Wellfield Optimization: Metrics-Driven Operations and Maintenance

While water treatment and wastewater treatment plants are precision-engineered and have become increasingly well instrumented and monitored, ground water-supply wells and wellfields are often treated as “forces of nature” - sited where the utility happens to have land, maybe without consideration for expanding service, and without regular monitoring of conditions and performance and little preventive planning.

Both design optimization for wellfields and preventive maintenance or asset management or asset optimization (depending on which trendy terms we are using this year) are cost-effective in several important ways: 1) preparing for future eventualities with the cost of "emergency" and reducing the cost of producing water, 2) lowering life-cycle costs by reducing costly rehabilitation and replacement, and 3) reducing large fluctuations in annual costs. Any of these benefits should be attractive in the current economic and regulatory climate.

Let’s use the overall term “wellfield optimization” for discussion. Your wellfield may be two wells or dozens, but it covers a three-dimensional space in contact with surrounding aquifer and environment. The wells themselves have individual characteristics and histories. They are subject to operational practices, and in turn they affect your raw water collection and treatment system. Wellfield optimization is the practice of considering a wellfield as a whole system and doing what you can to make it work as efficiently and trouble-free as possible. Benefits include:

- Avoiding contamination and associated health and regulatory costs
- Planning for future or opportunity growth
- Predictable and lower impact raw water quality
- Lower energy use
- Longer well and pump service life
- Predictable energy and service costs

“Lower” and “longer” are in comparison to an ummanaged “wild” wellfield. **Figure 1.**

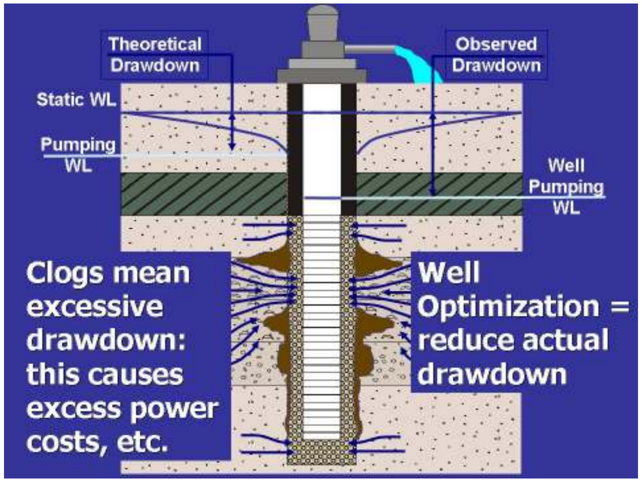
Source water protection: The most costly and insoluble wellfield problems are associated with ground water contamination by human-generated chemical pollution and microorganisms of potential health concern. Source water protection (SWP) has been demonstrated nationally to have significant benefits in cost- and problem-prevention. Your engineering advisors can refine the estimates, but treating ground water contamination (or moving a wellfield) are *really expensive* and takes a long time. SWP is the process of avoiding such external contamination through collection of hydrogeologic and risk information, calculating potential impacts, and taking action to avoid them. The old-fashioned military-background word for SWP is “vigilance” – *situational awareness* is another version -- keeping danger away from your precious asset.

While a SWP area (SWAP) generated using incomplete or area-wide file hydrogeologic information may have some protective benefit, information from actual well testing and monitoring in your SWAP is certainly better for defining a SWAP. For a SWP program (SWPP) to be “owned” by a utility and useful, it has to be integral to the operations and maintenance (O&M) process. This does not happen if the SWAP and SWPP are generated elsewhere and handed to you.

Opportunity growth: You may have access to a water resource that can supply more than your operations or core customer base needs. The age-old response to that situation is to sell the surplus. The first task is to understand what capacity you have or can develop. This requires hydrologic assessment, and possibly engineering planning as well. You may need to rehabilitate and upgrade existing wells to improve delivery. Then understand the customer: Maybe it is a struggling nearby community or population growth or establishment of irrigated agriculture/greenhouses for "local food". In "shale boom" areas such as eastern Ohio, oil and gas companies need water for hydrofracturing. They need a lot of raw water -- so the need is for just water without affecting treatment plant capacity. Once you know what you can supply and the needs of potential clients, you can plan on how to serve them, and details such as cost. With oil and gas companies (or brokers serving them), deal carefully. Don't get caught being contracted to supply all you have, or make huge investments in a "maybe" market. More on selling water (/resources/stuarts-blog/111-marketing-water-yes-you-can-be-a-water-tychoon.html).

"Boring" well operations – predictable and reducing maintenance and costs: The other four bullet points mostly relate to individual well O&M. Specifically, they revolve around those practices (especially material selection and well development) that minimize the well's deterioration over time and resistance to water flow from the aquifer into the well. Material choices can accelerate or slow the "rot" that results in coliform positives in many cases. *Well development* is the cleaning action performed after well construction to remove fines and debris left after the drilling process. Development has three major components: *time, energy,* and *focus.*

Reducing such hydraulic interference reduces observed drawdown in wells. This in turn improves specific capacity (unit flow rate (Q) pumped per unit drawdown (s) – in Ohio that is usually gal/min/ft). When specific capacity (Q/s or C_s) is improved, at any particular Q, drawdown is less at that Q. If drawdown is less, system head is reduced, so that fewer kilowatts are needed to pump any Q to the system. This is an improvement in *wire-to-water efficiency*. Resources spent on well development (*time*, *energy* and design to improve *focus*) are *investments* in reducing energy efficiency. **Figure 2.**



When action is taken to improve or restore well performance after a well is already in service, this is usually called *rehabilitation*. Rehabilitation includes *redevelopment* (that is, cleaning with agitation) and also other improvements, such as pump repair.

Both development and redevelopment reduce drawdown, and thus *oxidation* in the well system. Reducing oxidation reduces the build up of oxidized mineral products such as iron or manganese, and thus clogging. Development also tends to remove fine particles from the raw water, so these practices reduce two factors that shorten pump life: clogging and wear.

Besides all this "hydro" stuff, don't lose sight of "design for life cycle cost" and keep track of power supply. Veering over into the engineering-management side, "buy the best you can" applies to well pumps as much as it does to other equipment purchases. Research well pumps *objectively* for information on service life and efficiency. *More efficient* saves money, as in motor vehicles or air conditioners. Buy corrosion resistant.

Power: A common operating cost formula that is widely used in life cycle cost calculations for wells includes a variety of parameters, but I have found that *cost per kWh* is a dominant factor. Picking up the phone and negotiating with a power supplier for your multiple multiple-horsepower pumps is as cost-effective as anything you can do. If cost is static, reduce kWh however you can (off-peak operation, reduce system head, improve the pump motor's cooling, evaluate pump choices). Finally, focus on *power quality*. Well pumps (especially submersibles) need high-quality, consistent power. Burning out motors? Test the power supply for voltage and amperage consistency, small grounds, and phase imbalance. This is a low-cost, high-return effort.

Site history: It should be part of SWP discovery, but what do you know about where your wellfield is located? We have found it very useful to ask “old timers”. We find out things not in the Ohio EPA’s GIS data base. “You know about the storm water wells don’t you? Yeah, they collected water in those big 40-ft-deep cisterns…” “Did you know they used to dump tomato waste there? Yeah, for decades…” “That’s where the livery stable was.” Sometimes keys to this information can be found on old maps, and sometimes not.

So what about the “predictable” part? The only way to get to “predictable” in any engineered system is by way of experience and information. That’s where the “metrics” part in the title comes in. In this case, *metrics* involves data that can be measured and tracked. The merits of adopting the *metric system* (which are many) is a subject for another day. So what do we include in the metrics? A wellfield is subject to many influences:

- Aquifer geology and chemistry
- Aquifer hydrology – regional and local influences
- What comes with recharge: nutrients, synthetics, microorganisms
- The native ecosystem – the many small things that make a life in an aquifer
- The power supply we mentioned
- Local influences at the well: how it is used, how located in relation to other wells, construction materials – and how these interact with all of the above.

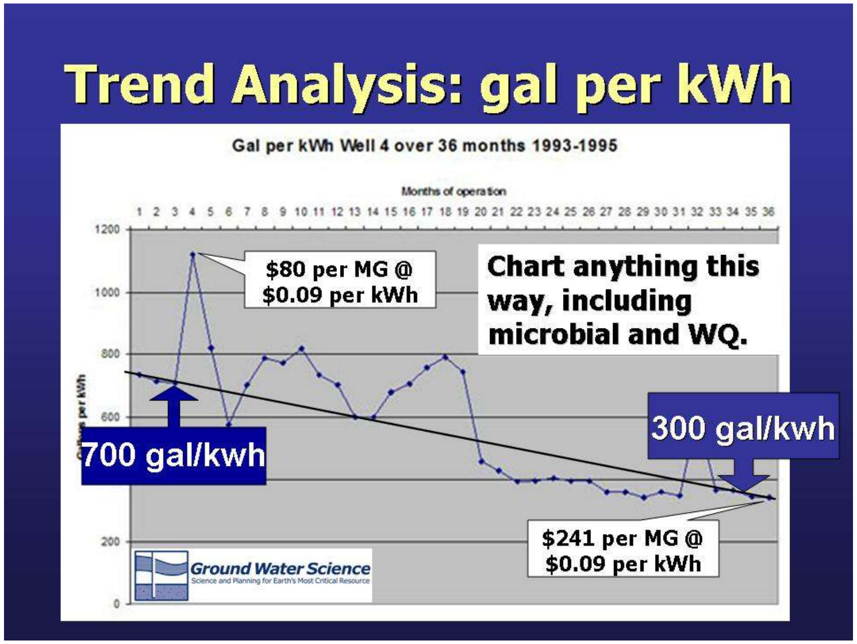

Trend Analysis: gal per kWh

Chart anything this way, including microbial and WQ.

Fortunately, a rather limited number of parameters can be used for tracking most of these issues, and these can be recorded in data bases or spreadsheets, and used in GIS layers for analysis of geospatial distribution (“is the new well permanently dropping water levels in the southwest part of the wellfield?”) or change over time (“is the specific capacity in Well 1 dropping?”). **Figure 3.** Numerous patterns can be evaluated in this way, for example: “how do gallons pumped per kWh expended differ in the northwest and the east wellfields?” or “is gallons/kWh dropping over time?” Or “is the drop in specific capacity related to the drought or not?” or “is nitrate coming off the limestone ridge?”

To collect metrics, wells must be instrumented: manually, electronically or in combination. Wells should each have a flow meter, a way to measure water level, an hour meter, and power meter, and a way to sample raw water quality. Then the data need to be collected and recorded. You can do all of this manually, but automatic data collection, a well-designed data base and data management system, and means of analyzing the data are all good investments and within reach of any public water supply utility.

The *boring* part: With this kind of information, managers can make wells and wellfields *boring*. That is, take the drama and excitement, uncertainty, fear and superstition out of well and wellfield management. If contamination, well deterioration, and change in hydrologic conditions can be detected and tracked, responses can be formed and budgets written well before a crisis would occur. For example, well deterioration can be detected well before severe loss of specific capacity occurs. If left to become severely impaired, wells are difficult to rehabilitate. If caught early, losses can be minimized and reversed and power usage kept in the optimal range. If kept up, this process permits a highly regular budgeting for wellfield O&M year to year

Reference: Smith, S.A. and A.E. Comeskey, 2009. S*ustainable Wells: Maintenance, Problem Prevention, and Rehabilitation* (/products-a-services/publications-a-manuals.html), Taylor & Francis CRC Press, 295 pp. More insight may be found in that short, lively book or in associated training events.

Stuart Smith, MS, CGWP, is a consulting hydrogeologist and partner in Smith-Comeskey Ground Water Science LLC (www.groundwaterscience.com (/) and Ground Water Science on social media). He has over 30 years professional experience in ground water and wells, a PG license in a state that cares (Kentucky), and appropriate and now-archaic academic degrees. He is active in revision of AWWA Manuals M21 *Groundwater* and M7 *Nuisance Organisms in Water: Identification and Treatment*, and *Standard Methods* Section 9240, Iron and Sulfur Bacteria..