BUILDING A WORLD OF DIFFERENCE

Optimizing Clarifier Performance—Are We Designing the Clarifiers Right?

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January 27, 2016

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ANNUAL CONFERENCE & EXHIBIT
BOSTON, MASSACHUSETTS
JANUARY 24-27, 2016

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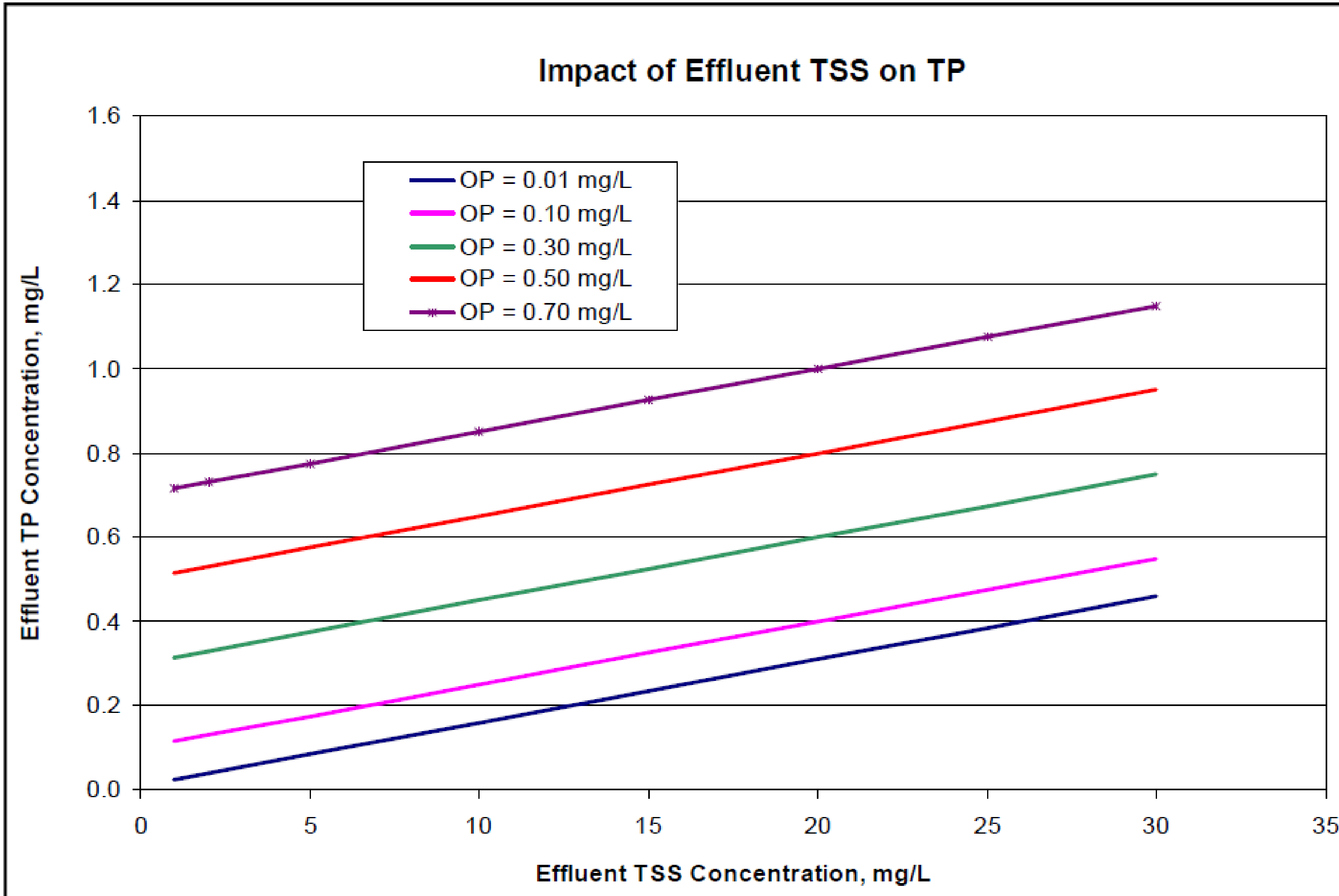
AGENDA

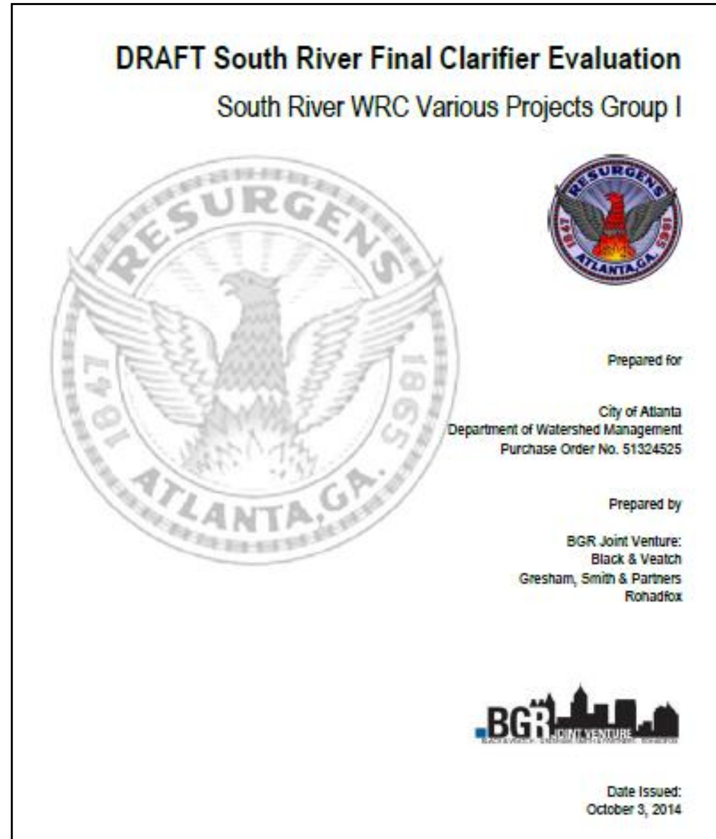
- Why it’s important
- Field testing and troubleshooting
- Design concepts
- Proofs

Low effluent TP requires good clarifiers



From P. Schauer and C. deBarbadillo (2009) Pushing the Envelope with Low Phosphorus Limits, PNCWA

South River WRC (Atlanta, GA)



DRAFT South River Final Clarifier Evaluation

South River WRC Various Projects Group I

Prepared for

City of Atlanta
Department of Watershed Management
Purchase Order No. 51324525

Prepared by

BGR Joint Venture:
Black & Veatch
Gresham, Smith & Partners
Rohadfox

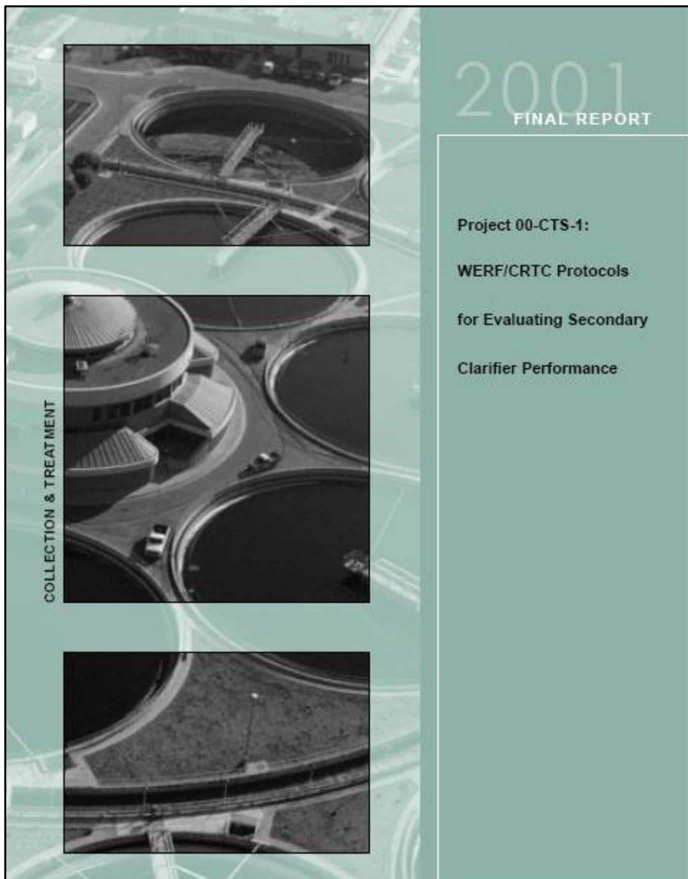
Date Issued:
October 3, 2014

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

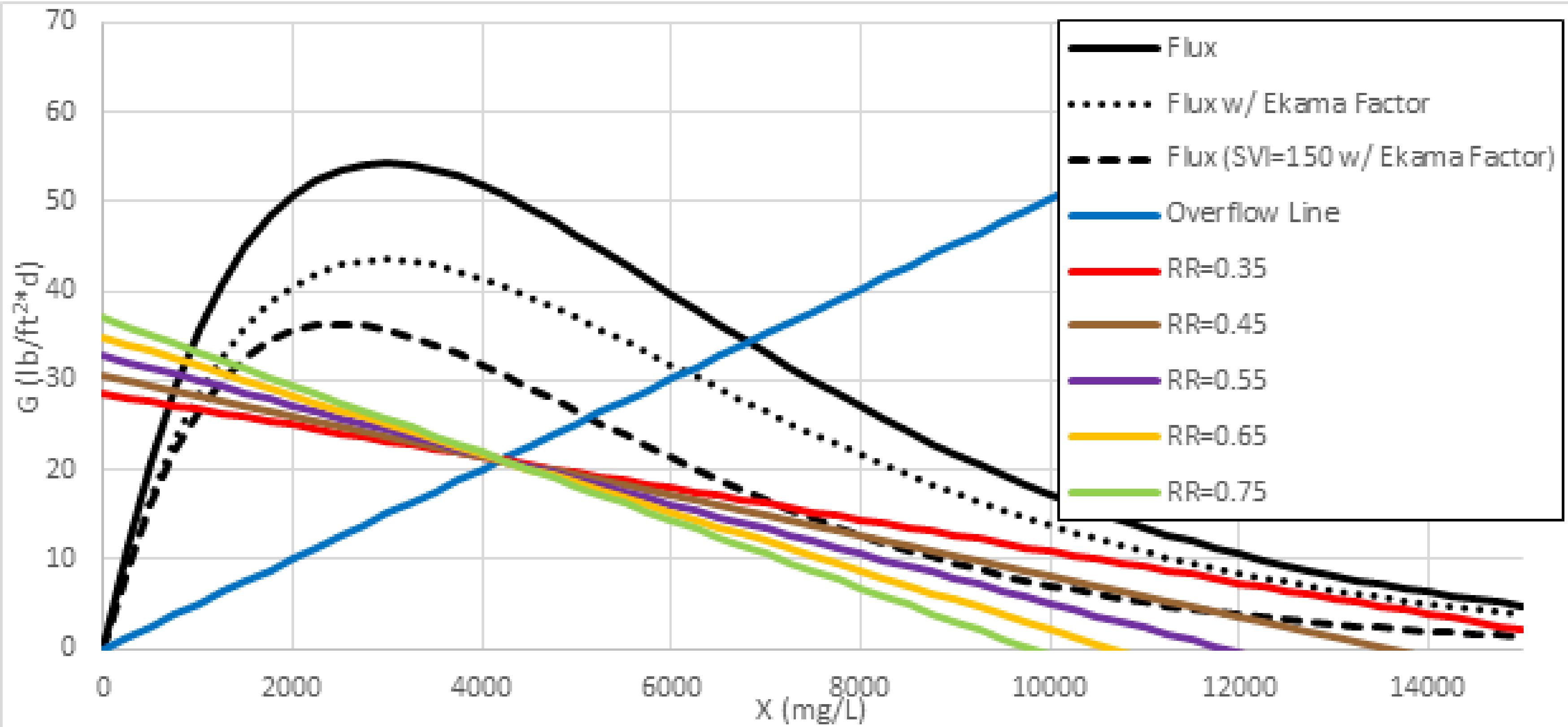
BNR upgrades for future load from decommissioning Intrenchment Creek WRC

Field testing secondary clarifiers

Phase	MLSS Settling	DSS/FSS	Stress Test
1 (Jul 31 - Aug 1)	✓	✓	
2 (Sep 9 - 11)	✓	✓	✓



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

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

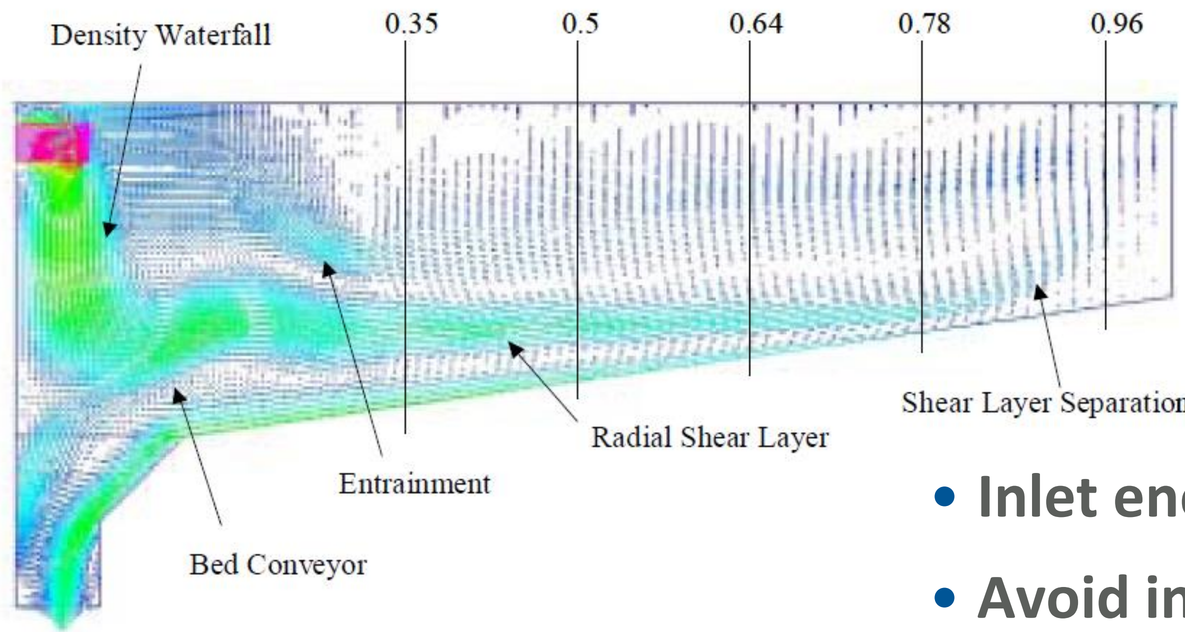
*Excluded from average due to uncharacteristic solids carryover.

Future hydrodynamic deficiencies revealed under "stressed" conditions

(Macrina *et al.*, 2015)

- **Adequate flocculation and floc integrity**
- **Density current baffles recommended**

Design concepts for density current control



From J. Burt & J. Ganeshalingham (2005) Design and Optimisation of Final Clarifier Performance with CFD Modelling, Presented at CIWEM/Aqua Enviro Joint Conference, Leeds, UK.

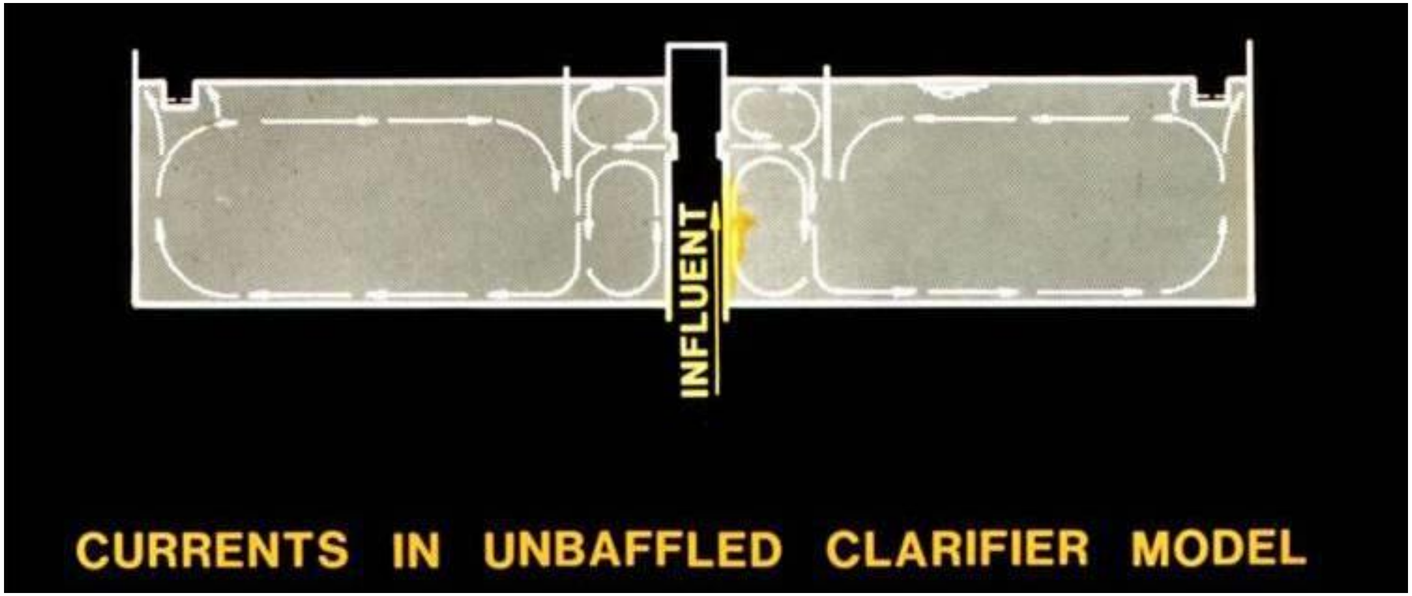
- Inlet energy dissipation
- Avoid inlet "waterfall effect"
- Avoid sludge blanket scour and entrainment
- Avoid solids carryover from "wall creep"

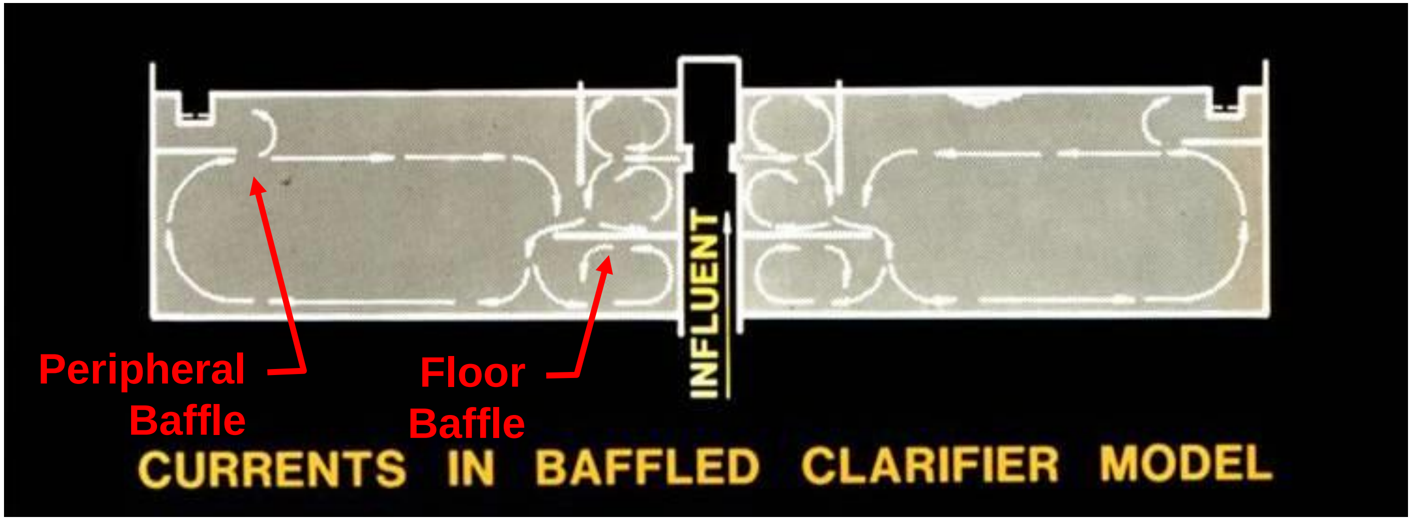
Secondary clarification is different than primary sedimentation.

McKinney density current baffles (1970's)

MIT & KU Professor

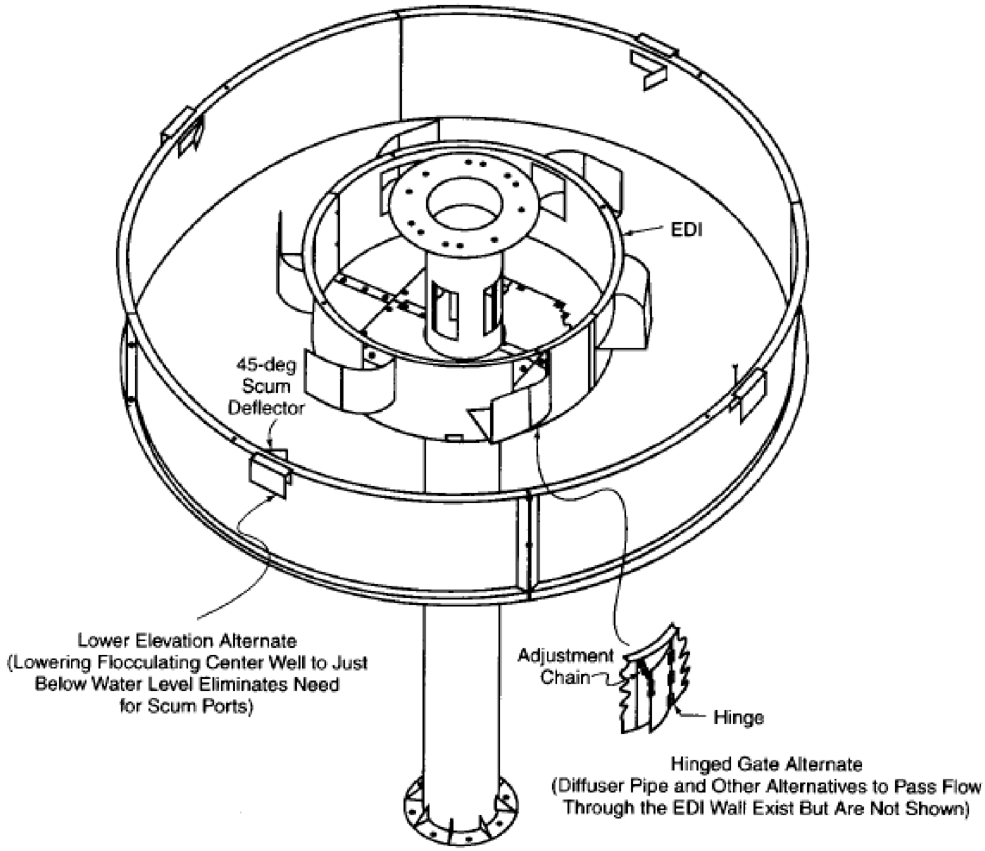
- KU Student
- B&V Head Partner (1982-92)



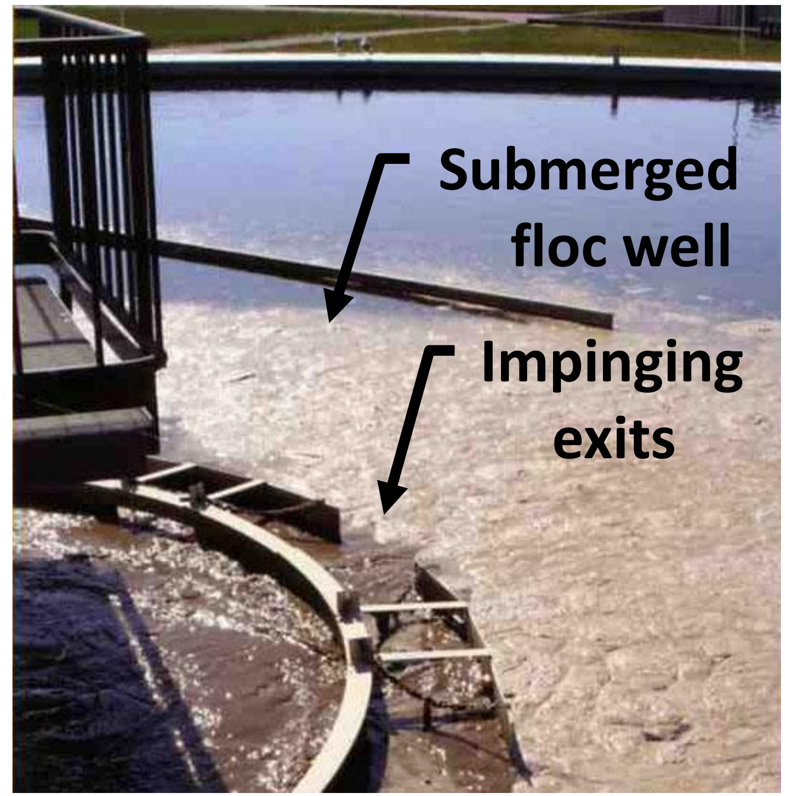


J. Robinson (1974) *A Study of Density Currents in Final Sedimentation Tanks*, M.S. Thesis, University of Kansas.

Conventional inlet design in America



From WEF (2005) *Clarifier Design*, Manual of Practice No. FD-8, 2nd Edition.

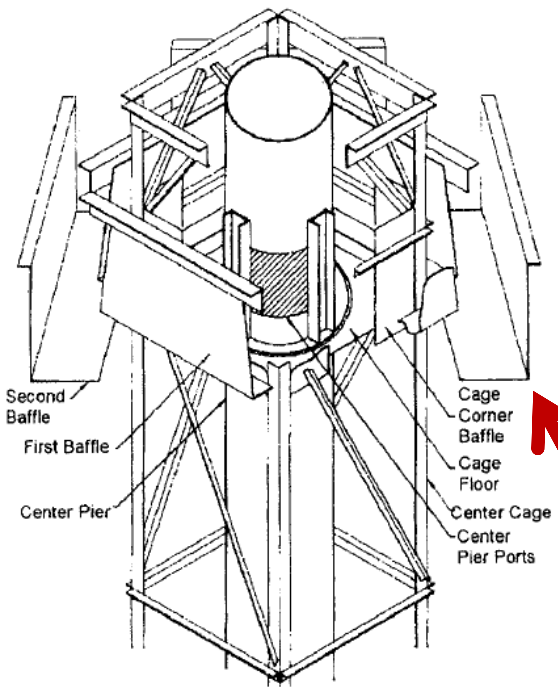


Courtesy WesTech Engineering, Inc.

- 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

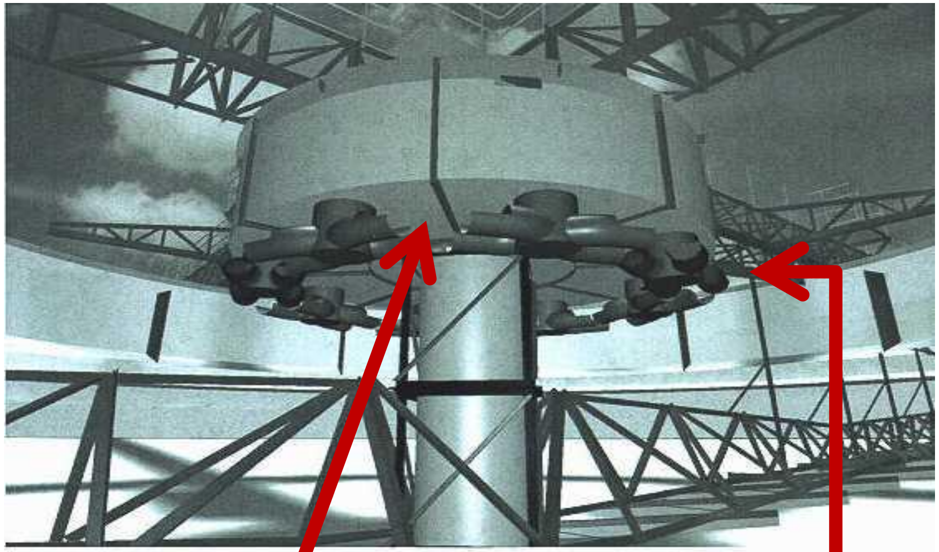
Other EDI examples

FEDWA (flocculating energy dissipating feedwell)



From WEF (2005) *Clarifier Design*, Manual of Practice No. FD-8, 2nd Ed.

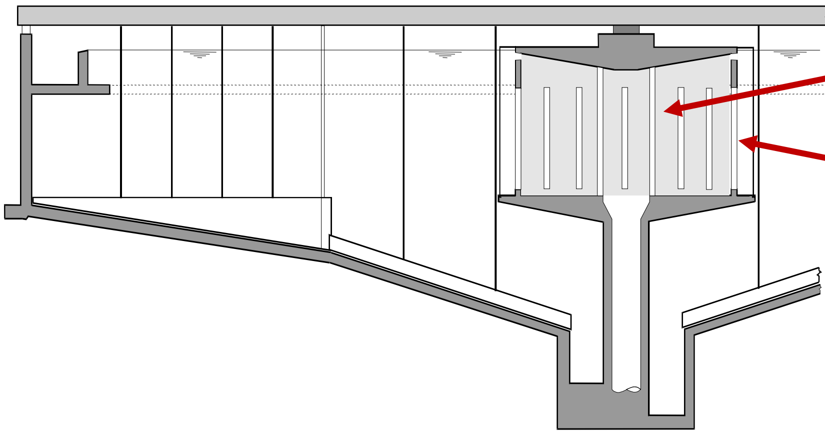
LA - EDI



Impinging outlets

Lower feed elevation

Side outlet low energy (SOLE) inlet design by Barnard

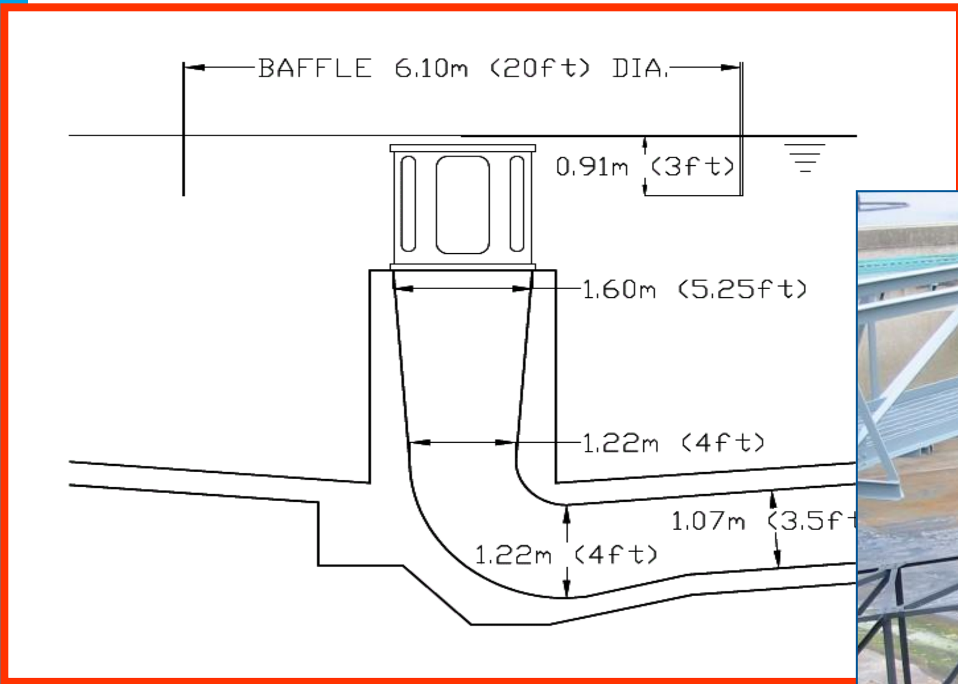


- Thin concrete columns to support the bridge
- Baffled outlet slots

- Diameter 115 ft
- SWD 13.33 ft
- Feedwell dia 23 ft
- Feedwell depth 11.5 ft
- Tested at SLR of 37.3 ppd/ft^2

Feed discharge vertically without restriction. Impinging side outlets.

Stickney WRF - 1938 design (Chicago, IL)

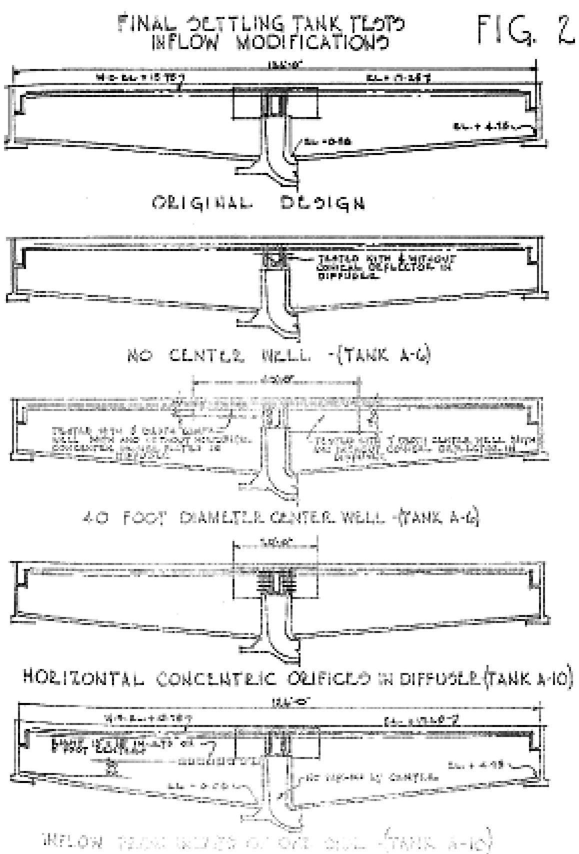


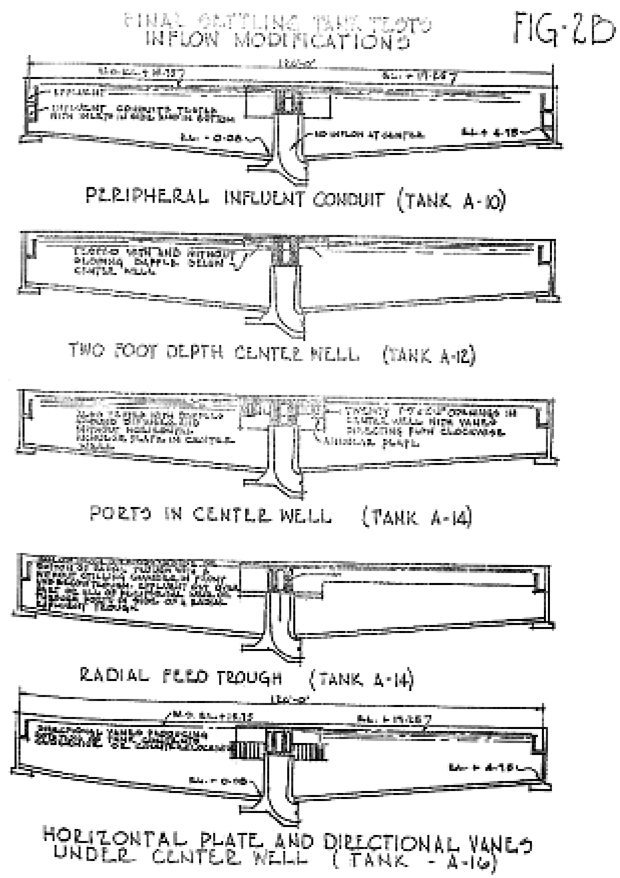
J. Barnard, T. Kunetz, J. Sobanski (2007) IWA Large WWTP Conference, Vienna

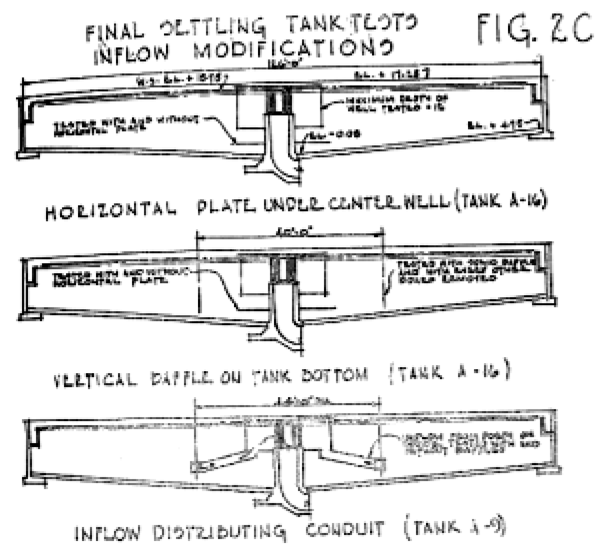
- 125 ft dia
- Peak SOR 1400 gpd/ft^2
- SLR 38 ppd/ft^2
- Effluent TSS 6 to 9 mg/L

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



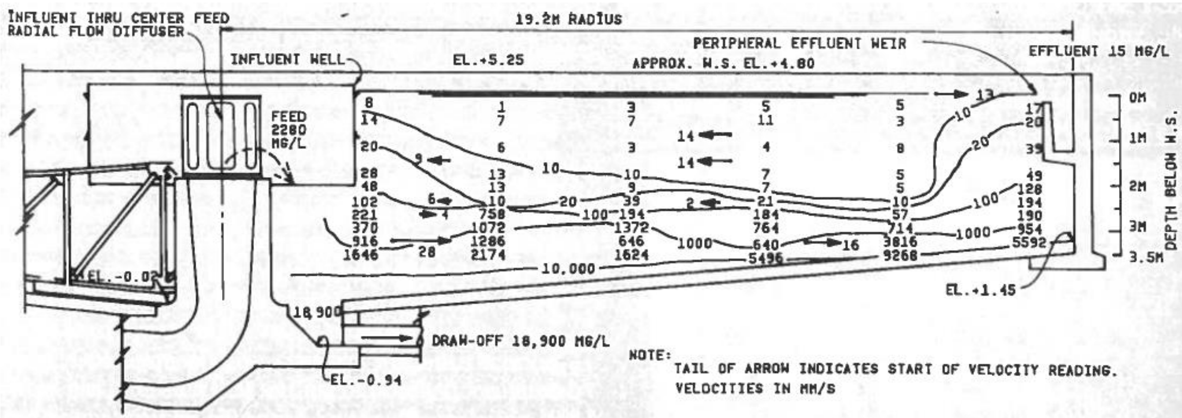




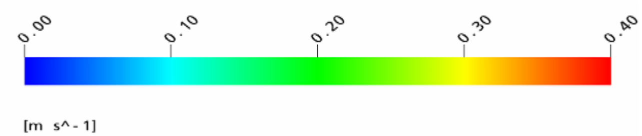
From the Sanitary District of Chicago (1940) Final Settling Tank Studies

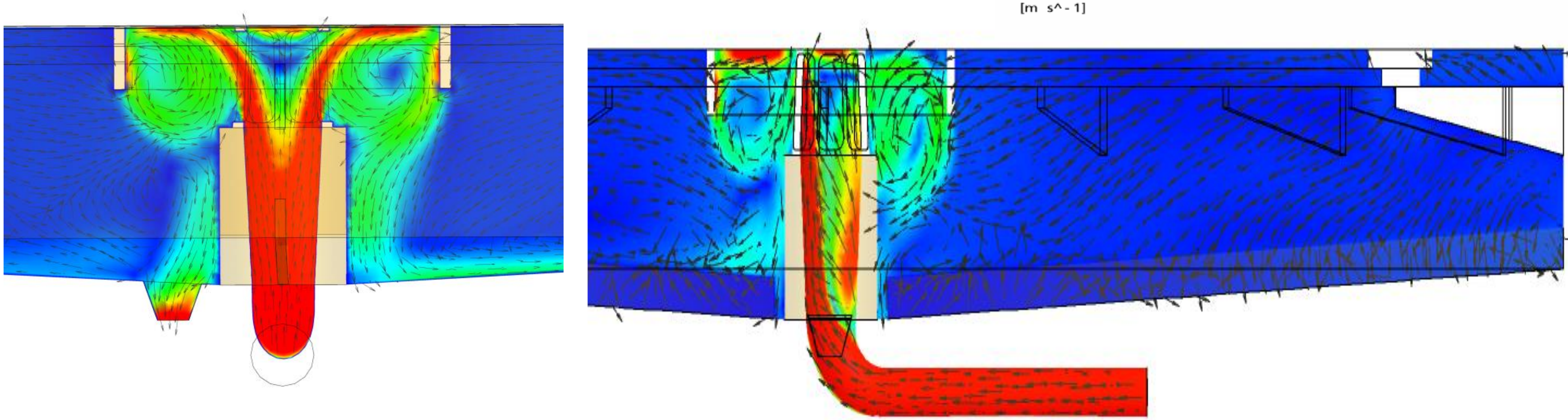
None worked better than original design by N.E. Anderson

Other studies of Stickney design



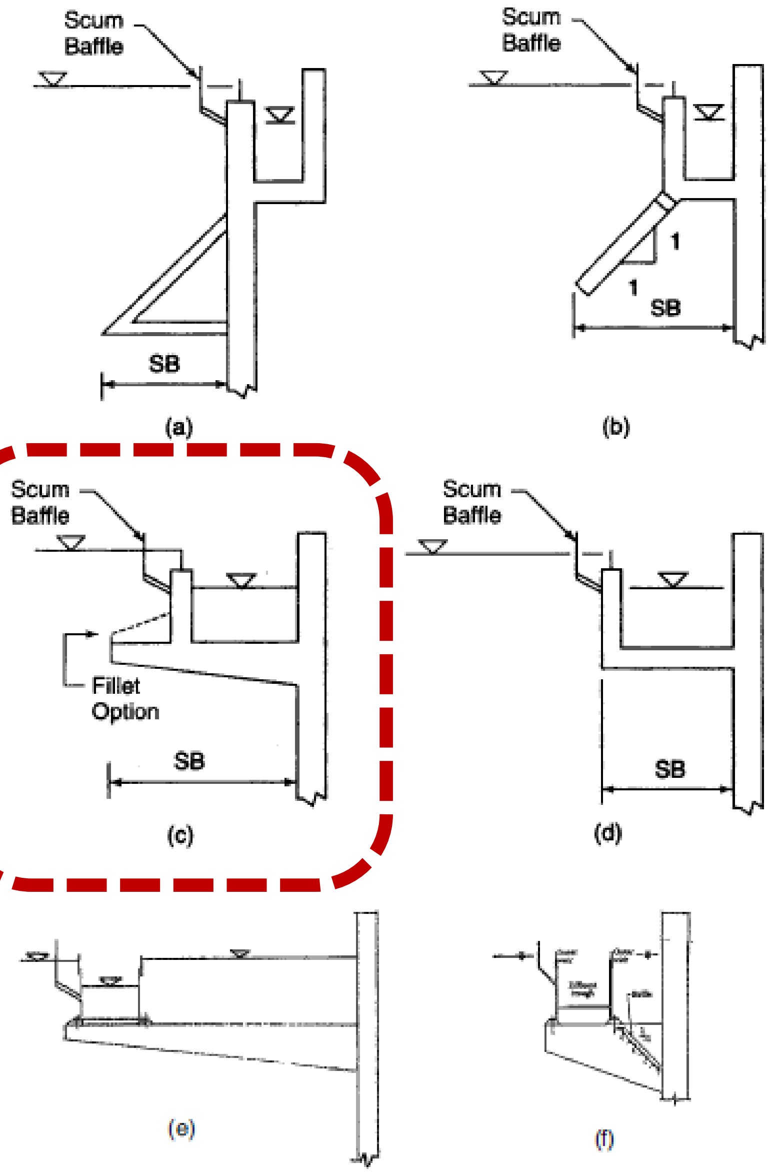
J. Stukenberg, L. Rodman, J. Touslee (1983) Activated Sludge Clarifier Design Improvements, Journal WPCF, **55**(4), 341-348.





J. Barnard, T. Kunetz, J. Sobanski (2007) IWA Large WWTP Conference, Vienna

Performance rivals current standard design



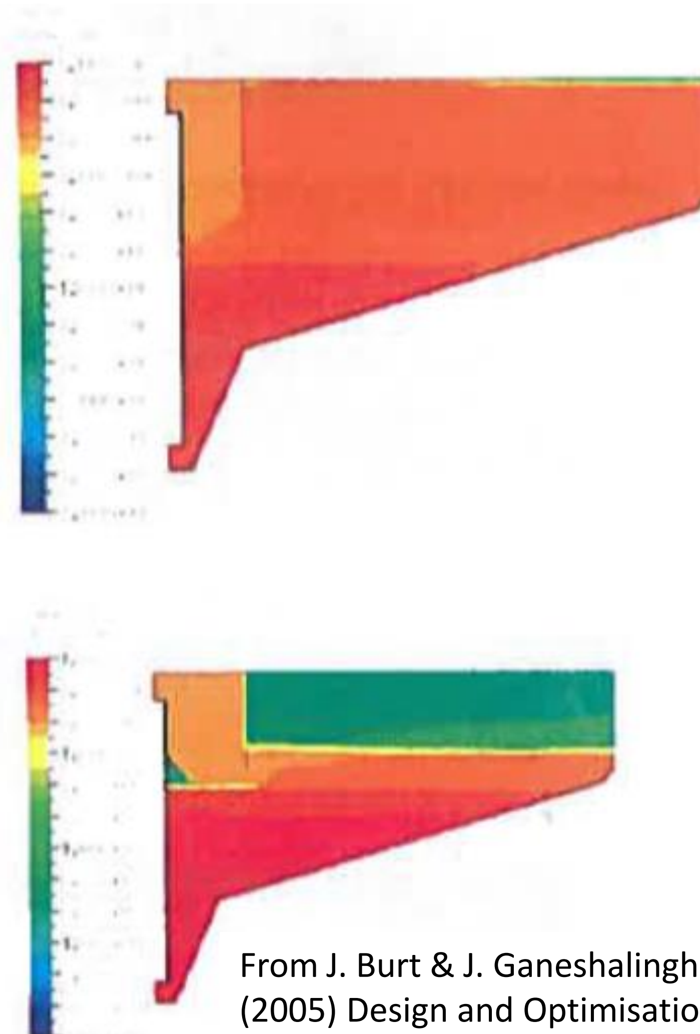
McKinney baffle – American version

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

From WEF (2005) *Clarifier Design*, Manual of Practice No. FD-8, 2nd Edition.

Peripheral baffle on sidewall/effluent launder

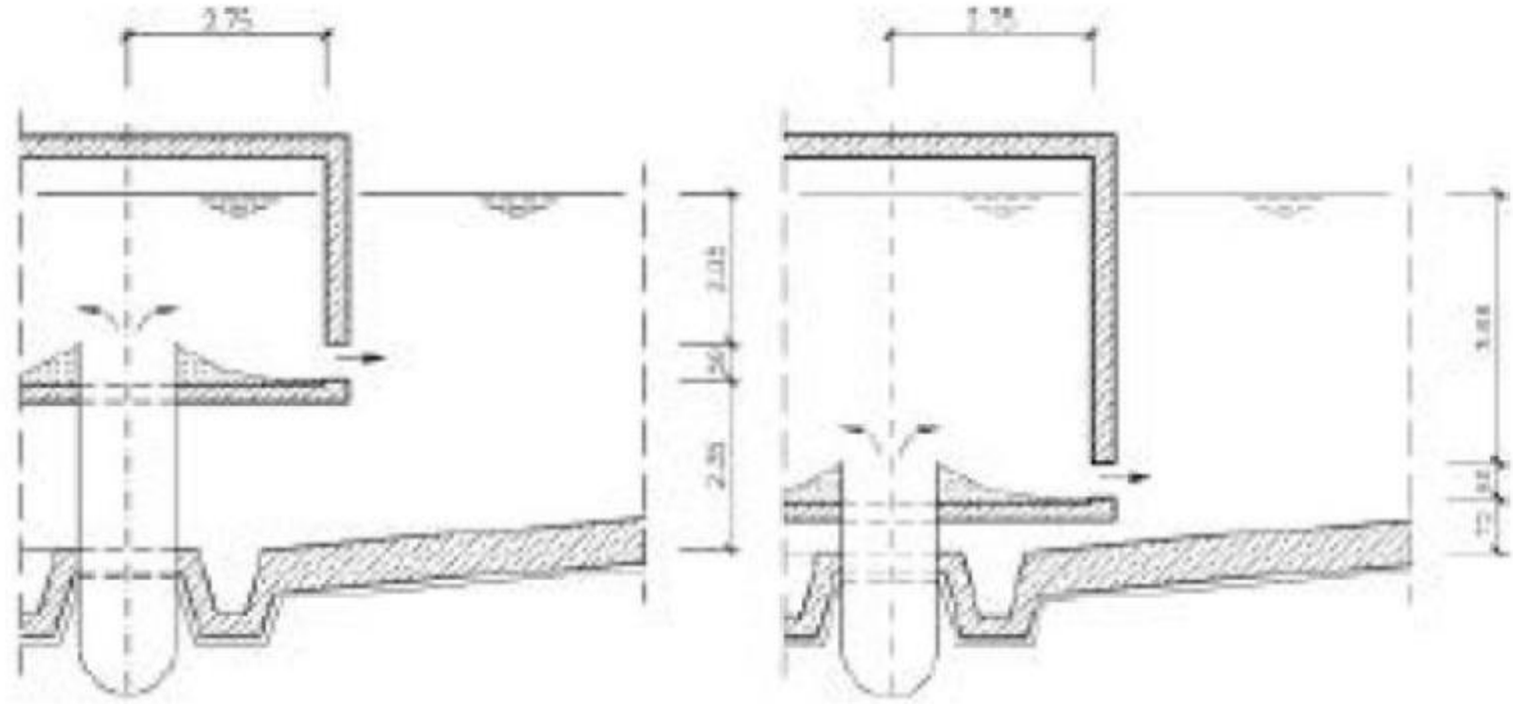
McKinney baffle – British version



From J. Burt & J. Ganeshalingham (2005) Design and Optimisation of Final Clarifier Performance with CFD Modelling, Presented at CIWEM/Aqua Enviro Joint Conference, Leeds, UK.

Inlet floor baffle

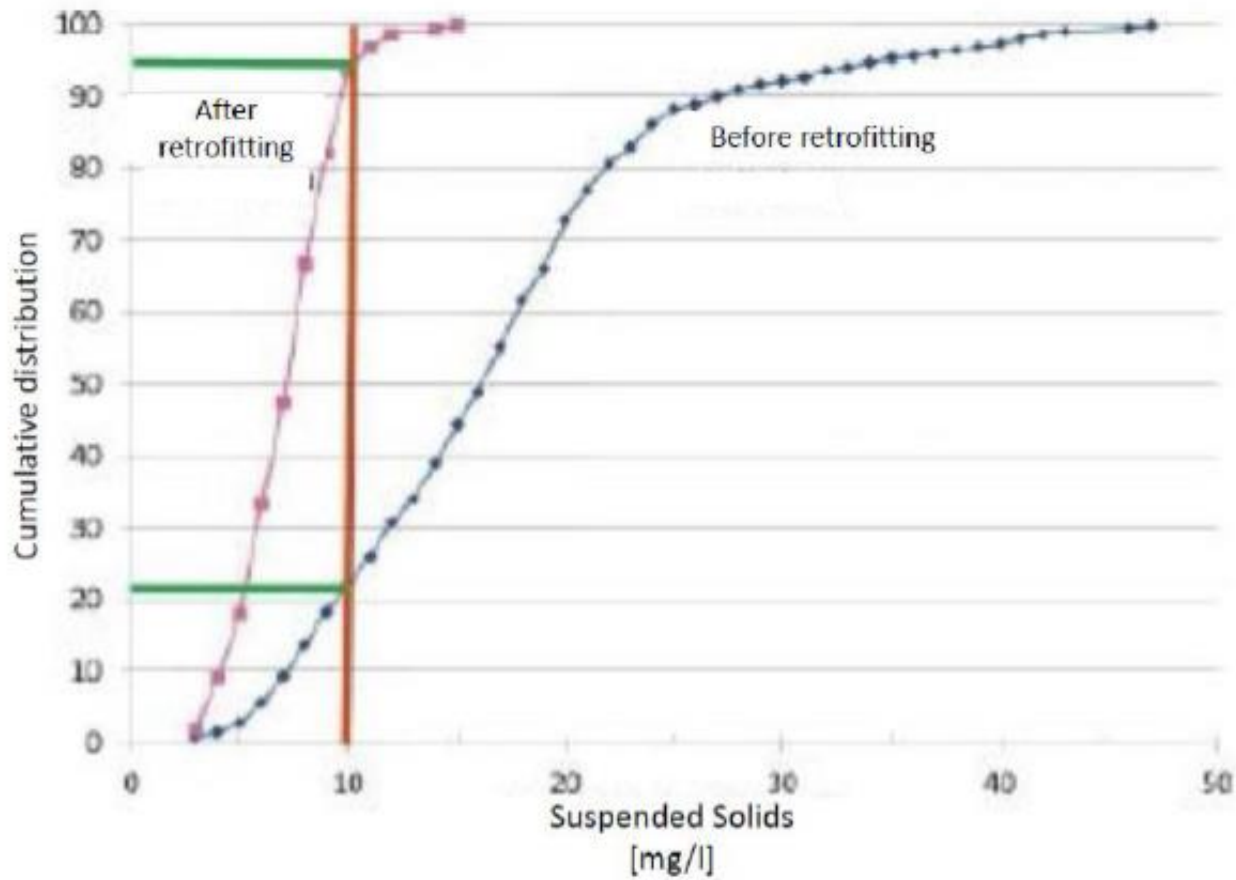
German approach being used by B&V in Australia



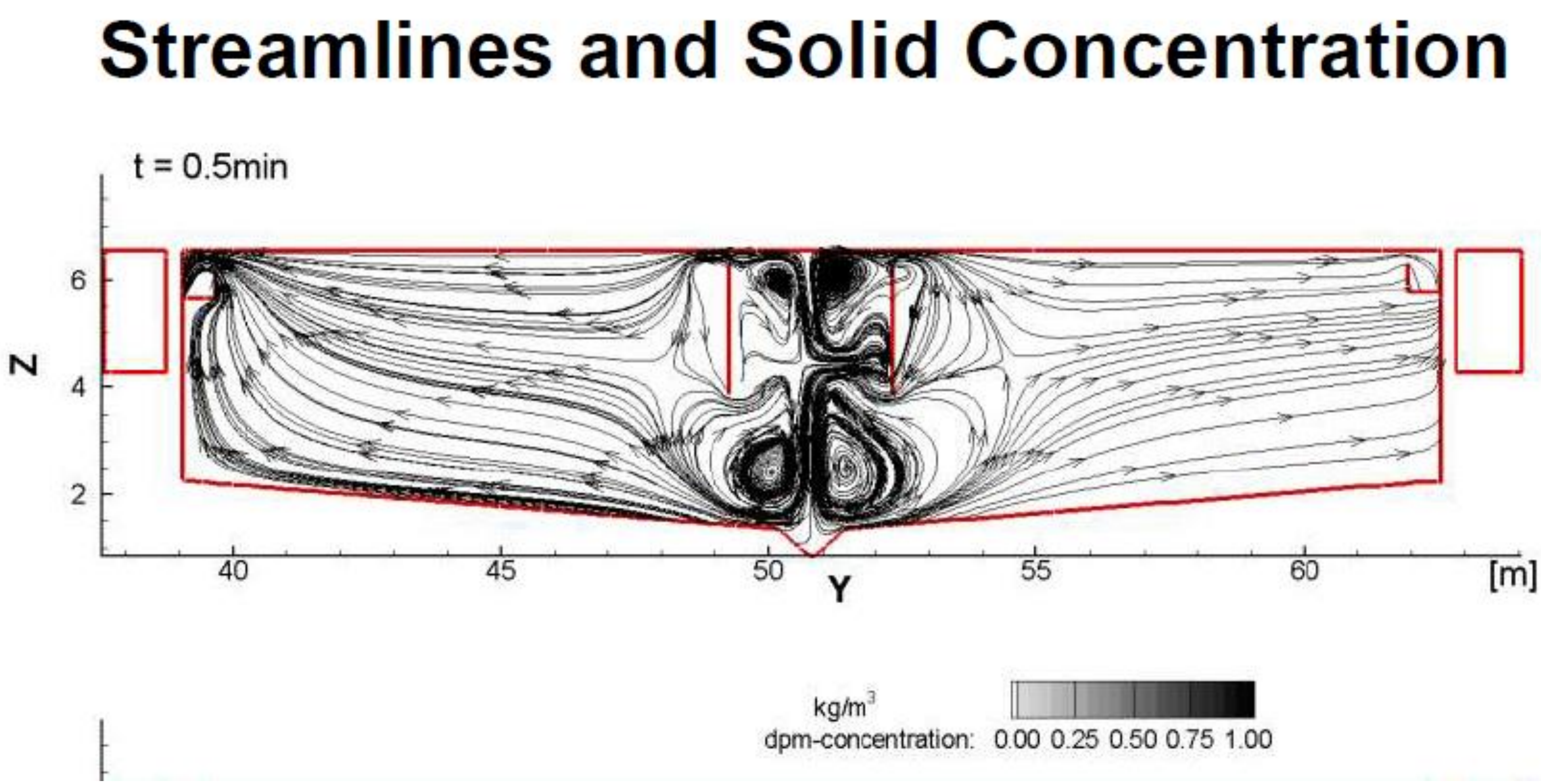
Waβmannsdorf WWTP near Berlin (Courtesy F.W. Günthert)

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

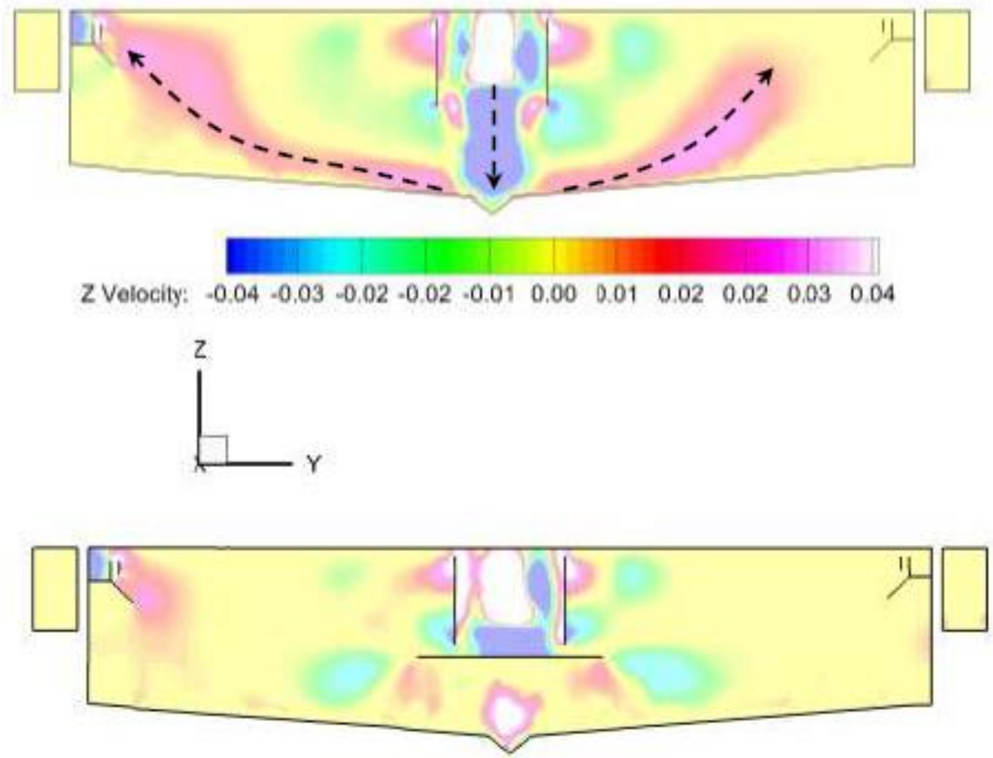
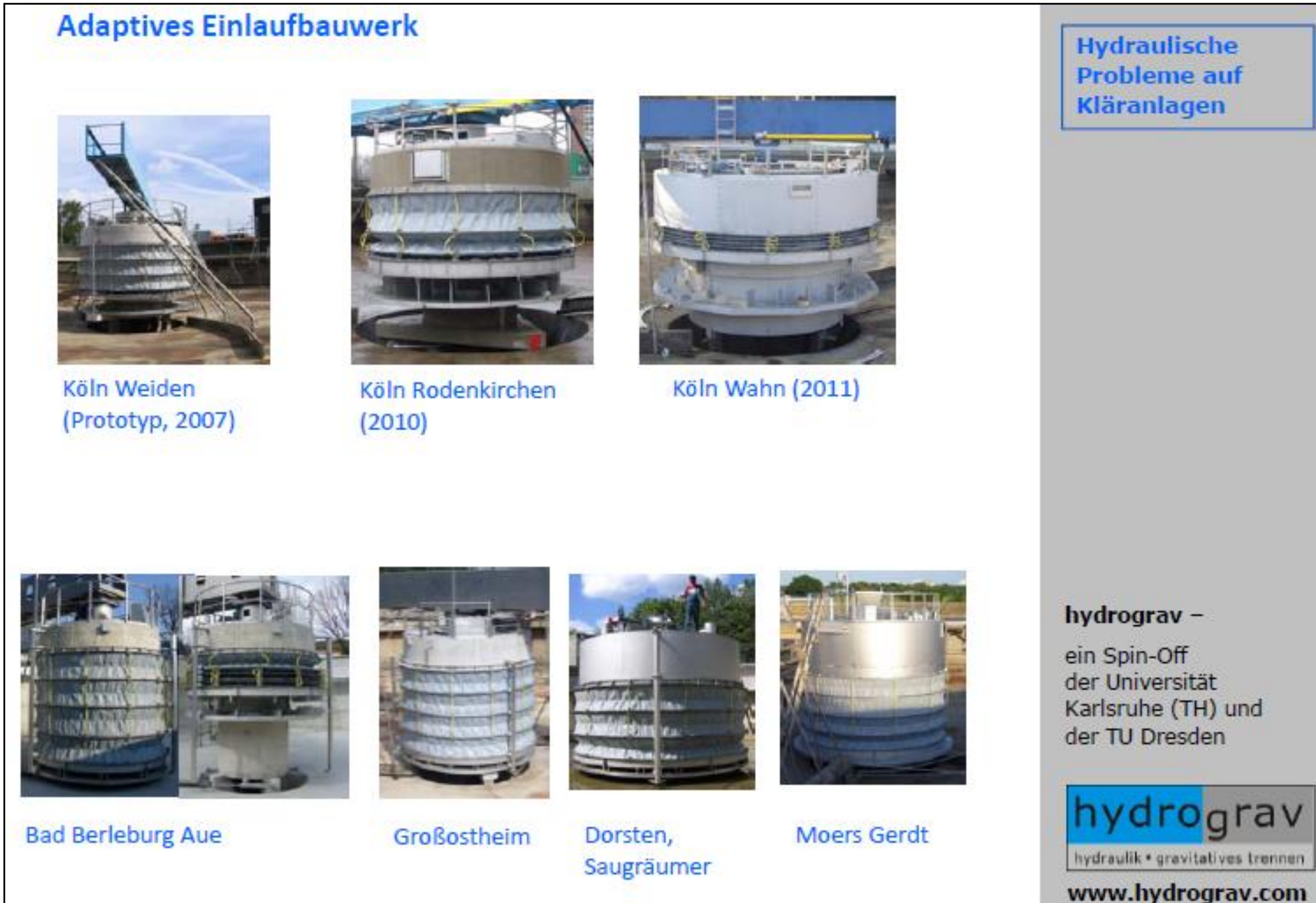


Plate D = 5m
h = 35cm

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)

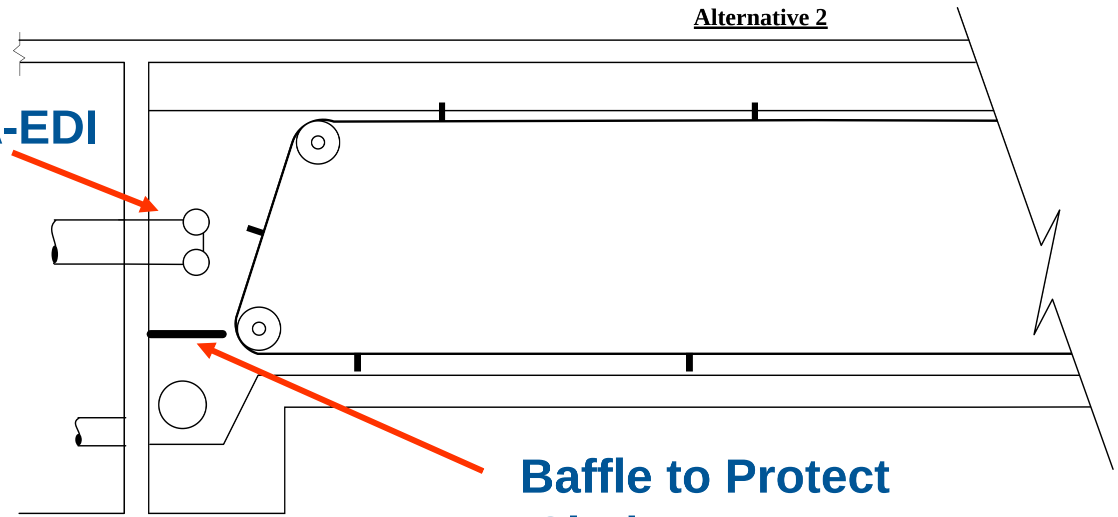
- BNR upgrade to achieve TN < 4.4 mg/L (353 ppd)
- Clarifier capacity expansion and optimization

6 Existing Clarifiers

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

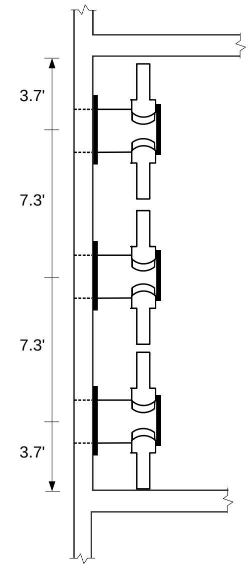
CFD model of simplest alternative

LA-EDI

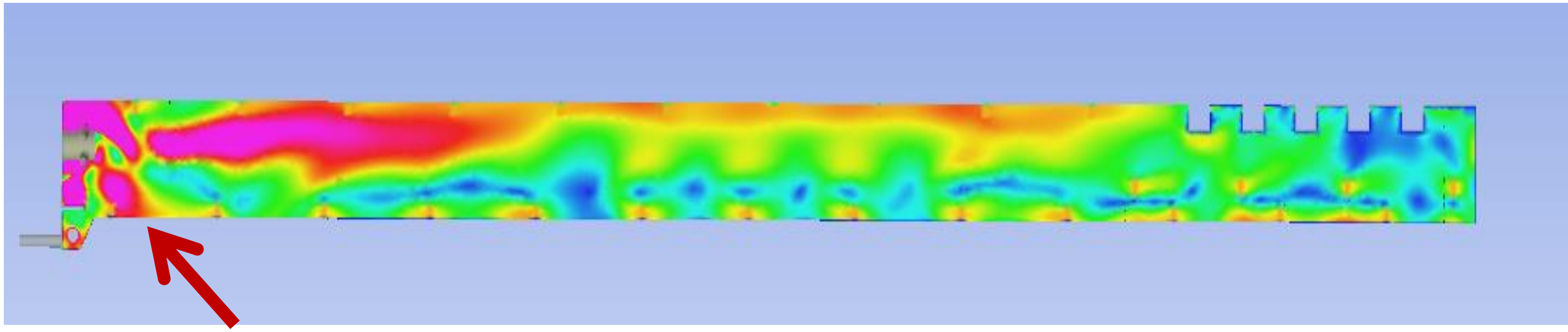


No Scale

Baffle to Protect Sludge Hopper

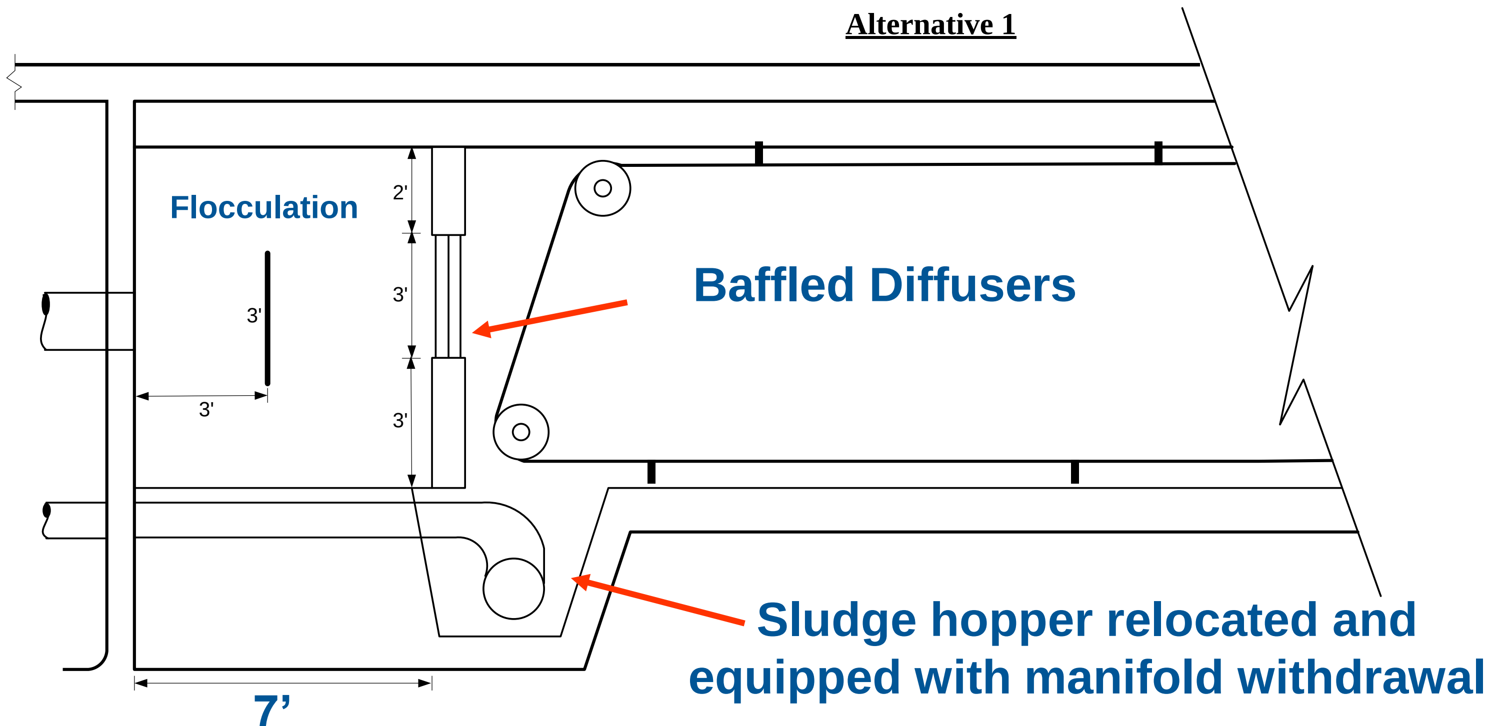


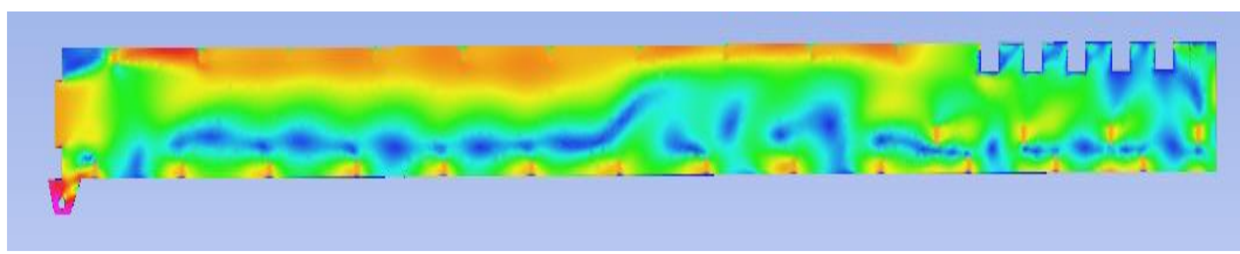
Alternative 2 Plan



Not ideal. High turbulence where sludge is scraped into hopper

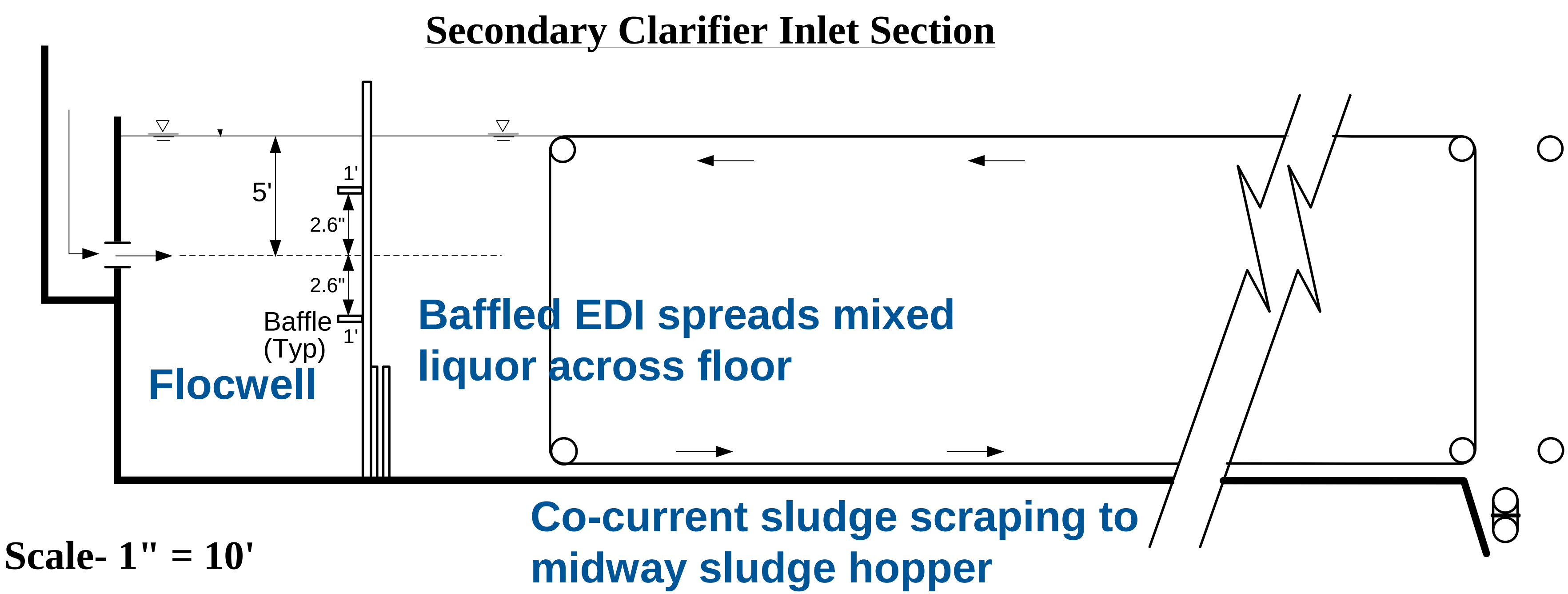
CFD model of selected alternative





Modified clarifiers have operated a few years now with excellent performance and low effluent TSS around 7 mg TSS/L

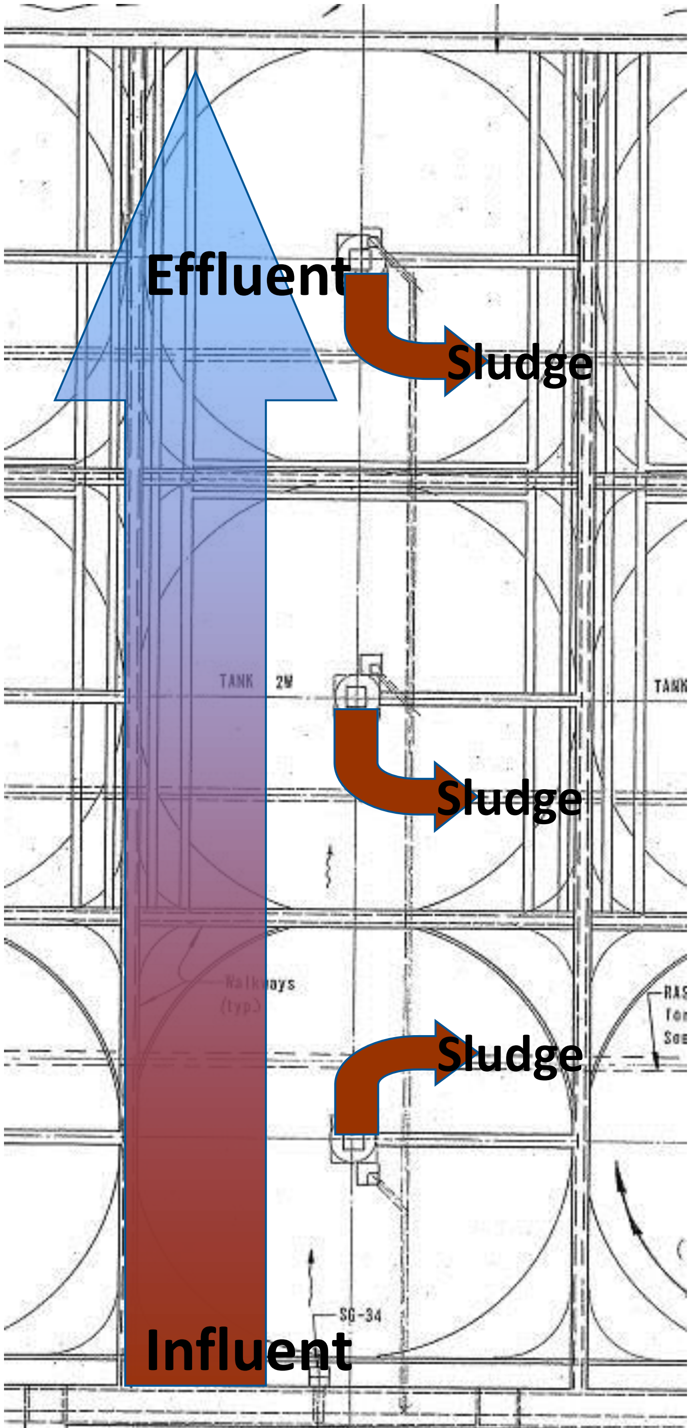
Gould Type II design for two new clarifiers at West Haven WPCP



Effluent TSS below 10 mg/L

Case study – triple squircles

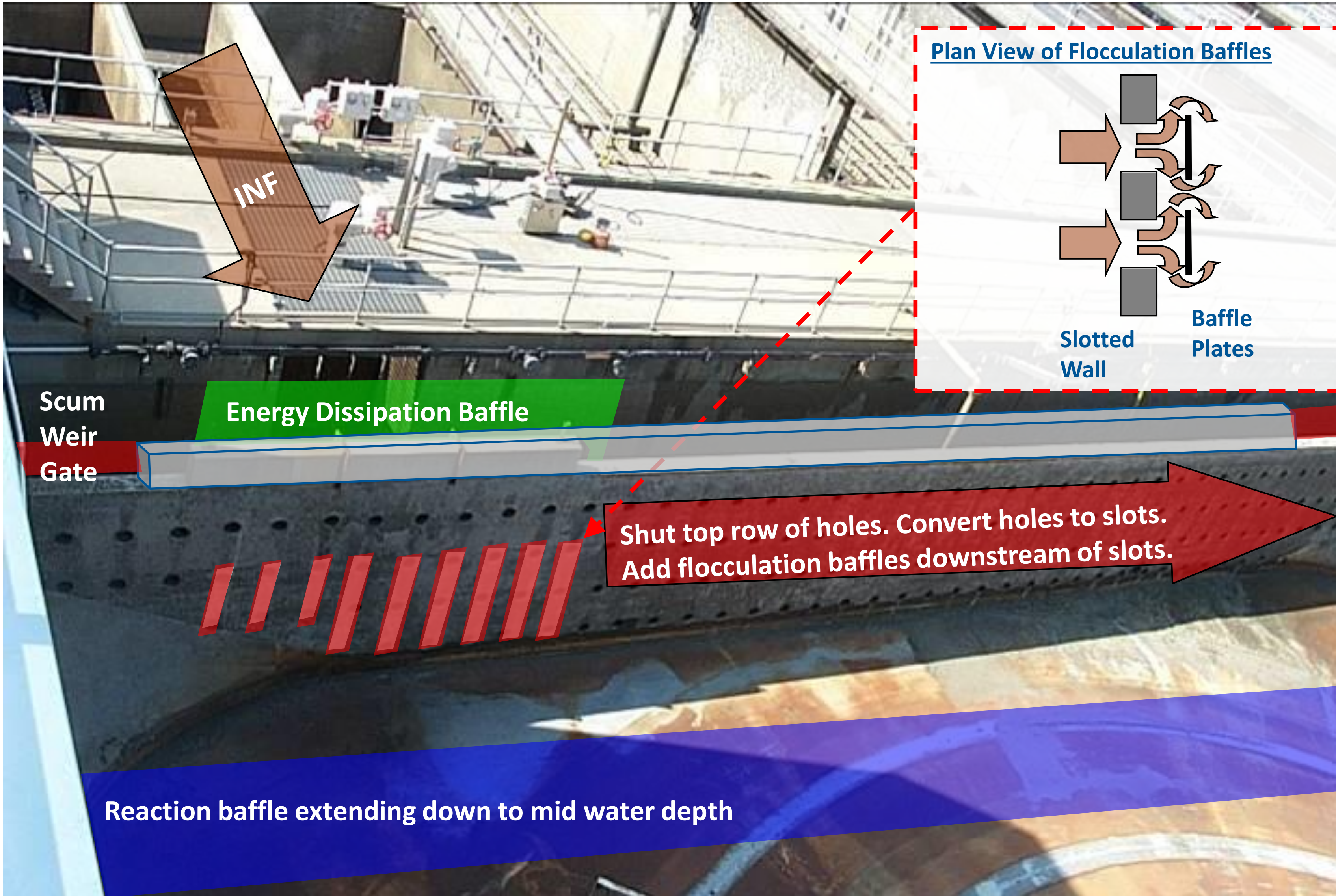
- **76% increase in secondary treatment peak flow capacity (170 mgd → 300 mgd)**
- **<10% of cost of adding separate HRT facility**



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



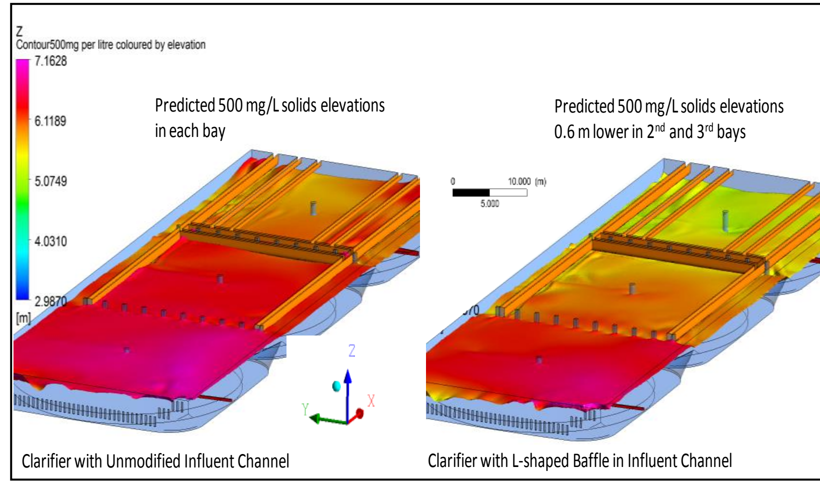
Evaluation tools

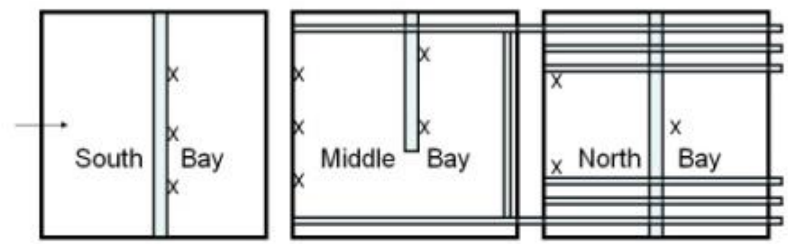
Pre-Design Studies

- 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)





Location of Drogue Current Measurements

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.

Additional information:

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