When Grafton, Wis., converted the two-stage nitrification system to a single-stage one, it included a selector for filament control.
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A 'PERFECT STORM' of Upgrades

Wisconsin treatment plant expands capacity without adding tanks

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As wastewater treatment plants age and communities grow, facilities must be improved to keep up with demand. However, capital improvements are an expensive means of increasing treatment plant capacity. Finding and modifying the capacity-limiting treatment processes can be a much more cost-effective solution.

Grafton, Wis., a village 40 km (25 mi) north of Milwaukee, is a growing community. In 1997, the Grafton Water and Wastewater Utility had to decide whether and when to abandon its existing wastewater treatment facility and build a new one jointly with a neighboring utility. Before making this decision, Grafton staff needed to know the plant's current capacity, its capacity-limiting treatment processes, and how much margin was left.

The project team evaluated the existing plant and found unused capacity that would enable the utility to postpone major capital improvements. Minor modifications to the existing plant would not only increase capacity but also improve effluent quality and reduce energy costs.

Room for Improvements

Grafton's treatment plant originally was designed in the 1970s as a compact activated sludge plant that could handle an average flow of 3785 m^3/d (1.0 mgd). A decade later, Grafton added a second compact plant and two remote clarifiers, and designed both plants to include a two-stage

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A new residuals truck-loading station features a solids-discharge hose that is elevated so haulers can operate it themselves.

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Grafton, Wis., was able to increase plant capacity from 6060 to 9460 m^3/d.

aeration system that also provided nitrification. In addition, the utility converted its two-stage anaerobic digestion system to a single-stage system and added a belt press to manage solids.

In 1997, the plant was operating at 5300 m^3/d (1.4 mgd) and received nearly 115 m^3/d (30,000 gal/d) of septage. The second stage of the two-stage nitrification system was idle, and waste activated sludge (WAS) was thickened in the primary clarifier. The dissolved-air flotation (DAF) thickener was not operating, and solids were liquid-hauled offsite at low concentration. The utility was not operating the belt press because of handling issues and a lack of seasonal storage. Treated solids were either land-applied or hauled to another community for processing and disposal, depending on the time of year.

The project team determined that the secondary treatment system had unused capacity and that anaerobic digestion was the capacity-limiting process. However, the primary clarifier co-thickened solids effluent only contained 3% solids, and the high percentage of liquid was cutting the detention time in the anaerobic digester, unnecessarily reducing its capacity.

The project team also learned that the DAF thickener had been performing poorly for several weeks because of "geysering" at the thickening end of the tank. (Geysering occurs when bubbles coalesce in floating solids, the result of mixing dissolved-air-pressurized return activated sludge [RAS] with feed solids.) Geysering caused floating solids to disperse, leading to a poor float solids concentration in the 3% to 4% range. Capacity would increase if this solids concentration rose to between 5% and 6%.

Meanwhile, the two-stage aeration system had a capacity of 6060 m^3/d (1.6 mgd), based on influent load and primary clarifier performance. The first-stage aeration basins, which had fine-bubble diffusers, were operating efficiently. However, filamentous bacteria outbreaks limited the mixed liquor concentration and degraded solids and effluent quality. Staff had to chlorinate RAS frequently to control filamentous microorganism growth and improve mixed liquor settling characteristics.

The second-stage aeration basins, which had coarse-bubble diffusers, were operated to keep first-stage effluent solids in suspension for removal in the second-stage remote clarifier. The second-stage RAS pumps functioned as waste pumps. Second-stage clarifiers removed more suspended solids from first-stage effluent before discharging to the Milwaukee River. Although effluent quality was within standards, the second-stage nitrification tanks were not being used efficiently.

A 'Road Map' to Success

The project team identified improvements that would increase treatment plant capacity from 6060 to 9460 m^3/d (1.6 mgd to 2.5 mgd; enough for a population of 17,200). This would give Grafton until at least 2020 to decide whether to participate in building a joint treatment plant. The improvements were to

- create a new residuals truck-loading station;
- install new separate WAS thickening and handling processes;
- convert the two-stage nitrification system into a single-stage one; and
- add a third anaerobic digester in the future, when necessary.

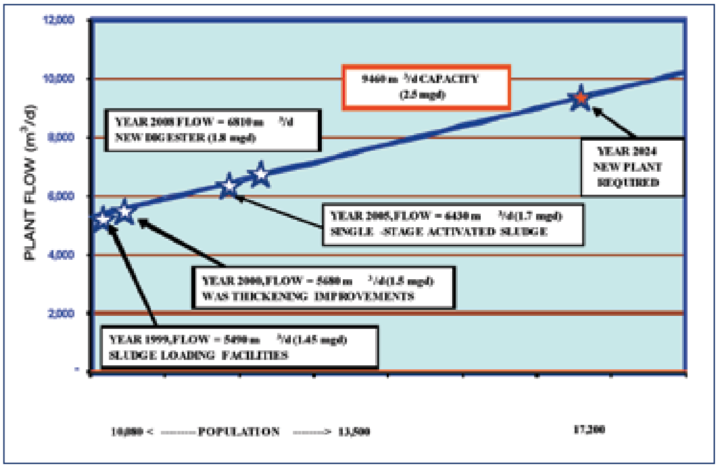
Except for the third digester (which would not be needed for 10 years), these improvements did not involve any new tanks. The project team's recommendations provided a "road map" that Grafton could follow as the village grew. Utility staff decided to make the first three changes over a 7-year period (see Figure 1, above).

Residuals truck-loading station. Grafton loads residuals trucks weekly, year-round. Creating a new truck-loading station involved installing a new centrifugal pump and the associated piping and valves. The project team also elevated the solids-discharge hose so contract haulers could operate it themselves, thereby reducing staff-hours for this operation. This improvement cost $70,800.

WAS thickening process. The project team had recommended replacing the DAF thickener with a gravity belt thickener. However, Grafton would need storage for both WAS and solids-thickener influent and effluent. So, the project team modified the existing DAF thickener to provide this storage and also modified the DAF thickener building to house the new gravity belt thickener, associated pumps, polymer-feed system, blower, and other related equipment. To do this, team members covered the DAF thickener tanks with cast-in-place concrete slabs that both supported the new equipment and isolated stored solids from the rest of the building.

The new thickener is a 1-m enclosed unit that

Figure 1. Implementation Schedule Based on Flow and Population



discharges thickened solids to a partitioned portion of one former DAF tank. The remaining tankage was aerated to hold WAS before thickening. Now, Grafton can thicken both WAS and anaerobically digested solids before storing them. This improvement cost $680,143.

Nitrification system conversion. Water management experts used to think that a two-stage nitrification process was necessary to remove ammonia from wastewater; they now know that a single-stage system can do the job. Single-stage systems also provide better solids flocculation.

When team members converted the two-stage nitrification process, they also included a selector for filament control (see Figure 2, p. 39). The selector has a four-zone gradient — two anoxic and two aerobic zones — with a total average food-to-microorganism ratio of 0.7.

The remaining modifications included combining the aeration tanks and then dividing the mixed liquor proportionately among the clarifiers. The team also installed a fine-bubble diffusion system in the second-stage aeration tank and opened the separation wall so floating and submerged solids could move efficiently. This improvement cost $591,862.

Excellent Return on Investment

The improvements were completed in 2005 at a total construction cost of $1.3 million. They increased capacity from 6060 to 9460 m^3/d (1.6 to 2.5 mgd; however, the anaerobic digestion process will need further expansion when treatment plant flow approaches 6810 m^3/d [1.8 mgd]).

Better effluent. Before these changes, the effluent's pollutant concentrations had approached permit limits. Grafton had not exceeded average effluent limits but had come close to the daily maximums for total suspended solids and bio-

Table 1. Grafton (Wis.) Effluent Quality

	Biochemical oxygen demand		Total suspended solids		Ammonia	
	Monthly average (mg/L)	Annual maximum (mg/L)	Monthly average (mg/L)	Annual maximum (mg/L)	Monthly average (mg/L)	Annual maximum (mg/L)
Permit limit	30		30		Summer: 2.1 Winter: 9.8	
2002–2004	6	20	8	19	1.115	12.32
2005	4	10	3	7	0.031	0.743
2006	5	11	4	9	0.077	3.99
2007	4	10	4	14	0.023	0.29
2008	5	10	5	11	0.026	0.92

chemical oxygen demand, and exceeded the daily maximum for ammonia. Effluent concentrations typically had been problematic when one of the compact plants was off-line, solids storage tanks were being decanted, solids with high ammonia levels were being thickened, or filamentous bacteria affected solids settleability.

Once the aeration-system conversion was complete, solids settleability improved and filaments were no longer an issue. Grafton has not had to chlorinate RAS since the single-stage system started up. Filamentous bacteria outbreaks used to occur 6 to 12 times a year; there have been no outbreaks since the new system went online. Also, the solids volume index has remained consistent and under control since 2006, and effluent total suspended solids, biochemical oxygen demand, and ammonia levels have improved (see Table 1, above).

Lower costs. Treatment plant expansions generally cost \$1057 to \$1321 per 1 m^3 (\$4 million to \$5 million per 1 mgd), excluding conveyance.

The selector has a four-zone gradient — two anoxic and two aerobic zones.

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Table 2. Grafton (Wis.) Solids Disposal Costs

	Volume disposed (m^3)	Percent solids	$/$m^3$	Annual average disposal cost
2000–2001 (before the gravity belt thickener)	7659	2.9%	$12.26	$93,920
2002–2003	4890	5.1%	$13.77	$67,315
2004–2005	5021	5.0%	$16.06	$80,650
2006–2007	4425	5.25%	$18.35	$81,226
2008	4765	5.5%	$18.50	$88,149

This one only cost $370 per 1 m^3/d ($1.4 million per 1 mgd), an estimated savings of $2.6 million or more.

The improvements also reduced operating costs. For example, the filamentous bacteria problem had led staff to install a chemical-feed system that injected sodium hypochlorite into the RAS airlift. This system had cost about $1300/yr in chemicals, plus the labor to install the system and make up the chlorine solution. These costs now have been eliminated.

Thickening WAS and eliminating co-settling in primary clarifiers reduced the volume of solids entering the digesters while increasing the solids concentration. This improved gas production, decreased heating requirements, and reduced the volume of solids hauled offsite by 36% the first year and 34% the second year. The digester's heating-fuel savings offset the polymer costs for the gravity belt thickener. Solids hauling costs were expected to drop by $30,500/yr, but the per-gallon hauling cost has increased steadily since 2001. However, if Grafton still had trucks haul away the same volume of solids in 2008 that it did in 2001, the cost would have been $141,645. Actual 2008 solids hauling costs were more than $53,500 less (see Table 2, above).

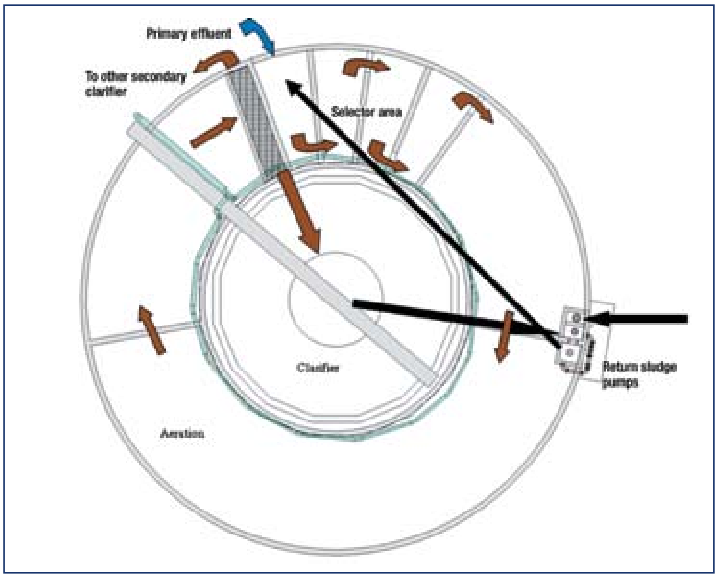
Replacing the coarse-bubble diffusers in the second-stage aeration tanks with fine-bubble ones cut annual electricity costs by an estimated 10% to 12%. During the first 2 years of single-stage process operations, kilowatt-hour consumption dropped by about 112,440 kWh/yr (on average), saving about $9200/yr (based on 2008 rates).

Other cost savings include staff time for maintaining equipment, such as blowers, solids pumps, chemical-feed systems, and the solids boiler/heat exchanger. This may be offset by gravity belt thickener operations, but staff believes the plant is easier to operate and maintain because of the modifications.

Win–Win–Win

Grafton achieved the trifecta — more capacity, better effluent, and energy reduction — with minimal capital improvements and no new tankage. The treatment plant's increased capacity has extended its service life into the 2020 decade. And although Grafton's population increased to 11,450 in January 2008, its sewer user rate remained in the lower 30th percentile ($4.12 per 3.8 m^3 [$4.12 per 1000 gal], based on a 2008 survey).

Figure 2. Flow Schematic of the Modified Compact Activated Sludge Plant



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