THE USE OF PROCESS MODELING SOFTWARE IN INDUSTRIAL WASTEWATER TREATMENT - CASE STUDIES THAT ADDRESS AIR EMISSION, METALS REMOVAL AND WATER REUSE

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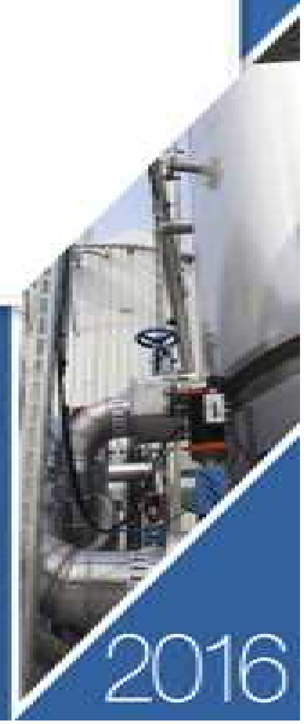
International Petroleum 23RD IPEC Environmental Conference



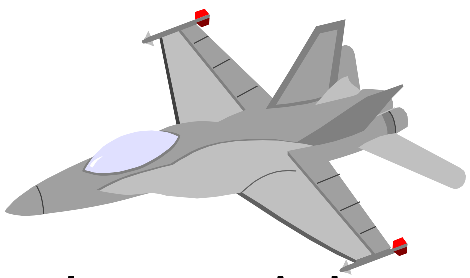
Agenda

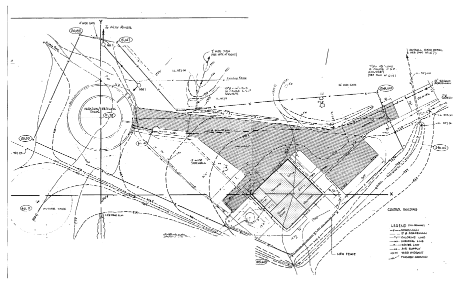
- Overview of industrial water & wastewater treatment
- What is modeling?
- Treatment Challenges
- Role of process models
- Case studies
- Conclusion

What Is Modeling?

What is a model?

- a representation of a system that can predict *some* system behavior





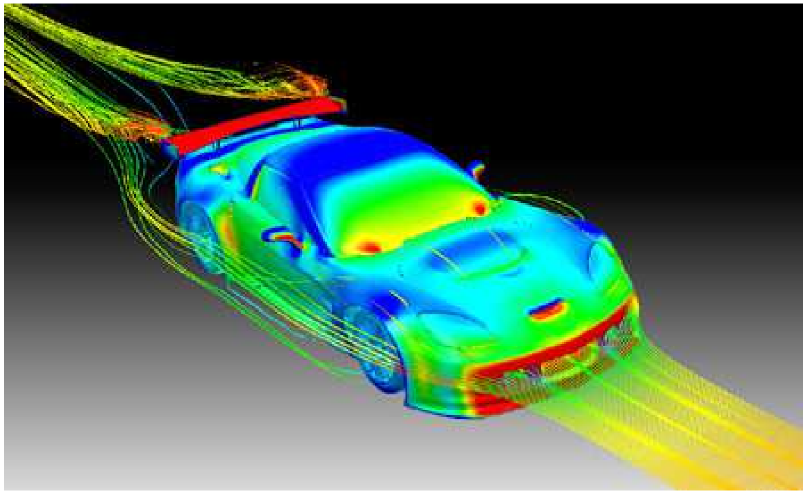
```
lb20..continue
      recnum&o=recnum&o+1
      read(textline&o,*) rinletx&o(recnum&o),rinlety&o(recnum&o),&
                 rinletz&o(recnum&o)
      if((rinletx&o(recnum&o).eq.0).and.(rinlety&o(recnum&o).eq.0)&
                 .and.(rinletz&o(recnum&o).eq.0)) then
          write(*,frmt2) o
      else
          write(*,frmt3) o,recnum&o,&
rinletx&o(recnum&o),rinlety&o(recnum&o),rinletz&o(recnum&o)
      endif

      frmt2..format('Tank #',I2,': No Recycle Inlets')
      frmt3..format('Tank #',I2,': Recycle #',I1,&
                       ' coordinates are ',I2,',',I2,',',I2)
      read(61,'(a)') textline&o
      if (textline&o(1:5).ne.'aerat') goto lb20
```

Why model a system?

- stand in for the real system (system may not exist or not feasible to “test” the system)

Models Reduce Complexity, Cost & Risk



Why Use Modeling?

- **Handles** complexity with relative ease
- **Cheaper** than building/modifying the real system
- **Easier** than carrying out testing on existing systems
- **Risk-free** - see the consequences **before** implementation
- Get results **quickly**

Drivers for Water & Wastewater Treatment

Regulatory Drivers

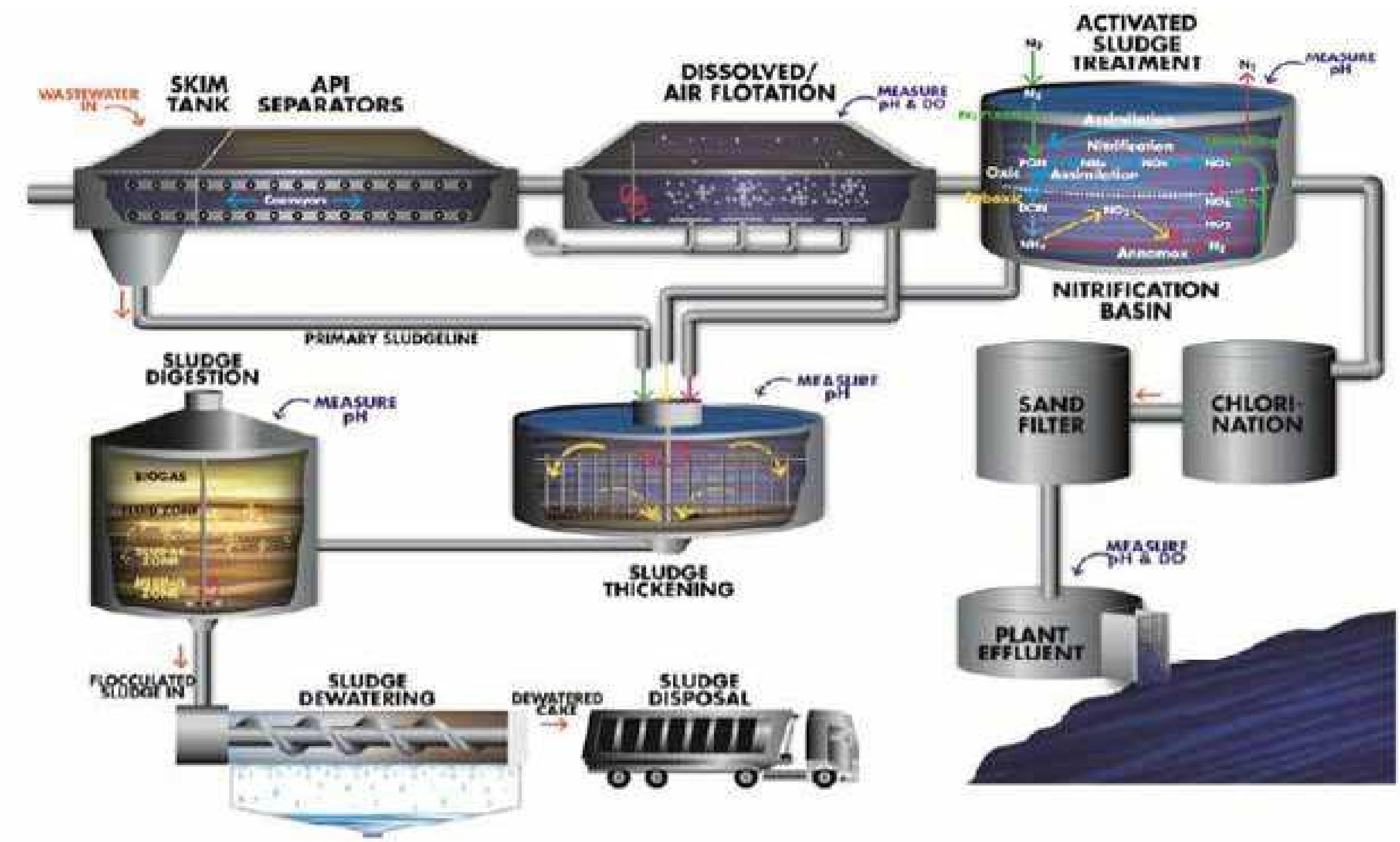
Phase	Regulations
Liquid	NPDES (CWA)
Solids	NPDES
Air	NESHAPS (CAA)

Sustainability & Economic Drivers

Industrial Wastewater Treatment

Wastewater Treatment

The Activated Sludge Process (Refinery Wastewater)



The last 100 years of Wastewater treatment

1914
Ardern & Lockett invent Activated Sludge Process

1950s
Cuyahoga River Problems

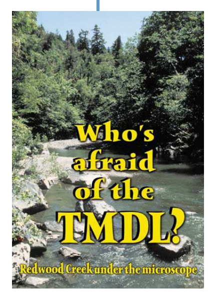

CLEVELAND PLAIN DEALER
OIL SLICK FIRE RUINS FLATS SHIPYARD
Surly Ohio Pen Rebels Fed at Gunpoint

1970
EPA Established

1972
Clean Water Act
COD removal

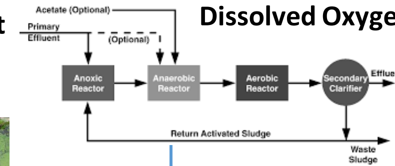
1990s
Growing concern about Nutrients (N,P) & NESHAPS

MBR

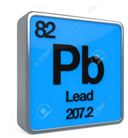


2001
Regulations for N, P added to NPDES permits

Multistage, varying Dissolved Oxygen

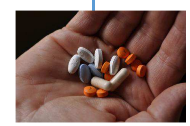


Metals



Nutrient recovery

Water Reuse

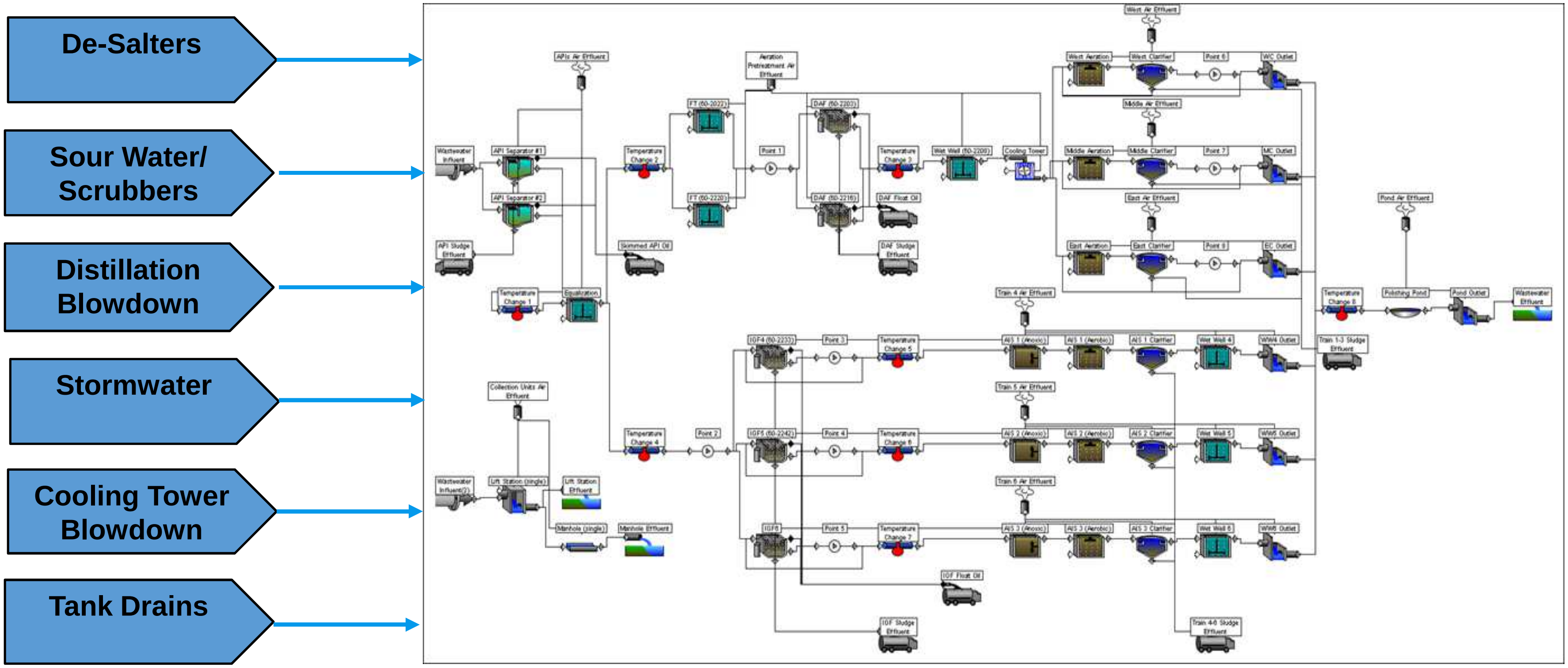


CEC

Removal of solids and large organic matter → Removal of soluble organics → Removal / Recovery of N,P

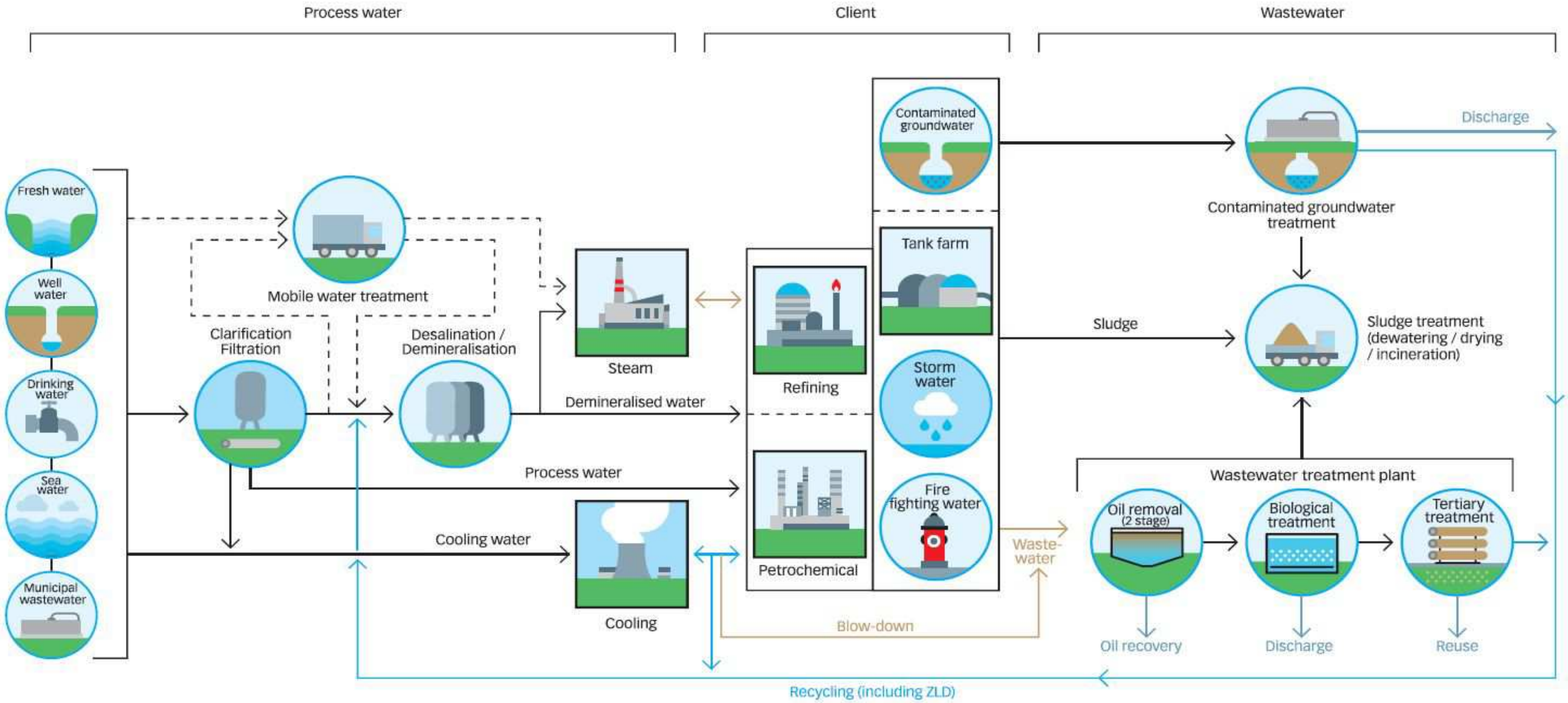
Increasing Complexity, Cost

Refinery Wastewater Systems



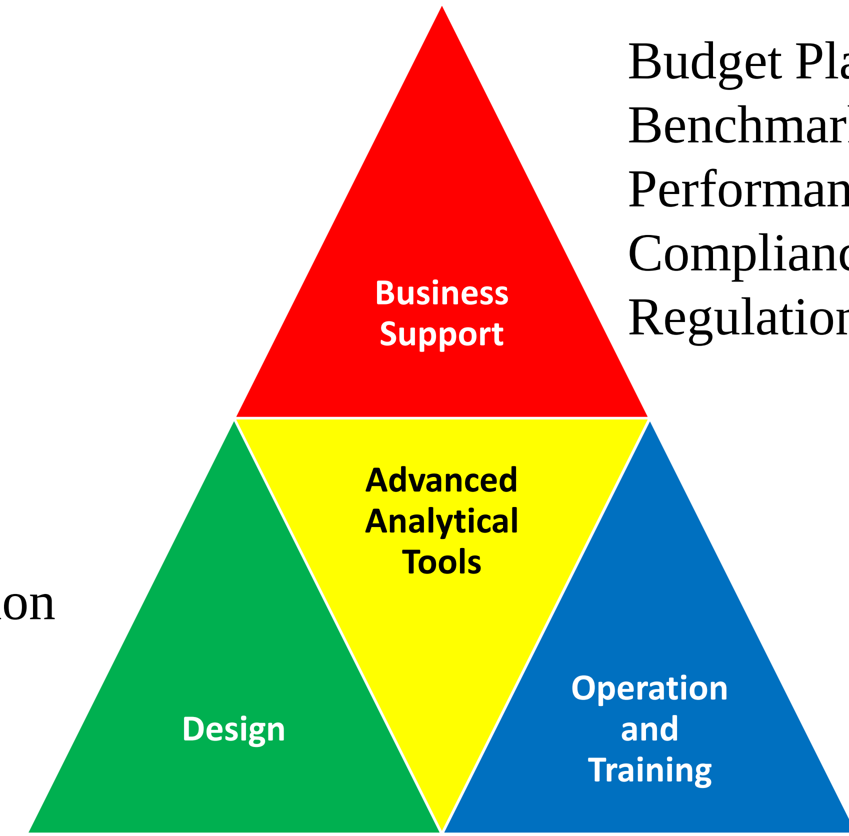
- Industrial wastewater comes from a variety of sources
- Highly complex mix of contaminants

Increasing complexity of water management



- Balance multiple sources
- Match treatment process to need / use
- Meet regulatory obligations

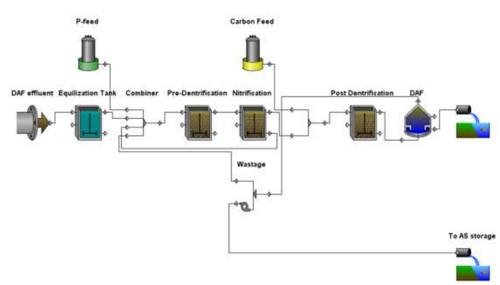
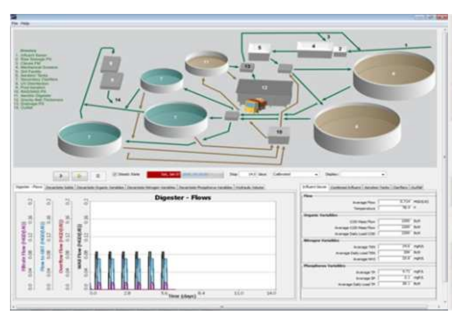
Use of Models in Wastewater Treatment



Budget Planning
Benchmarking
Performance reports
Compliance
Regulation

Technology evaluation
Capacity analysis
Optimization
Troubleshooting

Operation Support
Knowledge capture
Resource building
Succession planning


Hydromantis Software Solutions

GPS-X

Dynamic Wastewater Treatment Modeling

- Process design
- Energy models
- GHG models
- Controller models
- Real-time
- Optimization

TOXCHEM

Predict & Report Toxic Emissions

- **Volatilization**
- **Adsorption**
- **Biodegradation**
- **Metals**
- **Organics**

SimuWorks

Operator Training and Plant Analysis System

- Customized interface
- GPS-X™ platform
- Operational support
- Planning
- Training

WATPRO

Water Treatment Modeling

- Process design
- Disinfection
- Chemicals usage

CAPDET Works

Preliminary Design and Costing

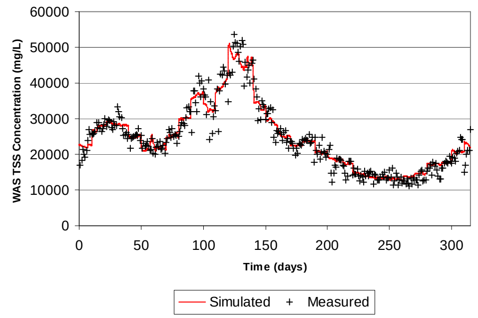
- Design & sizing
- Capital cost
- Operation cost
- Customizable Cost database
- Life cycle costs
- Sensitivity

ODM

Online Disinfection Manager

- Optimization
- Real time dosage estimation
- Minimize byproducts, THMs

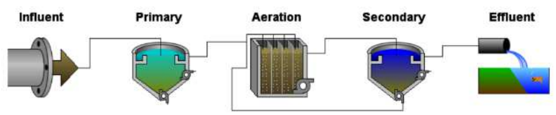
How Models are Used



Create Model

Calibrate to Known Performance

Simulate Different Scenarios



$$\frac{\mathrm{d}x_\ell}{\mathrm{d}t} = \frac{\mu_\mathrm{m} S_\mathrm{e}}{K_\mathrm{s} + S_\mathrm{e}} x_\ell - k_\mathrm{d} x_1$$

- **Hydraulic model**
- **Biological model (ASM, ADM, Mantis2)**
- **Aeration model**
- **Equilibrium chemistry**
- **Reaction kinetics**
- **Mechanical & Thermal effects**
- **Economic model**

Simulate "Base Case"

Compare and Evaluate

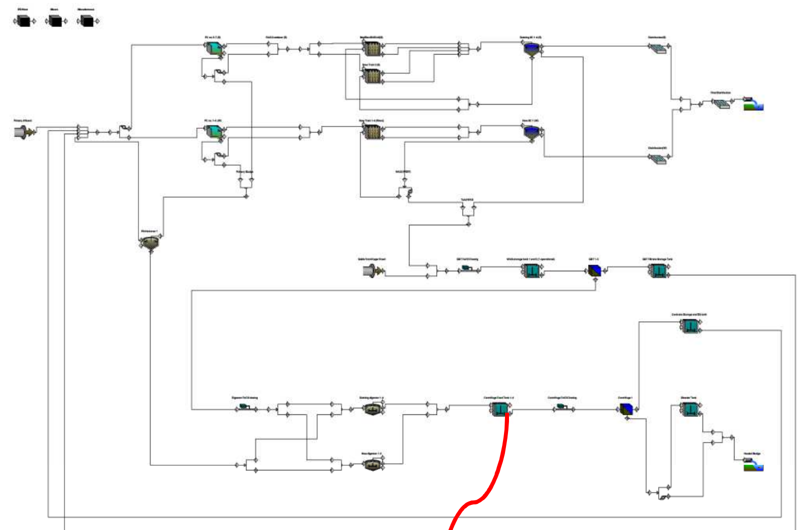
Models can be used to support training

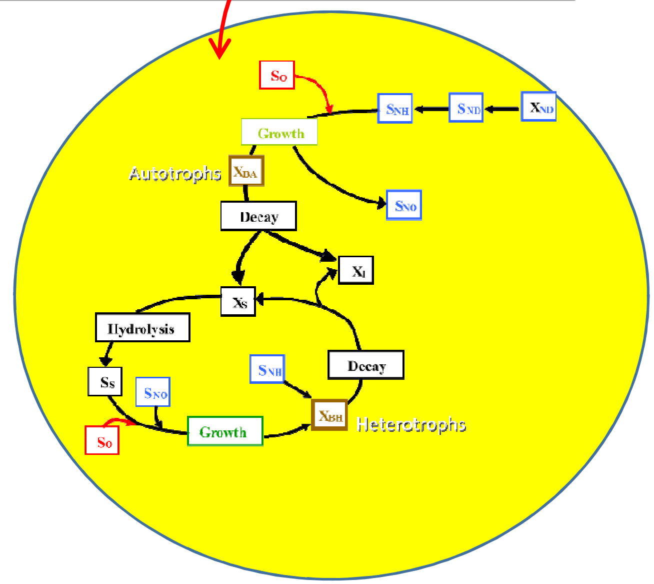
GPS-X™

Dynamic modeling and simulation tool

Real Plant

Virtual Plant





- Predicting and Assessment of Water Quality
- Water reuse, process water treatment
- Technology Evaluation (process, aeration, etc.)
- Limit of Technology
- Assessment of Compliance
- Operating cost estimates
- Optimization – process & cost

Preliminary Design & Costing

- **<u>Designs</u>** individual unit processes based on a user specified treatment plant layout
- **<u>Costs</u>** each unit process (±15%)
- **<u>Design Override Capability</u>** user can fine-tune design and/or costing
- Uses
  - Capital planning
  - Process & design screening
  - Life cycle cost analysis
  - Risk evaluation
  - Sustainability cost assessment
  - Technology screening

CapdetWorks™

Work Flow

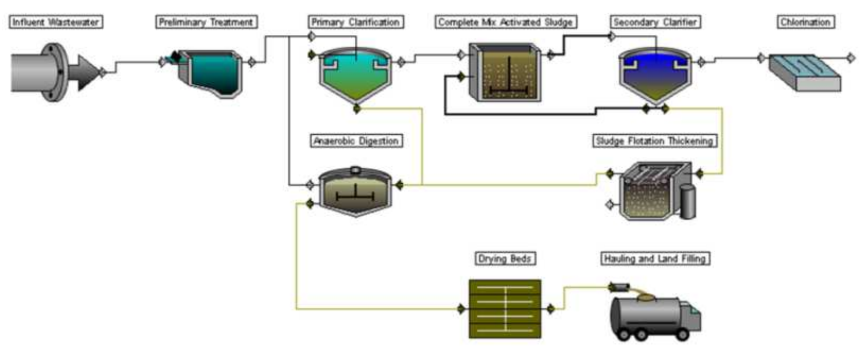
Layout Specification for a treatment objective

↓

Process Design Calculations
(ex: Tankage, Air requirements…)

↓

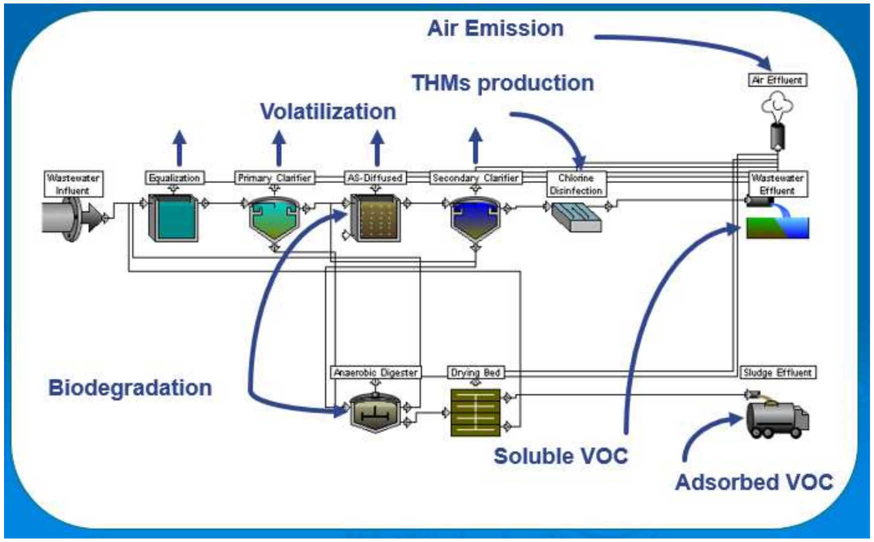
Cost Calculations (Structural, equipment, O&M)



TOXCHEM™

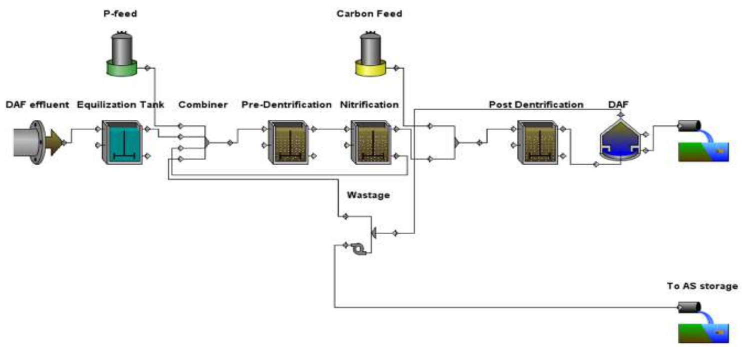
Contaminant Fate & Transport

- Estimates fate and emission rates of organic compounds and metals from collection and treatment system components
- Used since 1991, +840 compounds & metals
- Specified in regulations (CAAA, SARA – 40 CFR, Part 63)
- Customizable (processes, compounds, parameters)
- Applications
    - Contaminant fate
    - Technology evaluation
    - Parameter estimation / validation



Customized Operations & Training Tool

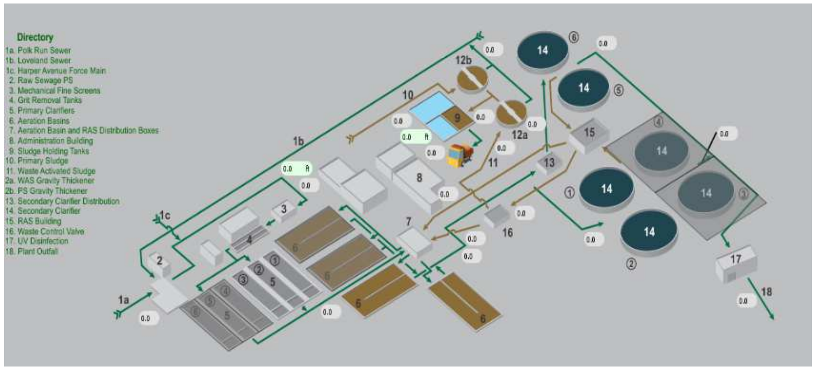
GPS-X™ Model of the facility



- "Flight simulator" concept
- Replicate pilot or full scale
- Scenario planning
- Operator training
- Troubleshooting & optimization

Bird's eye view of a wastewater plant

SimuWorks™ 3D interface of the facility

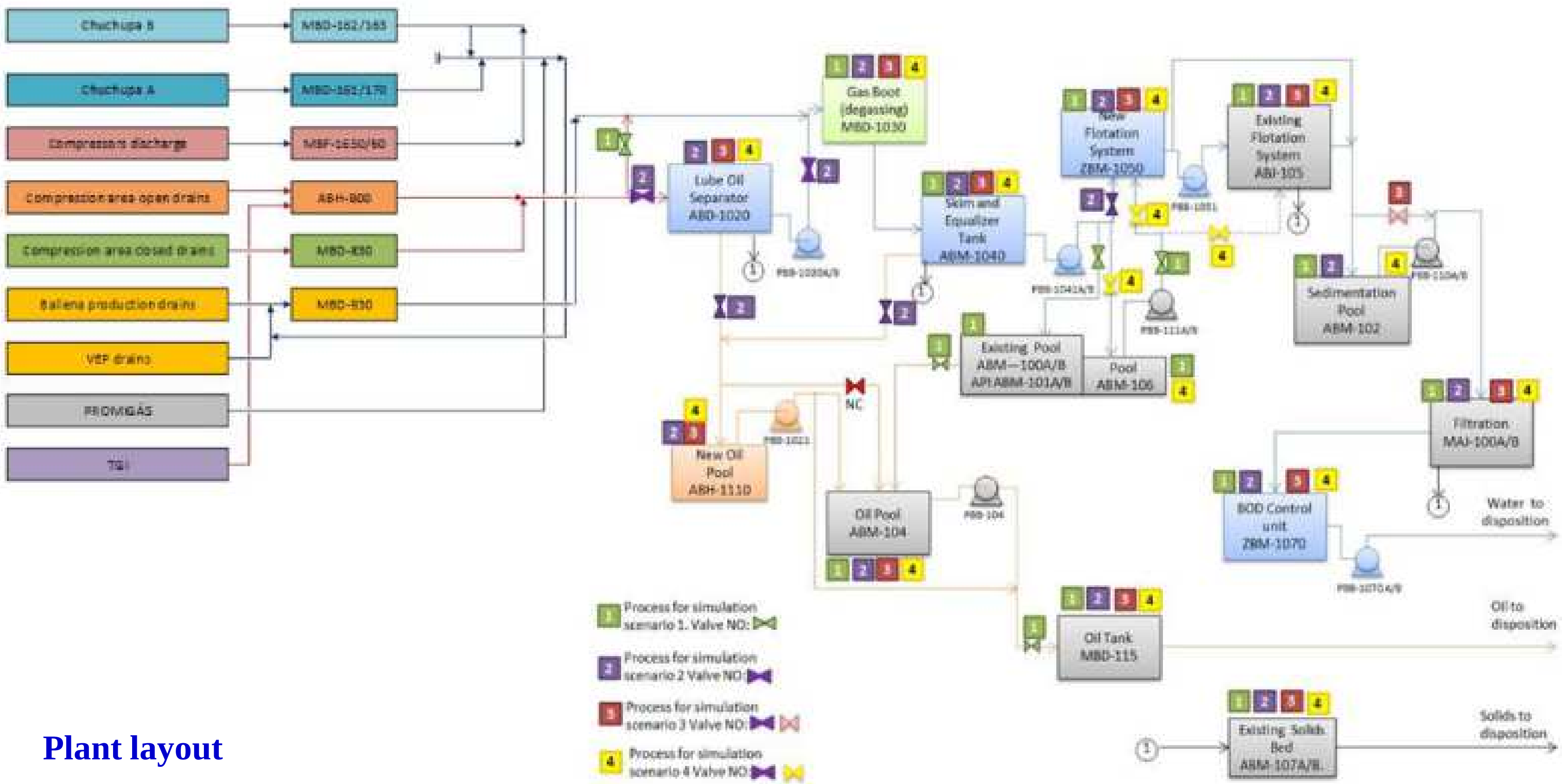


Training Benefit

…. Rotation in the WWTP

"It took me about 5-6 months to understand the activated sludge process" – Engineer at Major Refinery Facility

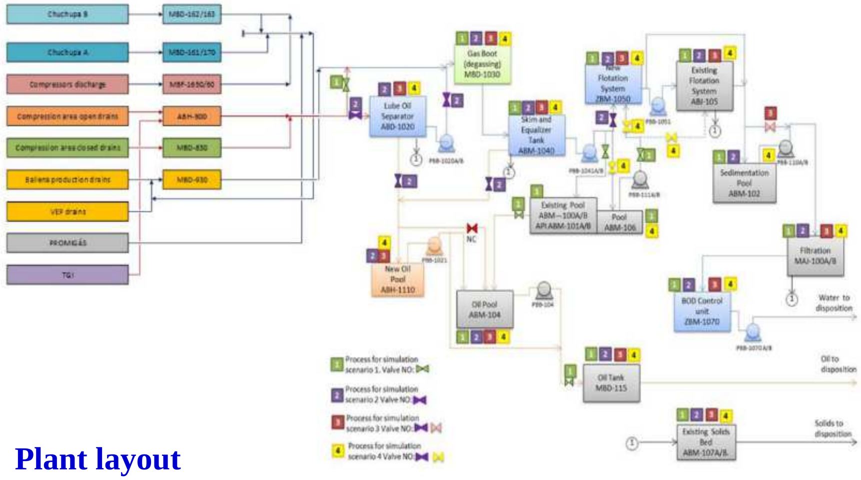
Case Study 1: Develop a calibrated model of a petroleum refinery WWTP



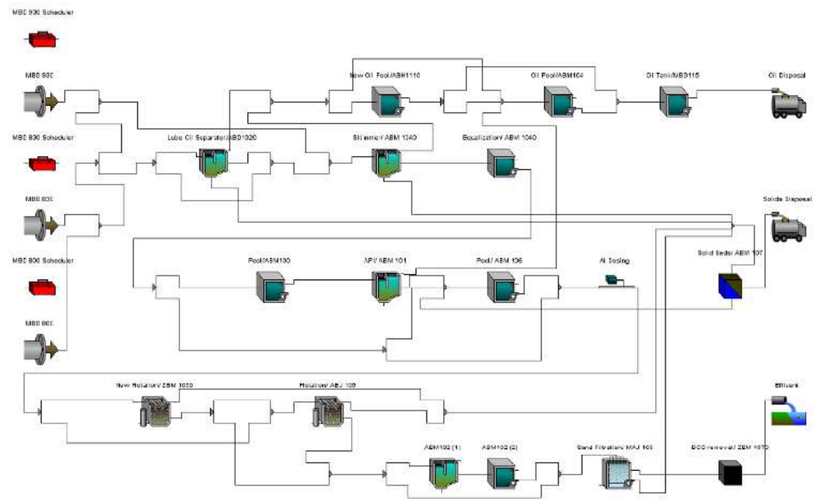
Plant layout

Goal: Support plant analysis, decision making and process optimization

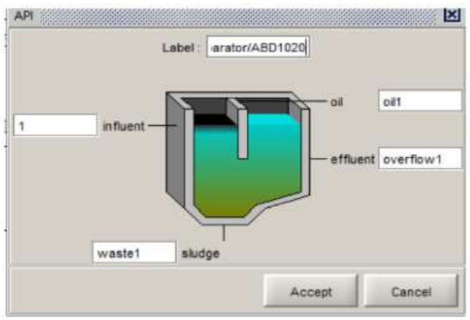
Case Study 1: Develop a calibrated model of a petroleum refinery WWTP



Plant layout



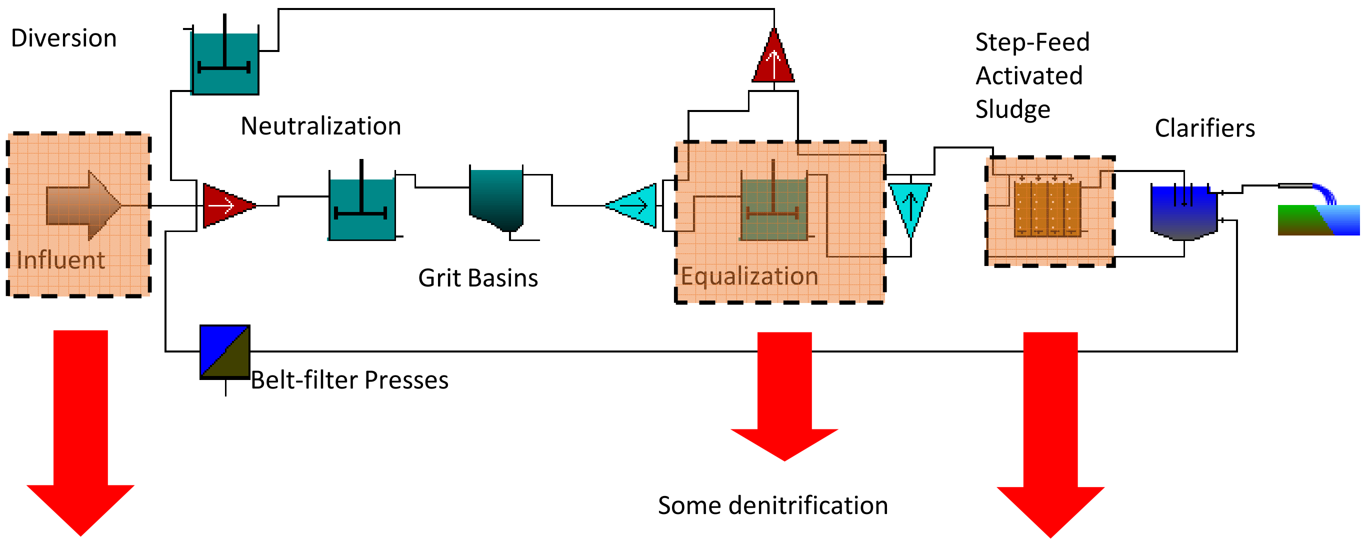
New API unit developed



- GPS-X™ provided accurate representation of WWTP
- Tool used to support decision making & water management – significant savings

Case Study 2: Development of model for assessing impacts of loading changes, operational changes, toxic spills, etc.

Chemical Manufacturing Facility, WWTP: Treats waste from plant that manufactures chemicals, plastics, and synthetic fibers



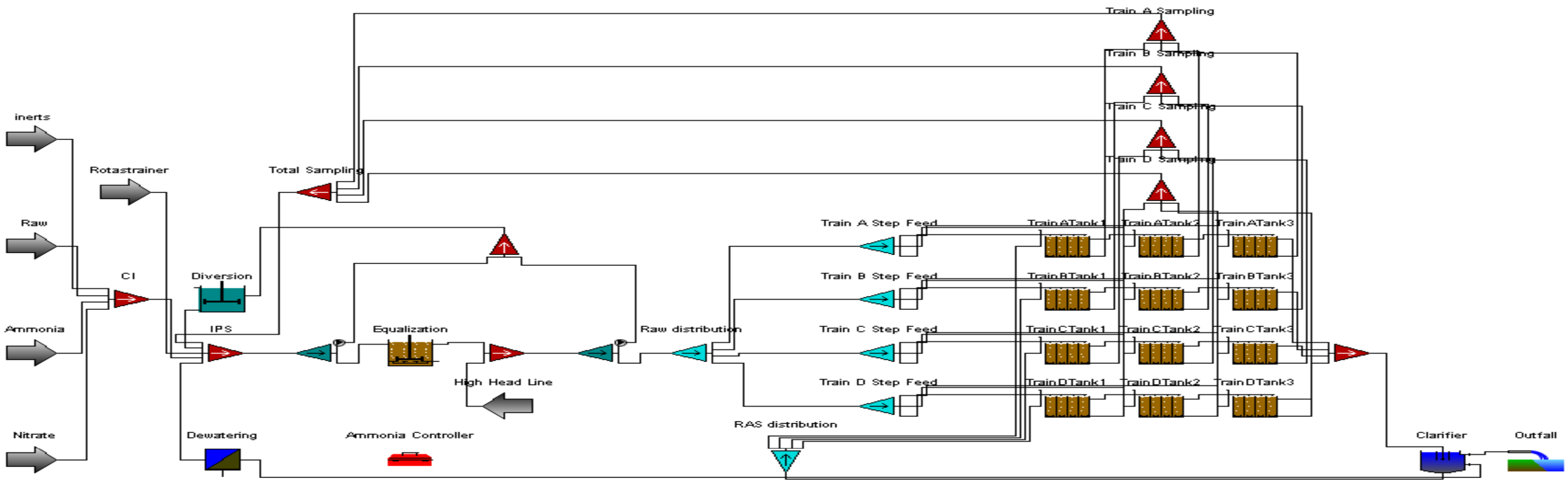
- Q = 27 MGD
- Organic acids & alcohols (COD = 1700 mg/L)
- Solids (TSS = 140 mg/L)
- Ammonia, nitrates, phosphates
- Elevated temperature 80 -100 ^{o}F

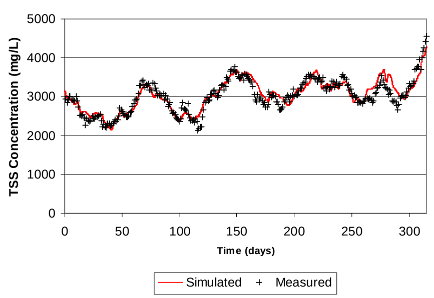
- 4 trains with 3 aeration basins each
- Step feed strategy varies
- Mixed liquor sampled from each basin

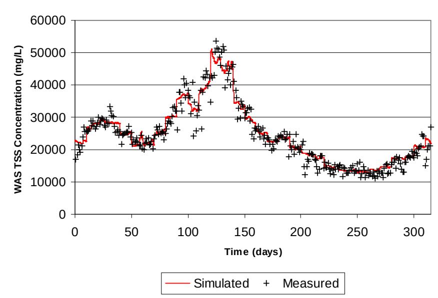
Goal: Develop optimization strategy for dealing with Spills & reliably meet regulations

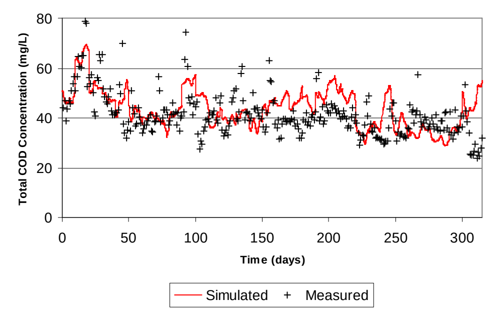
EASTMAN

Case Study 2: Model Setup - GPS-X™ Layout





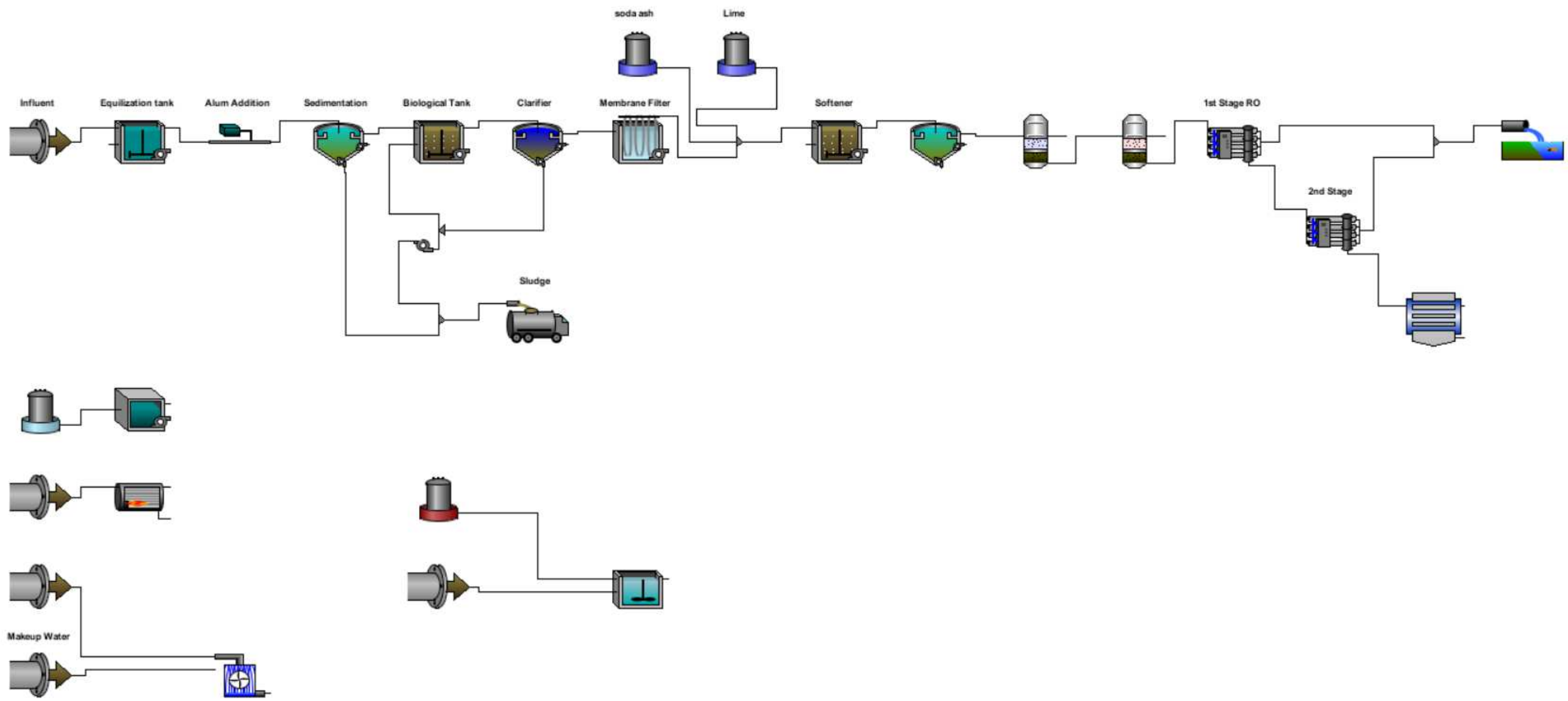




EASTMAN

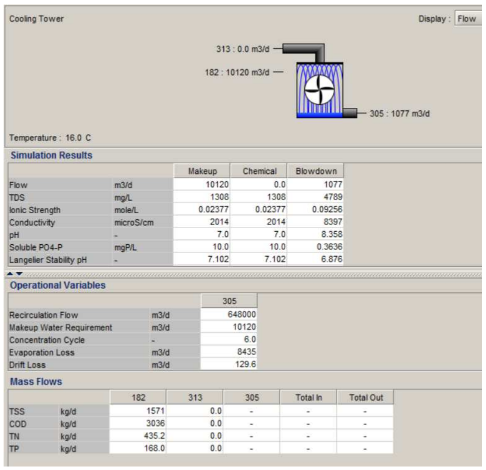
- Optimal diversion strategy was developed
- Added simultaneous nitrification/denitrification to ASM3 to handle observed denitrification in aeration basins
- Facility reliably met treatment goals

Case 3: Industrial Facility with Water Reuse

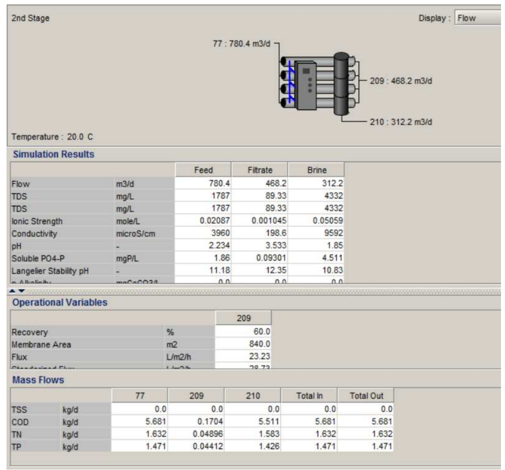


- Goal: Develop in-house water management platform to offset $200k per year cost

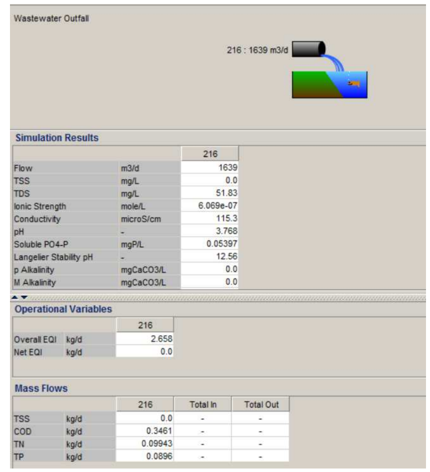
Case 3: Sample Output



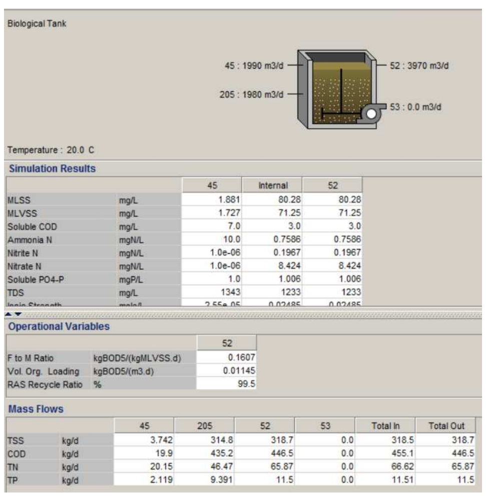
Make up water requirement



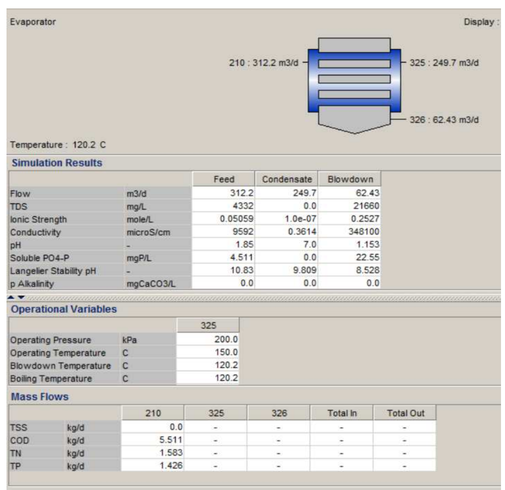
RO Process Treatment



Effluent Water Quality



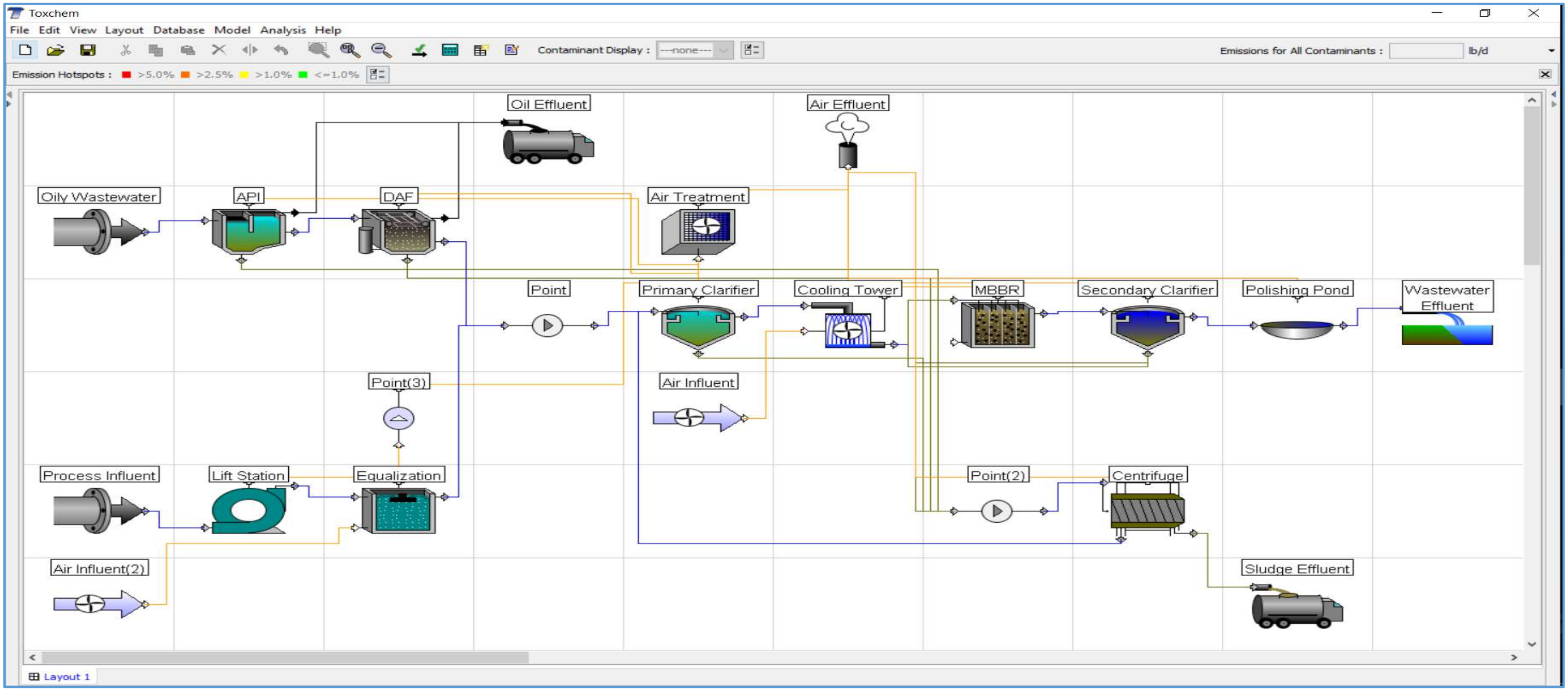
Biological Process Tank



Evaporator

- Robustly characterizes Physico-chemical and biological process
- Detailed cost and energy footprint
- Significant savings (< 1 year payback)

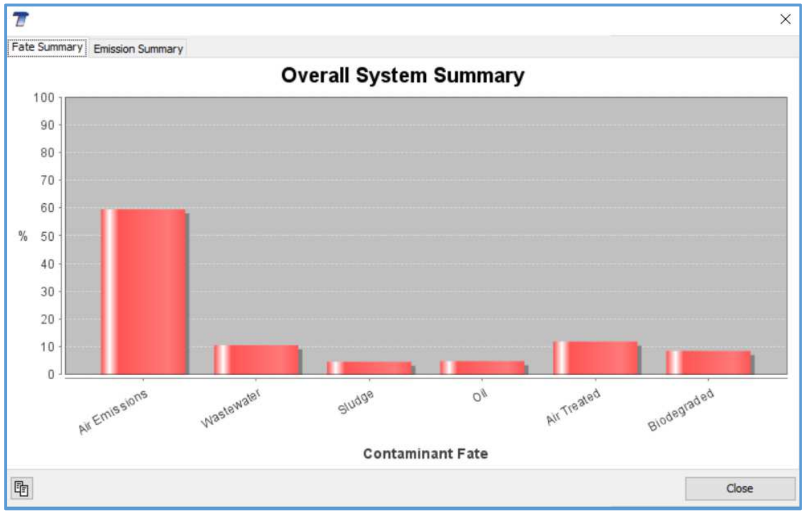
Case 4: Characterizing Emissions With Toxchem

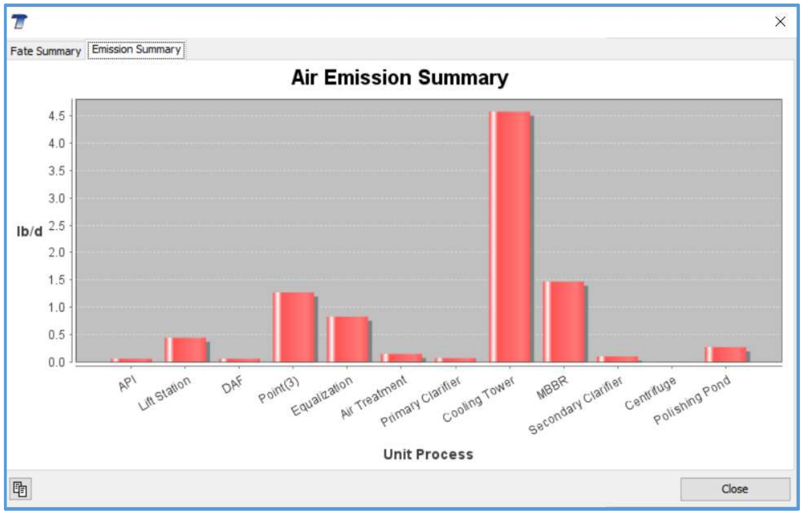


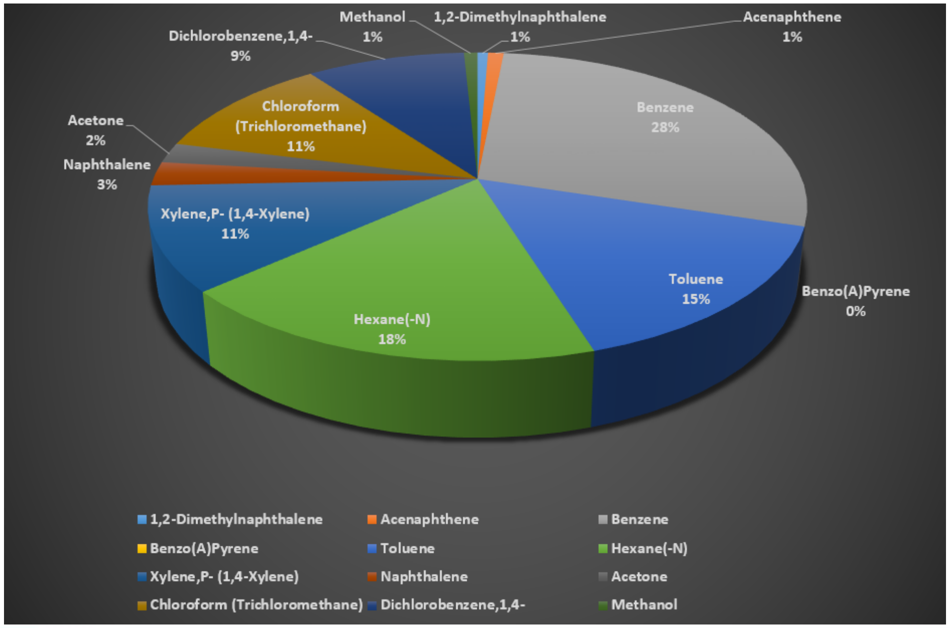
- 50,000 m^3/day of flow
- Multiple influent streams, with 13 contaminants across both streams
- Several unique process treatment steps
- **Goal: Determine total air emissions and composition for CAA reporting**

Characterizing contaminant Fate

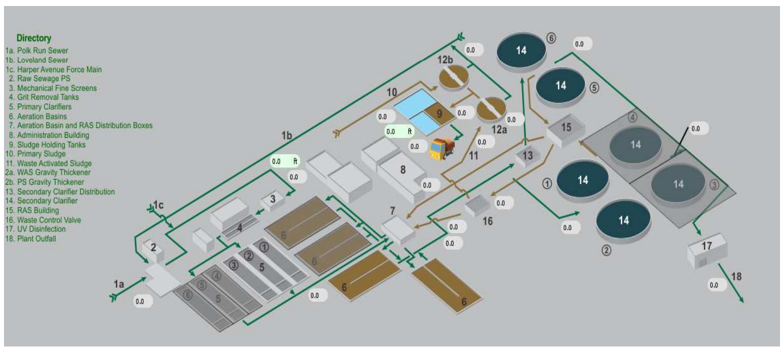
Benzene







Case 5: Wastewater "Flight Simulator" for Agency Operating Over 200 Facilities



- Advanced operator training and education
- Identification and validation of plant optimization and cost saving strategies
- Project and risk analysis
- Key decision making support tool for all levels of management
- Engagement with stakeholders

Conclusion

- Regulatory, sustainability and economic drivers are making water management more challenging
- Advanced tools and solutions are required to meet current & emerging challenges
- Process models are an effective solution for meeting water & wastewater challenges
- Modeling solutions are applicable to all segments of the industry

Questions

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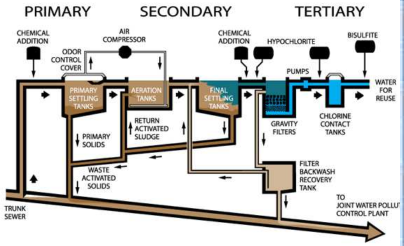
Use of Process Models



	GPS-X				WATPRO	
PROCESS DESIGN & OPTIMIZATION						
Preliminary Plant Design & Sizing	●	●				
Detailed Plant Design & Sizing	●				●	
Process Control & Optimization	●			●		
Process Technology Evaluation & Comparison	●	●	●		●	
Aeration System Sizing	●					
Biosolids Pretreatment	●					
Nutrient Removal & Recovery	●	●		●		
Co-Digestion & Biogas Generation	●			●		
GHG Footprint, Energy Optimization	●			●	●	
Limit of Technology Evaluation	●	●	●			
Drinking Water Treatment Process Modeling	●				●	
Compliance & Risk Assessment	●	●	●	●		
Disinfection – Water & Wastewater	●				●	●
AIR EMISSIONS MODELING						
VOC & Air Emission Modeling			●			
Contaminant Fate Estimation	●		●			
Regulatory Reporting (NESHAP)			●			
COSTING						
Life Cycle Analysis	●	●	●			
Life Cycle Cost Analysis	●	●	●			
Capital Cost Estimation		●				
Operating Cost Estimation	●	●				
Plant Layout & Process Flow Diagrams	●	●	●	●	●	
OPERATIONS & TRAINING						
Operator Training & Knowledge Management	●			●		
Customized Facility Interface (3D & SCADA)				●		
Dynamic Data Exchange	●			●		●
Online Disinfection Management				●		●