Integrating the sensor system into water treatment plant operations

- This document summarizes insights from interviews with managers as well as shadowing operators at both the Spring Hollow and Falling Creek facilities. It also poses hypotheses and ideas for what a "successful" integration might look like.
- Please use it only as an internal reference document for discussion and development of next steps. Due to potential issues related to protecting the source of information, please do not share outside our research team.

Insights

The insights below encapsulate "ways of thinking" by plant operators and managers followed by ways this informs or can inform the project's "way of thinking."

Insight: The concept of forecasting or formally predicting conditions does not exist in the operators' world

Although operators do analyze trends and use their familiarity with their system to understand what is going to happen, they do not forecast per se. And, forecasting is not a part of an operator's vocabulary. To boil down what they do, they watch and respond. While this requires some trend analysis and prediction, it is done ad hoc at the level of the individual.

- There are no tools that I recall that predict future conditions. So, they don't have prior knowledge about how forecasting can help.
- Operators "live and die by the numbers," meaning that they react to real-time changes in conditions. In this way, one of their core duties is to be sentinels and then respond to change.
- They may look at trends and appreciate the role historical patterns can play in helping them make their own predictions, but they never refer to it as forecasting or even predicting conditions.
- When talking about forecasting, they mostly asked to receive the numbers and the trends.

What this means: The operators don't necessarily feel that they *need* a forecast. "Just give me the numbers" was what I heard when talking about forecasts or visualizations. But, there is evidence that there is room for a forecast to really be helpful. It is difficult for operators to stay vigilant, especially at FCR where "things happen fast" and there's a potential for major impact on the plant. Thus, forecasting doesn't solve their problem. Instead, *forecasting's main value proposition is to tell them when to be vigilant.*

Insight: Operators have many jobs and they all serve water production

- Operators do everything. They monitor and treat the reservoir. They figure out the right chemical dosages for the rate of production. They monitor water quality as it is produced. They detect issues, determine the causes, and address them. This may be a chemical issue or a mechanical issue, or an electrical issue, or an engineering issue. They even cut the grass at the facility.
- Operators are not intrinsically interested in the water quality reservoir. They don't track water quality for water quality's sake. Addressing problems are focused on water quality production. Copper sulfate may have concerns ecologically, but this a non-issue for the operators who are using a tool that works and doesn't reside in the reservoir for a long time, and thus doesn't affect the quality of the water they produce.

What this means: The reservoir becomes salient *if and only if* it creates an issue for the plant's ability to produce water. This sounds strict but it is meant to clarify the lens through which they view the world. They have so much to do and it's all in service to efficiently producing high quality water.

Insight: Falling Creek is the problem child of the water treatment facilities

- The reservoir has physiographic properties that make it less stable than other reservoirs. The shallow nature of the reservoir makes turnover something that occurs multiple times per year (rather than once at Carvins, or never at Spring Hollow). When it does occur, the metals on the bottom have a greater chance of being a problem than at other, deeper, reservoirs because it can be hard for the operator will struggle to find an intake that avoids the issue. Not only is manganese a toxin, it "clings to everything" in the facility and requires a lot of time and effort to flush out of the plant.
- The plant setup is also unforgiving in the treatment of the water from the reservoir. Due to the nature of the plant, there really only exists 20 to 30 minutes from the time that water enters the intake pipe and the time that it is being deposited in the finished water reservoir. This puts constraints on the ability to treat the water. There may be times where the chemical reactions that would work at Carvin's Cove (due to greater detention times in the settling basins) cannot physically occur at Falling Creek. Therefore, being slightly off with the chemical dosages at Falling Creek is more consequential than at other facilities. You may end up more uncaptured debris or unreacted chemicals in the filters or chemicals in the filter that didn't react with debris.

What this means: The issues at Falling Creek are not universal and may only apply to a subset of water treatment facilities. The unique system may influence the level of confidence that operators would want to act on an algal bloom. Perhaps they would want to act sooner rather than later (This is my hypothesis. It doesn't come from explicit data.), which might mean they need less certainty before acting (as long as it's not too expensive to act). This may lower the threshold at which operators would want to be alerted.

Insight: Operators may see things coming but they largely react to issues rather than take proactive measures

- This is in the same vein as a doctor who reacts to a patient's problems, but rarely does preventative procedures. Operators don't do preventative procedures on the reservoir.
- This is a watch-and-plan modus operandi rather than a go-change-the-environment-that's-causing-this one (i.e., reactive rather than proactive).
- They didn't talk about stopping it at an early stage, but rather emphasized how they can react appropriately on the backside of the issue (i.e., in the plant). This is despite the fact that they do have some tools at their disposal including copper sulfate and the oxygenation system. It is important to note that I was always the one bringing up the oxygenation system—meaning it wasn't on their radar. Copper sulfate is out because it interferes with Virginia Tech's research.
  For example, forecasting would allow them to see the issue coming, plan for it, and then dose it as it happens. Dosing carbon at the intakes or upping the potassium permanganate levels were mentioned as ways to treat an algal bloom in process—still reactive but could be done to nullify the effect of a bloom on the plant.

What this means: The mental model of operators is not to be far out in front of problems in terms of shaping the system. Instead, they are event-focused and react to what is happening. While adaptive responses to the treatment plant system exist, responses for the ecological system are not already built into their repertoire. To do so would mean creating new ways of

thinking and likely the navigating the “our resources are already spread thin” issue of almost all organizations. (Although I didn’t actually hear this lament, it is true that one operator does everything at Falling Creek.)

Insight: Operators are numbers people, not trend people

- Operators may like to see the trends, but trends aren’t essential to the day-to-day production of high-quality water, and everything they do is in service to production. Trends may be helpful, but “Operationally, everything is about the numbers, the readings, we get.” This quote comes from the same person who likes to look at trends; the operator said he likes to see if the “numbers” are “going up” or if they are “really going up.” By this, the operator meant that he’s evaluating the rate of change to help him define the potential seriousness of the issue. Thus, trend information may be sought once an issue is identified.
- Another reason operators are “numbers people” is because they have to spot the exact transition when it occurs. Multiple accounts indicate that “things happen fast” at Falling Creek and that, because of this, the plant can “get away from you.” This means that there’s a short amount of time from when the reservoir transitions to when it’s impacting the water quality. So, it is not enough to know that something will happen tomorrow, they have to watch all day tomorrow to see when it happens and act accordingly.

What this means: Trends or any detailed data might better set aside for operator’s who are interested in doing a deeper dive once they are alerted to an issue. The operator’s use of information may follow a process of: Once they are alerted to a potential issue, they track the issue, and then deal with the issue as it occurs. They may use their own trend analysis to help identify patterns to inform future occurrances.

The insights from the data above make is sound like a daily timestep is not sufficient, but I don’t see it that way. There are things they could do to mitigate the issue and reduce the need to have to brace themselves for the transition. Again, copper sulfate, carbon, O_2 can potentially head off the issue. But they still need to watch for the instant at which transition occurs (and it occurs quickly). So, while a daily time step is useful, they still “need the numbers” to track the issue the day that it happens.

Insight #: Simplicity over complexity

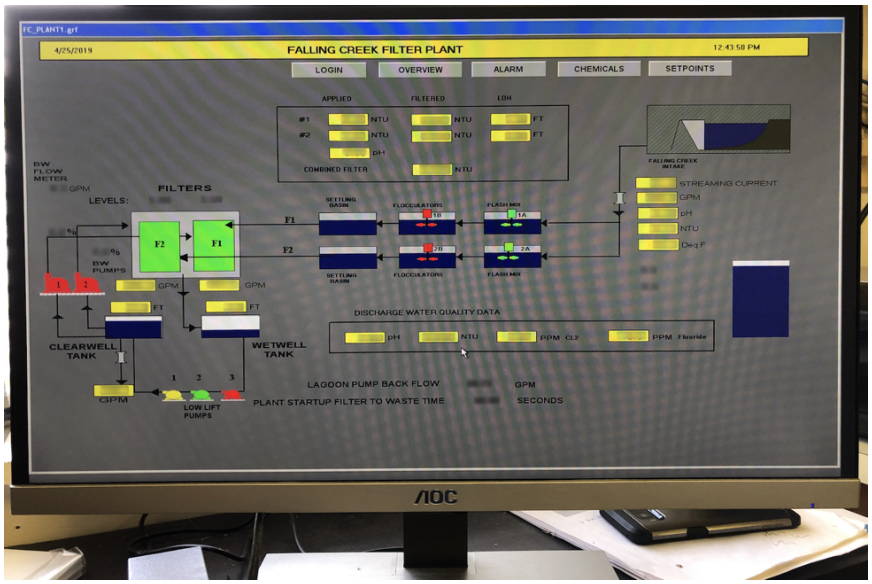

Figure 1. The home screen of the SCADA program shows an overview of key indicators for the plant. The reservoir is in the upper right corner (gray = dam; blue = water).

- The scaffolding exists for the forecasting system to be integrated into the current SCADA system. Note the upper right corner of the home screen, which contains a depiction of the reservoir/dam. In other systems, this system reports the elevation (i.e., depth) of the reservoir. Thus, there is precedent for information being in that spot.
- This screen is a gateway and monitors all of the key information related to plant operation. At Falling Creek, this computer is left on overnight with this screen and it is the first thing the operator looks at in the morning. It is also the main page they use to monitor throughout the day.
- The home screen has raw numbers (reinforcing that operators are "numbers people") for key points in the system. There are no trends or graphs on this screen.
- Trend information exists on screens deeper in the system, but I did not have a chance to look at them. Operators may be interested in and examine trends, but it is not a constant.
- The operators I talked to suggested that rather than colors or visualizations, just provide the numbers.

What this means: This homepage is the key touchpoint for the operators that alerts them to issues. Other screens provide more information. There is a possibility of giving them too much information on the home screen. Providing numbers is considered a simple and basic display. Color-coding is not of particular interest (although see next point.)

Insight #: Color matters

- Red means off. Green means on. Blue means "not energized." Yellow is a warning that typically represents an automated procedure that is not functioning properly (e.g., a pump that is supposed to come on but doesn't because of a fuse).
- Operators talked about color alerting them to an issue, so they do use it.

- But, color is limited to creating arousal—it tells that something is happening but not *what* is happening. Numbers supply the "what"

Insight: Manganese & Iron are equally problematic and nothing on the scada helps here.

- Mn/Fe issues are only known once water sampling (a daily process) tells you you're out of compliance. But, it really messes with the plant because getting back into compliance requires multiple backwashes of the filters.

What this means: Toxins are unaddressed in the instrumental system. To the degree that this can be incorporated, it would really increase the value proposition of the forecasting system.

Hypotheses

In human-centered design, the insights are used to generate hypotheses about how to integrate current ways of knowing with the new tool. These are not solutions. Next steps would be to test these hypotheses.

Hypothesis: Successful integration is multi-layered.
Operators are numbers people. "Just give me the numbers." However, they regularly rely on SCADA, a system that employs heuristics. The system also has layers of information to unpack. A focus on simple indicators on the home screen with an option to get more detailed information would match the current schema of operators.

Hypothesis: Successful integration uses a simple color-coded scheme with numbers on the scada home screen (Heuristics first)
Although operators are numbers people, they regularly rely on color. Whether it's daily water samples or the red/green/blue/yellow of the scada. Color is useful to put operators "on alert," which is what the forecast would ultimately do. The numbers help them monitor the situation once they are on alert; these monitoring numbers exist on the homepage for other key variables of the system.

Hypothesis: Successful integration allows operators to explore trends and forecasts but doesn't rely on trends as the primary information. (Similar to previous hypothesis but with a focus on data patterns rather than heuristics)
Trend data is considered helpful and operators use it, but they tend to be more event-focused. Archiving and making available the trends would be helpful (e.g., forecast and when things actually happened). Further, allowing them to look back at forecasts on the screen (an illustration, which Quinn already makes, I think) would be helpful but not entirely necessary.

Hypothesis: Successful integration allows operators to see the raw numbers
The raw numbers reflect the operators' need to be event focused (i.e., what's going to happen today at what time?). Not having "the numbers" would likely lead to feelings of uncertainty and would not help them determine when to respond at the plant-level.

I'll stop there for feedback and team discussion. Next steps would be to:

- Develop/pinpoints thresholds that put operators "on alert."
- Prototype and evaluate scada homepage designs based on these hypotheses