Metropolitan Water Reclamation District of Greater Chicago

DEVELOPMENT OF PROCESS AND HYDRAULIC MODELS FOR THE CALUMET WRP AS PLANNING TOOLS

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Education:	B.S. Civil Engineering (1979), Marquette University M.S. Civil and Environmental Engineering (1990), University of Wisconsin - Madison
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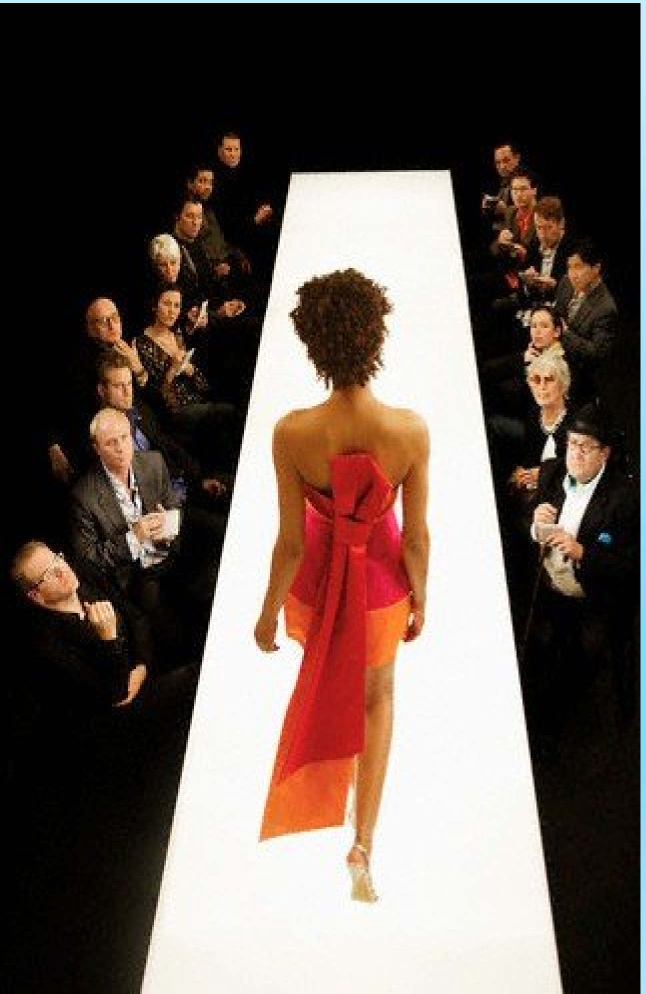
OUTLINE

- Reasons for modeling
- Project scope
- Hydraulic Model
  - Development Highlights
  - Model
  - Planning Tool
- Process Model
  - Development Highlights
  - Model
  - Planning Tool
- Concluding Remarks

MODELING


got talent?
Performers Wanted




COCKTAIL
PARTY


AMERICA'S NEXT
top model

PLANT MODELING - REASONS

- For better understanding and simplification of complex processes
  - Complicated and iterative equations
  - Vast number of elements and interaction between different treatment processes
- Less expensive and quicker to model than design and build
  - Whole plant modeling: $200,000
  - Pilot testing: $400,000
  - Engineering design Aerated Grit Facility & Primary Settling Tanks: $10,000,000
  - Construction cost: $230,000,000
- Planning Tool
  - Capital planning
  - Feasibility studies
  - Engineering evaluations
  - Predict plant performance for different flows/loads

"The Modelers"



PROJECT BACKGROUND & SCOPE

- Hydraulic Model
  - No previous models/software
- Process Model (GPS-X 4.1.2)
  - Completed in 2005
- Recent major infrastructure developments at Calumet
  - Aerated Grit Facilities and Primary Settling Tanks
  - Disinfection Facilities
  - Thornton Reservoir
- Upcoming stringent nutrient limits
  - TP 1.0 mg/L
  - TN in near future

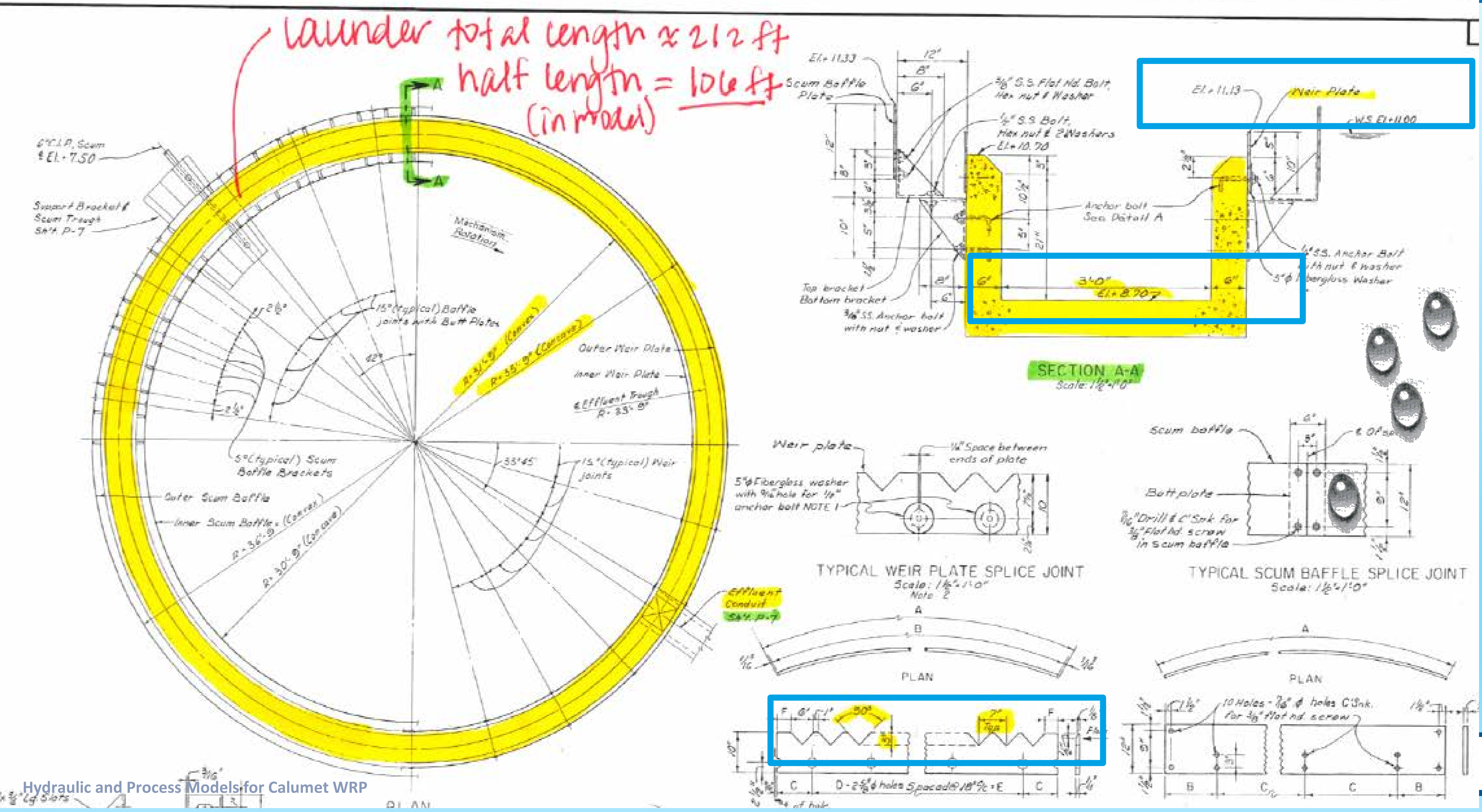
HYDRAULIC MODEL DEVELOPMENT

- Software selection
  - Visual Hydraulics 4.2+

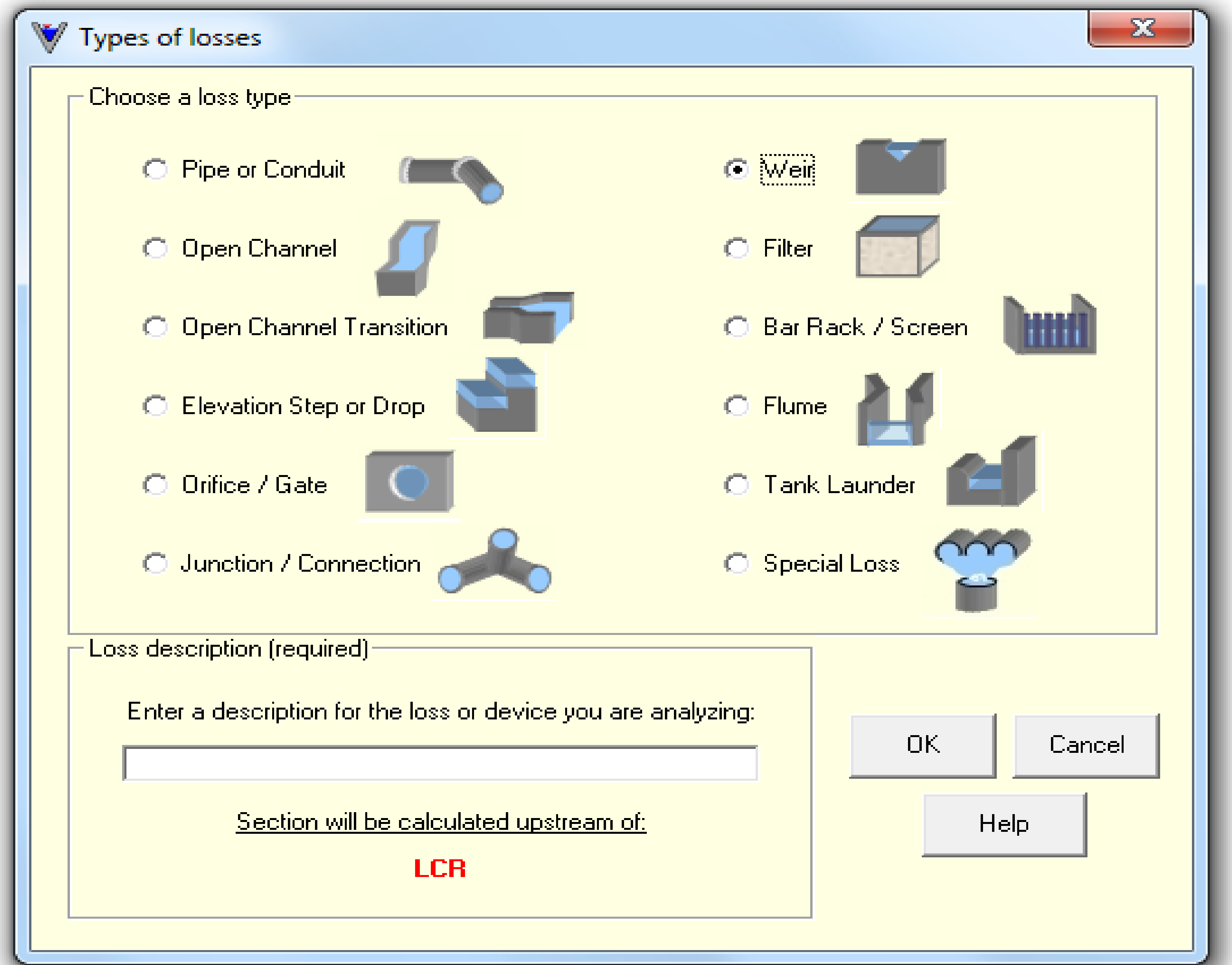
Visual Hydraulics

- Data collection
  - Contract drawings
  - Surveying
  - Operational data
  - Knowledge from plant Operators

EXAMPLE HYDRAULIC MODEL DOCUMENTATION

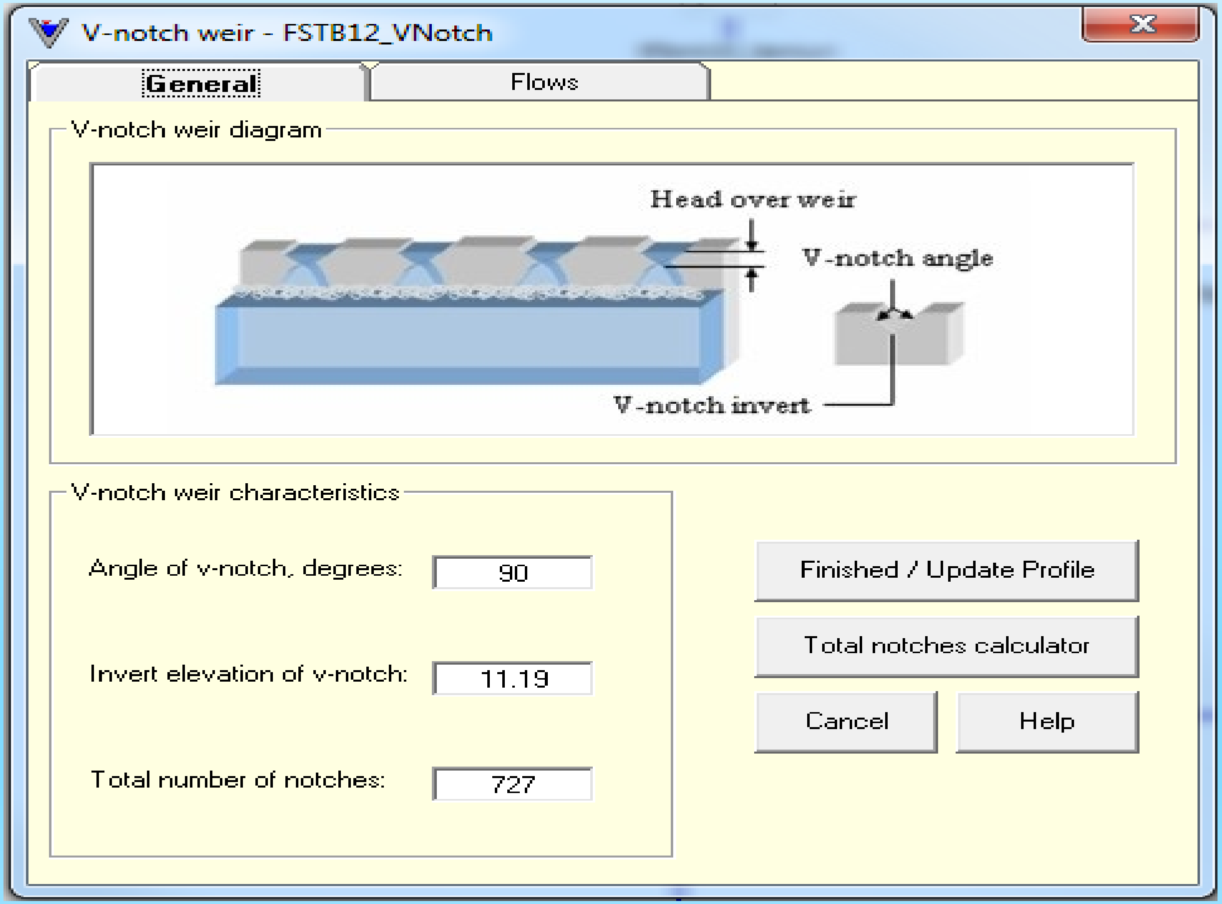


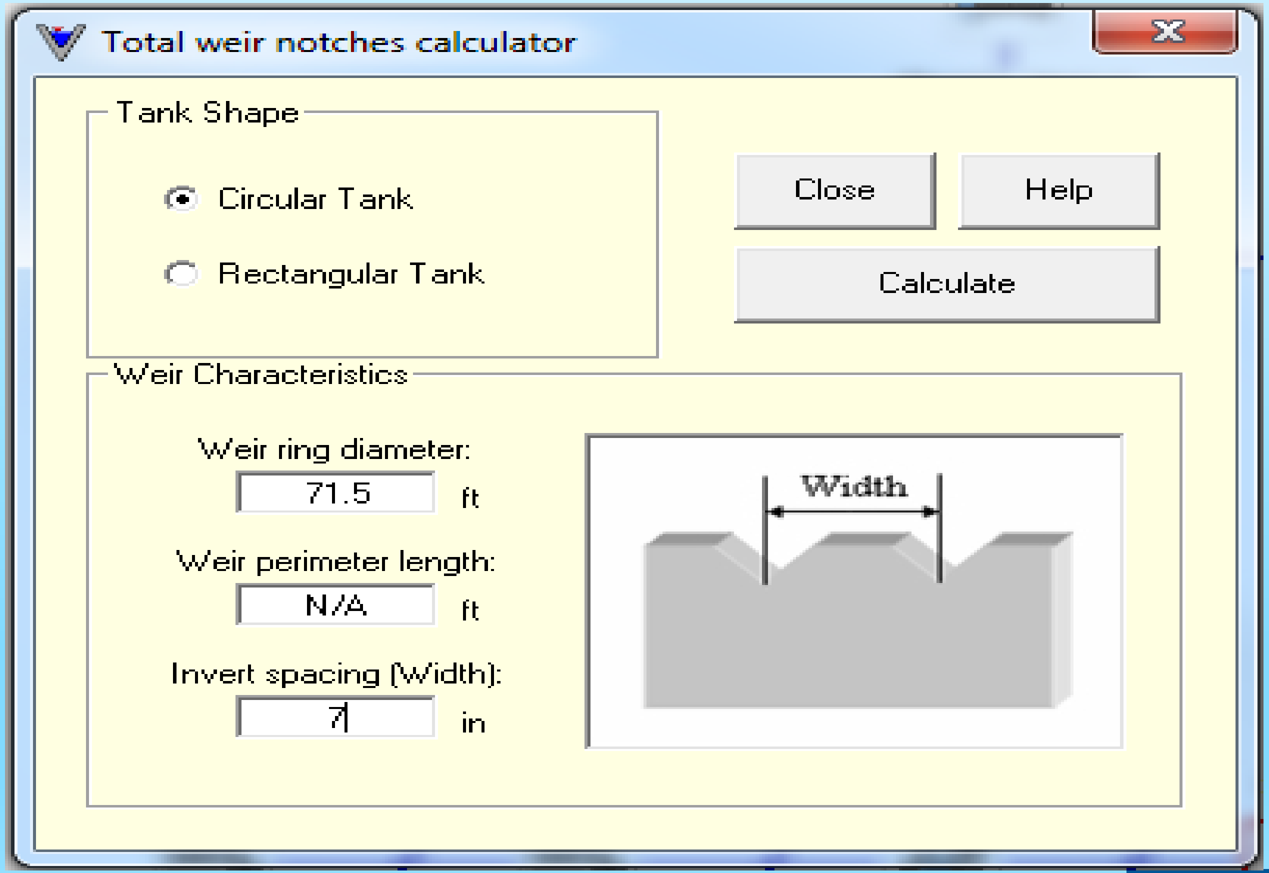
HYDRAULIC MODEL DEVELOPMENT



HYDRAULIC MODEL DEVELOPMENT

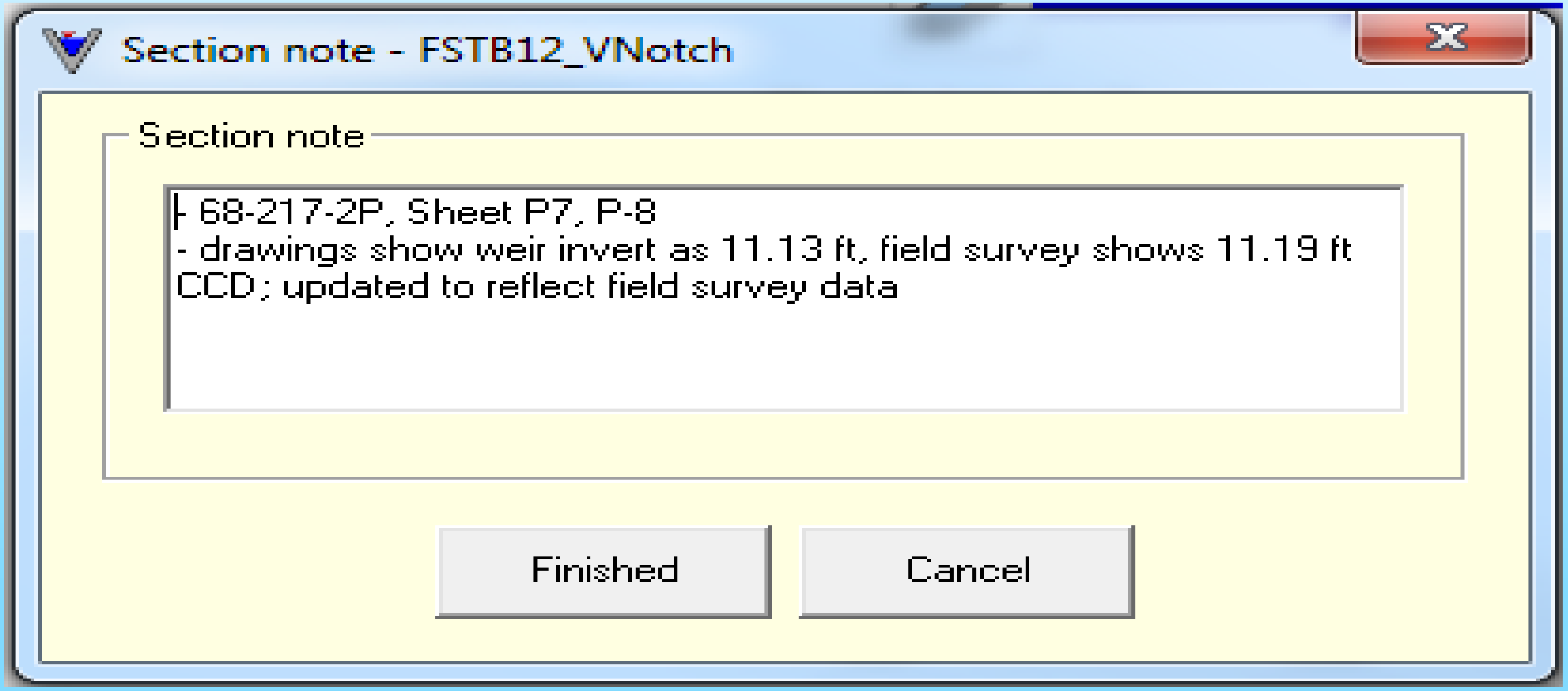
1. Battery B New FST V-Notch Weir Example





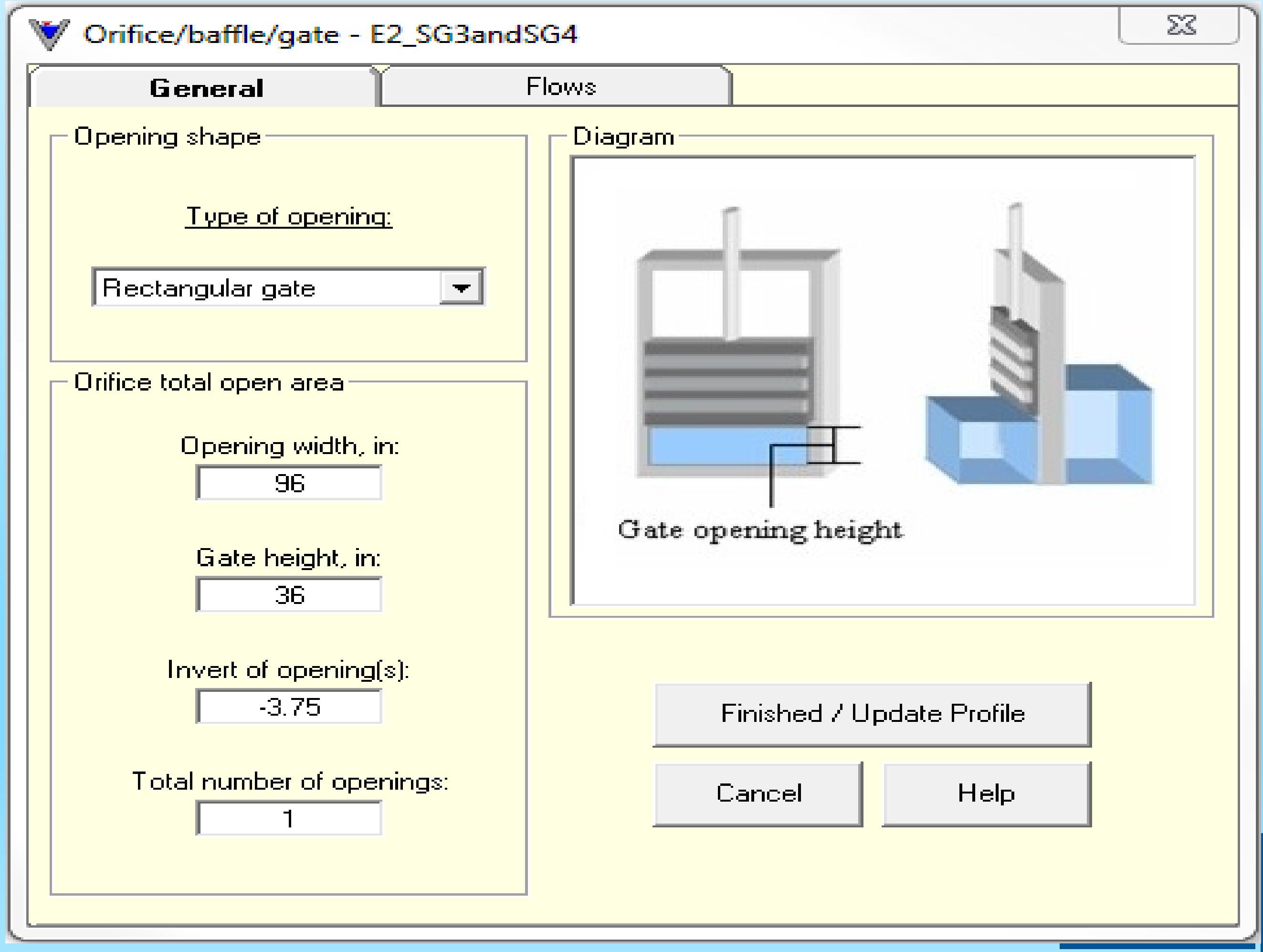
HYDRAULIC MODEL DEVELOPMENT

1. Battery B New FST V-Notch Weir Example



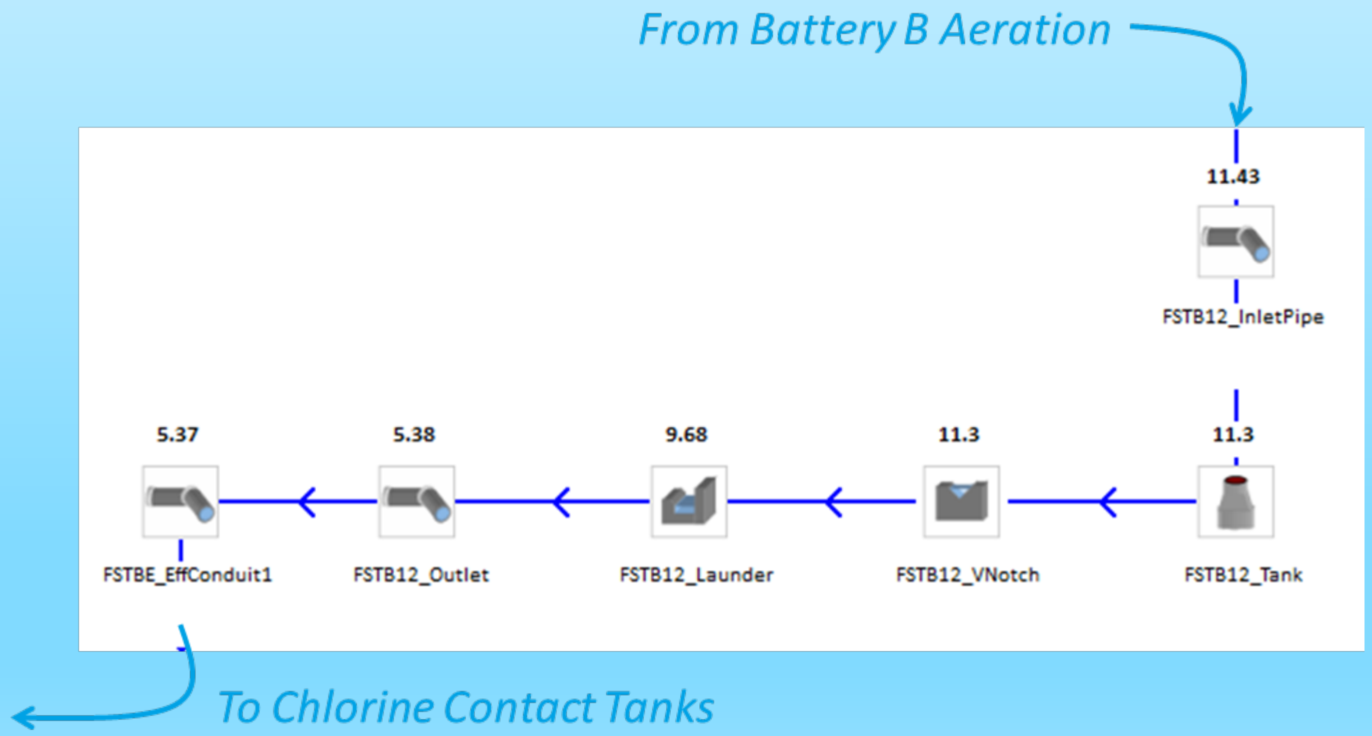
HYDRAULIC MODEL DEVELOPMENT

1. **Gate/weir settings**
   - **Battery E2 Influent Sluice Gates example**



HYDRAULIC MODEL DEVELOPMENT

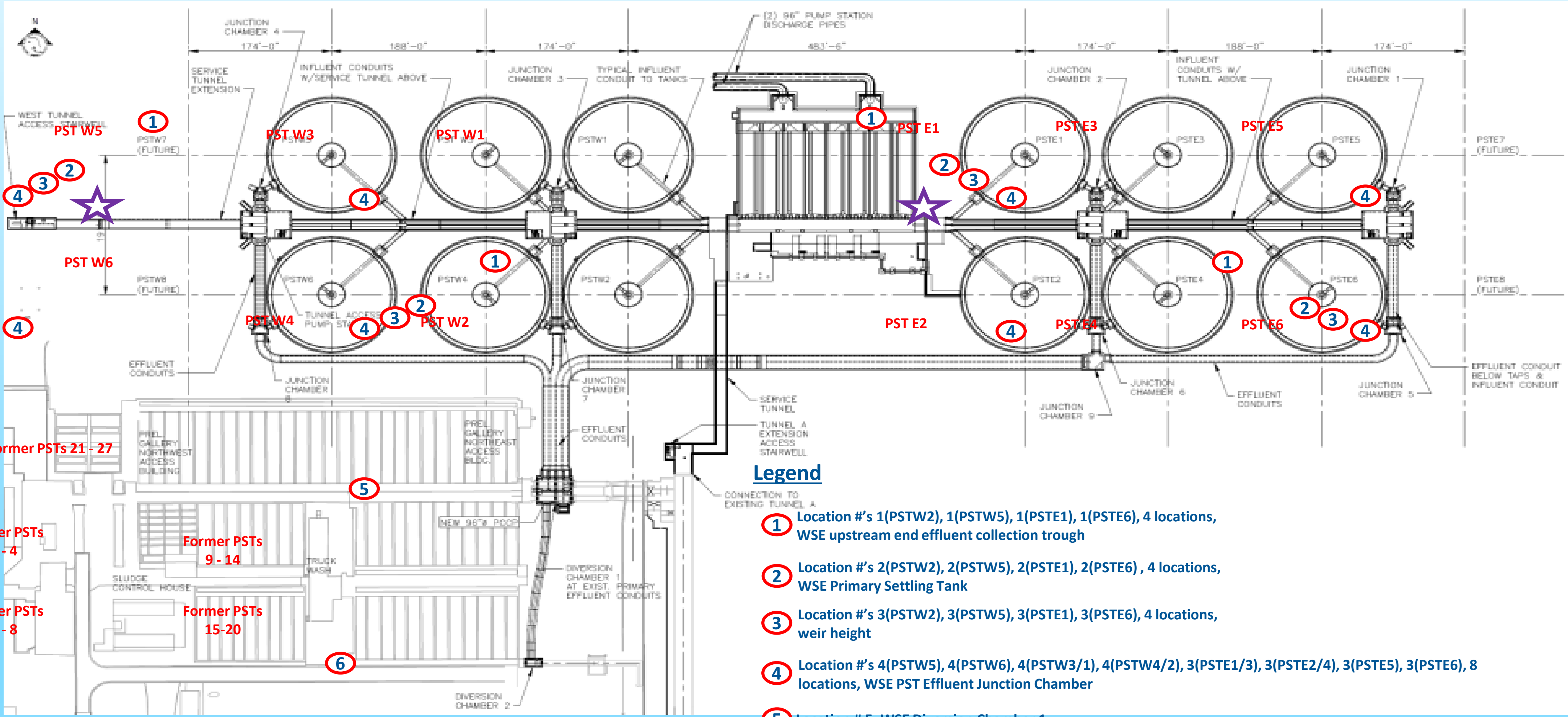
1. **Model constructed from downstream to upstream**



FIELD SURVEY SUMMARY

1. Recon Visit: May 12, 2016
   - Established over 100 Temporary Benchmarks around WRP
   - Error in loops ranged from -0.01 ft to +0.03 ft
2. Calibration Data Collection Survey: May 19, 2016
   - Flow = 206 mgd
   - Gathered WSE data, operational data
3. Validation Data Collection Survey: May 26, 2016
   - Maintained flow = 286 mgd
   - Gathered WSE data, operational data

Example Field Survey Plan: Primary Settling Tanks (PSTs), Primary Effluent Diversion Structures, and conduit along Former Preliminary Settling Tanks



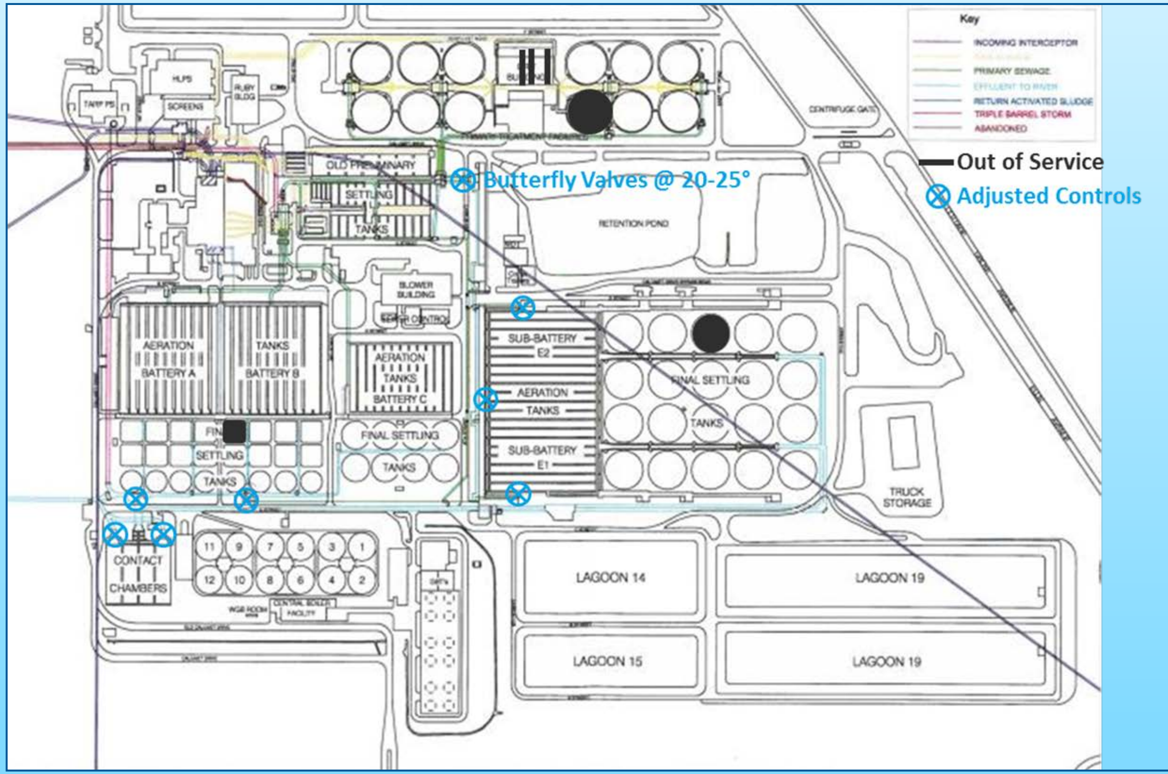
Legend

1. Location #'s 1(PSTW2), 1(PSTW5), 1(PSTE1), 1(PSTE6), 4 locations, WSE upstream end effluent collection trough
2. Location #'s 2(PSTW2), 2(PSTW5), 2(PSTE1), 2(PSTE6) , 4 locations, WSE Primary Settling Tank
3. Location #'s 3(PSTW2), 3(PSTW5), 3(PSTE1), 3(PSTE6), 4 locations, weir height
4. Location #'s 4(PSTW5), 4(PSTW6), 4(PSTW3/1), 4(PSTW4/2), 3(PSTE1/3), 3(PSTE2/4), 3(PSTE5), 3(PSTE6), 8 locations, WSE PST Effluent Junction Chamber
5. Location # 5, WSE Diversion Chamber 1
6. Location # 6, WSE Diversion Chamber 2
7. Location # 7, WSE Primary Effluent Conduit

☆ Survey Control Point

HYDRAULIC MODEL CALIBRATION

1. **Calibration Goals:**
   - Accurately simulate flow splits
   - Match measured WSEs from Field Survey
2. **Calibration Variables:**
   - Roughness Coefficients (Manning's n, HW)
   - Adjustable weir heights
   - Adjustable gate openings
   - Butterfly valve Cv values
   - Facilities on/off line

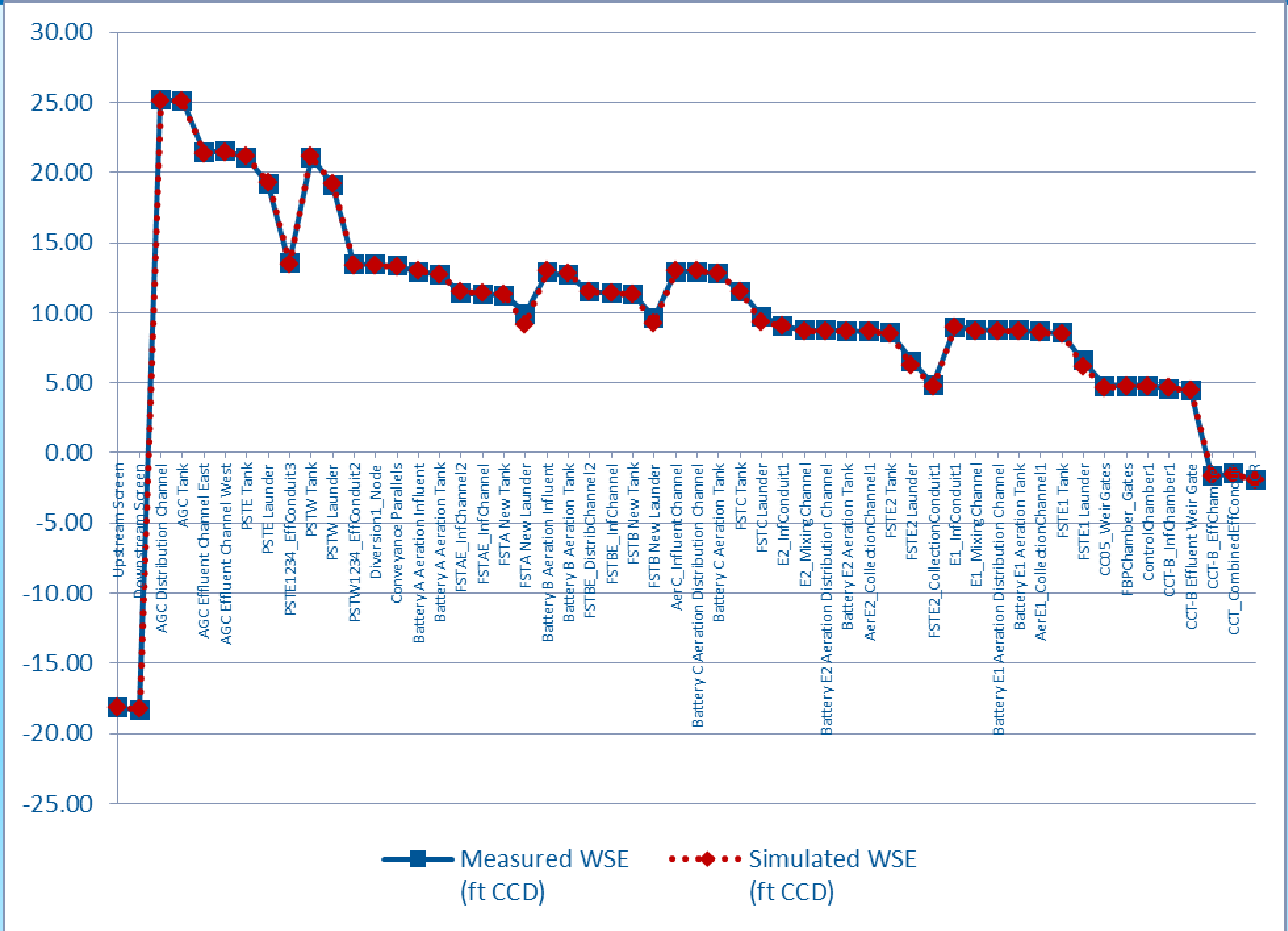


HYDRAULIC MODEL CALIBRATION RESULTS

1. **Calibrate flow splits based on downstream hydraulic losses and equalized head**

BATTERY	SIMULATED FLOW (MGD)	OBSERVED FLOW (MGD)	DIFFERENCE (%)
Battery A	40.1	38.7	3.7%
Battery B	42.5	41.5	2.4%
Battery C	37.4	40.4	-7.3%
Battery E1	39.9	39.9	0.0%
Battery E2	46.0	45.5	1.1%
TOTAL	206.0	206.0	

HYDRAULIC MODEL CALIBRATION RESULTS



CALIBRATION/VALIDATION

- **Excellent calibration within 0.12 ft at all points except clarifier launders and Chlorine contact tank effluent chamber**
  - Clarifier lauders difficult to survey and had algae buildup
  - High turbulence at CCT effluent chamber
- **Validation**
  - >75% of calibration points are within ±0.1 ft of the measured value

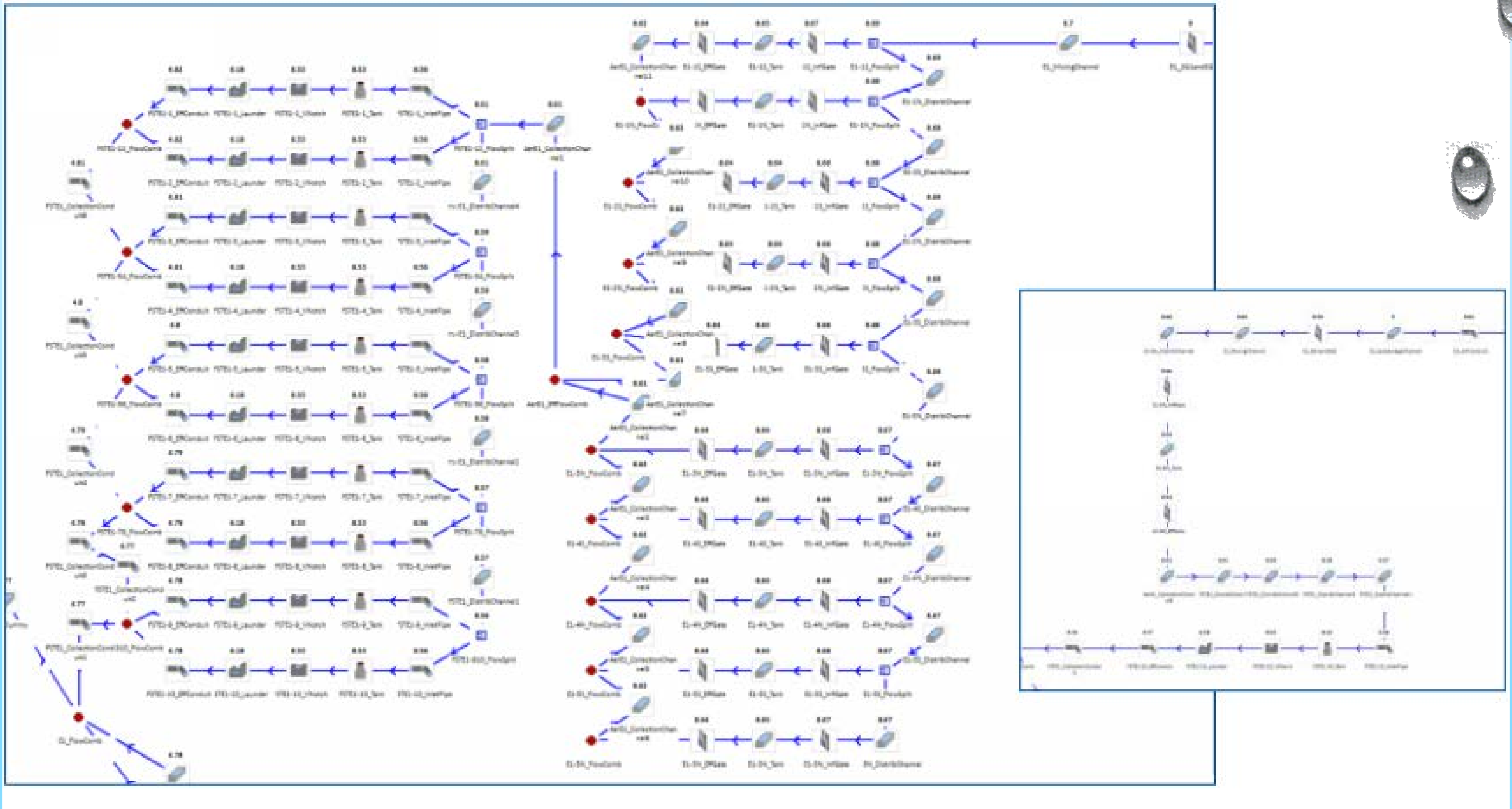
FULL PLANT MODEL VS CRITICAL PATH MODEL

- **Full Model**
  - Includes 1,018 model components
  - Includes 85 flow split elements
  - Use for Battery-specific analyses
  - Use in conjunction with Critical Path Model

- **Critical Path Model**
  - Includes 237 model components
  - Includes 7 flow split elements
  - Use for whole plant analyses
  - Model calibration
  - Determining operational controls/settings

MODEL CONFIGURATION – FULL PLANT MODEL VS CRITICAL PATH MODEL

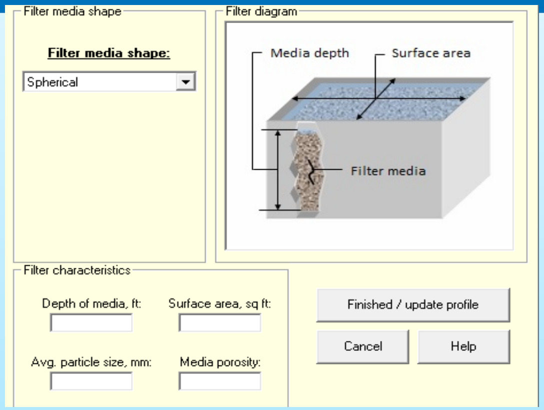
Battery E1

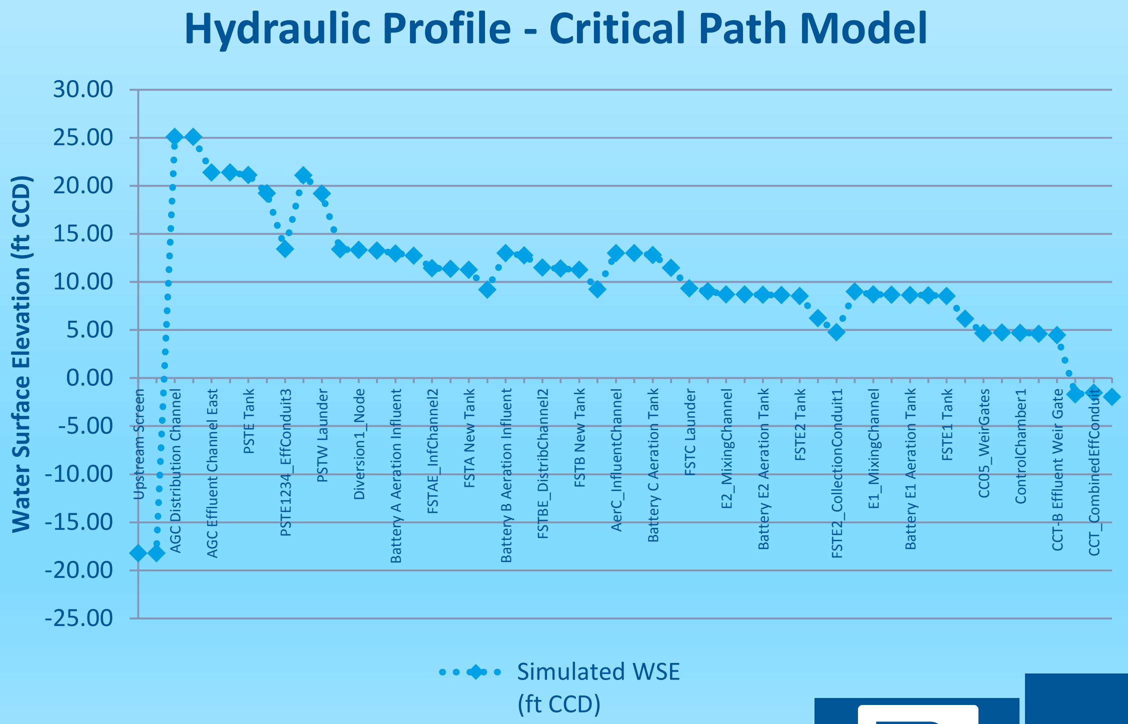


- **Critical Path has greater utility for full plant modeling – full plant model to be used for particular elements/basins**

HYDRAULIC MODEL AS PLANNING TOOL

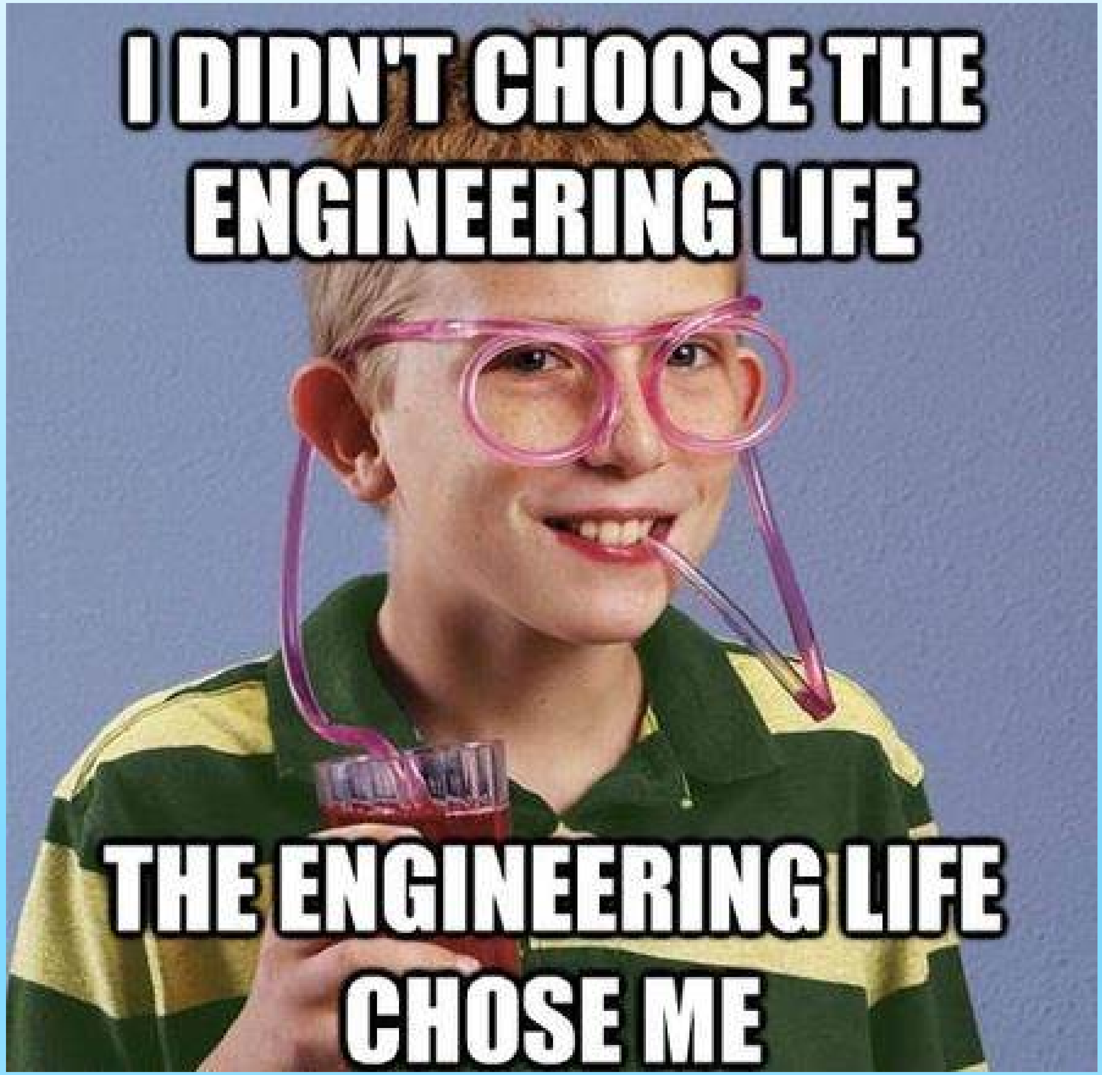
- **Plant upgrades/expansion – Capital Planning**
  - Adding tanks for more treatment volume
  - Convert chlorine disinfection to UV
  - Filters for meeting lower nutrient limits
    - Lift station possibility
- **Feasibility studies/evaluations**
  - Process model impacts
- **Optimize operational scenarios**
  - High flow/low flow
  - Taking infrastructure out of service





PROCESS MODEL

HAPPY ENGINEERS WEEK!

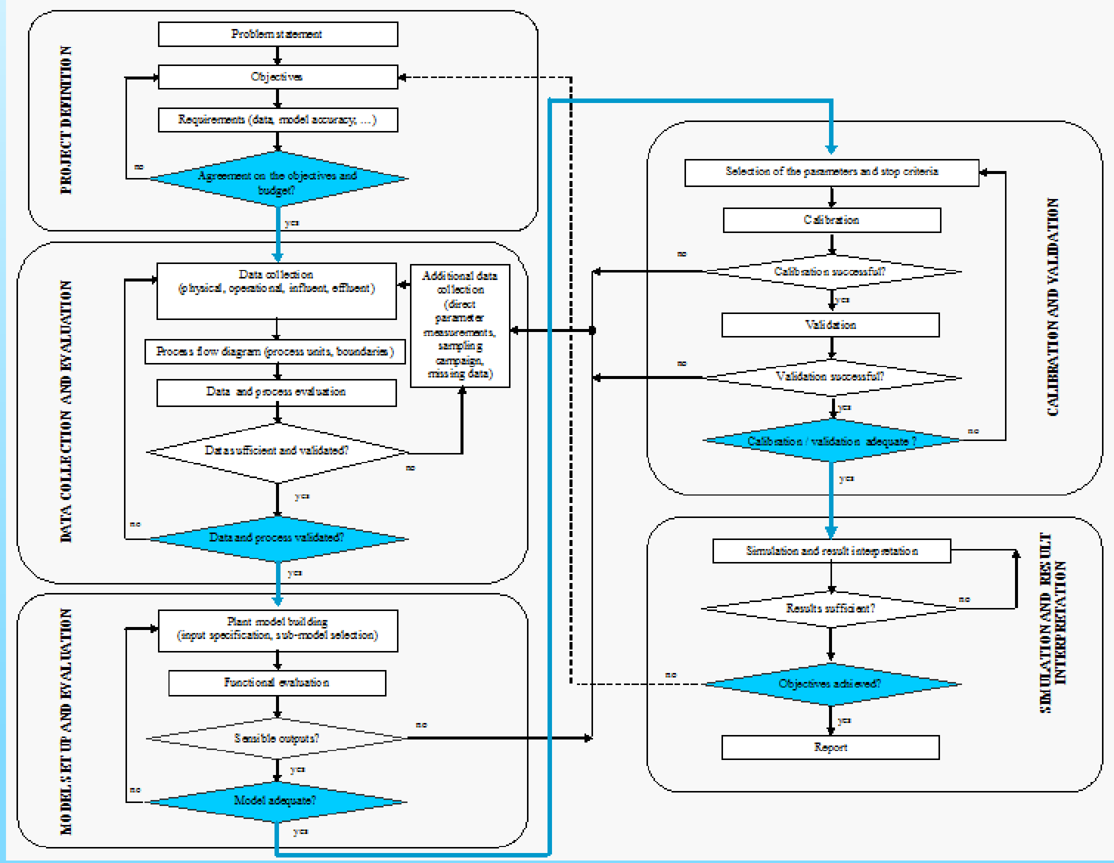


HAPPY ENGINEERS WEEK!

PROCESS MODEL DEVELOPMENT

Process Model Basis

- Steady state model suitable for planning
- Use of IWA's "Good Modeling Practice Unified Protocol" for developing process model
- Set goals for model calibration
  - +/- 10% for MLSS, WAS, PS
  - +/- 15% for DS, biogas
- Model limitations based on extent and quality of data



PROCESS MODEL

1. Simple growth/decay matrix

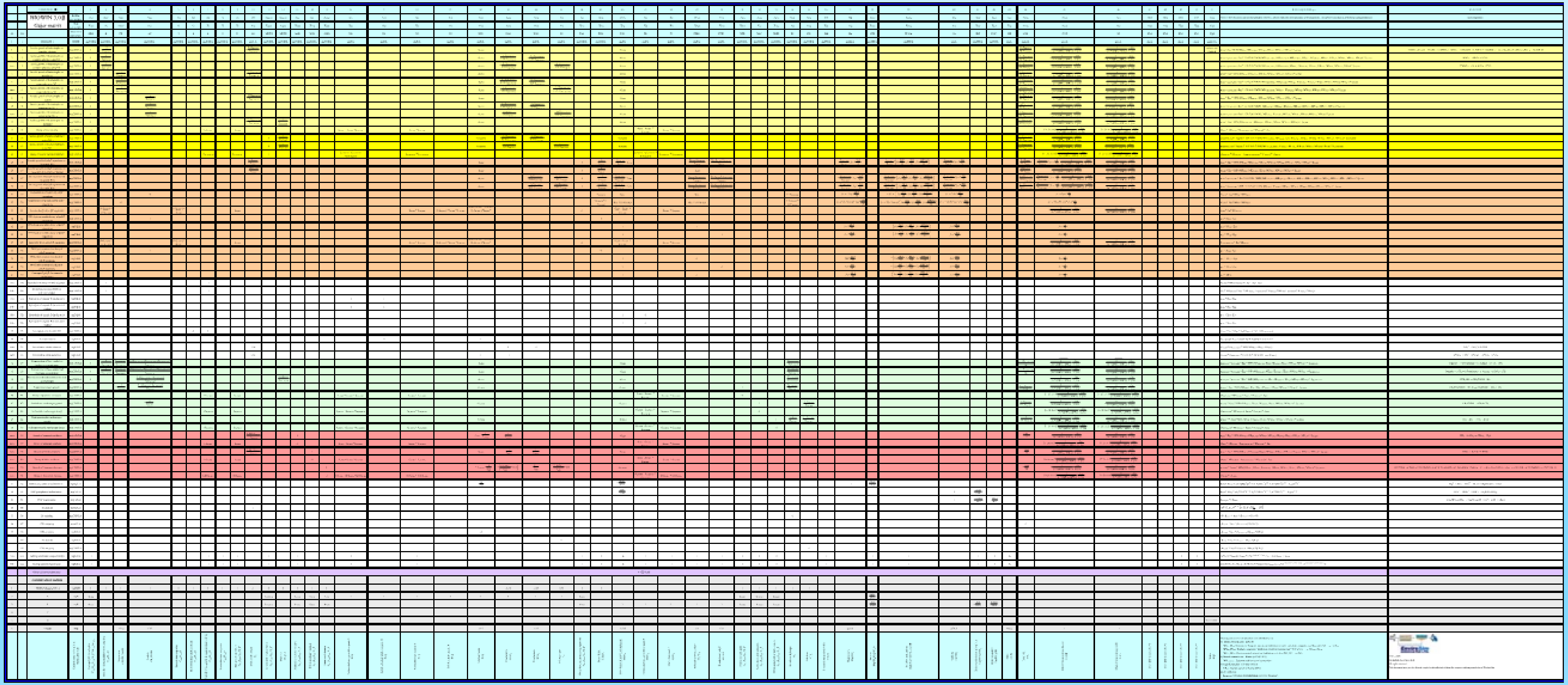
Table 1. Process kinetics and stoichiometry for heterotrophic bacterial growth in an aerobic environment

→ Continuity (across); ↓ Mass Balance (down)

Component → i / j Process ↓	1 X_B	2 S_S	3 S_O	Process Rate, ρ_j $[ML^{-3}T^{-1}]$
1 Growth	1	$-\frac{1}{Y}$	$-\frac{1-Y}{Y}$	$\frac{\hat{\mu} S_S}{K_S + S_S} X_B$
2 Decay	−1		−1	bX_B
Observed Conversion Rates $ML^{-3}T^{-1}$	$r_i = \sum_j r_{ij} = \sum_j \nu_{ij}\rho_j$			Kinetic Parameters:
Stoichiometric Parameters: True growth yield: Y	Biomass [M(COD) L^{-3}]	Substrate [M(COD) L^{-3}]	Oxygen (negative COD) [M(−COD) L^{-3}]	Maximum specific growth rate: $\hat{\mu}$ Half-velocity constant: K_S Specific decay rate: b

PROCESS MODEL

1. **Carbon, Nitrification, Denitrification, Bio-P, Anaerobic Dig, Chemical precipitation – 51 State Variables, 62 processes**

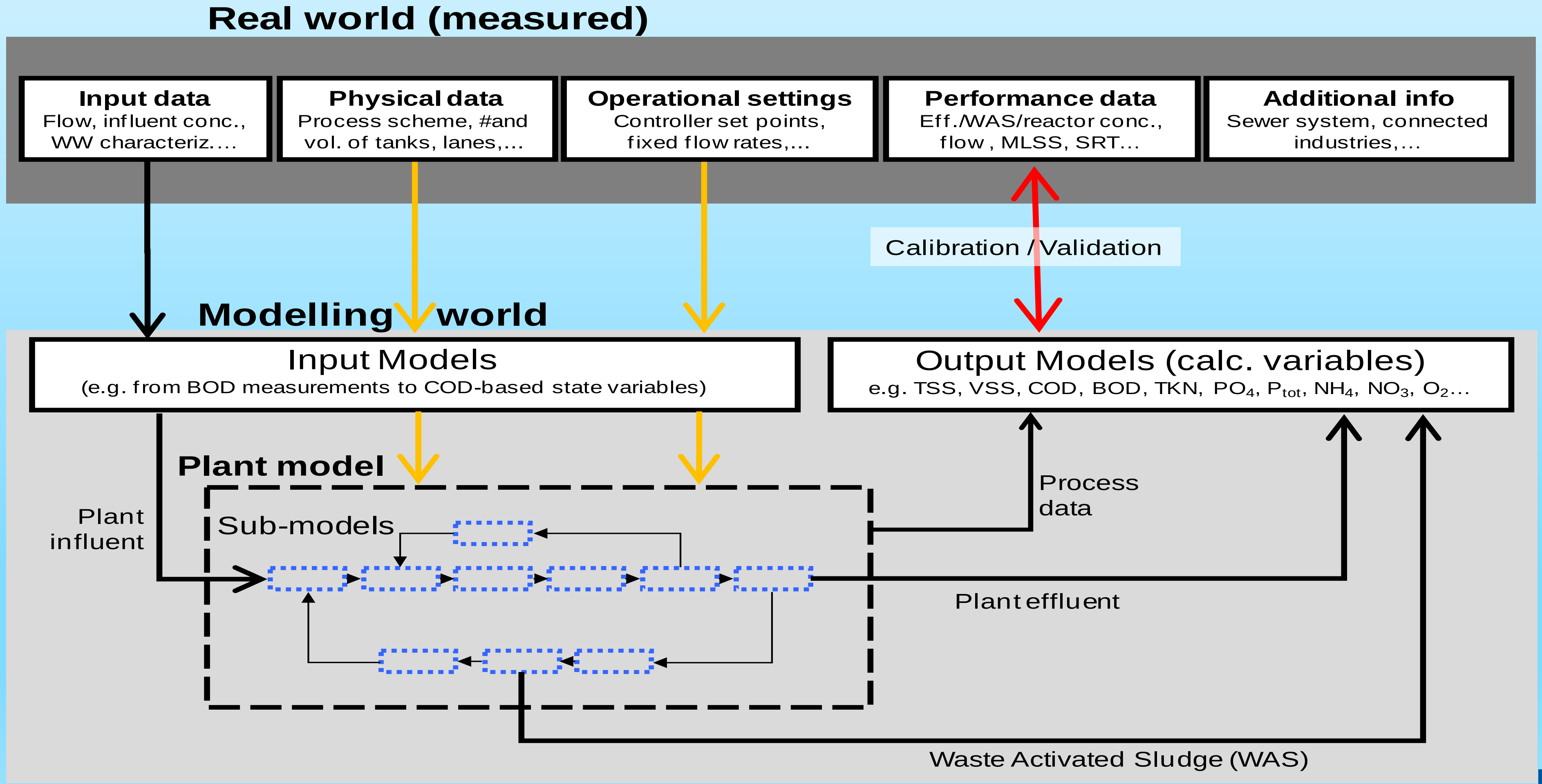


PROCESS MODEL

		COMPONENT ➔	i	1	2	3	47	48	49	50	51	RATE EQUATION, ρ_i
		Gujer matrix	BioWin nomenclature	Z_{BH}	S_{BSC}	S_{BSP}	UD1	UD2	UD3	UD4	S_{H2O}	NOTE: MIN functions are not the default in BioWin, default method is multiplication of Monod terms. Using MINs can lead to different process predictions
			IWA nomenclature	X_{OHO}	S_S	S_{PROP}	S_{UD1}	S_{UD2}	X_{UD1}	X_{UD2}	S_{H2O}	
2.2	3.0		Short form (subscript)	OHO	S	PR	UD1	UD2	UD3	UD4	H_2O	
j	j	PROCESS ↓	UNITS	mgCOD/L	mgCOD/L	mgCOD/L	mg/L	mg/L	mg/L	mg/L	mgH_2O/L	
1	1	Aerobic growth of heterotrophs on complex substrate	mgCOD/L/d	1	$-\frac{1}{Y_{HET,OX,S}}$						column not finished	$\mu_{ZBH} \cdot Z_{BH} * MIN(MS_{Sbsc} ; ME_{DO,Het} ; MN_{NH3} ; MN_{PO4} ; MN_{CAT} ; MN_{AN}) * I_{pH,ZBH}$
2	2	Anoxic growth of heterotrophs on complex substrate using NO_3	mgCOD/L/d	1	$-\frac{1}{Y_{HET,NO3,S}}$							$\mu_{ZBH} \cdot \eta_{ANOX,ZBH} \cdot Z_{BH} * 1.14/2.86 * MIN(MR_{SBSC,SBSA} ; MR_{SBSC,SBSP} ; MR_{NO3,NO2} ; MS_{Sbsc} ; IE_{SDN,Het} ; ME_{NO3} ; MN_{NH3} ; MN_{PO4} ; MN_{CAT}; MN_{AN}) * I_{pH,ZBH}$
new	3	Anoxic growth of heterotrophs on complex substrate using NO_2	mgCOD/L/d	1	$-\frac{1}{Y_{HET,NO2,S}}$							$\mu_{ZBH} \cdot \eta_{ANOX,ZBH} \cdot Z_{BH} * 1.71/2.86 * MIN(MR_{SBSC,SBSA} ; MR_{SBSC,SBSP} ; MS_{Sbsc} ; IE_{SDN,Het} ; ME_{NO2} ; MN_{NH3} ; MN_{PO4} ; MN_{CAT} ; MN_{AN}) * I_{pH,ZBH}$
5	4	Aerobic growth of heterotrophs on propionate	mgCOD/L/d	1		$-\frac{1}{Y_{HET,OX,PR}}$						$\mu_{ZBH} * Z_{BH} * MIN(MS_{Sbsp} ; ME_{DO,Het} ; MN_{NH3} ; MN_{PO4} ; MN_{CAT} ; MN_{AN}) * I_{pH,ZBH}$
6	5	Anoxic growth of heterotrophs on propionate using NO_3	mgCOD/L/d	1		$-\frac{1}{Y_{HET,NO3,PR}}$						$\mu_{ZBH} \cdot \eta_{ANOX,ZBH} \cdot Z_{BH} * 1.14/2.86 * MIN(MR_{SBSP,SBSA} ; MR_{NO3,NO2} ; MS_{Sbsp} ; IE_{SDN,Het} ; ME_{NO3} ; MN_{NH3} ; MN_{PO4} ; MN_{CAT}; MN_{AN}) * I_{pH,ZBH}$
new	6	Anoxic growth of heterotrophs on propionate using NO_2	mgCOD/L/d	1		$-\frac{1}{Y_{HET,NO2,PR}}$						$\mu_{ZBH} \cdot \eta_{ANOX,ZBH} \cdot Z_{BH} * 1.71/2.86 * MIN(MR_{SBSP,SBSA} ; MS_{Sbsp} ; IE_{SDN,Het} ; ME_{NO2} ; MN_{NH3} ; MN_{PO4} ; MN_{CAT} ; MN_{AN}) * I_{pH,ZBH}$
9	7	Aerobic growth of heterotrophs on acetate	mgCOD/L/d	1								$\mu_{ZBH} * Z_{BH} * MIN(MS_{Sbsa} ; ME_{DO,Het} ; MN_{NH3} ; MN_{PO4} ; MN_{CAT} ; MN_{AN}) * I_{pH,ZBH}$
10	8	Anoxic growth of heterotrophs on acetate using NO_3	mgCOD/L/d	1								$\mu_{ZBH} \cdot \eta_{ANOX,ZBH} \cdot Z_{BH} * 1.14/2.86 * MIN(MR_{NO3,NO2} ; MS_{Sbsa} ; IE_{SDN,Het} ; ME_{NO3} ; MN_{NH3} ; MN_{PO4} ; MN_{CAT}; MN_{AN}) * I_{pH,ZBH}$
new	9	Anoxic growth of heterotrophs on acetate using NO_2	mgCOD/L/d	1								$\mu_{ZBH} \cdot \eta_{ANOX,ZBH} \cdot Z_{BH} * 1.71/2.86 * MIN(; MS_{Sbsa} ; IE_{SDN,Het} ; ME_{NO2} ; MN_{NH3} ; MN_{PO4} ; MN_{CAT} ; MN_{AN}) * I_{pH,ZBH}$
13	10	Aerobic growth of heterotrophs on methanol	mgCOD/L/d	1								$\mu_{ZBH} * Z_{BH} * MIN(MS_{Sbmeth,AER} ; ME_{DO,Het} ; MN_{NH3} ; MN_{PO4} ; MN_{CAT} ; MN_{AN}) * I_{pH,ZBH}$
15	11	Decay of heterotrophs	mgCOD/L/d	-1								$(b_{ZBH} * ME_{DO,Het} + b_{ZBH,ANOX/ANA} * IE_{DO,Het}) * Z_{BH}$
21	12	Anoxic growth of methanol utilizers using NO_3	mgCOD/L/d									$\mu_{ZBMETH,ANOX} * Z_{BMETH} * 1.14/2.86 * MIN(MR_{NO3,NO2} ; MS_{Sbmeth,ANOX} ; IE_{DO,Het} ; ME_{NO3} ; MN_{NH3} ; MN_{PO4} ; MN_{CAT} ; MN_{AN}) * I_{pH,ZBMETH}$
22	13	Anoxic growth of methanol utilizers using NO_2	mgCOD/L/d									$\mu_{ZBMETH,ANOX} * Z_{BMETH} * 1.71/2.86 * MIN(MS_{Sbmeth,ANOX} ; IE_{DO,Het} ; ME_{NO2} ; MN_{NH3} ; MN_{PO4} ; MN_{CAT}; MN_{AN}) * I_{pH,ZBMETH}$
23	14	Decay of anoxic methanol utilizers	mgCOD/L/d									$(b_{ZBMETH} * ME_{DO,Het} + b_{ZBMETH,ANOX/ANA} * IE_{DO,Het}) * Z_{BMETH}$
26	15	Aerobic growth of polyP organisms on S_{PHB} with NH_3	mgCOD/L/d									$\mu_{ZBP} * Z_{BP} * MIN(MR_{Sphb} ; ME_{DO,Het} ; ME_{PO4} ; MN_{SNH3} ; MN_{Mg} ; MN_{CAT} ; MN_{Ca} ; MN_{AN}) * I_{pH,ZBP}$
28	16	Aerobic growth of polyP organisms on S_{PHB} with NH_3 if PO_4-P limited	mgCOD/L/d									$\mu_{PLIM} * Z_{BP} * MIN(MR_{Sphb} ; ME_{DO,Het} ; IE_{PO4} ; MN_{NH3} ; MN_{CAT} ; MN_{AN}) * I_{pH,ZBP}$
		Anoxic growth of polyP organisms on										

PROCESS MODEL CALIBRATION

1. **Model parameters adjusted to reach agreement between simulated and measured values**

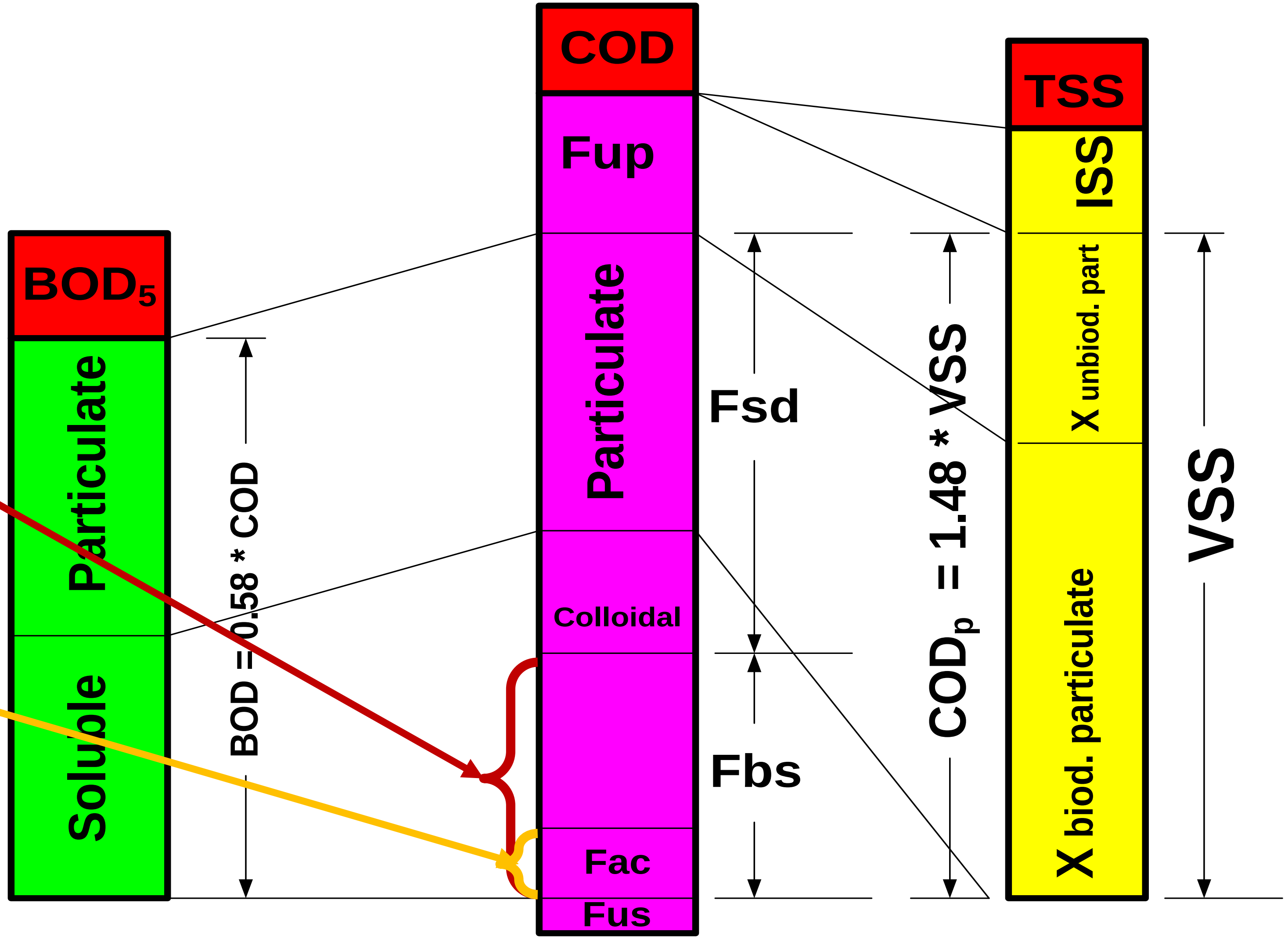


COD FRACTIONATION = KEY TO EBPR

1. Influent Parameters specific to Calumet WRP – Default Kinetic Parameters.

Readily biodegradable carbon (rbCOD)

Volatile fatty acids (VFA)



Fus - Non-biodegradable soluble
Fbs - Rapidly degradable soluble fraction
Fsd - Slowly degradable fraction

Fac - Fraction of Fbs that is SCVFA
Fxsd - Fraction of Fsd that is particulate
Fup - Non-biodegradable particulate fraction

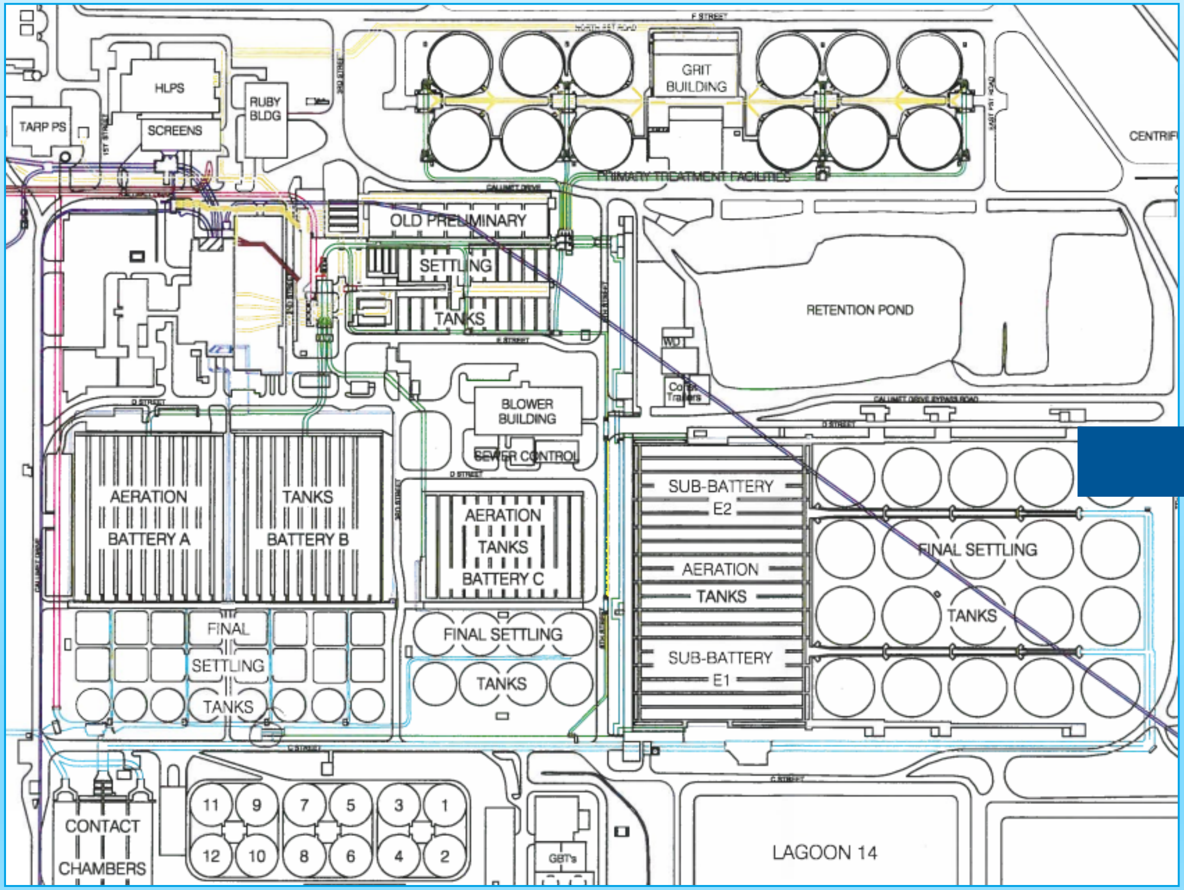
INFLUENT PARAMETERS VERSUS DEFAULT VALUES

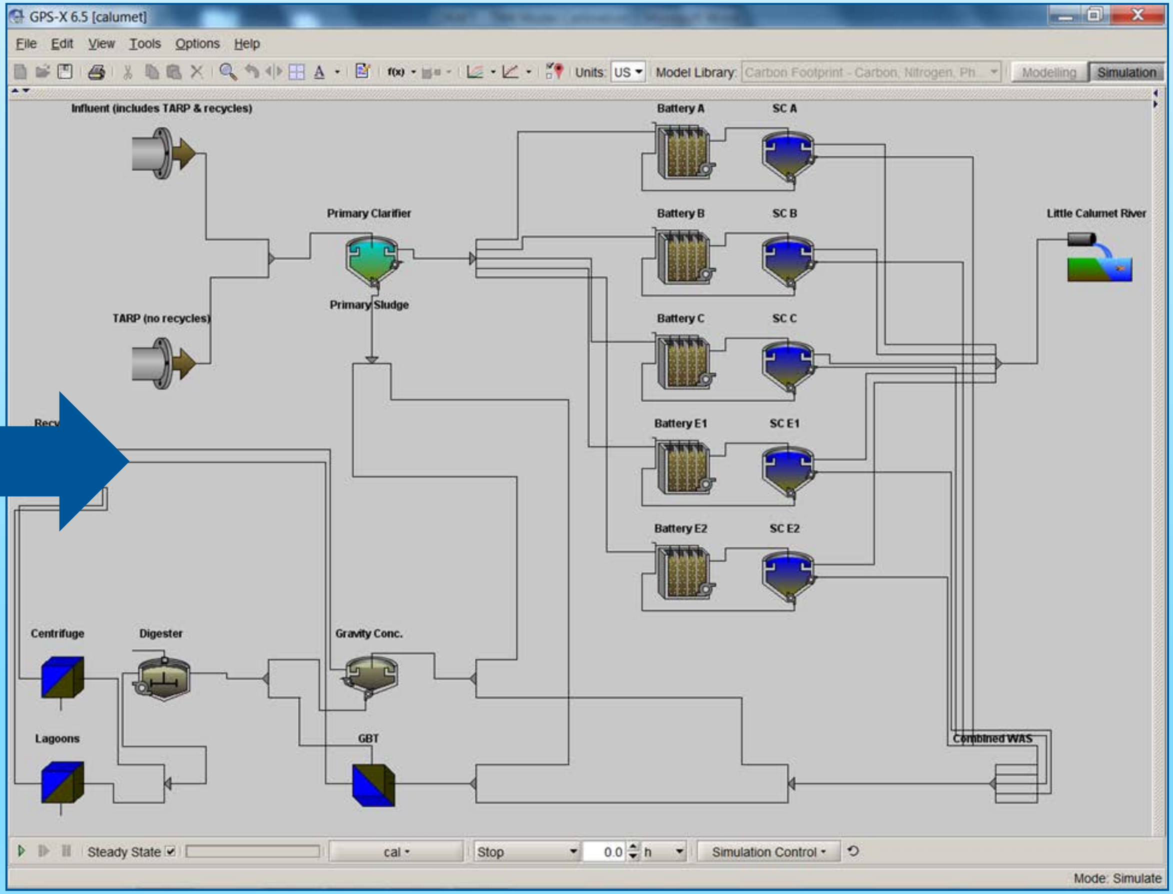
1. Influent parameters specific to Calumet WRP

FRACTION	DESCRIPTION	GPS-X DEFAULT	VALUE USED JULY 2015	VALUE USED MAY 2015	NOTES
frsi	soluble inert fraction of total COD	0.05	0.09	0.09	Estimated from Special Sampling
frss	readily biodegradable fraction of total COD	0.20	0.13	0.13	Estimated from Special Sampling
frxi	particulate inert fraction of total COD	0.13	0.24	0.23	Changed to best fit historical MLSS and WAS quantities
frscol	colloidal fraction of slowly biodegradable COD	0.15	0.23	0.23	Estimated from Special Sampling
XCOD/VSS particulate substrate	Ratio of particulate COD to volatile suspended solids	1.8	2.2	2.2	Changed to best fit historical MLSS and WAS quantities
XCOD/VSS inert particulate	Ratio of particulate COD to volatile suspended solids	1.8	1.2	1.0	Changed to best fit historical MLSS and WAS quantities through iterative process.

CALUMET WRP - 5 BATTERIES

1. Calibration – recycles included in influent flow





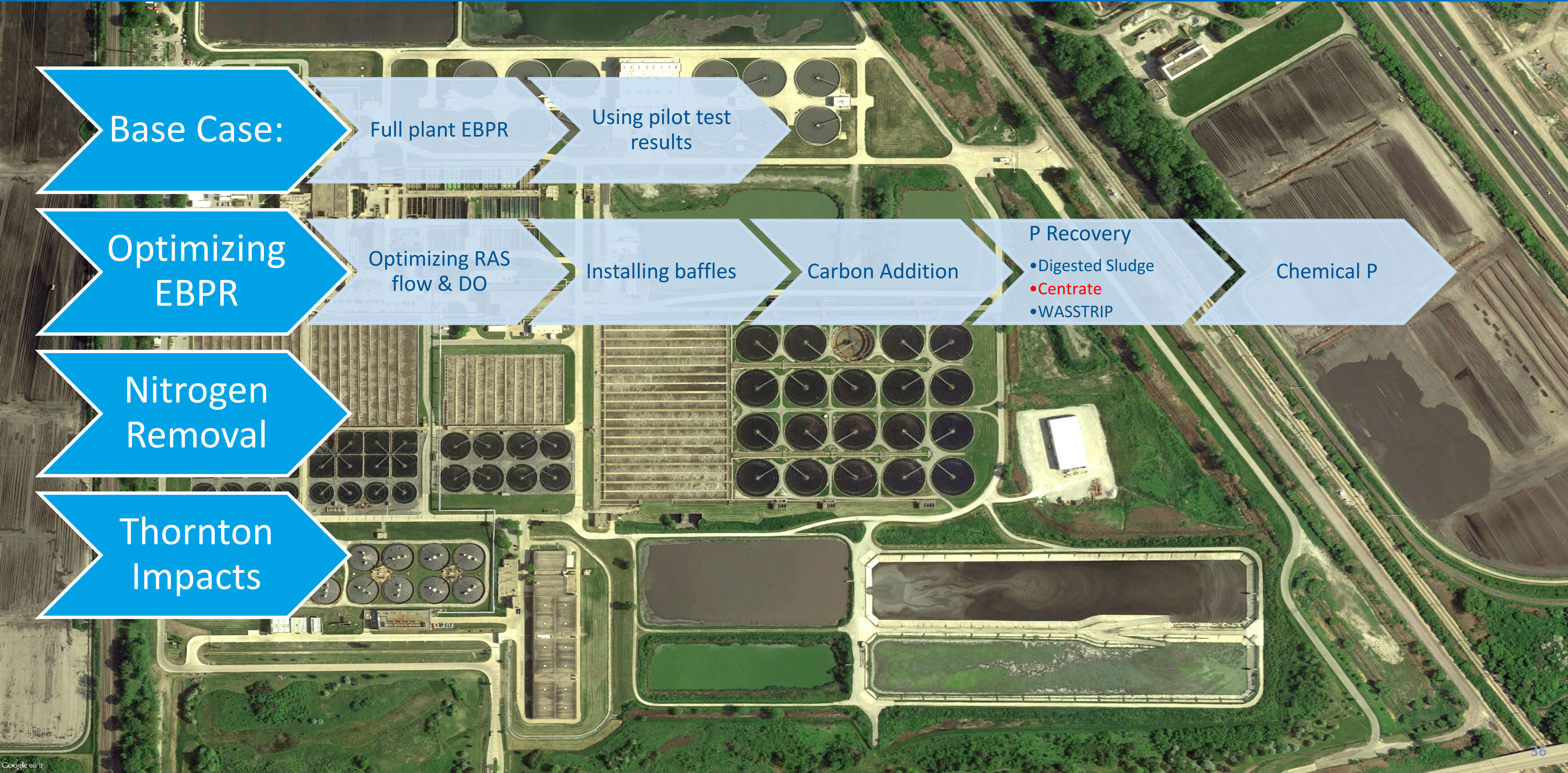
PROCESS MODEL CALIBRATION

1. Good correlation with liquid flow streams (influent, PE, effluent)
2. Marginal to poor correlation with solids flow streams (primary sludge, WAS, Thickened sludge, digested sludge)

PARAMETER	PLANT DATA	GPS-X	% ERROR	NOTES
MLSS, mg/L (Battery A)	2,008	1,970	2%	
WAS, ppd (Battery A)	20,200 Y = 0.83	13,600 Y = 0.55	33%	Confirm flowmeters are calibrated and sample is representative
Feed to Gravity Conc., ppd	379,000	207,000	45%	Discrepancy in primary sludge value.
Digester Feed, ppd	157,000	203,000	-29%	Confirm flowmeters are calibrated and sampling is representative
Digested Solids, ppd	122000	142,,000	-16%	

- Solids balance issues not unusual

PROCESS MODEL AS PLANNING TOOL



Base Case:
- Full plant EBPR
- Using pilot test results

Optimizing EBPR
- Optimizing RAS flow & DO
- Installing baffles
- Carbon Addition
- P Recovery
  - Digested Sludge
  - Centrate
  - WASSTRIP
- Chemical P

Nitrogen Removal

Thornton Impacts

CWRP WASTEWATER FLOWS AND LOADINGS

CONSTITUENT	AVERAGE 2015 (JULY)	SUSTAINED PEAK (1)
Flow	221 mgd	420 mgd
BOD	177,000 lb/d	197,000 lb/d
TSS	221,000 lb/d	245,000 lb/d
TP	9,200 lb/d	8,100 lb/d
TKN	35,400 lb/d	38,500 lb/d

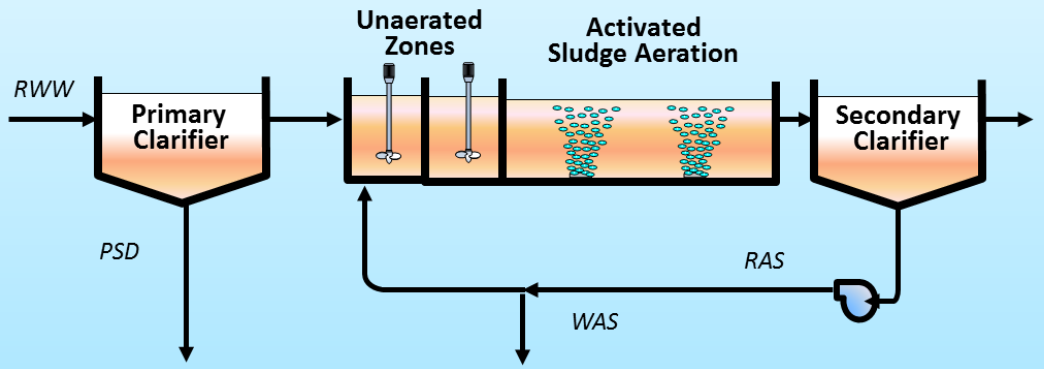
Notes:

1. **Sustained Peak occurred during March 2014 (5-day peak flow).** **144 MGD (of 420 MGD) was pumped from the TARP.**

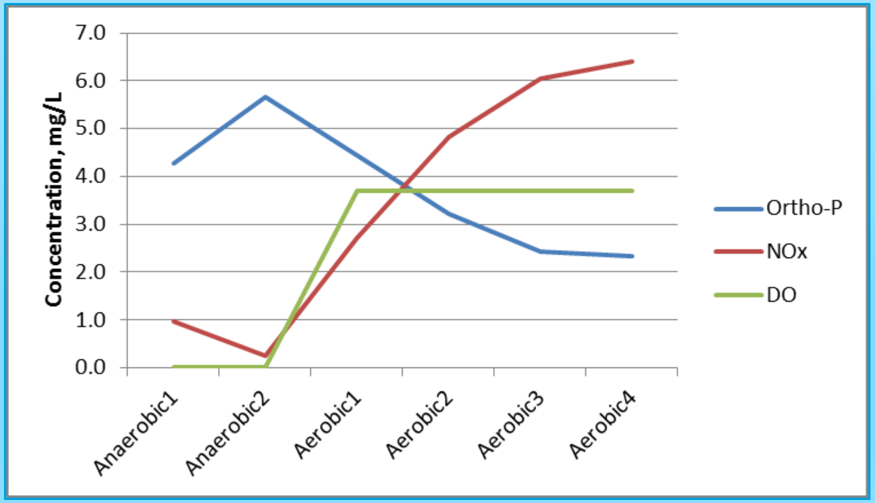
- **Recycles added in full-scale model, 10°C Temp**

BASE CASE – NO CARBON ADDITION

Parameter	Value
% Basins Unaerated (Volume)	33%
Solids Handling Operations	Gravity Conc, Centrifuge, Anaerobic Digester
RAS Flow	100% influent
DO in Aeration	3.8 mg/L



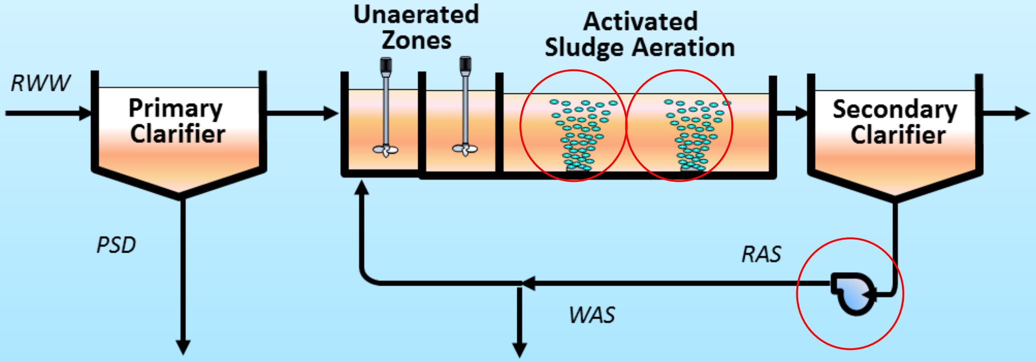
PARAMETER	EFFLUENT CONCENTRATION
BOD	4.1 mg/L
TSS	4.8 mg/L
Ammonia	0.2 mg/L
NOx	6.3 mg/L
Total Nitrogen	8.7 mg/L
Ortho-P	2.4 mg/L
Total Phosphorus	2.9 mg/L
MLSS Battery A	2,220 mg/L

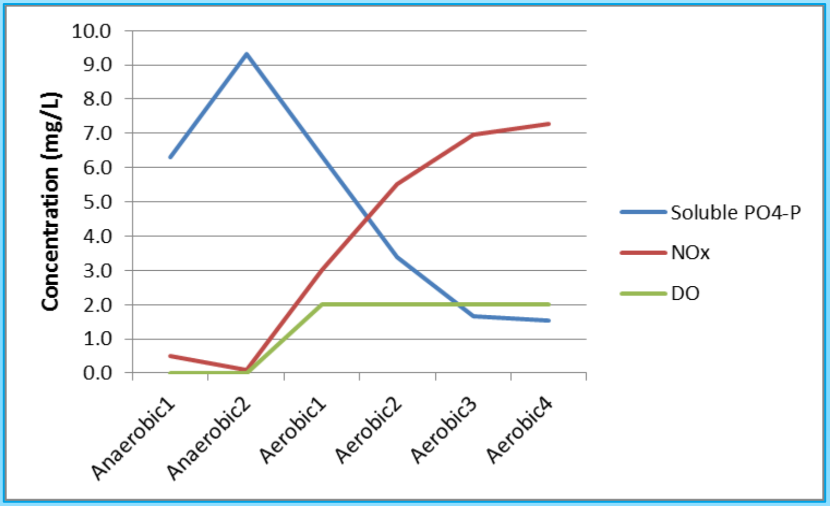


RAS FLOW AND DO OPTIMIZATION

BASE CASE	
NOx	6.3 mg/L
Total Nitrogen	8.7 mg/L
Ortho-P	2.4 mg/L
Total Phosphorus	2.9 mg/L
MLSS Battery A	2,220 mg/L

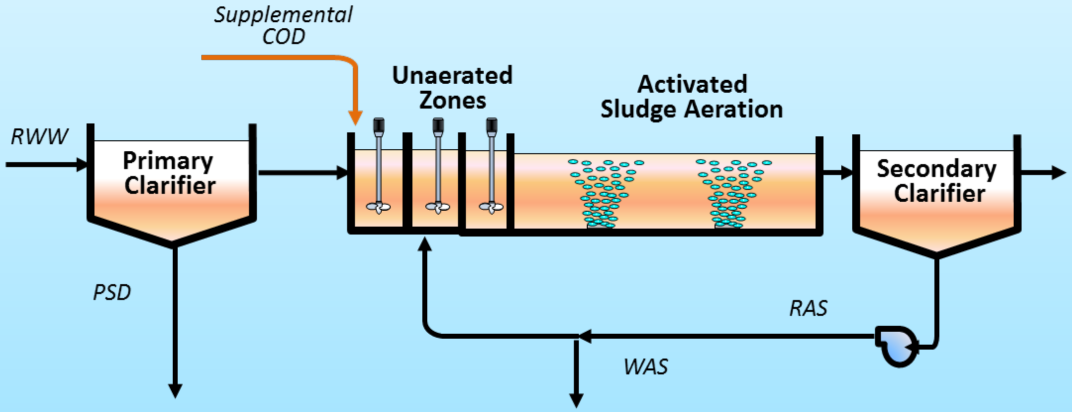
PARAMETER	EFFLUENT CONCENTRATION
BOD	4.3 mg/L
TSS	4.9 mg/L
Ammonia	0.2 mg/L
NOx	7.3 mg/L ↑
Total Nitrogen	9.7 mg/L ↑
Ortho-P	1.6 mg/L ↓
Total Phosphorus	2.2 mg/L ↓
MLSS Battery A	2,400 mg/L ↑





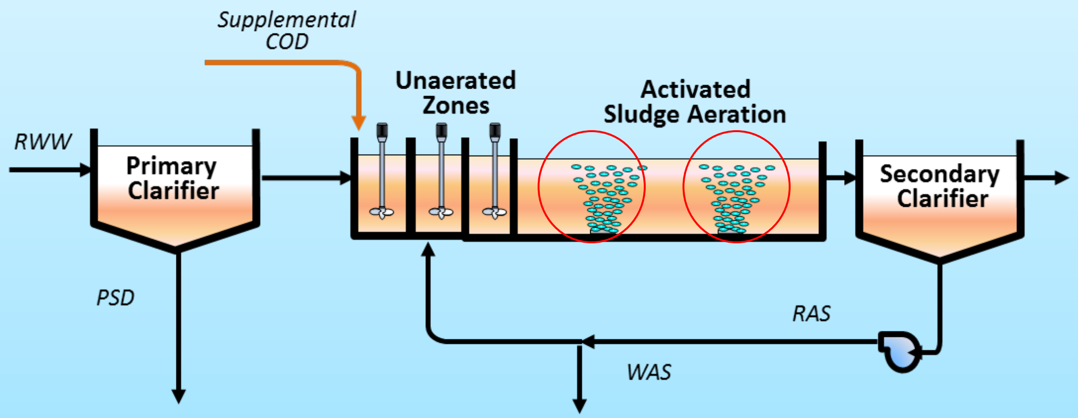
CARBON ADDITION W/ BAFFLES FOR CONTROL

BASE CASE	
NOx	6.3 mg/L
Total Nitrogen	8.7 mg/L
Ortho-P	2.4 mg/L
Total Phosphorus	2.9 mg/L
MLSS Battery A	2,220 mg/L
PARAMETER	EFFLUENT CONCENTRATION
BOD	3.7 mg/L
TSS	5.5 mg/L
Ammonia	0.2 mg/L
NOx	4.6 mg/L ↓
Total Nitrogen	7.2 mg/L ↓
Ortho-P	0.2 mg/L ↓
Total Phosphorus	0.8 mg/L ↓
MLSS Battery A	3,200 mg/L ↑
Supplemental Carbon	232,000 lb COD/day ↑



CARBON ADDITION W/ DO OPTIMIZATION

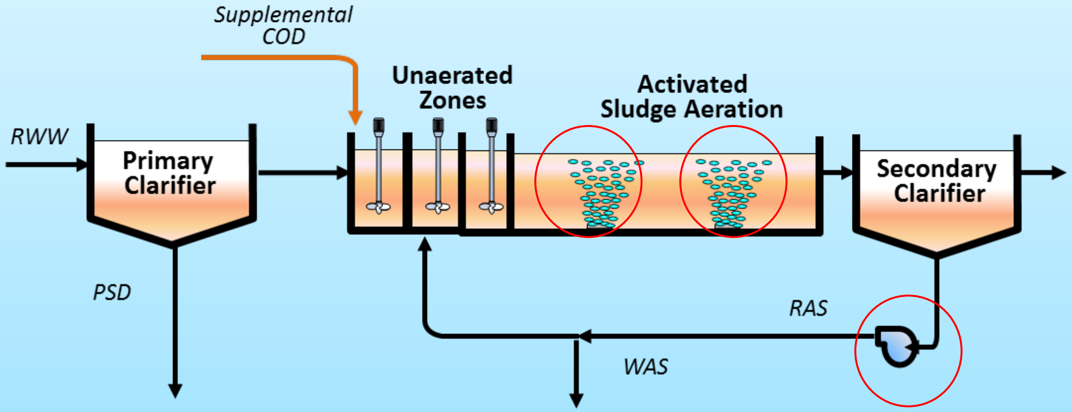
EBPR COMPARISON W/ BAFFLE & CARBON ONLY	
NOx	4.6 mg/L
Total Nitrogen	7.2 mg/L
MLSS Battery A	3,200 mg/L
Supplemental Carbon	232,000 lb COD/day
PARAMETER	**EFFLUENT CONCENTRATION**
BOD	3.7 mg/L
TSS	5.4 mg/L
Ammonia	0.2 mg/L
NOx	3.9 mg/L ⇩
Total Nitrogen	6.4 mg/L ⇩
Ortho-P	0.3 mg/L
Total Phosphorus	0.9 mg/L
MLSS Battery A	3,200 mg/L
Supplemental Carbon	210,000 lb COD/day ⇩

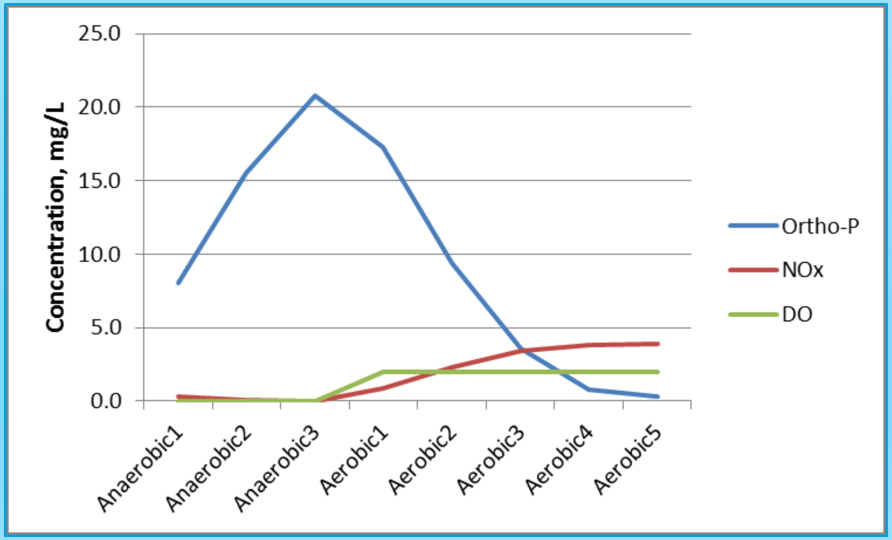


CARBON ADDITION W/ RAS OPTIMIZATION

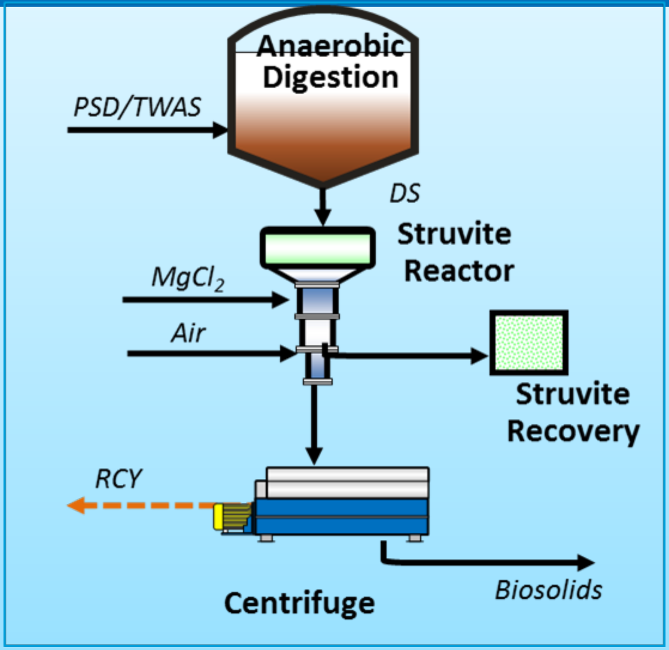
EBPR COMPARISON W/ BAFFLE, CARBON & DO OPTIMIZATION	
NOx	3.9 mg/L
Total Nitrogen	6.4 mg/L
MLSS Battery A	3,200 mg/L
Supplemental Carbon	210,000 lb COD/day

PARAMETER	EFFLUENT CONCENTRATION
BOD	3.5 mg/L
TSS	5.6 mg/L
Ammonia	0.2 mg/L
NOx	5.3 mg/L ⇧
Total Nitrogen	7.8 mg/L ⇧
Ortho-P	0.3 mg/L
Total Phosphorus	0.9 mg/L
MLSS Battery A	3,100 mg/L ⇩
Supplemental Carbon	193,000 lb COD/day ⇩

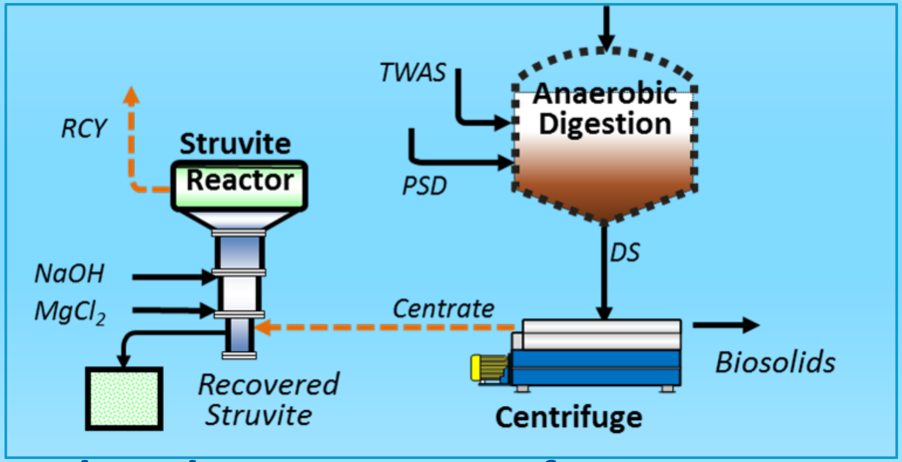




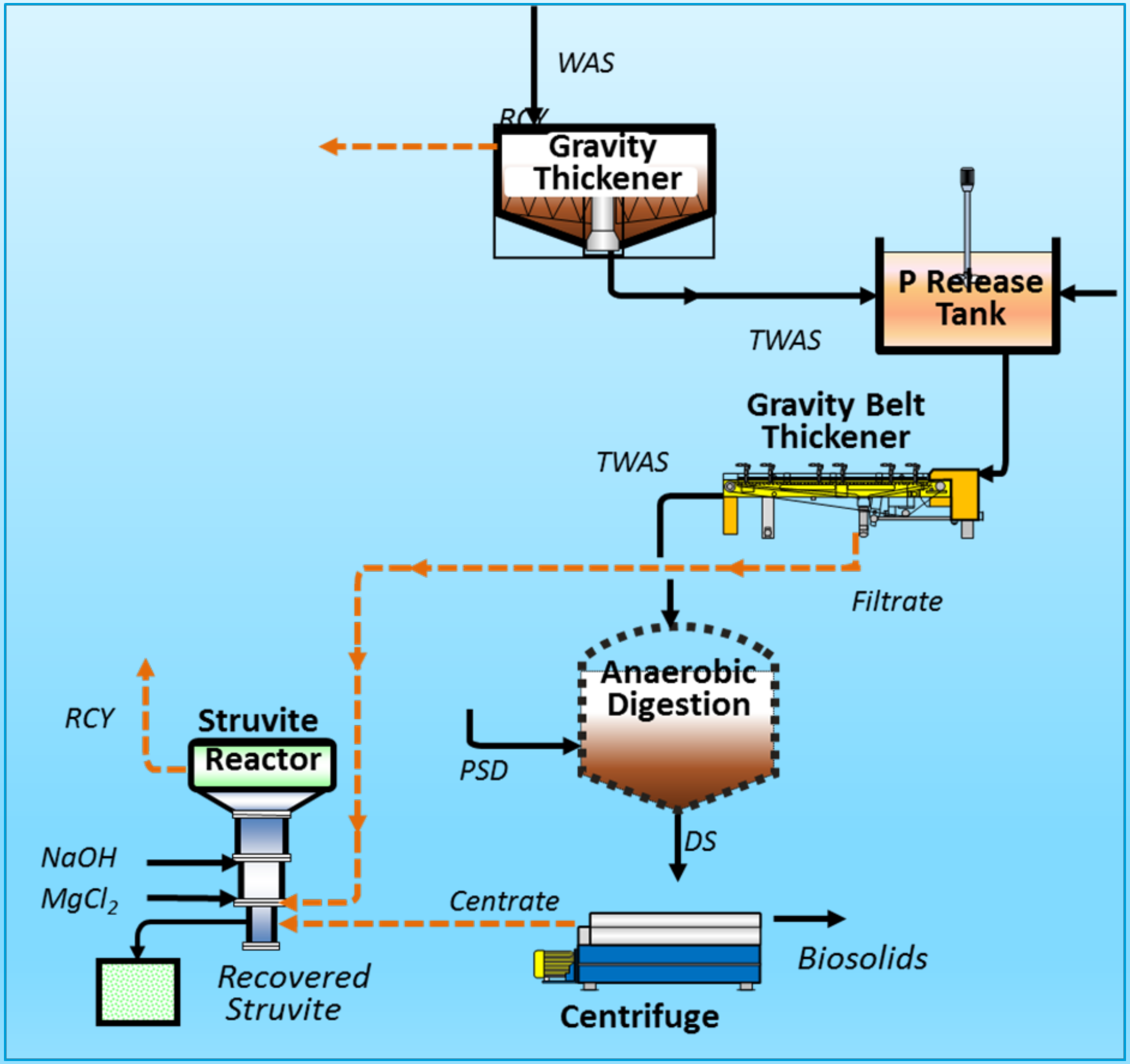
PHOSPHORUS RECOVERY



Phosphorus Recovery from Digested Sludge



Phosphorus Recovery from Centrate



WASSTRIP Process

CENTRATE P-RECOVERY

EBPR COMPARISON W/ BAFFLE, CARBON & DO OPTIMIZATION	
NOx	3.9 mg/L
Total Nitrogen	6.4 mg/L
MLSS Battery A	3,200 mg/L
Supplemental Carbon	210,000 lb COD/day

PARAMETER	EFFLUENT CONCENTRATION
BOD	3.7 mg/L
TSS	4.9 mg/L
Ammonia	0.2 mg/L
NOx	4.6 mg/L ⇧
Total Nitrogen	6.9 mg/L ⇧
Ortho-P	0.2 mg/L
Total Phosphorus	0.8 mg/L
MLSS Battery A	2,300 mg/L ⇩
Supplemental Carbon	99,200 lb COD/day (50%) ⇩
Magnesium	2,400 lb/day ⇧

CHEMICAL P-REMOVAL (BATT. A, B & C)

EBPR COMPARISON W/ BAFFLE, CARBON & DO OPTIMIZATION	
NOx	3.9 mg/L
Total Nitrogen	6.4 mg/L
MLSS Battery A	3,200 mg/L
Supplemental Carbon	210,000 lb COD/day

PARAMETER	EFFLUENT CONCENTRATION
BOD	3.0 mg/L
TSS	4.9 mg/L
Ammonia	0.2 mg/L
NOx	8.3 mg/L ↑
Total Nitrogen	10.6 mg/L ↑
Ortho-P	0.3 mg/L
Total Phosphorus	0.8 mg/L
MLSS Battery A/E1	2,300 mg/L / 2,900 mg/L ↓
Supplemental Carbon E1 & E2	49,000 lb COD/day ↓
Ferric Chloride	17,600 lb/day ↑

NITROGEN REMOVAL (6.0 MG/L)

EBPR COMPARISON W/ BAFFLE, CARBON & DO OPTIMIZATION	
NOx	3.9 mg/L
Total Nitrogen	6.4 mg/L
MLSS Battery A	3,200 mg/L
Supplemental Carbon	210,000 lb COD/day

PARAMETER	EFFLUENT CONCENTRATION
BOD	4.3 mg/L
TSS	5.7 mg/L
Ammonia	0.3 mg/L
NOx	2.0 mg/L ⇩
Total Nitrogen	4.7 mg/L ⇩
Ortho-P	0.2 mg/L
Total Phosphorus	0.9 mg/L
MLSS Battery A	3,700 mg/L ⇧
Supplemental Carbon	228,000 lb COD/day ⇧

THORNTON PUMP-BACK (BASE CASE W/ EBPR)

Parameter	Value
% Basins Unaerated (Volume)	25%
Solids Handling Operations	Gravity Conc, Centrifuge, Anaerobic Digester
RAS Flow	100% influent
DO in Aeration	2.0 mg/L

PARAMETER	EFFLUENT CONCENTRATION
BOD	4.7 mg/L
TSS	7.8 mg/L
Ammonia	0.2 mg/L
NOx	4.3 mg/L
Total Nitrogen	6.5 mg/L
Ortho-P	1.1 mg/L
Total Phosphorus	1.4 mg/L
MLSS Battery A	1,500 mg/L

THORNTON PUMP-BACK W/ EBPR & CARBON ADDITION

Parameter	Value
% Basins Unaerated (Volume)	25%
Solids Handling Operations	Gravity Conc, Centrifuge, Anaerobic Digester
RAS Flow	100% influent
DO in Aeration	2.0 mg/L

PARAMETER	EFFLUENT CONCENTRATION
BOD	5.5 mg/L
TSS	8.0 mg/L
Ammonia	0.3 mg/L
NOx	3.5 mg/L ⇩
Total Nitrogen	5.7 mg/L ⇩
Ortho-P	0.1 mg/L ⇩
Total Phosphorus	0.8 mg/L ⇩
MLSS Battery A	2,100 mg/L ⇧
Supplemental Carbon	48,000 lb COD/day ⇧

SUMMARY

PROCESS MODEL RUN	EFFLUENT ORTHO-P	EFFLUENT TOTAL P	EFFLUENT TOTAL NITROGEN	SUPPLEMENTAL CARBON	BATTERY A MLSS
Base Case	2.4 mg/L	2.9 mg/L	8.7 mg/L	0 lbCOD/d	2,220 mg/L
Install Baffling and Add Supplemental Carbon	0.2 mg/L	0.8 mg/L	7.2 mg/L	232,000 lbCOD/d	3,200 mg/L
Optimize DO, Install Baffling and Add Supplemental Carbon	0.3 mg/L	0.9 mg/L	6.4 mg/L	210,000 lbCOD/d	3,200 mg/L
Optimize RAS Flow and DO, Install Baffling and Add Supplemental Carbon	0.3 mg/L	0.9 mg/L	7.8 mg/L	193,000 lbCOD/d	3,100 mg/L
Optimized EBPR with Phosphorus Recovery from Centrate	0.2 mg/L	0.8 mg/L	6.9 mg/L	99,200 lbCOD/d	2,300 mg/L
Chemical Phosphorus Removal in Batteries A, B and C with Optimized EBPR in Batteries E1 and E2	0.3 mg/L	0.8 mg/L	10.6 mg/L	49,000 lbCOD/d	2,300 mg/L
Process Modeling of Additional Scenarios					
Nitrogen Removal to 6 mg/L	0.2 mg/L	0.9 mg/L	4.7 mg/L	228,000 lbCOD/d	3,700 mg/L
TCR Pump back Existing Plant	1.1 mg/L	1.4 mg/L	6.5 mg/L	0 lbCOD/d	1,500 mg/L
TCR Pump Back with Optimized EBPR without Phosphorus Recovery	0.1 mg/L	0.8 mg/L	5.7 mg/L	48,000 lbCOD/d	2,100 mg/L
TCR Pump Back with Optimized EBPR with Phosphorus Recovery	0.5 mg/L	0.9 mg/L	6.0 mg/L	0 lbCOD/d	1,800 mg/L

CWRP MODELING CONCLUSIONS

- Calibrated GPS-X model used to assess various nutrient removal upgrades/operational scenarios
  - Need jar testing for more accurate wastewater characteristics analysis and determine chemical dosing
- Useful for initial comparison of alternatives (planning, feasibility studies)
  - Design (sizing) of facilities not optimized
- Design of selected alternative requires further process modeling
  - Evaluate particular reactor sizes and multiple loading scenarios
  - Evaluate different process configurations, e.g., PS and RAS fermentation
- Investigate cost benefit in lowering DO in aeration tanks
- Investigate cost benefit in lowering RAS flow to 50%
- Removing P from side-streams/recycles has the most significant impact on lowering amount of carbon addition.

CONCLUDING REMARKS

CONCLUDING REMARKS

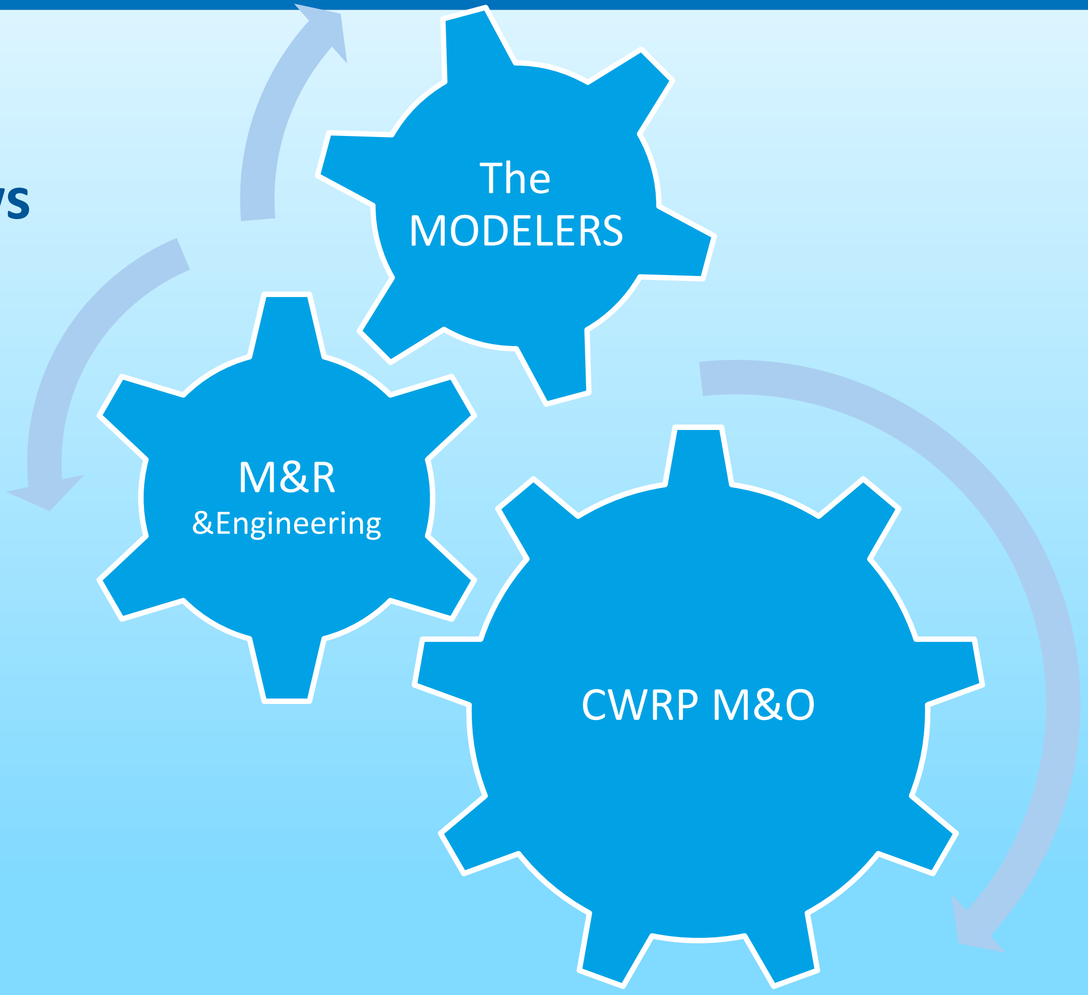
- Process model utilized for 1.0mg/L Total Phosphorus limit scenarios
- IEPA will soon issue new modified permits for CWRP, SWRP & OWRP
  - More stringent Total Phosphorus limits
    - 0.5 mg/L annual geometric mean
  - Require feasibility studies
  - Require modeling

We have the models!

ACKNOWLEDGEMENTS

M&R
- Judy Moran-Andrews
- Cindy Qin
- Joe Kozak
- Victor Olchowka
- Jonathan Grabowy
- William An
- M&R Lab Personnel

Engineering
- Junli Bai
- Glenn Rohloff



The Modelers (B&V)
- Amanda Burns
- Bikram Sabherval
- Steve Arant

Supporting Subs
- MPR Engineering
- McBride Engineering

Plant Operators:
- Sherry Kamenjarin
- Don Rohe
- Al Nichols

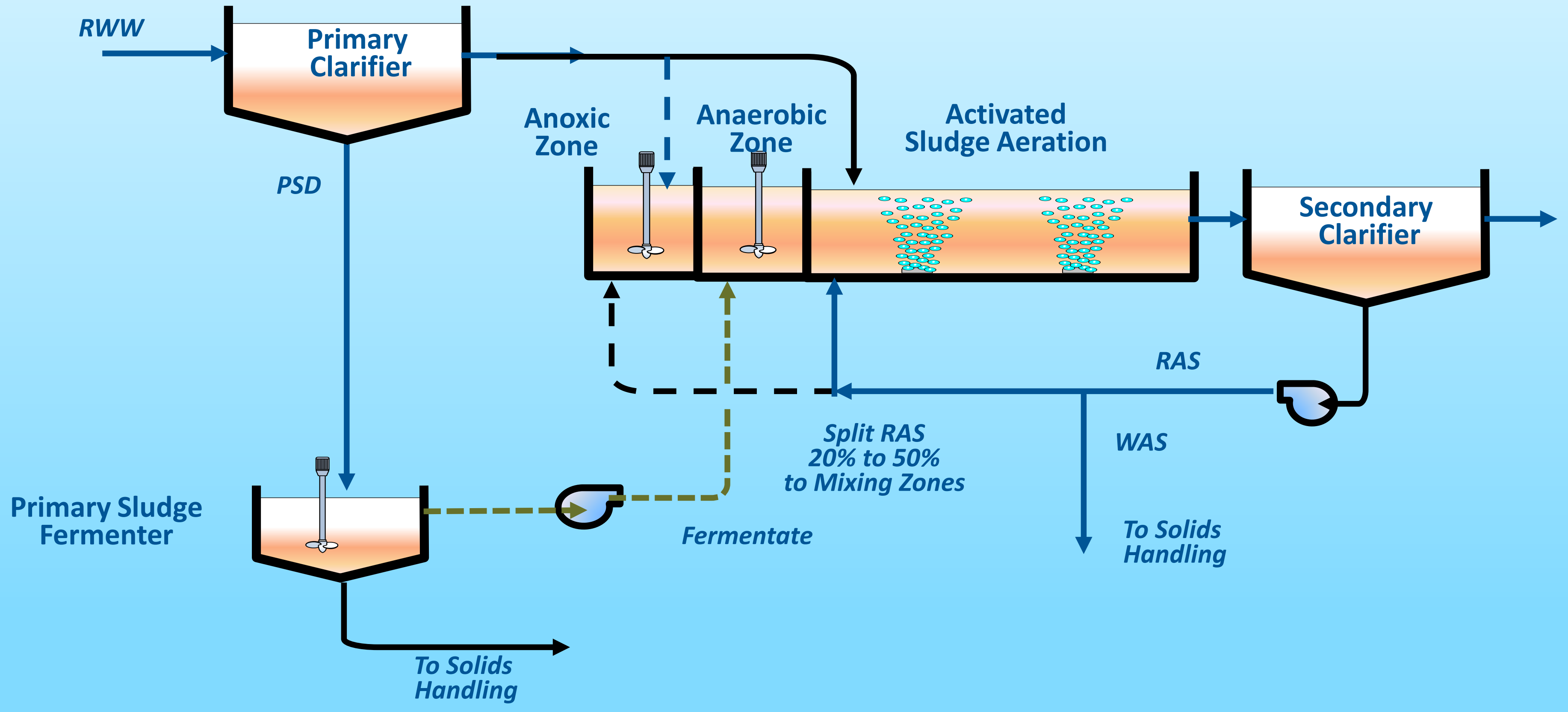
CWRP M&O Management
- Brian Perkovich
- Pat Connolly
- Reed Dring

Metropolitan Water Reclamation District of Greater Chicago

DEVELOPMENT OF PROCESS AND HYDRAULIC MODELS FOR THE CALUMET WRP AS PLANNING TOOLS

DANIEL SAŁABAJ, SENIOR CIVIL ENGINEER MWRDGC
STEVE ARANT, BIKRAM SABHERWAL AND AMANDA BURNS, BLACK & VEATCH

SIDESTREAM RAS FERMENTATION



PROCESS MODEL CALIBRATION TYPICAL RATIOS

1. Kinetic parameters set to default

Influent Parameter	Units	Mean	Std%	Median	Min	Max	Calumet WRP
N_T/COD_T	gN/g COD	0.09	0.21	0.09	0.05	0.20	0.09
NH_4/N_{TKN}	gN/g N	0.68	0.10	0.7	0.41	0.93	0.63
P_T/COD_T	gP/g COD	0.016	0.22	0.015	0.01	0.077	0.023
PO_4/P_T	gP/g P	0.60	0.18	0.6	0.3	0.8	0.8
COD_T/BOD_5	gCOD/gBOD	2.00	0.13	2.00	1.24	3.7	1.7
COD_S/COD_T	gCOD/gCOD	0.36	0.23	0.39	0.2	0.6	0.59
TSS/COD_T	gTSS/g COD	0.51	0.16	0.5	0.35	1.19	0.58
COD_X/VSS	gCOD/gVSS	1.73	0.12	1.7	1.3	2.2	1.5
VSS/TSS	gSS/gSS	0.77	0.10	0.8	0.55	0.9	0.75
BOD_5/BOD_{ULT}	gBOD/gBOD	0.66	0.15	0.66	0.45	0.85	0.72