Optimizing Clarifier Performance—Are We Designing the Clarifiers Right?

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AGENDA

• Why it’s important
• Field testing and troubleshooting
• Design concepts
• Proofs
Low effluent TP requires good clarifiers

Impact of Effluent TSS on TP

From P. Schauer and C. deBarbadillo (2009) Pushing the Envelope with Low Phosphorus Limits, PNCWA
South River WRC (Atlanta, GA)

- 48 mgd max monthly design
- 25 mgd current annual average
- Headworks, primary, BNR AS, filtration, UV disinfection

**BNR upgrades for future load from decommissioning Intrenchment Creek WRC**
# Field testing secondary clarifiers

<table>
<thead>
<tr>
<th>Phase</th>
<th>MLSS Settling</th>
<th>DSS/FSS</th>
<th>Stress Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Jul 31 - Aug 1)</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>2 (Sep 9 - 11)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
Results from state point analyses

2034 Max Month; 5 units; 4,200 mg/L; 603 gpd/ft² (Macrina et al., 2015)

- Adequate surface area (6 existing clarifiers)
- Increase RAS pumping to avoid thickening failure (sludge blanket height)
Results from DSS/FSS testing

<table>
<thead>
<tr>
<th>Common Mixed Liquor Channel</th>
<th>Clarifier No. 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MLSS DSS&lt;sub&gt;ML&lt;/sub&gt; FSS DSS&lt;sub&gt;CW&lt;/sub&gt; ESS DSS&lt;sub&gt;EFF&lt;/sub&gt;</td>
</tr>
<tr>
<td>24.5 MGD; 5 units SOR= 330 gpd/ft&lt;sup&gt;2&lt;/sup&gt; SLR=6.8 lb/ft&lt;sup&gt;2&lt;/sup&gt;-d</td>
<td>2,120 11 30* 15 9 9</td>
</tr>
<tr>
<td>Test 1</td>
<td>2,220 10 12 16 6 5</td>
</tr>
<tr>
<td>Test 2</td>
<td>2,400 11 9 16 13 8</td>
</tr>
<tr>
<td>Average</td>
<td>2,247 11 11 16 9 7</td>
</tr>
<tr>
<td>25.2 MGD; 4 Units SOR= 418 gpd/ft&lt;sup&gt;2&lt;/sup&gt; SLR=8.4 lb/ft&lt;sup&gt;2&lt;/sup&gt;-d</td>
<td>1,760 12 6 13 12 7</td>
</tr>
<tr>
<td>Test 1</td>
<td>2,070 10 7 17 10 6</td>
</tr>
<tr>
<td>Test 2</td>
<td>2,460 14 5 16 9 8</td>
</tr>
<tr>
<td>Average</td>
<td>2,097 12 6 15 10 7</td>
</tr>
<tr>
<td>30.3 MGD; 2 units SOR= 983 gpd/ft&lt;sup&gt;2&lt;/sup&gt; SLR=37.3 lb/ft&lt;sup&gt;2&lt;/sup&gt;-d</td>
<td>2,650 10 6 12 29 6</td>
</tr>
<tr>
<td>Test 1</td>
<td>2,870 9 6 17 22 7</td>
</tr>
<tr>
<td>Test 2</td>
<td>4,386 9 5 16 10 7</td>
</tr>
<tr>
<td>Average</td>
<td>3,302 9 6 15 20 7</td>
</tr>
</tbody>
</table>

*Excluded from average due to uncharacteristic solids carryover.

Future hydrodynamic deficiencies revealed under “stressed” conditions

- Adequate flocculation and floc integrity
- Density current baffles recommended

(Macrina et al., 2015)
Design concepts for density current control

- Inlet energy dissipation
- Avoid inlet “waterfall effect”
- Avoid sludge blanket scour and entrainment
- Avoid solids carryover from “wall creep”

Secondary clarification is different than primary sedimentation.

McKinney density current baffles (1970’s)

MIT & KU Professor

- KU Student
- B&V Head Partner (1982-92)

Conventional inlet design in America


- Relatively small inlet pipe and slots – potential floc shear
- Mixed liquor fed at top of tank – potential waterfall effect
- Impinging exits and submerged flocwell are steps in the right direction

Courtesy WesTech Engineering, Inc.
Other EDI examples

FEDWA (flocculating energy dissipating feedwell)

LA - EDI

Impinging outlets
Lower feed elevation

Side outlet low energy (SOLE) inlet design by Barnard

- Diameter 115 ft
- SWD 13.33 ft
- Feedwell dia 23 ft
- Feedwell depth 11.5 ft
- Tested at SLR of 37.3 ppd/ft²

Feed discharge vertically without restriction. Impinging side outlets.

- Thin concrete columns to support the bridge
- Baffled outlet slots
Stickney WRF - 1938 design (Chicago, IL)

- 125 ft dia
- Peak SOR 1400 gpd/ft²
- SLR 38 ppd/ft²
- Effluent TSS 6 to 9 mg/L

Feed discharged vertically without restriction into shallow stilling well. Flocculation from conical exit vortices.
25 different schemes and variations on inflow design were tested for Stickney.

None worked better than original design by N.E. Anderson.

From the Sanitary District of Chicago (1940) Final Settling Tank Studies
Other studies of Stickney design


Performance rivals current standard design
**McKinney baffle – American version**

(a) Stamford  
(b) Unnamed  
(c) McKinney (Lincoln)  
(d) Interior trough  
(e) Cantilevered  
(f) Cantilevered with deflectors


**Peripheral baffle on sidewall/effluent launder**
McKinney baffle – British version

Inlet floor baffle

German approach being used by B&V in Australia

Waßmannsdorf WWTP near Berlin (Courtesy F.W. Günthert)

Lowered floor baffle and exit slot.
Effluent TSS before and after retrofit at Waβmannsdorf WWTP
Testing of floor baffle at 72-mgd Kirie WRP (Chicago, IL)

Squircles with two feed pipes from opposite side clashing in the stilling well.
Before and after CFD modeling for Kirie WRP

• Bottom plate was fitted to one clarifier and tested
• Great improvement
• Now converting the remainder of the clarifiers

Plate D = 5m
h = 35cm
Maybe a little overkill, but the idea is there.

Adjust floor baffle inlet so ML feed is at height that matches sludge blanket TS. Ideal, but sludge blanket can be controlled by RAS rate.
Case study - rectangular clarifiers
West Haven WPCP (West Haven, CT)

- BNR upgrade to achieve TN < 4.4 mg/L (353 ppd)
- Clarifier capacity expansion and optimization

6 Existing Clarifiers

- 20’ x 133’ x 8’ SWD
- Counter-current sludge scrapers
- No EDI or floc zone
- Various vertical baffling in each
CFD model of simplest alternative

Not ideal. High turbulence where sludge is scraped into hopper
CFD model of selected alternative

Modified clarifiers have operated a few years now with excellent performance and low effluent TSS around 7 mg TSS/L.
Gould Type II design for two new clarifiers at West Haven WPCP

Secondary Clarifier Inlet Section

- Baffle (Typ)
- Scale: 1" = 10'
- Baffled EDI spreads mixed liquor across floor
- Flocwell
- Co-current sludge scraping to midway sludge hopper

Effluent TSS below 10 mg/L
Case study – triple squircles

- 76% increase in secondary treatment peak flow capacity (170 mgd → 300 mgd)
- <10% of cost of adding separate HRT facility
Existing clarifiers

- 3 East tanks + 3 West tanks
  - 105’ x 315’ x 12.7’ SWD
- Rectangular liquid flow
- 3 squircle sludge bays per tank
- 10 RAS draft tubes per bay
Concept for new inlet structure

Plan View of Flocculation Baffles

- Slotted Wall
- Baffle Plates

Energy Dissipation Baffle

Scum Weir Gate

Shut top row of holes. Convert holes to slots. Add flocculation baffles downstream of slots.

Reaction baffle extending down to mid water depth
Evaluation tools

Pre-Design Studies
- Dynamic process model (BioWin, GPS-X)
- Clarifier state point analysis
- CFD model
- Lessons learned from PVSC

Post-Construction Optimization
- CFD modeling
- Stress testing
- Drogue and dye testing (J. Esler)
SUMMARY

- Inlet design philosophy for circular, rectangular, squircle and multi-squircle tanks should be similar.

- Feed mixed liquor as low as sludge blanket allows.

- SOLE, Chicago, UK and German designs all feature vertical inlet pipe without EDI. No floc shearing and gentle flocculation achieving great results.

- Strongly consider McKinney floor baffle inlet instead of standard U.S. approach with EDI, especially for shallow clarifiers.
NEWEA | Optimizing Clarifier Performance—Are We Designing the Clarifiers Right? | January 27, 2016

Additional information:
Building a world of difference.

Together

Thank you!!!

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