Predictive Iron Dosing for Phosphorus Removal

A Data Driven Strategy

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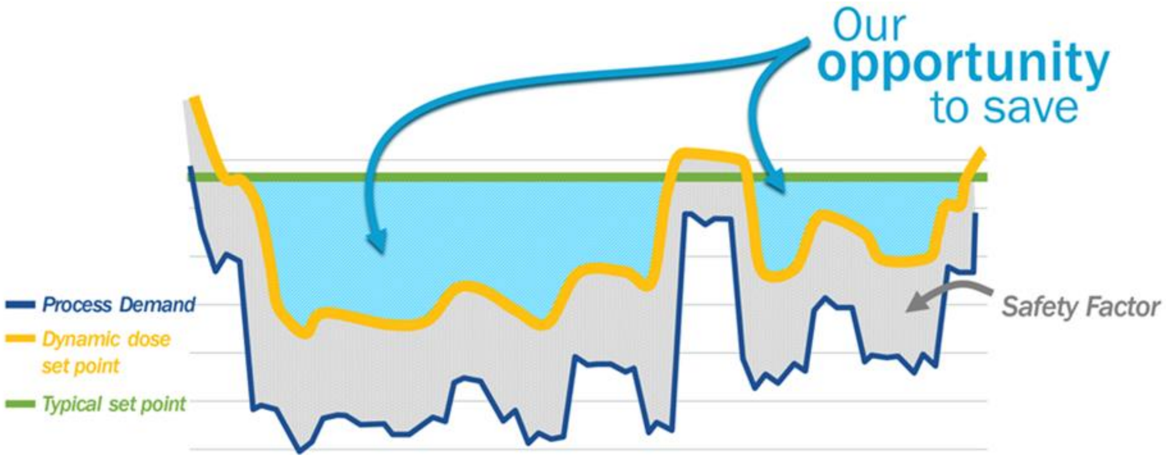

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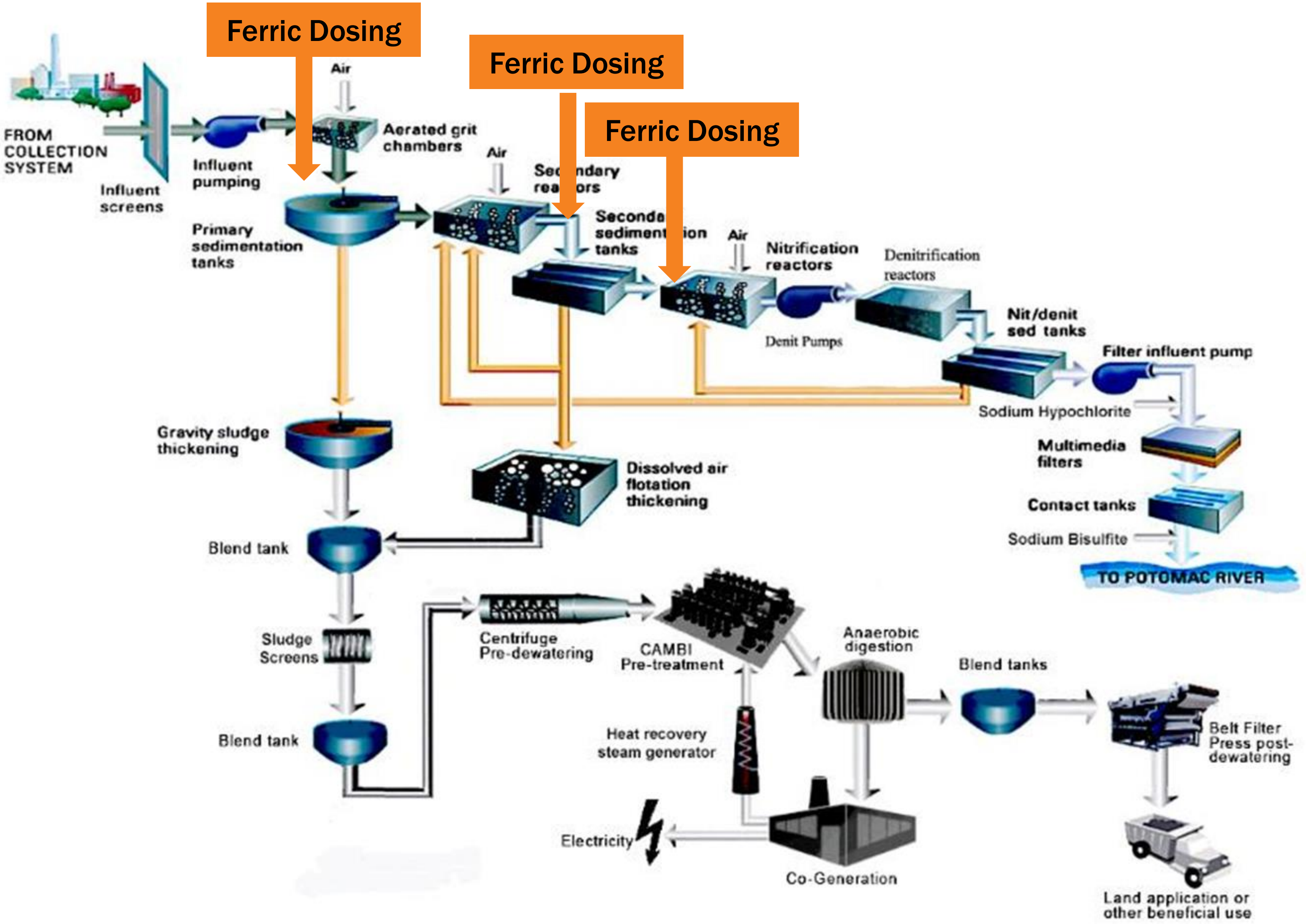
Haydee De Clippeleir, Ryu Suzuki – **DC Water**;

Chemical P Removal – Ferric Addition

- $FeCl3{\cdot}(6H_2O) + 2H_2PO_4^- + 2HCO3^- \rightarrow FePO_4 + 3Cl^- + 2CO_2 + 8H_2O$

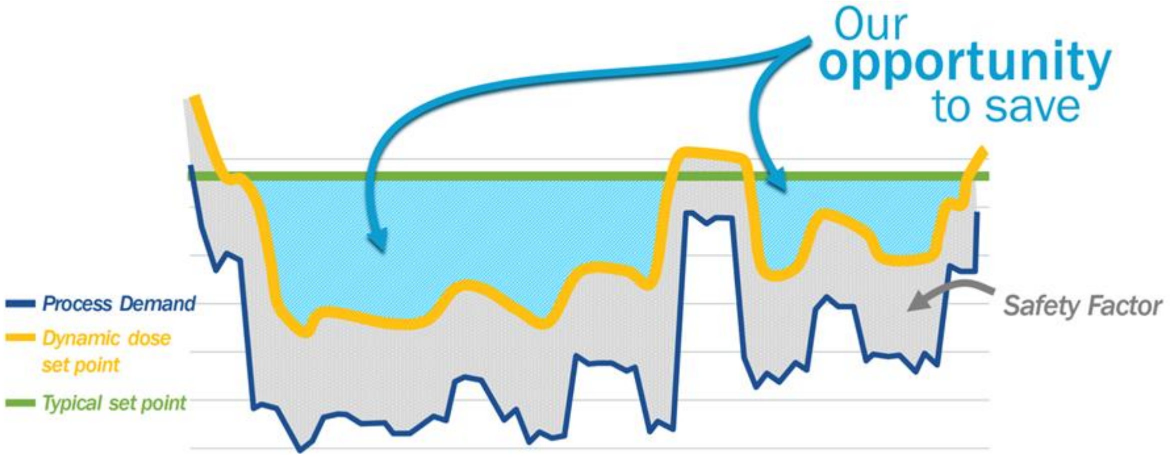
- Iron to P molar ratio is 1:1 without any competing reactions.
- Very complex chemical precipitation reaction with several factors impacting efficiency
  - formation of hydrous ferric oxides (HFO),
  - Aging of HFO,
  - HFO floc structure
  - sorption of orthophosphate (OP) to HFO
  - degree of mixing at addition point,
  - SRT
  - and many others….

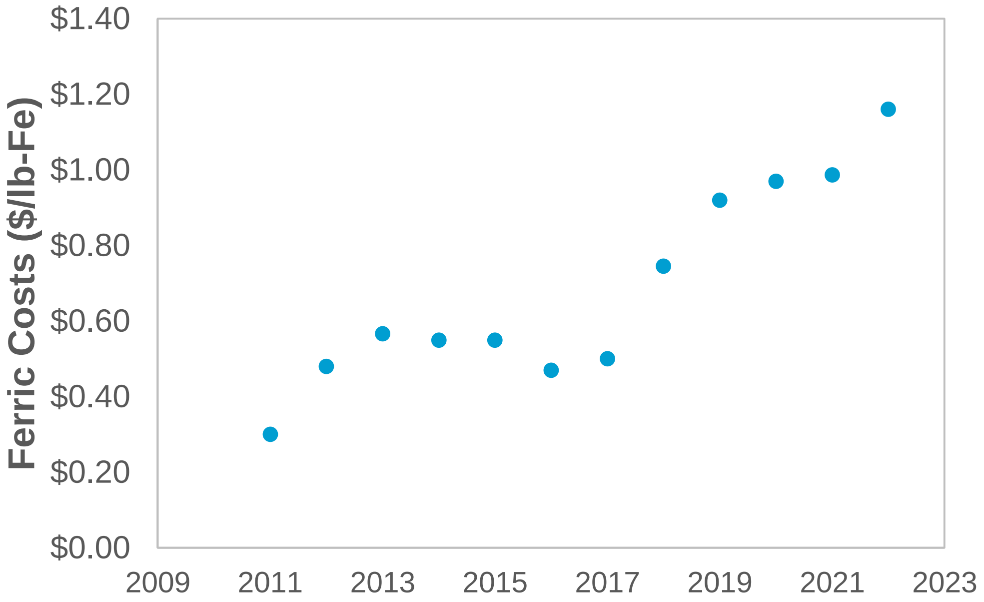
Blue Plains AWTP



- Average flow = 384 mgd
- Phosphorus limits
  - Monthly average = 0.17 mg/L
  - Weekly Average = 0.34 mg/L.
- Phosphorus removal is accomplished primarily through ferric chloride addition.
  - Multiple dosing locations

Why optimize ferric dosing?





- Most facilities operate at a fixed dosing rate.
- Flow-paced dosing can help optimize but is still not reactive to dynamic influent phosphorus concentrations

- Increasing ferric chloride costs
  - Average yearly increase = ~15 % (significantly higher than inflation)
- Uncertainty in future costs.
- Increased focus on sustainability

Key objectives

- Meet phosphorus permit
- Optimize ferric chloride dosing
- Provide decision support

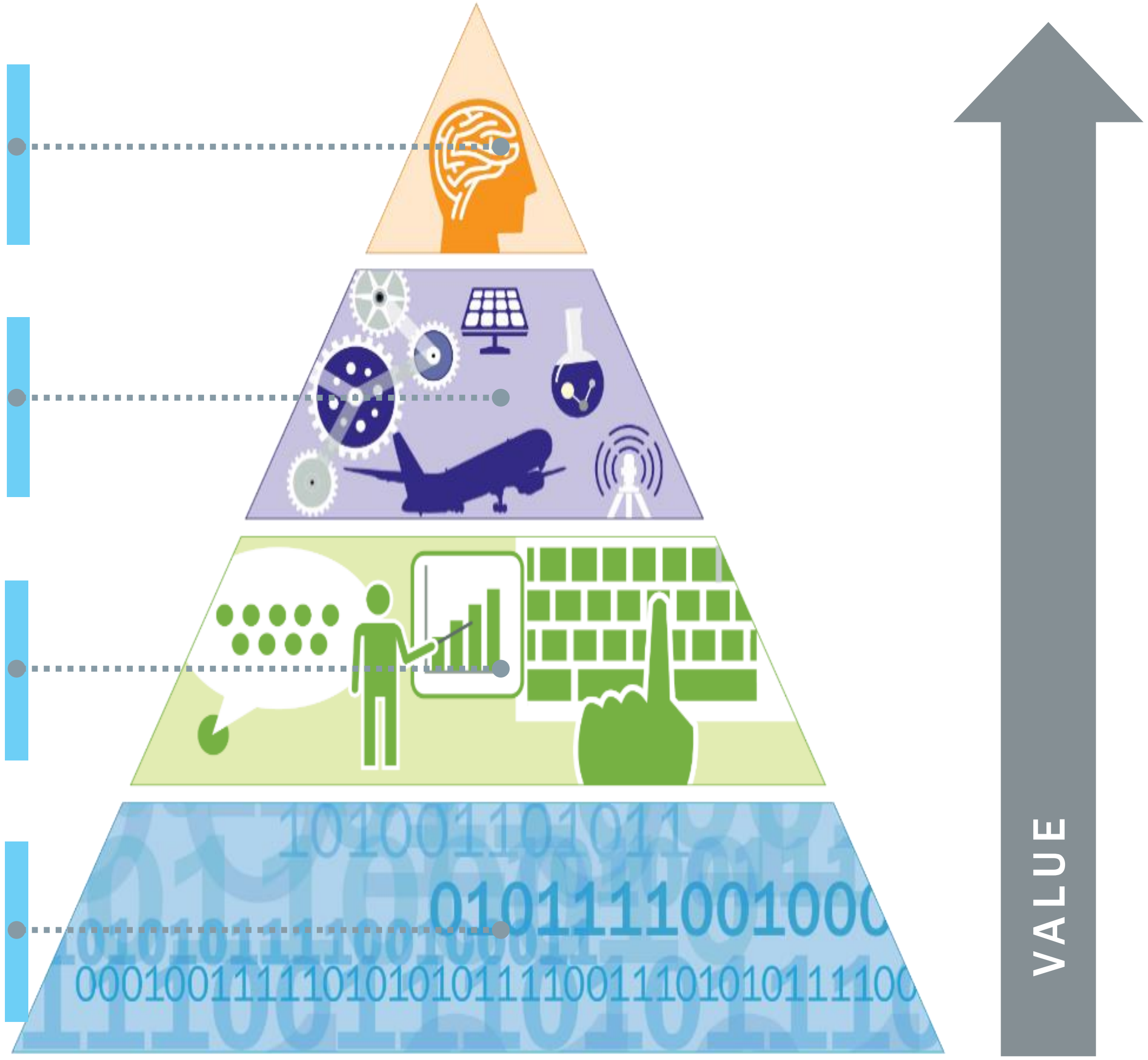
Why a data-driven strategy?

Wisdom
Predictive capabilities that enable best outcomes

Knowledge
Historical actions and results

Information
Combined data with context

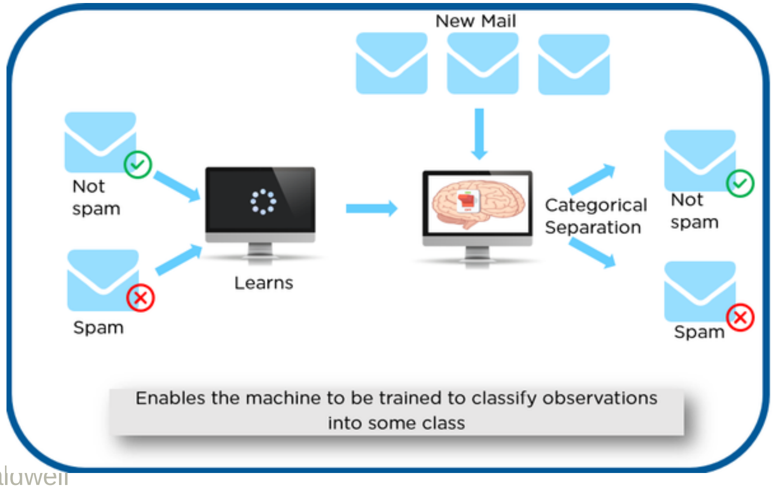
Data
Data obtained by the facility and stored in data silos



Machine Learning vs Artificial Intelligence (AI)

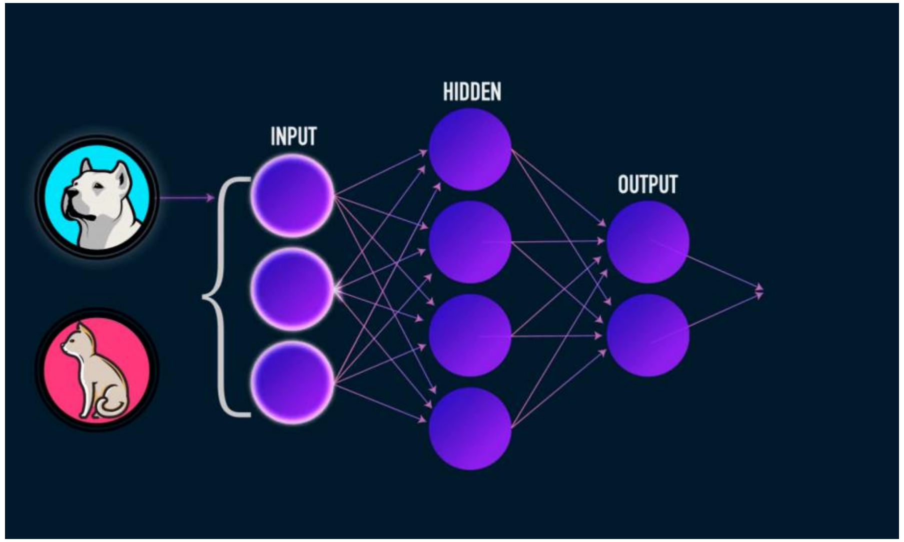
Machine Learning

- Machine learning is the ability of a computer to learn from data.
- Supervised Learning - learning from labeled data.
  - Can be done for classification and regression
- Unsupervised Learning - learning through characteristics of unlabelled data.



Artificial Intelligence

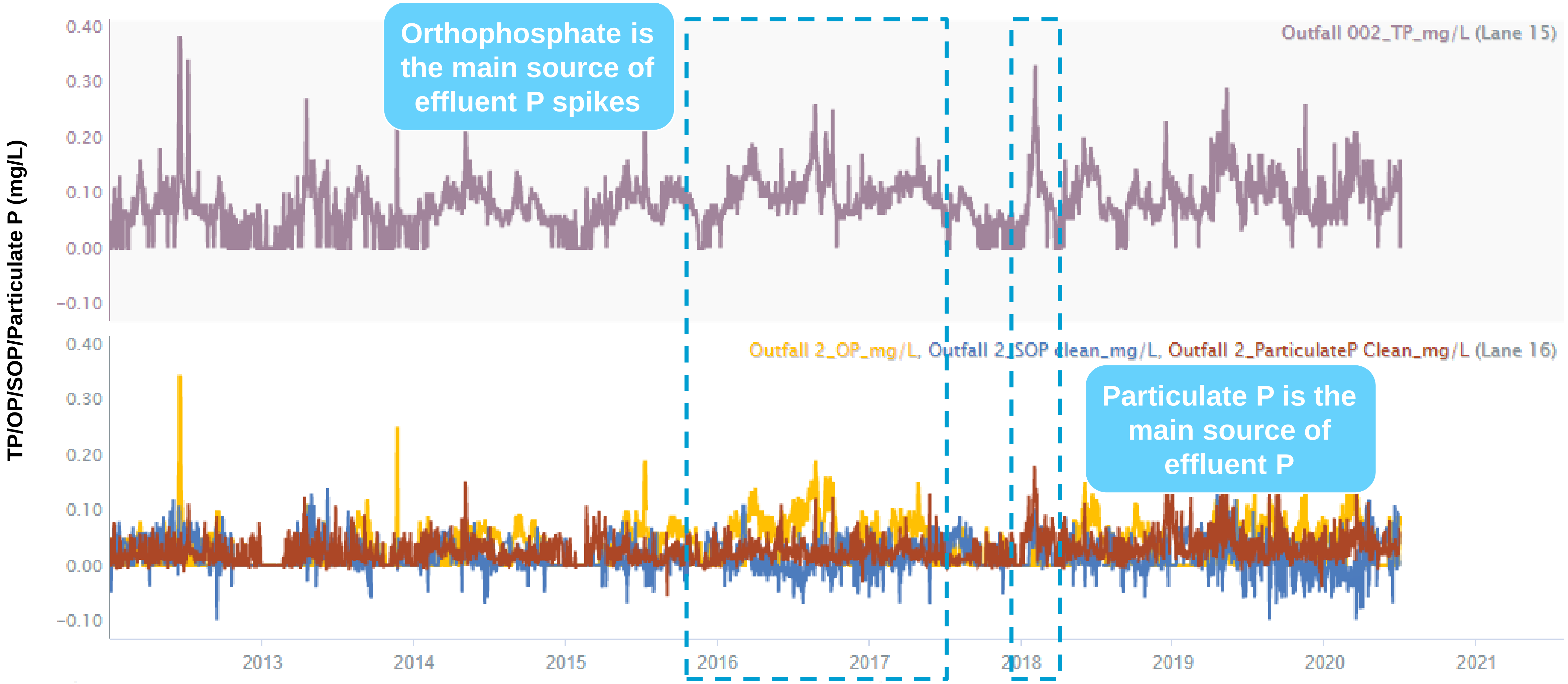
- Deep learning also learns from data
- Uses neural network to learn patterns in the data
- Deep learning models are typically black box models.



Approach

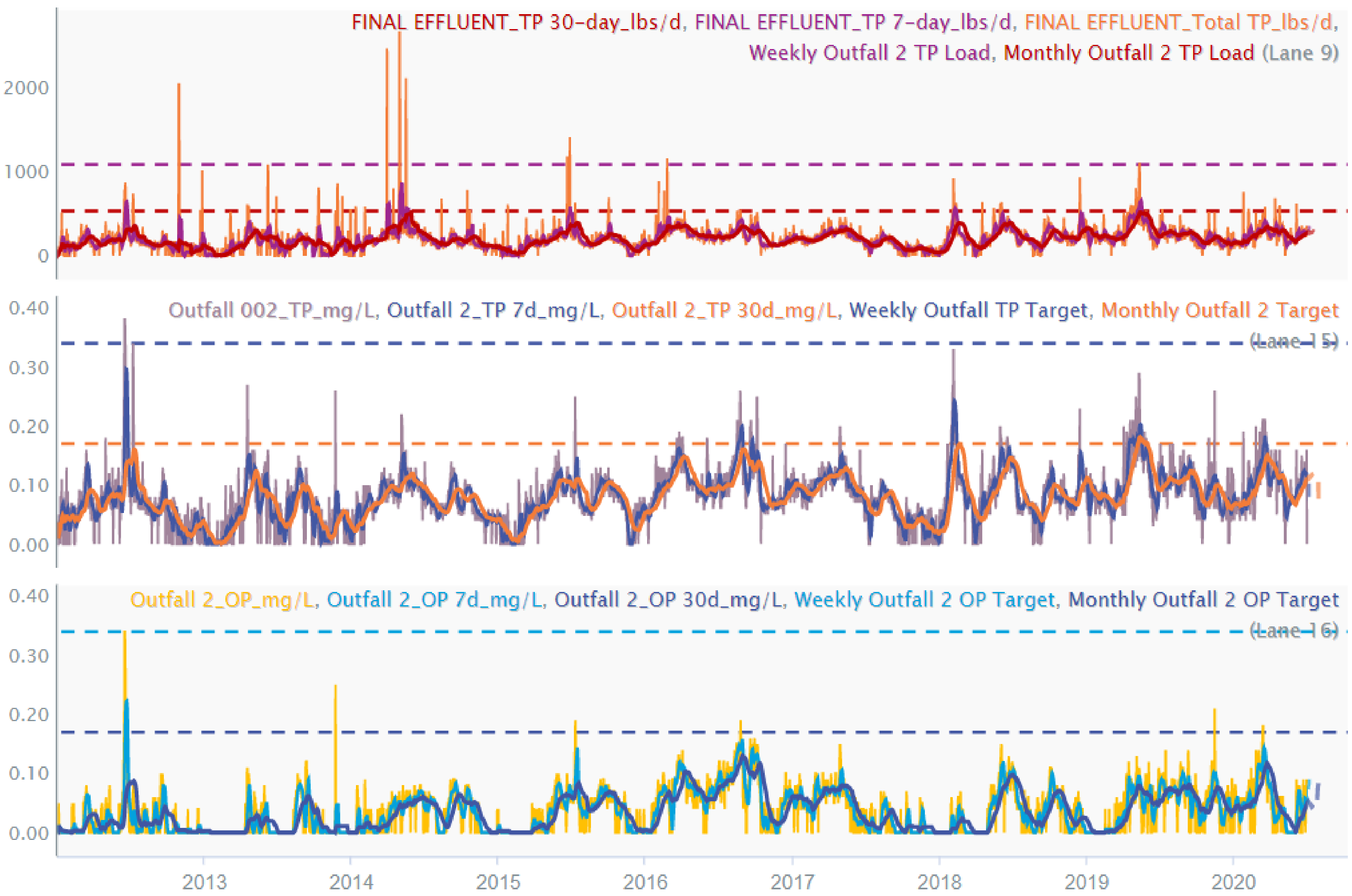
- **OBTAIN**: LIMS
- **SCRUB**: Outlier removal and smoothing
- **EXPLORE**: Use process knowledge to explore optimization opportunities
- **MODEL**: Use simple and AI/ML modeling approaches
- **INTERPRET**: Prescribe optimization opportunities based on modeling

Explore
Diagnosing source of effluent P upset



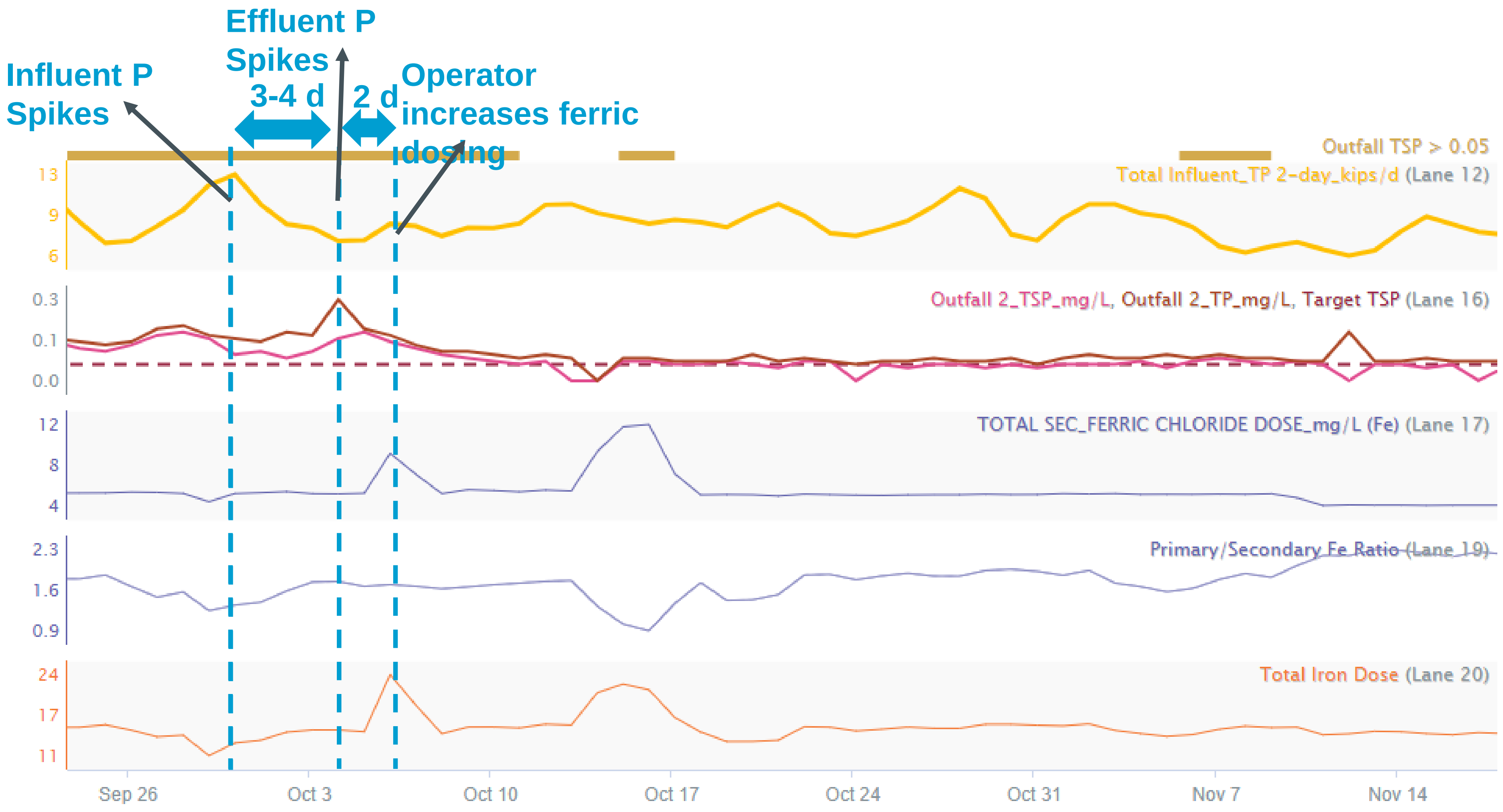
Explore

Permitting Requirements



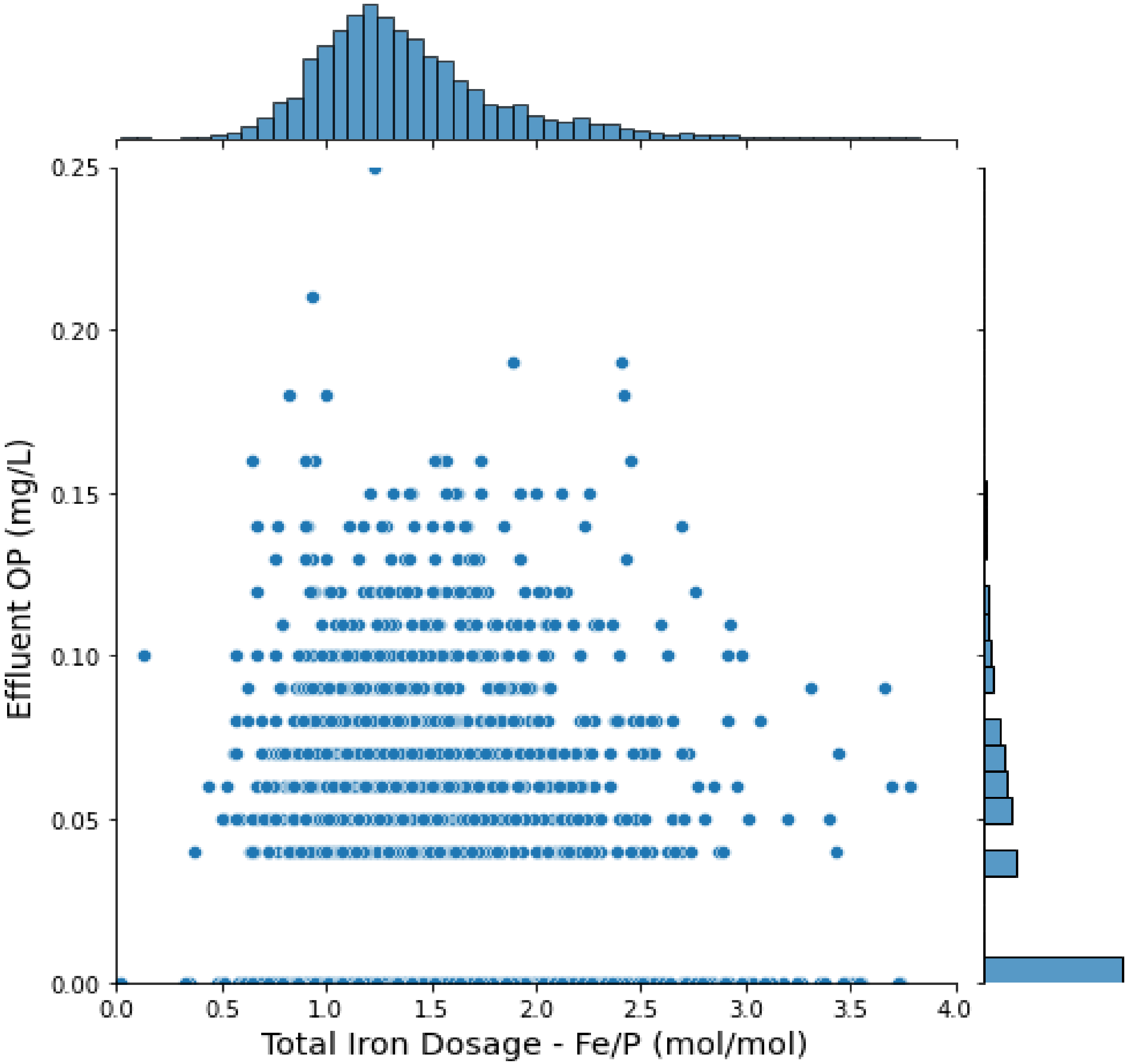
Explore

Understanding current ferric dosing strategy



Explore

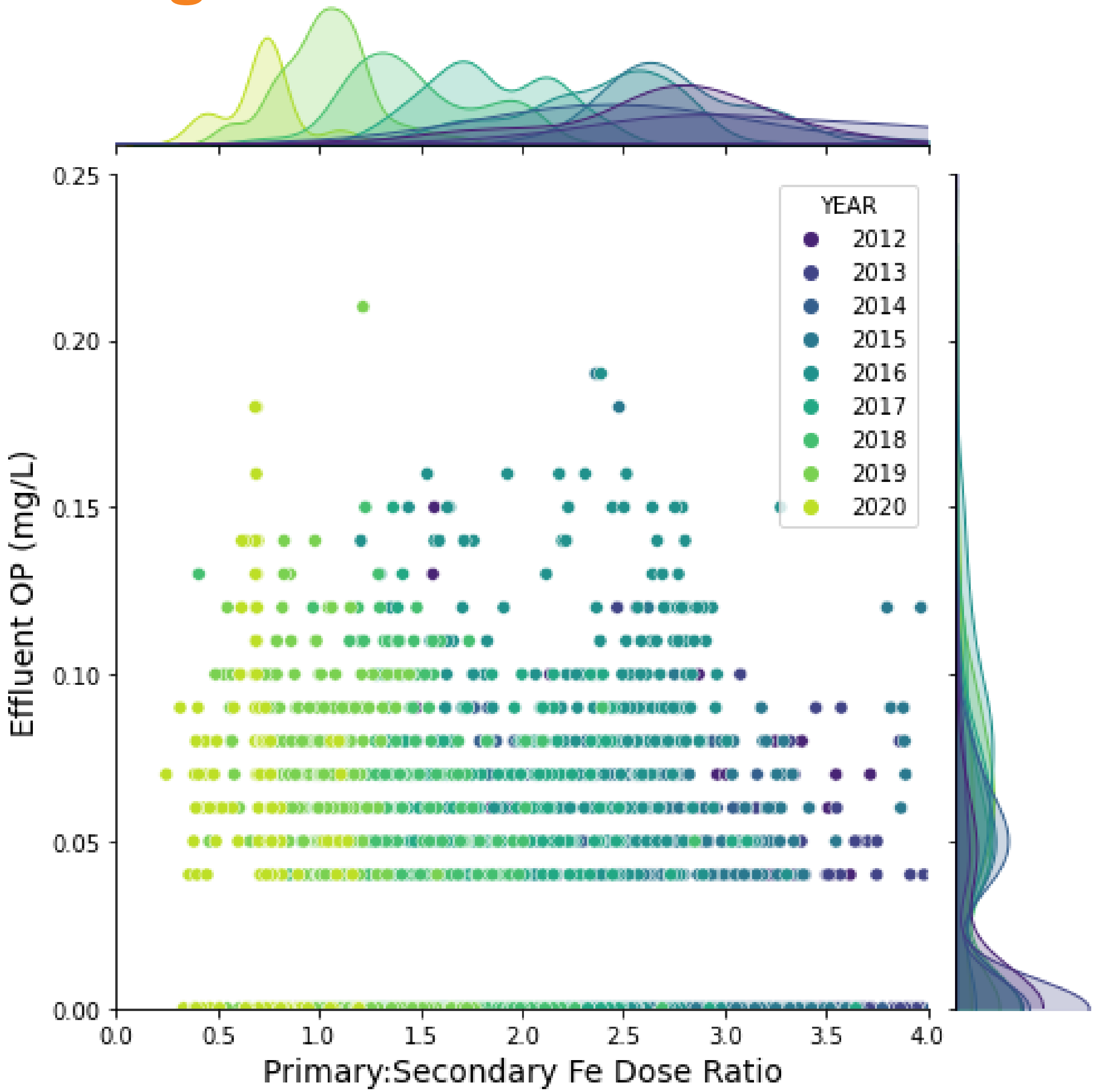
Effect of Fe:P Molar Ratio



- Historically, Fe/P ratio has been between 0.9-2 mol/mol
- No difference in effluent OP with different Fe:P dosages

Explore

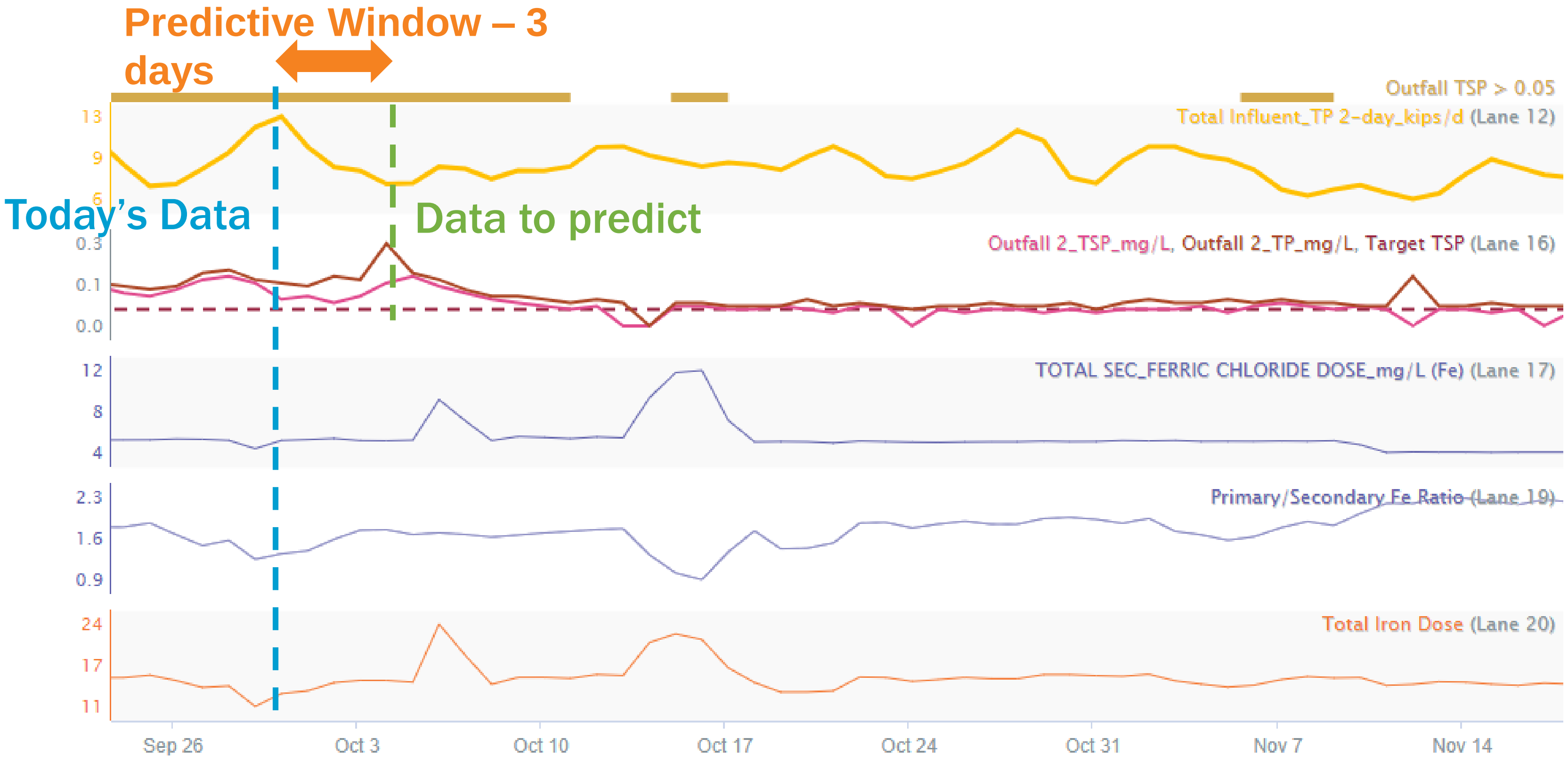
Effect of Dosing Location



Dosing has been trending towards more secondary Fe dosing

No difference in effluent OP in primary vs secondary Fe dosing

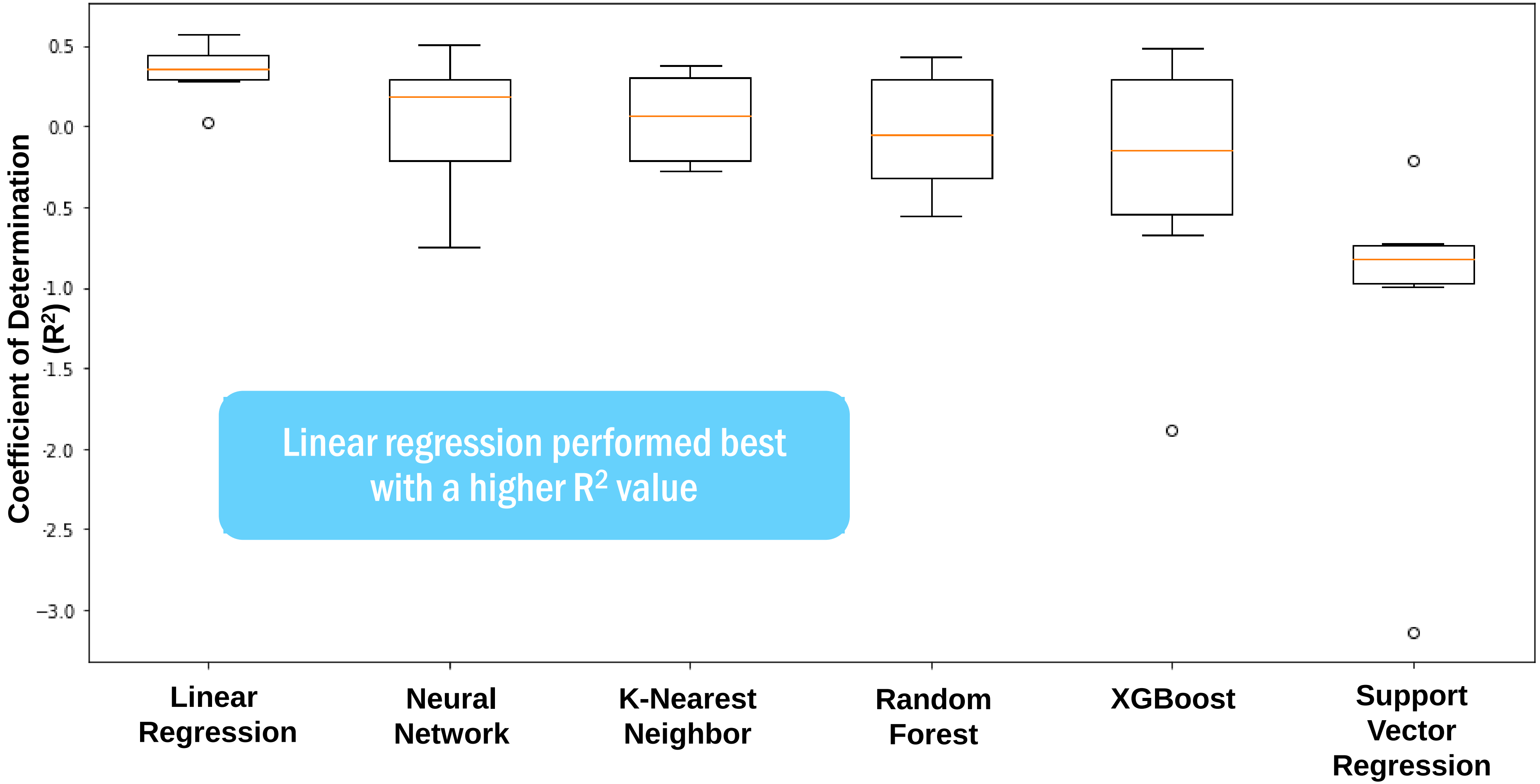
Model
Setup



- Predict effluent orthophosphate with a forecasting period of 3 days.
- Use predictive variables based on plant staff and expert input
  - Influent Phosphorus
  - Ferric Chloride Dose – Primary and Secondary
  - Historical Effluent Orthophosphate
  - Secondary Effluent TSS
- Split dataset into training (2012-2018) and test (2018-2020) to provide independent validation.

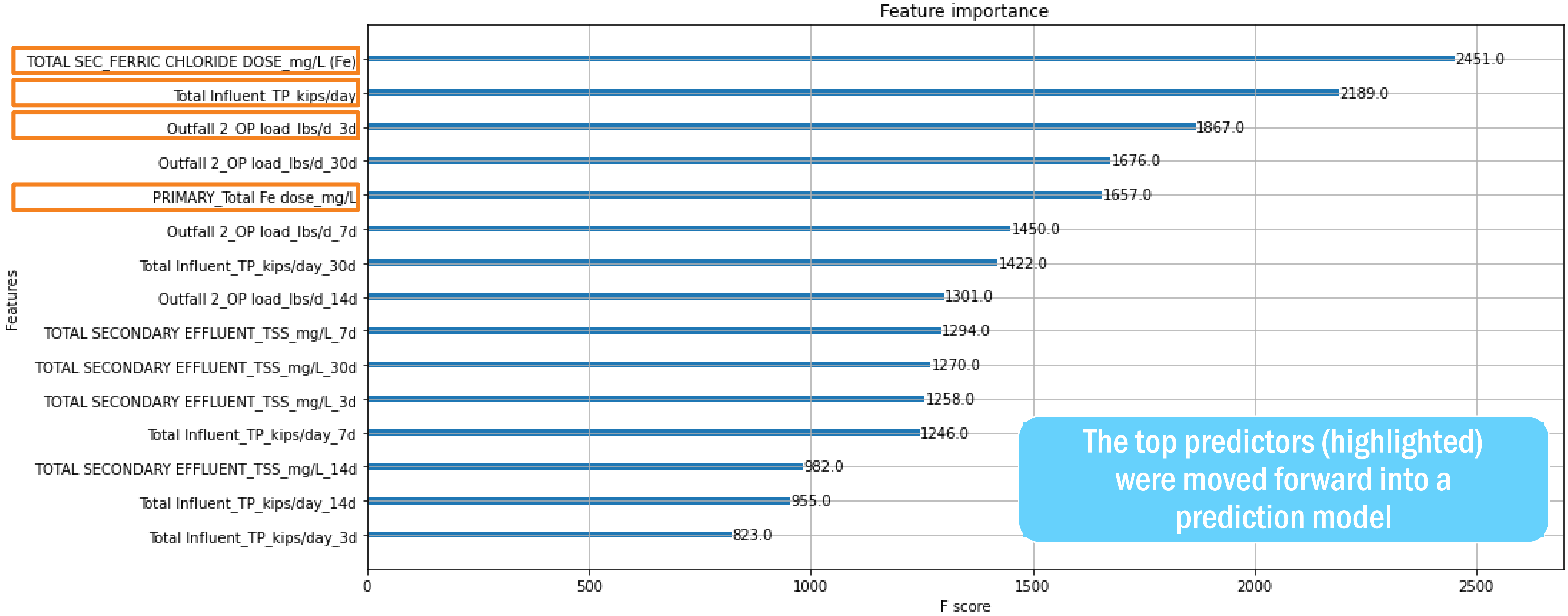
Model

Comparing modeling approaches



Interpret

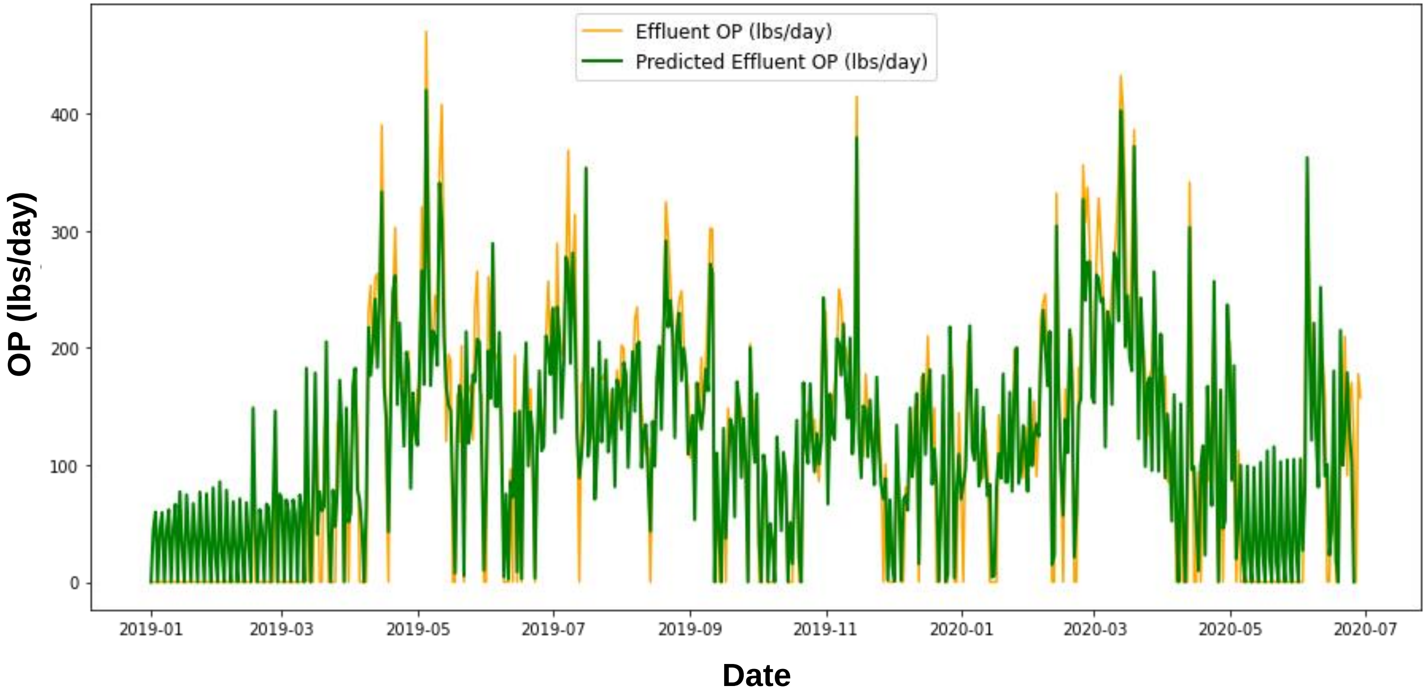
What are the best predictors of Effluent OP?

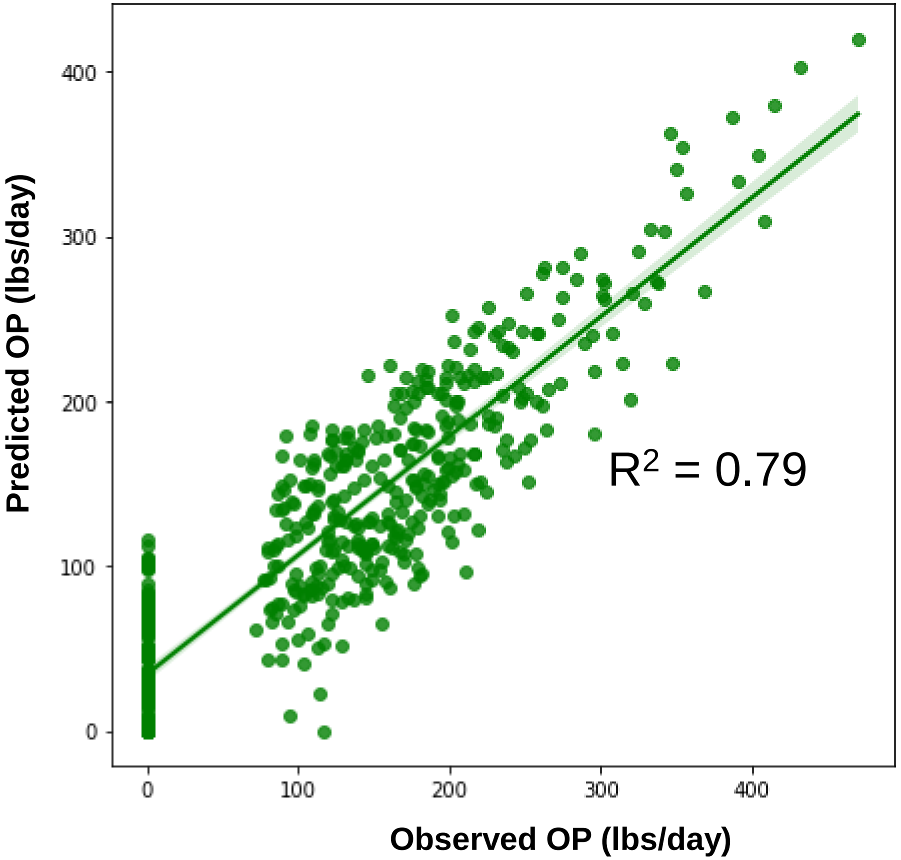


The top predictors (highlighted) were moved forward into a prediction model

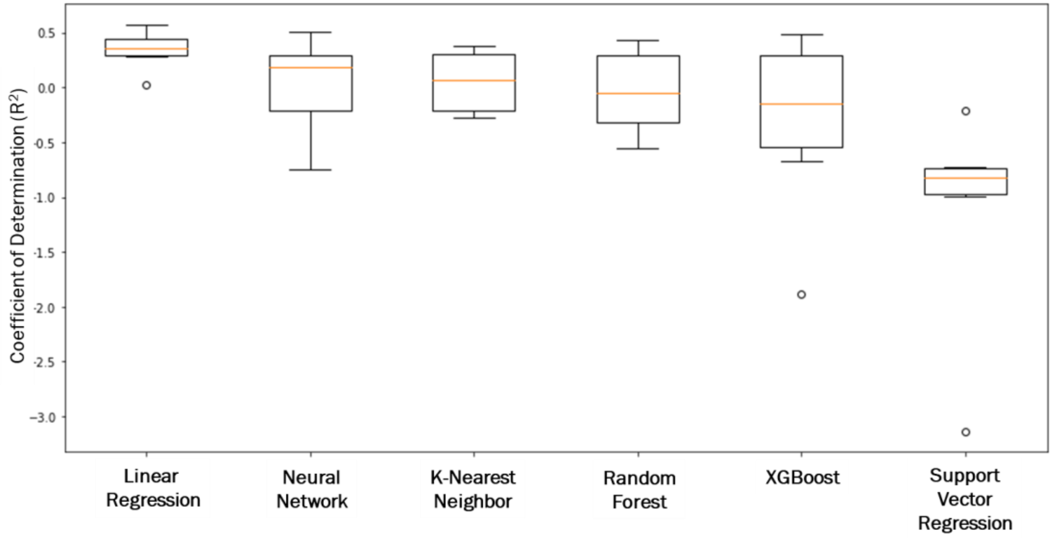
Model

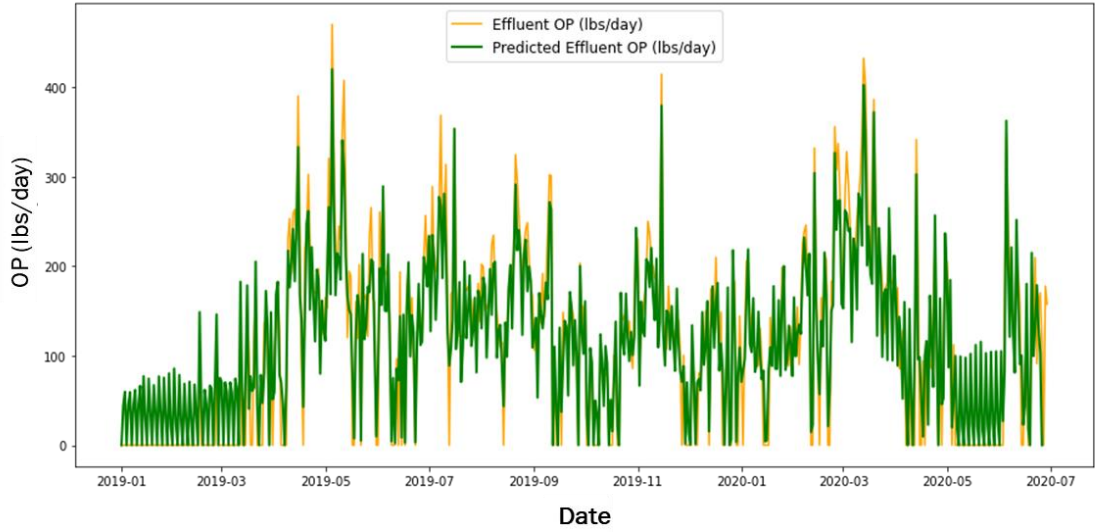
Predicting Effluent OP using Linear Regression





Conclusions

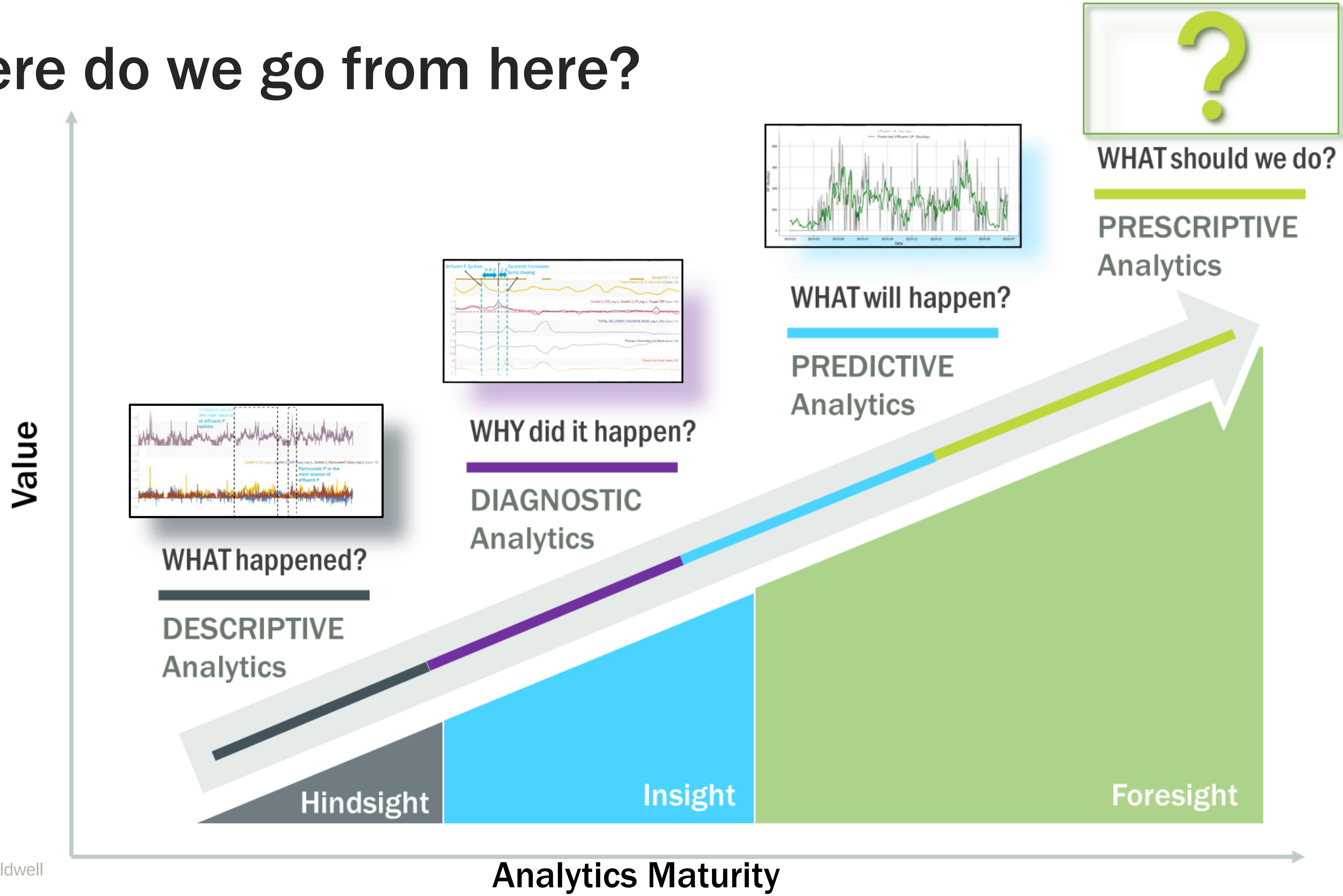




- Evaluating multiple modeling approaches can be useful to determine the right one.
- Simple linear regression can be powerful under the right circumstances
- ML models are more interpretable and can be a powerful tool

- Effluent OP was predicted with a ~80% accuracy.
- The model provides a 3-day forecasting period.

Where do we go from here?



How would an operator use this model?

- Ability to forecast increase in effluent orthophosphate
- Proactively increase ferric chloride dosing.
  - Might want to wait and see if increase in orthophosphate is going to be long-term or temporary
- Decision Support
  - When to change ferric chloride dosing?
  - What is the required ferric chloride dosing for achieving target effluent OP?

Thank you.

Questions?

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Brown AND Caldwell