NEW ENGLAND WATER ENVIRONMENT ASSOCIATION NEWEA WORKING FOR WATER QUALITY

Jacobs

Challenging today.
Reinventing tomorrow.

Navigating low effluent phosphorus limits: “Right sizing” phosphorus reduction strategies through Monte Carlo based evaluations.

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What is an Uncertainty Analysis based evaluation?

- Evaluation of performance **reliability**.
- Understand operational and design associated **risk**.
- To **minimize** over design tendencies.
- To compare **likely** operating cost ranges.

How is it useful?

- Also referred to as a **Monte Carlo analysis**.
- A statistical technique used to understand the **probability** of observing a given outcome based **uncertain** input parameters
- Static values associated with **uncertain parameters** are replaced with probability distributions.

Basis of an uncertainty analysis is understanding probability distributions and correlations between parameters.

- Relationship between 30-day average of parameters variables is factored into the randomization of model inputs
- Correlation values > 0.2 or < (0.2) are considered significant

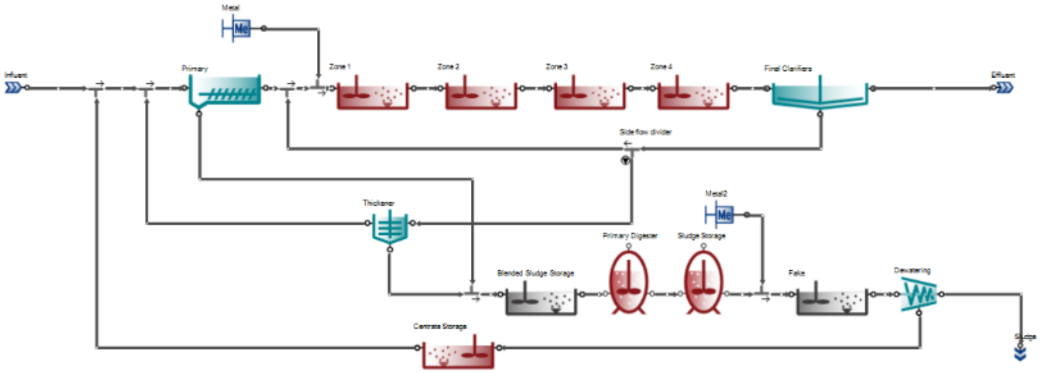
Green = positive correlation

Red = negative correlation

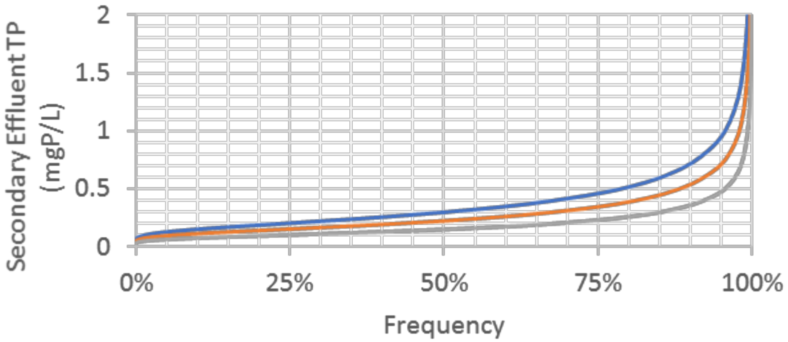
	Flow	Peak Flow	COD	TSS	TKN	TP	NH3/TKN	PC TSS	Temp	SVI
Flow	**1.00**	0.45	0.04	0.09	0.14	0.14	-0.24	-0.05	-0.59	0.26
Peak Flow	0.45	**1.00**	0.06	0.01	0.03	0.09	-0.17	0.09	-0.22	0.12
COD	0.04	0.06	**1.00**	0.12	0.19	0.19	-0.09	0.14	0.13	-0.11
TSS	0.09	0.01	0.12	**1.00**	0.43	0.65	-0.32	0.22	-0.08	-0.14
TKN	0.14	0.03	0.19	0.43	**1.00**	0.70	-0.24	0.18	-0.10	-0.13
TP	0.14	0.09	0.19	0.65	0.70	**1.00**	-0.30	0.16	-0.12	-0.02
NH3/TKN	-0.24	-0.17	-0.09	-0.32	-0.24	-0.30	**1.00**	-0.36	0.40	-0.05
PC TSS	-0.05	0.09	0.14	0.22	0.18	0.16	-0.36	**1.00**	0.07	-0.07
Temp	-0.59	-0.22	0.13	-0.08	-0.10	-0.12	0.40	0.07	**1.00**	-0.47
SVI	0.26	0.12	-0.11	-0.14	-0.13	-0.02	-0.05	-0.07	-0.47	**1.00**

Common uncertainty analysis applications:

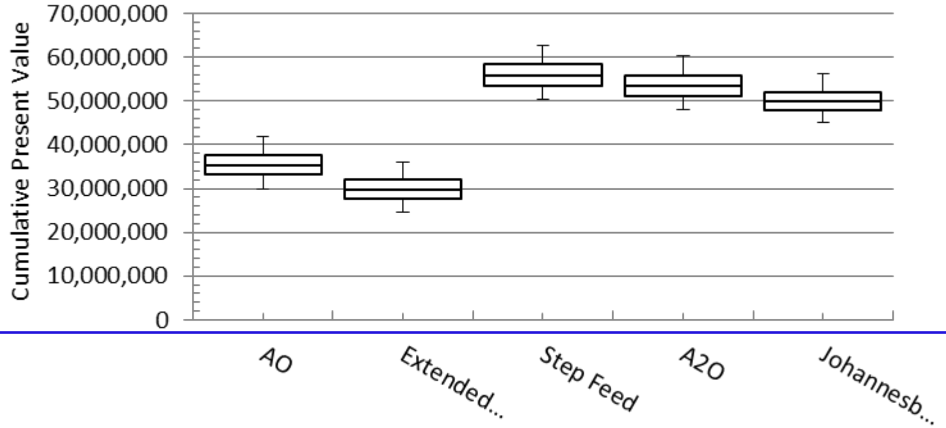
- Process Model



- Process Performance



- Economic



TMDL based limits drive implementation of uncertainty analysis methods

- New TMDL Based Limits
  - Set 6-month averaging periods (May to October and November to April).
  - Primarily driven by mass, some instances of concentration-based limits
  - TMDL results in more stringent limits for most utilities.

- Permits require:
  - Operational evaluations targeting optimization
  - Preliminary and Final Compliance Alternatives Plans identifying paths towards compliance through treatment or alternative approaches
  - Defined implementation schedule

Case studies implementing the uncertainty analysis method for Low – P planning.

City of Oshkosh, WI

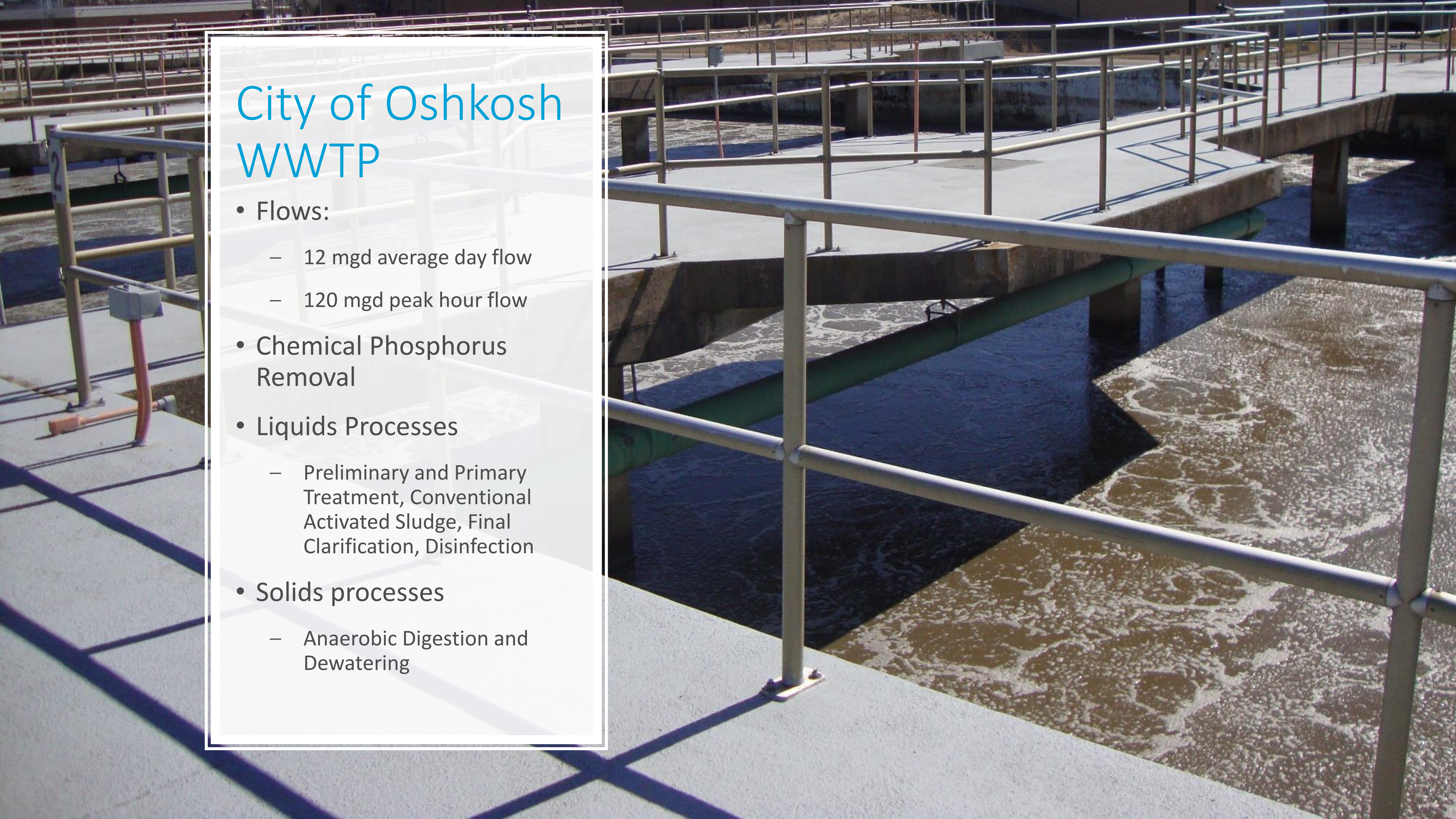
Secondary treatment stability, permit uncertainty, and tertiary sizing.

NEW Water (Green Bay MSD)

Secondary treatment stability, required mass reduction, tertiary sizing.

Uncertainty analysis drivers for the City of Oshkosh:

- Uncertainty in future effluent limits
  - Waiting completion of Lake Winnebago TMDL
  - Extremely stringent Water Quality Based Effluent Limit (WQBEL) for phosphorus.
    TP =0.04 mg/L & 6.8 ppd
- Biological vs. Chemical Phosphorus removal stability and life cycle cost
- "Right sized" tertiary treatment alternatives



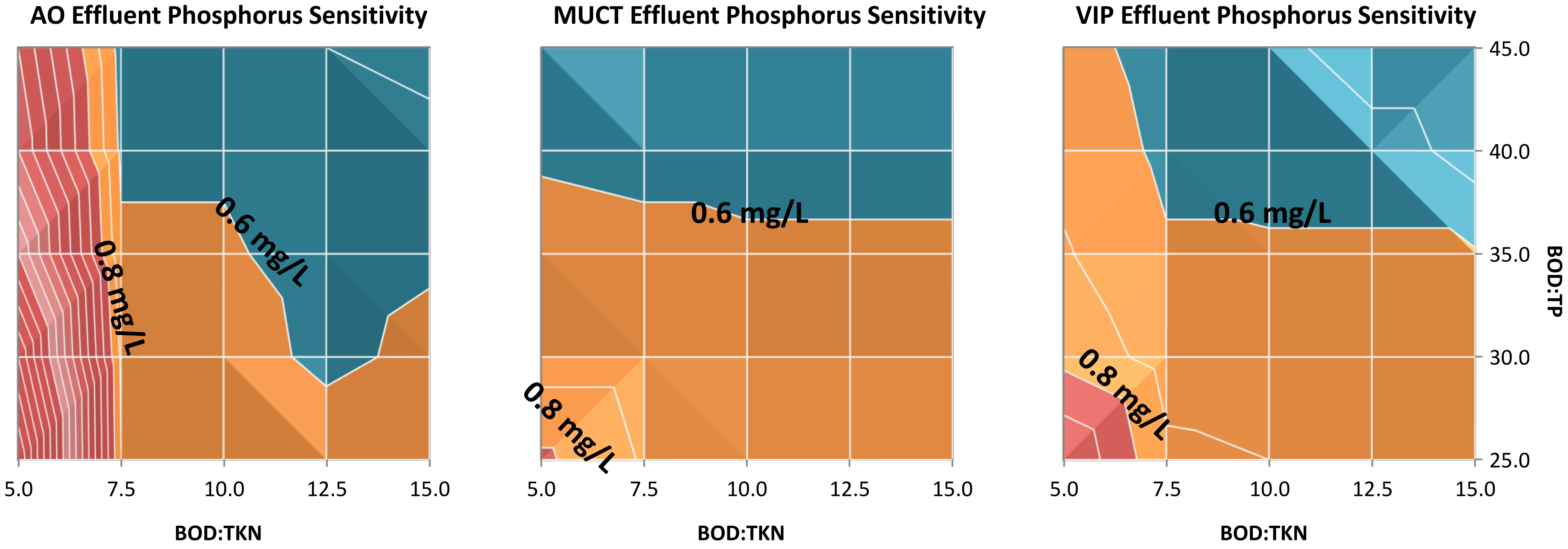
City of Oshkosh WWTP

- Flows:
  - 12 mgd average day flow
  - 120 mgd peak hour flow
- Chemical Phosphorus Removal
- Liquids Processes
  - Preliminary and Primary Treatment, Conventional Activated Sludge, Final Clarification, Disinfection
- Solids processes
  - Anaerobic Digestion and Dewatering

Secondary Treatment Evaluation Goals

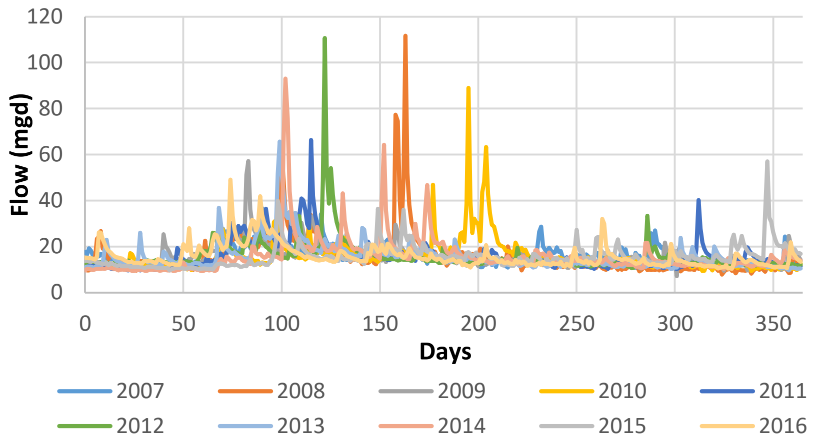
Identify	the most stable Bio-P alternative specific to Oshkosh WW characteristics.
Compare	performance of selected Bio-P alternative to the existing Chem-P
Establish	life-cycle cost considerations between alternatives

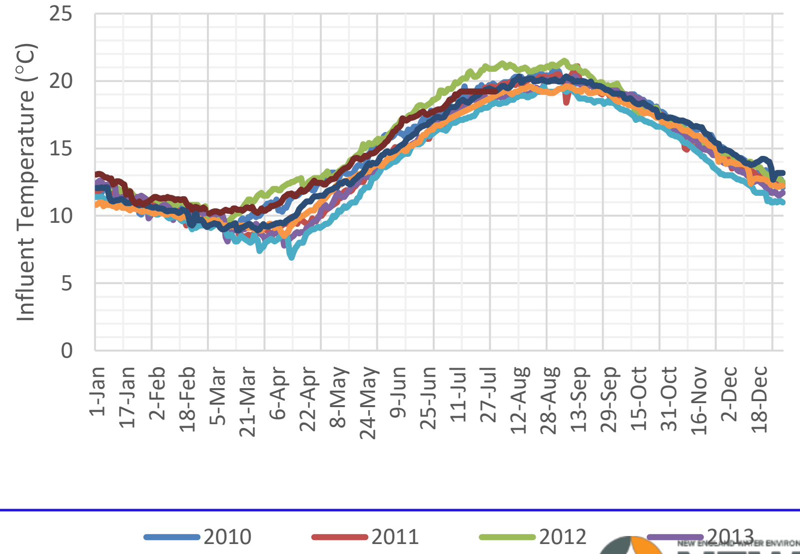
MUCT provides the highest stability of the Bio-P processes evaluated



Uncertainty analysis used to assess stability and life cycle costs

- Simulated 100 dynamic years with unique loading conditions.
- Hydrographs prorated to 2035 design flow 15.7 mgd and paired with loading conditions
- Consistent temperature profile used for all simulations.
- Uncertain Inputs:
  - BOD
  - TP
  - TKN
  - NH_3/TKN Ratio
  - PO_4/TP Ratio





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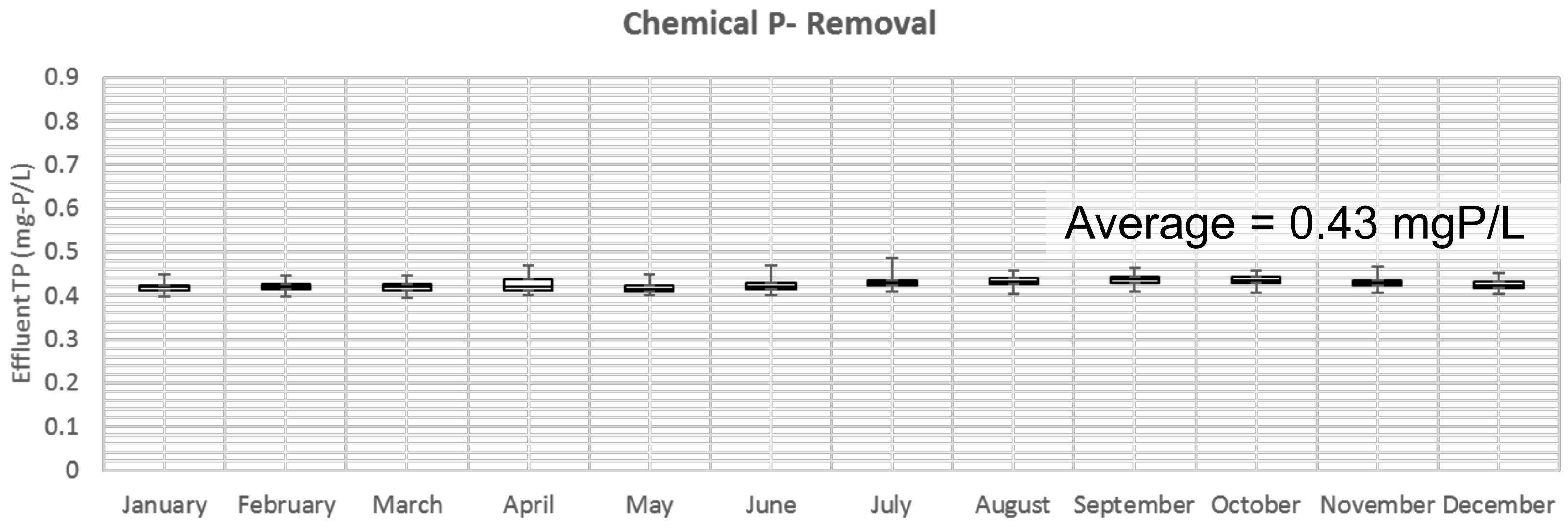
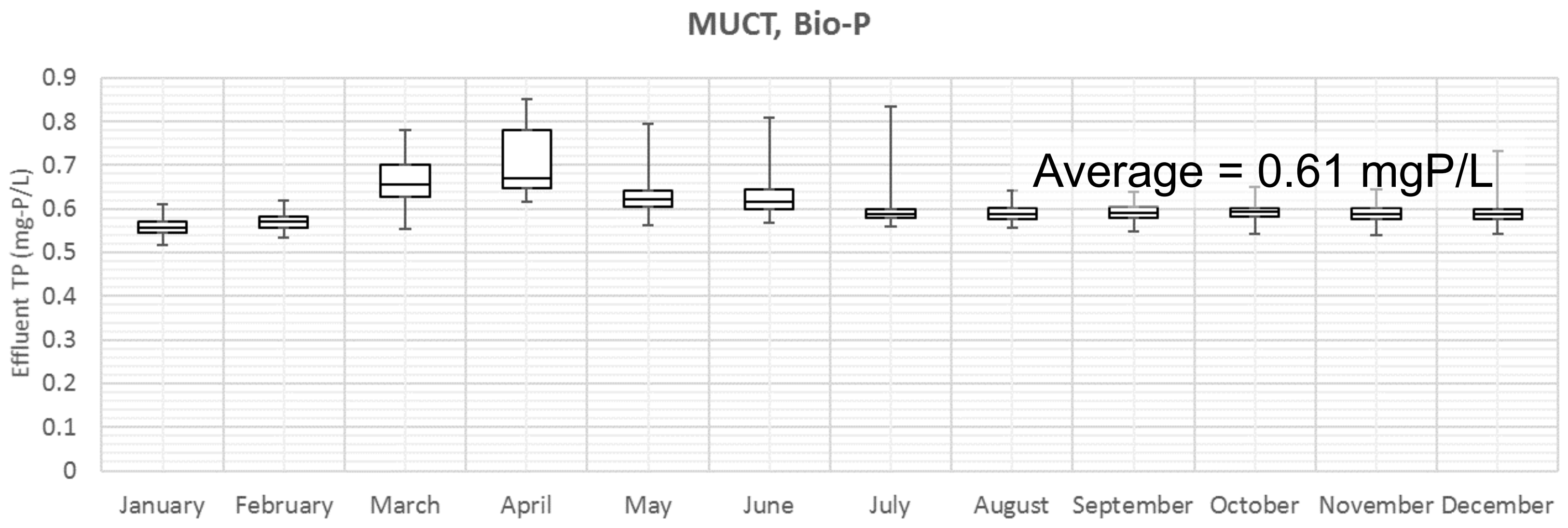
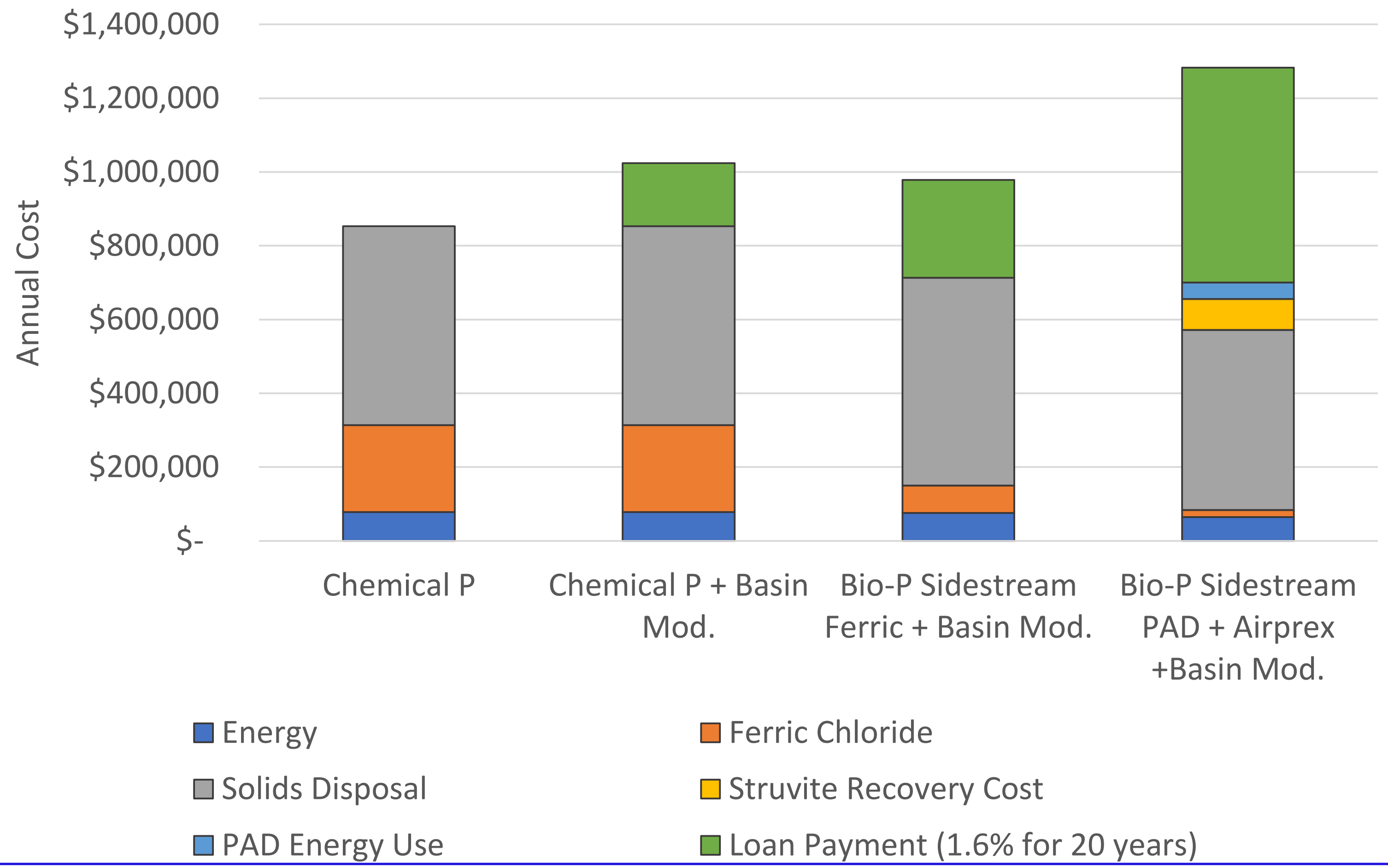
ChemP provides a lower average effluent phosphorus level with more stability



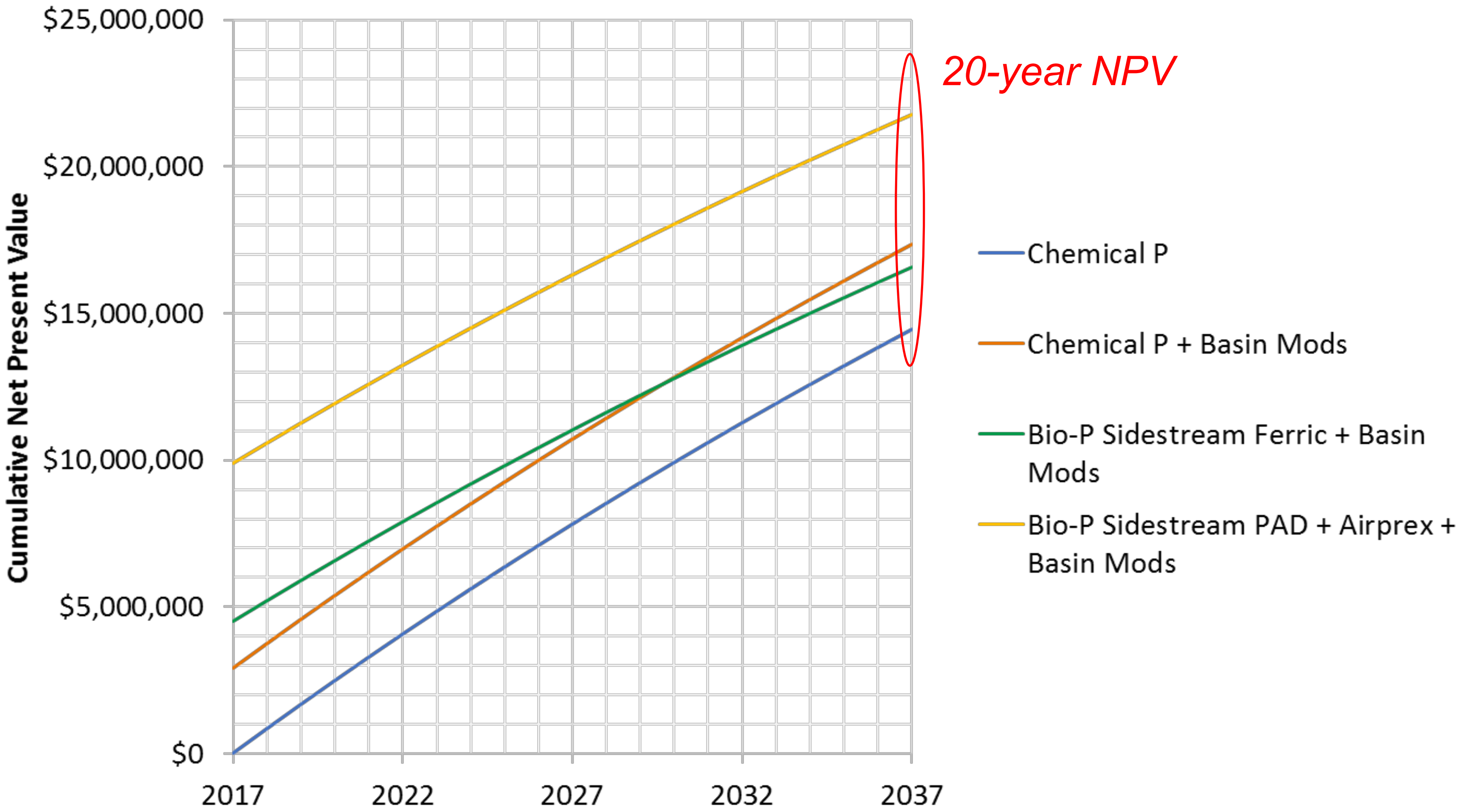


Incorporation of loan payment favors Chemical P with no capital improvements



**Polishing ferric added to Bio-P alternatives to create equivalent effluent concentrations*

No capital investment for ChemP results in lowest NPV *if* basin improvements are not completed



City of Oshkosh Conclusions

- Secondary Performance
  - The MUCT process provides the most stable Bio-P alternative.
  - Chem-P does not exhibit seasonal TP increases.

- Economic
  - Bio-P reduces annual operating costs compared to Chem-P
  - Chem-P with no modifications to the aeration basins provides the lowest life cycle cost.
- Results from secondary evaluation fed into tertiary system sizing approach.

Uncertainty analysis drivers for NEW Water:

- How much phosphorus will we need to remove in 20 years?
- Uncertainty in future performance due to new sidestream loads
- “Right sized” phosphorus management alternatives

NEW Water’s WWTPs

- Bubble Permit for the Green Bay Facility and De Pere Facility.
- TMDL Allocation will be 68 ppd
- Green Bay Facility
  - Average Day Flow = 30 mgd
  - Biological phosphorus removal
- De Pere Facility
  - Average Day Flow = 8 mgd
  - Biological phosphorus removal
  - Tertiary Sand Filtration (w/backup chem)
- Construction of Resource Recovery and Electrical Energy (R2E2) solids process will impact sidestream loading at the Green Bay Facility

Phosphorus Reduction Plan Goals

1

Understand the likely range of future effluent loads based on historical observations and future conditions

2

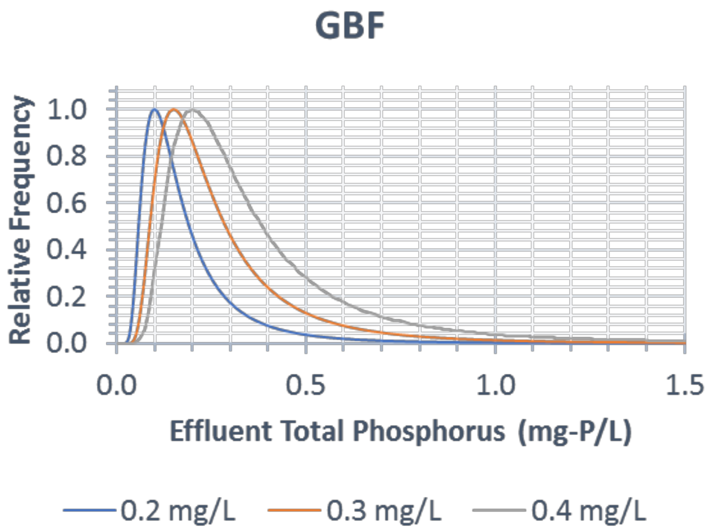
Establish an acceptable level of planning level risk to reduce costs, ease operations, and allow flexibility

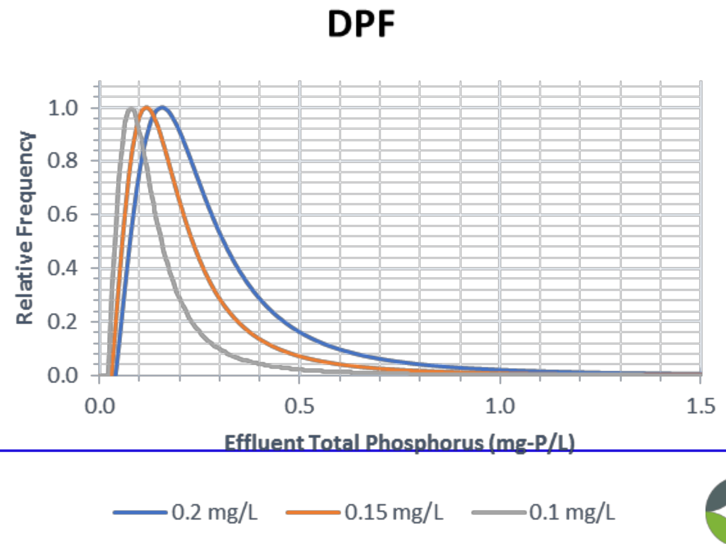
3

Identify a "No Regrets Plan"

Effluent Loads projected for both facilities using probability distributions of historical observations

- 9 combinations comprised of:
  - Historical Average performance:
    - DPF = 0.15 mg- P/L & GBF = 0.3 mg-P/L
  - "Optimized" Performance:
    - DPF = 0.1 mg-P/L & GBF = 0.2 mg-P/L
  - Worse Performance:
    - DPF = 0.2 mg-P/L & GBF = 0.4 mg-P/L
- 10-historical hydrographs prorated to 2040 design year.
- Hydrographs combined with performance to create 900 versions of the design year





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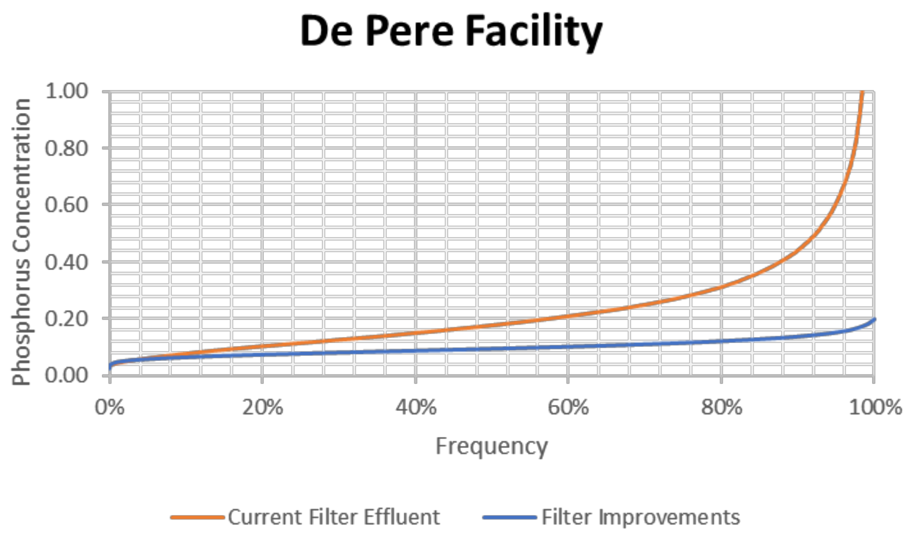
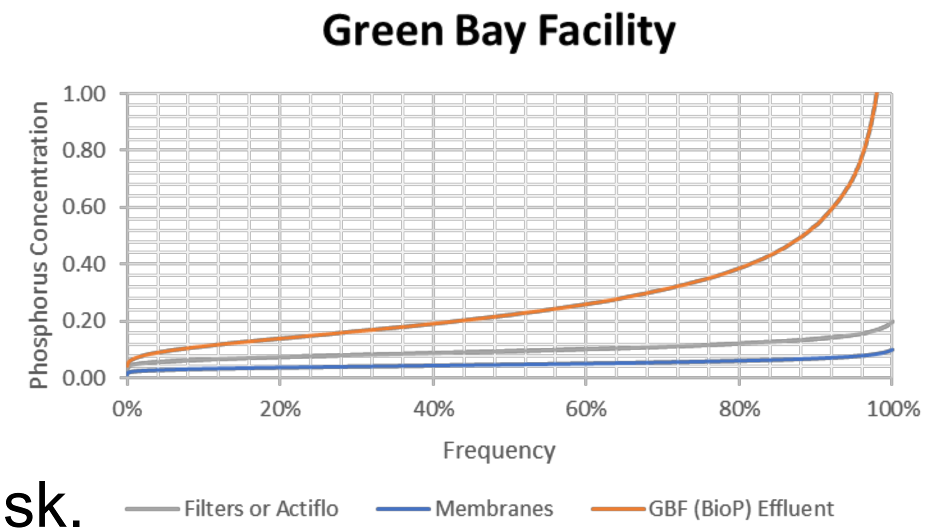
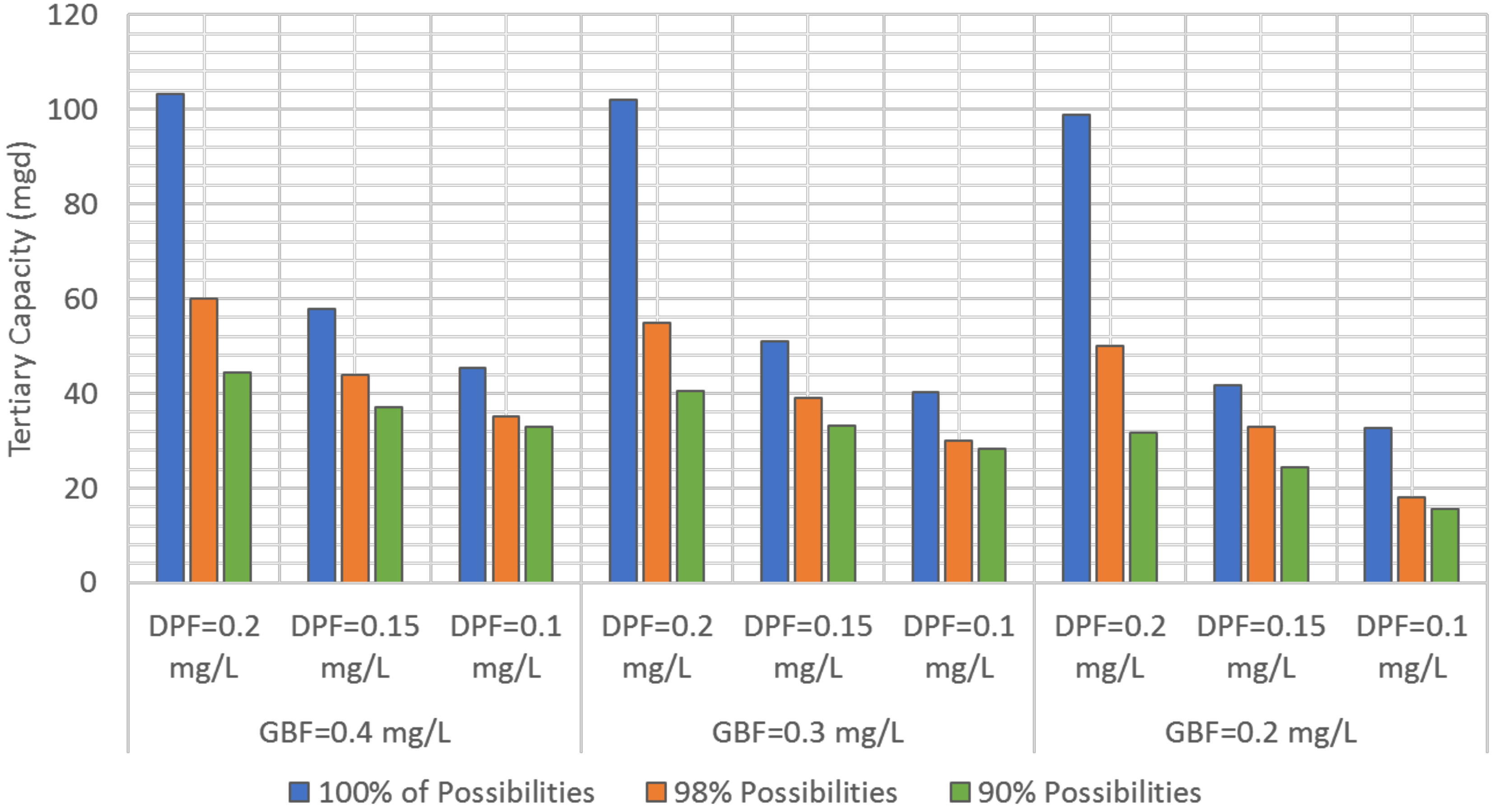
Phosphorus reduction alternatives evaluated

- Green Bay Facility Tertiary Treatment
  - Ballasted Flocculation
  - Tertiary Filtration
  - Tertiary Membranes
- De Pere Facility Improvements
  - Cloth Filter Retrofit
  - Tertiary Chemical Addition
- Alternatives Evaluated
  - 12.5 mgd + Watershed
  - 25 mgd Tertiary + Watershed
  - Full tertiary treatment
  - Full adaptive management
  - Water Quality Trading
- Tertiary Capacity size based on acceptable level of risk.





Balancing risk, tertiary capacity, and capital cost.



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Defining an acceptable level of “risk”

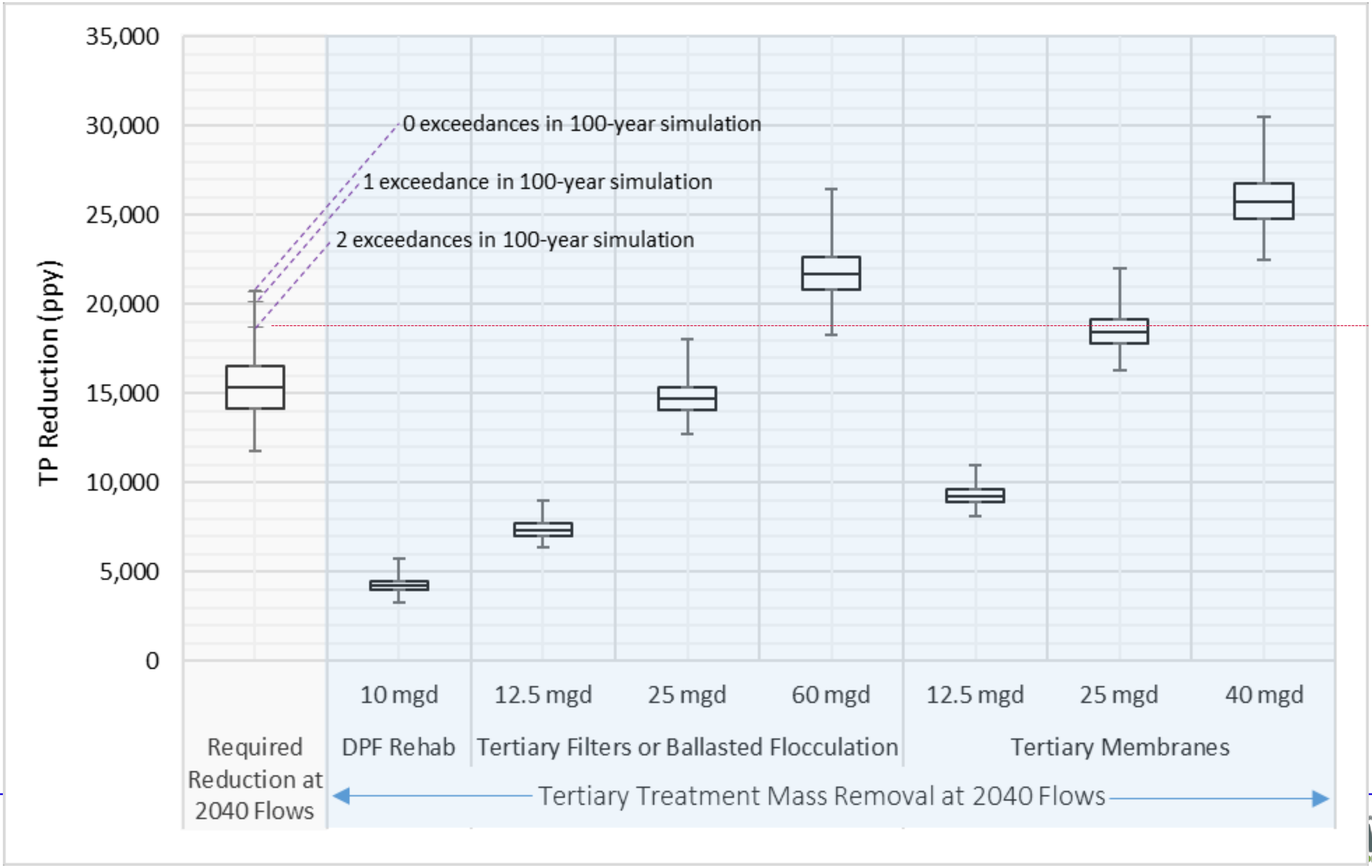
- Types of “risk”
  - **Interim:** Chance of annual permit violations
  - **Long-term:** Likelihood realizing flow and load projections
- Can the accepted risk be mitigated?
  - **Interim**: Mitigated through provisional methods (i.e. supplemental ferric addition)
  - **Long-term:** Provisions to accommodate infrastructure for the “worst case” scenarios
- Goal: Develop the “No Regrets” Plan

Acceptable "risk" established as 2 percent exceedance (one out 50 possible design years)

Number of Years Exceeded in 100 Simulations	Percent Exceedance	TP Reduction Req'd (lbs P/yr)	
		Current	Design Year 2040
0	0.0%	12,900	20,700
1	1.0%	12,600	20,300
2	2.0%	11,300	18,800
5	5.0%	11,200	18,700
10	10.0%	10,500	17,700
20	20.0%	9,600	16,800

Note: 1,500 ppd = 0.05 mg/L at 10 mgd

Estimated Annual reductions



NEW Water Conclusions

- Quantifying the range of future mass loadings allowed for informed decision making based on statistical likelihoods.
- Tertiary sizing optimized by accepting a marginal level of risk that can be mitigated.
- Approach was extended watershed based approaches to aid in watershed selection.
- Preliminary plan compared Watershed only alternatives, treatment only alternatives, and hybrid approaches.

Understanding Risk allows for the development of a “No Regrets Plan”

- Identify opportunities to reduce initial capital cost or deferment
- Quantifies uncertainty to allow for informed decisions
- Allows flexibility for chose solution to be adapted to future ‘realized’ conditions.

Acknowledgements

- Phil Mentink, Nate Qualls – NEW Water

- Steve Brand – City of Oshkosh

- Colin Fitzgerald, PE
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Questions?

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