Treatment of Dredge Return Water by Electrocoagulation
Lessons Learned: Effective Solids Management and pH Control Optimization

06 November 2015                   WEDA Pacific Chapter Annual Fall Meeting

Lindsey Davidge, EIT     Phillip Luedcke, EIT
Trevor Louviere, PE
Overview

1. Site Background & Project Objectives
2. 2013-2015 Dredge Return Water Treatment System Goals
3. Water Treatment Optimization
   1. Improvement of Floc Formation
   2. Improvement of Clarifier Effectiveness
   3. Optimization of Filtration/Polishing Step
4. Conclusion & Project Completion
5. Questions & Answers
Former aircraft manufacturing facility established in 1936
- Sediment surrounding parcel was contaminated by heavy metals and polychlorinated biphenyls (PCBs)
- Building demolition in 2011 allowed for the removal of contaminated sediment
- Dredging began in 2013
- Project goal: Remove ~160,000 cubic yards of contaminated sediment and restore habitat
- Dredge water is also contaminated by sediment and must be treated

Project Site Background & Location
Duwamish Waterway, Seattle, Washington
Dredge Schedule & Restrictions

River Access Issues

<table>
<thead>
<tr>
<th>Construction Season 1</th>
<th>Jun-12</th>
<th>Jul-12</th>
<th>Aug-12</th>
<th>Sep-12</th>
<th>Oct-12</th>
<th>Nov-12</th>
<th>Dec-12</th>
<th>Jan-13</th>
<th>Feb-13</th>
<th>Mar-13</th>
<th>Apr-13</th>
<th>May-13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish Window</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dredging &amp; Backfill</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tribal Fishing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish Window</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dredging &amp; Backfill</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tribal Fishing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish Window</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dredging &amp; Backfill</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tribal Fishing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Tidal influence restricted access for shallow dredging
- Noise permitting considerations with nearby residential areas
Additional Access Issues

High River Traffic

► Active channel with personal and commercial craft navigating the river

► Nearby construction and dredge operations
## Selected Water Quality Discharge Criteria

### Dredge water quality

<table>
<thead>
<tr>
<th>Constituent of Concern</th>
<th>Approximate Dredge Water Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper (ug/L)</td>
<td>0.478 – 6.25</td>
</tr>
<tr>
<td>Mercury (ug/L)</td>
<td>1.13 – 4.35</td>
</tr>
<tr>
<td>PCBs (ug/L)</td>
<td>1 – 6.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Conventional Parameter</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.5 – 8.5</td>
</tr>
<tr>
<td>Turbidity (NTU)</td>
<td>250 - &gt;1000</td>
</tr>
</tbody>
</table>

### Discharge water criteria

<table>
<thead>
<tr>
<th>Constituent of Concern</th>
<th>Acute</th>
<th>Chronic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper (ug/L)</td>
<td>4.8</td>
<td>3.1</td>
</tr>
<tr>
<td>Mercury (ug/L)</td>
<td>1.8</td>
<td>0.025</td>
</tr>
<tr>
<td>PCBs (ug/L)</td>
<td>10</td>
<td>0.03</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Conventional Parameter</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7 to 8.5, and &lt; 0.5 from background</td>
</tr>
<tr>
<td>Turbidity (NTU)</td>
<td>&lt; 5 above background</td>
</tr>
</tbody>
</table>

### Stormwater criteria

<table>
<thead>
<tr>
<th>WA Industrial Stormwater Benchmarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper (ug/L)</td>
</tr>
<tr>
<td>Mercury (ug/L)</td>
</tr>
<tr>
<td>PCBs (ug/L)</td>
</tr>
<tr>
<td>Not Applicable</td>
</tr>
</tbody>
</table>

### Conventional Parameter Range

- Between 5 and 9
- < 25 NTU

**ug/l = micrograms per liter**

**NTU = Nephelometric Turbidity Unit**
Treatment Considerations for Dredge Water

Water Treatment Design

► Variable dredge water production (0-1,000 gpm)

► Variable water quality (0-15% solids, salinity variation from seawater to rainwater)

► Restrictive dredging timeframe

PCB Sediment Contamination

Legend

Predicted Total PCB Concentration (ppb)

- ≤ 30
- > 30 - 60
- > 60 - 100
- > 100 - 240
- > 240 - 480
- > 480 - 720
- > 720 - 1,300
- > 1,300

PCB Sample Location
- Road
- Navigation Channel
- River Mile Marker
- Early Action Area (Cleanup Complete)

Project Area
Final Water Treatment Process Design

- Mechanical Dredging DSOA Areas
- Transload Facility
- Hydraulic Dredging DSOA Areas
- Mechanical Dredging ERA Areas
- TRI-FLO
- Settling Basin
- 800 GPM EC System
- Clarifier
- Polishing Step
- To Duwamish Waterway
- Cone Tanks
- SPA Area
- Trucks to Landfill
EC Reaction

\[ Fe + 2H_2O \rightarrow Fe(OH)_2 + H_2 \]
Optimization Target Areas

Improve Clarifier Settlement

► Better floc formation at EC trailers
  ► Adjust voltage/amperage
  ► Supplementation of solids

► Better floc preservation before clarifier
  ► Flocculation tank modification
  ► Clarifier modifications

Increase Maintenance Intervals

► Treatment optimization upstream reduces solids loading at filtration

CS2 Post-Clarification Turbidity (average): 85
CS3 Post-Clarification Turbidity (average): 25
Voltage and Amperage Adjustments

► Voltage limiting system – voltage set to defined value and amperage allowed to change
  ► Automatic amperage adjustments allowed to change based on influent water conductivity fluctuations
► Power settings changed to adjust iron dose

Reactor Changes

► Patented reactor design
  ► Allows for easy removal of reactors for reactor changes to accommodate changing water conditions
  ► Multiple reactors used at once
  ► In place reactor cleaning
Electrocoagulation Optimization
Supplementation of Solids at the EC Influent

Addition of Solids to Influent Water at the EC Reactors

► Line to maintain 70-100NTU water at the system influent
Post-EC Aeration Optimization
Floc Oxidation

► Original design included aeration by motorized mixers
  ► Mixing sheared floc particulate
► Diesel-powered compressor installed to aerate through sparge manifolds at 375 CFM
  ► Operations were costly and caused maintenance downtime for treatment system
► Compressors were replaced by regenerative blowers and fine-bubble diffusers
  ► Final configuration providing optimal aeration

Initial CS2 aeration configuration
Floc Transport Improvements
Preserve good floc for clarification/settlement

Diminished floc, homogenous color with poor settlement

Good floc with channels forming
Floc Transport Improvements
Preserve good floc for clarification/settlement

Installed a ramp to decrease shear forces on floc at weir
Seeding of the Flocculation Tank

- Introduction of settled and semi-compressed floc from the sludge thickening tanks into the flocculation tank
Clarifier Flow Diagram
Improve Clarifier Effectiveness

Management of Settled Solids

► Variable influent water quality and changes in EC settings resulted in highly variable sludge production at the clarifier
  ► Consistent monitoring of sludge levels and production rates informed solids removal rates
  ► A high sludge bed at the clarifier contributed to floc destruction and poor settlement for incoming particles due to decreased retention time

Addition of a variable frequency drive to the clarifier rake

► Enabled control to optimize clarifier performance
Modification Logistics
Decrease Solids Loading at Filters

Cost savings due to reduced consumables

Low Turbidity at the Clarifier
Effluent means Less Filtration

► Reduced the solids loading at the sand filters
► Increases the life of the filters
  ► Allowed for scheduling of sand filter and GAC filter backwashing
  ► Reduced the frequency of bag filter replacement
    ► ~$800/day in CS2 on bag filter maintenance
    ► ~$200/day in CS3 on bag filter maintenance
Other Lessons Learned

**pH Probe Issues**

**CO₂ Dosing**
- EC technology raises the pH of water
- CO₂ dosing used to create carbonic acid to lower the pH
  - Early on, large amounts of CO₂ were used for pH adjustment
    - CO₂ mixing pipe was inadequate for reaction time
  - This became a problem for rainwater, which already had a LOW pH
    - Had to use the Kaselco EC units to raise the pH of rainwater before discharging

**Turbidity Recirculation at System Effluent**
- Added controls to recirculate based on high turbidity at system effluent

**Redundancy & Spare parts**
- Two EC trailers run in parallel
  - Option for maintenance while continuing to treat water with single trailer
- Spare transformers, instruments, pumps, impellers, valves, screens as well as standard parts kept onsite
## Tuning a Dynamic System
### Summary of Water Treatment Optimization Parameters

<table>
<thead>
<tr>
<th>Modification/Parameter</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce EC power settings to reduce iron dose</td>
<td>-Reduce dissolved iron</td>
<td>-Reduced floc size</td>
</tr>
<tr>
<td></td>
<td>-Minimizing pH rise (eliminated need for CO₂)</td>
<td></td>
</tr>
<tr>
<td>Raise influent turbidity to 70-100 NTU</td>
<td>-Increase floc density</td>
<td>-Increase cleaning frequency at EC influent</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Increase solids loading at the clarifier</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-difficult to maintain consistent solids loading</td>
</tr>
<tr>
<td>Use of fine bubble diffusers instead of sparging pipes</td>
<td>-Increase oxidation rate at the flocculation tank</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-Reduce maintenance</td>
<td></td>
</tr>
<tr>
<td>Stopped mixer operation at the flocculation tank</td>
<td>-Reduced shear forces on the floc and prevented good floc from being broken up before it reached the clarifier</td>
<td></td>
</tr>
<tr>
<td>Installed a ramp at the flocculation tank weir</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Installed a variable frequency drive at the clarifier rake</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cut clarifier inlet from 90° elbow to 45° elbow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Add cone tank sludge to head of basin</td>
<td>-Improved solids settlement in the basin</td>
<td></td>
</tr>
</tbody>
</table>
Tuning a Dynamic System
Many Possibilities for System Feedback

Mechanical Dredging DSOA Areas

Transload Facility

Mechanical Dredging ERA Areas

Hydraulic Dredging DSOA Areas

TRI-FLO

Settling Basin

800 GPM EC System

Clarifier

Polishing Step

To Duwamish Waterway

Cone Tanks

SPA Area

Trucks to Landfill

.settling Basin

800 GPM EC System

Clarifier

Polishing Step

To Duwamish Waterway
Key Lessons Learned

Importance of optimizing the treatment system

► Proper solids management
► Controlled solids separation
► pH control

Importance of redundancy

► Ability to maintain or replace system components while minimizing downtime
Conclusion

ZERO delayed dredging shifts due to DRWS
Total Solids Removed: 160,000 cubic yards
Total Volume Treated & Discharged: 47,000,000 gal

- Met Washington State acute and chronic water quality criteria with ZERO discharge exceedances

Essentially all optimization was done while the system was running!

<table>
<thead>
<tr>
<th>Season and Duration</th>
<th>Cubic Yards Removed</th>
<th>Gallons of Water Treated &amp; Discharged</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS2 (2 months)</td>
<td>48,500 CY dredged</td>
<td>18 million gallons treated and discharged</td>
</tr>
<tr>
<td>CS3 (5 months)</td>
<td>75,000 CY dredged</td>
<td>45 million gallons treated 29 million gallons discharged</td>
</tr>
</tbody>
</table>