L with a mean of 195.8 ug/L and a 95 UCL of 427.5 ug/L												
Koc index ranges from 3.7 to 5.0 with a mean of 4.3												
Active Layer Mix of Organoclay and granular media												
	Oclay	2.28	14.20	14%	7.6	30.5	4.3	427.5	24.75	281.05	439.28	482.73
	Oclay	1.52	9.47	9%	15.22	30.5	4.3	427.5	0.74	131.86	373.12	468.94
	Oclay	5.32	33.14	45%	7.6	30.5	4.3	427.5	0.02	15.03	103.24	230.87
	Oclay	**2.28**	**14.20**	**14%**	**15.22**	**30.5**	**4.3**	**427.5**	**< 0.01**	**14.47**	**142.16**	**317.19**
***	Oclay	3.8	23.67	27%	15.22	30.5	3.7	958.2	25.23	215.75	258.64	261.60
	AC	1.95	na	na	1	30.5	4.3	427.5	71.29	209.75	300.43	357.02
Area B:												
Extent of removal ranges from none to 1 feet of sediment to reach a target elevation of 573 feet												
Porewater concentrations range from < 1 ug/L to 119.9 ug/L with a mean of 23.76 ug/L and a 95 UCL of 41 ug/L												
Koc index ranges from 3.8 to 5.6 with a mean of 4.6												
Active Layer Mix of Organoclay and granular media												
	Oclay	0.76	4.73	4%	7.6	30.5	4.6	41	20.95	78.90	90.14	91.29
	Oclay	0.76	4.73	4%	15.22	30.5	4.6	41	0.11	23.04	67.93	86.38
	Oclay	**1.52**	**9.47**	**9%**	**7.6**	**30.5**	**4.6**	**41**	**0.67**	**26.21**	**62.56**	**81.30**
	Oclay	2.28	14.20	14%	7.6	30.5	4.6	41	0.02	5.63	28.73	54.64
	Oclay	2.28	14.20	14%	15.22	30.5	4.6	41	< 0.01	< 0.01	0.23	3.13
***	Oclay	3.8	23.67	27%	15.22	30.5	3.8	119.9	0.81	23.75	38.28	40.70
	AC	1.95	na	na	1	30.5	4.6	41	11.76	37.63	55.42	66.74

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EBGCR Cap Specification

2.2 ADSORPTIVE LAYER – BASE DESIGN

The adsorptive layer shall consist of *virgin organoclay bound to an aggregate material substrate*. The properties of the organoclay are summarized below:

- The organoclay shall have minimal swelling after placement and shall have a minimum predicted long-term permeability of 10-3 centimeters per second (cm/s)
- The organoclay shall have a documented partition coefficient (Kd) of at least 50,000 L/Kg for light weight PAHs (eg. phenanthrene) and 350,000 L/Kg for mid to heavy weight PAHs (eg. pyrene).
- The organoclay will have a minimum quaternary amine loading of 25%.
- The organoclay shall applied such that the loading is at a minimum 4.1 kg/m2/cm (25.5 lb/ft3) in Area A and 1.37 kg/m2/cm (8.5 lb/ft3) in Area B.
- Aggregate material used in the adsorptive layer shall meet the gradation shown in Table 2

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Overview of Capping Material

AquaGATE+ ORGANOCLAY™

Uniform Placement of Small Quantities of High-Value Material

- Uniform Distribution of Reactive Material Within Layer
- Positive Placement Through Water – No Drift / Separation
- Adsorbs Approximately 15% by Weight - Pure Phase Oil
- High Surface Area / Adsorption Capacity
- Flexible/Rapid Installation – Range of Methods/Equipment

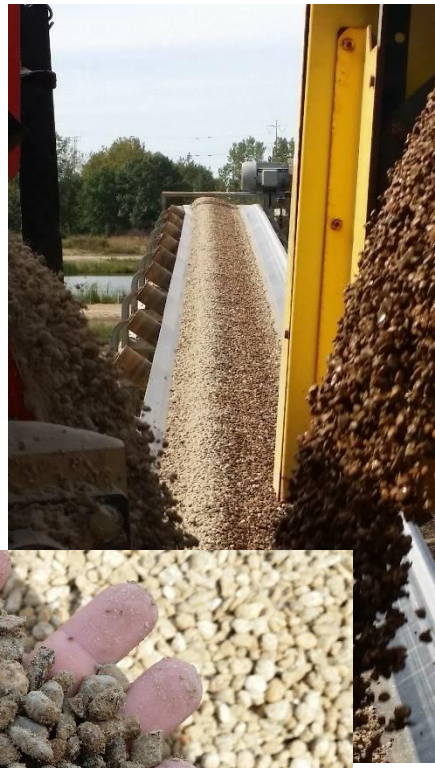

Shipment / On-Site Stockpile

This Project is Believed to be the <u>Largest Installation of an Organoclay-Based Active Cap</u> for Contaminated Sediment Remediation

- Deliveries in 2,500lb Bulk Bags
- Approximately 4-5 Trucks/Day – at 22 tons
- Stockpile protected During Storage
- Placement Began in August – Completed November
- Production = + ***<u>16,600 tons</u>***

J.F. Brennan – Broadcast Capping System (BCS™)

- Able to accurately place over soft sediment with limited intermixing
- Limits resuspension of in-situ sediments
- Onboard tracking system records thickness, volume, and position of material placement
- Can accurately spread materials in very thin lifts, while achieving even distribution.



Post Placement QA/QC

Was the *Quantity* of Reactive Material Assumed in the Design Successfully Placed on the Sediment Surface?

B-Cap				
Bucket Number	ID #	Fines %	Ave. Fines	lb/cu ft
1	092514465	12.79% 15.87% 14.48%	14.38%	14.04
2	092614474	6.37% 4.91% 4.79%	5.36%	5.23
3	092914549	6.38% 7.34% 12.75%	8.82%	8.61
4	092914557	8.66% 7.67% 10.34%	8.89%	8.68
Average Fines			9.36%	
Target lb/cu ft			7.0 - 7.2	
Actual lb/cu ft			9.14	

A-Cap				
Bucket Number	ID #	Fines %	Ave. Fines	lb/cu ft
5	100214689	39.63% 27.49% 26.12%	31.08%	25.64
6	100814783	25.78% 36.48% 31.18%	31.15%	25.70
7	110614534	28.10%		23.19
8	111114665	28.03%		23.13
9	111814798	26.78%		22.09
Average Fines			29.03%	
Target lb/cu ft			21.45	
Actual lb/cu ft			23.95	

Specification: “The organoclay shall applied such that the loading is at a minimum 4.1 kg/m2/cm (21.45 lb/ft3) in Area A and 1.37 kg/m2/cm (8.5 lb/ft3) in Area B.”

Post-Placement Active Material Properties Confirmation Testing & Analysis

Did the Reactive Material Placed on the Sediment Surface Retain the Adsorptive Properties Assumed in the Design?

#1 Oil Sorption Capacity – Pre/Post Placement

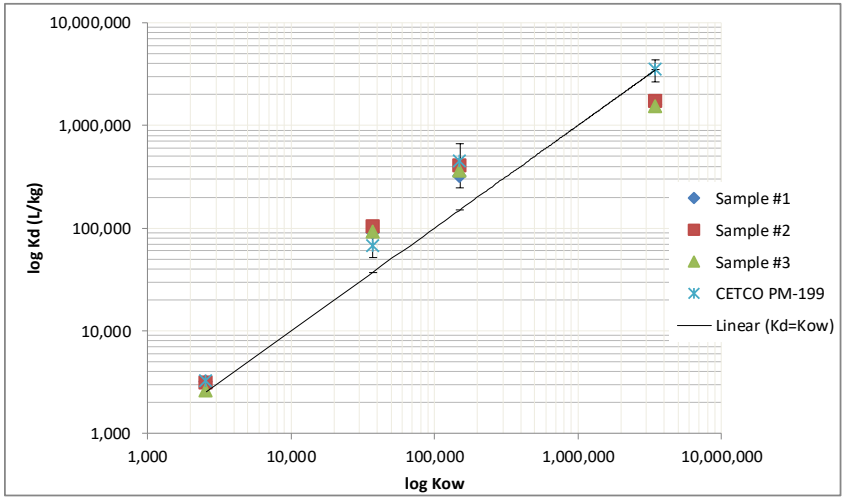
Sample Description	Samples	Oil sorption capacity (%)
Raw Orgaoclay (Control)	1-1	71.70
	1-2	68.36
	1-3	68.61
	1-4	70.04
	1	average 69.68
As Manufactured Organoclay	2-1	65.82
	2-2	64.88
	2-3	63.44
	2-4	60.59
	2	average 63.68
Sample Buckets - (As-Placed Material Recovered from River Bottom)	3-1	62.86
	3-2	62.65
	3-3	61.40
	3-4	61.99
	3	average 62.22

Oil Sorption Capacity (% dry wt.) for samples

Samples of material were sent to CETCO for testing utilizing Test Method: LP-Organoclay Powdered Sorption Oil Centrifuge-modified to 72 hours

Post-Placement Active Material Properties Confirmation Testing & Analysis

Did the Reactive Material Placed on the Sediment Surface Retain the Adsorptive Properties Assumed in the Design?



Texas Tech University Lab partition coefficients as a function of Kow.

Sample #1 – CETCO Powder OC as Received

Sample #2 – As Manufactured Coating, Prior to Placement

Sample #3 – Post Placement Sample Recovered From River

	NAP	PHE	PYR	BaP
log Kow	3.41	4.57	5.18	6.54
Kow	2,570	37,154	151,356	3,467,369
Sample #1	3,223	91,619	323,459	1,603,265
Std Dev	178	8,709	45,948	404,779
Sample #2	3,161	105,183	406,830	1,747,376
Std Dev	432	9,499	57,680	532,597
Sample #3	2,609	93,367	359,871	1,537,488
Std Dev	86	4,516	30,370	684,176
CETCO PM-199	3280	68,000	454,000	3,510,000
Std Dev		8,420	104,900	442,000
+/- 95% confidence interval		16,503	205,604	866,320

Octanol-water partition coefficients of PAHs and partition coefficients - standard deviation in estimate for the three tested organophilic clays. Values reported for CETCO PM-199 from TR-840[2]

Specification: “The organoclay shall have a documented partition coefficient (Kd) of at least 50,000 L/Kg for light weight PAHs (eg. phenanthrene) and 350,000 L/Kg for mid to heavy weight PAHs (eg. pyrene).”

Post-Placement Confirmation of Active Material Design Characteristics: Conclusions

- Ability to ***confirm the quantity of high-value amendment material*** (organoclay coating weight) being supplied and placed.
- ***Confirmation of material placement assumptions*** such as bulk density (*determines layer thickness*) which is critical to demonstration that this key design parameter is met.
- ***Verification of uniform distribution*** of active-treatment materials is achieved through the thickness of the capping layer.
- Enables ability to perform post-placement confirmation of active-treatment material testing of ***adsorption capacity*** (partition coefficient) that satisfies the specification.
- ***Modeling assumptions can be confirmed*** through comparison of input/assumptions to post-placement physical and material property data.
- Results can support modeling assumptions and be used to ***reduce costs associated with excessive factors of safety*** due to lack of certainty of achievement of a design / specification as well as the ability to provide post-placement verification.

Full-scale verification of quantity and post-placement material properties relative to project objectives

AquaBlok® Composite Particle System