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Water Environment Federation

Wastewater Treatment Modeling 101

Wednesday, May 14th, 2014

1:00 – 3:00 pm Eastern

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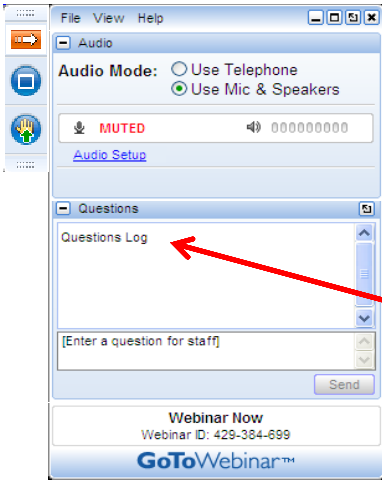
How to Participate Today



- **Audio Modes**
  - Listen using Mic & Speakers
  - Or, select "Use Telephone" and dial the conference (please remember long distance phone charges apply).
- **Submit your questions using the Questions pane.**
- **A recording will be available for replay shortly after this webcast.**

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Today's Moderator

John B. Copp, Ph.D., Primodal Inc.

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Modeling 101 – May 14, 2014

Introduction to Modeling

- Speakers:
  - John B. Copp (Primodal Inc.)
  - Andrew Shaw (Black & Veatch)
  - Peter Vanrolleghem (Université Laval)
  - Leiv Rieger (InCtrl Solutions)
  - Ken Brischke (MWH)

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Introduction to Modeling

- Questions:
  - What are the benefits of modeling?
  - What is modeling?
  - How do I structure a modeling project?
  - What are the data requirements?
  - What modeling pitfalls exist?

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Modeling Benefits

Andrew Shaw, P.E.
Black & Veatch

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Benefits of Good Modeling

- Cost benefits
- Modeling for design
  – simple applications
  – more complex applications
- The GMP Application Matrix
- Conclusions

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Cost Benefits

- Modeling is cheaper than piloting
- Modeling is much cheaper than full-scale
- Try things in *Virtual Space* before trying it in *Real Space*

$5k-$50k → $50k-$500k → $500k - ???

Model → Pilot → Full-scale

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Design

- BNR design
- Dynamic models give us max/min and averages
  - Blower sizing
  - Diffusers
  - Pumping
- Sensitivity analyses

United States Environmental Protection Agency | Office of Research and Development Washington, DC 20460 | EPA/600/R-10/100 August 2010

EPA

Nutrient Control Design Manual

"…modeling is the recommended approach for designing WWTP upgrades for biological nutrient removal (BNR) because of (1) its flexibility in enabling designers to quickly test many different configurations and operating scenarios and (2) its ability to simulate treatment performance under a wide range of conditions using dynamic modeling."

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Simple Applications

- Sludge production
- **Blower sizing**
- Long-term performance

Birthday Cake Input

PD/MM Load Factors:

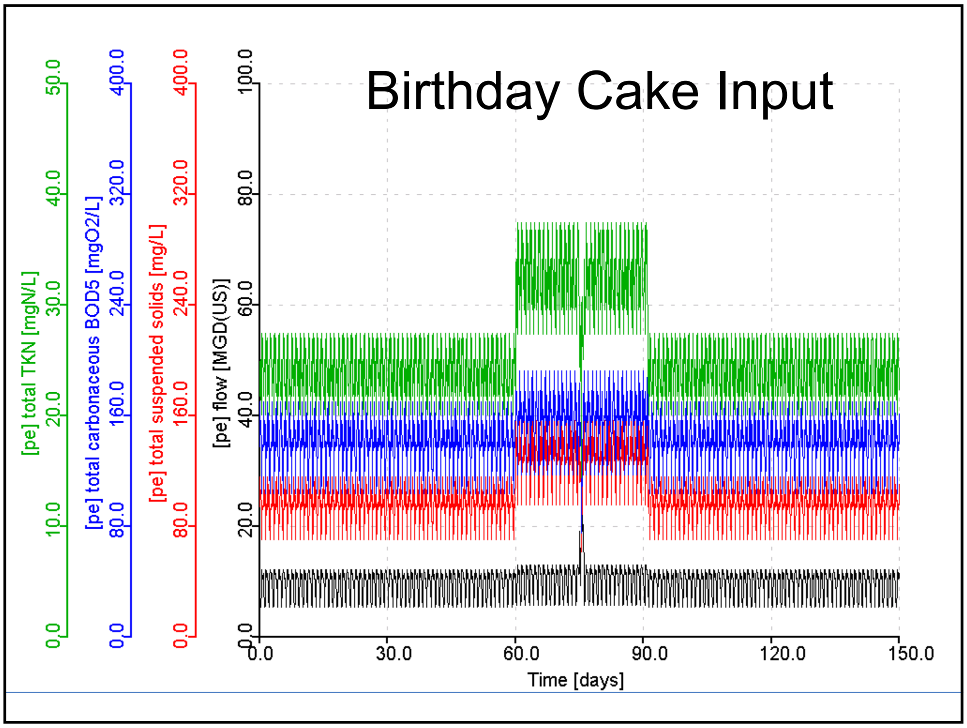
BOD =	1.5
TKN =	1.4

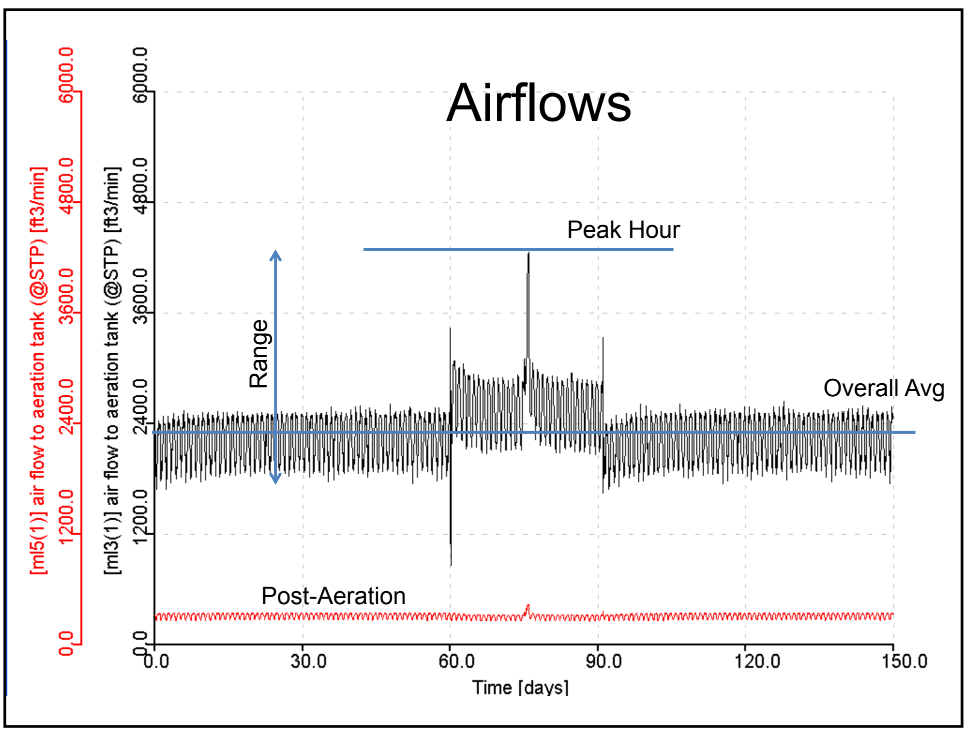
STEADY STATE MODEL INPUTS:

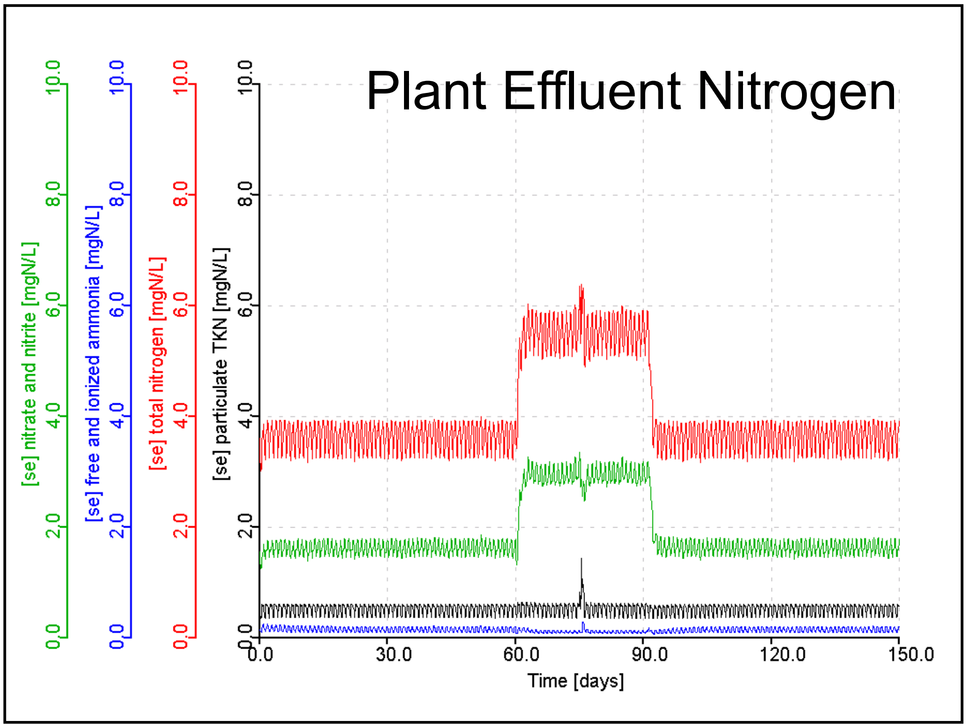
	AA	MM	PD	PH
Flowrate =	9.7	10.4	18.0	33.0
Temp =	17	25	25	25
DO =	4.0	3.5	2.0	2.0
WAS Flow, mgd =	0.1300	0.2000	0.2000	0.2000
WAS Flow, m3/day =	492	757	757	757
COD =	283	334	289	158
TKN =	24	32.7	26.4	14.4
Ammonia =	19	22.0	17.8	9.7
XCOD/VSS ratio =	1.80	1.58	1.58	1.58
BOD5/BODu =	0.625	0.614	0.614	0.614
VSS/TSS ratio =	0.813	0.784	0.784	0.784
Soluble fraction of total COD =	0.503	0.452	0.452	0.452
Inert fraction of soluble COD =	0.143	0.166	0.166	0.166
Substrate fraction of particulate COD =	0.734	0.748	0.748	0.748
Ammonium fraction of soluble TKN =	0.93	0.90	0.90	0.90
N in Inerts =	0.034	0.034	0.034	0.034

BIRTHDAY CAKE =

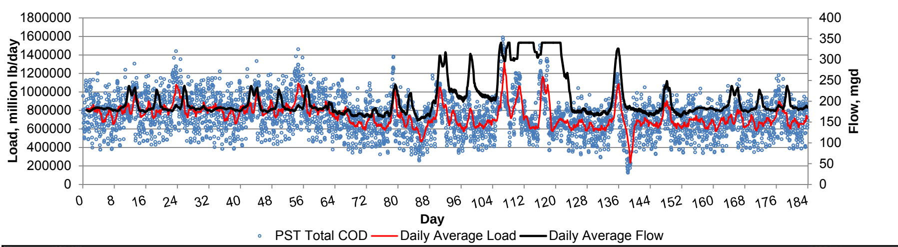
		day #
60	days AA	60
15	days MM	75
1	days PD (with PH)	76
15	days MM	91
60	days AA	151
151	days total	151

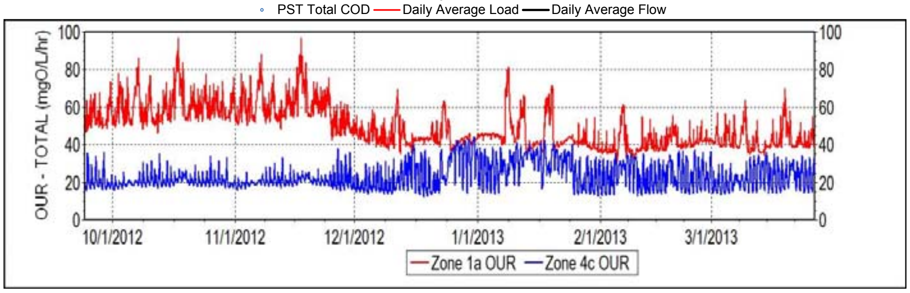

Birthday Cake Input
[pe] total TKN [mgN/L]
[pe] total carbonaceous BOD5 [mgO2/L]
[pe] total suspended solids [mg/L]
[pe] flow [MGD(US)]
Time [days]


Airflows
Peak Hour
Range
Overall Avg
Post-Aeration
[ml5(1)] air flow to aeration tank (@STP) [ft3/min]
[ml3(1)] air flow to aeration tank (@STP) [ft3/min]
Time [days]



Airflows Using Input Inventory





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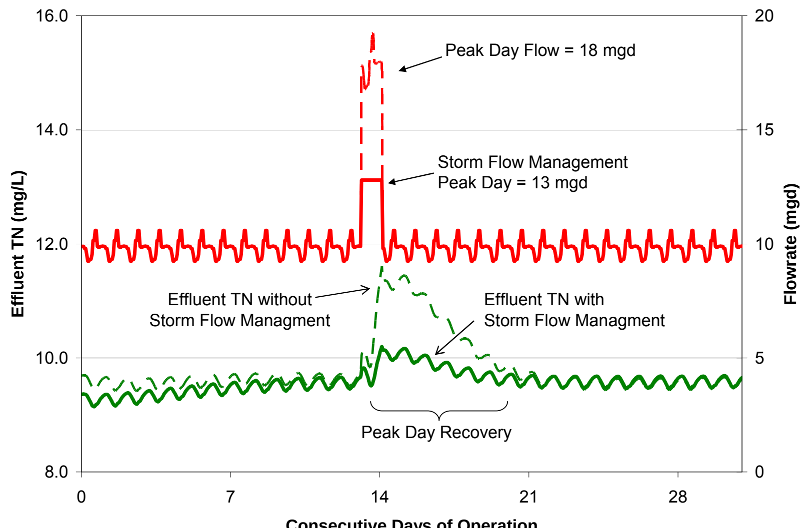
More Complex Applications

- Whole-plant modeling
- Control development
- **Wet-weather impacts**
- **Optimization**

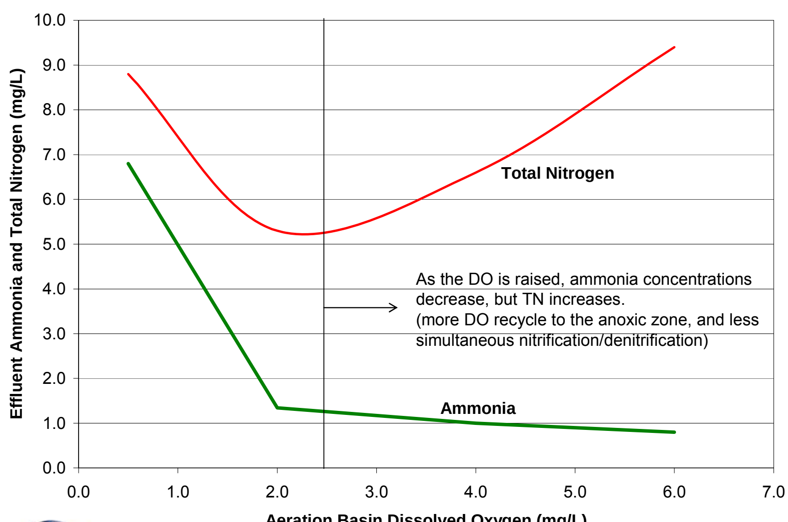
Wet Weather Impacts



Optimization Using a Sensitivity Analysis

- **Step 1: Build a Model.**
  - Input basin sizes, wastewater characteristics, etc.
- **Step 2: Calibrate the Model.**
  - Does the model output match the plant data?
- **Step 3: Test the Model's Sensitivity**
  - Choose one parameter to examine.
  - Change the variable, run the model, record results, repeat.
- **Step 4: Graph and Interpret Results**
- **Step 5: Use the Results!**

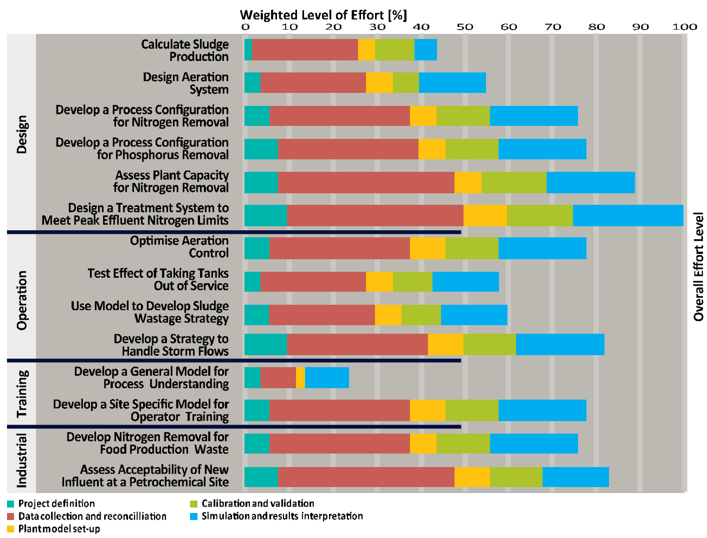
Dissolved Oxygen Sensitivity



Horses for Courses…

- Need clearly defined goals for your modeling
- Use model to answer your questions
- Use a model that's complex enough to meet your goals, but no more complex

The GMP Application Matrix



Conclusions

- Models are cool (and useful too)
- Modeling is cost-effective
- Models useful for simple calculations
  - Dynamic models give more information on ranges
- Models for more complex applications
  - Sensitivity analysis is a useful approach
- Match complexity to goals

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Modeling 101 – May 14, 2014

Modeling Intro

Vanrolleghem Peter
modelEAU - Université Laval

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Outline

- Definitions and terminology
- Types of models
- What is modeling?
- Why do we model?
- Industry-standard modeling protocol
- Design versus process models

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Definitions

- System

  Part of reality that is separated from its environment on the basis of a purpose defined by the researcher
- Model

  An approximate description of a part of reality considering only those aspects that are of interest
- Simulator (= Virtual experimenter)

  Tool that allows efficient manipulation of a model to gain insight in the "behavior" of the real system

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Definitions

- Steady state simulation

  Variables are independent of time

  because time is not considered in the model (steady state model)

  OR the input to the dynamic model is constant (influent AND operation)
- Dynamic simulation

  Variables are function of time

  because time is considered in the model (dynamic model)

  AND the input to the dynamic model is varying (influent OR operation)

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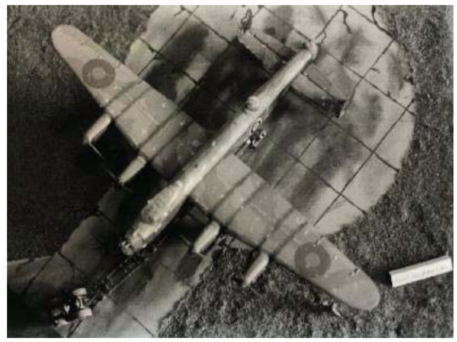
Models take many forms

- Mental models (ideas, concepts, ...)
- Verbal models (“description in words”)
- Scale models (“house in cardbord”)

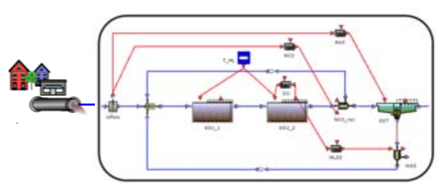


Model kit (1/72)
of the Lancaster bomber
of Florent Van Rolleghem
(1944)

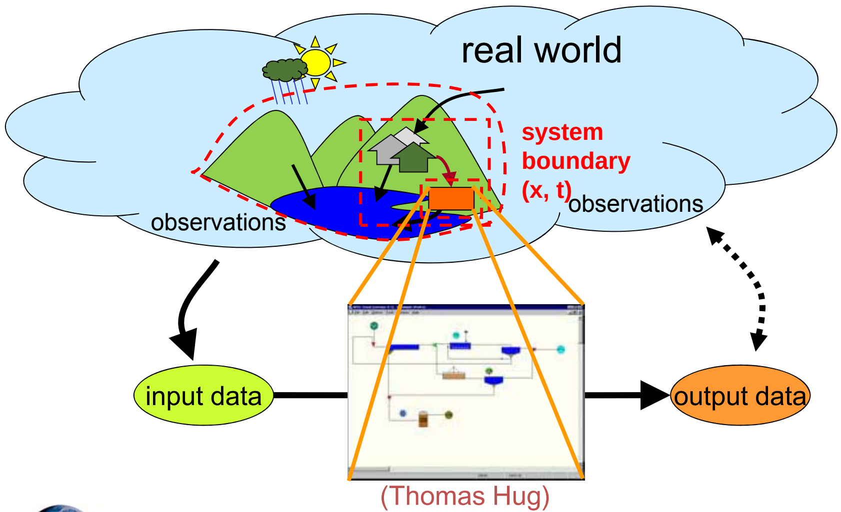
Models take many forms

- Mental models (ideas, concepts, ...)
- Verbal models (“description in words”)
- Scale models (“house in cardbord”)
- Mathematical models (“equations”)

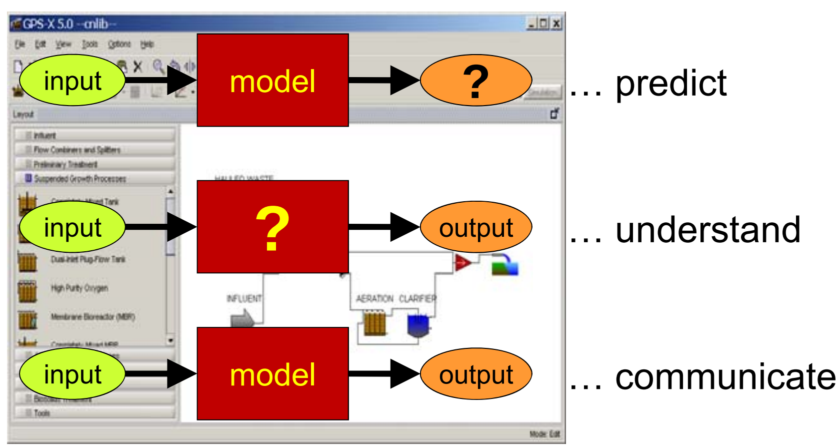
  - Different sets of equations, leading to:
    - ✓ Design models
    - ✓ Process models
    - ✓ Cost models
    - ✓ Influent models
    - ✓ Controller models



What is modeling?

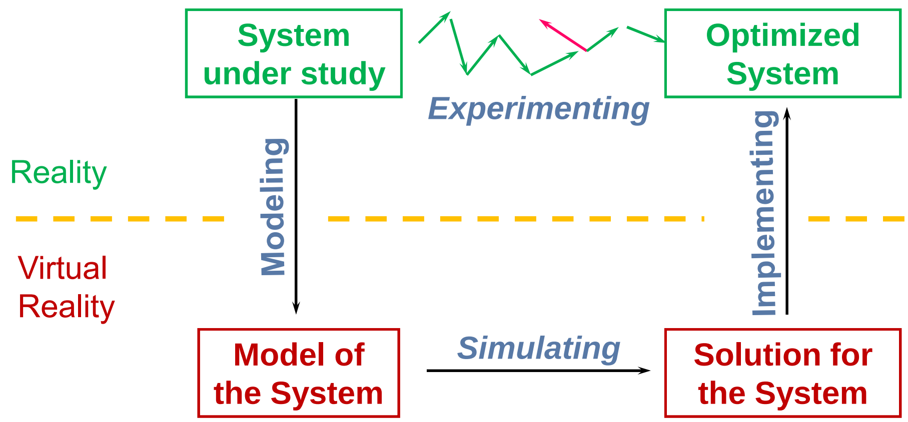


Why modeling?



Why modeling?

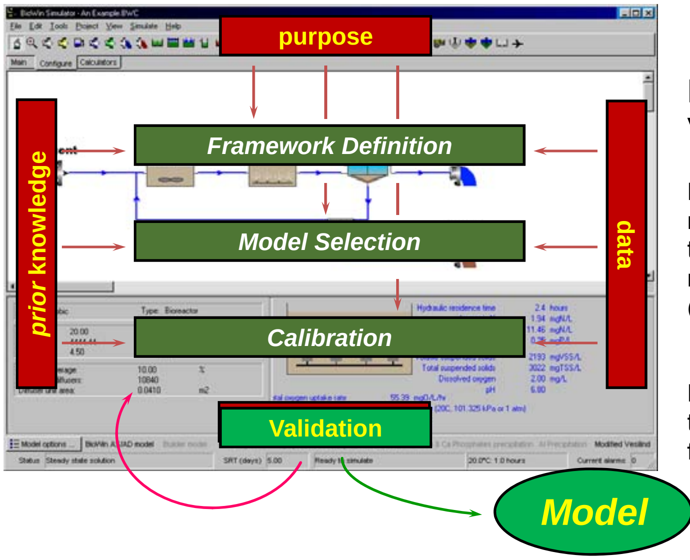
Solving Problems for complex systems



Model building: Starting points

- Purpose of the model
  - Increasing understanding *(Think tank)*
  - Summary of knowledge/data *(Communication)*
  - Prediction of future behavior *(Control)*
- *Prior* knowledge
  - Experience
  - Existing models
  - Literature (facts, phenomena, theories, ...)
- Data
  - Existing data
  - New data collected in view of model building

The model building exercise

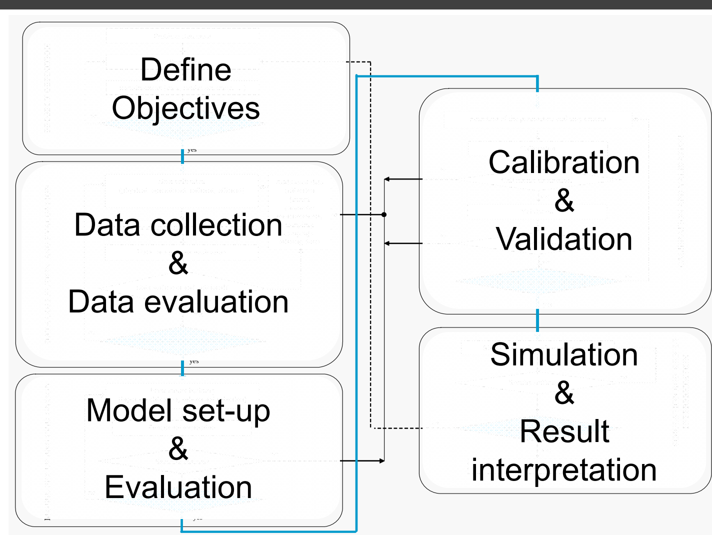


Model Validation:

Evaluate how the model performs to describe a new set of data (not used before during modeling)

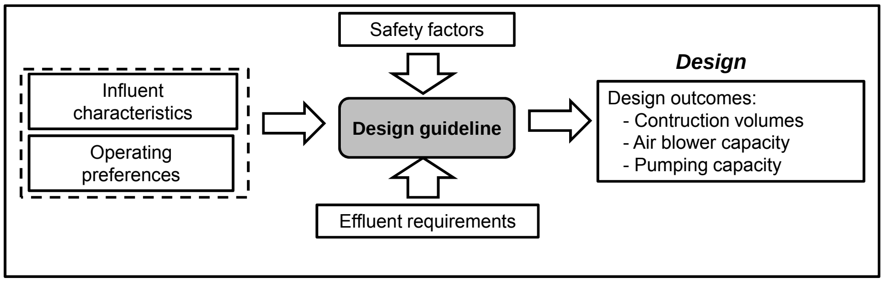
Evaluate whether the model will be fit-for-purpose

Modeling protocol

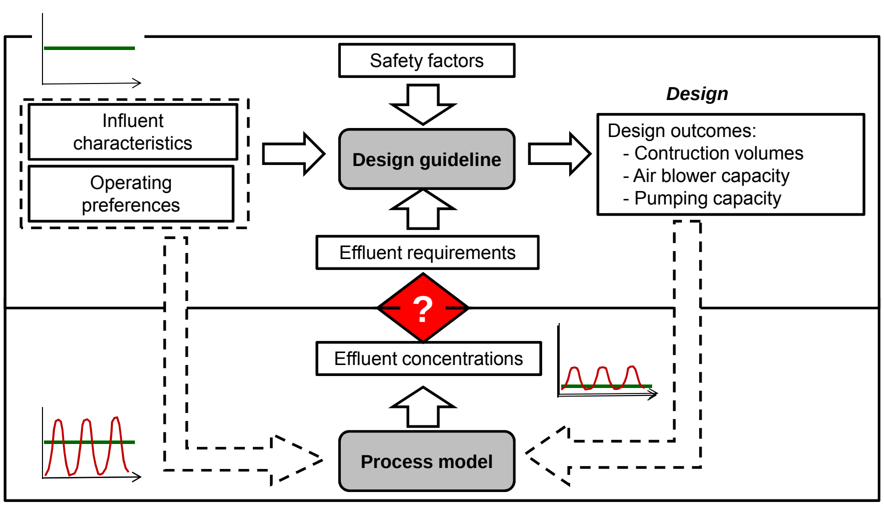


Design versus Process model

- Typical use of spreadsheet design model



Design versus Process model



Conclusions

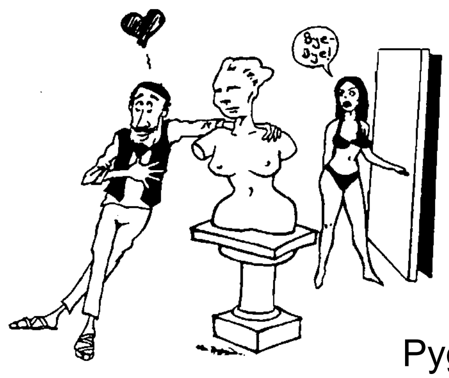
- Models are:
  - – multi-purpose
  - – a summary of current knowledge
  - – cost-effective tools for solving problems
  - – easy to use thanks to protocols that have a proven record
  - – included in industry-standard software

Conclusions

Modeling is a structured way to capture and use existing knowledge and information for a given purpose

Epilogue

“Do not fall in love with your model”



Pygmalion

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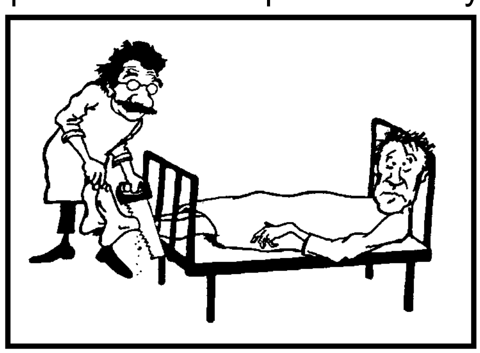
Epilogue

Models are and can be very useful,
but they are only an approximate description of reality

Procrustes' bed:
(Greek mythology)

“Do not adjust reality to the model”



Modeling should be done
with knowledge about the application!

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Presenter contact information

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Structuring a Modeling Project

Leiv RIEGER, Ph.D., P.Eng.
InCTRL Solutions Inc.

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Overview

- ➢ Sources of Information
- ➢ GMP Task Group
- ➢ The GMP Unified Protocol
  - ❖ Project Definition
  - ❖ Data collection & Reconciliation
  - ❖ Plant Model Set-Up
  - ❖ Calibration/Validation
  - ❖ Simulation & Results Interpretation

Sources of Information

Overview

- ➢ GMP Guidelines Scientific & Technical Report

- ➢ WEF MOP31

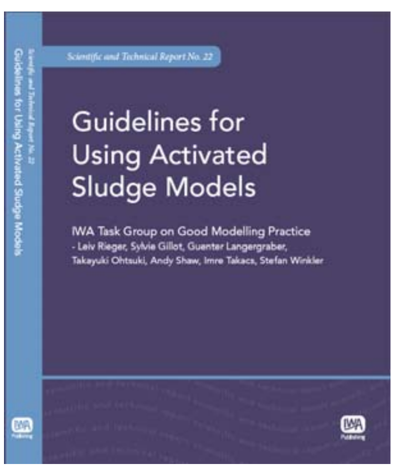
- ➢ ASM Scientific & Technical Report

- ➢ WERF Methods for WW Characterization in AS Modeling
- ➢ AS modeling intro book Makinia, 2010

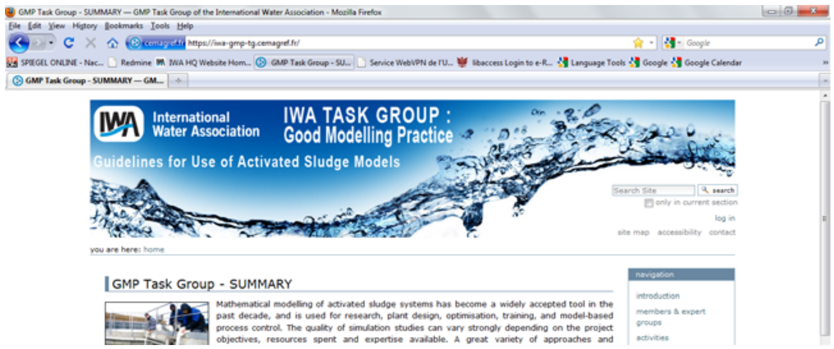
Sources of Information
Overview

- Scientific papers
- Conference proceedings (e.g. WEFTEC, WWTmod, Watermatex)
- Simulator manuals
- Training courses
- …

GMP Task Group
GMP Scientific & Technical Report



GMP Task Group
More info



Website GMP Task Group:

https://iwa-gmp-tg.irstea.fr

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GMP Task Group

Leiv Rieger (Chair)
Sylvie Gillot
Günter Langergraber
Takayuki Ohtsuki
Andy Shaw
Imre Takács
Stefan Winkler

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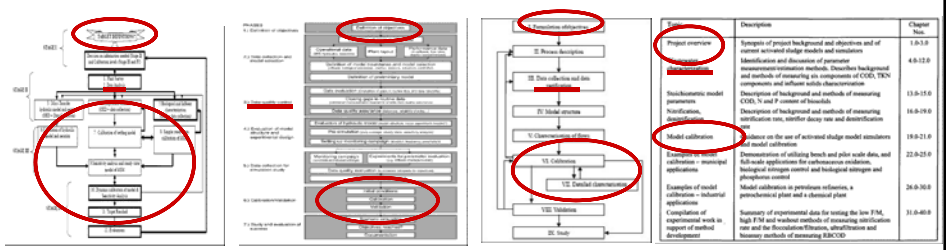
The GMP Unified Protocol

Development



BIOMATH HSG STOWA WERF

The GMP Unified Protocol

Development

- Step 1: Project Definition
- Step 2: Data collection & Reconciliation
- Step 3: Plant Model Set-Up
- Step 4: Calibration/Validation
- Step 5: Simulation & Results Interpretation

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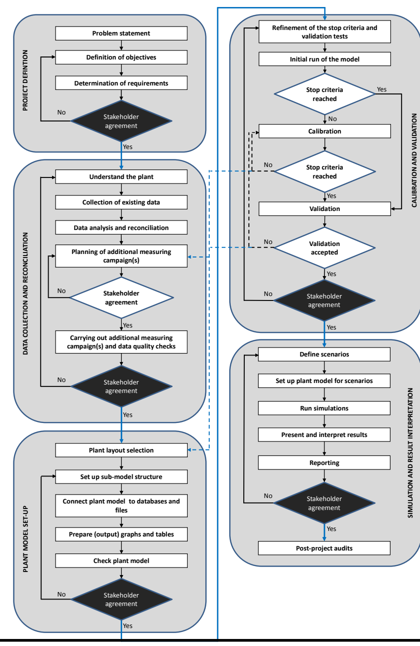
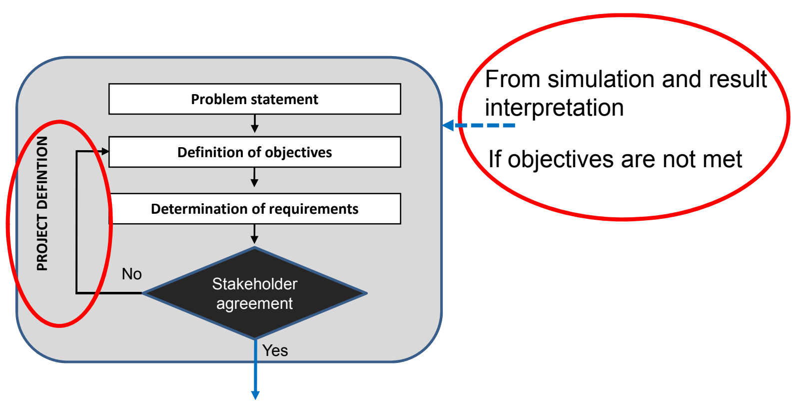
The GMP Unified Protocol
Overview



The GMP Unified Protocol
Step 1: Project Definition



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The GMP Unified Protocol
Step 1: Project Definition

Interview

Focus

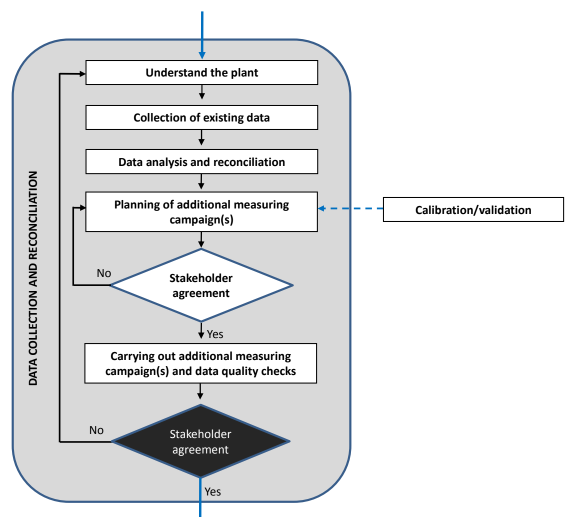
Revise

- Client's requirements
  - Which questions to be answered?
- Client's restrictions
  - Available data, budget, time…

Proposal

- Objectives
- Model boundary
- Acceptable preconditions
- Performance criteria (model accuracy, acceptable uncertainty)
- Responsibility
- Required data
- Fixed budget

The GMP Unified Protocol
Step 2: Data Collection and Reconciliation



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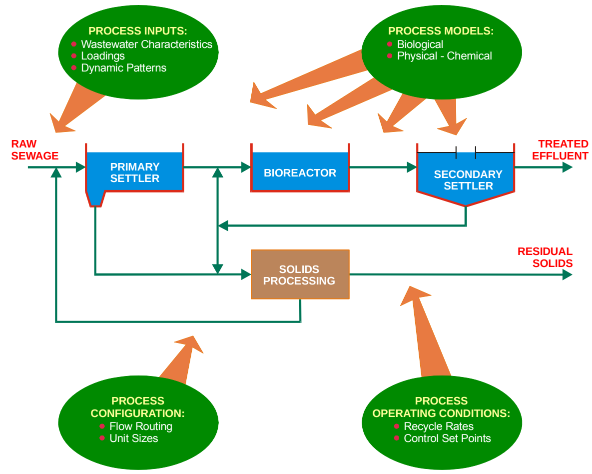
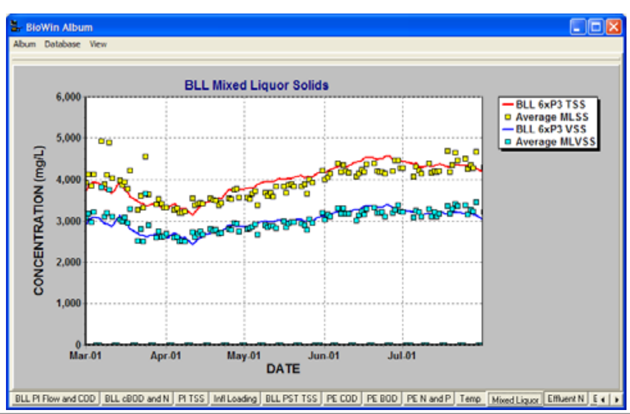
The GMP Unified Protocol
Step 2: **Data Collection** and Reconciliation



The GMP Unified Protocol
Step 2: **Data Collection** and Reconciliation

Data requirements determined by objective:

- Long term trends

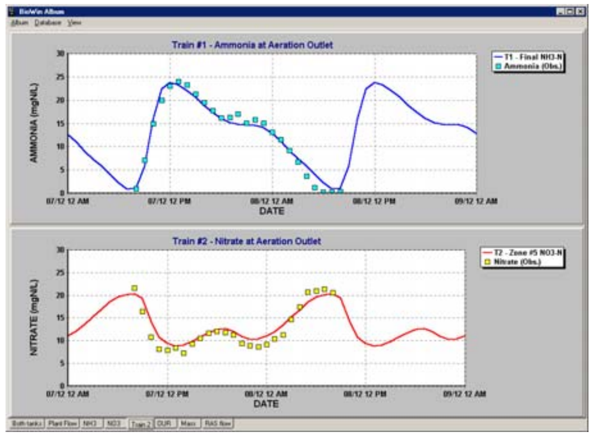


The GMP Unified Protocol

Step 2: **Data Collection** and Reconciliation

Data requirements determined by objective:

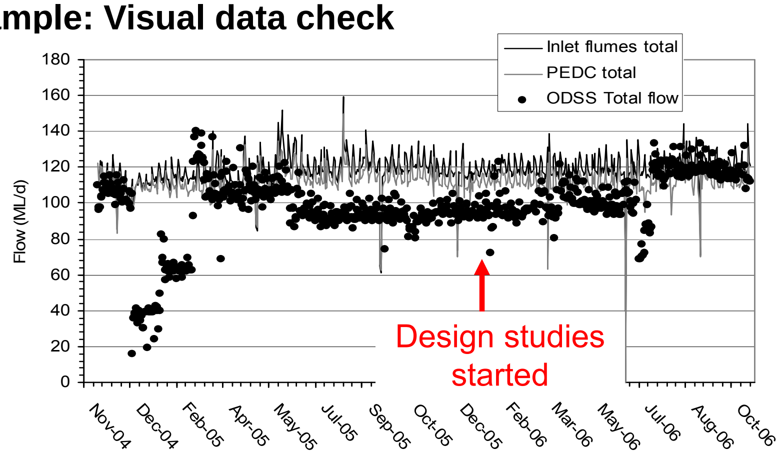
- Diurnal Variations



The GMP Unified Protocol

Step 2: **Data** Collection and **Reconciliation**

Example: Visual data check



- **Underestimation by -25%**

The GMP Unified Protocol

Step 2: **Data** Collection and **Reconciliation**

Example: Typical ratios

	A	C	D	E	F	G
1						
2	Date	Flow	TSS	VSS	VSS/TSS	BOD
3						
4	Average	192.4	169	145	0.84	155.7
5	Std. dev.	38.2	98	89	0.07	49.4
6						
7	Minimum	109.4	34	28	0.50	50.8
8	Maximum	385.0	896	800	1.10	426.6
9	Std. dev. Mult.	1.96	1.96	1.96	1.96	1.96
10						
11	01/01/2002	129.92	292	**320**	**1.10**	208.3
12	02/01/2002	131.61	184	156	0.85	208.7
13	03/01/2002	132.26	88	70	0.80	131.6
14	04/01/2002	**109.39**	276	250	0.91	244.7
15	05/01/2002	144.89	212	180	0.85	223.1
16	06/01/2002	204.53	126	80	**0.63**	164
17	07/01/2002	177.86	82	64	0.78	127
18	08/01/2002	170.62	138	104	0.75	144.8
19	09/01/2002	168.44	148	102	**0.69**	137.5
20	10/01/2002	164.43	98	84	0.86	96.45
21	11/01/2002	186.43	118	102	0.86	171
22	12/01/2002	167.2	122	110	0.90	170
23	13/01/2002	166.86	148	114	0.77	162.2
24	14/01/2002	169.03	262	238	0.91	191.6
25	15/01/2002	162.13	172	152	0.88	179.4

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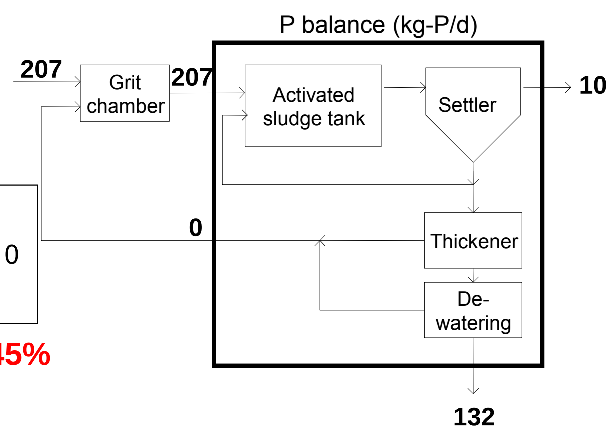
Step 2: **Data** Collection and **Reconciliation**

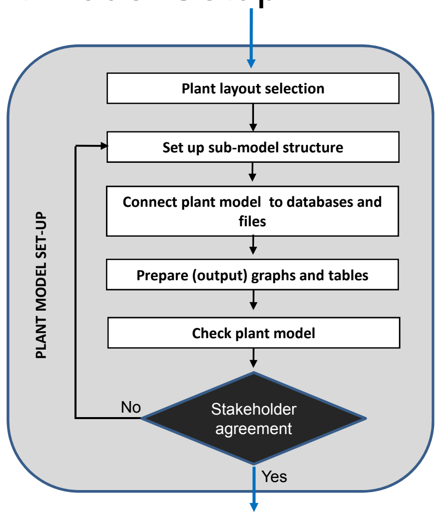
Example: Mass balance



P-in	**= 207**
P-out	= 132 + 10 + 0
	= 142

➔ Contradiction 45%

The GMP Unified Protocol
Step 3: Plant Model Setup



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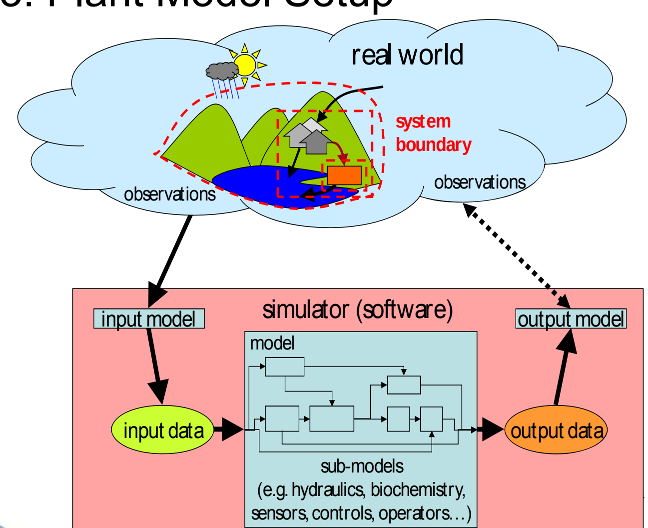
The GMP Unified Protocol
Step 3: Plant Model Setup



Hug, 2007

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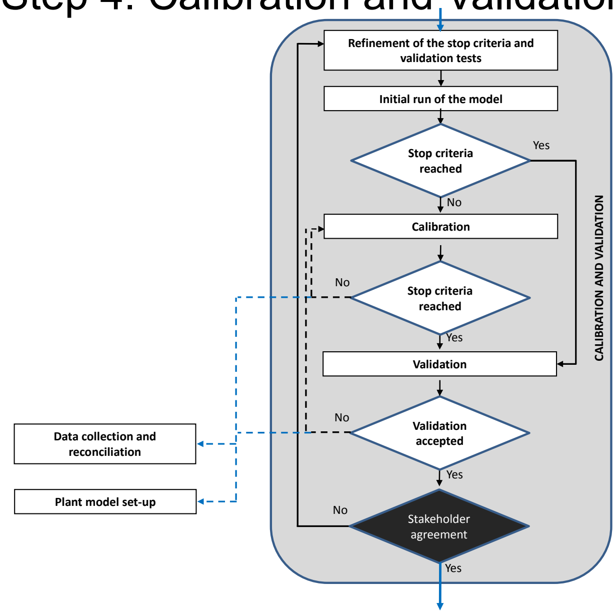
Step 4: Calibration and Validation



The GMP Unified Protocol
Step 4: Calibration and Validation

- BNR Calibration Procedure

1) Hydraulic model (tanks in series)

2) Influent characterization

3) Sludge production (first COD then TSS)

4) Nitrification

5) Denitrification

6) Phosphorus Removal

Iterative procedure!

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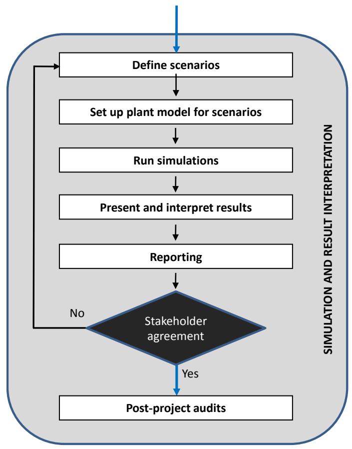
The GMP Unified Protocol
Step 5: Simulation and Result Interpretation



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The GMP Unified Protocol
Step 5: Simulation and Result Interpretation

Set up and simulate scenarios that answer questions laid out in objectives

- Steady-state simulations
  - Overall mass balancing
  - Long term performance check
- Dynamic simulations
  - Diurnal peaks – to determine equipment limits
  - Controller design
  - Seasonal changes – long term operating strategies
  - Storm events – optimal handling

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The GMP Unified Protocol
Step 5: Simulation and Result Interpretation

Documentation

- Repeatability
- Make quality evaluation possible
- Should contain all major agreements with client
- Should contain all used data, assumptions, parameter sets, etc.

Detailed enough to allow other modelers to come to the same results

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Conclusions

- Models capture existing knowledge and experience in a structured way → no magic
- The GMP Guidelines synthesize best industry practices
- Modeling and simulation guidelines help:
  - estimating required data and efforts
  - ensuring quality standards
  - prevent typical pitfalls

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Modeling 101 – May 14, 2014

Data Requirements

John B. Copp Ph.D.
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Objectives

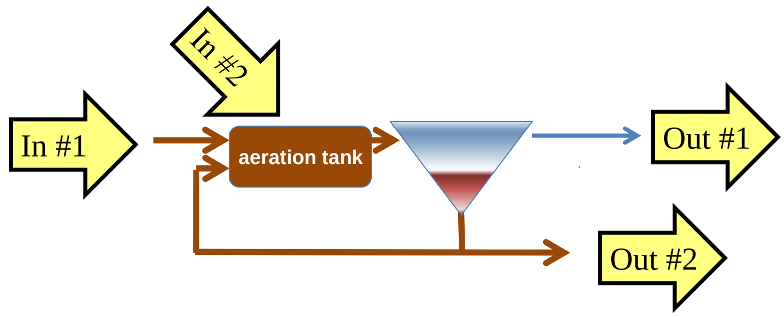
- How much data?
- Data Types
- Data Sources
- Data Frequency
- Project Dependency
- Typical Plant Data

Common Question

- Very common question:
  - *"How much data do I need?"*
- Short answer:
  - *"Depends on your model objective."*

Data Purpose

- Why ?
  - Primary purpose of the data to reduce model uncertainty wrt the question being ask of it…..



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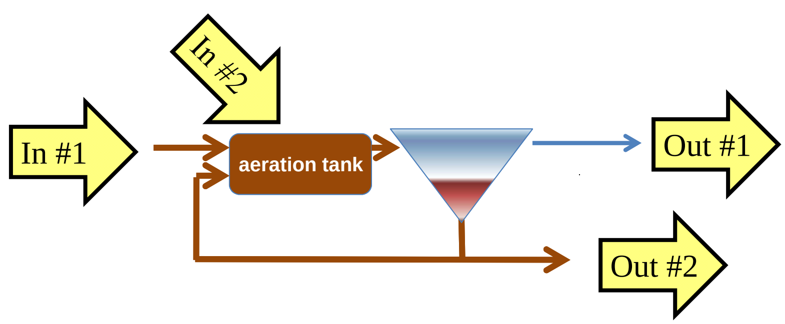
Data Purpose

- Model Uncertainty
  - Derived from the confidence that the predicted mass balances are correct …



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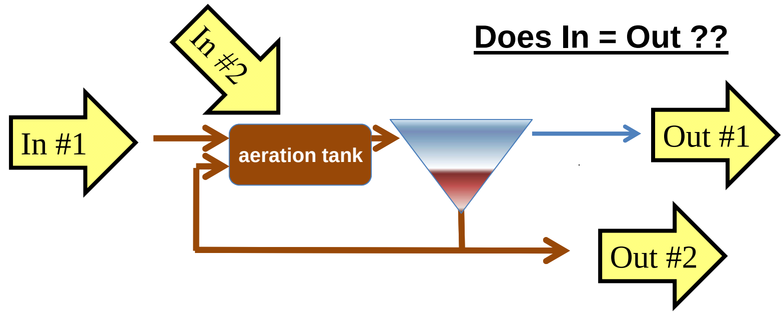
Data Purpose

- Model Confidence
  - Increased when reconciled data can be matched by the model predictions



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Data Uncertainty

- Less data = greater uncertainty
  BUT, more data ≠ better
- Cost of data acquisition/handling *vs* implications of application

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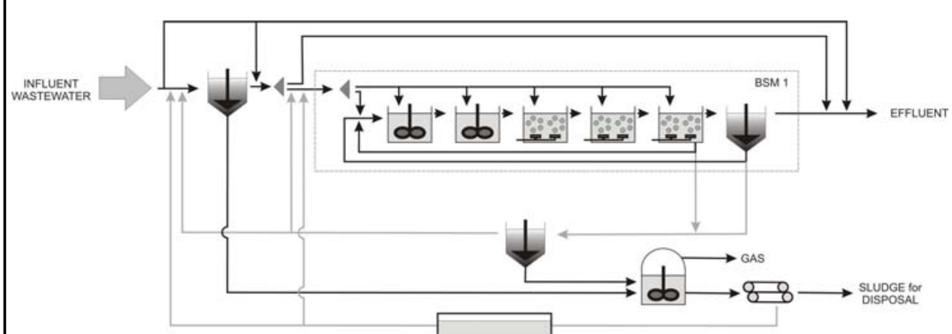
Categories

- Physical
  - tank sizes, connectivity
- Operational
  - controllers, RAS and WAS rates
- Composition
  - influent quality, MLSS, effluent quality
- Mechanistic
  - yield, growth rates, etc.

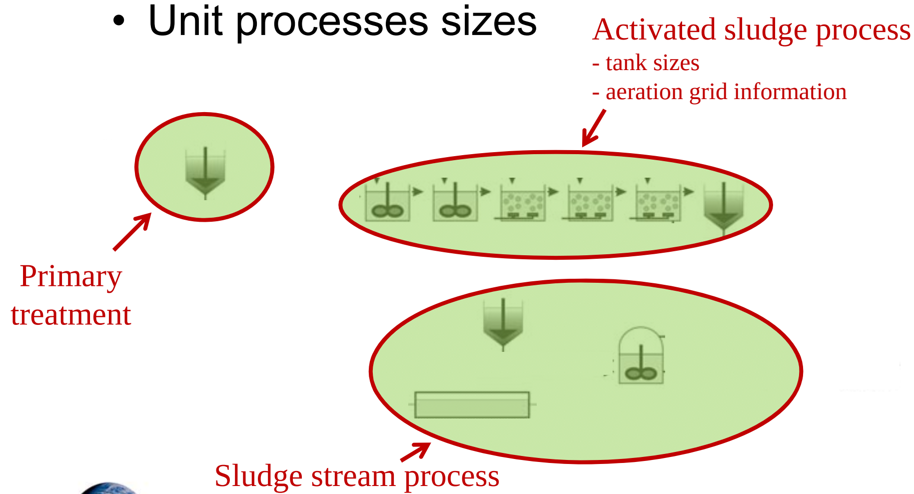
Physical

- Unit processes sizes



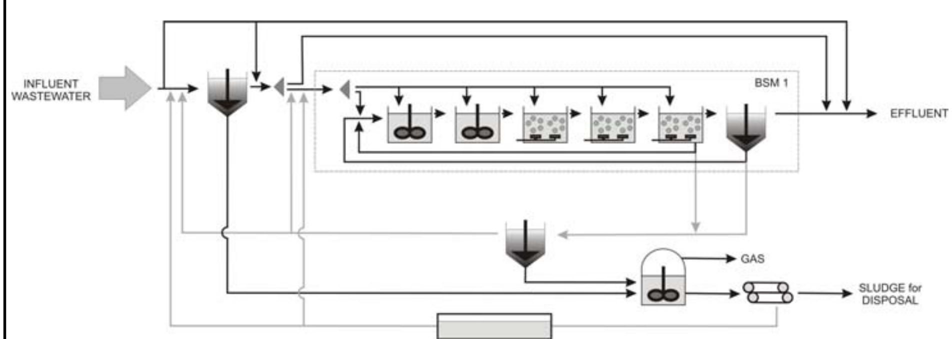
Physical

- Unit processes sizes



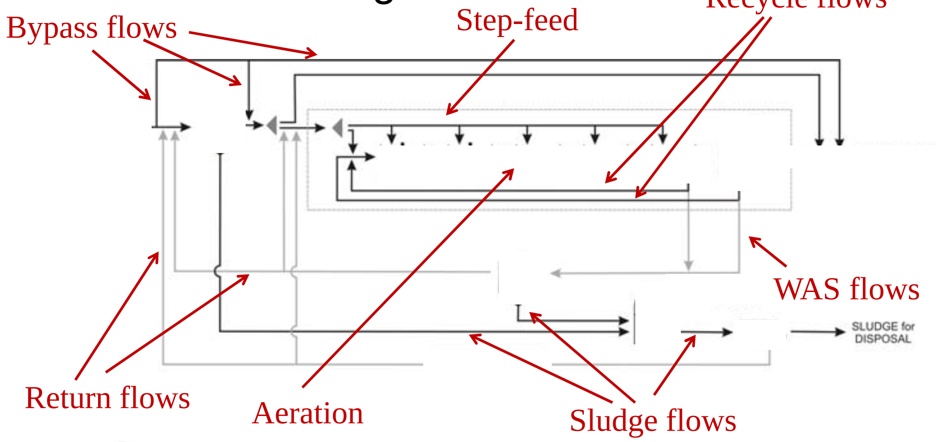
Operational

- Flows & Logic



Operational

- Flows & Logic

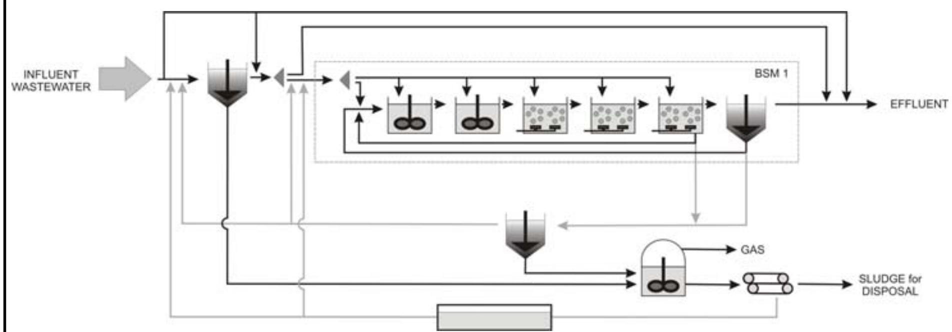


Composition (2 types)

- What is "driving" the system
  - influent quantity and quality
- System performance
  - effluent quality

Composition

- Water Quality



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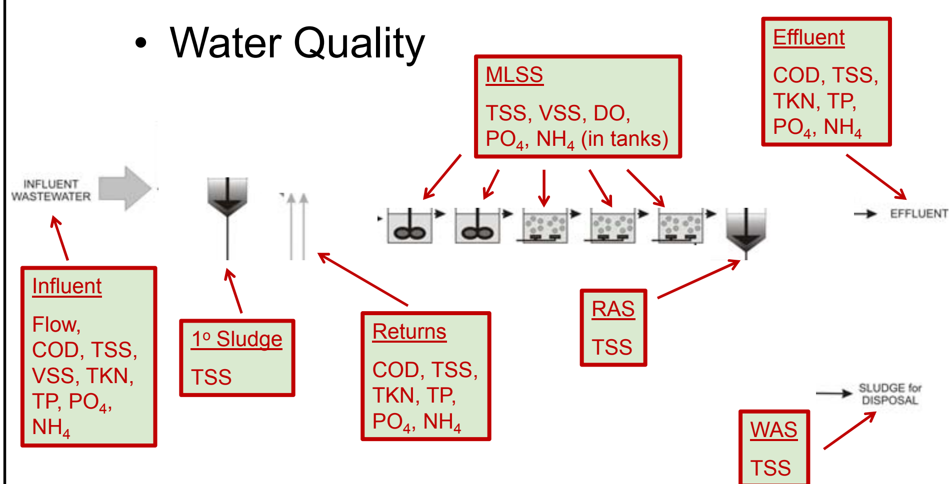
Composition

- Water Quality



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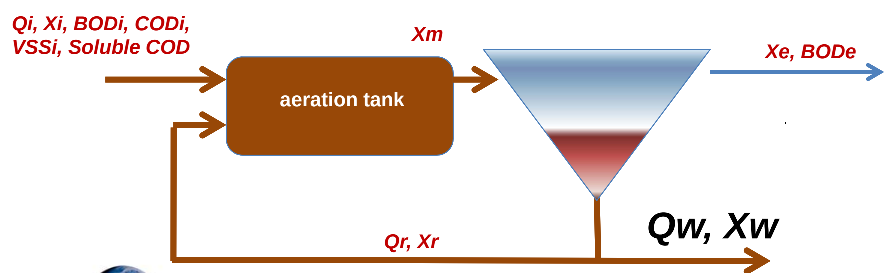
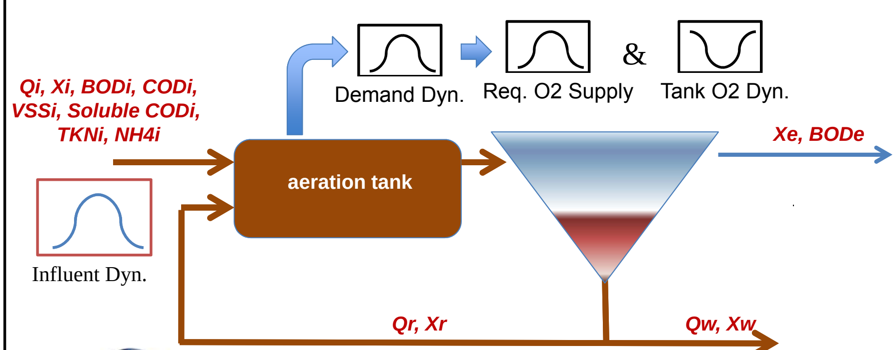
Data Example

- Sludge Production (steady state)
  - Physical Data
  - Average Conditions (maybe winter, summer)
  - Flows and Influent Composition



Data Example

- Aeration System Design
  - Influent diurnal variations in flow and composition
  - Airflows and aeration system dynamics (blowers)



Sources of Data

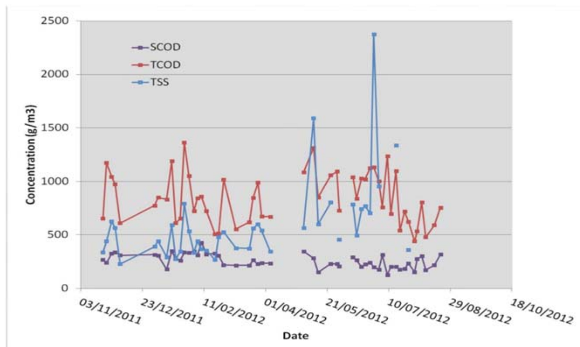
- Plant logs (written, database)
  - on-line sensors
  - off-line lab results
- Sampling/monitoring program
- Plant personnel
- Literature

Frequency

- Depends on ***Project Goal***
  - Planning, design *vs* operation
  - Steady-state *vs* dynamic
- Depends on ***Variable Dynamics***
  - Once
  - Infrequent (monthly, seasonal)
  - Daily (composite, grab)
  - Continuous (*in-situ, in-line* sensors)

Grab Sample Data

- Typical Data
  - Grab samples
  - 1-yr time period
  - Variations
    - Time
    - Weather
    - Location
    - Personnel
    - …



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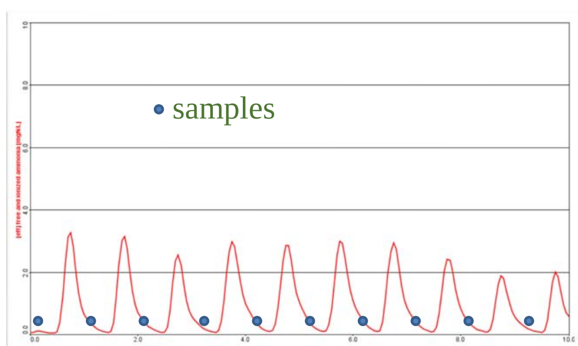
Grab Sample Issues

- Grab Sample Issues
  - Behavior missed
  - Trends missed
  - Events missed
  - Average case missed



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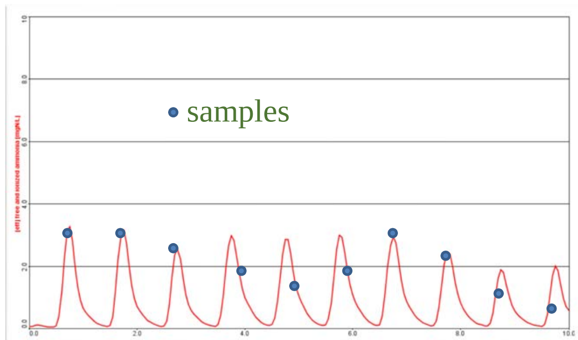
Grab Sample Issues

- Grab Sample Issues
  - Concentrations unrepresentative
  - Trends incorrect
  - Impacts incorrectly inferred



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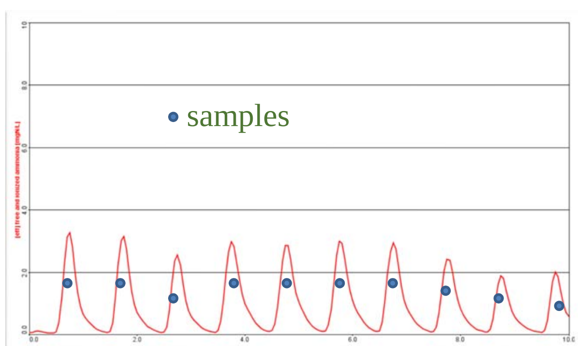
Composite Data

- Composite Sampling
  - Multiple samples / day; mixed & analysed
  - Average case
  - Trends, missed
  - Events missed



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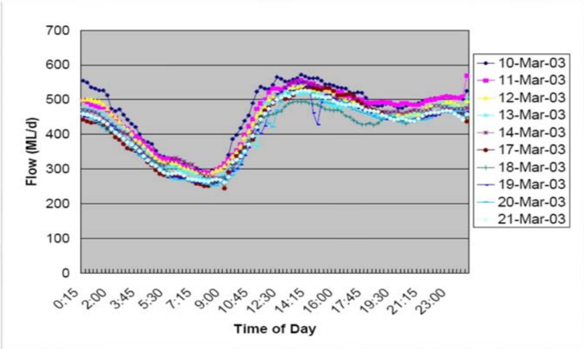
Mass Loading is Key

- Mass Load Critical – <u>NOT</u> Concentration
  - Models concerned with **<u>MASS LOAD</u>**
  - Even with composite data, flow is critical



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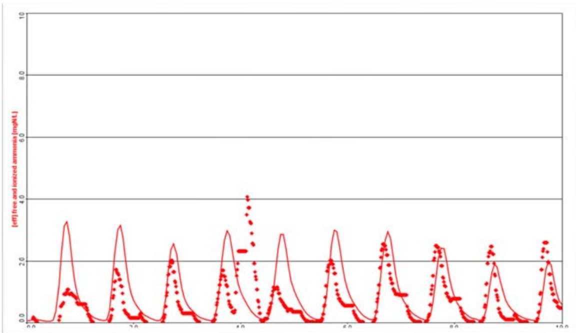
High-Frequency Monitoring

- High Frequency Monitoring (i.e. NH_4)
  - Multiple sample/d or essentially continuous
  - Trends
  - Event detection
  - Dynamic model behavior checked



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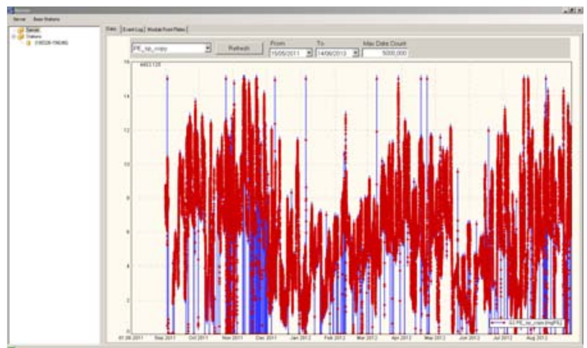
Real Sensor Data

- Typical Real-Time Data
  - Outliers
  - Sensor Faults
    - Noise
    - Malfunction
    - Calibration



Real Sensor Data

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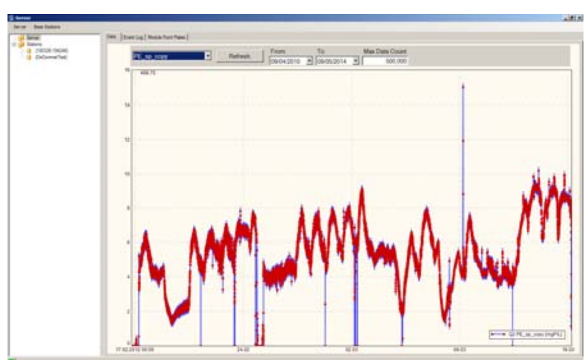
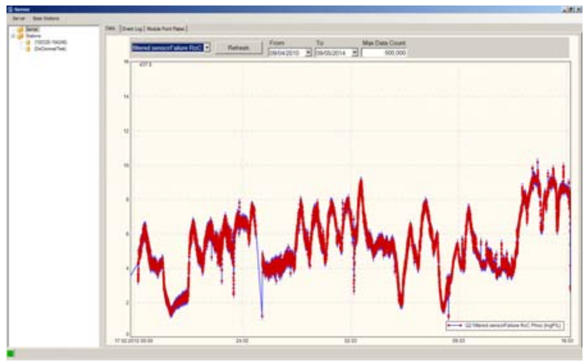


Improved Data Quality

- After Data Validation (batch or real-time)
  - Outliers, anomalies removed
  - High quality dynamic data



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Conclusion

- Data requirements are ***project dependent***
- Data collection should be designed to produce data which helps to minimize model uncertainty irrespective of goal
- Data quality must be a primary goal during collection and the importance of data validation cannot be underestimated

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Thank-you !

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Earth Essential Technologies

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Modeling 101 – May 14, 2014

Modeling Pitfalls

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MWH
BUILDING A BETTER WORLD

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Modeling Pitfalls

Outline

- Pitfalls You May Experience
- Developing a Sampling and Analysis Program
- Sampling Problems
- Rules of Thumb
- Checking Sludge Production
- Problems with Data Analysis and Interpretation
- Is Your Model Configuration Correct?
- Changing Default Parameters

Some Pitfalls You May Experience

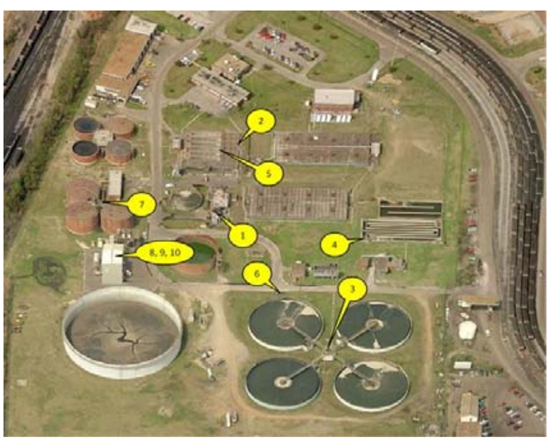
- Sampling locations
- Samplers are maintained
- Measured data is accurate
- Assuming samples were analyzed in a timely manner
- Results were logged correctly
- CBOD = BOD
- Assuming VSS data
- Model configuration is correct
- Flow splitting differences
- Forcing a model to fit bad data
- Changing default parameters
- Modeling batch operation as continuous
- Modeling storms
- Assuming DO concentrations
- Aeration control dynamics
- Flow meter accuracy: influent, RAS, WAS
- Assuming recycle/sidestream characteristics
- Neglecting recycle/sidestreams
- Not considering minimum conditions
- Expecting precision

Sampling and Analysis Program

- Collect the **right** data in the **right** locations
  - Walk the plant if possible
  - Take the time to survey sampling locations
- Match the required additional data to the appropriate/available budget

Sampling and Analysis Program:

Collect the Right Data in the Right Locations



Sampling Locations

1. Influent
2. Primary Effluent
3. Mixed Liquor
4. Final Effluent
5. Primary Sludge
6. RAS
7. Digester Feed
8. Centrifuge Feed
9. Dewatered Solids
10. Centrate

Sampling and Analysis Program:

Match Data Needs to Budget

Baseline Daily and Diurnal Sampling and Analytical Requirements for Wastewater Characterization

Treatment Facility: [redacted]

Values in cells represent number of analyses per day at each sampling point.

Minimum number of days required for composite analysis is: **14**

Minimum number of days required for diurnal analysis is: **5**

Number of days to collect centrate samples **3**

COLOR CODE:
- Analysis of flow weighted daily composite sample
- Analysis of flow weighted discrete auto-samples at 2-hourly intervals
- Analysis of 1 grab sample per shift, composited into one sample per day
- Daily total

Composite of samples taken from all daily leachate deliveries

	1. Influent Wastewater		2. Primary Effluent		3. Mixed Liquor		4. Secondary Effluent		5. Primary Sludge		6. Wasted Sludge		7. Digester Feed		8. Centrifuge Feed		9. Dewatered Solids		10. Centrate Recycle		11. Leachate		Sugested Method	Analysis Totals				
No. of Sampling Locations	1		1		1		1		1		1		1		1		1		1		1			Composite	Diurnal	Total		
	Daily	Diurnal	Daily	Diurnal	Daily	Diurnal	Daily	Diurnal	Daily	Diurnal	Daily	Diurnal	Daily	Diurnal	Daily	Diurnal	Daily	Diurnal	Daily	Diurnal	Daily	Diurnal		Day	Day	Analyses	**LEGEND:**	
Flow	1								1		1		1		1				1					6	0	84	**Flow**	*Electronic data is prefereble
TSS	1	12	1		1		1		1		1		1		1		1		1		1		2540D	154	60	214	**TSS**	Total suspended solids
VSS	1	12	1		1		1		1		1		1		1						1		160.4	126	60	186	**VSS**	Volatile suspended solids
COD	1	12	1				1												1		1		5220C	70	60	130	**COD**	Total COD
sCOD(GF)	1		1				1														1		5220C	56	0	56	**sCOD (GF)**	Soluble COD (glass fiber filtrate)
ffCOD	1						1														1		5220C	42	0	42	**ffCOD**	"Floc" COD as per test
TBOD5	1		1																		1		5210B	42	0	42	**TBOD5**	Total 5-day BOD (uninhibited)
sTBOD5 (GF)	1																				1		5210B	28	0	28	**sTBOD5**	Soluble Total 5-day BOD
NO3 at end of TBOD test	1		1																		1		300	42	0	42	**NO3 end of TBOD**	Nitrate at end of TBOD test
CBOD5	1						1																5210B	28	0	28	**CBOD5**	Carbonaceous 5-day BOD
sCBOD (GF)	1																						5210B	14	0	14	**sCBOD**	Soluble Carbonaceous 5-day BOD (glass fiber filtrate
TKN	1	12	1				1												1		1		4500N	70	60	130	**TKN**	Total TKN
sTKN (GF)	1																				1		351.2	28	0	28	**sTKN (GF)**	Soluble TKN (glass fiber filtrate)
NH3-N	1		1				1												1		1		4500NH3G	70	0	70	**NH3-N**	Total ammonia
NO3-N	1						1														1		300	42	0	42	**NO3-N**	Nitrate
NO2-N							1																	14	0	14	**NO2-N**	Nitrite
TP	1	12	1				1												1		1		365.3	70	60	130	**TP**	Total P
sTP (GF)	1																						365.4	14	0	14	**sTP (GF)**	Soluble TP (glass fiber filtrate)
PO4-P	1		1				1														1		300	56	0	56	**PO4-P**	Orthophosphate P
Alk	1						1								1				1		1		2320B	70	0	70	**Alk**	Alkalinity (as CaCO3)
pH																					1			14	0	14	**pH**	Note: in-situ (mixed liquor pH in final aeration zone)
Dissolved Sulfide	1																				1		376.1	28	0	28	**Dissolved Sulfide**	dissolved sulfides
Temp	1																							14	0	14	**Temp**	Mixed liquor temperature, deg C

Estimated Sampling and Analysis Cost

Lab analyses by type	Number analyses by type	Est. Cost per test	Est Total Cost
TSS	214	$16	$3,424
VSS	186	$20	$3,720
COD	130	$30	$3,900
sCOD	56	$30	$1,680
ffCOD	42	$30	$1,260
TBOD	70	$24	$1,680
sTBOD	42	$24	$1,008
TKN	130	$32	$4,160
sTKN	28	$32	$896
NH3-N	70	$20	$1,400
NO3-N	84	$20	$1,680
NO2-N	14	$16	$224
TP	130	$20	$2,600
sTP	14	$20	$280
PO4-P	56	$20	$1,120
Alk	70	$16	$1,120
Dis Sulfide	28	$24	$672
Estimated Total Analytical Cost			$30,824

Sampling Problems

- Sampler location
- Sampler maintenance
- Sample degradation

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Sampling Problems:
Sampler Location

- Well mixed
- Adequate access
- Identify recycle/sidestream return locations



Sampling Problems:
Sampler Care and Maintenance

- Refrigerated samplers
- Clean inlet tubing regularly
- Keep batteries charged



Sampling Problems:
Sample Degradation

- Sample storage

Sampling and storage: Test unstable samples without delay. Homogenize samples containing settleable solids in a blender to permit representative sampling. If there is to be a delay before analysis, preserve the sample by acidification with sulfuric acid. Make initial dilutions in volumetric flasks for wastes containing a high COD in order to reduce error inherent in measuring small volumes.

Total COD

Sample	0 Days	Refrigerated	Acidified
Duplicate 1	397	451	482
Duplicate 2	374	347	350
Duplicate 3	399	327	343
Average	**390**	**375**	**392**

Filtered COD

Sample	0 Days	Refrigerated	Acidified
Duplicate 1	136	99	85
Duplicate 2	125	99	78
Average	**131**	**99**	**82**

Flocculated-Filtered COD

Sample	0 Days	Refrigerated	Acidified
Duplicate 1	110	89	114
Duplicate 2	95	72	101
Average	**103**	**81**	**107**

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Rules of Thumb

- BOD/TSS ~ 0.9 to 1.1
- CBOD/BOD ~ 0.6 to 1
- COD/BOD ~ 1.9 to 2.2
- ffCOD/COD ~ 0.25
- sCOD/COD ~ 0.4
- VSS/TSS ~ 0.80 to 0.84

Example: COD = 333;

BOD_5 = 155;

TSS = 200

COD:BOD_5 = 2.15 (okay)

BOD_5:TSS = 0.77 (low ?)

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Check Sludge Production

- Overall Sludge Production:

$$\frac{\text{TSS in (Primary Sludge + WAS + Effluent)}}{\text{Influent BOD}} = \frac{\text{kg TSS}}{\text{kg BOD}}$$

- Across Activated Sludge

$$\frac{\text{VSS in WAS + Effluent}}{\text{Input COD – Effluent sol. COD}} = \frac{\text{kg VSS}}{\text{kg COD}}$$

From WEFTEC 2007, Workshop W201, Fundamental of Wastewater Process Modeling, Peter Dold

Check Sludge Production:
Overall Sludge Production

Overall sludge production - Example

Typically ~ 0.9 to 1.0 kgTSS/kgBOD

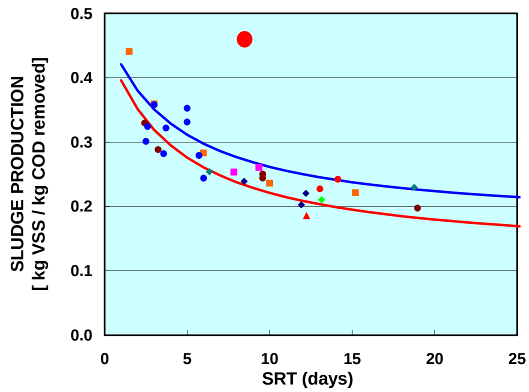
Raw Sewage:		**Primary Sludge:**	
Flow	75494	Flow	791
BOD	155	TSS	21053
Mass BOD	11676	Mass TSS	16658
		SAS:	
		Flow	2837
		TSS	2806
		Mass TSS	7960
		Effluent:	
		Flow	70126
		TSS	5
		Mass TSS	354
		Total TSS out	24972
Overall (PS+SAS) sludge production (TSS/BOD):			2.14

2.14?

From WEFTEC 2007, Workshop W201, Fundamental of Wastewater Process Modeling, Peter Dold

Check Sludge Production:

Across Activated Sludge



$$\frac{\text{VSS in WAS + Effluent}}{\text{Input COD – Effluent sol. COD}} = \frac{\text{kg VSS}}{\text{kg COD}}$$

Main components:

Q_{WAS} x VSS_{WAS}

Q_{INFL} x COD_{INFL}

First check:

Q_{WAS}

$VSS_{WAS} = MLVSS \times (Q_{INFL} + Q_{RAS}) / Q_{RAS}$

COD_{INFL}

Mass balances on downstream solids

From WEFTEC 2007, Workshop W201, Fundamental of Wastewater Process Modeling, Peter Dold

Data Analysis and Interpretation

- BOD or CBOD
- Samples homogenized prior to analysis?
- Results logged correctly?

Data Analysis and Interpretation:
BOD or CBOD

Plant	CBOD (mg/L)	BOD (mg/L	CBOD/BOD
Alabama	171	178	0.95
Colorado #1	251	283	0.89
Colorado #2	301	363	0.83
Florida #1	116	173	0.67
Florida #2	167	216	0.77
Florida #3	221	263	0.84
Louisiana #1	124	152	0.82
Louisiana #2	112	129	0.87
Massachusetts #1	70	234	0.3
Massachusetts #2	174	178	0.98

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Data Analysis and Interpretation:
Samples Homogenized Prior to Analysis?

DATE	COD		Factor
	Not Blended	Blended	
15-Jul	299	349	0.86
17-Jul	218	293	0.74
18-Jul	172	181	0.95
19-Jul	168	193	0.87
21-Jul	290	304	0.95
22-Jul	303	316	0.96
23-Jul	254	308	0.82
24-Jul	250	280	0.89
AVERAGE	244	278	0.88

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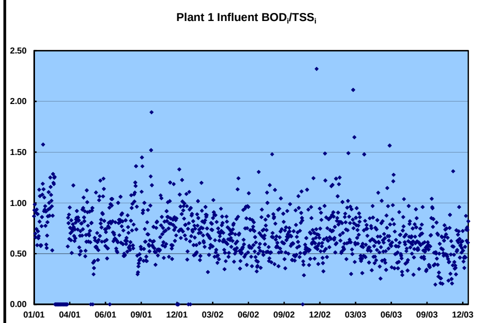
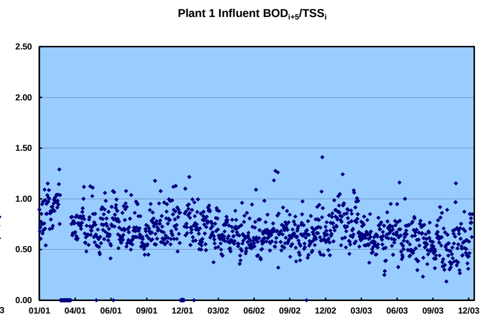
Data Analysis and Interpretation:

Results logged correctly?





- BOD/TSS ratio showed too much scatter
- BOD results logged on the day received, not on sample day
- BOD/TSS ≠ ~1; which is why BOD/TSS ratio is a “rule of thumb”

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Data Analysis and Interpretation:

Results logged correctly?

- COD > sCOD > ffCOD
- BOD > sBOD
- TSS > VSS
- TSS – ISS = VSS
- TKN > sTKN > NH_3

Day	Flow	TSS	VSS	ISS	VSS/TSS	VSS	VSS/TSS
2/2/13	21185	119	21	98	0.18	98	0.82
2/3/13	19229						
2/4/13	17181	96	15	81	0.16	81	0.84
2/5/13	17901	108	12	96	0.11	96	0.89
2/6/13	18472	86	10	76	0.12	76	0.88
2/7/13	16735	174	28	146	0.16	146	0.84
2/8/13	16427	108	6	102	0.06	102	0.94
2/9/13	17113	208	16	192	0.08	192	0.92
2/10/13	20797	134	6	128	0.04	128	0.96
2/11/13	21900	42	2	40	0.05	40	
2/12/13	21275	60	13	47	0.22	47	0.78
2/13/13	20274	86	8	78	0.09	78	0.91
2/14/13	20928	128	20	108	0.16	108	0.84
2/15/13	20673	84	14	70	0.17	70	0.83
2/16/13	19374	132	37	95	0.28	95	0.72
2/17/13	18616	134	37	97	0.28	97	0.72
2/18/13	18528	248	17	231	0.07	231	0.93
2/19/13	16779	174	45	129	0.26	129	0.74
2/20/13	15769	360	32	328	0.09	328	0.91
2/21/13	15213	376	39	337	0.10	337	0.90
2/22/13	14908	192	19	173	0.10	173	0.90
2/23/13	14343	106	11	95	0.10	95	0.90
2/24/13	14392	136	15	121	0.11	121	0.89
2/25/13	15302	304	20	284	0.07	284	0.93
2/26/13	13694	276	39	237	0.14	237	0.86
2/27/13	13272	288	49	239	0.17	239	0.83
2/28/13	13112	264	30	234	0.11	234	0.89
3/1/13	12799	175	30	145	0.17	145	0.83
Average	17364	170	22	148	0.13	148	0.86

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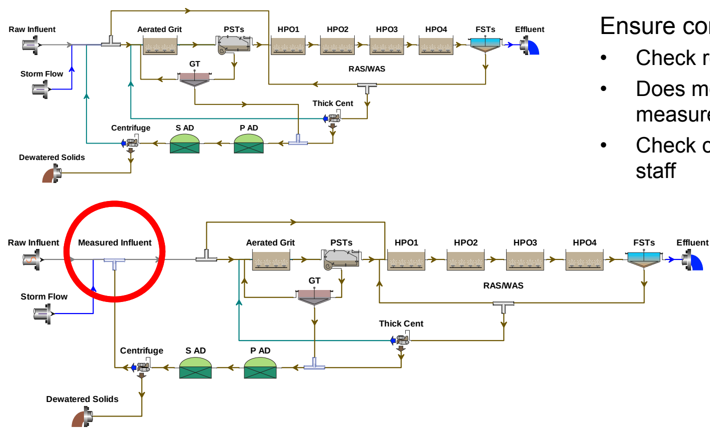
Is Your Model Configuration Correct?



Ensure configuration is correct

- Check recycle return locations
- Does model output match measured data?
- Check configuration with plant staff

Changing Default Parameters

Change Default Parameters

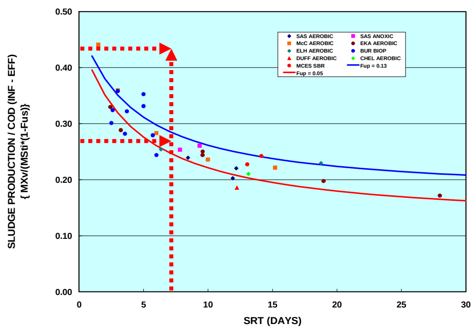
- Don't change default parameters for the sake of changing them
- Minimize the number of default parameters changed
- Understand why you feel the need to change them

Changing Default Parameters

Forcing a model to fit bad data

Change heterotroph yield coefficient (Y) from default of 0.666 to 0.905

- Predicts significantly lower oxygen requirements - 65% of actual
- Predicts a significant increased sludge production - 150% of actual



- At SRT of 6.5 d, expected VSS production range is 0.27 – 0.29
- Y = 0.905
  - 0.43 lbVSS/lbCOD
- Y = 0.666
  - 0.285 lbVSS/lbCOD

Conclusions

- Treat data with care. Don't necessarily accept it
- Check the data thoroughly
- Remember the "Rules of Thumb"
- Walk through the plant to confirm things yourself
- Check solids production
- Be very wary changing default parameters
- Don't trust flow meter results blindly

Use the model to help diagnose problems

Thank you !

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Modeling 101 – May 14, 2014

Introduction to Modeling

- <u>Final Q & A:</u>
  - John B. Copp (Primodal Inc.)
  - Andrew Shaw (Black & Veatch)
  - Peter Vanrolleghem (Université Laval)
  - Leiv Rieger (InCtrl Solutions)
  - Ken Brischke (MWH)

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