4th SWAN Americas Alliance Workshop

"From Cloud to Proud: Making Data Work For You"

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September 28-29, 2023  
Badger Meter’s HQ Milwaukee, Wisconsin
Harnessing the Power of **Cloud Solutions:**
Journey from Data to Wisdom for Nutrient Management,
Case Study, Loudoun Water, VA

**Javad Roostaei**, Katya Bilyk, Kendra Sveum, Wendell Khunjar, Phill Yi, Malia Turner, Ankit Pathak, Craig Lee, Yiman Song, Nader Maramkhah

September 28, 2023
Introduction
Completing the Data-Driven (ML) Model Cycle: Deployment is the Final Puzzle Piece
However, A Successful Deployment Requires Many Components:

- Configuration
- Data Collection
- Data Verification
- Feature Engineering
- Testing and Debugging
- Recourse Management
- ML Code
- Model Analysis
- Process Management
- Metadata Management
- Serving Infrastructure
- Monitoring

The main objectives of this presentation are:

- Evaluate different ML model deployment strategies
- Review a case study for ML deployment
- Discuss opportunities and Challenges of cloud deployment
Analytics Platforms in Water Industry

Deployment

On-Premises

On the Cloud

Hybrid Analytics

Edge Analytics
Case Study:
Phosphorus Control at Broad Run WRF, Virginia
Case Study – BRWRF, VA

<table>
<thead>
<tr>
<th>Final Effluent Parameter</th>
<th>Monthly Average Permit Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical Oxygen Demand (COD)</td>
<td>10 mg/L</td>
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<tr>
<td></td>
<td>1.0 mg/L</td>
</tr>
<tr>
<td>Total Kjeldahl Nitrogen (TKN)</td>
<td>1.0 mg/L</td>
</tr>
<tr>
<td>Total Nitrogen (TN)*</td>
<td>4.0 mg/L</td>
</tr>
<tr>
<td>Total Phosphorus (TP)*</td>
<td>0.1 mg/L</td>
</tr>
<tr>
<td></td>
<td>0.5 NTU</td>
</tr>
<tr>
<td></td>
<td>&lt; 2 cfu / 100 mL</td>
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</tbody>
</table>

P Removal accomplished via alum addition, filtration and adsorption

The only operational action to elevated MP TP was to add Alum
Loudoun Water Has Observed Periods Where Membrane Permeate and Final Effluent TP Converge or Diverge
Key Questions

01 What factors contribute to divergence and convergence?

02 Can we accurately predict when readings will diverge or converge?

03 Can we inform operational strategy to influence MP and FE TP at BRWRF?
Workflow For Addressing Effluent TP Challenge

Model 1: Membrane Permeate DOP

Model 2: Membrane Permeate OP Chemscan

Particulate TP (Represented by Membrane permeate turbidity)

Model 3: Membrane Permeate TP (as P)

Model 4: Final Effluent TP

Explanatory Models

Model 5: Membrane Permeate TP (as P)

Model 6: Final Effluent TP

Predictive + Explanatory Models
A Data Architecture Developed During this Project

Step 1: Daily Plant Data in HachWIMS

Step 2: ML model trained offline
- ML Pickle File
- Operational Insights
- ML Training

Step 3: ETL Transformer and Data Quality Check

Step 4: ML Model Deployment
- Push the Predictions, and Operational Insights to the Data Lake

Step 5: Run ML Models

Step 6: Power BI Visualization

SCADA Domain
SCADA Historian
Client Business Network
iconics
SAP
GIS

Data Factory
Loudoun Data Lake
ML Studio
Loudoun Domain

Loudoun Cloud
Data Architecture Using Azure Data Lake and ML Studio for Data-driven Modeling

Performed by Hazen
Performed by LW
BPI Dashboard Development

Data Quality Module & Nutrient Removal Management Predictive Analytics Model

Loudoun Water

Hazen

Table of Contents
- Data Inventory
- Data Explorer
- Model Prediction
- Historical vs. Model Prediction
- Sensitivity Analysis: Turbidity
- Sensitivity Analytic Orthophosphate
- Sensitivity Analytic DCP
- Percentile Hots
- Decision Tree
- Input Weights
- Condition Selection
- Daily Data Quality
- Hourly Data Quality
- Data Quality Boundaries

Last refreshed at 8/16/2023 4:19:46 PM
Industry Lessons, Summary
Operational Support Through Secure Cloud-Based Analytics
Summary and Key Takeaways

Data Insight
- data-driven modeling provides deeper understanding and insights into operational processes

Model Synergy
- Data-driven models serve as excellent complementary tools to traditional expertise and mechanistic models

Opportunities
- Can use cloud data security to access data
- Robust on performance monitoring
- Scalable computing
- Better for CI/CD

Challenges
- Latency and disconnected operation
- May get costly
- Requires technical knowledge

Cloud Security
- A good example of how we can securely work on private Azure cloud for delivering advanced analytics
Thank you!

Questions

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Enabling Optimization through Hybrid Modeling

Leon Downing, PhD, PE
Global Practice and Technology Leader
The Challenge at Fond du Lac

Located 1.5 hours north of Milwaukee
Population served: 75,000
Resource Recovery Facility focus on sustainability

Largest challenge: Effluent phosphorus requirement of 0.22 mg/L
A series of improvements moved them close to their goal
Biological phosphorus removal has a “memory” and requires both forecasting and response simulations.

Events that happen on **Tuesday** may cause the effluent increase on **Friday**.
A combination of tools have been combined in a hybrid model used by operators for informed decision making.
Fond du Lac has been implementing hybrid modeling
Key considerations

• Accessing data continues to be the largest challenge
• A small utility often presents opportunities for innovation
• Collaboration across multiple shareholders is the key
• Digital tools should not make decisions, but inform decisions
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Digital T-winning from Source to Customer
How Two Providers Collaborated for the Mutual Benefit of Their Customers

4th SWAN Americas Alliance Workshop – Milwaukee, WI
Presented by: Matt Rolls, Vice President Business Development
28th September 2023
Specific Energy: Cellular Communications Architecture

**Plant data**
- Sensors
- Pumps
- Tanks
- Valves
- Instrumentation
- Controller (PLC/VFD)

**Edge device**
- Hardened industrial computer
- Size of 2 decks of cards
- Embedded wireless modem
- Collects data at the edge from local controller
- Data scanning at 0.5/s rate

**Cloud server**
- Unlimited cloud data storage
- Easily export high resolution data
- Unparalleled uptime
- Secure and locked down

**Operations**
- Configure SMS alarms
- Customizable dashboards
- Custom reports
- Unlimited user logins
- View data on any mobile device

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Model-based control | Optimized performance | Informed decisions | Actionable results

**SPECIFIC ENERGY**
Preferred Operating Range: A Moving Target
Specific Energy Illustrated

Lowest point is system minimum Specific Energy

Narrowest point is typically pump Best Efficiency Point (BEP)
Case Studies: Lakewood, CA & Murfeesboro, TN

Groundwater supply w/limited treatment
Multiple direct serve wells
No elevated storage – single pressure plane

Surface water supply, extensive treatment
Single treatment plant (Stones River WTP)
5 Elevated storage tanks – single pressure plane
Worst alternative has a SEC of 387 kWh/MG. That’s a 43% increase with ALL pumps outside of POR.

DPO recommendation is to run Pumps 1 & 5 at shown speeds. SEC is 271 kWh/MG.
Murfeesboro Distribution System Dashboard
Lakewood’s challenge is quite different. They have numerous sources all pumping into the same pressure plane with no buffering storage. Water demands change dramatically and unfortunately, so do their electrical rates…
The digital twin here allowed them to find the optimum combination of pumps and speeds from approximately 2.2 trillion different possibilities…
It also allowed them to see the affect of wear and tear on not only efficiency, but also capacity. This is where we were introduced to Qatium. Lakewood was attempting to calibrate a new model with Qatium, but was struggling to do so with standard factory curves.

Once they were using our Tested Curves instead of Factory Curves, the model calibrated...
Specific Energy & Qatium

DPO is now sending the real-time pump curves into Qatium via an API, allowing the model to calibrate. This provides Lakewood with the ability to run simulations more accurately across their system for operational awareness and modelling future scenarios.
At the same time, Murfreesboro had hoped to find a hydraulic model that was easier for their operators to understand, and that could merge with what we were doing to create a digital twin of the distribution system to go with our digital twin of the pumping systems.
Now, data from our digital twin is feeding directly into Qatium’s model, which allows them to calculate “Model Accuracy” which compares theory to reality.
Value & Benefit to our Mutual Customers

- Access to real-time pump operation for increased model accuracy.
- Combined holistic Digital Twin of pump system(s) and network.
- Ability to build energy profiles into simulations – time of use savings not diluted due to inefficient pump selections.
- Minimum effort on the customer part for set-up and operation.
Thank You

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Water Authority Valleil & Veluwe – The Netherlands

- 75 MGD
- 1.1 million people
- 16 WWTP's

“We are committed to reusing raw materials from sewage and producing energy from sun, wind and water. We have been completely energy neutral since 2020 and our ambition is to be completely circular and climate positive by 2050.”

Water Authority Vallei en Veluwe
Amersfoort APC implementation

Challenges:
- Improve treatment performance to compliance limit of TN 10 mg/L
- Save energy
- Reduce time spent on operational issues

Approach:
- Upgrade aeration controller to Advanced Process Control (APC) using influent flow prediction → On premise
- Increase visibility to the data and controller performance → On the cloud
On premise environment

Aeration setpoints

Self learning feed forward

Prediction with machine learning

Main variables at the aeration tank

Influent

Belasting

Influent eq.

Nh3 0.4 mg/l
NO3 Aerobic 1.5 mg/l
PO4 Aerobic 0.6 mg/l
O2 2.6 mg/l
MLSS 4.0 g/l

Controller

Aeration
- Active
- Feed forward
- VK Zijstroom

Limit

- NH4
- O2 min
- O2 max
- HOA Aerobic
- PO4 Aerobic

Belasting Influent eq.
2.8 kg N/h
40 m^3/h
**DWF with APC**

- Air flow follows influent pattern

**DWF with PLC only**

- Flows
- Concentrations

Stable DO
### Controlled Experiment

- Start of APC: Jan/2022
- Experiment: 16 days in Jul/2022
- Both lanes were intermittently run with APC/PLC
- 1 day for transition between APC and PLC
- Only DWF days selected for comparison

⇒ Days with APC on AT1 had the best performance in terms of energy savings

#### Specific Energy

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<td>PLC</td>
<td>APC</td>
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<td>APC</td>
<td>PLC</td>
<td>APC</td>
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Results of controlled test in Amersfoort

Comparison of overall results in Amersfoort to previous tests in other WVV’s plants:

- Total N: -30%, -10%, -6%
- Energy: -30%, -9%, -5%
- PO4: -30%, -13%

Benefits not yet quantified:
- Ease of operation
- Extension of assets life cycle due to less variations
- Increased visibility to plant indicators
- Reduction of metal dosing for PO4 reduction

Decision: maintain APC instead of only PLC control
Letting data work for you

- Clear goals
- Open for innovation
- Flexibility
- Team work
- Long term vision
- Partnering