Irrigation Training and Research Center

Walk-Through Audit of Small Community Water System

Pixley Public Utility District

Sierra Layous
Audit Date: 3/21/2017
Report Date: 4/7/2017

moving water in new directions
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TECHNICAL MEMORANDUM

Date:	7 April 2017	
To:	Jennifer Blevins – Pixley PUD pixleyppud@gmail.com	Randy Masters – Pixley PUD mastersppud@abcglobal.net
From:	Sierra Layous, PE – ITRC slayous@calpoly.edu	Dr. Stuart Styles, PE – ITRC sstyles@calpoly.edu
Subject:	**Summary of Walk-through Audit of Pixley PUD's Water System**	

The Cal Poly Irrigation Training and Research Center (ITRC) audited the following sectors within Pixley Public Utility District's ("Pixley PUD") water system on March 21, 2017:

- Water Supply (WS)
- Potable Water Treatment (PWT)
- Water Distribution (WD)
- End Use (EU)
- Wastewater Collection (WWC)
- Wastewater Treatment (WWT)
- Recycling (RD)

Background – Distribution of Energy Use

District energy use data from 2016 was analyzed and compared between sectors (**Figure 1**). The sectors were then ranked based on energy use and cost (**Figure 2**). The water supply sector uses the most energy, followed by the wastewater treatment sector. These two sectors have the most potential for energy/cost savings. The wastewater collection system (lift pumps) also contributes a portion of the energy use/cost. Slight differences between energy use and cost are due primarily to different rate structures for different types of accounts.

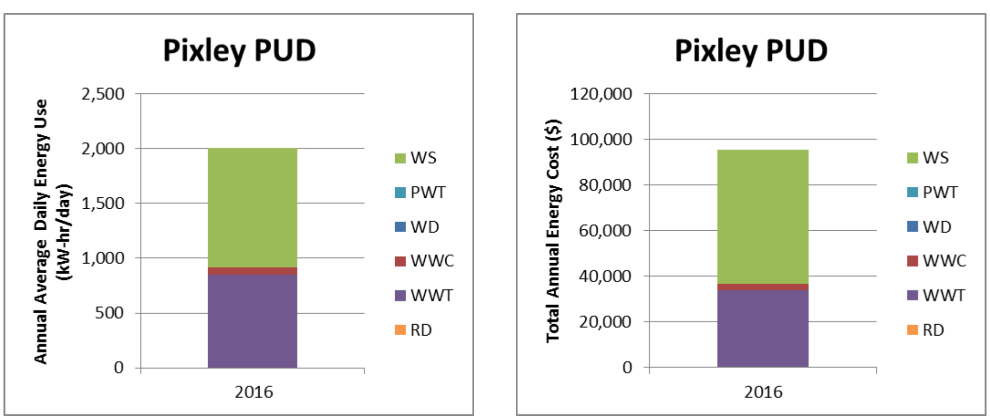


Figure 1. Energy (electricity) use (left) and energy cost (right) by sector in 2016

Score*	Abbrev.	Sector
10	WS	Water Supply
0	PWT	Potable (Drinking) Water Treatment
0	WD	Water Distribution
1	WWC	Wastewater Collection
7	WWT	Wastewater Treatment
0	RD	Recycled Water Distribution

*Highest value denotes highest energy use (greatest energy savings potential)

Figure 2. Ranking of sectors based on energy use and cost

Water Supply

The water supply system is composed of three wells (referred to as “Well 2a”, “Well 3a” and “Well 4”). The following graph shows the approximate monthly water supply and energy use from those three wells in 2016. Well 2a supplies the most water, followed by Well 3a, then Well 4. This sequencing correlates with the energy intensity (kWh/gallon) of the wells; Well 2a requires the least energy to extract water and Well 4 requires the most energy to extract water.

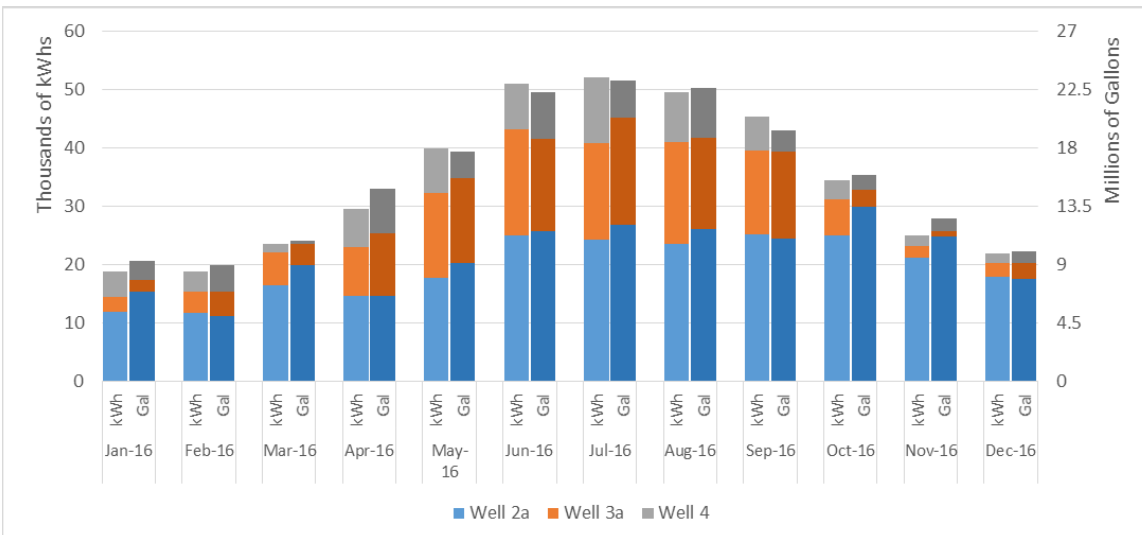


Figure 3. Monthly supply from wells, 2016

The following conclusions were generated from the background analysis and walk-through audit of the water supply system:

- Pump curves were not available and the district did not know if the well pumps were operating at maximum efficiency on the pump curves. The operating point on the pump curve should be confirmed, and adjustments/modifications (such as trimming or replacing impellers) should be made if the pumps are not operating at maximum efficiency. Estimates of energy savings related to adjustments/ modifications can be calculated and compared to the cost associated with the modification(s). Pumps may have been designed to operate at the maximum efficiency of the pump initially, but wear on the system and changes in groundwater levels will cause the system to operate at a different point along the pump curve.

- Analysis of energy and flow records indicate the supply well pumps should be sequenced as follows to minimize energy use and cost:
    1. Pump 2a (should turn on first and turn off last)
    2. Pump 3a
    3. Pump 4 (should turn on last and turn off first)

  Energy and flow records should be reanalyzed periodically with changing groundwater levels, demand, and energy costs to re-evaluate the sequencing of the pumps. Sequencing is not simply based on the pressure directly downstream of each pump. Consideration should be given to the infrastructure between the pumps and storage (distances, pipe sizes, and flow rates) when determining pressure set-points at each site.

- Well 2a's motor appears to be slightly undersized given the current load (flow rate and total head) from the pump. This may be due to changes in the groundwater level. Southern California Edison's (SCE) pump tests from 2014 show all three well pump motors operating above their rating. If a motor is constantly operating above its rated load, replacement of the motor should be considered.

- The district currently sets the drip rate for oil lubrication of the bearings and lineshaft at one drop per 6 seconds (10 drops per minute) at all three of the well sites. Turbine well pump manufacturers generally recommend[1] using the following equation for wells with a 1-11/16" shaft diameter (district wells have 1-11/16" diameter):

  $$\text{Drops per minute} = 7 + [3 \times \text{Setting Depth (ft)}/100]$$

  For wells with bowls set at 500 ft (such as Wells 2a and 3a), this results in a drip rate of <u>22 drops per minute</u>. The district should consider adjusting the drip rate. Also, this is the initial drip rate, when a tank is full. As the tank empties, the drip rate will decrease. There are two recommendations to minimize this:

  (1) Install a large oil tank (> 4 gallons) (the district has done this already), and

  (2) Install the large tank at least 3 tank diameters above the adjusting valve. The tanks at all of the wells appear to currently be about 2 diameters above the connection to the lineshaft, with the adjusting valve near the oil tank; relocating the adjusting valve to near the connection to the lineshaft and raising the tank further would both reduce fluctuation in drip rate as the tank empties.

  See the *Deep Well Oil Lubrication Fact Sheet* for more information.

- The district currently operates the water supply during peak hours; the district does not have the capacity to store water to minimize on-peak pumping. Future upgrades should consider options to reduce on-peak energy use (the district indicated that plans for a future well include storage to reduce on-peak pumping).

- The motor on Well 3a is not premium efficiency (it is standard efficiency). The estimated savings per year associated with replacing the motor with a premium

[1] Christensen Pumps *O&M Manual Deep Well Turbine Pumps,* Goulds (Xylem) *IOM Instructions for Deep Well Turbine Pumps,* American-Marsh Pumps *IOM for Lineshaft Turbine Pumps*

efficiency motor are estimated at about $630/year. If the motor needs to be rewound or replaced, the cost should be compared to the cost of a premium efficiency motor.

- The motor on Well 4 is not premium efficiency (it is standard efficiency). The estimated savings per year associated with replacing the motor with a premium efficiency motor are estimated at about $430/year. If the motor needs to be rewound or replaced, the cost should be compared to the cost of a premium efficiency motor.

- Arsenic levels from Well 2a and Well 3a routinely exceed water quality limits. Arsenic readings from all three wells, as well as the maximum contaminant level (MCL) for arsenic, are shown in **Figure 4** below.

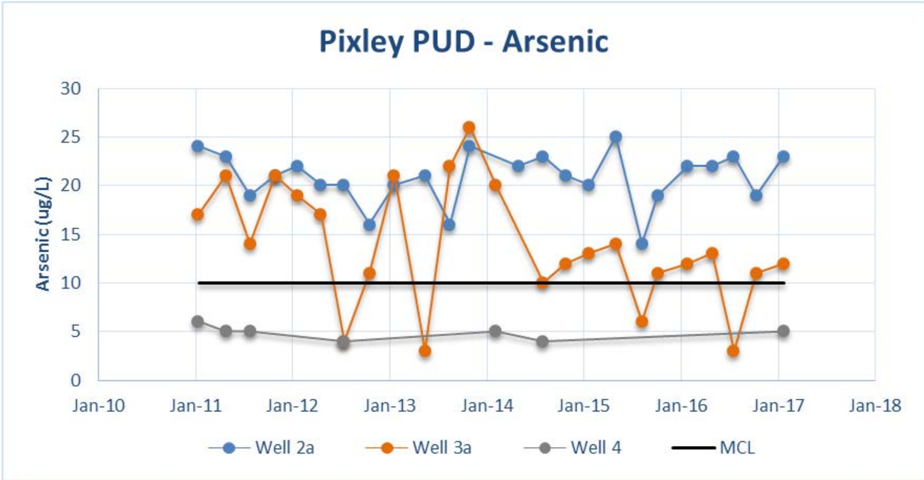


Figure 4. Arsenic levels from district wells, 2011 to present

The district indicated that treatment and non-treatment options had been analyzed. The plans for compliance include blending the existing water with a new well with low arsenic levels and modifying (partially abandoning) the existing, non-compliant wells.

- Well 3a has recently tested positive for Total Coliform. The source of the contamination is unknown. The district is limiting the use of this well pending further information.

Potable Water Treatment

The water treatment consists solely of chlorine injection at each of the wells. The chlorine pumps are very small (~0.04 kW/ 0.05 HP each. There were no significant conclusions generated for the water treatment system.

Water Distribution

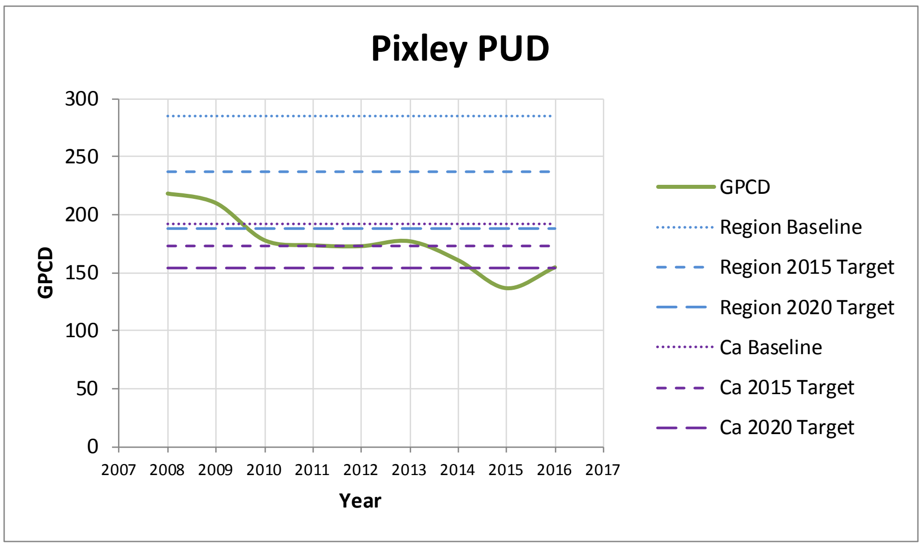
Pixley PUD's water system is supplied by a 50,000 gallon water tower near the now-abandoned Well 1 and a 15,000 gallon water tank adjacent to Well 3a. As such, there are no energy-consuming devices associated with the water distribution system. The following was the only significant conclusion generated for the water distribution system:

- Pixley PUD does not study and/or estimate delivery losses, or have an active leak program. All or any of these actions could help identify and reduce losses in the system.

End Use

The following conclusions were generated from the background and walk-through audit of the PUD's end use:

- Pixley PUD has a relatively low per capita water use rate when compared to the region. The chart below shows Pixley PUD's estimated per capita water use rate compared to the regional and state baselines and targets outlined in California's 20x2020 mandate. The per capita water use rate is based on the 2000 and 2010 census estimates of the population in Pixley.



5 year average	160	GPCD
9 year average	176	GPCD

Figure 5. Annual average per capita water use, 2008-2016 (GPCD = average gallons per capita per day)

- The distribution of water use by customer type is estimated in **Figure 6**. A majority (nearly 75%) of the water is used by residential customers, about 25% by commerical customers, and 1% by recreational users (a small park in the community).

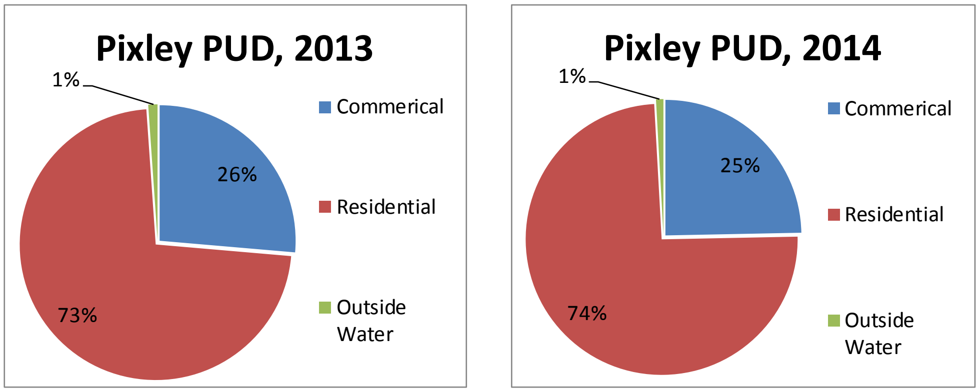


Figure 6. Distribution of water use by end use category (customer type), 2013 and 2014

- The installation of water meters on all customer's lines in 2012 and the use of tiered billing likely contributed to the recent decrease in per capita water use.
- There are a variety of low to moderate cost incentives/devices that can be implemented by the PUD to encourage active leak detection and water conservation by end users.
- Meeting with the top water users and providing education on water use and conservation methods can provide significant water savings with minimal effort.

Wastewater Collection

The only pumps in Pixley PUD's wastewater collection system are at the inlet of the wastewater treatment plant. These pumps are included in the analysis of the wastewater treatment plant (see conclusions in that section, below).

Wastewater Treatment

Pixley PUD's wastewater treatment plant consists of lift pumps at the inlet, a spiral screen, two aeration basins that have fixed film and activated sludge (nitrification and denitrification), two clarifiers, an aerobic digester, sludge drying beds, and effluent ponds. **Figure 7** shows the general layout of Pixley PUD's Wastewater Treatment Plant.

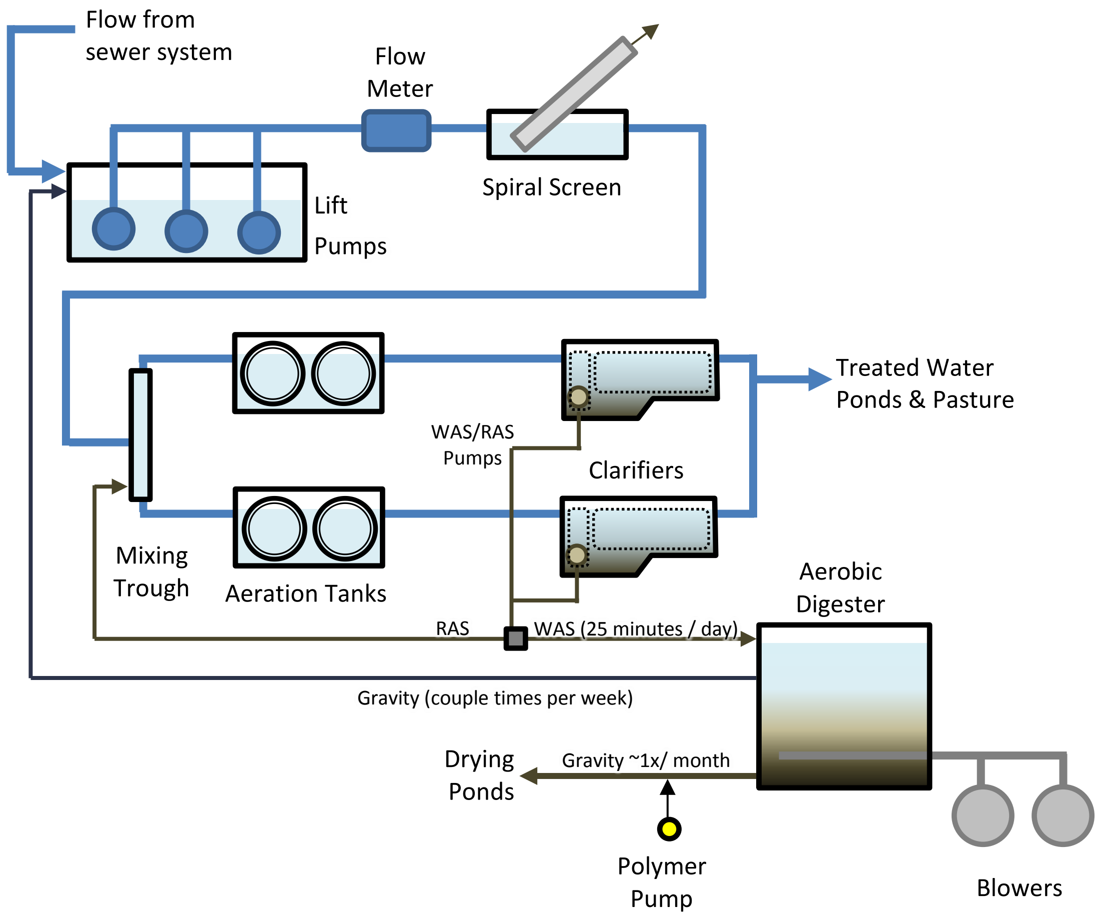
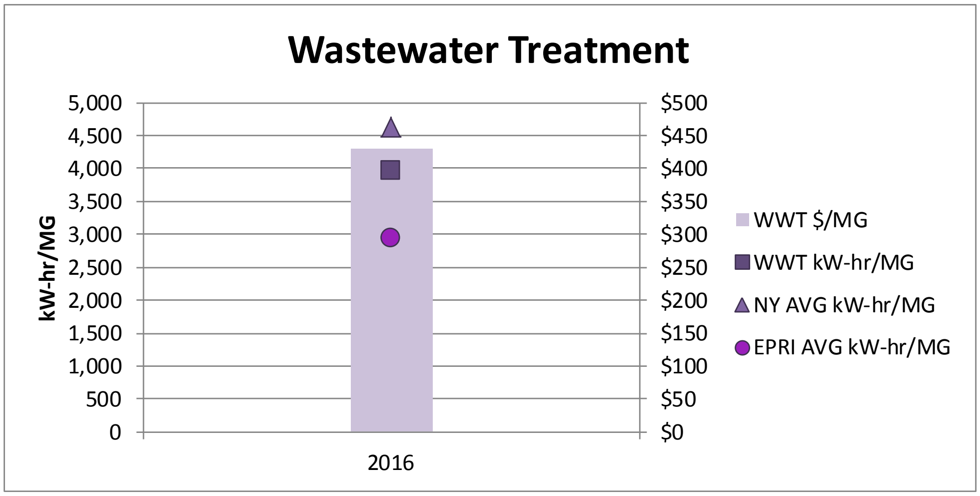


Figure 7. Conceptual layout of Pixley PUD wastewater treatment plant

The following conclusions were generated from the background analysis and walk-through audit of the PUD's wastewater treatment:

- The Pixley PUD wastewater treatment plant energy intensity (kWh/MG) falls between the values from the two sources (see footnote). The energy and flow records from the wastewater treatment plant in 2016 were used to calculate the energy intensity of the plant. **Figure 8** compares the energy intensity to the average energy intensity of wastewater treatment plants of similar size (< 1 MGD) and treatment type (advanced treatment with nitrification) according to the two sources.



Average Volume at WWTP (MG): 0.22 (This is the average of all entered data)
Type of Treatment: Advanced Wastewater Treatment with Nitrification

Figure 8. Energy and cost intensity of the Pixley PUD wastewater treatment plant compared to NYSERDA[2] and EPRI[3] studies

- **Figure 9**, below, shows an estimate of the breakdown of the energy use/cost at the wastewater treatment plant. A majority (>75%) of the energy used in the treatment plant is used by the STM-Aerotors in the aeration tanks and the blowers in the aerobic digester. Therefore, optimizing these devices/processes will provide the largest reduction in energy use and cost.
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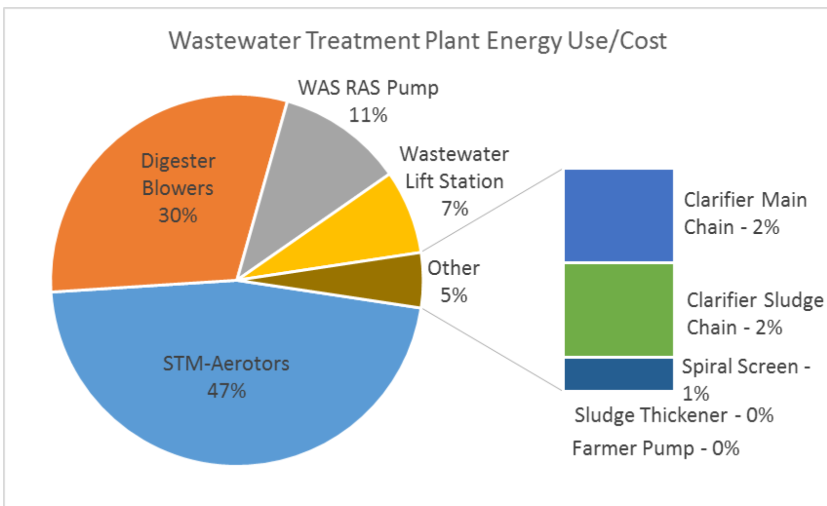

Figure 9. Estimate of breakdown of energy use/cost at the wastewater treatment plant

[2] "NY AVG" is an estimate of the average energy intensity for a wastewater treatment plant of similar size estimated by NYSERDA (NYSERDA. 2008. Statewide Assessment of Energy Use by the Municipal Water and Wastewater Sector.)

[3] "EPRI AVG" is an estimate of the average energy intensity for a wastewater treatment plant of similar size and type estimated by EPRI (EPRI. 2002. Water and Sustainability (Volume 4): U.S. Electricity Consumption for Water Supply & Treatment - The Next Half Century.)

- It is estimated that the cost to operate the STM-Aerotors is approximately $15,000 per year. The treatment plant was originally designed to adjust the speed of the STM-Aerotors based on the DO levels in the tank, but issues with the DO sensors caused the district to abandon the automatic control. The district currently manually adjusts the speed of the STM-Aerotors seasonally. While the treatment plant currently meets water quality regulations, automatically adjusting the speed of the STM-Aerotors based on the dissolved oxygen (DO) levels in the tanks may allow the system to continue to meet water quality regulations while reducing energy use and cost. Newer/different technology for the DO sensors may be more successful than the original sensors.

- It is estimated that the cost to operate the blowers in the digester is approximately $10,000 per year. Currently, one of the blowers is on nearly continuously at a constant speed. The energy use and cost of the digester blowers may be reduced by installing VFDs or guide vanes to automatically adjust the speed of ("turndown") the blowers based on water quality parameters in the digesters (such as DO). Additionally, the efficiency of the blowers is not known. The high efficiencies and control options of newer technology can make replacing existing blowers economical.

- The motors on the digester blowers are not premium efficiency (they are energy efficient). While the savings per year associated with replacing the motors is not significant (estimated at about $300/year if both motors were upgraded), if the motors needs to be rewound or replaced, the cost should be compared to the cost of premium efficiency motors.

- Automatically adjusting the RAS flow rate based on plant flow and biosolids settling characteristics can reduce the energy use and cost associated with excess recirculation.

- The performance of the lift pumps at the head of the wastewater treatment plant has declined significantly. The district is in the process of repairing/replacing the pumps. The district should consider the benefit of a constant inflow to the treatment plant that could be achieved with VFDs on the lift pumps. Currently, the pumps turn on and off based on the water level in the sump. Analysis of pump hours (from the SCADA system) and treatment plant inflows (from the flow meter) indicate the pumps are turned on less than half of the time.

Recycling

Pixley PUD's recycling system consists of a gravity system to the district's pasture (43 acres), and a combination gravity/pump system to a neighboring farmer's pasture (160 acres). Due to reductions in wastewater plant inflows (and therefore outflows), excess water had not been available to provide to the farmer in recent years, and the lift pump has not been used. The lift pump from the pond to the farmer's field was evaluated with the wastewater treatment plant (see conclusions in that section, above). The following was the only significant conclusion generated for the recycling system:

- If the lift pump is used in the future, the PUD could consider if the pump could be operated during off-peak hours only.

Small Community Water System Water/Energy Audit Report

Pixley PUD

Background

April 7, 2017

Sierra Layous

Irrigation Training and Research Center (ITRC)
Cal Poly, San Luis Obispo
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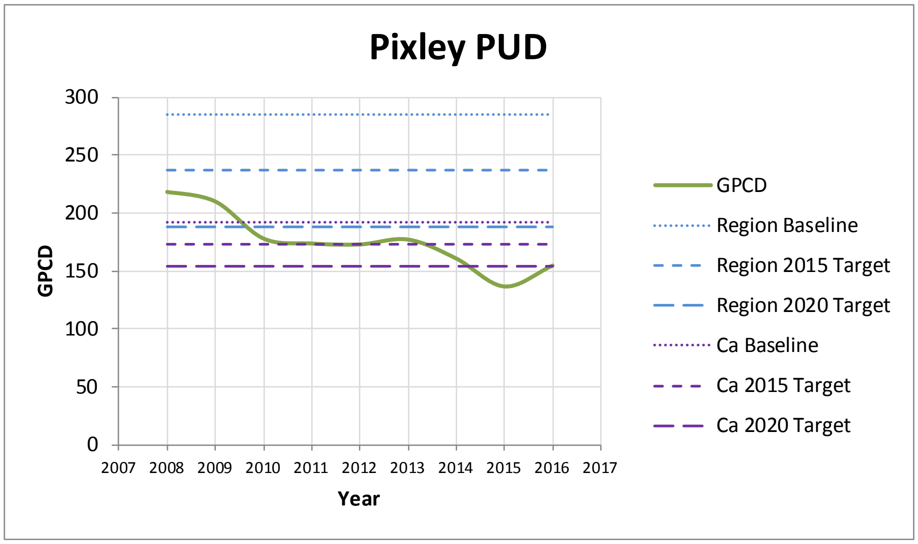
BACKGROUND - PIXLEY PUD

End Use Output

Characterization of End Use Consumption

Pixley PUD

Historical Water Use (per capita)



5 year average	160	GPCD
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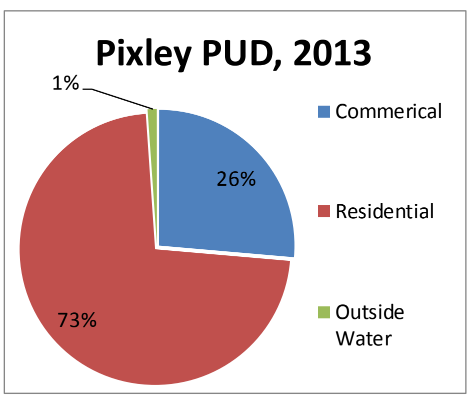
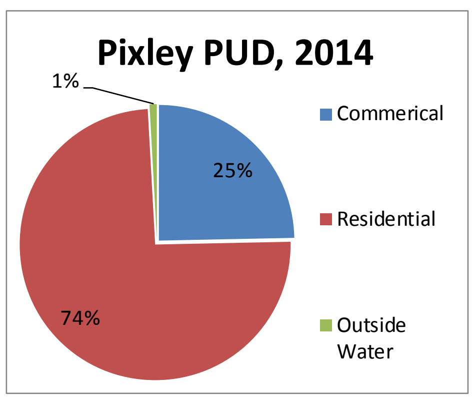
Distribution of Water Use by Category





GPCD = average gallons per capita per day

End Use Conclusions

- The population used for Pixley PUD is from the 2000 and 2010 censuses, and is therefore an estimate. However, the PUD appears to have a relatively low per-capita water use when compared to the region.
- Pixley PUD installed meters on all water users in 2012 and converted to tiered rate billing. This appears to have contributed to a decline in recent water use.

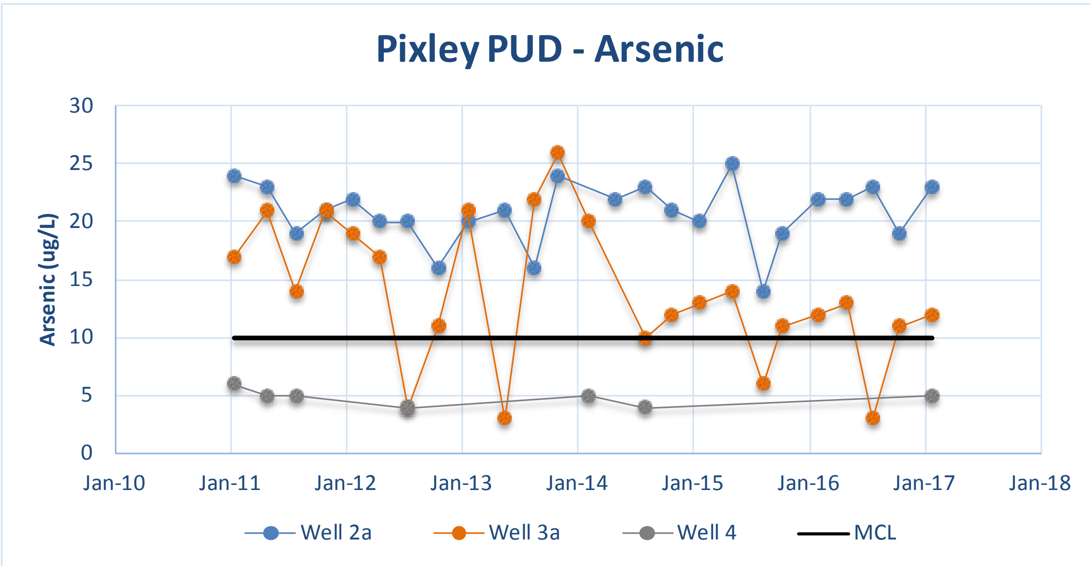
Constituent: Arsenic Output

Analysis of water quality data and a survey of the district indicated that arsenic is an issue for the district.

Constituent Data Output

Pixley PUD

Arsenic

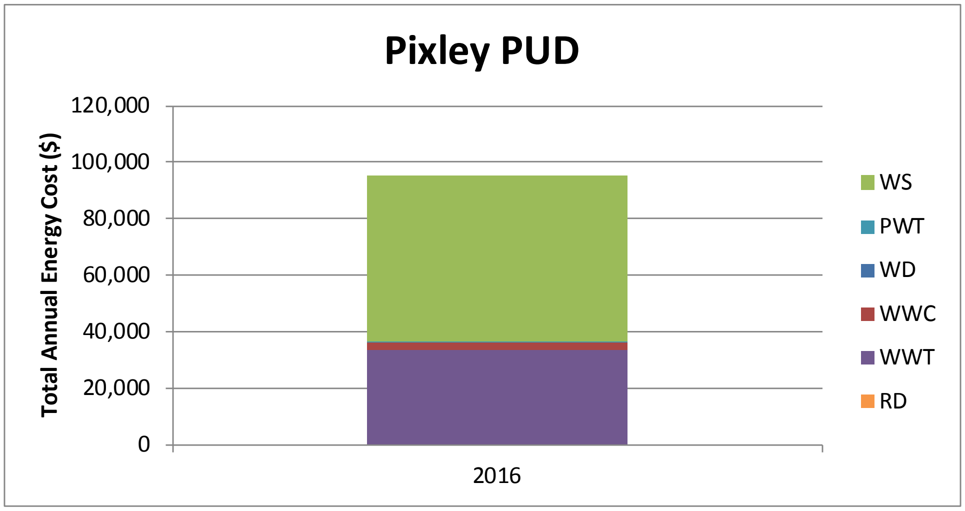


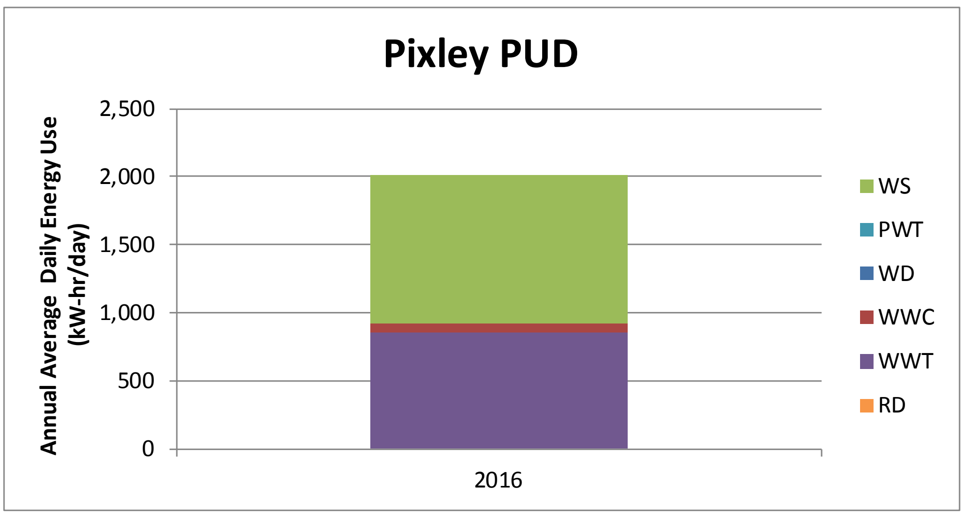
Constituent: Arsenic Conclusions

- Water from Well 2a continuously exceeds the MCL for arsenic.
- Water from Well 3a almost always exceeds the MCL for arsenic.
- Water from Well 4 does not exceed the MCL for arsenic.

Power Use Output

Pixley PUD

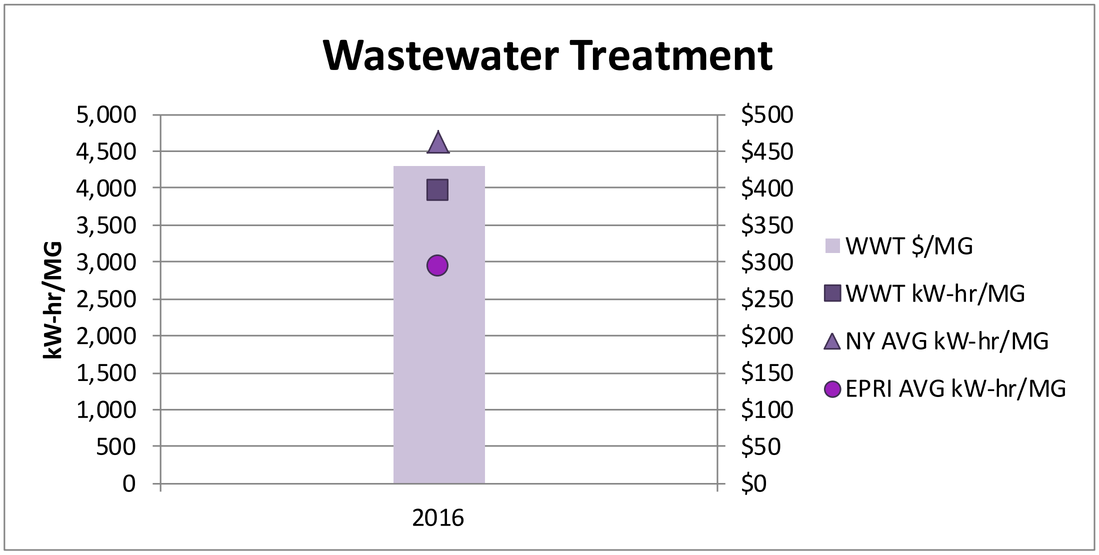




Score*	Abbrev.	Sector
10	WS	Water Supply
0	PWT	Potable (Drinking) Water Treatment
0	WD	Water Distribution
1	WWC	Wastewater Collection
7	WWT	Wastewater Treatment
0	RD	Recycled Water Distribution

*Highest value denotes highest energy use (greatest energy savings potential)

Wastewater Treatment



Average Volume at WWTP (MG):	0.22 (This is the average of all entered data)
Type of Treatment:	Advanced Wastewater Treatment with Nitrification

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Power Use Conclusions

- Nearly all of Pixley PUD's energy is used by the water supply (wells) and wastewater treatment sectors. A small portion is used by the wastewater collection sector (wastewater lift pumps).
- Pixley PUD's wastewater treatment plant's energy intensity (kWh/MG) falls between the average values for treatment plants of similar size (<1 MGD) and type (advanced treatment with nitrification) from two studies.

Time-of-Use Output

No time-of-use data was available.

Time-of-Use Conclusions

- No conclusions can be drawn regarding time-of-use energy use.

Small Community Water System Water/Energy Audit Report

Pixley PUD

Sector: Water Supply

Audit Date: March 21, 2017
Report Date: April 7, 2017

Sierra Layous

Irrigation Training and Research Center (ITRC)
Cal Poly, San Luis Obispo

WATER SUPPLY - PIXLEY PUD

Water Supply Sector – Conclusions

- Pump curves were not available and the district did not know if the well pumps were operating at maximum efficiency on the pump curves. The operating point on the pump curve should be confirmed, and adjustments/modifications (such as trimming or replacing impellers) should be made if the pumps are not operating at maximum efficiency. Estimates of energy savings related to adjustments/modifications can be calculated and compared to the cost associated with the modification(s). Pumps may have been designed to operate at the maximum efficiency of the pump initially, but wear on the system and changes in groundwater levels will cause the system to operate at a different point along the pump curve.

- Analysis of energy and flow records indicate the supply well pumps should be sequenced as follows to minimize energy use and cost:
    1. Pump 2a (should turn on first and turn off last)
    2. Pump 3a
    3. Pump 4 (should turn on last and turn off first)

  Energy and flow records should be reanalyzed periodically with changing groundwater levels, demand, and energy costs to re-evaluate the sequencing of the pumps. Sequencing is not simply based on the pressure directly downstream of each pump. Consideration should be given to the infrastructure between the pumps and storage (distances, pipe sizes, and flow rates) when determining pressure set-points at each site.

- Well 2a's motor appears to be slightly undersized given the current load (flow rate and total head) from the pump. This may be due to changes in the groundwater level. Southern California Edison's (SCE) pump tests from 2014 show all three well pump motors operating above their rating. If a motor is constantly operating above its rated load, replacement of the motor should be considered.

- The district currently sets the drip rate for oil lubrication of the bearings and lineshaft at one drop per 6 seconds (10 drops per minute) at all three of the well sites. Turbine well pump manufacturers generally recommend[1] using the following equation for wells with a 1-11/16" shaft diameter (district wells have 1-11/16" diameter):

  $$\text{Drops per minute} = 7 + [3 \times \text{Setting Depth (ft)}/100]$$

  For wells with bowls set at 500 ft (such as Wells 2a and 3a), this results in a drip rate of <u>22 drops per minute</u>. The district should consider adjusting the drip rate. Also, this is the initial drip rate, when a tank is full. As the tank empties, the drip rate will decrease. There are two recommendations to minimize this:

  (1) Install a large oil tank (> 4 gallons) (the district has done this already), and

  (2) Install the large tank at least 3 tank diameters above the adjusting valve. The tanks at all of the wells appear to currently be about 2 diameters above the connection to the lineshaft, with the adjusting valve near the oil tank; relocating the adjusting valve to near the connection to the lineshaft and raising the tank further would both reduce fluctuation in drip rate as the tank empties.

  See the *Deep Well Oil Lubrication Fact Sheet* for more information.

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[1] Christensen Pumps *O&M Manual Deep Well Turbine Pumps,* Goulds (Xylem) *IOM Instructions for Deep Well Turbine Pumps*, American-Marsh Pumps *IOM for Lineshaft Turbine Pumps*

WATER SUPPLY - PIXLEY PUD

- The district currently operates the water supply during peak hours; the district does not have the capacity to store water to minimize on-peak pumping. Future upgrades should consider options to reduce on-peak power use (the district indicated that plans for a future well include storage to reduce on-peak pumping).
- The motor on Well 3a is not premium efficiency (it is standard efficiency). The estimated savings per year associated with replacing the motor with a premium efficiency motor are estimated at about $630/year. If the motor needs to be rewound or replaced, the cost should be compared to the cost of a premium efficiency motor.
- The motor on Well 4 is not premium efficiency (it is standard efficiency). The estimated savings per year associated with replacing the motor with a premium efficiency motor are estimated at about $430/year. If the motor needs to be rewound or replaced, the cost should be compared to the cost of a premium efficiency motor.
- Arsenic levels from Well 2a and Well 3a exceed federal standards. The district indicated that treatment and non-treatment options had been analyzed. The plans for compliance include blending the existing water with a new well with low arsenic levels and modifying (partially abandoning) the existing, non-compliant wells.
- Well 3a has recently tested positive for Total Coliform. The source of the contamination is unknown. The district is limiting the use of this well pending further information.

Water Supply Sector – Inventory List

Walk-through Inventory List:

Water Supply

	(a)	(b)	(c.)	(d)	(e)		(f)		(g)		(h)	(i) (f) * (g)	(j) (h) * (i)	(k)
	Location / Name	Equipment Type	Quantity	Controls	HP/kW per unit		Typical Total HP/kW		Estimate of total hours/yr (or %)		Estimate of Power Cost ($/kW-hr)	Estimate of kW-hr/yr	Estimate of yearly cost ($)	Device Score*
1	2a (near office)	Well pump	1	Maintains pr in line d/s (on 34 psi off 39 psi)	100	HP	110.9	HP	32	%	0.12	231,339	27,298	10
2	3a (across town)	Well pump	1	Maintains pr in line d/s (on >34 psi off 38 psi)	100	HP	105.4	HP	15	%	0.17	104,434	18,067	7
3	4 (@ shop)	Well pump	1	Maintains pr in line d/s (on >34 psi off 39 psi)	75	HP	92.9	HP	10	%	0.22	61,680	13,693	5
4														
5														
6														
7														
8														
9														
10														

Total Yearly Expense:	$59,058
Average Daily Energy Use:	1089 kW-hr

*The Device Score (k) is a sector-specific score, indicative of the energy use by each device/set of devices. A higher score indicates higher energy use, and therefore more energy-saving potential.

WATER SUPPLY - PIXLEY PUD

Walk-through Inventory List:

Supply Wells

	(a) Location / Name	(b) Flow Rate (GPM)	(c.) Static Depth to Water Table (ft)	(d) Pumping Depth to Water Table	(e.) Depth of Well (ft)	(f) Well Log Available? (Y/N)	(g) Water Quality Issues? (Y/N, list contaminants)	(h) Water Treatment? (Y/N)	(i) Well Age (years)
1	2a	746	329	347	800 (bowls @ 500)	Unk	Y, arsenic	Y	
2	3a	620	329	344	800 (bowls @ 500)	Unk	Y, arsenic & TC	Y	
3	4	519	326	343	600	Unk	N	Y	
4									
5									
6									
7									
8									
9									
10									

Water Supply Sector – Output: Triggered Questions

Triggered Questions

The following table is sorted by score (right column). Scores are relative, estimated values meant to help prioritize recommendations; higher scoring recommendations should be explored first.

A score of zero indicates no recommendation is given; the question is included for reference.

If more than 100 recommendations were generated, only the top 100 will appear in the table below.

	Section	Question Number	Question	Answer	Program Output	Notes	Score				Energy Savings	Water Savings	Water Quality
							Device	Ease of Implement-ation	Savings Potential	Total			
1	Well 2a	19	Is/are the pump(s) operating at maximum efficiency on the curve during normal operation?	Unknown	Further investigation needed.		10	5	3	18	✓		
2	Well 2a	30	Do the starts per hour exceed the appropriate value in the chart below?	Unknown	Further investigation needed.	5 starts per hour allowable. Don't think this is exceeded.	10	5	3	18	✓		
3	Well 2a	20	Are pumps sequenced based on relative efficiency (kWh or $ per million gallons)?	Unknown	Further investigation needed.	Based on flow rate and water quality.	10	4	2	16	✓		
4	Well 2a	21	Is/are the pump(s) correctly sized for normal operation?	Unknown	Further investigation needed.		10	3	3	16	✓		
5	Well 2a	27	Is/are the motor(s) correctly sized?	No	Consider replacing motor with correctly sized (premium efficient) motor. Small (<50 HP) oversized motors can be especially inefficient. The motor should run between 65-100% load during normal operation. If a large capacity is required for peak flows, consider multiple motors. See Fact Sheet M3.	(746 gpm x 441 ft) / 3960 = 83.1 WHP. Motor is 100 HP. Motor is slightly undersized.	10	3	3	16	✓		
6	Well 2a	13	Is the lubrication oil reservoir raised at least 3 times the tank height above the solenoid valve?	No	Raising the oil reservoir will help maintain a more constant drip rate. Consider raising the oil reservoir. See Fact Sheet W1.	Probably 2 diameters above valve.	10	2	3	15	✓		
7	Well 2a	14	Does the drips/minute settling meet the guidelines from the following table?	No	An insufficient drip rate can contribute to pump failure. Consider correcting the drip rate. See Fact Sheet W1.	1.6875" diam, 500' to bowls; currently 10 drips per minute. ~22 drips per minute recommended.	10	2	3	15	✓		
8	Well 2a	15	Is/are the pump(s) operated during peak hours?	Yes	Consider if operating the pump(s) during off-peak and part peak hours is feasible. See Fact Sheet G1.	Don't have storage to pump during off-peak only. May have storage in future.	10	2	3	15	✓		

WATER SUPPLY - PIXLEY PUD

9	Well 3a	19	Is/are the pump(s) operating at maximum efficiency on the curve during normal operation?	Unknown	Further investigation needed.		7	5	3	15	✓		
10	Well 3a	30	Do the starts per hour exceed the appropriate value in the chart below?	Unknown	Further investigation needed.	5 starts per hour allowable. Don't think this is exceeded. Currently is last in sequence, so hasn't turned on much.	7	5	3	15	✓		
11	Well 4	19	Is/are the pump(s) operating at maximum efficiency on the curve during normal operation?	Unknown	Further investigation needed.		5	5	3	13	✓		
12	Well 4	30	Do the starts per hour exceed the appropriate value in the chart below?	Unknown	Further investigation needed.	5 starts per hour allowable. Don't think this is exceeded.	5	5	3	13	✓		
13	Well 3a	20	Are pumps sequenced based on relative efficiency (kWh or $ per million gallons)?	Unknown	Further investigation needed.	Based on flow rate and water quality.	7	4	2	13	✓		
14	Well 3a	21	Is/are the pump(s) correctly sized for normal operation?	Unknown	Further investigation needed.		7	3	3	13	✓		
15	Well 3a	26	Is/are the motor(s) premium efficiency?	No	Consider replacing motors with premium efficiency motors. See Fact Sheet M1.	Type RU = WPI, Standard Efficiency, NEMA, VHS 92.1 (ODP; 1800; STD)	7	3	3	13	✓		
16	WS Checklist	4	Are wells sequenced based on efficiency/cost to operate?	Unknown	Further investigation needed.	Sequenced based on production: Well 2a is supposed to turn on first because it produces the most. Well 3 should turn on second.	-	4	2	6	✓		
17	Well 3a	13	Is the lubrication oil reservoir raised at least 3 times the tank height above the solenoid valve?	No	Raising the oil reservoir will help maintain a more constant drip rate. Consider raising the oil reservoir. See Fact Sheet W1.	Probably 2 diameters above valve.	7	2	3	12	✓		
18	Well 3a	14	Does the drips/minute settling meet the guidelines from the following table?	No	An insufficient drip rate can contribute to pump failure. Consider correcting the drip rate. See Fact Sheet W1.	1.6875" diam, 500' to bowls; currently 10 drips per minute. ~22 drips per minute recommended.	7	2	3	12	✓		
19	Well 3a	15	Is/are the pump(s) operated during peak hours?	Yes	Consider if operating the pump(s) during off-peak and part peak hours is feasible. See Fact Sheet G1.	Don't have storage to pump during off-peak only. May have storage in future.	7	2	3	12	✓		
20	Well 4	20	Are pumps sequenced based on relative efficiency (kWh or $ per million gallons)?	Unknown	Further investigation needed.	Based on flow rate and water quality.	5	4	2	11	✓		

WATER SUPPLY - PIXLEY PUD

21	Well 4	21	Is/are the pump(s) correctly sized for normal operation?	Unknown	Further investigation needed.		5	3	3	11	✓		
22	Well 4	26	Is/are the motor(s) premium efficiency?	No	Consider replacing motors with premium efficiency motors. See Fact Sheet M1.	91.5% (ODP; 1200; STD)	5	3	3	11	✓		
23	Well 4	13	Is the lubrication oil reservoir raised at least 3 times the tank height above the solenoid valve?	No	Raising the oil reservoir will help maintain a more constant drip rate. Consider raising the oil reservoir. See Fact Sheet W1.	Probably 2 diameters above valve.	5	2	3	10	✓		
24	Well 4	14	Does the drips/minute settling meet the guidelines from the following table?	No	An insufficient drip rate can contribute to pump failure. Consider correcting the drip rate. See Fact Sheet W1.	1.6875" diam, ~400' to bowls; currently 10 drips per minute. ~19 drips per minute recommended.	5	2	3	10	✓		
25	Well 4	15	Is/are the pump(s) operated during peak hours?	Yes	Consider if operating the pump(s) during off-peak and part peak hours is feasible. See Fact Sheet G1.	Don't have storage to pump during off-peak only. May have storage in future.	5	2	3	10	✓		
26	WS Checklist	2	Are pumps operated during peak hours?	Yes	It may be possible to use the existing storage in the system to operate the pumps off-peak, relying on storage during peak hours. See Fact Sheet G1.	Not enough storage to pump off-peak. Possibly will have storage with new tank.	-	2	3	5	✓		
27	WS Checklist	5	Does the well water have water quality issues?	Yes	See the following questions.	Wells 2a and 3a have high arsenic. Well 4 does not.	-	-	-	-			✓
28	Well 2a	1	Are there water quality problems with: Arsenic	Yes	Enter the current approximate concentration. See Fact Sheets Q1 to Q3.	14-18 PPM	-	-	-	-			✓
29	Well 3a	1	Are there water quality problems with: Arsenic	Yes	Enter the current approximate concentration. See Fact Sheets Q1 to Q3.	12-14 PPM; has come into compliance sometimes.	-	-	-	-			✓
30	Well 3a	11	Are there water quality problems with: Other	Yes	Enter the current approximate concentration. See Fact Sheets Q1 to Q3.	Has recently tested positive for total coliform.	-	-	-	-			✓

Water Supply Sector – Output: Notes

Questions with Notes

The table below contains all notes that were indicated in the program.

If more than 100 notes were indicated, only the first 100 notes will appear in the table below.

	Section	Question Number	Question	Answer	Program Output	Notes
1	WS Checklist	2	Are pumps operated during peak hours?	Yes	It may be possible to use the existing storage in the system to operate the pumps off-peak, relying on storage during peak hours. See Fact Sheet G1.	Not enough storage to pump off-peak. Possibly will have storage with new tank.
2	WS Checklist	3	Does the site use generators during peak hours?	N/A		Likely not allowed.
3	WS Checklist	4	Are wells sequenced based on efficiency/cost to operate?	Unknown	Further investigation needed.	Sequenced based on production: Well 2a is supposed to turn on first because it produces the most. Well 3 should turn on second.
4	WS Checklist	5	Does the well water have water quality issues?	Yes	See the following questions.	Wells 2a and 3a have high arsenic. Well 4 does not.
5	WS Checklist	6	For groundwater quality, has the city ruled out or pursued: Blending	Yes	No suggestion.	Well 4 does not produce enough to blend out arsenic. New well should.
6	WS Checklist	7	For groundwater quality, has the city ruled out or pursued: Consolidating with nearby small towns	Yes	No suggestion.	Not close enough.
7	WS Checklist	8	For groundwater quality, has the city ruled out or pursued: Connecting with a nearby large town	N/A		Not close enough.

WATER SUPPLY - PIXLEY PUD

8	WS Checklist	9	For groundwater quality, has the city ruled out or pursued: Abandoning/destroying contaminated well(s)	Yes	No suggestion.	Need the flow from the 3 wells.
9	WS Checklist	10	For groundwater quality, has the city ruled out or pursued: Building a new well	Yes	No suggestion.	In process of adding a well
10	WS Checklist	11	For groundwater quality, has the city ruled out or pursued: Modifying (partially abandoning) contaminated well(s)	Yes	No suggestion.	Will modify Wells 2a and 3a to try to reduce arsenic (waiting for $).
11	WS Checklist	12	For groundwater quality, has the city ruled out or pursued: Treatment	Yes	No suggestion.	State will provide money to add well to blend water, rather than treat water.
12	Well 2a	1	Are there water quality problems with: Arsenic	Yes	Enter the current approximate concentration. See Fact Sheets Q1 to Q3.	14-18 PPM
13	Well 2a	13	Is the lubrication oil reservoir raised at least 3 times the tank height above the solenoid valve?	No	Raising the oil reservoir will help maintain a more constant drip rate. Consider raising the oil reservoir. See Fact Sheet W1.	Probably 2 diameters above valve.
14	Well 2a	14	Does the drips/minute settling meet the guidelines from the following table?	No	An insufficient drip rate can contribute to pump failure. Consider correcting the drip rate. See Fact Sheet W1.	1.6875" diam, 500' to bowls; currently 10 drips per minute. ~22 drips per minute recommended.
15	Well 2a	15	Is/are the pump(s) operated during peak hours?	Yes	Consider if operating the pump(s) during off-peak and part peak hours is feasible. See Fact Sheet G1.	Don't have storage to pump during off-peak only. May have storage in future.
16	Well 2a	17	Does/could the flow vary significantly with time and a VFD is not used?	No	No suggestion.	On/off filling tank. VFD could be used to maintain pressure in line.

17	Well 2a	18	Have pump efficiency tests been performed?	Yes	No suggestion.	2014 by SCE.
18	Well 2a	20	Are pumps sequenced based on relative efficiency (kWh or $ per million gallons)?	Unknown	Further investigation needed.	Based on flow rate and water quality.
19	Well 2a	25	Are there any components upstream or downstream of the pump that may be causing unnecessary losses (such as globe valves)?	No	No suggestion.	DS: air vent, check valve, flow meter, gate valve.
20	Well 2a	27	Is/are the motor(s) correctly sized?	No	Consider replacing motor with correctly sized (premium efficient) motor. Small (<50 HP) oversized motors can be especially inefficient. The motor should run between 65-100% load during normal operation. If a large capacity is required for peak flows, consider multiple motors. See Fact Sheet M3.	(746 gpm x 441 ft) / 3960 = 83.1 WHP. Motor is 100 HP. Motor is slightly undersized.
21	Well 2a	30	Do the starts per hour exceed the appropriate value in the chart below?	Unknown	Further investigation needed.	5 starts per hour allowable. Don't think this is exceeded.
22	Well 3a	1	Are there water quality problems with: Arsenic	Yes	Enter the current approximate concentration. See Fact Sheets Q1 to Q3.	12-14 PPM; has come into compliance sometimes.
23	Well 3a	11	Are there water quality problems with: Other	Yes	Enter the current approximate concentration. See Fact Sheets Q1 to Q3.	Has recently tested positive for total coliform.

WATER SUPPLY - PIXLEY PUD

24	Well 3a	13	Is the lubrication oil reservoir raised at least 3 times the tank height above the solenoid valve?	No	Raising the oil reservoir will help maintain a more constant drip rate. Consider raising the oil reservoir. See Fact Sheet W1.	Probably 2 diameters above valve.
25	Well 3a	14	Does the drips/minute settling meet the guidelines from the following table?	No	An insufficient drip rate can contribute to pump failure. Consider correcting the drip rate. See Fact Sheet W1.	1.6875" diam, 500' to bowls; currently 10 drips per minute. ~22 drips per minute recommended.
26	Well 3a	15	Is/are the pump(s) operated during peak hours?	Yes	Consider if operating the pump(s) during off-peak and part peak hours is feasible. See Fact Sheet G1.	Don't have storage to pump during off-peak only. May have storage in future.
27	Well 3a	17	Does/could the flow vary significantly with time and a VFD is not used?	No	No suggestion.	On/off filling tank. VFD could be used to maintain pressure in line.
28	Well 3a	18	Have pump efficiency tests been performed?	Yes	No suggestion.	Tested in 2014 by SCE.
29	Well 3a	20	Are pumps sequenced based on relative efficiency (kWh or $ per million gallons)?	Unknown	Further investigation needed.	Based on flow rate and water quality.
30	Well 3a	25	Are there any components upstream or downstream of the pump that may be causing unnecessary losses (such as globe valves)?	No	No suggestion.	DS: air vent, check valve, flow meter, gate valve
31	Well 3a	26	Is/are the motor(s) premium efficiency?	No	Consider replacing motors with premium efficiency motors. See Fact Sheet M1.	Type RU = WPI, Standard Efficiency, NEMA, VHS 92.1 (ODP; 1800; STD)
32	Well 3a	27	Is/are the motor(s) correctly sized?	Yes	No suggestion.	(620 gpm x 436 ft) / 3960 = 68.3 WHP. Motor is 100 HP. Motor is correctly sized.

33	Well 3a	30	Do the starts per hour exceed the appropriate value in the chart below?	Unknown	Further investigation needed.	5 starts per hour allowable. Don't think this is exceeded. Currently is last in sequence, so hasn't turned on much.
34	Well 4	1	Are there water quality problems with: Arsenic	No	No suggestion.	~4 PPM
35	Well 4	13	Is the lubrication oil reservoir raised at least 3 times the tank height above the solenoid valve?	No	Raising the oil reservoir will help maintain a more constant drip rate. Consider raising the oil reservoir. See Fact Sheet W1.	Probably 2 diameters above valve.
36	Well 4	14	Does the drips/minute settling meet the guidelines from the following table?	No	An insufficient drip rate can contribute to pump failure. Consider correcting the drip rate. See Fact Sheet W1.	1.6875" diam, ~400' to bowls; currently 10 drips per minute. ~19 drips per minute recommended.
37	Well 4	15	Is/are the pump(s) operated during peak hours?	Yes	Consider if operating the pump(s) during off-peak and part peak hours is feasible. See Fact Sheet G1.	Don't have storage to pump during off-peak only. May have storage in future.
38	Well 4	17	Does/could the flow vary significantly with time and a VFD is not used?	No	No suggestion.	On/off filling tank. VFD could be used to maintain pressure in line.
39	Well 4	18	Have pump efficiency tests been performed?	Yes	No suggestion.	Tested in 2014 by SCE.
40	Well 4	20	Are pumps sequenced based on relative efficiency (kWh or $ per million gallons)?	Unknown	Further investigation needed.	Based on flow rate and water quality.
41	Well 4	25	Are there any components upstream or downstream of the pump that may be causing unnecessary losses (such as globe valves)?	No	No suggestion.	DS: air vent, check valve, flow meter, gate valve.

42	Well 4	26	Is/are the motor(s) premium efficiency?	No	Consider replacing motors with premium efficiency motors. See Fact Sheet M1.	91.5% (ODP; 1200; STD)
43	Well 4	27	Is/are the motor(s) correctly sized?	Yes	No suggestion.	(519 gpm x 437 ft) / 3960 = 57 WHP. Motor is 75 HP. (57/75 = 76%). Motor is very slightly undersized.
44	Well 4	30	Do the starts per hour exceed the appropriate value in the chart below?	Unknown	Further investigation needed.	5 starts per hour allowable. Don't think this is exceeded.

Water Supply Sector – Calculations

Inputs: Motor Upgrade Calculator - Well 3a

Nameplate Horsepower	100	hp	Number of Units	1	
Motor Speed	1800	RPM	Annual Operating Hours (Each)	1291	
Enclosure Type	ODP		Cost of Electricity	0.17	$/kWh
Nameplate Nominal Efficiency (if given)	92.08	%			
Standard Efficiency (used if no Nameplate Efficiency given)	92.08	%			

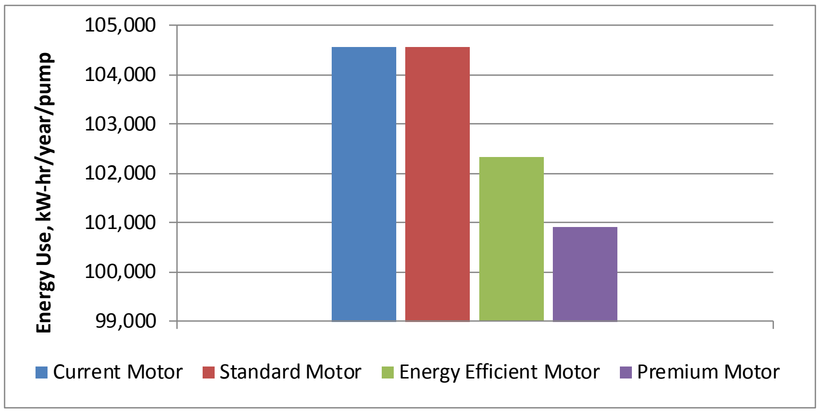
Optional:

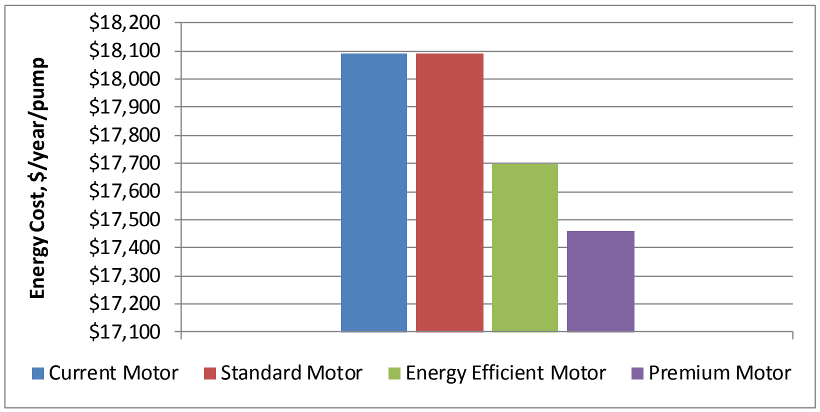
Cost to rewind motor:		$	Cost of energy efficient motor:		$
Cost of standard motor:		$	Cost of premium motor:		$
			Cost to install motor:		$

Outputs: Motor Upgrade Calculator - Well 3a

Energy and Cost Savings - Per Pump

	Current Motor	Standard Motor	Energy Efficient Motor	Premium Motor	
Efficiency	92.1	92.1	94.1	95.4	%
Annual Energy Use	104,562	104,562	102,317	100,923	kWh/yr
Annual Energy Cost	18,089	18,089	17,701	17,460	$/yr
Annual Energy Savings		0	2,245	3,639	kWh/yr
Annual Cost Savings		0	388	630	$/yr





WATER SUPPLY - PIXLEY PUD

Inputs: Motor Upgrade Calculator - Well 4

Nameplate Horsepower	75	hp	Number of Units	1	
Motor Speed	1200	RPM	Annual Operating Hours (Each)	1009	
Enclosure Type	ODP		Cost of Electricity	0.22	$/kWh
Nameplate Nominal Efficiency (if given)	91.51	%			
Standard Efficiency (used if no Nameplate Efficiency given)	91.51	%			

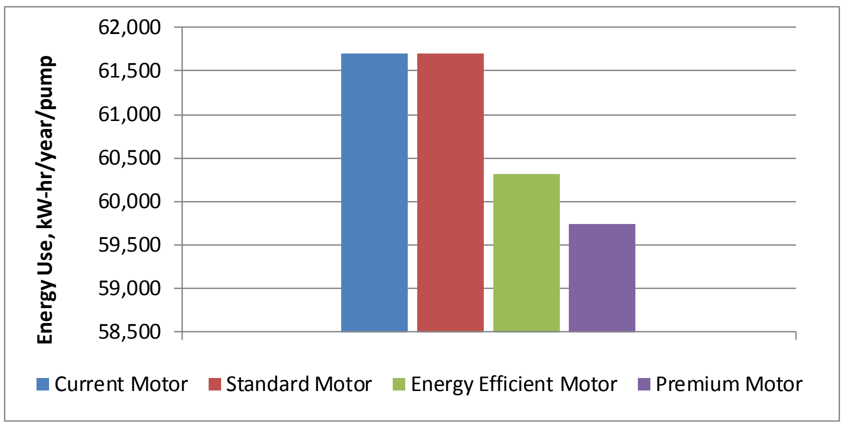
Optional:

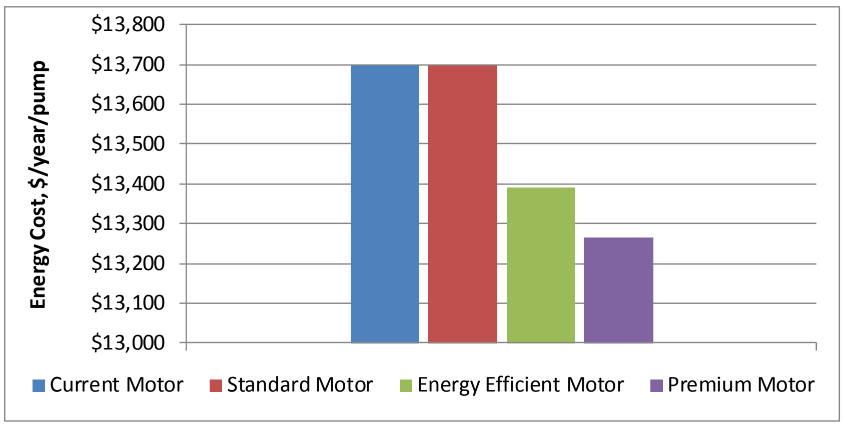
Cost to rewind motor:		$	Cost of energy efficient motor:		$
Cost of standard motor:		$	Cost of premium motor:		$
			Cost to install motor:		$

Outputs: Motor Upgrade Calculator - Well 4

Energy and Cost Savings - Per Pump

	Current Motor	Standard Motor	Energy Efficient Motor	Premium Motor	
Efficiency	91.5	91.5	93.6	94.5	%
Annual Energy Use	61,700	61,700	60,323	59,748	kWh/yr
Annual Energy Cost	13,697	13,697	13,392	13,264	$/yr
Annual Energy Savings		0	1,378	1,952	kWh/yr
Annual Cost Savings		0	306	433	$/yr





Small Community Water System Water/Energy Audit Report

Pixley PUD

Sector: Potable Water Treatment

Audit Date: March 21, 2017
Report Date: April 7, 2017

Sierra Layous

Irrigation Training and Research Center (ITRC)
Cal Poly, San Luis Obispo

POTABLE WATER TREATMENT - PIXLEY PUD

Potable Water Treatment Sector – Conclusions

- The water treatment for Pixley PUD consists solely of chlorine injection at each of the wells. The chlorine pumps are very small (~0.04 kW/ 0.05 HP each).
- Due to the small size of the pumps, there are no major energy/water savings recommendations. The treatment could be shifted off-peak in the future in conjunction with the water supply.

Potable Water Treatment Sector – Inventory List

Walk-through Inventory List:

Potable Water Treatment

	(a) Location / Name	(b) Equipment Type	(c.) Quantity	(d) Controls	(e) HP/kW per unit		(f) Typical Total HP/kW		(g) Estimate of total hours/yr (or %)		(h) Estimate of Power Cost ($/kW-hr)	(i) (f) * (g) Estimate of kW-hr/yr	(j) (h) * (i) Estimate of yearly cost ($)	(k) Device Score*
1	2a (near office)	Chlorine injection pump	1	on when well pump is on	0.039	kW	0.039	kW	32	%	0.12	109	13	10
2	3a (across town)	Chlorine injection pump	1	on when well pump is on	0.039	kW	0.039	kW	16	%	0.17	55	9	7
3	4 (@ shop)	Chlorine injection pump	1	on when well pump is on	0.039	kW	0.039	kW	10	%	0.35	34	12	9
4														
5														
6														
7														
8														
9														
10														

Total Yearly Expense:	$34
Average Daily Energy Use:	1 kW-hr

*The Device Score (k) is a sector-specific score, indicative of the energy use by each device/set of devices. A higher score indicates higher energy use, and therefore more energy-saving potential.

Potable Water Treatment Sector – Output: Triggered Questions

Triggered Questions

The following table is sorted by score (right column). Scores are relative, estimated values meant to help prioritize recommendations; higher scoring recommendations should be explored first.

A score of zero indicates no recommendation is given; the question is included for reference.

If more than 100 recommendations were generated, only the top 100 will appear in the table below.

	Section	Question Number	Question	Answer	Program Output	Notes	Score				Energy Savings	Water Savings	Water Quality
							Device	Ease of Implement-ation	Savings Potential	Total			
1	Injection Pump 2a	5	Is/are the pump(s) operating at maximum efficiency on the curve during normal operation?	Unknown	Further investigation needed.	Very small pump.	10	5	3	18	✓		
2	Injection Pump 2a	18	Do the starts per hour exceed the appropriate value in the chart below?	Unknown	Further investigation needed.	Unlikely.	10	5	3	18	✓		
3	Injection Pump 4	18	Do the starts per hour exceed the appropriate value in the chart below?	Unknown	Further investigation needed.	Unlikely.	9	5	3	17	✓		
4	Injection Pump 2a	8	Is most of the pump's discharge head used to overcome friction losses or elevation lift?	Unknown	Further investigation needed.		10	4	2	16	✓		
5	Injection Pump 4	8	Is most of the pump's discharge head used to overcome friction losses or elevation lift?	Unknown	Further investigation needed.		9	4	2	15	✓		
6	Injection Pump 3a	5	Is/are the pump(s) operating at maximum efficiency on the curve during normal operation?	Unknown	Further investigation needed.	Very small pump.	7	5	3	15	✓		
7	Injection Pump 3a	18	Do the starts per hour exceed the appropriate value in the chart below?	Unknown	Further investigation needed.	Unlikely.	7	5	3	15	✓		
8	Injection Pump 2a	1	Is/are the pump(s) operated during peak hours?	Yes	Consider if operating the pump(s) during off-peak and part peak hours is feasible. See Fact Sheet G1.		10	2	3	15	✓		
9	Injection Pump 4	1	Is/are the pump(s) operated during peak hours?	Yes	Consider if operating the pump(s) during off-peak and part peak hours is feasible. See Fact Sheet G1.		9	2	3	14	✓		

POTABLE WATER TREATMENT - PIXLEY PUD

10	Injection Pump 3a	8	Is most of the pump's discharge head used to overcome friction losses or elevation lift?	Unknown	Further investigation needed.		7	4	2	13	✓		
11	Injection Pump 3a	1	Is/are the pump(s) operated during peak hours?	Yes	Consider if operating the pump(s) during off-peak and part peak hours is feasible. See Fact Sheet G1.		7	2	3	12	✓		
12	PWT Checklist	1	Does the supply operate during peak hours?	Yes	Storage at the head of the water treatment plant could allow the supply system to operate off-peak, even if the water treatment plant doesn't. See Fact Sheet G1.		-	3	2	5	✓		
13	PWT Checklist	2	Does the water treatment plant operate during peak hours?	Yes	It may be possible to shift operation to off-peak hours. Operating off-peak requires appropriate storage. Additionally, you must consider staff flexibility. See Fact Sheet G1.		-	3	2	5	✓		
14	PWT Checklist	36	Is there enough storage at the end of the plant so that water treatment can operate off-peak?	No	Consider if storage can be made available to allow water treatment operations to cease during off-peak hours . See Fact Sheet G1.	Planned for future.	-	1	2	3	✓		

Potable Water Treatment Sector – Output: Notes

Questions with Notes

The table below contains all notes that were indicated in the program.

If more than 100 notes were indicated, only the first 100 notes will appear in the table below.

	Section	Question Number	Question	Answer	Program Output	Notes
1	PWT Checklist	3	Does the site use generators during peak hours?	N/A		Likely not allowed.
2	PWT Checklist	4	Does the site have an electric demand controller?	N/A		Only a single chlorine pump.
3	PWT Checklist	5	Are treatment plants sequenced based on cost/energy required to operate (this includes the cost/energy associated with the supply)?	N/A		Treatment plants are identical.
4	PWT Checklist	36	Is there enough storage at the end of the plant so that water treatment can operate off-peak?	No	Consider if storage can be made available to allow water treatment operations to cease during off-peak hours . See Fact Sheet G1.	Planned for future.
5	Injection Pump 2a	4	Have pump efficiency tests been performed?	N/A		Very small pump.
6	Injection Pump 2a	5	Is/are the pump(s) operating at maximum efficiency on the curve during normal operation?	Unknown	Further investigation needed.	Very small pump.
7	Injection Pump 2a	18	Do the starts per hour exceed the appropriate value in the chart below?	Unknown	Further investigation needed.	Unlikely.
8	Injection Pump 3a	4	Have pump efficiency tests been performed?	N/A		Very small pump.

9	Injection Pump 3a	5	Is/are the pump(s) operating at maximum efficiency on the curve during normal operation?	Unknown	Further investigation needed.	Very small pump.
10	Injection Pump 3a	18	Do the starts per hour exceed the appropriate value in the chart below?	Unknown	Further investigation needed.	Unlikely.
11	Injection Pump 4	4	Have pump efficiency tests been performed?	N/A		Very small pump.
12	Injection Pump 4	5	Is/are the pump(s) operating at maximum efficiency on the curve during normal operation?	Yes	No suggestion.	Very small pump.
13	Injection Pump 4	18	Do the starts per hour exceed the appropriate value in the chart below?	Unknown	Further investigation needed.	Unlikely.

Small Community Water System Water/Energy Audit Report

Pixley PUD

Sector: Water Distribution

Audit Date: March 21, 2017
Report Date: April 7, 2017

Sierra Layous

Irrigation Training and Research Center (ITRC)
Cal Poly, San Luis Obispo

WATER DISTRIBUTION - PIXLEY PUD

Water Distribution Sector – Conclusions

- Pixley PUD does not study and/or estimate delivery losses, or have an active leak program. All or any of these actions could help identify and reduce losses in the system.

Water Distribution Sector – Inventory List

The Water Distribution system relies solely on the water supply tanks. There are no other devices used in the water distribution system.

Water Distribution - Pixley PUD

Water Distribution Sector – Output: Triggered Questions

Triggered Questions

The following table is sorted by score (right column). Scores are relative, estimated values meant to help prioritize recommendations; higher scoring recommendations should be explored first.
A score of zero indicates no recommendation is given; the question is included for reference.
If more than 100 recommendations were generated, only the top 100 will appear in the table below.

	Section	Question Number	Question	Answer	Program Output	Notes	Score				Energy Savings	Water Savings	Water Quality
							Device	Ease of Implement-ation	Savings Potential	Total			
1	WD Checklist	6	Is there a leak reduction program?	No	Active leak management reduces lost water, conserving water and energy. See Fact Sheet D2.	No active program. California Rural Water Assoc looked at an older steel line in 2016 and didn't find any leaks.	-	2	3	5	✓	✓	
2	WD Checklist	4	Does the city know their losses from delivery?	No	"If you can't measure it, you can't manage it." Consider studying and estimating delivery losses to better understand and manage the losses. See Fact Sheet D3.		-	1	3	4	✓	✓	

Water Distribution Sector – Output: Notes

Questions with Notes

The table below contains all notes that were indicated in the program.

If more than 100 notes were indicated, only the first 100 notes will appear in the table below.

	Section	Question Number	Question	Answer	Program Output	Notes
1	WD Checklist	3	Does the city have accurate metering?	Yes	No suggestion.	At wells and at end users
2	WD Checklist	6	Is there a leak reduction program?	No	Active leak management reduces lost water, conserving water and energy. See Fact Sheet D2.	No active program. California Rural Water Assoc looked at an older steel line in 2016 and didn't find any leaks.
3	WD Checklist	7	If valves and hydrants are tested periodically, is the water collected and used for a secondary purpose?	Yes	No suggestion.	Pixley ID uses the water.

Small Community Water System Water/Energy Audit Report

Pixley PUD

Sector: End Use

Audit Date: March 21, 2017
Report Date: April 7, 2017

Sierra Layous

Irrigation Training and Research Center (ITRC)
Cal Poly, San Luis Obispo

END USE - PIXLEY PUD

End Use Sector – Conclusions

- The installation of water meters on all customer's lines in 2012 and the use of tiered billing has decreased water use in the community.
- There are a variety of low to moderate cost incentives/devices that can be implemented by the PUD to encourage active leak detection and water conservation by end users.
- Meeting with the top water users and providing education on water use and conservation methods can provide significant water savings with minimal effort.

End Use - Pixley PUD

End Use Sector – Inventory List

Walk-through Inventory List:

End Use

	Sector	Techniques
1	Residential	Lawns can only be watered 2 days per week, not in afternoon.
2	Commercial	
3	Recreational - Park	Main park in Pixley has its own well, is part of Tulare County.
4	Recreational - Park	Small park is managed by Pixley PUD; has sprinklers for lawn and drip for trees; no scheduling plan, adjust hours based on appearance.
5	Schools - elementary school	
6	Schools - middle school	Has own well for irrigation.
7	All	2012 - half of town was metered; grant allowed entire town to be metered; can read meters with radio.
8	All	Reporting and patrol; about 6 tickets written last year - 1st ticket is a warning, 2nd $25 (one last year), 3rd $50.
9		
10		

End Use Sector – Output: Triggered Questions

Triggered Questions

The following table is sorted by score (right column). Scores are relative, estimated values meant to help prioritize recommendations; higher scoring recommendations should be explored first.
A score of zero indicates no recommendation is given; the question is included for reference.
If more than 100 recommendations were generated, only the top 100 will appear in the table below.

	Section	Question Number	Question	Answer	Program Output	Notes	Score				Energy Savings	Water Savings	Water Quality
							Device	Ease of Implement-ation	Savings Potential	Total			
1	End Use Checklist	2	Has the city notified or met with the top water users in the system to help identify potential modifications?	No	Targeting top water users can maximize water conservation efforts.	The elementary school is the biggest user (irrigation).	-	5	5	10	✓	✓	
2	End Use Checklist	1	Does the city complete AWWA's Water Loss Control Committee (WLCC) Free Water Audit Software, or equivalent?	No	Maintaining an auditing tool for water use can help water utilities account for and manage system water losses. The American Water Works Association (AWWA) provides a free tool that is available online (www.awwa.org).		-	5	4	9	✓	✓	
3	End Use Checklist	15	Does the city provide toilet leak detection tablets to residential customers?	No	Leak detection tablets can alert customers to issues, instigating repair. See Fact Sheet E1.		-	4	5	9	✓	✓	
4	End Use Checklist	17	Does the city offer incentives to residential customers for: Irrigation scheduling	No	Offering incentives, such as rebates, for residential outdoor water efficient measures and equipment can improve water conservation. See Fact Sheet E1.		-	4	5	9	✓	✓	
5	End Use Checklist	34	Does the city provide toilet leak detection tablets to CII customers?	No	Leak detection tablets can alert customers to issues, instigating repair. See Fact Sheet E2.		-	4	5	9	✓	✓	
6	End Use Checklist	36	Does the city offer incentives to CII customers for: Irrigation scheduling	No	Offering incentives, such as rebates, for CII outdoor water efficient measures and equipment can improve water conservation. See Fact Sheet E2.		-	4	5	9	✓	✓	
7	End Use Checklist	42	Do all recreational users have meters?	No	Meters provide accountability to users and typically reduce water use by 20%. See Fact Sheet E3.	Park does not have meter	-	4	5	9	✓	✓	
8	End Use Checklist	3	Does the city know the breakdown of its water users (residential, industrial, institutional, commercial)?	Unknown	Further investigation needed.		-	5	3	8	✓	✓	
9	End Use Checklist	13	Does the city offer incentives to residential customers for: Faucet Aerators	No	Offering incentives, such as rebates, can improve water conservation. See Fact Sheet E1.		-	5	3	8	✓	✓	

End Use - Pixley PUD

10	End Use Checklist	29	Does the city offer incentives to CII customers for: Low-flow spray rinse nozzles	No	Offering incentives, such as rebates, can improve water conservation. See Fact Sheet E2.		-	5	3	8	✓	✓	
11	End Use Checklist	31	Does the city offer incentives to CII customers for: Faucet Aerators	No	Offering incentives, such as rebates, can improve water conservation. See Fact Sheet E2.		-	5	3	8	✓	✓	
12	End Use Checklist	10	Does the city offer incentives to residential customers for: Low-flush toilets	No	Offering incentives, such as rebates, can improve water conservation. See Fact Sheet E1.		-	3	4	7	✓	✓	
13	End Use Checklist	11	Does the city offer incentives to residential customers for: Low-flow shower heads	No	Offering incentives, such as rebates, can improve water conservation. See Fact Sheet E1.		-	5	2	7	✓	✓	
14	End Use Checklist	28	Does the city offer incentives to CII customers for: Low-flush toilets/low flow urinals	No	Offering incentives, such as rebates, can improve water conservation. See Fact Sheet E2.		-	3	4	7	✓	✓	
15	End Use Checklist	12	Does the city offer incentives to residential customers for: High efficiency washing machines	No	Offering incentives, such as rebates, can improve water conservation. See Fact Sheet E1.		-	3	3	6	✓	✓	
16	End Use Checklist	19	Does the city offer incentives to residential customers for: Xeriscape or low water use landscaping	No	Offering incentives, such as rebates, for residential outdoor water efficient measures and equipment can improve water conservation. See Fact Sheet E1.		-	2	4	6	✓	✓	
17	End Use Checklist	20	Does the city offer incentives to residential customers for: Lawn replacement	No	Offering incentives, such as rebates, for residential outdoor water efficient measures and equipment can improve water conservation. See Fact Sheet E1.		-	2	4	6	✓	✓	
18	End Use Checklist	26	Has the city invested in water education measures for CII customers regarding indoor water conservation?	No	Water education can reduce the amount of water consumed by users. See Fact Sheet E2.		-	3	3	6	✓	✓	
19	End Use Checklist	30	Does the city offer incentives to CII customers for: High efficiency washing machines	No	Offering incentives, such as rebates, can improve water conservation. See Fact Sheet E2.		-	3	3	6	✓	✓	
20	End Use Checklist	33	Does the city offer any incentives to CII customers for cooling towers, ice making, laundry processing, or medical imaging equipment?	No	Offering incentives, such as rebates, for commercial/industrial water-efficient equipment can improve water conservation. See Fact Sheet E2.		-	2	4	6	✓	✓	

END USE - PIXLEY PUD

21	End Use Checklist	38	Does the city offer incentives to CII customers for: Xeriscape or low water use landscaping	No	Offering incentives, such as rebates, for CII outdoor water efficient measures and equipment can improve water conservation. See Fact Sheet E2.		-	2	4	6	✓	✓	
22	End Use Checklist	39	Does the city offer incentives to CII customers for: Lawn replacement	No	Offering incentives, such as rebates, for CII outdoor water efficient measures and equipment can improve water conservation. See Fact Sheet E2.		-	2	4	6	✓	✓	
23	End Use Checklist	41	Does the city offer any incentives to CII customers for on-site water treatment and reuse (includes industrial processes, landscape irrigation, agricultural irrigation, fountains, fire protection)?	No	Offering incentives, such as rebates, for CII water reuse can reduce the demand on the municipal potable water system. See Fact Sheet E2.		-	2	4	6	✓	✓	
24	End Use Checklist	18	Does the city offer incentives to residential customers for: Efficient equipment	No	Offering incentives, such as rebates, for residential outdoor water efficient measures and equipment can improve water conservation. See Fact Sheet E1.		-	2	3	5	✓	✓	
25	End Use Checklist	37	Does the city offer incentives to CII customers for: Efficient equipment	No	Offering incentives, such as rebates, for CII outdoor water efficient measures and equipment can improve water conservation. See Fact Sheet E2.		-	2	3	5	✓	✓	

End Use Sector – Output: Notes

Questions with Notes

The table below contains all notes that were indicated in the program.

If more than 100 notes were indicated, only the first 100 notes will appear in the table below.

	Section	Question Number	Question	Answer	Program Output	Notes
1	End Use Checklist	2	Has the city notified or met with the top water users in the system to help identify potential modifications?	No	Targeting top water users can maximize water conservation efforts.	The elementary school is the biggest user (irrigation).
2	End Use Checklist	5	For residential users, does the city use any of the following tiered-rate structures?	Yes	No suggestion.	3/4-1" line - 27,000 gallon base, $2/1000 gal after, no cap. Commercial customers have 4" line, bigger base
3	End Use Checklist	6	Does the city provide indoor water audits to residential customers?	Yes	No suggestion.	If high usage is noted, PUD will flag and look over for leaks to see if a cause can be found.
4	End Use Checklist	7	Does the city provide outdoor water audits to residential customers?	Yes	No suggestion.	As needed.
5	End Use Checklist	8	Has the city invested in water education measures for residential customers regarding indoor water conservation?	Yes	No suggestion.	As needed.
6	End Use Checklist	9	Has the city invested in water education measures for residential customers regarding outdoor water conservation?	Yes	No suggestion.	Watering 2x per week, no watering in afternoons
7	End Use Checklist	16	Does the city reduce the pressure or recommend pressure reducing valves to residential customers with excess pressure?	N/A		Water tower limits pressure to 40 PSI max

END USE - PIXLEY PUD

8	End Use Checklist	24	Does the city provide indoor water audits to CII customers?	Yes	No suggestion.	As needed.
9	End Use Checklist	25	Does the city provide outdoor water audits to CII customers?	Yes	No suggestion.	As needed.
10	End Use Checklist	27	Has the city invested in water education measures for CII customers regarding outdoor water conservation?	Yes	No suggestion.	Watering 2x/week, not in afternoons
11	End Use Checklist	35	Does the city reduce the pressure or recommend pressure reducing valves to CII customers with excess pressure?	N/A		Water tower limits pressure to 40 PSI
12	End Use Checklist	42	Do all recreational users have meters?	No	Meters provide accountability to users and typically reduce water use by 20%. See Fact Sheet E3.	Park does not have meter
13	End Use Checklist	43	For recreational users, does the city use any of the following tiered-rate structures?	N/A		PUD manages park

Small Community Water System Water/Energy Audit Report

Pixley PUD

Sector: Wastewater Collection

Audit Date: March 21, 2017
Report Date: April 7, 2017

Sierra Layous

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WASTEWATER COLLECTION - PIXLEY PUD

Wastewater Collection Sector – Conclusions

The only pumps in Pixley PUD's wastewater collection system are at the inlet of the wastewater treatment plant. These pumps are included in the analysis of the wastewater treatment plant.

WASTEWATER COLLECTION - PIXLEY PUD

Wastewater Collection Sector – Inventory List

Walk-through Inventory List:

Wastewater Collection

	(a)	(b)	(c.)	(d)	(e)	(f)	(g)	(h)	(i) (f) * (g)	(j) (h) * (i)	(k)
	Location / Name	Equipment Type	Quantity	Controls	HP/kW per unit	Typical Total HP/kW	Estimate of total hours/yr (or %)	Estimate of Power Cost ($/kW-hr)	Estimate of kW-hr/yr	Estimate of yearly cost ($)	Device Score*
1	Wastewater	Lift Pumps	are	included in	WWTP	Sector					
2											
3											
4											
5											
6											
7											
8											
9											
10											

Total Yearly Expense:	$0
Average Daily Energy Use:	0 kW-hr

*The Device Score (k) is a sector-specific score, indicative of the energy use by each device/set of devices. A higher score indicates higher energy use, and therefore more energy-saving potential.

Wastewater Collection Sector – Output: Triggered Questions

Triggered Questions

The following table is sorted by score (right column). Scores are relative, estimated values meant to help prioritize recommendations; higher scoring recommendations should be explored first.
A score of zero indicates no recommendation is given; the question is included for reference.
If more than 100 recommendations were generated, only the top 100 will appear in the table below.

	Section	Question Number	Question	Answer	Program Output	Notes	Score: Device	Score: Ease of Implement-ation	Score: Savings Potential	Score: Total	Energy Savings	Water Savings	Water Quality
1	WWC Checklist	2	Are pumps operated during peak hours?	Yes	It may be possible to use the existing storage in the system to operate the pumps off-peak, relying on storage during peak hours. See Fact Sheet G1.	Not sufficient storage in system.	-	2	3	5	✓		

Wastewater Collection Sector – Output: Notes

Questions with Notes

The table below contains all notes that were indicated in the program.

If more than 100 notes were indicated, only the first 100 notes will appear in the table below.

	Section	Question Number	Question	Answer	Program Output	Notes
1	WWC Checklist	1	Is the city working to reduce inflows into the system?	N/A		Storm is county - different system. There are slightly higher flows at the WWTP during storms, but not signficant.
2	WWC Checklist	3	Does the site use generators during peak hours?	N/A		Likely not allowed.

Small Community Water System Water/Energy Audit Report

Pixley Public Utility District

Sector: Wastewater Treatment

Audit Date: March 21, 2017
Report Date: April 7, 2017

Sierra Layous

Irrigation Training and Research Center (ITRC)
Cal Poly, San Luis Obispo

Wastewater Treatment Sector – Conclusions

- A majority (>75%) of the energy used in the treatment plant is used by the STM-Aerotors in the aeration tanks and the blowers in the aerobic digester. Therefore, optimizing these devices/processes will provide the largest reduction in energy use and cost.
- It is estimated that the cost to operate the STM-Aerotors is approximately $15,000 per year. The treatment plant was originally designed to adjust the speed of the STM-Aerotors based on the DO levels in the tank, but issues with the DO sensors caused the district to abandon the automatic control. The district currently manually adjusts the speed of the STM-Aerotors seasonally. While the treatment plant currently meets water quality regulations, automatically adjusting the speed of the STM-Aerotors based on the dissolved oxygen (DO) levels in the tanks may allow the system to continue to meet water quality regulations while reducing energy use and cost. Newer/different technology for the DO sensors may be more successful than the original sensors.
- It is estimated that the cost to operate the blowers in the digester is approximately $10,000 per year. Currently, one of the blowers is on nearly continuously at a constant speed. The energy use and cost of the digester blowers may be reduced by installing VFDs or guide vanes to automatically adjusting the speed of (“turndown”) the blowers based on water quality parameters in the digesters (such as DO). Additionally, the efficiency of the blowers is not known. The high efficiencies and control options of newer technology can make replacing existing blowers economical.
- The motors on the digester blowers are not premium efficiency (they are energy efficient). While the savings per year associated with replacing the motors is not significant (estimated at about $300/year if both motors were upgraded), if the motor needs to be rewound or replaced, the cost should be compared to the cost of a premium efficiency motor.
- Automatically adjusting the RAS flow rate based on plant flow and biosolids settling characteristics can reduce the energy use and cost associated with excess recirculation.
- The performance of the lift pumps at the head of the wastewater treatment plant has declined significantly. The district is in the process of repairing/replacing the pumps. The district should consider the benefit of a constant inflow to the treatment plant that could be achieved with VFDs on the lift pumps. Currently, the pumps turn on and off based on the water level in the sump. Analysis of pump hours (from the SCADA system) and treatment plant inflows (from the flow meter) indicate the pumps are turned on less than half of the time.

Wastewater Treatment Sector – Inventory List

Walk-through Inventory List:

Wastewater Treatment

	(a) Location / Name	(b) Equipment Type	(c.) Quantity	(d) Controls	(e) HP/kW per unit		(f) Typical Total HP/kW		(g) Estimate of total hours/yr (or %)		(h) Estimate of Power Cost ($/kW-hr)	(i) (f) * (g) Estimate of kW-hr/yr	(j) (h) * (i) Estimate of yearly cost ($)	(k) Device Score*
1	Wastewater Lift Station	Lift Pumps	3	based on WL, rotates primary by cycle	10	HP	10	HP	36	%	0.11	23,542	2,543	2
2	Spiral Screen	Motor	1	on/off with lift pumps	1	HP	1	HP	36	%	0.11	2,354	254	0
3	STM-Aerotors	Mixer	4	always on, fixed speed adjusted seasonally	7.5	HP	23	HP	100	%	0.11	150,407	16,244	10
4	Clarifier Main Chain	Motor	2	fixed constant speed	0.5	HP	1	HP	100	%	0.11	6,539	706	0
5	Clarifier Sludge Chain	Motor	2	fixed constant speed	0.5	HP	1	HP	100	%	0.11	6,539	706	0
6	WAS RAS Pump	Pump	2	fixed constant speed	2.7	HP	5.4	HP	100	%	0.11	35,313	3,814	2
7	Digester Blowers	Blower	2	one always on, switch manually	30	HP	15	HP	100	%	0.11	98,092	10,594	7
8	Sludge Thickener	Chemical Pump	1	on when digester is dumped (~every 4 weeks)	0.029	kW	0.029	kW	50	hrs/yr	0.11	1	0	0
9	Farmer Pump	Pump	1	manual, never on	10	HP	10	HP	0	%	0.11	0	0	0
10														

Total Yearly Expense:	$34,861
Average Daily Energy Use:	884 kW-hr

*The Device Score (k) is a sector-specific score, indicative of the energy use by each device/set of devices. A higher score indicates higher energy use, and therefore more energy-saving potential.

Wastewater Treatment Sector – Output: Triggered Questions

Triggered Questions

The following table is sorted by score (right column). Scores are relative, estimated values meant to help prioritize recommendations; higher scoring recommendations should be explored first.
A score of zero indicates no recommendation is given; the question is included for reference.
If more than 100 recommendations were generated, only the top 100 will appear in the table below.

	Section	Question Number	Question	Answer	Program Output	Notes	Score				Energy Savings	Water Savings	Water Quality
							Device	Ease of Implement-ation	Savings Potential	Total			
1	WWT Checklist	20	Is the DO in the suspended growth system maintained automatically with sensors?	No	Maintaining the DO automatically via sensors and VFDs reduces wasted energy from excess aeration.	It was initially, but the sensors weren't working, so they switched to constant speed, adjusted seasonally.	-	5	4	9	✓		
2	WWT Checklist	21	Does the DO probe provide an accurate measurement of the dissolved oxygen in the aerated basin?	Unknown	Further investigation needed.		-	5	4	9	✓		
3	STM-Aerotors	3	Is the speed (or height of the mechanical aerator) automatically adjusted based on inflow, DO level, or other pertinent measurement?	No	Consider installing sensors and controls to automatically adjust speed or height. Manually adjusting equipment to meet flow and wastewater strength often leads to over-aeration or over-mixing, which wastes energy. Automatic measurement and adjustment ensures optimum mixing and aeration. See Fact Sheet B3.	Set up to adjust automatically based on DO, but sensors and unit didn't work together so they manually adjust the speed seasonally.	10	3	5	18	✓		
4	WWT Checklist	23	Is the RAS rate in the suspended growth system adjusted automatically based on plant flow and biosolids settling characteristics?	No	Adjusting the RAS flow automatically via sensors and VFDs reduces wasted energy from excess recirculation. See Fact Sheet G5.	RAS flow is constant.	-	3	5	8	✓		
5	STM-Aerotors	4	Is/are the motor(s) premium efficiency?	Unknown	Further investigation needed.	Unknown (TEFC; 1200)	10	3	3	16	✓		
6	STM-Aerotors	5	Is/are motor(s) correctly sized?	Unknown	Further investigation needed.		10	3	3	16	✓		
7	STM-Aerotors	1	Is/are the mixer(s) operated during peak hours?	Yes	Consider if operating the mixer(s) during off-peak and part peak hours is feasible. See Fact Sheet G1.		10	2	3	15	✓		

8	Digester Blowers	5	Is/are the blower(s) automatically adjusted based on inflow, DO, or an other pertinent parameter?	No	Consider installing sensors and controls to automatically adjust speed (with VFD). Manually adjusting equipment to meet flow and wastewater strength often leads to over-aeration, which wastes energy. Automatic measurement and adjustment ensures optimum aeration. See Fact Sheet B3.		7	3	5	15	✓		
9	Digester Blowers	11	Are fine bubble diffusers used?	Unknown	Further investigation needed.		7	3	5	15	✓		
10	WWT Checklist	28	Is the bio-solids pumping rate adjusted based on accumulation in the secondary clarifiers?	No	Biosolids pumping could be optimized. Basing pumping on accumulation ensures a solids content in the water pumped, minimizing pumping as well as the energy associated with the dewatering process.		-	3	4	7	✓		
11	WWT Checklist	51	Is aerobic digestion used?	Yes	Consider switching to anaerobic digestion. Anaerobic digestion is less energy intensive (does not require oxygen and produces less sludge) and produces an energy source (biogas). However, anaerobic digestion requires heat, is a slower process, and is sensitive to variations in flow or composition.	Not ideal for small systems.	-	2	5	7	✓		
12	Digester Blowers	2	Are the main blowers single stage centrifugal blowers with VFDs (geared or turbo blowers)?	No	Consider newer technologies. The higher efficiencies of newer technologies may make replacing existing blowers economical. See Fact Sheet B1.		7	3	4	14	✓		
13	Digester Blowers	4	Is a VFD or guide vanes used?	No	In most applications, the blower output can be adjusted based on the flow or pressure needed. For most blowers, VFDs can be installed to "turndown" the blower. See Fact Sheets B5 and M2.		7	3	4	14	✓		

PIXLEY PUBLIC UTILITY DISTRICT - WASTEWATER TREATMENT

14	Digester Blowers	8	Is/are the blower(s) operating at maximum efficiency on the curve during normal operation?	Unknown	Further investigation needed.		7	3	4	14	✓		
15	Digester Blowers	10	Is/are the blower(s) correctly sized for normal operation?	Unknown	Further investigation needed.		7	3	3	13	✓		
16	Digester Blowers	13	Is/are the motor(s) premium efficiency?	No	Consider replacing motors with premium efficiency motors. See Fact Sheet M1.	92.4% (TEFC; 1800; EE)	7	3	3	13	✓		
17	Digester Blowers	14	Is/are the motor(s) correctly sized?	Unknown	Further investigation needed.		7	3	3	13	✓		
18	WWT Checklist	2	Does the site have an electric demand controller?	No	Electric demand controllers are used to ensure multiple cyclic equipment do not operate at the same time. They can also be used for load shedding, turning off non-critical equipment when the load reaches a certain threshold. See Fact Sheet G4.		-	2	4	6	✓		
19	WWT Checklist	4	Is freshwater used rather than final effluent?	Yes	If water quality of final effluent is adequate, using effluent rather than freshwater can reduce overall pumping requirements.	Secondary effluent, not suitable.	-	2	4	6	✓	✓	
20	WWT Checklist	18	Is the speed of the RBC units or number of units operating adjusted based on flow?	No	Basing the speed/number of units operating on the flow rate in the system can help optimize the system and reduce energy.	Initially based on DO, but sensors weren't working, so they switched to constant speed, adjusted seasonally.	-	2	4	6	✓		
21	WWT Checklist	29	Is there air and/or water spraying for foam and scum control in the secondary clarifiers?	Yes	If yes, if it operates automatically on a timer, it may be operating too frequently, especially during low flows. Consider basing the operation on the flow.		-	2	4	6	✓		
22	Digester Blowers	1	Is/are the blower(s) operated during peak hours?	Yes	Consider if operating the blower(s) during off-peak and part peak hours is feasible. See Fact Sheet G1.		7	2	3	12	✓		
23	WAS RAS Pumps	4	Have pump efficiency tests been performed?	No	Consider performing pump tests. See Fact Sheet P5.		2	5	3	10	✓		
24	WAS RAS Pumps	5	Is/are the pump(s) operating at maximum efficiency on the curve during normal operation?	Unknown	Further investigation needed.		2	5	3	10	✓		

25	WWT Checklist	1	Does the wastewater treatment plant operate any components off-peak?	No	Operating off-peak can reduce energy costs. However, it requires appropriate storage. Additionally, you must consider staff flexibility. An alternative could be to use generators during peak hours. See Fact Sheet G1.		-	2	3	5	✓		
26	WWT Checklist	5	Is the whole utility water system pressurized?	Yes	It may be possible to reduce power consumption by installing small booster pumps where necessary, rather than pressurizing the whole system.	From city, not pressurized on-site.	-	3	2	5	✓		
27	Lift Pumps	4	Have pump efficiency tests been performed?	No	Consider performing pump tests. See Fact Sheet P5.	There has been noticeable decline in the performance of the pumps. PUD is in process of repairing/replacing the pumps.	2	5	3	10	✓		
28	Lift Pumps	5	Is/are the pump(s) operating at maximum efficiency on the curve during normal operation?	Unknown	Further investigation needed.		2	5	3	10	✓		
29	Lift Pumps	9	Are there any abrupt in-line (not tee) pipe size changes?	Unknown	Further investigation needed.		2	3	5	10	✓		
30	Lift Pumps	10	Are there any unnecessary sharp elbows?	Unknown	Further investigation needed.		2	4	4	10	✓		
31	Lift Pumps	18	Do the starts per hour exceed the appropriate value in the chart below?	Unknown	Further investigation needed.	10 HP 1800 RPM; max 10 starts per hour recommended	2	5	3	10	✓		
32	WAS RAS Pumps	3	Does/could the flow vary significantly with time and a VFD is not used?	Yes	Consider a VFD. VFDs allow the pump to be adjusted based on actual needs (such as flow rate). See Fact Sheet M2.		2	3	4	9	✓		
33	Lift Pumps	3	Does/could the flow vary significantly with time and a VFD is not used?	Yes	Consider a VFD. VFDs allow the pump to be adjusted based on actual needs (such as flow rate). See Fact Sheet M2.	Right now, turns on and off based on WL. This means no flow into plant at times.	2	3	4	9	✓		
34	Lift Pumps	11	Are there any components upstream or downstream of the pump that may be causing unnecessary losses (such as globe valves)?	Unknown	Further investigation needed.		2	3	4	9	✓		
35	WAS RAS Pumps	7	Is/are the pump(s) correctly sized for normal operation?	Unknown	Further investigation needed.		2	3	3	8	✓		

PIXLEY PUBLIC UTILITY DISTRICT - WASTEWATER TREATMENT

36	WAS RAS Pumps	14	Is/are the motor(s) premium efficiency?	Unknown	Further investigation needed.		2	3	3	8	✓		
37	WAS RAS Pumps	15	Is/are the motor(s) correctly sized?	Unknown	Further investigation needed.		2	3	3	8	✓		
38	Farmer Pump	4	Have pump efficiency tests been performed?	Unknown	Further investigation needed.	Installed in 2009	0	5	3	8	✓		
39	Farmer Pump	5	Is/are the pump(s) operating at maximum efficiency on the curve during normal operation?	Unknown	Further investigation needed.		0	5	3	8	✓		
40	Sludge Thick Pump	5	Is/are the pump(s) operating at maximum efficiency on the curve during normal operation?	Unknown	Further investigation needed.		0	5	3	8	✓		
41	WAS RAS Pumps	1	Is/are the pump(s) operated during peak hours?	Yes	Consider if operating the pump(s) during off-peak and part peak hours is feasible. See Fact Sheet G1.		2	2	3	7	✓		
42	Lift Pumps	1	Is/are the pump(s) operated during peak hours?	Yes	Consider if operating the pump(s) during off-peak and part peak hours is feasible. See Fact Sheet G1.		2	2	3	7	✓		
43	Clarifier Main Flight	4	Is/are the motor(s) correctly sized?	Unknown	Further investigation needed.		0	3	3	6	✓		
44	Clarifier Sludge Flight	4	Is/are the motor(s) correctly sized?	Unknown	Further investigation needed.		0	3	3	6	✓		
45	Spiral Screen	3	Is/are the motor(s) premium efficiency?	No	Consider replacing motors with premium efficiency motors. See Fact Sheet M1.	82.5% (TEFC; 1800; EE); likely too small to warrant cost to upgrade.	0	3	3	6	✓		
46	Spiral Screen	4	Is/are the motor(s) correctly sized?	Unknown	Further investigation needed.		0	3	3	6	✓		
47	Farmer Pump	7	Is/are the pump(s) correctly sized for normal operation?	Unknown	Further investigation needed.		0	3	3	6	✓		
48	Farmer Pump	14	Is/are the motor(s) premium efficiency?	No	Consider replacing motors with premium efficiency motors. See Fact Sheet M1.	89.5% (TEFC, 1800, EE)	0	3	3	6	✓		
49	Farmer Pump	15	Is/are the motor(s) correctly sized?	Unknown	Further investigation needed.	Motor is on VFD?	0	3	3	6	✓		
50	Sludge Thick Pump	7	Is/are the pump(s) correctly sized for normal operation?	Unknown	Further investigation needed.		0	3	3	6	✓		
51	Clarifier Main Flight	1	Is/are the motor(s) operated during peak hours?	Yes	Consider if operating the motor(s) during off-peak and part peak hours is feasible. See Fact Sheet G1.		0	2	3	5	✓		

52	Clarifier Sludge Flight	1	Is/are the motor(s) operated during peak hours?	Yes	Consider if operating the motor(s) during off-peak and part peak hours is feasible. See Fact Sheet G1.		0	2	3	5	✓		
53	Spiral Screen	1	Is/are the motor(s) operated during peak hours?	Yes	Consider if operating the motor(s) during off-peak and part peak hours is feasible. See Fact Sheet G1.		0	2	3	5	✓		
54	Farmer Pump	1	Is/are the pump(s) operated during peak hours?	Yes	Consider if operating the pump(s) during off-peak and part peak hours is feasible. See Fact Sheet G1.	But not used	0	2	3	5	✓		
55	Sludge Thick Pump	1	Is/are the pump(s) operated during peak hours?	Yes	Consider if operating the pump(s) during off-peak and part peak hours is feasible. See Fact Sheet G1.	It runs only when sludge is dumped from digester.	0	2	3	5	✓		

Wastewater Treatment Sector – Output: Notes

Questions with Notes

The table below contains all notes that were indicated in the program.

If more than 100 notes were indicated, only the first 100 notes will appear in the table below.

	Section	Question Number	Question	Answer	Program Output	Notes
1	WWT Checklist	3	Does the site use generators during peak hours?	N/A		Likely not allowed
2	WWT Checklist	4	Is freshwater used rather than final effluent?	Yes	If water quality of final effluent is adequate, using effluent rather than freshwater can reduce overall pumping requirements.	Secondary effluent, not suitable.
3	WWT Checklist	5	Is the whole utility water system pressurized?	Yes	It may be possible to reduce power consumption by installing small booster pumps where necessary, rather than pressurizing the whole system.	From city, not pressurized on-site.
4	WWT Checklist	8	Are the trash racks and/or bar screens automatically cleaned?	Yes	No suggestion.	plus manual cleaning every couple weeks
5	WWT Checklist	18	Is the speed of the RBC units or number of units operating adjusted based on flow?	No	Basing the speed/number of units operating on the flow rate in the system can help optimize the system and reduce energy.	Initially based on DO, but sensors weren't working, so they switched to constant speed, adjusted seasonally.
6	WWT Checklist	20	Is the DO in the suspended growth system maintained automatically with sensors?	No	Maintaining the DO automatically via sensors and VFDs reduces wasted energy from excess aeration.	It was initially, but the sensors weren't working, so they switched to constant speed, adjusted seasonally.
7	WWT Checklist	23	Is the RAS rate in the suspended growth system adjusted automatically based on plant flow and biosolids settling characteristics?	No	Adjusting the RAS flow automatically via sensors and VFDs reduces wasted energy from excess recirculation. See Fact Sheet G5.	RAS flow is constant.

8	WWT Checklist	51	Is aerobic digestion used?	Yes	Consider switching to anaerobic digestion. Anaerobic digestion is less energy intensive (does not require oxygen and produces less sludge) and produces an energy source (biogas). However, anaerobic digestion requires heat, is a slower process, and is sensitive to variations in flow or composition.	Not ideal for small systems.
9	Lift Pumps	3	Does/could the flow vary significantly with time and a VFD is not used?	Yes	Consider a VFD. VFDs allow the pump to be adjusted based on actual needs (such as flow rate). See Fact Sheet M2.	Right now, turns on and off based on WL. This means no flow into plant at times.
10	Lift Pumps	4	Have pump efficiency tests been performed?	No	Consider performing pump tests. See Fact Sheet P5.	There has been noticeable decline in the performance of the pumps. PUD is in process of repairing/replacing the pumps.
11	Lift Pumps	6	Are pumps sequenced based on relative efficiency (kWh or $ per million gallons)?	N/A		Supposed to be identical (have worn out and are currently being repaired/replaced one-by-one)
12	Lift Pumps	15	Is/are the motor(s) correctly sized?	Yes	No suggestion.	(600 GPM * 30 ft / 3960 = 4.5 HP) Motor is slightly oversized.
13	Lift Pumps	18	Do the starts per hour exceed the appropriate value in the chart below?	Unknown	Further investigation needed.	10 HP 1800 RPM; max 10 starts per hour recommended
14	Spiral Screen	3	Is/are the motor(s) premium efficiency?	No	Consider replacing motors with premium efficiency motors. See Fact Sheet M1.	82.5% (TEFC; 1800; EE); likely too small to warrant cost to upgrade.

15	STM-Aerotors	2	Is a VFD used?	Yes	No suggestion.	Only used to change speed seasonally, manually.
16	STM-Aerotors	3	Is the speed (or height of the mechanical aerator) automatically adjusted based on inflow, DO level, or other pertinent measurement?	No	Consider installing sensors and controls to automatically adjust speed or height. Manually adjusting equipment to meet flow and wastewater strength often leads to over-aeration or over-mixing, which wastes energy. Automatic measurement and adjustment ensures optimum mixing and aeration. See Fact Sheet B3.	Set up to adjust automatically based on DO, but sensors and unit didn't work together so they manually adjust the speed seasonally.
17	STM-Aerotors	4	Is/are the motor(s) premium efficiency?	Unknown	Further investigation needed.	Unknown (TEFC; 1200)
18	STM-Aerotors	8	Do the starts per hour exceed the appropriate value in the chart below?	No	No suggestion.	Constantly on.
19	Clarifier Main Flight	3	Is/are the motor(s) premium efficiency?	N/A		<1 HP - 82.5% (TEFC, 1800, EE?)
20	Clarifier Main Flight	6	Do the starts per hour exceed the appropriate value in the chart below?	No	No suggestion.	Always on
21	Clarifier Sludge Flight	3	Is/are the motor(s) premium efficiency?	N/A		<1 HP - 82.5% (TEFC, 1800, EE)
22	WAS RAS Pumps	18	Do the starts per hour exceed the appropriate value in the chart below?	No	No suggestion.	Always on.
23	Digester Blowers	13	Is/are the motor(s) premium efficiency?	No	Consider replacing motors with premium efficiency motors. See Fact Sheet M1.	92.4% (TEFC; 1800; EE)
24	Digester Blowers	17	Do the starts per hour exceed the appropriate value in the chart below?	No	No suggestion.	Always on

25	Farmer Pump	1	Is/are the pump(s) operated during peak hours?	Yes	Consider if operating the pump(s) during off-peak and part peak hours is feasible. See Fact Sheet G1.	But not used
26	Farmer Pump	4	Have pump efficiency tests been performed?	Unknown	Further investigation needed.	Installed in 2009
27	Farmer Pump	14	Is/are the motor(s) premium efficiency?	No	Consider replacing motors with premium efficiency motors. See Fact Sheet M1.	89.5% (TEFC, 1800, EE)
28	Farmer Pump	15	Is/are the motor(s) correctly sized?	Unknown	Further investigation needed.	Motor is on VFD?
29	Farmer Pump	18	Do the starts per hour exceed the appropriate value in the chart below?	No	No suggestion.	Not currently used.
30	Sludge Thick Pump	1	Is/are the pump(s) operated during peak hours?	Yes	Consider if operating the pump(s) during off-peak and part peak hours is feasible. See Fact Sheet G1.	It runs only when sludge is dumped from digester.
31	Sludge Thick Pump	8	Is most of the pump's discharge head used to overcome friction losses or elevation lift?	N/A		Chemical pump
32	Sludge Thick Pump	15	Is/are the motor(s) correctly sized?	N/A		Single unit

Wastewater Treatment Sector – Calculations

Inputs: Motor Upgrade Calculator - WWTP Digester Blower Motor

Nameplate Horsepower	30	hp	Number of Units	2	
Motor Speed	1800	RPM	Annual Operating Hours (Each)	8760	
Enclosure Type	TEFC		Cost of Electricity	0.11	$/kWh
Nameplate Nominal Efficiency (if given)	92.4	%			
Standard Efficiency (used if no Nameplate Efficiency given)	89.56	%			

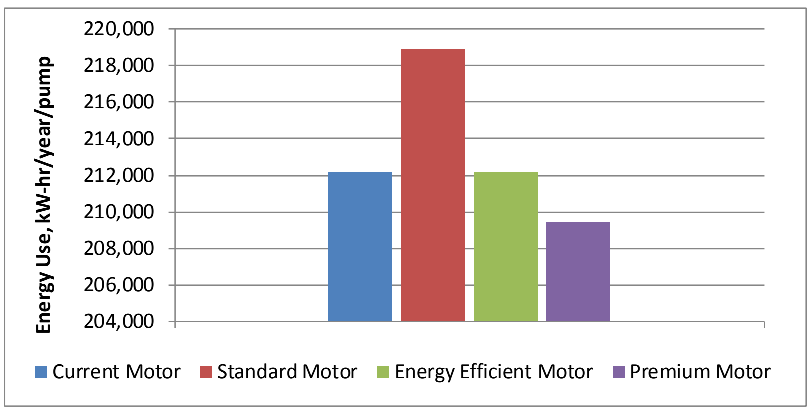
Optional:

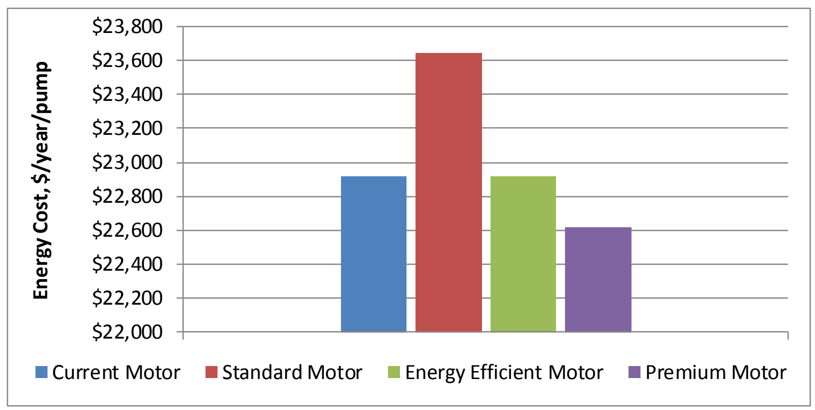
Cost to rewind motor:		$	Cost of energy efficient motor:		$
Cost of standard motor:		$	Cost of premium motor:		$
			Cost to install motor:		$

Outputs: Motor Upgrade Calculator - WWTP Digester Blower Motor

Energy and Cost Savings - Per Pump

	Current Motor	Standard Motor	Energy Efficient Motor	Premium Motor	
Efficiency	92.4	89.6	92.4	93.6	%
Annual Energy Use	212,174	218,902	212,174	209,454	kWh/yr
Annual Energy Cost	22,915	23,641	22,915	22,621	$/yr
Annual Energy Savings		-6,728	0	2,720	kWh/yr
Annual Cost Savings		-727	0	294	$/yr





Small Community Water System Water/Energy Audit Report

Pixley PUD

Sector: Recycling

Audit Date: March 21, 2017
Report Date: April 7, 2017

Sierra Layous

Irrigation Training and Research Center (ITRC)
Cal Poly, San Luis Obispo

RECYCLING - PIXLEY PUD

Recycling Sector – Conclusions

- The pump to the farmer's field is included in the analysis of the wastewater treatment plant. The pump is not currently used.
- If the field pump is used in the future, the PUD should consider if the pump could be operated during off-peak hours only.

Recycling Sector – Inventory List

Walk-through Inventory List:

Recycling

	(a) Location / Name	(b) Equipment Type	(c.) Quantity	(d) Controls	(e) HP/kW per unit	(f) Typical Total HP/kW	(g) Estimate of total hours/yr (or %)	(h) Estimate of Power Cost ($/kW-hr)	(i) (f) * (g) Estimate of kW-hr/yr	(j) (h) * (i) Estimate of yearly cost ($)	(k) Device Score*
1	Farmer Pump	included in	WWTP	Sector							
2											
3											
4											
5											
6											
7											
8											
9											
10											

Total Yearly Expense:	$0
Average Daily Energy Use:	0 kW-hr

*The Device Score (k) is a sector-specific score, indicative of the energy use by each device/set of devices. A higher score indicates higher energy use, and therefore more energy-saving potential.

Recycling Sector – Output: Triggered Questions

Triggered Questions

The following table is sorted by score (right column). Scores are relative, estimated values meant to help prioritize recommendations; higher scoring recommendations should be explored first.
A score of zero indicates no recommendation is given; the question is included for reference.
If more than 100 recommendations were generated, only the top 100 will appear in the table below.

	Section	Question Number	Question	Answer	Program Output	Notes	Score				Energy Savings	Water Savings	Water Quality
							Device	Ease of Implement-ation	Savings Potential	Total			
1	Recycling Checklist	1	Is recycled water pumped during peak hours?	Yes	Consider storage or encouraging users to use water off-peak, allowing recycle system to operate off-peak. See Fact Sheet G1.	But not currently used.	-	2	3	5	✓		

Recycling Sector – Output: Notes

Questions with Notes

The table below contains all notes that were indicated in the program.
If more than 100 notes were indicated, only the first 100 notes will appear in the table below.

	Section	Question Number	Question	Answer	Program Output	Notes
1	Recycling Checklist	1	Is recycled water pumped during peak hours?	Yes	Consider storage or encouraging users to use water off-peak, allowing recycle system to operate off-peak. See Fact Sheet G1.	But not currently used.

Fact Sheet	*Description*
Blowers	
B1	Replacing Old Blowers
B2	Fine Bubble Diffusers
B3	Automatic Aeration Control
B4	MOV Logic
B5	Variable Output Blowers
B6	Incorrectly Sized Blowers
Distribution	
D1	Maintenance Flushing
D2	Leaks
End Use	
E1	End Use: Residential Measures
E2	End Use: CII Measures
E3	End Use: Recreational Measures
General	
G1	Minimize On-Peak Operation
G2	Hydropower
G3	Filter Backwashing
G4	Demand Control
G5	Automatic Control and Monitoring
G6	Ultraviolet Disinfection
G7	Ozone
G8	Generators
G9	Treatment Water Recycling
Motors	
M1	Premium Efficiency Motors
M2	VFDs on Motors
M3	Correctly Sized Motors
M4	Hydraulic and Pneumatic Drives
Potable Water Treatment	
PW1	Air Stripper Air-to-Water Optimization
Pumps	
P1	Incorrectly Sized Pumps
P2	Pump Optimization
P3	Pump Losses
P4	Head Loss Control
P5	Pump Efficiency Tests
Water Quality	
Q1	Potable Water Treatment Options
Q2	Potable Water Non-Treatment Options
Q3	Partial Abandonment of a Well
Wastewater	
WW1	Cogeneration
WW2	Recycled Water
Wells	
W1	Shaft Lubrication

FACT SHEET

REPLACING OLD BLOWERS

Overview

Older blowers and compressors typically do not have the turndown capabilities or efficiencies of newer blowers. Multi-stage centrifugal blowers are typically used in older plants and can only be turned down to 60-70% of full capacity, with a significant efficiency loss. Single-stage centrifugal blowers maintain their efficiency during turndown, and can be adjusted down to around 40% of capacity. Single-stage blowers can be adjusted with either (1) variable inlet vanes and outlet diffusers or (2) variable frequency drives (VFDs); VFDs are more efficient.

Single-stage centrifugal blowers are 5-25% more efficient than positive displacement blowers, and 5 to 10% more efficient than multi-stage centrifugal blowers.

Application

Blowers are used in many aspects of water and wastewater treatment. Primarily, blowers are used in aeration basins at wastewater treatment plants. Blowers can also be used in grit chambers, dissolved-air floatation chambers, and filter backwashing.

Considerations

Single stage blowers can be noisier than multistage blowers.

The initial cost of single stage blowers can be three times that of multi-stage blowers, and four times the capital cost of positive displacement blowers. The city of Oneida in New York (2.5 MGD WWTP) performed a life cycle analysis on the different types of blowers and found that the energy cost savings associated with single-stage centrifugal blowers created the lowest net present value assuming a 10 year life.[107]

Costs

Single-stage centrifugal blowers are nearly three times the cost of multi-stage centrifugal blowers and four times the cost of positive displacement blowers [107, 21]. However, the higher efficiency can allow for a simple payback of 2-4 years [21].

Additional Benefits

New high-speed turbo blowers require lower maintenance than other types of blowers.

Resources

[21] California Sustainability Alliance. 2013. Measures: Aeration System Improvement. Available online at: http://sustainca.org/programs/water_energy/measures/aeration_system_improvement

[57] Loera, J. 2012. Math and Maintenance for Pumps and Blowers: Overview of Blower Technologies and Comparison of High-Speed Turbo Blowers.

[107] U.S. Environmental Protection Agency (EPA). 2010. Publication EPA 832-R-10-005. Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities.

The following table is adapted from "Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities" [107].

Blower Type	Nominal Blower Efficiency (%)[i]	Nominal Turndown (% of rated flow)[i]	Range of Discharge Pressure, Flow, and Horsepower	Cost Range[a]
Positive displacement rotary lobe blower	45 – 65 (variable speed)	50 (variable speed)	8 psi and 8,000 scfm, 380 hp[b] 15 psi at 5,000 scfm, 400 hp[b]	Not provided[b]
Positive displacement rotary screw compressor	45 – 65 (variable speed)	50 (variable speed)	15 psi at 5,000 scfm, 330 hp[b]	Not provided[b]
Centrifugal multi-stage	50 – 70 (inlet throttled) 60 – 70 (variable speed)	60 (inlet throttled) 50 (variable speed)	8 psi and 7,500 – 30,000 cfm, 600-2,500 hp	$150k to $250k[c]
			8 psi and 1,000 – 7,500 cfm 50-700 hp	$50k to $150k[c]
			8 psi and 100 – 1,250 cfm, 50-700 hp	$35k to $75k[c]
Centrifugal single-stage integrally geared (with inlet guide vanes and variable diffuser vanes)	70 - 80	45	12 psi and 4,800 – 6,800 cfm, 200-700 hp	$350 k to $400k[h]
			12 psi and 6,800 – 10,000 cfm, 250-1,250 hp	$380k to $450k[h]
			12 psi and 10,000 – 22,100 cfm, 600 – 2,100 hp	$440k to $550k[h]
			12 psi and 22,400 – 33,200 cfm, 900 – 3,500 hp	$490k to $600k[h]
Centrifugal single-stage gearless (high speed turbo)	70 - 80	50	8 psi and 2,500 – 8,000 cfm, 200 – 300 hp	$120k to $175k[c]
			8 psi and 1,000 – 2,500 cfm, 75 – 150 hp	$75k to $120k[c]
			8 psi and 100 – 1,000 cfm, 5 – 50 hp	$35k to $75k[d]
			10 psi and 600 – 1,500 cfm, 30 – 75 hp	$50k to $90k[d]
			10 psi and 2,000 – 4,000 cfm, 100 – 200 hp	$115k to $160k[d]
			10 psi and 5,000 – 8,000 cfm, 250 – 400 hp	$180k to $275k[d]
			10 psi and 10,000 – 15,000 cfm, 500 – 700 hp	$325k to $450k[d]
			ABS, Inc. – 330 HP with Automated Control System	Approx $141,700[e]
			K-Turbo, Inc. – 50 HP with Automated Control System	Approx $102,000[f]
			K-Turbo, Inc. – 50 HP with Multiple DO Probes and Integrated Control Systems	Approx $56,000[g]

[a]Costs are for estimating only – actual equipment cost may vary depending on model, control system and other specific requirements. Installation will vary depending on specific project location and site conditions.
[b]Information on available models provided by AERZEN USA, 108 Independence Way, Coatesville PA. (Contact manufacturer for cost information at 484-288-6329)
[c]Information supplied by HIS, 7901 Hansen, Houston, TX 77061. Non-standard blowers are available in larger sizes (contact manufacturer for details at 713-947-1623
[d]Information supplied by APG-Neuros, Inc., 3200 Cours Le Corbusier, Boisbriand, Quebec, J7JG-3E8, Canada. Non-standard blowers are available in larger sizes (contact manufacturer for details at 450-739-0799)
[e]Information extracted from the Green Bay, WI, De Pere WWTP case example in Section 5.2. See Appendix A for full case study details
[f]Information provided by the Mukilteo Water and Wastewater District.
[g]Information extracted from Burlington, VT, WWTP case example.
[h]Information supplied by Atlas Copco Compressors, LLC, 134 Wagon Trail Way, Downingtown, PA 19335. Visit www.atlascopco.com for more details
[i]Values may vary with the application. Adapted from Gass, J.V. (Black & Veatch) 2009. Used with permission.

CASE STUDIES

REPLACING OLD BLOWERS

Technologies*	Energy Savings (of process, unless indicated)	Simple payback (years)	Name	Location	Plant Capacity (MGD)	Average Daily Flow (MGD)	Source	Implemented**
Belt to direct drive, replace constant speed with variable speed, high efficiency blowers	42% of plant energy	10	Waimea WWTP	Waimea, Kauai, HI	0.3	0.25	91	R
Multi-stage to turbo		<1 (1.6 without incentives)	Burlington Main WWTP	Burlington, VT	2	1	107	I
Coarse bubble upgrade, HE single-stage centrifugal (Turblex) blower	49% of plant energy		City of Oneida WWTP	Oneida, NY	2.5		107	I
Mechanical aeration upgrade, automated DO control, automated nitrification control	11% of plant energy	135 [1]	Big Gulch WWTP	Mukilteo, WA	2.6	1.5	107/ 115	I
Fine bubble diffusers + others	39%		Taylorville, IL Sanitary District WWTP	Taylorville, IL	3		10	I
Multi-stage to single stage with VFD		1.5		Northern California	5.5		27	R
Downsize, coarse bubble upgrade		<2 (3.6 without incentives)	Glen Falls WWTP	Glen Falls, NY	8.5		74	I
Positive displacement to turbo blowers	50% (38% of cost)	13.3	Green Bay Metropolitan Sewerage District De Pere WWTP	De Pere, WI	14.2	8	107	I

Technologies*	Energy Savings (of process, unless indicated)	Simple payback (years)	Name	Location	Plant Capacity (MGD)	Average Daily Flow (MGD)	Source	Implemented**
Multi-stage to single stage	23%	6		California	17		58	I
Positive displacement to Turblex blowers, DO control, SCADA	30% (6.2% of plant energy)	14	Sheboygan Regional WWTP	Sheboygan, MI	18.4	11.8	107/ 115	I
Multi-stage to single-stage		2-4					21	G
HE blower	36%						86	
HE blower	15-50%	<3					87/66	G
Aeration blower replacement	3-8%						53	G

*Upgrade indicates upgrade to fine bubble diffusers
**I = Implemented, R = Recommended, G = General Value
HE = high efficiency; VFD = variable frequency drive; WWTP = wastewater treatment plant

FACT SHEET

FINE BUBBLE DIFFUSERS

Overview

Aeration systems account for a majority (30 to 80% [80]) of the energy consumed in wastewater treatment plants. Fine bubble (pore) diffusers can be used in aeration systems. They can be used in a new installation or as part of a retrofit. Fine bubble diffusers systems use an average of 38% less energy compared to coarse bubble diffuser systems, and an average of 44% less energy than mechanical aeration systems [21].

Application

Fine bubble diffusers can be used in any system requiring aeration. If converting from mechanical aeration, a blower would also be required.

Considerations

Diffuser fouling is more likely with fine bubble diffusers than coarse bubble diffusers. The system must have routine maintenance to ensure it is operating properly.

Fine bubble diffusers can be combined with DO sensors, automatic control, and a variable output blower for a fully-automated, optimized aeration system.

Fine bubble aeration may not be cost-effective for the following situations; an in-depth review should be performed:

- The system operates at a solids concentration of 2.5% or higher
- Short solids retention time (SRT), carbonaceous, or high-rate activated sludge systems where there is a low aeration transfer efficiency due to the presence of surfactants
- Shallow aeration basin applications

The following table is adapted from "Energy Consumption and Typical Performance of Various Types of Aeration Equipment" [44] and shows efficiencies of common aeration systems.

Aeration System		Use or Application	Oxygen Transfer Efficiency (lb O_2/hp-hr)
Submerged Diffused Aeration Systems			
Coarse-bubble (nonporous) system		All types of activated-sludge processes, channel and grit chamber aeration and aerobic digestions	2.0 to 3.0
Fine-bubble (fine pore) system	Disk/Dome	All types of activated-sludge processes	5 to 7
	Membrane	All types of activated-sludge processes	Up to 12
Flexible Membrane Disk/Tube Grid		All types of activated-sludge processes	4 to 7
Surface Mechanical Aeration System			
Rotors (brush aerators)		Oxidation ditch, channel aeration, and aerated lagoons	2.5 to 3.5
Low speed turbine aerator		Conventional activated-sludge processes, aerated lagoons, and aerobic digestion	3.0 to 3.5
High speed floating aerator		Aerated lagoons and aerobic digestion	2.5 to 3.5
Induced surface aeration		Aerated lagoons	1.0 to 1.5

B2

Costs

The payback on a new system is typically less than a year. The payback on a retrofit depends on the inefficiencies of the existing system.

Additional Benefits

Fine bubble diffusers can improve biosolids management, reduce polymer use, improve clarification, and improve overall effluent quality. They also can contribute to better ammonia reduction, less sludge production, increased plant capacity, and lower tank maintenance costs.

Resources

[21] California Sustainability Alliance. 2013. Measures: Aeration System Improvement.

[44] Environmental Dynamics Inc. 2003. Technical Bulletin 127. Energy Consumption and Typical Performance of Various Types of Aeration Equipment.

[80] Pakenas, L.J. for New York State Energy Research and Development Authority (NYSERDA). 1995. Energy Efficiency in Municipal Wastewater Treatment Plants: Technology Assessment.

[87] Science Applications International Corporation (SAIC) for Focus on Energy. 2006. Water & Wastewater Industry Energy Best Practice Guidebook: Technical Best Practice Wastewater 11: Fine-Bubble Aeration & 12: Aerobic Digestion Options.

CASE STUDIES

FINE BUBBLE DIFFUSERS

Technologies*	Energy Savings (of process, unless indicated)	Simple payback (years)	Name	Location	Plant Capacity (MGD)	Average Daily Flow (MGD)	Source	Implemented**
Coarse bubble upgrade, VFD, automatic DO control, SCADA	45%	2	Bowling Green WWTP	Bowling Green, MI	0.75		21	I
Mechanical aeration upgrade, automated control	11% of plant energy	135	Big Gulch WWTP	Mukilteo, WA	2.6	1.5	107/115	I
Coarse bubble upgrade, HE single-stage centrifugal blower	49% of plant energy		City of Oneida WWTP	Oneida, NY	2.5		21	I
Fine bubble diffusers + others	39%		Taylorville, IL Sanitary District WWTP	Taylorville, IL	3		10	I
Fine bubble diffusers		2.2	Big Rapids WWTP	Big Rapids, MI	6	2.4	10	R
Mech. aeration upgrade		1.7	Joint Regional WWTP	West Haverstraw, NY		8	77	I
Downsize, coarse bubble upgrade		<2 (3.6 without incentives)	Glen Falls WWTP	Glen Falls, NY	8.5		74	I
Mech. aeration upgrade		10	Lake Street WWTP	Chemung, NY	9.5		61/64	R
Fine bubble diffusers and DO control	21% (12,000 kWh/day)		Durham Advanced Wastewater Treatment Facility	Durham, OR	20		10	I
Expand FBD system, DO probes, automated control	33% of plant energy	2.4	Waco Metropolitan Area Region Sewer System WWTP	Waco, TX	37.8	22.8	107/115	I

Technologies*	Energy Savings (of process, unless indicated)	Simple payback (years)	Name	Location	Plant Capacity (MGD)	Average Daily Flow (MGD)	Source	Implemented**
Upgrade to fine bubble diffusers	2,920,000 kWh/yr		Encina Wastewater Authority	Carlsbad, CA	43	26	15	I
Fine bubble diffusers	$450-575,000/yr		City of Flint WWTP	Flint, MI	50		10	I
Coarse bubble upgrade	25% less HP required		Central Regional Wastewater System	Dallas, TX	90		10	I
Fine bubble diffusers	>20%	2-5+					10	G
Fine bubble diffusers	30-40% common						107	G
Coarse bubble upgrade	40-50%	5-7					80	G
Mech. aeration upgrade	40-50%	4-5					80	G
Coarse bubble or mech. aeration upgrade	20-75%						87/66	G
New system		<1					87/66	G
Coarse bubble or mech. aeration upgrade		2-4					21	G
Fine bubble diffusers	20-75%						28	G
Coarse/med. bubble upgrade	20-40%	2-4					58	G

*Upgrade indicates upgrade to fine bubble diffusers
**I = Implemented, R = Recommended, G = General Value
HE = high efficiency; VFD = variable frequency drive; DO = dissolved oxygen; WWTP = wastewater treatment plant

FACT SHEET

B3

AUTOMATIC AERATION CONTROL

Overview

Mechanical aerators and blowers/compressors can be automated based on the dissolved oxygen (DO) level or other measureable value in the water being treated. For mixers and mechanical aerators, the speed of the device (or height of a mechanical aerator) should be automatically adjusted based on the inflow or DO level; for blowers (compressors), the airflow should be adjusted based on the inflow or DO level. With manual control of the DO level, aerated systems typically end up over-aerated to ensure limits are met. Automation allows a system to more closely meet guidelines, saving considerable energy in some systems.

Application

Automation can be applied to any aeration system that needs to maintain a set DO level (or other parameter).

Considerations

The DO probes need to be installed in the correct locations. They should be placed in locations representative of the aerated region (not too close or too far from aerators).

Costs

Payback from improving monitoring and controls using DO control is typically 2 to 3 years [87]. See the following page for case studies related to automated aeration control.

Additional Benefits

Automated control can reduce labor requirements in addition to power consumption.

Resources

[87] Science Applications International Corporation (SAIC) for Focus on Energy. 2006. Water & Wastewater Industry Energy Best Practice Guidebook: Technical Best Practice Water Supply 1: Automate to Monitor and Control, Wastewater 10: Optimize Aeration System, Wastewater 15: Variable Blower Air flow Rate: Aerobic, & Wastewater 16: dissolved Oxygen Control: Aerobic.

[107] U.S. Environmental Protection Agency (EPA). 2010. Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities, Section 4.3: Control of the Aeration Process.

CASE STUDIES

AUTOMATIC AERATION CONTROL

Technologies	Area	Energy Savings (of process, unless indicated)	Simple payback (years)	Name	Location	Plant Capacity (MGD)*	Average Daily Flow (MGD)	Source	Implemented**
PE motors, automated DO control	Mechanical Aeration		1.4	LangeTwins Winery	Acampo, CA			7	R
VFD, DO control	Blower		2.3		California			81	R
VFD, DO control	Mechanical Aerator		5		California			81	R
VFDs on blowers and pumps, DO probes and control	Blower	$20,000/yr		WWTP	Pacifica, CA			10	I
Auto VFD control of rotors with DO probe	Mechanical Aeration	13%	1.5	WWTP No. 1	Bartlett, TN	2.2	1	107/115	I
Mechanical aeration upgrade, automated DO control, automated nitrification control	Mechanical Aerator	11% of plant energy	135 [1]	Big Gulch WWTP	Mukilteo, WA	2.6	1.5	107/115	I
DO probes, VFD on blowers	Blower	24%		WWTP	Columbia, TN	7		10	I
Automated DO sensor system, solar powered mixers	Mechanical Aeration	$80,000/year		Discovery Bay Community Service District WWTP	Discovery Bay, CA	11.5	1.6	56	I
Blower upgrade, DO control, SCADA	Blower	30% (6.2% of plant energy)	14	Sheboygan Regional WWTP	Sheboygan, MI	18.4	11.8	107/115	I
Fine bubble diffusers and DO control	Blower	21% (12,000 kWh/day)		Durham Advanced Wastewater Treatment Facility	Durham, OR	20		10	I

Technologies	Area	Energy Savings (of process, unless indicated)	Simple payback (years)	Name	Location	Plant Capacity (MGD)*	Average Daily Flow (MGD)	Source	Implemented**
DO probes, control	Aeration	34%		Washington Suburban Sanitary Commission Advanced WWTP	Piscataway, MD	30		10	I
Installed DO probe, updated control	Aeration	20%	2.5	Oxnard WWTP	Oxnard, CA	32	22	107	I
DO controls	Compressor		46	Albany County Sewer District North Plant	Menands, NY	35	23	60/64	R
Diffuser upgrade, DO probes, automated DO control	Blower	33% of plant energy	2.4	Waco Metropolitan Area Region Sewer System WWTP	Waco, TX	38	23	107/115	I
VFD, automatic DO control	Aeration	25%	3.3	Greater Lawrence Sanitary District	N. Andover, MA		30	10	I
Fine bubble diffusers, DO probes, automated aeration, load management	Blower	$600,000/year		Encina Wastewater Authority	Carlsbad, CA	43	26	56	I
Automatic DO control, MOV logic	Blower	12%	1.5	Bucklin Point WWTP	East Providence, RI	46 (116)	24	107	I
DO control	Aeration	3-20%	0-5					10	G
Automatic DO control	Aeration	25-40%, up to 50%						27	G
Improved monitoring and control using DO control	Aeration	20-50%	2-3					55	G

*Values in parentheses indicated storm flows (retention basins and/or reduced treatment)
**I = Implemented, R = Recommended, G = General Value
PE = premium efficiency; VFD = variable frequency drive; DO = dissolved oxygen; MOV = most-open valve; SCADA = supervisory control and data acquisition; WWTP = Wastewater Treatment Plant

FACT SHEET

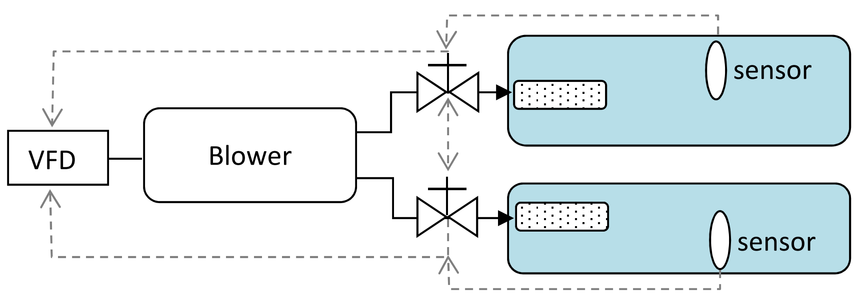
B4

MOST-OPEN-VALVE CONTROL LOGIC

Overview

Most-open-valve (MOV) control logic is used in aeration systems with more than one outlet (i.e. multiple bays) and ensures at least one outlet valve is fully open, minimizing system pressure. This allows for simplified, robust and more accurate control of the aeration system. The goal of MOV logic is to avoid excess throttling downstream of the blower leading to wasted energy.

The conceptual schematic below shows the control of discharge valves downstream of a single blower for two separate aeration chambers. A VFD is being used to control the air flow demand. MOV logic ensures that at least one of the outlet valves ( ) is fully open at all times. If the air requirements to the basin with an open valve decrease, rather than close down the outlet valve, the VFD will adjust the motor speed to maintain the aeration requirements in the basins.



Application

MOV control is applicable for new or upgrading aeration systems. Converting to MOV may not be cost effective for existing aeration control systems.

Resources

[107] US EPA. 2010. Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities: 4.3.1.2 Advances in DO Control Strategies – Most Open Valve (MOV) Control.

FACT SHEET

BLOWER FLOW VARIATIONS

B5

Overview

There are many methods available to vary the output (flow rate) of a blower, fan, or compressor. The most common methods are inlet guide vanes, outlet dampers, inlet throttling valves, and variable frequency drives. Each has a different initial cost, mode of operation, and efficiencies at different turndowns (% of maximum airflow).

Blower guide vanes can be used to achieve variable air flow demands on single stage centrifugal blowers. The guide vanes are installed on the inlet to the blower, and extend out into the air stream causing the air flow path to become swirled. The swirling of the air flow changes the angle of the air stream entering the blower blades, which causes the energy load, air flow, and pressure to decrease. Guide Vanes are energy efficient for air flows 80% to 100% of the full air flow. The efficiency of the blower drops drastically when guide vanes reduce the air flow below 80%.

Dampers can also be installed to vary the air flow from a single stage centrifugal blower. Dampers are typically located at the outlet of a blower, causing a reduction in the air flow demand by increasing the upstream air pressure. Although dampers are inexpensive and easy to install, they provide a limited amount of air flow adjustment and are not energy efficient. Since dampers adjust the system curve away from the best efficiency point on the blower curve, they can cause higher operating and maintenance costs. Dampers should only be considered when minor, infrequent flow changes are required.

Inlet (butterfly) valves can be installed on multi-stage centrifugal blowers. When throttled, the valve creates a pressure drop, which shifts the blower curve and reduces power consumption. Throttling does not save as much energy as VFDs.

Variable frequency drives (VFD) should be installed into a blower system when frequent and highly variable air flow demand is required. A VFD adjusts the speed of the blower motor to efficiently achieve a wide range of air flow demands. If large air flow variations are required, a variable speed drive (VFD) should be installed with the blower. If air flow variations are not required on a regular basis, a VFD may not be the optimal option because of its high initial cost.

Application

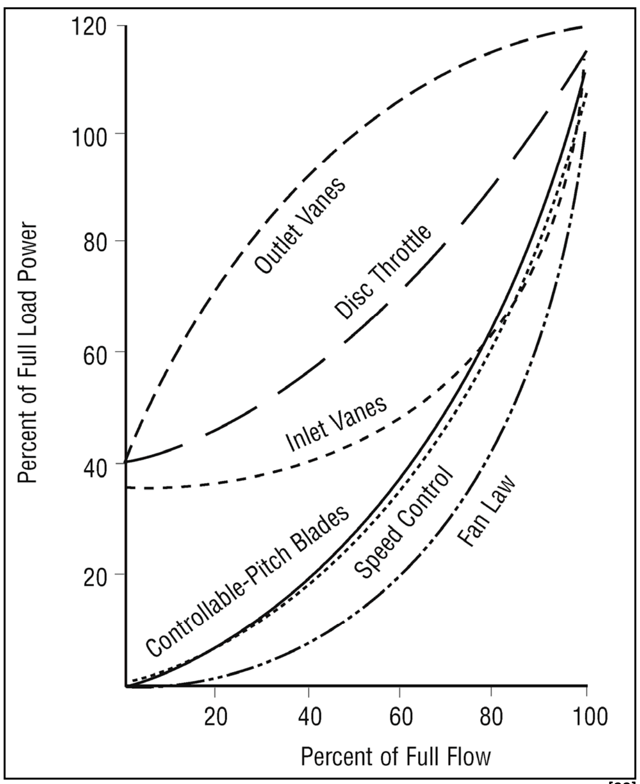
If air flow variation is required in a blower system, some sort of flow control device must be used.

Considerations and Costs

The following table lists the relative cost and ability to vary the flow efficiently for different devices. The applicable blower types for each device are shown on the right. The type of air flow control most applicable for blower systems is based on the range of air flow variation and time duration of the variable air flow.

Device	Cost	Ability to Vary Flow Efficiently (Range of Flows)	Applicable Blower Type		
			Positive Displacement	Multistage Centrifugal	Single Stage Centrifugal
Inlet Guide Vane	Medium	Moderate			✓
Damper	Low	Small			✓
VFD	High	Large	✓	✓	✓
Inlet (Butterfly) Valve	Low	Small		✓	

A life cycle cost evaluation should be considered when deciding which air flow control system is the most cost effective for a site specific project. The figure below shows the power requirement versus air flow volume comparing the use of inlet guide vanes, outlet damper vanes, as well as a VFD (speed control).



Relative Power Consumption for Flow Control Options [99]

Guide vanes can save 10-20% of the process power and have a typical payback of 2-5 years [10].

Resources

[10] Burton, F. and EPRI Community Environmental Center for Electric Power Research Institute (EPRI). 1996. Report CR-106941. Water and Wastewater Industries: Characteristics and Energy Management Opportunities.

[87] Science Applications International Corporation (SAIC) for Focus on Energy. 2006. Water & Wastewater Industry Energy Best Practice Guidebook: Technical Best Practice Wastewater 1: Variable Frequency Drive Applications, Wastewater 15: Variable Blower Air flow Rate: Aerobic, & General Facility 8: Variable Speed Technologies.

[99] US Department of Energy (US DOE), Energy Efficiency and Renewable Energy (EERE), 2003. Improving Fan System Performance – a Sourcebook for Industry.

[107] U.S. Environmental Protection Agency (EPA). 2010. EPA 832-R-10-005. Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities.

[110] Water Environment Federation (WEF). 2010. Manual of Practice No. 32: Energy Conservation in Water and Wastewater Treatment Facilities – Chapter 9: Blowers.

The following table is adapted from "Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities" [107].

Blower Type	Nominal Blower Efficiency (%)[i]	Nominal Turndown (% of rated flow)[i]	Range of Discharge Pressure, Flow, and Horsepower	Cost Range[a]
Positive Displacement Rotary Lobe Blower	45 – 65 (variable speed)	50 (variable speed)	8 psi and 8,000 scfm, 380 hp[b] 15 psi at 5,000 scfm, 400 hp[b]	Not provided[b]
Positive Displacement Rotary Screw Compressor	45 – 65 (variable speed)	50 (variable speed)	15 psi at 5,000 scfm, 330 hp[b]	Not provided[b]
Centrifugal Multi-Stage	50 – 70 (inlet throttled)	60 (inlet throttled)	8 psi and 7,500 – 30,000 cfm, 600-2500 hp	$150k to $250k[c]
			8 psi and 1,000 – 7,500 cfm 50-700 hp	$50k to $150k[c]
	60 – 70 (variable speed)	50 (variable speed)	8 psi and 100 – 1,250 cfm, 50-700 hp	$35k to $75k[c]
Centrifugal Single-Stage Integrally Geared	70 - 80	45	12 psi and 4,800 – 6,800 cfm, 200-700 hp	$350 k to $400k[h]
			12 psi and 6,800 – 10,000 cfm, 250-1,250 hp	$380k to $450k[h]
			12 psi and 10,000 – 22,100 cfm, 600 – 2,100 hp	$440k to $550k[h]
			12 psi and 22,400 – 33,200 cfm, 900 – 3,500 hp	$490k to $600k[h]
Centrifugal Single-Stage Gearless (High Speed Turbo)	70 - 80	50	8 psi and 2,500 – 8,000 cfm, 200 – 300 hp	$120k to $175k[c]
			8 psi and 1,000 – 2,500 cfm, 75 – 150 hp	$75k to $120k[c]
			8 psi and 100 – 1,000 cfm, 5 – 50 hp	$35k to $75k[d]
			10 psi and 600 – 1,500 cfm, 30 – 75 hp	$50k to $90k[d]
			10 psi and 2,000 – 4,000 cfm, 100 – 200 hp	$115k to $160k[d]
			10 psi and 5,000 – 8,000 cfm, 250 – 400 hp	$180k to $275k[d]
			10 psi and 10,000 – 15,000 cfm, 500 – 700 hp	$325k to $450k[d]
			ABS, Inc. – 330 HP with Automated Control System	Approx $141,700[e]
			K-Turbo, Inc. – 50 HP with Automated Control System	Approx $102,000[f]
			K-Turbo, Inc. – 50 HP with Multiple DO Probes and Integrated Control Systems	Approx $56,000[g]

[a]Costs are for estimating only – actual equipment cost may vary depending on model, control system and other specific requirements. Installation will vary depending on specific project location and site conditions.
[b]Information on available models provided by AERZEN USA, 108 Independence Way, Coatesville PA. (Contact manufacturer for cost information at 484-288-6329)
[c]Infomration supplied by HIS, 7901 Hansen, Houston, TX 77061. Non-standard blowers are available in larger sizes (contact manufacturer for details at 713-947-1623
[d]Information supplied by APG-Neuros, Inc., 3200 Cours Le Corbusier, Boisbriand, Quebec, J7JG-3E8, Canada. Non-standard blowers are available in larger sizes (contact manufacturer for details at 450-739-0799)
[e]Information extracted from the Green Bay, WI, De Pere WWTP case example in Section 5.2. See Appendix A for full case study details
[f]Information provided by the Mukilteo Water and Wastewater District.
[g]Information extracted from Burlington, VT, WWTP case example.
[h]Information supplied by Atlas Copco Compressors, LLC, 134 Wagon Trail Way, Downingtown, PA 19335. Visit www.atlascopco.com for more details
[i]Values may vary with the application. Adapted from Gass, J.V. (Black & Veatch) 2009. Used with permission

Case Studies

Blower Flow Variations

Technologies	Energy Savings (of process, unless indicated)	Simple payback (years)	Name	Location	Plant Capacity (MGD)	Average Daily Flow (MGD)	Source	Implemented*
VFD, fine bubble diffusers, automatic DO control, SCADA	45% (18% of cost)	2	Bowling Green WWTP	Bowling Green, MI	0.75		1	I
VFDs, automatic DO control		2.7		California		4	49	R
VFDs		1		California		4	49	R
VFD, DO control	20% of total plant energy	1.7	Lake Street WWTP	Chemung, NY	9.5	5.7	61/64	R
VFD, automatic DO control	25%	3.3	Greater Lawrence Sanitary District	N. Andover, MA		30	10	I
VFD, DO control		2.3		California			81	R
VFD	32% of total plant energy	<1	City of Winooski Water Pollution Control Facility	Winooski, VT			32	I
Blower guide vane control	10-20%	2-5					10	G
VFD	>50% secondary treatment						66/87	G

*I = Implemented, R = Recommended, G = General Value

VFD = variable frequency drive; DO = dissolved oxygen; SCADA = supervisory control and data acquisition

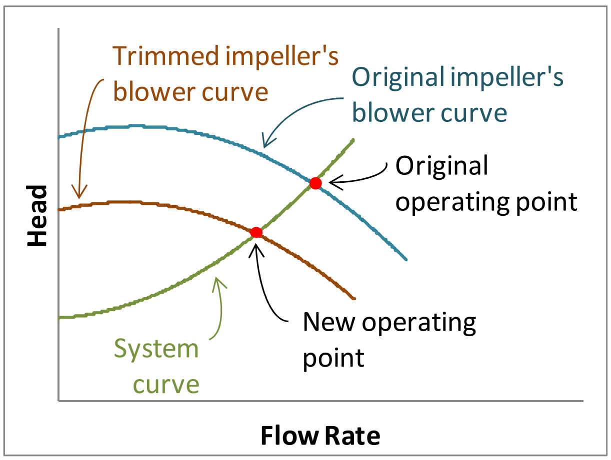
FACT SHEET

INCORRECTLY SIZED BLOWERS

B6

Overview

Often in water and wastewater system designs, the blowers are oversized either (1) because the current conditions are not known or (2) in anticipation of future conditions. This can lead to throttling or bypassing of flows to achieve a desired flow rate or over-aeration. For centrifugal blowers, trimming or replacing impellers can be more efficient.



For positive displacement blowers, the sheaves can be changed to adjust the flow rate and conserve energy.

Application

Properly sized impellers can use less energy than improperly sized impellers with throttling valves, bypass valves, or excess aeration.

Indications of a situation where trimming or replacing an impeller may be applicable include:

- A bypass valve is used during normal operation
- A throttling valve is used during normal operation
- The blower provides more aeration than is required for the system
- The blower does not operate at the design point during normal operation

Considerations

Only centrifugal blower impellers can be trimmed. The sheaves on positive displacement blowers can be changed to adjust the flow rate.

Impellers can usually only be trimmed to about 75% of the shaft diameter without significant efficiency loss.

Impellers can also be replaced. In some instances, it may be desirable to replace the impeller with a smaller one, and retain the old impeller for future situations. Impellers can also be replaced to increase the capacity.

It may be desirable to retain the current impeller and install a VFD. Cost analysis of this option should be compared to trimming/replacing the current impeller and installing a VFD.

For positive displacement pumps, before adjustment, it should be confirmed that the motor can accommodate the new flow rate.

Additional Benefits

B6

Trimmed impellers can be replaced in the future if the required flow rate increases.

Unlike VFDs, trimmed impellers do not add any additional electronic equipment to the pump set-up.

Resources

[110] Water Environment Foundation (WEF) Energy Conservation in Water and Wastewater Treatment Facilities Task Force. 2010. Manual of Practice No. 32: Energy Conservation in Water and Wastewater Treatment Facilities – Chapter 9: Blowers.

[99] U.S. Department of Energy (DOE) Energy Efficiency and Renewable Energy (EERE), 2003. Improving Fan System Performance – a Sourcebook for Industry.

Case Studies

Trimming/Replacing Impellers

Technologies	Energy Savings	Simple payback (years)	Type	Name	Location	Plant Capacity (MGD)*	Average Daily Flow (MGD)	Source	Implemented**
VFDs, PE motors, optimize pumping	2.81 million kWh/yr	1.1	WWTP	Metropolitan Syracuse WWTP	Onondaga County	126 (240)	84	98	I
Replace oversized impeller	$1,000/month		WS/WD	Philadelphia Water Department	Philadelphia, PA			55	I
Reduce capacity and head, and trim impeller	$9,400/month		WS/WD	Philadelphia Water Department	Philadelphia, PA			55	I
Trim impeller to match capacity	$3,800/yr	2.4	PWTP	Peoria Water System	Peoria, IL			3	I
Install larger impellers	$11,000/yr	3.1	PWTP	Peoria Water System	Peoria, IL			3	I
Replace impeller		0.5	PWTP/ WWTP					4	G

*Values in parentheses indicated storm flows (retention basins and/or reduced treatment)
**I = Implemented, R = Recommended, G = General Value
PE = Premium Efficiency (NEMA); WWTP = Wastewater Treatment Plant; PWTP = Potable Water Treatment Plant; WD = Water Delivery; WS = Water Supply

FACT SHEET

MAINTENANCE FLUSHING

D1

Overview

Hydrant flushing in a public water system is necessary maintenance. Flushing helps maintain water quality by flushing the lines and ensures fire hydrants have adequate flow and pressure. However, the water used during flushing should be made available for secondary uses. Secondary uses include:

- Filling up fire trucks and/or highway tankers
- If needed, flushing local sewer connection lines
- Cleaning street surfaces
- Providing the water to local landscape contractors (possibly selling)
- Providing the water to local farmers for livestock use or irrigating crops (possibly selling)
- In extreme situations, the water could be trucked back to the water treatment plant

Considerations

A flushing water reuse program improves public relations and aids in participation in consumer conservation efforts (consumers are more likely to conserve water if they believe the utility is doing the same).

Resources

[138]Satterfield, Z. (2011) Water Efficiency and Conservation. Tech Brief. National Environmental Services Center; vol. 11 issue 1.

FACT SHEET

SYSTEM LEAK DETECTION AND MANAGEMENT

Overview

Leak detection is a necessary component to the management of a water distribution system. Water lost to leaks is unmetered and nonrevenue water; accurate determination of the location of leaking pipes are subsequent repair conserves water, energy, and money.

Considerations

Water audits and metering are valuable components to leak detection. They help locate and quantify leaks. Free software for performing a water audit is available through the American Water Works Association (AWWA).

Usually, large leaks are not the largest contributors to the volume of water lost; large leaks are usually detected and repaired quickly. Small leaks can lead to large quantities of lost water over time.

Leak detection programs can target locations with the greatest likelihood of leaks first. This includes locations where:

- There is a history of leaks and breaks
- Leaks would cause significant property damage
- The pressure in the system is high
- The system is exposed to electric current and/or traffic vibrations
- There are stream crossings
- Loads on the pipe exceed the design loads

There are a variety of methods for detecting water distribution system leaks. Resource [144] provides an overview of the different methods.

Additional Benefits

There are a variety of additional benefits related to a leak detection and management program, including:

- Leaks can damage nearby roads, infrastructure, and buildings. Managing leaks reduces the potential for legal liability.
- A leak detection and repair program improves public relations and aids in participation in consumer conservation efforts (consumers are more likely to conserve water if they believe the utility is doing the same).
- A leak detection program will increase the district's knowledge of its distribution system, allowing it to respond more quickly to emergencies and to set priorities for replacement/rehabilitation programs.
- Minimizing leaks can delay the need to develop new water sources and/or expand the capacity of the system.

Resources

[141]California Department of Water Resources (DWR) and American Water Works Association (AWWA) (1992). Water Conservation Guidebook No. 5: Water Audit and Leak Detection Guidebook. Sacramento, CA: State of California, The Resources Agency.

[142]U.S. Environmental Protection Agency (EPA) (2013). Water audits and water loss control for public water systems. US EPA Office of Water: EPA 816-F-13-002.

[143]Lahlou, Z. (2001). Leak Detection and Water Loss Control. Tech Brief. National Drinking Water Clearinghouse.

[144]Jeffs, C., C. Lloyd, and D. Pospishill (1989). An Introduction to Water Loss and Leak Detection. Duncan, OK: National Rural Water Association

FACT SHEET

END USE: RESIDENTIAL

E1

Overview

Reduction of end use of water decreases the amount of water needed. Many incentives, services, and educational measures can be provided by a municipality to increase water conservation by residential users. This document provides descriptions of possible options.

Options

Water Meters

All residential users should have water meters. Water meters provide accountability and can help locate leaks and major water consumers. Water meters typically reduce residential water use by 20%.

Tiered-Rate Structure

Tiered-rate structures incentivize water conservation by increasing the cost of water for consumers who use more water, or use water during peak hours.

- Increasing block rate pricing – increases the price per unit of water as a user consumes more.
- Time-of-day pricing – increases the price of water consumed during peak hours
- Excessive water user surcharge – charges users who consume large amounts of water a flat surcharge

Products/Services

Municipalities can offer products and services to help customers improve water conservation.

- Water audits - water audits can identify leaks and provide consumers with information about possible water-saving devices.
- Toilet leak detection tablets – distribution of toilet leak detection tablets can make customers aware of leaks, instigating correction and water conservation.
- Pressure reduction (must consider customer complaints if reducing pressure in existing areas) – pressure reduction can be done by the municipality or can be recommended to the customer during water audits.

Indoor Water Conservation Incentives

Incentives and/or requirements for implementation of indoor water-conserving devices can improve water conservation. The following devices are water-saving devices that reduce water use compared to their conventional counterparts.

- Low-flush toilets (ULFT or HET) or retrofits (quick-closing flapper valve, toilet dams)
- Low-flow shower heads
- High efficiency dishwashers
- High efficiency washing machines
- Faucet aerators

Indoor water-saving devices can be implemented in a variety of ways. Some examples are listed below.

- Offering incentives to or requiring new houses to install water efficient devices
- Requiring houses that are for sale to upgrade devices before the sale can close
- Offering incentives to or requiring houses with older devices to upgrade.

Outdoor Water Conservation Incentives

Residential landscape and lawn water use typically has large room for optimization and water conservation. The following areas are possibilities for focusing incentives to reduce water use.

- Irrigation scheduling – Awareness of the actual requirements of the landscaping/lawn will help reduce over-irrigation. Incentive options include: controllers/clocks for automatic adjustment of watering schedule based on real-time weather information as well as rain shut-off devices.
- Avoiding peak hours – Irrigation during off-peak hours will reduce the cost to the municipality to provide water during peak hours (reduce the peak system flow).
- Xeriscape™ landscaping – Installing landscaping with low water requirements will reduce the amount of water required for irrigation. This can provide large cost savings for conversions from conventional lawns.
- Lawn replacement – Removing lawns and replacing them with non-water consuming material will reduce or eliminate the amount of water required for irrigation.

E1

Water Education Measures

General water education through seminars, events, and public outreach can increase water consumption awareness and water conservation.

- Indoor education can include:
  - Techniques for shaving, teeth brushing, dishwashing, etc.
  - Information about water saving devices
- Outdoor education can include:
  - Techniques for car washing, rain water collecting, etc.
  - Information about lawn and landscaping water requirements and irrigation scheduling

Resources

9 Brown and Caldwell for U.S. Department of Housing and Urban Development (HUD). 1989. Finally, Some Hard Data on Water Conservation.

109 U.S. Environmental Protection Agency (EPA). 2012. How to Conserve Water and Use It Effectively. Available online at: http://water.epa.gov/polwaste/nps/chap3.cfm

111 Water Resource Engineering, Inc. 2002. Retrofitting Apartment Buildings to Conserve Water: A Guide for Managers, Engineers, and Contractors.

114 Whitcomb, J. for the Southwest Florida Water Management District. 2005. Florida Water Rates Evaluation of Single-Family Homes.

FACT SHEET

END USE: COMMERCIAL/INDUSTRIAL/INSTITUTIONAL MEASURES

Overview

Reduction of end use of water decreases the amount of water needed. Many incentives, services, and educational measures can be provided by a municipality to increase water conservation by commercial, industrial, and institutional (CII) users. This document provides descriptions of possible options.

Options

Water Meters

All commercial, industrial, and institutional users should have water meters. Water meters provide accountability and can provide help on locating leaks and major water consumers.

Tiered-Rate Structure

Tiered-rate structures incentivize water conservation by increasing the cost of water for consumers who use more water or use water during peak hours

- Increasing block rate pricing – increases the price per unit of water as a user consumes more.
- Time-of-day pricing – increases the price of water consumed during peak hours
- Excessive water user surcharge – charges users who consume large amounts of water a flat surcharge

Products/Services

Municipalities can offer products and services to customers help improve water conservation.

- Water audits - water audits can identify leaks and provide consumers with information about possible water-saving devices.
- Toilet leak detection tablets – distribution of toilet leak detection tablets can make customers aware of leaks, instigating correction and water conservation.
- Pressure reduction (must consider customer complaints if reducing pressure in existing areas) – pressure reduction can be done by the municipality, or can be recommended to the customer during water audits.

Indoor Water Conservation Incentives

Incentives and/or requirements for implementation of indoor water-conserving equipment can improve water conservation. The following devices/processes are potential areas for water-conserving incentives.

- Low-flush toilets/urinals (ULFT or HET) or retrofits (quick-closing flapper valve, toilet dams)
- Low-flow spray rinse nozzles
- High efficiency washing machines
- Ozonated laundry systems
- Laundry processing
- Faucet aerators
- Ice makers
- Cooling towers
- Medical Equipment
- Other industrial water-intensive processes

Outdoor Water Conservation Incentives

CII landscape and lawn water use typically has significant room for optimization and water conservation. The following areas are possibilities for focusing incentives to reduce water use.

- Irrigation scheduling – Awareness of the actual requirements of the landscaping/lawn will help reduce over-irrigation. Incentive options include: controllers/clocks for automatic adjustment of watering schedule based on real-time weather information as well as rain shut-off devices.
- Avoiding peak hours – Irrigation during off-peak hours will reduce the cost to the municipality to provide water during peak hours (reduce the peak system flow).
- Xeriscape™ landscaping – Installing landscaping with low water requirements will reduce the amount of water required for irrigation. This can provide large cost savings for conversions from conventional lawns.
- Lawn replacement – Removing lawns and replacing them with non-water consuming material will reduce or eliminate the amount of water required for irrigation.

E2

Water Reuse

CII water can, in some cases, be reused for a variety of purposes, including industrial processes, landscape irrigation, agricultural irrigation, fountains, and fire protection. The municipality may provide incentives or education to CII customers for/regarding potential reuse.

Recycled Water

Recycled water from the central treatment plant can be used by CII customers in place of potable water for irrigation of landscaping and lawns. See ***Fact Sheet WW1****.*

Additional Benefits

Reduction of end use of water also saves energy throughout the water/wastewater system.

Resources

[9] Brown and Caldwell for U.S. Department of Housing and Urban Development (HUD). 1989. Finally, Some Hard Data on Water Conservation.

[109] U.S. Environmental Protection Agency (EPA). 2012. How to Conserve Water and Use It Effectively. Available online at: http://water. epa.gov/polwaste/nps/chap3.cfm

[111] Water Resource Engineering, Inc. 2002. Retrofitting Apartment Buildings to Conserve Water: A Guide for Managers, Engineers, and Contractors.

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FACT SHEET

END USE: RECREATIONAL MEASURES

Overview

Reduction of end use of water decreases the amount of water needed. Many incentives, services, and educational measures can be provided by a municipality to increase water conservation by recreational users. This document provides descriptions of possible options.

Options

Water Meters

All recreational users should have water meters. Water meters provide accountability and can help locate leaks as well as major water consumers.

Tiered-Rate Structure

Tiered-rate structures create incentives for water conservation by increasing the cost of water for users who use more water, or use water during peak hours.

- Increasing block rate pricing – increases the price per unit of water as a user consumes more.
- Time-of-day pricing – increases the price of water consumed during peak hours
- Excessive water user surcharge – charges users who consume large amounts of water a flat surcharge

Products/Services

Municipalities can offer products and services to customers help improve water conservation.

- Water audits - water audits can identify leaks and provide consumers with information about possible water-saving devices.
- Toilet leak detection tablets – distribution of toilet leak detection tablets can make customers aware of leaks, instigating correction and water conservation.
- Pressure reduction (must consider customer complaints if reducing pressure in existing areas) – pressure reduction can be done by the municipality, or can be recommended to the customer during water audits.

Outdoor Water Conservation Incentives

Recreational landscape and lawn water use typically has significant room for optimization and water conservation. The following areas are possibilities for focusing incentives and education to reduce water use.

- Irrigation scheduling – Awareness of the actual requirements of the landscaping/lawn will help reduce over-irrigation. Incentive options include: controllers/clocks for automatic adjustment of watering schedule based on real-time weather information as well as rain shut-off devices.
- Avoiding peak hours – Irrigation during off-peak hours will reduce the cost to the municipality to provide water during peak hours (reduce the peak system flow).

Recycled Water

*Recycled water from the central treatment plant can be used by recreational customers in place of potable water for irrigation of landscaping and lawns. See **Fact Sheet WW1**.*

Additional Benefits

Reduction of end use of water also saves energy throughout the water/wastewater system.

Resources

[112] California Department of Water Resources (DWR) Water Use and Efficiency Branch & Commercial, Institutional, and Industrial Task Force. 2013. Commercial, Institutional and Industrial Task Force Best Management Practices Report to the Legislature, Volume II.
Provides examples and estimates of water conservation for water savings devices.

[66] Malcolm Pirnie for New York State Energy Research and Development Authority (NYSERDA). 2010. Water and Wastewater Energy Management, Best Practices Handbook: Water Best Practices 7 – Promote Water Conservation, 8 – Sprinkling Reduction Program, and 9 – Manage High Volume Users

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E3

FACT SHEET

MINIMIZE ON-PEAK OPERATION

Overview

Operation of devices, processes, and even treatment plants off-peak can save money when on a time-of-use pricing structure. Off-peak operation is typically achieved through storage. Operation does not have to fully shift to off-peak. Flow equalization (storage) can allow an even distribution of flows throughout the day, which can also minimize pump sizes.

Application

Common applications of minimizing on-peak operation include:

- Operate Water Supply (WS) off-peak or evenly – requires Potable Water Treatment Plant (PWTP) to operate off-peak as well, or storage at head of PWTP
- Operate PWTP off-peak or evenly – requires storage at head (if WS does not operate off-peak) and end of PWTP
- Pump potable water to reservoir or tank (draw down during peak hours) – requires storage in water distribution system
- Operate Wastewater Treatment Plant (WWTP) off-peak or evenly – requires storage at head of WWTP; consideration must be given to solids settling
- Operate recycled water system off-peak – required storage at end of PWTP; typically recycled water is used for landscape and irrigation purposes, which can be done at night.
- Backwash filters during off-peak hours or fill storage slowly for backwash.
- Test back-up motor systems (such as monthly or weekly star-ups) off-peak – requires operator education or automation.

Operate generators during peak hours to reduce or eliminate the load on the electric grid.

Considerations

Off-peak operation may require automation or scheduling adjustments. Some treatment plants have had issues with staff retention and morale when staff members are required to work off-peak hours.

Any time water is stored, settling and growth need to be considered. An aerator or a mixer (which could be solar-powered) may be able to off-set any potential issues. G1

While a plant may not be able to operate entirely off-peak, it may be able to equalize flows, reducing the on-peak load (and possibly improving plant performance).

Costs

The “rule of thumb” for initial cost of new storage is $1 per gallon. This must be compared against the savings associated with reduced rates (off-peak, minimize peak loads) as well as reduced power use (more even distribution).

Resources

[10] Burton, F. Electric Power Research Institute (EPRI). 1996. Water and Wastewater Industries: Characteristics and Energy Management Opportunities.

[66] Malcolm Pirnie for New York State Energy Research and Development Authority (NYSERDA). 2010. Water and Wastewater Energy Management, Best Practices Handbook: Water Best Practice 6 – Optimize Storage Capacity.

[87] Science Applications International Corporation (SAIC) for Focus on Energy. 2006. Water & Wastewater Industry Energy Best Practice Guidebook: Technical Best Practice Wastewater 3: Optimize Flow with Controls & General 2: Real Time Energy Monitoring.

Case Studies

Minimize On-Peak Operation

Technologies	Area	Energy Savings (of process, unless indicated)	Simple payback (years)	Type	Name	Location	Plant Capacity (MGD)	Average Daily Flow (MGD)	Source	Implemented*
Installed valve to fill storage tank during off-peak	Pumping	$12,500/year	2	WD	Queensbury Water District	Queensbury, NY		7.5 summer, 4.0 winter	55	I
Demand control	Pumping, treatment processes	$50,000/year		WWTP	Encina Wastewater Authority	Carlsbad, CA	43	26	15	I
Storage reservoirs		>20% of load (kW)		WD					10	G
Flow equalization	Preliminary treatment	10-20% of load (kW)		WWTP					10	G
Storage			0-2	All					4	G

*I = Implemented, R = Recommended, G = General Value
WWTP = wastewater treatment plant, WD = water delivery, All = all sectors

FACT SHEET

HYDROELECTRIC POWER

Overview

Locations in the system with pressure reducing valves (such as in the distribution system) or large elevation drops (such as at the exit of a wastewater treatment plant) may be able to produce hydropower with turbines.

Application

There are two main locations where hydroelectric power may be applicable:

1. Outfalls: locations where an open water body has significant head loss. Typically found at the end of wastewater treatment plants.
2. In conduit: locations in conduit (closed pipe) where pressure reducing valves (PRVs) are used to reduce the pressure of the water. Typically found in water supply and water distribution systems.

To estimate the power generation of the system, use one of the following equations[a]:

$$\frac{Flow \times Head}{Constant} = Power$$

$$\frac{[MGD] \times [ft]}{10.6} = [kW]$$

$$\frac{[cfs] \times [ft]}{16.4} = [kW]$$

[a] These equations assume 10% head loss and 80% turbine efficiency

Considerations

In the past, outfalls have typically needed 10-15 feet of fall and a minimum flow of 15 MGD – an installed capacity of at least 300 kW – to make the unit economical[2]. Newer systems are able to economically produce power at less than 100 kW (some as low as 10 kW). Investigation into the current availability of hydroelectric units should be done to determine the applicability of hydroelectric for a given situation.

Resources

[79] OEL Hydrosys, Inc. 2008. HydroHelp. Available online at: http://www.hydrohelp.ca

This is a program (Excel based) that can be used to help select the appropriate turbine-generator for hydroelectric sites. The program is in SI units.

[80] Pakenas, L. for New York State Energy Research and Development Authority (NYSERDA). 1995. Energy Efficiency Strategies for Municipal Wastewater Treatment Facilities.

[87] Science Applications International Corporation (SAIC) for Focus on Energy. 2006. Water & Wastewater Industry Energy Best Practice Guidebook: Technical Best Practice General Facility 12: Renewable Energy Options.

[94] Torrey, D. for New York State Energy Research and Development Authority (NYSERDA). 2011. Report 12-04. Hydropower from Wastewater.

[100] U.S. Department of Energy (DOE) Energy Efficiency & Renewable Energy (EERE). Water Power Program: Hydropower Technologies.

G2

Case Studies

Hydroelectric Power

Technologies	Energy Savings (of process, unless indicated)	Simple payback (years)	Type	Name	Location	Plant Capacity (MGD)	Average Daily Flow (MGD)	Source	Implemented*
WWTP ocean outfall	Produces 10% of plants energy requirements		WWTP	Massachusetts Water Resource Authority Deer Island WWTP	MA	436	380	28	I
WWTP ocean outfall	1.35 MW hydroturbine installed	3.7	WWTP	Point Loma WWTP	San Diego, CA	240	175	28	I
In-line hydraulic turbine	33,000 MWh/yr	11-12	WS	Rancho Pensaquito Pressure Control Hydroelectric Facility	San Diego, CA		194 (198 ft of head)	25	R
WWT outfall	15 kW	<5	WWT	North Albany WWTP	North Albany, NY		12 (12 ft of head)	94	I
Replace PRVs with hydro-turbines	202,138 kWh ($40,000/yr)	1.9	PWTP/WD	Deerfield Reservoir control building, Mohawk Valley Water Authority	Utica, NY			55	I
Replace PRVs with hydro-turbines	812,490 kWh ($28,000/yr)	20.1	PWTP, WD	Marcy Regulator House, Mohawk Valley Water Authority	Utica, NY			55	R

*I = Implemented, R = Recommended, G = General Value

PRV = pressure reducing valve; WWTP = wastewater treatment plant; PWTP = potable water treatment plant; WWC = wastewater collection; WS = water supply; WD = water delivery

FACT SHEET

FILTER BACKWASHING

Overview

Filter backwashing can be a water- and energy-intensive process; it requires large flow rates for short periods of time. If pumps are used, they must be large, and can contribute to peak demand charges. If air scouring is used, large blowers also contribute to peak demand charges. There are multiple water- and/or energy-savings measures available to filter backwashing.

Application

The following are water- and/or energy-savings measures available to filter backwashing:

- Backwashing during off-peak hours – reduces on-peak energy costs
- Gravity backwash system (storage) – pump water (at a reduced flow rate) to storage, then using gravity to provide large flows during backwash
- Sequencing backwash cycles – ensures only one backwash cycle occurs at a time, reduces demand charges
- Optimization of backwashing
    - Automatic controls based on effluent water quality and/or head loss across filter
    - Adding a surface wash or air scour system
    - Proper length of time for backflush
    - Proper backwash flow rate

Any backwash system may be able to benefit from the options listed above.

Considerations

If backwash is to occur manually during off-peak hours, staffing needs/labor costs need to be considered.

Recycling the backwash water will further conserve water. Typically, the water is routed to a sedimentation basin, where the supernatant is then routed to the start of the treatment plant. See **Fact Sheet G12** for further information.

Resources

[37] Electric Power Research Institute (EPRI) for California energy Commission (CEC). 1999. Report CR-104300. Energy Audit Manual for Water/Wastewater Facilities.

[66] Malcolm Pirnie for New York State Energy & Development Authority (NYSERDA). 2010. Water and Wastewater Energy Management: Best Practices Handbook – General Best Practice G20 – Filtration: Sequence Backwash Cycles.

[137] Satterfield, Z. (2005) Filter Backwashing. Tech Brief. National Environmental Services Center; vol. 5 issue 3.

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CASE STUDIES

FILTER BACKWASHING

Technologies	Energy Savings (of process, unless indicated)	Type	Name	Location	Plant Capacity (MGD)	Average Daily Flow (MGD)	Source	Implemented*
Fill reservoir and backwash filters during off-peak, load management	$1,500-2,000/month (1999-2001)	PWTP	City of Ann Arbor Water Utilities Department	Ann Arbor, MI	50		40	I
Gravity backwash filters	10-20%+	PWTP					10	G
Automatic backwash filters	10-20%+	PWTP					10	G

*I = Implemented, R = Recommended, G = General Value
PWTP = Potable Water Treatment Plant

FACT SHEET

DEMAND CONTROL

Overview

Demand control consists of managing system loads to reduce peak demand. Most energy providers charge based on actual power used (kW-hours) as well as peak demand (kW) in a time period (such as 15 minute increments). Demand control is typically achieved by monitoring major power consumers and ensuring:

- Units that draw large amounts of power on start-up do not start at the same time (or during peak hours)
- Units that consume significant power during operation do not operate at the same time, if possible
- Processes that can be performed off-peak are performed off-peak (such as filter backwashing)
- Units that are not in use are turned off
- Available storage is used to shift pumping off-peak

Application

The ability to shift start times and operation of different pumps, blowers, and motors depends on the specific application. The demand control must not undermine regulatory requirements at treatment plants.

Considerations

Demand control can be manual or automatic. In general, more savings can be realized if the control is automated.

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Additional Benefits

Automatic demand control can reduce operator time spent measuring parameters and adjusting equipment.

Resources

[87] Science Applications International Corporation (SAIC) for Focus on Energy. 2006. Water & Wastewater Industry Energy Best Practice Guidebook: Technical Best Practice General 2: Real Time Energy Monitoring & General 6: Idle or Turn Off Equipment.

[3] Arora, H. and M.W. LeChevallier. 1998. American Water Works Association (AWWA) Journal 90:2. Energy Management Opportunities

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Case Studies

Demand Control

Technologies	Area	Energy Savings (of process, unless indicated)	Simple payback (years)	Type	Name	Location	Plant Capacity (MGD)	Average Daily Flow (MGD)	Source	Implemented*
Electrical demand management system			7.5	WWTP	Hilo WWTP	Hilo, HI	5	3	89	I
Electrical demand management system	Pump stations		0.6	WWTP	Kailua WWTP	Honolulu. HI	15	12	90	R
Stagger pump starts during peak hours			1.8	WWTP	R.L. Jackson WWTP	Morrow, GA		18-40	10	R
Demand control (peak shaving/ off-peak pumping)		$50,000/year (in 2000)		WWTP	Encina Wastewater Authority	Carlsbad, CA	43	26	15	I

*I = Implemented, R = Recommended, G = General Value
WWTP = Wastewater Treatment Plant

FACT SHEET

AUTOMATIC CONTROL AND SCADA SYSTEMS

Overview

Automatic control can reduce energy requirements in many water and wastewater related systems. Automatic control can allow the system to match requirements (such as a water level or dissolved oxygen concentration) closer than manual adjustment, resulting in less energy and man-hours used. Automatic control can also help with load management, ensuring processes operate off-peak and reducing the number of processes running at any one time. Monitoring provides feedback to the operator, allowing the operator to adjust limits and optimize operation. A Supervisory Control and Data Acquisition (SCADA) system can provide central monitoring as well as setpoint adjustment and control of many components.

Application

Automatic control and monitoring can be applied to all aspects of water and wastewater systems, including pumping, mixing, and aeration.

Considerations

The proper value needs to be monitored and controlled for. For aeration systems, this is likely the dissolved oxygen (DO) content (consideration should be given to the location at which the DO is being measured). For pumping, this is likely the flow rate or a water level. For mixing, the flow rate is typically used to match the speed of the mixer.

Costs

See *Case Studies* below for example savings and payback estimates.

Additional Benefits

Aeration automation typically results in better effluent water quality and less energy required for dewatering.

Automatic control can reduce man-hours spent calculating values and adjusting equipment.

SCADA systems can detect malfunctioning equipment and/or inefficient operation. This can lead to reduced maintenance cost, reduced system downtime, and improved reliability.

Resources

[28] Crawford, G. and J. Sandino for Water Environment Research Federation (WERF). 2010. *Energy Efficiency in Wastewater Treatment in North America: A Compendium of Best Practices and Case Studies of Novel Approaches* – 2.4.4.3 Supervisory Control and Data Acquisition Systems.

[35] Electric Power Research Institute (EPRI). 2009. *Program on Technology Innovation: Electric Efficiency through Water Supply Technologies – A Roadmap*.

[87] Science Applications International Corporation (SAIC) for Focus on Energy. 2006. *Water & Wastewater Industry Energy Best Practice Guidebook: Technical Best Practice* Water Supply 1: Automate to Monitor and Control.

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Case Studies

Automatic Control and SCADA Systems

Technologies	Area	Energy Savings (of process, unless indicated)	Simple payback (years)	Type	Name	Location	Plant Capacity (MGD)*	Average Daily Flow (MGD)	Source	Imple-mented**
VFD, PLC	Well Pumps	25% of cost		WS	Madera Valley Water Company	Madera, CA	8.2		16	I
PLC for off-peak pumping	Pumping	31% of cost [a]		PWTP	Moulton Niguel Water District	Laguna Beach, CA	48		17	I
Belt to direct drive, replace constant speed with variable speed, HE blowers and automated control	Aeration	42% of plant energy	10	WWTP	Waimea WWTP	Waimea, Kauai, HI	0.3	0.25	91	R
VFD, DO control	Mechanical Aerator	13%	1.5	WWTP	WWTP No. 1	Bartlett, TN	2.2	1	115	I
Mechanical aeration upgrade, automated DO control, automated nitrification control		11% of plant energy	33 [b]	WWTP	Big Gulch WWTP	Mukilteo, WA	2.6	1.5	107/115	I
VFDs on blowers and pumps, DO monitoring, PLC	Aeration and Pumping	$20,000/year		WWTP	WWTP	Pacifica, CA	3.3	2.5	10	I
Effluent monitoring and control	Pumping		3.6	WWTP	Kihei WWTP #3	Kihei, Maui, HI	7.5	3.5	92	R
Timers and temperature based on/off	Digester heating recirculation pumps		0.4	WWTP	Elk River Wastewater Treatment Plant	Eureka, CA	12	8.6 (32)	10	R
Operate pumps on timers	Digester hot water pumps		0.2	WWTP	Ventura Water Renovation Facility	San Buenaventura, CA	14	9	10	R

Technologies	Area	Energy Savings (of process, unless indicated)	Simple payback (years)	Type	Name	Location	Plant Capacity (MGD)*	Average Daily Flow (MGD)	Source	Imple-mented**
Control wastewater flows with PID and VFD	Pumps	4% of cost		WWTP	Moulton Niguel Water District	Laguna Beach, CA	17		17	I
Positive displacement to Turblex blowers, DO control, SCADA	Aeration	30% (6.2% of plant energy)	14	WWTP	Sheboygan Regional WWTP	Sheboygan, MI	18.4	11.8	107/115	I
Optimize and control SRT and DO using proprietary process modeling based control algorithms	Aeration	20%	5	WWTP	Oxnard Plant #32	Oxnard, CA		22.4	107	I
Aeration automated control	Aeration	34%		WWTP	Washington Suburban Sanitary Commission Advanced WWTP	Piscataway, MD	30		10	I
Expand fine bubble diffuser system, DO probes, automated DO control	Aeration	33% of plant energy	2.4	WWTP	Waco Metropolitan Area Region Sewer System WWTP	Waco, TX	37.8	22.8	107/115	I
Upgraded blower control system	Aeration	20%	1.5	WWTP	Bucklin Point WWTP	East Providence, RI	46 (116)	24	107/115	I
VFD on blower, DO control system	Aeration	25%	3.3	WWTP	Greater Lawrence Sanitary District WWTP	N. Andover, MA		30	10	I
Installed control systems	Pumping, Aeration	Pumping: 20% Pulsed air mixing: 23% DAF: 64%	0.25	WWTP	San Jose/Santa Clara Water Pollution Control Plant	San Jose, CA	167	107	107/115	I
Instrumentation and control		10-20%	2-5+ years	PWTP					10	G
Automation			0-5	PWTP/WWTP					4	G
Daily monitoring and optimizing		5-20%		PWTP/WWTP					87	G
Automated aeration controls	Aeration		1	WWTP					77	R

Technologies	Area	Energy Savings (of process, unless indicated)	Simple payback (years)	Type	Name	Location	Plant Capacity (MGD)*	Average Daily Flow (MGD)	Source	Imple-mented**
Instrumentation and control		10-20%	2-5+ years	WWTP					10	G
Automated DO monitoring and control		up to 30%		WWTP					80	G
Upgrade from manual to automatic DO control	Aeration	20-40%		WWTP					36	G
Aeration system control optimization	Aeration	10-30%		WWTP					53	G
Automated aeration controls	Aeration	10-30% of total energy	2-3	WWTP					21	G

[a] This value is adjusted for a 14% rate increase.

[b] Influent load changed significantly during construction. Payback value was adjusted.

*Values in parentheses indicated storm flows (retention basins and/or reduced treatment)

**I = Implemented, R = Recommended, G = General Value

VFD = variable frequency drive; DO = dissolved oxygen; SCADA = supervisory control and data acquisition; PLC = programmable logic controller; WWTP = Wastewater Treatment Plant; PWTP = Potable Water Treatment Plant; WS = Water Supply

FACT SHEET

ULTRAVIOLET DISINFECTION

Overview

Ultraviolet (UV) disinfection can be used in place of chlorination or ozonation at wastewater and potable water (typically groundwater) treatment plants. Unlike chlorination and ozonation, UV disinfection does not have any residuals. UV systems consist of five main components: lamps, quartz sleeves, ballasts, supports, and power supply. There are three types of lamps used in UV disinfection for water and wastewater treatment: low-pressure, low-intensity (output); low-pressure, high-intensity; and medium-pressure, high-intensity. Ballasts can be either electric or electromagnetic. The system can be set up vertically or horizontally. The following sections outline the major energy opportunities in UV disinfection.

Dose Pacing

Ultraviolet (UV) disinfection can use dose pacing to conserve power when flow rates are not at the maximum values. Dose pacing control strategies can either (1) turn banks of lights on or off, or (2) adjust lamp power up or down. Dose pacing should be automated with a PLC. Automation of the system based on water quality, flow, and level of disinfection required can save considerable energy.

Lamps can be arranged in open or closed channels, vertically or horizontally, parallel or perpendicular to flow. Orientation of the lamps will determine what dose pacing control strategies can be used.

Low Pressure Lamps

Low pressure systems are recommended over medium pressure systems for the energy saving potential. However, medium pressure systems may be necessary if the footprint area is limited or in large (>38 MGD) systems.

The following table lists some major features of the three types of lamps (adapted from "Essential Criteria for Selecting an Ultraviolet Disinfection System" [30]).

Type	Low Pressure, Low-Intensity	Low Pressure, High-Intensity	Medium Pressure High-Intensity Lamps
Plant Maximum Capacity [MGD]	38	38	>38
Input Power [Watts/Lamp]	15 - 75	150 – 400	1,000 – 20,000
UV-C Efficiency [%]	32 - 38	30-36	12-16
Hg Pressure [atm]	0.01	0.01	1-2
Lifetime [Hours]	8,000 – 12,000	8,000 – 15,000	3,000 – 9,000
Operation	Long warm-up time	Long warm-up time	Short warm-up time

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Type	Low Pressure, Low-Intensity	Low Pressure, High-Intensity	Medium Pressure High-Intensity Lamps
Performance – Effect of Water Temperature on Output	Efficiency very dependent on water temperature	Efficiency somewhat dependent on water temperature	Efficiency independent of water temperature
Maintenance - Cleaning	Low fouling rate. Manual, offsite cleaning required	Low fouling rate. Automatic lamp cleaning available	High fouling rate. Automatic lamp cleaning available
Maintenance – Lamp Replacement	Long lamp life but high number of lamps to replace	Long lamp life and average number of lamps to replace	Average lamp life but low number of lamps to replace
Maintenance – Sleeve and Ballast Life [years]	Sleeve: 4-6 Ballast: 10-15	4-6 10-15	1-3 1-3
Installation – Footprint	Large	Medium	Small
Installation – Head Loss	High	Medium	Low
Configuration Options	Open Channel	Open Channel Closed Vessel	Closed Vessel

Hg – mercury, UV – ultraviolet, UV-C efficiency – the amount of electrical power, in watts, converted into watts of UV light emitted in the range of 240-290 nm, which is the effective germicidal range

Electronic Ballasts

Ultraviolet (UV) ballasts can be either electronic or electromagnetic. Due to increased energy efficiency, electronic ballasts are recommended over electromagnetic ballasts for new installations and retrofits (ballast replacement). Electronic ballasts generate less heat (electromagnetic ballasts may require air conditioning), are more compact, consume less power, and are less affected by power supply variability than electromagnetic ballasts. Also, electronic ballasts have the ability to vary the output.

Electronic ballasts are, in general, about 10% more efficient than electromagnetic ballasts [67]. However, electronic ballasts have a higher risk of damage and a shorter life than electromagnetic ballasts. Overall, electromagnetic ballasts are recommended to be switched to electronic ballasts.

The following table is adapted from “Essential Criteria for Selecting an Ultraviolet Disinfection System” [30].

Selection Criteria	Electromagnetic	Electronic
Installation – Room Temperature	High heat generation will require a cooling system (ventilation or air conditioning) in the control panel	Low heat generation
Installation – Footprint	Large (coils, wiring, etc)	Compact
Operation – Power Consumption	High (low efficiency and constant output)	Low (high efficiency and variable output)
Operation – Power Supply	Negatively affected by power supply variability (surges, power interruptions, sags, brownouts, etc)	Limited effect from power-supply variability
Operation – Reliability	Reliable, proven technology	Higher risk of damage
Maintenance	Long life	Average Life

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Lamp Maintenance

Ultraviolet (UV) disinfection lamp sleeves must be cleaned regularly, manually or automatically. Lamps and ballasts must be replaced periodically. As lamp sleeves foul (build up material on the sleeves), less UV light is able to be transferred to the water, and more energy is required to deliver the same dose to the water. Similarly, as lamps age, the same electrical input produces less UV light, resulting in more energy required for the same lamp intensity. This reduction must be balanced with the cost to replace lamps.

Lamp Replacement – Lamps can be replaced either on a schedule (say 4,000 hours) or when their output has reduced to a certain level, even after cleaning (say 75%) or both (whichever occurs first).

Sleeve Cleaning – Sleeve cleaning can be performed automatically or manually. If performed manually, cleaning, like lamp replacement, can occur on a schedule or when output is decreased by a certain amount. The amount of fouling and severity of the fouling are highly dependent on the water in the system.

Emerging Technologies

The following list is of emerging UV disinfection technologies. These technologies may be researched to determine applicability and feasibility.

- Narrow-band Excimer Lamps
- Pulsed UV

Resources

[30] Dussert , B.W. 2005. American Water Works Association (AWWA) Journal 97:7. Essential Criteria for Selecting an Ultravoilet Disinfection System.

[39] Electric Power Research Institute (EPRI). 1998. Quality Energy Efficiency Retrofits for Wastewater Systems.

[67] Metcalf and Eddy. 2006. Water Reuse: Issues, Technologies, and Applications.

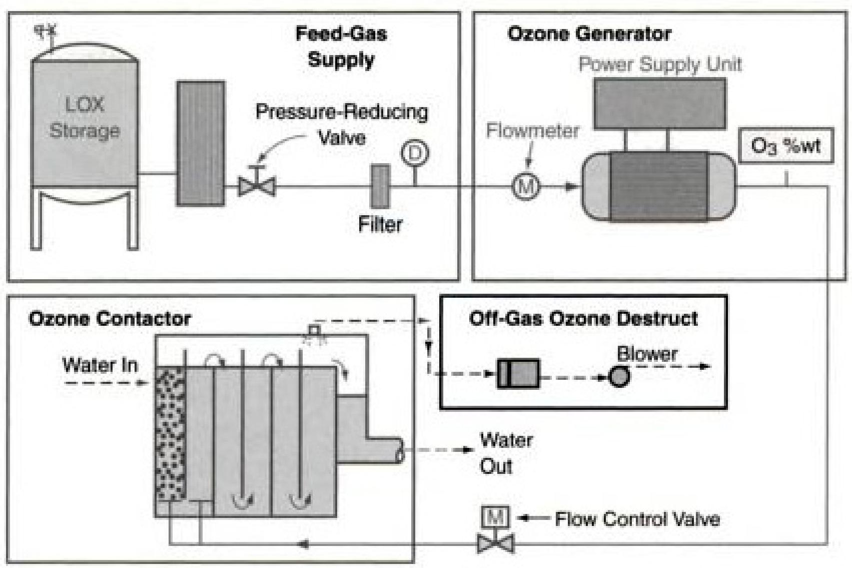
[87] Science Applications International Corporation (SAIC) for Focus on Energy. 2006. Water & Wastewater Industry Energy Best Practice Guidebook: Technical Best Practice Wastewater 18: Ultraviolet (UV) Disinfection Options.

FACT SHEET

OZONE DISINFECTION

Overview

The ozonation process consists of four steps: (1) feed gas preparation, (2) ozone generation, (3) ozone contacting, and (4) off-gas treatment. The feed gas can be liquid oxygen (LOX), on-site generated oxygen (VPSA for large operations or PSA for smaller operations), or ambient air.



Main ozone system components[83] (liquid oxygen feed gas shown)

Ozone System Technology

Advancements in generator technology over the past decade have increased generator efficiency by 10-20%[35]. It may be economically beneficial to upgrade an older system with newer technology. Additionally, most older systems use ambient air (which can be a complicated and power-consuming process), while newer systems used on-site oxygen or LOX. A cost analysis should be done to determine the actual benefit of upgrading an existing system.

Ozone System Size

If a system is oversized for normal operation (i.e. sized for peak flow), it may be beneficial to install a small system for normal conditions. Ozone systems operate most efficiently at their "design ozone concentration."

Feed Gas Options

G7

It may be possible to reduce energy use and costs by purchasing liquid oxygen (LOX). LOX could be used in place of VPSA or PSA. The cost of LOX depends largely on the location of the treatment plant with respect to a LOX supply. Depending on the cost, it may be beneficial to use LOX in place of VPSA/PSA oxygen during peak hours or possibly all hours. For some older air-fed systems, the savings associated with a new VPSA/PSA or LOX system may justify replacement. A cost analysis should be performed.

Off-Gas Destruct Blower VFD

If the water flow through the ozone system varies, the off-gas from the system likely also varies. Depending on the size of the system and hours of operation, it may be beneficial to install a VFD on the off-gas destruct blower(s) to more closely match the output.

Performance/Contact Time Ratio

The performance or contact time (CT) ratio is a ratio of the actual divided by the required minimum. For energy efficiency, this value should be close to 1. For safety, the ratio is typically between 1.2 and 1.5. When the ratio gets higher than 1.5, it may be possible to optimize the performance of the system to reduce the ratio and reduce energy use.

Resources

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FACT SHEET

ON-SITE POWER GENERATION

Overview

Many water and wastewater treatment/conveyance sites are charged for electricity on a time-of-use (TOU) rate structure. This means power costs more during peak hours and less during off-peak hours. While some processes can be shifted to occur during off-peak hours, there are some that cannot. A possible method for reducing energy costs and electricity use may be to produce power on-site during peak hours. Many water and wastewater sites (such as lift stations and treatment plants) already have backup generators for emergency situations that could be used for peak shaving (reducing energy use during peak hours). It may also be possible to install a natural gas and/or biogas (from anaerobic sludge digestion) co-generation unit.

Application

Using generators to off-set peak power use may be applicable to any part of a municipality's water/wastewater system that is on a TOU rate structure.

Considerations

Either all or part of the peak load can be supplied by the on-site power source.

For existing back-up generators, the added costs related to operation and maintenance of the generator(s) must be considered when determining the economic viability of peak shaving/load reduction with the back-up generators. Additionally, some back-up generators may not be allowed to operate outside of emergency situations due to air pollution regulations and permits.

At wastewater treatment plants, it may be possible to power generators with biofuel created in anaerobic sludge digestion rather than, or in addition to purchasing fuel. Cogeneration (heat and fuel) may be more economically feasible than biofuel generation alone.

Costs

Costs can vary greatly depending on the existing equipment.

When emergency generators are already installed and operational, the only additional costs typically added are in the following areas:

- Direct fuel and supply costs
- Environmental permits required for additional air pollution
- Staff time and training required to operate the equipment at an increased frequency

For cogeneration units, the major economic factors include:

- The size, capacity, and capital cost of a unit
- The cost and availability of fuel (either purchased or produced)
- Operations and maintenance costs
- The ability of the site to use thermal energy produced by the unit

Additional Benefits

Using backup and standby generators during peak periods can allow a system to use interruptible rates (reduced energy rates in exchange for interruptible service during peak loads).

G8

Resources

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[10] Burton, F. and EPRI Community Environmental Center for Electric Power Research Institute (EPRI). 1996. Report CR-106941. Water and Wastewater Industries: Characteristics and Energy Management Opportunities.

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CASE STUDIES

GENERATORS

Technologies	Energy Savings	Simple payback (years)	Type	Name	Location	Plant Capacity (MGD)	Average Daily Flow (MGD)	Source	Implemented*
Operate diesel pump to limit demand	5% of total plant energy cost ($6,000/yr)		PWTP	Milton WTP	Milton, PA	5.5	3.2	3	R
Implementation of on-site generation	262,800 kWh/yr ($20,236/yr)	12	WWTP	Lake Street WWTP	Elmira, NY	9.5	5.7	61/64	R
Upgrade existing co-generation units	210,240 kWh/yr ($29,114/yr)	6.0	WWTP	Ithica Sewage Treatment Plant	Ithica, NY	10	6.5	64	R
Replace existing co-generation units	525,600 kWh/yr ($78,006/yr)	4.5	WWTP	Ithica Sewage Treatment Plant	Ithica, NY	10	6.5	64	R
Use emergency generator and interruptible rate	12% of total plant energy cost ($36,500/yr)	2.7	PWTP	Peoria Water System	Peoria, IL	13	10	3	R
Use standby generator and interruptible rate	5.5% of total plant energy cost ($16,800/yr)	6.0	PWTP	Peoria Water System	Peoria, IL	13	10	3	R
Implementation of on-site generation	2,505,882 kWh/yr ($213,000/yr)	30	WWTP	Albany County Sewer District North Plant	Menands, NY	35	22.3	60/64	R

Implementation of peak shaving using existing generators	28,710 kWh/yr ($12,000/yr)	0.7	WWTP	Albany County Sewer District North Plant	Menands, NY	35	22.3	60/64	R
On-site generators	$450,000/year	<10	PWTP	North Columbus Water Resources Treatment Facility	Columbus, CA	90	27.5	55	I
Gas or diesel equipment for peak demand periods	3-10% of total plant energy (>20% decrease in peak kW)		WWTP					10	G

*I = Implemented, R = Recommended, G = General Value
WWTP = Wastewater Treatment Plant, PWTP = Potable Water Treatment Plant

FACT SHEET

TREATMENT WATER RECYCLING

Overview

Filter backwashing can be a water-intensive process. If the backwashing system has been optimized (See **Fact Sheet G1**), another method to further reduce water requirements is to recycle the backwash water. Typically, the water would be routed to a settling basin, and then rerouted to the head of the treatment plant.

Applications

The following flows can be considered for recycling:

- Spent Filter Backwash Water: A stream containing particles that are dislodged from filter media when water is forced back through a filter (backwashed) to clean the filter.
- Thickener Supernatant: A stream containing the decant from a sedimentation basin, clarifier, or other unit that is used to treat water, solids, or semi-solids from the primary treatment processes.
- Liquids from Dewatering Processes: A stream containing liquids generated from a unit used to concentrate solids for disposal.

Considerations

There are rules regarding the recycling of backwash water. Federal regulations called the Filter Backwash Recycling Rule should be consulted. That document requires that no more than a 10 percent mixture of backwash water with raw water feeding back into the plant.

Resources

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FACT SHEET

PREMIUM EFFICIENCY MOTORS

Overview

Premium efficiency motors are typically 2 to 10% more efficient than standard efficiency motors and 1 to 4% more efficient than EPAct motors. Because the lifetime energy costs to run a continuous duty motor are 10 to 20 times higher than the initial motor price, the added cost for premium efficiency motors (usually 15 to 25% more than standard efficiency motors) are often recouped quickly with the energy cost savings of a frequently used motor.

Application

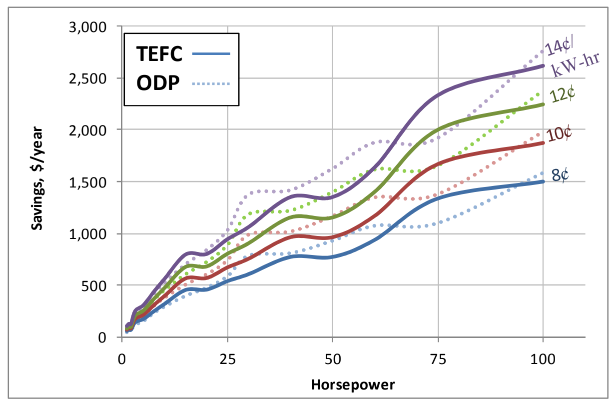
As a rule of thumb, if a standard motor is more than 5 years old and runs more than 75% of the time, it should be replaced with a premium efficiency motor. Also, if motors are oversized by more than 50%, they should be replaced with correctly sized, high or premium efficiency motors.

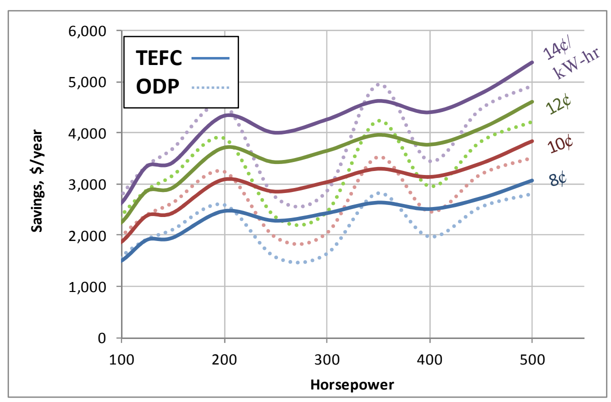
For a more detailed examination, the Department of Energy (DOE) provides a program called MotorMaster+, which allows the user to compare motors. The program has a manufacturers' database of price and performance.

Costs

The following two charts can be used to estimate the savings associated with upgrading from a standard to premium motor for totally enclosed fan cooled (TEFC) and open drip proof (ODP) motors based on utility rate. These charts assume the motor runs an <u>80% load 100% of the time</u>. Therefore, multiply the savings by the percent of time the motor will run divided by 100. Additionally, if the actual load is known, multiply the savings by the actual load (%) divided by 80.

$$\text{Actual Savings [\$]} = \text{Chart Savings [\$]} \times \frac{\text{\% of time motor runs}}{100\%} \times \frac{\text{Actual load \%}}{80\%}$$





These savings should be compared to the cost of upgrading the motor. The cost of upgrading the motor depends on the useful life of the current motor and if the current motor needs to be rewound.

For actual and estimated savings for motor upgrades at water and wastewater facilities, see the case study table below.

Additional Benefits

Premium efficiency motors typically have longer insulation and bearing lives, lower heat output, and less vibration. In some cases, the premium motors come with longer warranties than the standard motors.

Resources

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[102] U.S. Department of Energy (DOE) Energy Efficiency and Renewable Energy (EERE) Advanced Manufacturing Office. 2012. Energy Tips: Motor Systems Tip Sheet #1. *When to Purchase Premium Efficiency Motors*.

[105] U.S. Department of Energy (DOE) Industrial Technologies Program (ITP). *MotorMaster+ software*. Available online at: http://www1.eere.energy.gov/manufacturing/tech_ deployment/software_ motormaster.html

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[107] U.S. Environmental Protection Agency (EPA). 2010. *Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities*.

CASE STUDIES

PREMIUM EFFICIENCY MOTORS

	Technologies	Area	Energy Savings (of process, unless indicated)	Simple payback (years)	Type	Name	Location	Plant Capacity (MGD)*	Avg Daily Flow (MGD)	Source	Imple-mented**
Air	Upgrade to PE motors	Mechanical Aeration		8	WWTP	Wallkill Wastewater Treatment Facility	Wallkill, NY	4	3	63/64	R
	PE motors, automated DO control	Mechanical Aeration		17	WWTP	LangeTwins Winery	Acampo, CA			7	R
Water	Upgrade to HE motors			8.2	WWTP	Waimea WWTP	Waimea, HI	0.3	0.25	91	R
	PE motors			7.3	WWTP	South Fallsburg Sewer District	Fallsburg, NY	3.3	2.1	64	R
	Upgrade to PE motors			17	WWTP	Wallkill Wastewater Treatment Facility	Wallkill, NY	4	3	63/64	R
	Upgrade to HE motors			4	WWTP	Hilo WWTP	Hilo, HI	5	3	89	I
	HE motors	Well pumps	2.5% of cost		WS	Madera Valley Water Company	Madera, CA	8.2		16	I
	Upgrade to PE motors		1.3% of cost		WS	Madera Valley Water Company	Madera, CA	8.2		16	I
	Upgrade to HE motors	Pumps (influent and trickling filter)		7.6	WWTP	Lake Street WWTP	Chemung, NY	9.5		61/64	R
	HE motors			0.3-2.5	PWTP	Stenner Canyon WTP	San Luis Obispo, CA	16	5.7	10	R
	PE motors			76	WWTP	Gloversville-Johnstown Joint WWTP	Johnstown, NY	13.1	6.7	64	R
	New PE motors		8% of cost		PWT/WWTP	Moulton Niguel Water District	Laguna Beach, CA	17WW/48 W		17	I
	Upgrade to PE motors		16% of cost		PWT/WWTP	Moulton Niguel Water District	Laguna Beach, CA	17WW/48 W		17	I

	Technologies	Area	Energy Savings (of process, unless indicated)	Simple payback (years)	Type	Name	Location	Plant Capacity (MGD)*	Avg Daily Flow (MGD)	Source	Imple-mented**
	Upgrade to HE motors			4.4-9.6 for 5-100 HP	WWTP	R.L. Sutton WWTP	Atlanta, GA		18-40	10	R
	Upgrade to HE motors	High pressure service water pumps	1% of cost	15.2	WWTP	Tonawanda WWTP	Tonawanda, NY	30	20	62	R
	Upgrade to PE motors			13.2	WWTP	Tonawanda WWTP	Tonawanda, NY	30	20	62	R
	PE motors, VFDs	Pumps	26%	3	WWTP	Albany County Sewer District North Plant	Menands, NY	35	23	60/64	R
	PE motors	Pumps		15	WWTP	Albany County Sewer District North Plant	Menands, NY	35	23	60/64	R
	Upgrade to HE motors	Booster pumps	5% of cost		PWTP	San Juan Water District Sidney N. Peterson WTP	Granite Bay, CA	120		18	I
	VFDs, HE pumps, HE motors	Pumps	51%		WWTP	East Bay Municipal Utility District Special District 1 WWTP	Oakland, CA	168 (415)	63	14	I
	VFDs, PE motors, optimize pumping	Pumps	2.81 million kWh/yr	1.1	WWTP	Metropolitan Syracuse WWTP	Onondaga County	126 (240)	84	98	I
	PE motors	Pumps		23	WWTP	Frank E Van Lare Sewage Treatment Plant	Rochester, NY	135	96	64	R
	PE motors	Sludge pumps		102	WWTP	Frank E Van Lare Sewage Treatment Plant	Rochester, NY	135	96	64	R
	HE motors			<1 for 7.5 to 200 HP	WWTP	Central Mill Creek WWTP	Cincinnati, OH	240 (430)	130	10	R
	Upgrade to HE motors			3.8 for 4-50 HP	WWTP	R.L. Jackson WWTP	Morrow, GA			10	R
	PE motors, VFDs, Rotary Press	Pumps, drying		3.9	WWTP	Town of Richmond Water Pollution Control Facility	Richmond, VT			33	R
	PE motors, VFDs, optimization		26% of cost		WS, PWTP, WD	City of Oswega Water Department	Oswega, NY			69	R

	Technologies	Area	Energy Savings (of process, unless indicated)	Simple payback (years)	Type	Name	Location	Plant Capacity (MGD)*	Avg Daily Flow (MGD)	Source	Imple-mented**
	Upgrade to PE motors			1.5	WWTP		California			81	R
General Estimate	New HE motors			2-3	PWTP/WWTP					4	G
	HE motors		5-10% minimum	<2	PWTP/WWTP					66/87	G
	HE motors		3-10% of entire plant		WWTP					10	G
	Upgrade to HE motors		4%		WWTP					5	G
	PE motors		3-5% of entire plant	<5	WWTP					23	G
	PE motors			1.8	PWTP					6	G
	HE motors		3-10% of entire plant		PWTP					10	G

*Values in parentheses indicated storm flows (retention basins and/or reduced treatment)
**I = Implemented, R = Recommended, G = General Value
HE = high efficiency, PE = premium efficiency (NEMA); VFD = variable frequency drive; DO = dissolved oxygen; WWTP = wastewater treatment plant, PWTP = potable water treatment plant, WWC = wastewater collection, WS = water supply

FACT SHEET

VARIABLE FREQUENCY DRIVES

Overview

Variable Frequency Drives (VFDs) can be used on motors that have or could have varying loads. On pumps, VFDs can be used in place of bypass valves or throttling valves. VFDs can be installed on most existing pumps. VFDs can be used in conjunction with sensors and PLCs (Programmable Logic Controller) to automate some processes, optimizing system performance.

Application

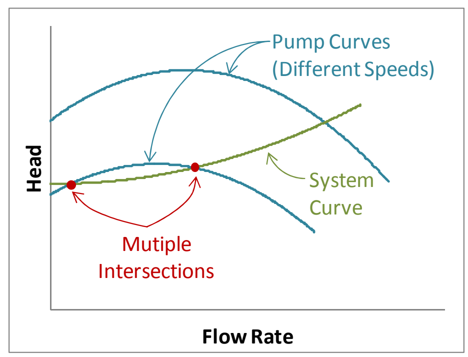
On pumps and blowers, variable frequency drives (VFDs) can use less energy than throttling valves, bypass valves, and on/off control in high-friction situations.

VFDs are most applicable for situations with a combination of the following characteristics: high HP (>15), high utility rates, variable load types, low static head, and high (>2,000 hours/year) operating hours.

One VFD can be used in situations with two pumps that operate in duty/standby mode. If both pumps are run in lead/lag mode, they would likely both need VFDs. In 3+ pump systems, depending on the range of flows, it may be possible to have one or two VFDs. Installing a new, small pump with a VFD may be more economical than retrofitting a large existing pump.

Considerations

Some pumps have pump curves that can allow a pump curve to intersect a system curve at multiple points (see points in the following figure). This can cause the system to "hunt" for the operating point, causing the flow rate to suddenly shift and damage the system. Do not install VFDs on these pumps.



VFDs can increase vibration and cause structural resonance problems.

A VFD needs to be sized for the motor input (not motor output). A rule of thumb is to upsize the controller by one size above the motor rating.

In general, the motor should operate for at least 2,000 hours/year for a VFD to be economical.

Positive displacement pumps will not have as high of energy savings as centrifugal pumps, but there can still be significant savings in certain applications.

In pumping systems with predominantly static lift, bypass valves may be more efficient than throttling valves or VFDs.

If a system has "non-continuous," set outputs (i.e. a pumping system operates at either, and only, 1,000 or

3,000 gpm), a multiple-speed pump may be a better option.

In systems that must operate for long periods at low-load conditions, a pony pump (or blower) may be more economical.

In systems that operate at near-full load for long periods, the efficiency of the VFD may make it less economical than other options.

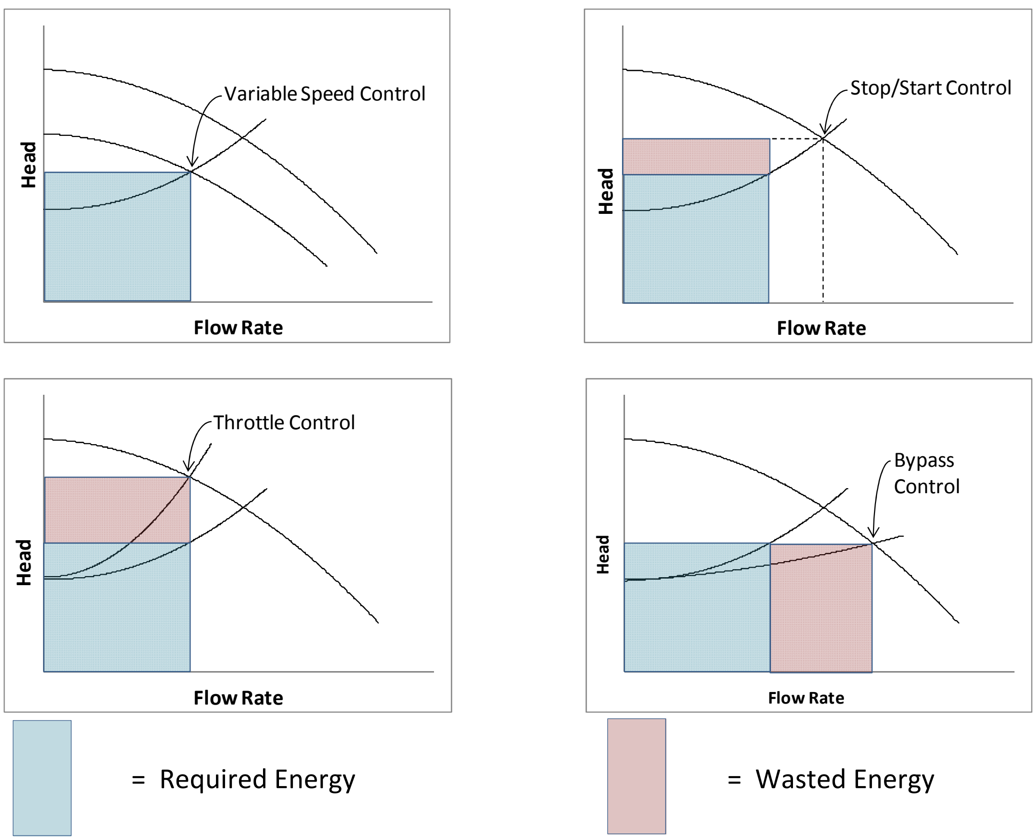
VFDs require a good quality power source due to altering energy requirements [101].

VFDs can cost from $3,000 for small (5 HP) models up to over $45,000 for large (300 HP) custom-engineered models, plus installation costs. Payback is typically a few months to a few years [13].

In wastewater applications, VFDs can result in low velocities that can lead to solids deposition in pipes. Minimum velocities must be considered.

Energy Comparison

The following graphs compare the energy used for variable speed control, stop/start control, throttling valve control, and bypass valve control for a system with static head (elevation) as well as dynamic head (friction). Note that the graphs do not account for energy wasted due to operating at a lower efficiency.



Costs

See the case studies table below for example energy and cost savings, as well as payback for proposed and implemented VFD installations. Typical payback ranges from <u>six months to five years.</u>

VFD retrofits typically save 15% to 35% of energy.

Additional Benefits

VFDs allow soft-starts, reducing the mechanical and electrical stress on the motor system and reducing the risk of water hammer.

VFDs (with PLCs and sensors) allow the control of a system to be automated.

VFDs can reduce pump noise.

Resources

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CASE STUDIES

VARIABLE FREQUENCY DRIVES

	Technologies	Area	Energy Savings (of process, unless indicated)	Simple payback (years)	Type	Name	Location	Plant Capacity (MGD)	Average Daily Flow (MGD)	Source	Imple-mented*
Air	VFD, fine bubble diffusers, automatic DO control, SCADA	Blower	45% (18% of cost)	2	WWTP	Bowling Green WWTP	Bowling Green, MI	0.75		1	I
Air	VFD, DO control	Mechanical Aerator	13%	1.5	WWTP	WWTP No. 1	Bartlett, TN	2.2	1	115	I
Air	VFD	Mechanical Aerator	25%-38%	7.1-11	WWTP	Wallkill Wastewater Treatment Facility	Wallkill, NY	4	3	63/64	R
Air	VFDs, automatic DO control	Blower		2.7	WWTP		California		4	49	R
Air	VFDs	Blower		1	WWTP		California		4	49	R
Air	VFD, DO control		20% of total plant energy	1.7	WWTP	Lake Street WWTP	Chemung, NY	9.5	5.7	61/64	R
Air	VFD	Mechanical Aerator		1.5	WWTP	Lake Street WWTP	Chemung, NY	9.5	5.7	61/64	R
Air	VFD, automatic DO control		25%	3.3	WWTP	Greater Lawrence Sanitary District	N. Andover, MA		30	10	I
Air	VFDs	Mixing, Chemical Pumps	30% of cost		PWTP	San Juan Water District Sidney N. Peterson WTP	Granite Bay, CA	120		18	I
Air	VFD, DO control	Blower		2.3	WWTP		California			81	R
Air	VFD, DO control	Mechanical Aerator		5	WWTP		California			81	R
Air	VFD	Blower	32% of total plant energy	<1	WWTP	City of Winooski Water Pollution Control Facility	Winooski, VT			32	I
Water	VFDs, control optimization		17%	7.5	WWTP	Waimea WWTP	Waimea, HI	0.3	0.25	91	R
Water	Replace pump, VFD	Pumps	20%			Crested Butte WWTP	Crested Butte, CO	0.6		29	R
Water	VFD	Pumps	39% replacing 2-		WWTP	Willits Water Quality Control Plant	Willits, CA	0.7		10	I

Technologies	Area	Energy Savings (of process, unless indicated)	Simple payback (years)	Type	Name	Location	Plant Capacity (MGD)	Average Daily Flow (MGD)	Source	Imple-mented*
		speed								
VFD, pony pump	Pumps	37%	7.7	WWTP	Hilo WWTP	Hilo, HI	5	3	89	I
VFD	Blower	24%		WWTP	City of Columbia WWTP	Columbia, TN	7		10	I
VFDs, replace pumps	Pumps	498,600 kWh/yr	4.1	WWTP	South Tahoe Public Utility District	South Tahoe, CA	7.7	4	19/20	I
VFD, PLC	Well Pumps	25% of cost		WS	Madera Valley Water Company	Madera, CA	8.2		16	I
VFD	Trickling filter pump		3.5	WWTP	Lake Street WWTP	Chemung, NY	9.5	5.7	61/64	R
VFD	Trickling Filter Return Flow	48%	2.5	WWTP	Lake Street WWTP	Chemung, NY	9.5		61/64	R
VFD	sludge pump		1.7	WWTP	Ventura Water Renovation Facility	San Buenaventura, CA	14	9	10	R
VFD	pump		<1	WWTP	Ventura Water Renovation Facility	San Buenaventura, CA	14	9	10	R
VFD	Mechanical Aerators		2	WWTP	Fitchburg WWTP	Fitchburg, MA	12.4	10	10	R
VFD	sludge pump		2	WWTP	Fitchburg WWTP	Fitchburg, MA	12.4	10	10	R
VFDs, automated control	Pumps	4% of cost		WWTP	Moulton Niguel Water District	Laguna Beach, CA	17		17	I
Upgrade VFDs	pump		15	WWTP	East Lansing WWTP	East Lansing, MI	18.75	12.6	10	R
VFD, controls	High Pressure Service Pumps	42% of cost	3.3	WWTP	Tonawanda WWTP	Tonawanda, NY	30	20	62	R
VFD	Activated Sludge RAS	10%	15	WWTP	Albany County Sewer District North Plant	Menands, NY	35	22.3	60/64	R
PE motors, VFDs	Pumps	26%	3	WWTP	Albany County Sewer District North Plant	Menands, NY	35	23	60/64	R
VFD		12% of total plant energy ($21,000)		WWTP	Encina Wastewater Authority	Carlsbad, CA	36		15	I
VFD replacement		625,000 kWh	1.4	PWTP/WWTP	Vallejo Sanitation and Flood Control District	Vallejo, CA	60		47	I

	Technologies	Area	Energy Savings (of process, unless indicated)	Simple payback (years)	Type	Name	Location	Plant Capacity (MGD)	Average Daily Flow (MGD)	Source	Imple-mented*
	VFDs, HE pumps, HE motors	Pumps	51%		WWTP	East Bay Municipal Utility District Special District 1 WWTP	Oakland, CA	168 (415)	63	14	I
	VFDs, PE motors, optimize pumping	Pumps	2.81 million kWh/yr	1.1	WWTP	Metropolitan Syracuse WWTP	Onondaga County	126 (240)	84	98	I
	VFD	Pumps	13%	11	WWTP	Frank E Van Lare Sewage Treatment Plant	Rochester, NY	135		64	R
	VFD	Lift Pumps	78,800 kWh/yr	8	WWC	South Tahoe PUD	South Tahoe PUD			19/20	I
	PE motors, VFDs, Rotary Press	Pumps, Drying		3.9	WWTP	Town of Richmond Water Pollution Control Facility	Richmond, VT			33	R
	VFD	Well Pumps		6.7	WS	Bexar Metropolitan Water District	San Antonio, TX			40	I
General Estimates	VFD	General	15-30% typical	0.5-5	PWTP, WWTP					66/87	G
General Estimates	VFD	Pump	10-40% replacing throttling valve		PWTP, WWTP					66/87	G
General Estimates	Optimize distribution network	Pump		0.5-3	PWTP/WWTP					4	G
General Estimates	VFD	Blower	>50% secondary treatment		WWTP					66/87	G
General Estimates	VFD		70,000 kWh/yr		WWTP				7-10	107	G
General Estimates	VFD		2,800,000 kWh/yr		WWTP				80	107	G
General Estimates	VFD		10-20% avg, up to 60%		WWTP					23	G
General Estimates	VFD		3-20%	2-5	WWTP					10	G
General Estimates	VFD		15%		WWTP					53	G
General Estimates	VFD		10-20%	2-5	PWTP					10	G
General Estimates	VFD	Pump		2.5	PWTP					6	G
General Estimates	VFD		as much as 50%		PWTP					55	G

*Values in parentheses indicated storm flows (retention basins and/or reduced treatment)
**I = Implemented, R = Recommended, G = General Value
HE = high efficiency, PE = premium efficiency (NEMA); VFD = variable frequency drive, DO = dissolved oxygen, SCADA = supervisory control and data acquisition; WWTP = wastewater treatment plant, PWTP = potable water treatment plant, WWC = wastewater collection, WS = water supply

FACT SHEET

M3

CORRECTLY SIZED MOTORS

Overview

Motors should operate primarily between 65 and 100% of the rated load. The efficiency of the motor diminishes when it is operated outside this range. *As a general rule, if a motor is oversized by more than 50%, it should be replaced with a correctly sized high- or premium-efficiency motor.* If a large capacity is required for peak flows, multiple motors could be used. Efficiency losses for oversized motors are greater for smaller sized motors (<50 HP); large, oversized motors may not have a significant loss of efficiency operating at a partial load.

Motors can also be undersized. Undersized motors can overheat and decrease in efficiency when run for long periods of time above their rated power. An undersized motor should be replaced any time the motor is constantly operating above the rated load.

Considerations

If a motor appears to be incorrectly sizes, MotorMaster+ (a program provided by the U.S. Department of Energy – [105]) can be used to evaluate the current motor and compare it to other options.

Costs

Energy savings of 5-30% are typical when replacing a motor with a correctly sized motor [53].

Resources

[53] KEMA-XENERGY, for California Public Utilities Commission. 2003. Proposal for Wastewater Treatment Plant Improvement Program in the PG&E Service Area.

[66] Malcolm Pirnie for New York State Energy Research and Development Authority (NYSERDA). 2010. Water and Wastewater Energy Management, Best Practices Handbook: General Best Practice 13 – Electric Motors: Correctly Size Motors.

[101] U.S. Department of Energy (DOE) Energy Efficiency and Renewable Energy (EERE). 2006. Improving Pumping System Performance: A Sourcebook for Industry.

[105] U.S. Department of Energy (DOE) Industrial Technologies Program (ITP). MotorMaster+ software. Available online at: http://www1.eere.energy.gov/manufacturing/tech_ deployment/software_ motormaster.html

[106] U.S. Department of Energy (DOE) Motor Challenge. 2001. Fact Sheet: Replacing an Oversized and Underloaded Electric Motor.

FACT SHEET

M4

HYDRAULIC AND PNEUMATIC DRIVES

Overview

Electric drives are typically more efficient than hydraulic (water or hydraulic oil driven) drives or pneumatically driven pumps in water systems.

Hydraulic drives are inherently less efficient as they convert energy from electric to mechanical to hydraulic, and back to mechanical, whereas electric drives convert energy directly from electric to mechanical. New electric drives can also provide better performance than hydraulic drives.

The cost of pressurized air makes pneumatically-driven pumps inefficient. Additionally, air leaks are common, which lower the efficiency further. Pneumatic drive systems are typically only cost effective when small masses need to be moved at high speeds across short distances, an application not typically found in water systems.

Electric drives are typically less maintenance than hydraulic or pneumatic drives. Electrical drives allow for better motor control as well as easier set-ups.

Application

Drives are used on motors to control pumps, blowers, mixers, mechanical aerators, and any other motor-driven device.

Considerations

Hydraulic and/or pneumatic drives that are used on pumps, blowers, mixers, and/or mechanical aerators should be replaced with electrical drives.

Costs

Motor manufacturers have reported that replacing a hydraulic drive with an electric drive resulted in an energy saving of over 20% [5, 45].

Pneumatic pumps can have efficiencies in the range of 10%. Therefore, replacing a pneumatic pump with an electric driven pump can save around 80% of the pump's energy (depending on pump size) [5, 45].

Additional Benefits

If the output needs to vary with time (such as a pump or blower with variable flow), electric variable frequency drives (VFDs) are more efficient than their hydraulic and pneumatic counterparts.

Converting from pneumatic pumps to electric-driven pumps eliminates inefficiencies due to air leaks.

Resources

[5] Base Energy Inc. for PG&E. 2006. Energy Baseline Study for Municipal Wastewater Treatment Plants.

[45] Etc Group, LLC and the American Council for an Energy Efficient Economy for Southern California Edison (SCE) and PG&E. 2008. Screening Tool to Identify Energy Efficiency Opportunities in Wastewater Treatment Plant Pumping Systems.

[101] U.S. Department of Energy (DOE) Energy Efficiency and Renewable Energy (EERE). 2006. Improving Pumping System Performance: A Sourcebook for Industry.

M4

[105] U.S. Department of Energy (DOE) Industrial Technologies Program (ITP). MotorMaster+ software. Available online at: http://www1.eere.energy.gov/manufacturing/tech_ deployment/software_ motormaster.html

[106] U.S. Department of Energy (DOE) Motor Challenge. 2001. Fact Sheet: Replacing an Oversized and Underloaded Electric Motor.

FACT SHEET

AIR STRIPPER AIR-TO-WATER RATIO

PW1

Overview

Air strippers are used in water treatment to remove volatile organic compounds and other taste- and odor-contributing compounds from the water. They work by transferring the compounds from the water phase to air phase by mixing the contaminated water with sufficient air. The amount of air needed to strip different contaminants is defined by Henry's Law. Over-aeration (an air-to-water ratio higher than what is necessary to remove desired contaminants) wastes energy; also, if off-gas destruct is required, additional energy is wasted with the treatment of the excess air.

Application

This energy conservation measure is specific to air strippers.

Considerations

Henry's Law Constants change significantly with changes in temperature. The following table is adapted from "Design of Aeration Towers to Strip Volatile Contaminants from Drinking Water [52]. These values assume a stripping factor R = 3 (>90% removal).

Volatile Organic Contaminant	Henry's Law Constant (atm) @ 20°C	Air-to-Water Ratio (Theoretical)
Vinyl Chloride	3.55×10^5	0.011
Methane	3.8×10^4	0.11
Carbon Dioxide	1.51×10^3	2.6
Carbon Tetrachloride	1.29×10^3	3.1
Tetrachloroethylene	1.1×10^3	3.6
Trichloroethylene	550	7.2
Hydrogen Sulfide	515	7.7
1,1,1 - Trichloroethane	400	9.9
Chloroform	170	23
1,2 - Dichloroethane	61	65
1,1,2 - Trichloroethane	43	92
Bromoform	35	110
Ammonia	0.76	5200

If it appears air stripping is not optimized, specialists should analyze the system and recommend proper operation.

Additional Benefits

Ensuring air strippers are optimized ensures proper water quality.

Resources

[52] Kavanaugh, M.C. and R.R. Trussel. 1980. *Design of Aeration Towers to Strip Volatile Contaminants from Drinking Water*. American Water Works Association (AWWA) Journal 72:12.

[110] Water Environment Federation (WEF) Energy Conservation in Water and Wastewater Treatment Facilities Task Force. 2010. *Energy Conservation in Water and Wastewater Facilities: Manual of Practice No. 32*.

FACT SHEET

INCORRECTLY SIZE PUMPS

Overview

P1

Often in water and wastewater system designs, the pumps are oversized because the current conditions are not known or in anticipation of future conditions. This can lead to throttling or bypassing of flows to achieve a desired flow rate. For centrifugal pumps, trimming or replacing impellers can be more efficient.

Application

Properly sized impellers can use less energy than improperly sized impellers with throttling valves or bypass valves.

Indicators of a situation where trimming or replacing an impeller may be applicable include:

- A bypass valve is used during normal operation
- A throttling valve is used during normal operation
- The pump does not operate at the design point during normal operation

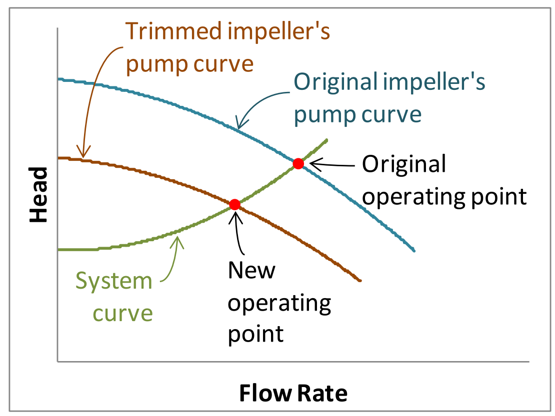
Considerations

Only centrifugal pumps can be trimmed (not positive displacement pumps).

Impellers can usually only be trimmed to about 75% of the shaft diameter without significant efficiency loss.

Trimming impellers increases the pump's required net positive suction head (NPSH). Confirm impeller trimming will not raise required NPSH above actual NPSH.

It may be desirable to retain the current impeller and install a VFD. Cost analysis of this option should be compared to trimming/replacing the current impeller and installing a VFD.



Costs

Typical payback ranges from six months to five years.

Trimming or replacing impellers can save up to 40% of energy.

Additional Benefits

Trimmed impellers can be replaced in the future if the required flow rate increases.

Unlike VFDs, trimmed impellers do not add any additional electronic equipment to the pump set-up.

Resources

[3] Arora, H. and M.W. LeChevallier. 1998. American Water Works Association (AWWA) Journal 90:2. Energy Management Opportunities.

[42] Energy Center of Wisconsin. 1999. Fact Sheet: Pumping System Impeller Trimming.

[45] Etc Group, LLC for Southern California Edison, 2008. Screening Tool to Identify Energy Efficiency Opportunities in Wastewater Treatment Plant Pumping Systems.

[55] Leiby, B.M. and M.E. Burke for the Water Research Foundation (WRF) and New York State Energy Research and Development Authority (NYSERDA). 2011. Energy Efficiency Best Practices for North American Drinking Water Utilities.

[93] The McNally Institute. 1998. Increasing the Centrifugal Pump Performance by Modifying the Impeller. http://www.mcnallyinstitute.com/12-html/12-06.html

[101] U.S. Department of Energy (DOE) Energy Efficiency and Renewable Energy (EERE). 2006. Improving Pumping System Performance: A Sourcebook for Industry – 3. Indications of Oversized Pumps & 10. Impeller Trimming.

[119] U.S. Department of Energy (DOE) Energy Efficiency and Renewable Energy (EERE) Industrial Technologies Program (ITP). 2005. Pumping Systems Tip Sheets #6. Match Pump to System Requirements & #7. Trim or Replace Impellers on Oversized Pumps.

P1

Case Studies

Incorrectly Size Pumps

Technologies	Energy Savings	Simple Payback (years)	Type	Name	Location	Plant Capacity (MGD)*	Average Daily Flow (MGD)	Source	Implemented**
Trim impeller to match capacity	$3,800/yr	2.4	PWTP	Peoria Water System	Peoria, IL	13	10	3	I
Install larger impellers	$11,000/ yr	3.1	PWTP	Peoria Water System	Peoria, IL	13	10	3	I
VFDs, PE motors, optimize pumping	2.81 million kWh/yr	1.1	WWTP	Metropolitan Syracuse WWTP	Onondaga County, NY	126 (240)	84	98	I
Replace oversized impeller	$1,000/ month		WS/WD	Philadelphia Water Department	Philadelphia , PA			55	I
Reduce capacity and head, and trim impeller	$9,400/ month		WS/WD	Philadelphia Water Department	Philadelphia , PA			55	I
Replace impeller		0.5	PWTP/ WWTP					4	G

*Values in parentheses indicated storm flows (retention basins and/or reduced treatment)
**I = Implemented, R = Recommended, G = General Value
VFD = variable frequency drive; PE = premium efficiency (NEMA); WWTP = wastewater treatment plant; PWTP = potable water treatment plant; WWC = wastewater collection; WS = water supply

FACT SHEET

PUMP OPTIMIZATION

P2

Overview

Often in water and wastewater system designs, the pumps are oversized because the current conditions are not known or in anticipation of future conditions. This can lead to throttling or bypassing of flows to achieve a desired flow rate. Altering the set-up of the pump system can help reduce power consumption. The following options are discussed:

- Supplementing the pump with a pony pump
- Replacing the pump with 2+ smaller pumps

Application

Supplementing the existing pump with a pony pump would be applicable if there is a typical base flow that is much lower than the full load rating of the existing pump. The existing pump can remain and be used for emergencies/high load flow that is not frequently required.

Replacing the pump with multiple smaller pumps would be applicable if the flow rate varies significantly (multiple values) daily or seasonally. Also, multiple smaller pumps can be an economical option in high static lift situations and/or storage applications that utilize time-of-use electricity rates.

VFDs could be used with either system if the flows vary. See *Fact Sheet M2* for details on VFDs.

Systems with on/off operation (such as filling a reservoir or tank) can benefit from one of the alterations listed above if the pump cycles on and off quickly. Operating a smaller pump for more hours reduces the friction losses in the system, and minimizes the starts/stops of the motor. See *Fact Sheet P4* for further details.

Considerations

Multiple parallel pumps without VFDs require flow changes in incremental "steps," which may not be acceptable for the system. Parallel pumps are as effective in friction-dominated systems as compared to static head-dominated system.

Costs

The initial cost of a pump is typically a small portion of the total life cycle cost. See Case Studies on the following page for examples of energy savings and payback.

Resources

[101] U.S. Department of Energy (DOE) Energy Efficiency and Renewable Energy (EERE). 2006. *Improving Pumping System Performance: A Sourcebook for Industry* – 3. Indications of Oversized Pumps, 8. Multiple Pump Arrangements, & 9. Pony Pumps.

[119] U.S. Department of Energy (DOE) Energy Efficiency and Renewable Energy (EERE) Industrial Technologies Program (ITP). 2006. *Energy Tips: Pumping Systems Tip Sheet #8. Optimize Parallel Pumping Systems*.

CASE STUDIES

PUMP OPTIMIZATION

Technologies	Area	Energy Savings (of process, unless indicated)	Simple Payback (years)	Type	Name	Location	Plant Capacity (MGD)	Average Daily Flow (MGD)	Source	Implemented*
Replace oversized impeller, optimize pumps	Pumping	$1,000/month		WS/WD	Philadelphia Water Department	Philadelphia, PA			55	I
Reduce capacity and head, and trim impeller	Pumping	$9,400/month		WS/WD	Philadelphia Water Department	Philadelphia, PA			55	I
Replace large pumps with smaller pumps	Pumping	$1,300		WS/WD	Philadelphia Water Department	Philadelphia, PA			55	I
Optimize pumping	Pumping		1.7	WWC	City of Milford Sewer System	Milford, CT			97	I
VFD, pony pump	Pumping	37%	7.7	WWTP	Hilo WWTP	Hilo, HI	5	3	89	I
Replace RAS pumps	Activated Sludge		8.1	WWTP	Gloversville-Johnstown Joint WWTP	Johnstown, NY	13.1	6.7	64	R
Replace WAS pumps	Activated Sludge		21	WWTP	Gloversville-Johnstown Joint WWTP	Johnstown, NY	13.1	6.7	64	R
Replace effluent pumps	Effluent Pumping		9.7	WWTP	Gloversville-Johnstown Joint WWTP	Johnstown, NY	13.1	6.7	64	R
Modify high pressure service pumps	High pressure service area pumps		1.3	WWTP	Tonawanda WWTP	Tonawanda, NY	30	20	62	R
Multiple parallel pumps		10-50%							55	G
Correcting oversized pumps		15-25%							55	G
Optimize pumping	Pumping	15-30% typical, up to 70%	0.25-3						87	G
HE pumps	Pumping		1	PWTP					6	G
Correctly sized pumps	Pumping	5-30%							53	G

*I = Implemented, R = Recommended, G = General Value
RAS = return activated sludge, WAS = waste activated sludge; HE = high efficiency; WWTP = wastewater treatment plant; PWTP = potable water treatment plant; WWC = wastewater collection; WS = water supply, WD = water delivery

FACT SHEET

PIPE, VALVE, AND FITTING LOSSES

P3

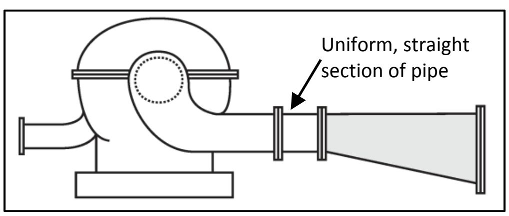
Overview

The pipes, valves, and fittings installed upstream and downstream of a pump can contribute to head losses, air entrapment, and other issues. Avoidable losses/poor configurations should be corrected.

Application

Pipe Configurations

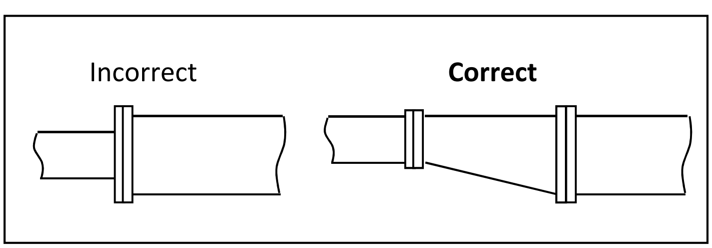
Bends or fittings near the pump can affect the pump performance. There should be a uniform, straight section of pipe leading to and from the pump.

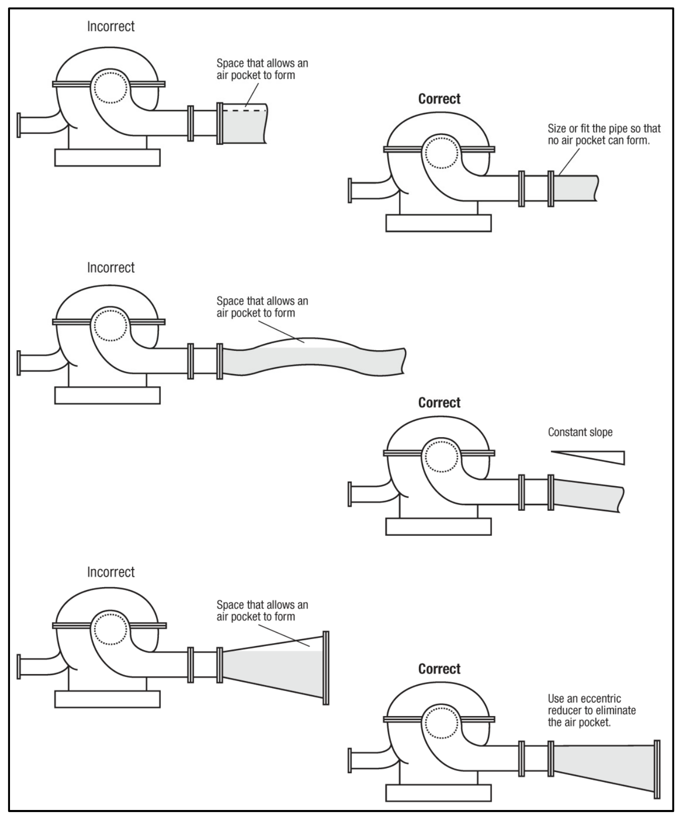


If air becomes entrained in a pipe, it will detrimentally affect the performance of the pump. Any of the situations shown in the figure to the right should be rectified.

Sharp elbows should be avoided, if possible. It may be possible to use a wider radius elbow to reduce pressure losses through the elbow.

Sudden in-line pipe size changes should be avoided; smooth reducers should be used.





Common Pipe Configuration Problems and Solutions[101]

Valves and Fittings

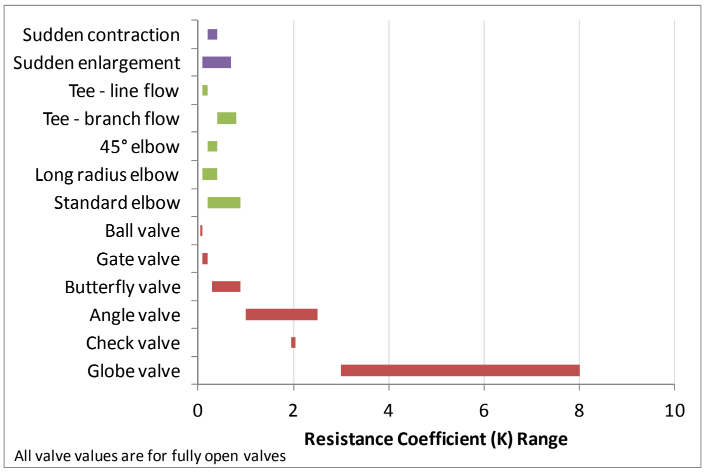
If a control valve is needed at a location, a type should be selected that minimizes the pressure drop (head loss) across the valve. The resistance coefficient (K) is used in the following formula to determine the pressure drop across a valve:

$$\text{Head Loss [ft]} = K \times \frac{V^2}{64.4}$$

$$\text{Where } V = \text{Velocity [ft/sec]}$$
$$K = \text{Resistance Coefficient}$$

The following chart shows resistance coefficient (K) ranges for various fittings. Note that for fittings with large ranges, larger pipes (20") are at the low end of the range and small pipes (2") are at the high end of the range.

P3



If possible, replace high loss components with lower loss components (such as a globe valve with a butterfly valve).

Considerations

A Variable Frequency Drive (VFD) can be installed to meet different system demand flow rates that would require throttling a control valve otherwise. The control valve could possibly then be eliminated from the pumping system or replaced with a control valve with a lower head loss.

Costs

The Department of Energy (DOE) provides a program called Pumping System Assessment Tool (PSAT) to estimate control valve energy losses in terms of energy costs.

Resources

[101] U.S. Department of Energy (DOE) Energy Efficiency and Renewable Energy (EERE). 2006. Improving Pumping System Performance: A Sourcebook for Industry – 4. Piping Configurations to Improve Pumping System Efficiency.

[103] U.S. Department of Energy (DOE) Energy Efficiency & Renewable Energy (EERE) Advanced Manufacturing Office. Pumping System Assessment Tool (PSAT). Available online at: www1.eere.energy.gov/manufacturing/tech_assistance/software_psat.html

[119] U.S. Department of Energy (DOE) Energy Efficiency and Renewable Energy (EERE) Industrial Technologies Program (ITP). 2006. Pumping Systems Tip Sheet #10. Energy Saving Opportunities in Control Valves.

FACT SHEET

HEAD LOSS CONTROL

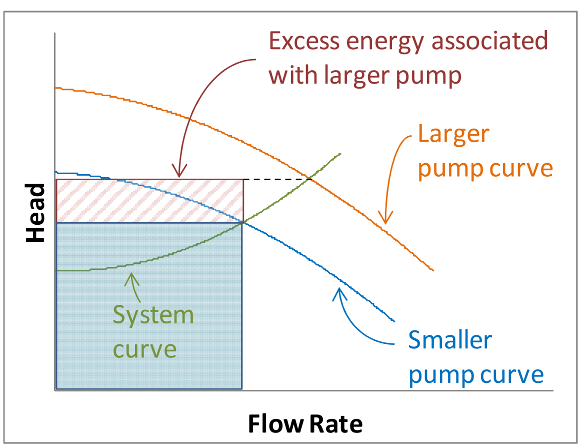
Overview

Running a larger pump or multiple pumps in parallel for less time will use more energy overall than running a smaller pump continuously. This is because frictional head loss increases with increased velocity (flow).

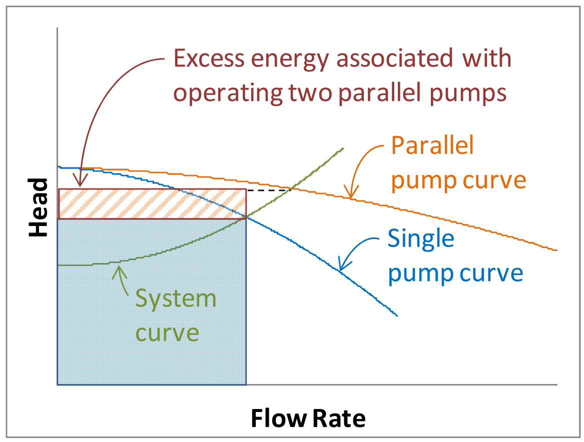
Application

Pumping reduced flows for more hours is applicable in any system that runs periodically for a short amount of time or that cycles on and off.

If possible, a smaller pump should be operated near-continuously during normal operation rather than a larger pump cycling on and off. If necessary, a larger pump can be kept on standby for peak periods. In systems where large flows are required for periodic short amounts of time (such as backwashing a filter), storage may be combined with a smaller pump to achieve energy savings.



Additionally, operating two pumps together in parallel when one pump could provide the necessary flow wastes energy in the same manner. If possible, use storage to reduce required pumping flow rates.



P4

Considerations

Operating a larger pump or two pumps in parallel may be economical if the operator is pumping to storage to avoid peak rates.

The excess energy decreases as the portion of head due to static head, rather than friction, increases. In static head-dominated systems, multiple parallel pumps may provide good operational flexibility.

If the flow varies with time, a VFD may provide flexibility and energy savings without having to replace an existing pump.

Additional Benefits

Minimizing stops and starts of a motor prolongs the life of the motor.

For systems where large flows are required periodically for relatively short amounts of time (such as filter backwashing), combining storage with smaller pumps can reduce the on-peak energy use if the activity that requires the large flow cannot be shifting to off-peak hours.

Resources

[66] Malcolm Pirnie for New York State Energy Research and Development Authority (NYSERDA). 2010. Water and Wastewater Energy Management, Best Practices Handbook: General Best Practices 17 – Pumps: Reduce Pumping Flow and 20 – Filtration: Sequence Backwash Cycles

[119] U.S. Department of Energy (DOE) Energy Efficiency and Renewable Energy (EERE) Industrial Technologies Program (ITP). 2006. Energy Tips, Pumping Systems Tip Sheet #8. Optimize Parallel Pumping Systems.

P4

FACT SHEET

PUMP EFFICIENCY TESTS

Overview

To determine the actual operating performance and energy consumption of an existing pump, a pump test should be performed. The results from pump tests can help operators sequence pumps at a site to reduce energy use. Periodic pump testing can help identify problems before a breakdown occurs or energy bills increase.

Application

All new or existing pumps should have a pump test performed to determine the actual operating performance of the pump. After initial testing, pump tests should be performed every one to three years, depending on the hours of operation and the operating conditions.

If a pump is found to be under-performing (leading to higher energy consumption and higher energy costs), modifications should be made to the pumping system to improve pump performance.

A pump test can indicate the decrease in pump performance due to many different problems, including:

- Excessive seal or bearing wear
- Excessive wear ring deteriorations
- Excessive impeller wear
- An oversized motor
- Alteration of operating conditions (such as the water table on a well lift pump)
- Pump and motor alignment issues
- Internal surface wear due to cavitation

Considerations

A pump test should be performed every one to three years depending on annual usage and the load applied to the pump.

By performing routine pump tests, the overall efficiency of the pump can be monitored over time. This can help determine any issues that may be causing a decrease in pump performance such as impeller wear. Additionally, minor problems leading to a decrease in performance can be determined early and fixed before becoming a serious performance problem.

To accurately determine the overall pumping plant efficiency, accurate flow rate, pumping lift (or inlet pressure), and discharge pressure readings, as well as power consumption must be measured.

Pump tests are valid only for the conditions (flow and lift) measured during the test. For this reason, the pump should be operating as close to "normal" operating conditions as possible during the test.

Costs

Energy savings will depend on the type of pump system modifications to improve the overall pumping plant efficiency.

Additional Benefits

Conducting routine pump tests provides documented historical performance results over time. Historical pump performance documents could be used to plan and schedule maintenance repairs to keep the pump operating at a high efficiency.

P5

Resources

[101] U.S. Department of Energy (DOE) Energy Efficiency and Renewable Energy (EERE). 2006. Improving Pumping System Performance: A Sourcebook for Industry – 4. Piping Configurations to Improve Pumping System Efficiency.

[119] U.S. Department of Energy (DOE) Energy Efficiency and Renewable Energy (EERE) Industrial Technologies Program (ITP). 2006. Energy Tips, Pumping Systems Tip Sheet #4. Test for Pumping System Efficiency & #5 Maintain Pumping Systems Effectively.

P5

FACT SHEET

POTABLE WATER TREATMENT OPTIONS

Overview

The table on the following page is meant to give a general summary of common contaminants in California's raw and treated drinking water and applicable treatment processes. Not all notes are included in the table; refer to the California Department of Drinking Water (DDR) or U.S. EPA rules and guidelines when selecting actual processes for treatment.

The attached handout is from the National Drinking Water Clearinghouse, and provides further information on different treatment technologies for small water systems.

Resources

[120]California Code of Regulations. 2014. Drinking Water-Related Regulations. CCR Title 17 and 22. Available online at: http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/lawbook/dwregulations-2014-07-01.pdf.

[128]Jensen, A., V.B., Darby, J.L., Seidel, C. & Gorman, C. 2012. Drinking Water Treatment for Nitrate. Technical Report 6 in: Addressing Nitrate in California's Drinking Water with a Focus on Tulare Lake Basin and Salinas Valley Groundwater: Chapter 2 – Non-Treatment Options for Nitrate Contaminated Potable Water. Report for the State Water Resources Control Board Report to the Legislature. Center for Watershed Sciences, University of California, Davis. Available online at: http://groundwaternitrate.ucdavis.edu/files/139107.pdf

[132]U.S. EPA. 1998. Small System Compliance Technology List for the NonMicrobial Contaminants Regulated Before 1996. EPA-815-R-98-002. Available online at: http://www.epa.gov/ogwdw/standard/tlstnm.pdf.

[133]U.S. EPA. 1998. Small System Compliance Technology List for the Surface Water Treatment Rule and Total Coliform Rule. EPA-815-R-98-001. Available online at: http://www.epa.gov/ogwdw/standard/tlisttcr.pdf.

[134]U.S. EPA. 1998. Variance Technology Findings for Contaminants Regulated Before 1996. *Congress 2007 proceedings*. EPA-815-R-98-003. Available online at: http://www.epa. gov/ogwdw/standard/varfd.pdf.

Q1

Q1

Treatment Process	Complexity (if identified)	Arsenic	Fluoride	Nitrate	Per-chlorate	Gross Alpha Activity	Uranium	PCE	TCE	DBCP	Carbon Tetra-chloride	MTBE	TCR	Crypto	Turbidity	TTHMs
Ion Exchange	Intermediate (PUO – Basic)	BAT	BAT	BAT	BAT		BAT									
Electrodialysis / EDR	Basic / Intermediate	BAT		BAT		SSCT										
Activated Alumina	Advanced	BAT	BAT			SSCT	SSCT									
Lime Softening	Advanced	BAT[1]				SSCT	BAT[2]									
Granular Activated Carbon	Basic							BAT	BAT	BAT	BAT					BAT
Packed Tower Aeration	Intermediate							BAT	BAT	BAT	BAT	BAT	BAT			
Biological Fluidized Bed Reactor					BAT											
Enhanced Coagulation																BAT
Enhanced Softening																BAT
Coagulation / Filtration	Advanced	BAT[1]				SSCT	BAT						Yes	ACE	Yes	
Oxidation Filtration		BAT														
Conventional Filtration	Advanced												Yes	EPA	Yes	
Direct Filtration	Advanced												Yes	EPA	Yes	
Slow Sand Filtration	Basic												Yes	EPA	Yes	
Diatomaceous Earth Filtration	Intermediate												Yes	EPA	Yes	
Reverse Osmosis	Advanced (PUO – Basic)	BAT	BAT	BAT		BAT	BAT[2]						Yes	EPA	Yes	
Microfiltration	Basic / Intermediate												Yes	EPA	Yes	
Ultrafiltration	Basic / Intermediate												Yes	EPA	Yes	
Nanofiltration	Intermediate / Advanced												Yes	EPA	Yes	
Bag and Cartridge Filters	Basic												Yes	EPA	Yes	
Contact Clarification													Yes	Yes	Yes	
Pressure Filters	Basic												Yes	Yes	Yes	
Disinfection													EPA	ACE		
Ultraviolet	Basic															
UV Variations	Varies															
Ozone	Intermediate															
Chlorine	Basic															
Chloramines	Intermediate															
On-Site Oxidant	Basic															
Chlorine Dioxide	Intermediate															

[1] Not BAT for systems < 500 connections
[2] Not BAT for systems with population < 500
BAT = Best Available Technology, identified in: California Code of Regulations. 2014. Title 17 and Title 22: California Regulations Related to Drinking Water.
EPA = BAT identified by the U.S. EPA for small systems
SSCT = Small system compliant technology identified by the U.S. EPA
ACE = Treatment recommended in: U.S. Army Corps of Engineers. 1999. Design of Small Water Systems. Engineer Manual 1110-2-503.
Yes = Treatment option is generally accepted as effective at reducing contaminant

Tech Brief

Treatment Technologies for Small Drinking Water Systems

To ease many of the demands placed on small systems, the 1996 Safe Drinking Water Act amendments require the U.S. Environmental Protection Agency (EPA) to evaluate affordable technologies and address existing and future regulations, which establish a maximum contaminant level or treatment technique.

The following tables are taken from three EPA guidance documents: EPA-815-R-98-001, *Small System Compliance Technology List for the Surface Water Treatment Rule and Total Coliform Rule*; EPA-815-R-98-002, *Small System Compliance Technology List for the Non-Microbial Contaminants Regulated Before 1996*; and EPA-815-R-98-003, *Variance Technology Findings for Contaminants Regulated Before 1996*.

For information about the availability of these guidance and supporting documents, please contact the Safe Drinking Water Hotline: phone (800) 426-4791, fax (703) 285-1101, or e-mail *hotline-sdwa@epamail.epa.gov*.

Surface Water Treatment Rule Compliance Technologies for Disinfection

Unit technology	Limitations (see footnotes)	Operator skill level required	Raw water quality range and considerations[1]	Removals: Log *Giardia* & Log Virus w/CT's indicated in ()[1]
Free Chlorine	(a, b)	Basic	Better with high quality. High iron or manganese may require sequestration or physical removal.	3 log (104) & 4 log (6).
Ozone	(c, d)	Intermediate	Better with high quality. High iron or manganese may require sequestration or physical removal.	3 log (1.43) & 4 log (1.0).
Chloramines	(e)	Intermediate	Better with high quality. Ammonia dose should be tempered by natural ammonia levels in water.	3 log (1850) & 4 log (1491).
Chlorine Dioxide	(f)	Intermediate	Better with high quality.	3 log (23) & 4 log (25).
Onsite Oxidant Generation	(g)	Basic	Better with high quality.	Research pending on CTvalues. Use free chlorine.
Ultraviolet (UV) Radiation	(h)	Basic	Relatively clean source water required. Iron, natural organic matter and turbidity affect UV dose.	1 log *Giardia* (80-120) & 4 log viruses (90-140) mW/sec/cm2 doses in parentheses [2].

1 CT(Concentration × Time), in mg-min/L, based upon 1989 Surface Water Treatment Rule Guidance Manual. Temp. 10 C, mid-pH range, unless otherwise indicated.

2 UV dose is product of mW/cm2 (intensity) x sec (time); bases of viral inactivation ranges are rotavirus and MS–2 tests.

Limitations Footnotes

a. Providing adequate CT(time/storage) may be a problem for some supplies.
b. Chlorine gas requires special caution in handling and storage, and operator training.
c. Ozone leaks represent hazard: air monitoring required.
d. Ozone used as primary disinfectant (i.e., no residual protection).
e. Long CT. Requires care in monitoring of ratio of added chlorine to ammonia.
f. Chlorine dioxide requires special storage and handling precautions.
g. Oxidants other than chlorine not detected in solution by significant research effort. CTshould be based on free chlorine until new research determines appropriate CTvalues for electrolyzed salt brine.
h. No disinfectant residual protection for distributed water.

Surface Water Treatment Rule Compliance Technology for Filtration

Unit technology	Limitations (see footnotes)	Operator skill level required	Raw water quality range and considerations[1]	Removals: Log *Giardia* & Log Virus
Conventional Filtration (includes dual-stage and dissolved air flotation)	(a)	Advanced	Wide range of water quality. Dissolved air flotation is more applicable for removing particulate matter that doesn't readily settle: algae, high color, low turbidity—up to 30-50 nephelometric turbidity units (NTU) and low-density turbidity.	2-3 log *Giardia* & 1 log viruses.
Direct Filtration (includes in-line filtration)	(a)	Advanced	High quality. Suggested limits: average turbidity 10 NTU; maximum turbidity 20 NTU; 40 color units; algae on a case-by-case basis.[1]	0.5 log *Giardia* & 1–2 log viruses (1.5—2 log *Giardia* w/coagulation).
Slow Sand Filtration	(b)	Basic	Very high quality or pretreatment. Pretreatment required if raw water is high in turbidity, color, and/or algae.	4 log *Giardia* & 1–6 log viruses.
Diatomaceous Earth Filtration	(c)	Intermediate	Very high quality or pretreatment. Pretreatment required if raw water is high in turbidity, color, and/or algae.	Very effective for *Giardia*; low bacteria and virus removal.
Reverse Osmosis	(d, e, f)	Advanced	Requires prefiltrations for surface water—may include removal of turbidity, iron, and/or manganese. Hardness and dissolved solids may also affect performance.	Very effective (cyst and viruses).
Nanofiltration	(e)	Intermediate	Very high quality of pretreatment. See reverse osmosis pretreatment.	Very effective (cyst and viruses).
Ultrafiltration	(g)	Basic	High quality or pretreatment.	Very effective *Giardia*,>5—6.
Microfiltration	(g)	Basic	High quality or pretreatment required.	Very effective *Giardia*,>5—6 log; Partial removal viruses.
Bag Filtration	(g, h, i)	Basic	Very high quality or pretreatment required, due to low particulate loading capacity. Pretreatment if high turbidity or algae.	Variable *Giardia* removals & disinfection required for virus credit.
Cartridge Filtration	(g, h, i)	Basic	Very high quality or pretreatment required, due to low particulate loading capacity. Pretreatment if high turbidity or algae.	Variable *Giardia* removals & disinfection required for virus credit.
Backwashable Depth Filtration	(g, h, i)	Basic	Very high quality or pretreatment required, due to low particulate loading capacity. Pretreatment if high turbidity or algae.	Variable *Giardia* removals & disinfection required for virus credit.

1 National Research Council (NRC), Committee on Small Water Supply Systems. "Safe Water From Every Tap: Improving Water Service to Small Communities." National Academy Press, Washington, D.C. 1997.

2 Adham, S.S., Jacangelo, J.G., and Laine, J.M. "Characteristics and Costs of MF and UF Plants." *Journal American Water Works Association*, May 1996.

Limitations Footnotes

a. Involves coagulation. Coagulation chemistry requires advanced operator skill and extensive monitoring. A system needs to have direct full-time access or full-time remote access to a skilled operator to use this technology properly.
b. Water service interruptions can occur during the periodic filter-to-waste cycle, which can last from six hours to two weeks.
c. Filter cake should be discarded if filtration is interrupted. For this reason, intermittent use is not practical. Recycling the filtered water can remove this potential problem.
d. Blending (combining treated water with untreated raw water) cannot be practiced at risk of increasing microbial concentration in finished water.
e. Post-disinfection recommended as a safety measure and for residual maintenance.
f. Post-treatment corrosion control will be needed prior to distribution.
g. Disinfection required for viral inactivation.
h. Site-specific pilot testing prior to installation likely to be needed to ensure adequate performance.
i. Technologies may be more applicable to system serving fewer than 3,300 people.

Compliance Technology For The Total Coliform Rule

40 CFR 141.63(d)–Best technologies or other means to comply (Complexity level indicated)	Comments/Water quality concerns
Protecting wells from contamination, i.e., placement and construction of well(s) (Basic).	Ten State Standards and other standards (AWWA A100–90) apply; interfacing with other programs essential (e.g., source water protection program).
Maintenance of a disinfection residual for distribution system protection (Intermediate).	Source water constituents may affect disinfection: iron, manganese, organics, ammonia, and other factors may affect dosage and water quality. Total Coliform Rule (TCR) remains unspecific on type/amount of disinfectant, as each type differs in concentration, time, temperature, pH, interaction with other constituents, etc.
Proper maintenance of distribution system: pipe repair/replacement, main flushing programs, storage/reservoir and operation and maintenance (O&M) programs (including cross-connection control/backflow prevention), and maintenance of positive pressure throughout (Intermediate).	O&M programs particularly important for smaller systems needing to maintain water purity. States may vary on distribution protection measures. See also EPA's Cross-Connection Control Manual (#EPA 570/9-89-077).
Filtration and/or disinfection of surface water or other groundwater under direct influence; or disinfection of groundwater (Basic thru Advanced).	Same issues as cited above under maintaining disinfection residual; pretreatment requirements affect complexity of operation. Refer to Surface Water Treatment Rule Compliance Technology List; and other regulations under development.
Groundwaters: Compliance with State Wellhead Protection Program (Intermediate).	EPA/State Wellhead Protection Program implementation (per §1428 SDWA): may be used to assess vulnerability to contamination, and in determination of sampling and sanitary survey frequencies.

Technologies for Inorganic Contaminants

Unit Technology	Limitations (see footnotes)	Operator skill level required	Raw water quality range
1. Activated Alumina	(a)	Advanced	Groundwaters, competing anion concentrations will affect run length.
2. Ion Exchange (IO)		Intermediate	Groundwaters with low total dissolved solids, competing ion concentrations will affect run length.
3. Lime Softening	(b)	Advanced	Hard ground and surface waters.
4. Coagulation/Filtration	(c)	Advanced	Can treat wide range of water quality.
5. Reverse Osmosis (RO)	(d)	Advanced	Surface water usually require prefiltration.
6. Alkaline Chlorination	(e)	Basic	All groundwaters.
7. Ozone Oxidation		Intermediate	All groundwaters.
8. Direct Filtration		Advanced	Needs high raw water quality.
9. Diatomaceous earth filtration		Intermediate	Needs very high raw water quality.
10. Granular Activated Carbon		Basic	Surface waters may require prefiltration.
11. Electrodialysis Reversal		Advanced	Requires prefiltration for surface water.
12. Point of Use (POU)-IO	(f)	Basic	Same as Technology #2.
13. POU-RO	(f)	Basic	Same as Technology #5.
14. Calcium Carbonate Precipitation	(g)	Basic	Waters with high levels of alkalinity and calcium.
15. pH and alkalinity adjustment (chemical feed)	(g)	Basic	All ranges.
16. pH and alkalinity adjustment (limestone contactor)	(h)	Basic	Waters that are low in iron and turbidity. Raw water should be soft and slightly acidic.
17. Inhibitors		Basic	All ranges.
18. Aeration	(i)	Basic	Waters with moderate to high carbon dioxide content.

Limitations Footnotes

a. Chemicals required during regeneration and pH adjustments may be difficult for small systems to handle.
b. Softening chemistry may be too complex for small systems.
c. It may not be advisable to install coagulation/filtration solely for inorganics removal.
d. If all of the influent water is treated, post-treatment corrosion control will be necessary.
e. pH must exceed pH 8.5 to ensure complete oxidation without build-up of cyanogen chloride.
f. When POU devices are used for compliance, programs for long-term operation, maintenance, and monitoring must be provided by water utility to ensure proper performance.
g. Some chemical feeds require high degree of operator attention to avoid plugging.
h. This technology is recommended primarily for the smallest size category.
i. Any of the first five aeration technologies listed for volatile organic contaminants can be used.

Technologies for Volatile Organic Contaminants

Unit technology	Limitations (see footnotes)	Operator skill level required	Raw water quality range[1]
1. Packed Tower Aeration (PTA)	(a)	Intermediate	All groundwaters.
2. Diffused Aeration	(a, b)	Basic	All groundwaters.
3. Multi-Stage Bubble Aerators	(a, c)	Basic	All groundwaters.
4. Tray Aeration	(a, d)	Basic	All groundwaters.
5. Shallow Tray Aeration	(a, e)	Basic	All groundwaters.
6. Spray Aeration	(a, f)	Basic	All groundwaters.
7. Mechanical Aeration	(a, g)	Basic	All groundwaters.
8. Granular Activated Carbon (GAC)	(h)	Basic	All groundwaters.

1 National Research Council (NRC). "Safe Water from Every Tap: Improving Water Service to Small Communities." National Academy Press. Washington, DC. 1997.

Limitations Footnotes

a. Pretreatment for the removal of microorganisms, iron, manganese, and excessive particulate matter may be needed. Post-treatment disinfection may have to be used.
b. May not be as efficient as other aeration methods because it does not provide for convective movement of the water thus limiting air-water contact. It is generally used only to adapt exisiting plant equipment.
c. These units are highly efficient; however, the efficiency depends upon the air-to-water ratio.
d. Costs may increase if a forced draft is used. Slime and algae growth can be a problem but can be controlled with chemicals such as copper sulfate or chlorine.
e. These units require high air-to-water ratios (100-900 m3/m3).
f. For use only when low removal levels are needed to reach a maximum contaminant level (MCL) because these systems may not be as energy efficient as other aeration methods because of the contacting system.
g. For use only when low removal levels are needed to reach an MCLbecause these systems may not be as energy efficient as other aeration methods because of the contacting system. The units often require large basins, long residence times, and high energy inputs, which may increase costs.
h. See the Synthetic Organic Compounds (SOC) compliance technology table for limitation regarding these technologies.

Technologies for Synthetic Organic Compounds

Unit technology	Limitations (see footnotes)	Operator skill level required[1]	Raw water quality range and considerations[1]
1. Granular Actived Carbon (GAC)		Basic	Surface water may require prefiltration.
2. Point of Use GAC	(a)	Basic	Surface water may require prefiltration.
3. Powdered Activated Carbon	(b)	Intermediate	All waters.
4. Chlorination	(c)	Basic	Better with high quality waters.
5. Ozonation	(c)	Basic	Better with high quality waters.
6. Packed Tower Aeration (PTA)	(d)	Intermediate	All groundwaters.
7. Diffused Aeration	(d, e)	Basic	All groundwaters.
8. Multi-Stage Bubble Aerators	(d, f)	Basic	All groundwaters.
9. Tray Aeration	(d, g)	Basic	All groundwaters.
10. Shallow Tray Aeration	(d, f)	Basic	All groundwaters.

1 National Research Council (NRC). "Safe Water from Every Tap: Improving Water Service to Small Communities." National Academy Press. Washington, DC. 1997.

Limitations Footnotes

a. When POU devices are used for compliance, programs for long-term operation, maintenance, and monitoring must be provided by water utility to ensure proper performance.
b. Most applicable to small systems that already have a process train including basins mixing, precipitation or sedimentation, and filtration. Site specific design should be based on studies conducted on the system's particular water.
c. See the Surface Water Treatment Rule compliance technology tables for limitations associated with this technology.
d. Pretreatment for the removal of microorganisms, iron, manganese, and excessive particulate matter may be needed. Post-treatment disinfection may have to be used.
e. May not be as efficient as other aeration methods because it does not provide for convective movement of the water thus limiting air-water contact. It is generally used only to adapt existing plant equipment.
f. These units are highly efficient; however, the efficiency depends upon the air-to-water ratio.
g. Forces may increase if a forced draft is used.

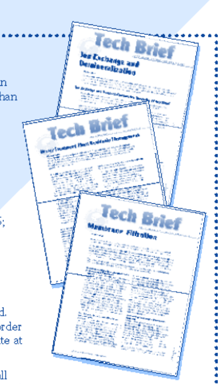
Technologies for Radionuclides

Unit technology	Limitations (see footnotes)	Operator skill level required[1]	Raw water quality range and considerations[1]
1. Ion Exchange (IO)	(a)	Intermediate	All groundwaters.
2. Point of Use (POU) IO	(b)	Basic	All groundwaters.
3. Reverse Osmosis (RO)	(c)	Advanced	Surface waters, usually require prefiltration.
4. POU RO	(b)	Basic	Surface waters, usually require prefiltration.
5. Lime Softening	(d)	Advanced	All waters.
6. Green Sand Filtration	(e)	Basic	
7. Co-precipitation with Barium Sulfate	(f)	Intermediate to Advanced	Groundwaters with suitable water quality.
8. Electrodialysis/Electrodialysis Reversal		Basic to Intermediate	All groundwaters.
9. Pre-formed Hydrous Manganese Oxide Filtration	(g)	Intermediate	All groundwaters.

1 National Research Council (NRC). "Safe Water from Every Tap: Improving Water Service to Small Communities." National Academy Press. Washington, DC. 1997.

Limitations Footnotes

a. The regeneration solution contains high concentrations of the contaminant ions. Disposal options should be carefully considered before choosing this technology.
b. When POU devices are used for compliance, programs for long-term operation, maintenance, and monitoring must be provided by water utility to ensure proper performance.
c. Reject water disposal options should be carefully considered before choosing this technology. See other RO limitations described in the Surface Water Treatment Rule Compliance Technologies Table.
d. The combination of variable source water quality and the complexity of the chemistry involved in lime softening may make this technology too complex for small surface water systems.
e. Removal efficiencies can vary depending on water quality.
f. This technology may be very limited in application to small systems. Since the process requires static mixing, detention basins, and filtration; it is most applicable to systems with sufficiently high sulfate levels that already have a suitable filtration treatment train in place.
g. This technology is most applicable to small systems that already have filtration in place.



The National Drinking Water Clearinghouse assists small communities by collecting, developing, and providing timely information relevant to drinking water issues.

(800) 624-8301/(304) 293-4191
http://www.ndwc.wvu.edu

National Drinking Water Clearinghouse
West Virginia University
P.O. Box 6064
Morgantown, WV 26506-6064

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Treatment Technologies for Small Drinking Water Systems

Introduction

Small systems still face difficulties in meeting the requirements of the Safe Drinking Water Act (SDWA) because many technologies available to large systems may be too expensive or complicated for small systems to consider. Furthermore, trained operators and maintenance personnel may not always be available or affordable, leading to standards violations.

Overview of Some Treatment Technologies Used by Small Systems

When the SDWA was reauthorized in 1996, it addressed small system drinking water concerns and required the U.S. Environmental Protection Agency (EPA) to assess treatment technologies relevant to small systems serving fewer than 10,000 people. With this requirement, the SDWA also identified two classes of technologies:

- compliance technologies—which refer to affordable technologies or other treatment techniques (TT) that comply with the maximum contaminant level (MCL) and to technologies that satisfy a TT requirement. Options include package plants or modular systems, and point-of-entry (POE) or point-of-use (POU) treatment; and
- variance technologies—which refer to technologies that must reduce contaminants to levels that protect public health. These technologies may not achieve compliance with the MCL or TT requirement, but must achieve the maximum reduction or inactivation efficiency affordable to a system, considering its size and the quality of the source water.

With small systems' needs in mind, the National Research Council (NRC) recently published the results of a study—*Safe Water From Every Tap: Improving Water Service to Small Communities*—which found that continuous technical and financial assistance is still needed to help more than 54,000 small systems comply with changing regulations. In addition, the NRC study discussed some water treatment technologies that small systems may use to provide safe drinking water to their customers. These treatment technologies are also explained separately through Tech Briefs, four-page water treatment fact sheets, offered by the National Drinking Water Clearinghouse (NDWC). These fact sheets are available online at *http://www.ndwc.wvu.edu* or by calling (800) 624-8301.

1. Disinfection

The Surface Water Treatment Rule (SWTR) requires public water systems to disinfect water obtained from surface water supplies or groundwater sources under the influence of surface water. Primary methods of disinfection are chlorine gas, chloramines, ozone, ultraviolet light, chlorine dioxide, and hypochlorite.

Chlorine (gas)

Chlorine gas removes almost all microbial pathogens and is appropriate as both a primary and secondary disinfectant. Chlorine is a dangerous gas that is lethal at concentrations as low as 0.1 percent air by volume. Adequate mixing and contact time must be provided after injection to ensure complete disinfection of pathogens.

Hypochlorites

Sodium hypochlorite is available as a solution in concentrations of five to 15 percent chlorine, but is more expensive than chlorine gas. Sodium hypochlorite is easier to handle than gaseous chlorine or calcium hypochlorite, but it is very corrosive and must be kept away from equipment that can be damaged by corrosion.

Calcium hypochlorite is a solid white substance, which is 65 percent available chlorine and dissolves easily in water. It is a corrosive material with a strong odor that must be kept away from organic materials, such as wood, cloth, and petroleum products because of the dangers of fire or explosion. Calcium hypochlorite readily absorbs moisture, forming chlorine gas so shipping containers must be emptied completely or carefully resealed.

Chloramines

Chloramines are formed when water containing ammonia is chlorinated or when ammonia is added to water containing chlorine. An effective bactericide that produces fewer disinfection byproducts, chloramine is generated onsite. It is a weak disinfectant and is much less effective against viruses or protozoa than free chlorine. Chloramine is appropriate for use as a secondary disinfectant to prevent bacterial regrowth in a distribution system. Nitrogen trichloride appears to be the only detrimental reaction. Adequate contact and mixing time must be provided.

Ozonation

Ozone is a powerful oxidizing and disinfecting agent formed by passing dry air through a system of high voltage electrodes. Requiring shorter contact time and a smaller dosage than chlorine, ozone is widely used as a primary disinfectant. Ozone does not directly produce halogenated organic materials unless a bromide ion is present. A secondary disinfectant, usually chlorine, is required because ozone does not maintain an adequate residual in water. The capital costs of ozonation systems may be high and operation and maintenance are relatively complex.

Ultraviolet Light

Ultraviolet (UV) radiation, which is generated by a special lamp, penetrates the cell wall of an organism, rendering it unable to reproduce. UV radiation effectively destroys bacteria and viruses. As with ozone, a secondary disinfectant must be used to prevent regrowth of microorganisms. UV radiation:

- is readily available,
- produces no known toxic residuals,
- requires short contact times, and
- is easy to operate and maintain.

Conventional UV radiation may not inactivate *Giardia lamblia* or *Cryptosporidium* cysts in a cost-effective way, and should be used only by groundwater systems not directly influenced by surface water and where there is virtually no risk of protozoan cyst contamination. UV radiation is unsuitable for water with high levels of suspended solids, turbidity, color, or soluble organic matter. However, microorganisms can be killed without generating byproducts of chemical oxidation or halogenation.

Chlorine Dioxide

Chlorine dioxide, although a powerful oxidant, may be more difficult to handle than other forms of chlorine. Chlorine dioxide requires trained staff to manage its use and is so reactive that it may not provide a residual disinfectant in the distribution system. Photochemical decomposition of chlorine dioxide in reservoirs may increase chlorate concentrations, and other factors, including the generation process used and water pH, can affect chlorate and chlorite levels.

2. Filtration

Federal and state laws require all surface water systems and systems under the influence of surface water to filter their water. Filtration methods include slow and rapid sand filtration, diatomaceous earth filtration, direct filtration, membrane filtration, and cartridge filtration

Slow Sand Filtration

The filter consists of a bed of fine sand approximately three to four feet deep supported by a one-foot layer of gravel and an underdrain system. It is a low-cost, simple to operate, reliable technology, and it is able to achieve greater than 99.9 percent *Giardia* cyst removal. Slow sand filtration is not suitable for water with high turbidity. The filter surface requires maintenance. Extensive land is required due to low-flow operation. Biological processes and chemical/physical processes common to various types of filters occur on the surface of the filter bed. Slow sand filters do not require coagulation/flocculation and may not require sedimentation.

Diatomaceous Earth Filtration

Diatomaceous earth (DE) filtration, also known as precoat or diatomite filtration, relies on a layer of diatomaceous earth approximately 1/8-inch thick placed on a septum or filter element. Septums may be placed in pressure vessels or operated under a vacuum in open vessels. The filters are simple to operate and effective in removing cysts, algae, and asbestos. They have been chosen for projects with limited initial capital, and for emergency or standby capacity to service large seasonal increases in demand. This filter is most suitable for water with low bacterial counts and low turbidity. Coagulant and filter aids are required for effective virus removal. Since chemical coagulation is not required, small water systems have used DE filtration for many years.

Direct Filtration

Direct filtration systems are similar to conventional systems, but omit sedimentation. Effective direct filtration performance ranges from 90 to 99 percent for virus removal and from 10 to 99.99 percent for *Giardia* removal. Coagulation must be included for *Giardia* removal. Direct filtration is often used with steel pressure vessels to maintain the pressure in a water line to avoid repumping after filtration. Direct filtration is only applicable for systems with high quality and seasonally consistent influent supplies. Direct filtration requires advanced operator skill and has frequent monitoring requirements.

Membrane Filtration

More stringent water quality regulations and inadequate water resources are making membrane technology increasingly popular as an alternative treatment technology for drinking water. Capital, operation, and maintenance costs continue to decline, making membrane processes more viable.

Nanofiltration (NF) : This membrane process employs pressures between 75 to 150 pounds per square inch (psi) for operation. While it provides removal of ions contributing to hardness (i.e., calcium and magnesium), the technology is also very effective for removing color and disinfection byproducts precursors.

Ultrafiltration (UF) : Operational pressures range from 10 to 100 psi, depending upon the application. UF may be employed for removal of some organic materials from freshwater, and may be used for liquid/solid separation.

Microfiltration (MF) : A major difference between MF and UF is membrane pore size. The primary applications for this membrane process are particulate and microbial removal.

Bag Filtration

Bag filtration systems are based on physical screening processes. If the pore size of the bag filter is small enough, parasite removal will occur. Unless the quality of the raw water precludes the need for pretreatment, EPA recommends pretreatment of the raw water using sand or multimedia filters, followed by preliminary bag or cartridge filtration, and the use of micron filters as final filters to increase particulate removal efficiencies and to extend the life of the filter.

Cartridge Filtration

Cartridge filters are an emerging technology suitable for removing microbes and turbidity. These filters are easy to operate and maintain, making them suitable for treating low-turbidity influent. They can become fouled relatively quickly and must be replaced with new units. Although these filter systems are operationally simple, they are not automated and can require relatively large operating budgets. A disinfectant is recommended to prevent surface-fouling microbial growth on the cartridge filters and to reduce microbial pass-through.

Backwashable Depth Filtration

Backwashable depth filters operate in part like cartridge filters. This method filters uncoagulated water and is designed to be backwashed when terminal head loss is attained or turbidity breakthrough occurs.

3. Corrosion Control

Corrosion in a system can be reduced by adjusting pH and alkalinity, softening the water, and changing the level of dissolved oxygen. Any corrosion adjustment program should include monitoring as water characteristics change over time.

pH Adjustment : Operators can promote the formation of a protective calcium carbonate coating (scale) in water lines by adjusting pH, alkalinity, and calcium levels.

Lime Softening: Lime softening affects lead's solubility by changing the water's pH and carbonate levels. Hydroxide ions are then present, and they decrease metal solubility by promoting the formation of solids that protect the surface of the pipe.

Dissolved Oxygen Levels: The presence of excessive dissolved oxygen increases water's corrosive activity. However, removing oxygen from water is not practical because of the expense. The following strategies may be used to minimize the presence of oxygen:

- exclude the aeration process in groundwater treatment,
- increase lime softening,
- extend the detention periods for treated water in reservoirs, or
- use the correct size water pumps in the treatment plant to minimize the introduction of air during pumping.

4. Ion Exchange and Demineralization

Ion exchange and membrane processes are becoming used extensively in water and wastewater treatment. Ion exchange is primarily used to remove of hardness ions, such as magnesium and calcium, and for water demineralization. Reverse osmosis and electrodialysis, both membrane processes, remove dissolved solids from water using membranes.

Ion Exchange (IO)

IO units can be used to remove any charged (ionic) substance from water, but are usually used to remove hardness and nitrate from groundwater. Ion exchange effectively removes more than 90 percent of barium, cadmium, chromium, silver, radium, nitrites, selenium, arsenic, and nitrate. Ion exchange is usually the best choice for removing radionuclides.

Reverse Osmosis (RO)

RO systems are compact, simple to operate, and require minimal labor, making them suitable for small systems where there is a high degree of seasonal fluctuation in water demand. RO can effectively remove nearly all inorganic contaminants from water. Properly operated units will attain 96 percent removal rates. RO can also effectively remove radium, natural organic substances, pesticides, and microbiological contaminants. RO is particularly effective when used in series. Water passing through multiple units can achieve near zero effluent contaminant concentrations.

Electrodialysis

Electrodialysis is very effective in removing fluoride and nitrate and can also remove barium, cadmium, and selenium.

Some of the advantages are:

- all contaminant ions and most dissolved non-ions are removed,
- it is relatively insensitive to flow and total dissolved solids (TDS)level, and
- it may have low effluent concentration.

Some of the limitations are:

- high capital and operating costs,
- high level of pretreatment required,
- reject stream is 20 to 90 percent of feed flow, and
- electrodes require replacement.

Activated Alumina

Activated Alumina (AA) is a physical and chemical process in which ions in the feed water are sorbed to an oxidized AA surface. AA is used in packed beds to remove contaminants such as fluoride, arsenic, selenium, silica, and natural organic matter .

5. Organic Removal

The technologies most suitable for organic contaminant removal in drinking water systems are granular activated carbon (GAC) and aeration. GAC has been designated by the EPA as the best available technology (BAT) for synthetic organic chemical removal.

Granular Activated Carbon

Several operational and maintenance factors affect the performance of GAC. Contaminants in the water can occupy GAC adsorption sites, whether they are targeted for removal or not. Also, adsorbed contaminants can be replaced by other contaminants with which GAC has a greater affinity. Therefore, the presence of other contaminants might interfere with the removal of the contaminants of concern.

After a period of months or years, depending on the concentration of contaminants, the surface of the pores in the GAC can no longer adsorb contaminants. The carbon must then be replaced.

Aeration

Aeration, also known as air stripping, mixes air with water to volatilize contaminants (turn them to vapor), which are either released directly to the atmosphere or treated and released. Aeration is used to remove volatile organic chemicals (VOC) and can also remove radon. A small system might be able to use a simple aerator constructed from relatively common materials instead of a specially designed aerator system. Aerators include:

- a system that cascades the water or passes it through a slotted container,
- a system that runs water over a corrugated surface, or
- an airlift pump that introduces oxygen as water is drawn from a well.

Other Aeration Types

Packed Column Aeration (PCA): PCA or packed tower aeration (PTA) is a waterfall aeration process that drops water over a medium within a tower to mix the water with air. The medium is designed to break the water into tiny droplets and to maximize its contact with air bubbles for removal of the contaminant. Air is also blown in from underneath the medium to enhance this process. Packed columns usually operate automatically and need only daily visits to ensure that the equipment is running satisfactorily. Maintenance requirements include servicing pump and blower motors and replacing air filters on the blower.

Diffused Aeration: In a diffused aeration system, a diffuser bubbles air through a contact chamber for aeration. The diffuser is usually located near the bottom of the chamber where pressurized air is introduced. The main advantage of diffused aeration systems is that they can be created from existing structures, such as storage tanks. However, these systems are less effective than PCA and usually are employed only in systems with adaptable existing structures.

Multiple Tray Aeration : Multiple tray aeration directs water through a series of trays made of slats, perforations, or wire mesh. A blower introduces air from underneath the trays. Multiple tray aeration units have less surface area than PCA units and can experience clogging from iron and manganese, biological growth, and corrosion problems. Multiple tray aeration units are readily available from package plant manufacturers.

Shallow Tray Aeration (STA): STAs involve the use of shallow trays and are more efficient than multiple tray aerators. STAs increase the available area of mass transfer; thereby increasing the removal efficiency of most VOCs. However, because of the high air-to-water ratio, greater energy costs may be incurred.

Spray Aeration: Spray aeration is an accepted technology in which the contaminated water is sprayed through nozzles. The small droplets produced expose a large interfacial surface area through which VOCs can migrate from a liquid (water) phase to the gaseous (air) phase. Spray aerators have been used to effectively treat VOCs, but are not energy efficient and need a large operational area.

Mechanical Aeration : Mechanical aeration uses mechanical stirring mechanisms to mix air with the water. These systems can effectively remove VOCs. Mechanical aeration units need large amounts of space because they demand long detention times for effective treatment. As a result, they often require open-air designs, which can freeze in cold climates. However, mechanical aeration systems are easy to operate and are less susceptible to clogging from biological growth than PCA systems.

6. Lime Softening

Lime softening is best suited to groundwater sources, which have relatively stable water quality. The combination of variable source water quality and the complexity of the chemistry of lime softening may make it too complicated for small systems that use surface water sources. Lime softening is unlikely to be suitable for treating groundwater in systems serving 500 or fewer people unless those systems have access to a trained operator who can monitor the treatment process. Either hydrated lime or quicklime may be used in the softening process. The choice depends upon economic factors, such as the relative cost per ton of the two materials as well as the size and equipment of the softening plant.

What are other softening alternatives?

The selection of lime, lime-soda ash, or caustic soda softening is based on cost, TDS criteria, sludge production, carbonate and noncarbonate hardness, and chemical stability. Water containing little or no noncarbonate hardness can be softened with lime alone. Caustic soda softening increases the TDS of treated water, while lime and lime-soda ash softening often decrease TDS. Caustic soda softening produces less sludge than lime and lime-soda ash softening. Caustic soda does not deteriorate during storage, while hydrated lime may absorb carbon dioxide and water during storage, and quicklime may slake in storage causing feeding problems. The final selection is generally based on cost, water quality, and owner and operator preference.

For More Information

Small drinking water systems are more likely to violate SDWA regulations because when MCLs were set, they were based upon systems serving larger metropolitan areas. Thus, small systems must explore innovative technologies that they can afford. The NDWC's RESULTS (Registry of Equipment Suppliers of Treatment Technologies for Small Systems) database houses information related to small drinking water systems. The clearinghouse gathered this information from system operators, drinking water state offices, vendors, and others.

Database searches are available from the NDWC through combinations of site location, vendor name, type of technology, type of contaminant, and system size—and they include contact names and telephone numbers. Consulting engineers, local officials, private owners, and regulators may use RESULTS to understand new technologies that are affordable, appropriate, and reliable. Information in RESULTS may be obtained three ways: access the database through the NDWC's Web site located at http://www.ndwc.wvu.edu; call the NDWC at (800) 624-8301 or (304) 293-4191 and ask a technical assistant to perform a search for you; or order a copy of the RESULTS diskette, available in DOS or Macintosh versions, from the NDWC for a small fee.

BIBLIOGRAPHY

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National Research Council. 1997. Safe Water From Every Tap: Improving Water Service to Small Communities National Academy Press. Washington D.C.

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NDWC Tech Brief: Filtration, item #DWBLPE50.*

NDWC Tech Brief: Corrosion Control, item #DWBLPE52.*

NDWC Tech Brief: Ion Exchange and Demineralization, item #DWBLPE56.*

NDWC Tech Brief: Organics Removal, item #DWBLPE59.*

NDWC Tech Brief: Package Plants, item #DWBLPE63.*

NDWC Tech Brief: Lime Softening, item #DWBLPE67.*

NDWC Tech Brief: Iron and Manganese Removal, item #DWBLPE70.*

NDWC Tech Brief: Membrane Filtration, item #DWBLPE81.*

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* NDWC RESULTS Database: Small Water Systems Technologies report and Tech Briefs are available online at http://www.ndwc.wvu.edu or by calling (800) 624-8301 or (304) 293-4191.

FACT SHEET

POTABLE WATER NON-TREATMENT OPTIONS

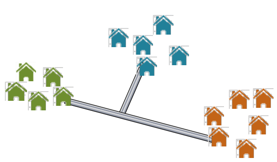
Q2

Overview

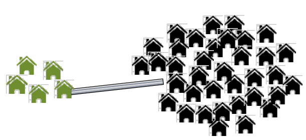
There are a variety of options available that can be used to reach water quality requirements (referred to as maximum contaminant levels, or MCLs). Some are treatment options, which remove or inactivate constituents in the water. These are discussed in **Fact Sheet Q1**. Non-treatment options employ other methods to meet MCLs. These options include:

- Blending – mixing of water from different sources to allow the output flow to meet requirements. For example, if Source 1 had twice the MCL for contaminant Z and Source 2 had no contaminant Z, Source 2 could be blended with up to 50% of Source 1 and meet the MCL.

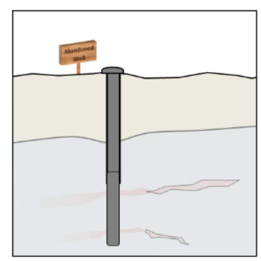
- Consolidation with nearby small towns – consolidation of nearby small towns allows the towns to invest in more expensive (and effective) technology. Often, treatment technologies become significantly less costly (on a per unit of output basis) when the total output increases.



- Connecting to nearby large town – connecting to a nearby large town can allow the small town to receive clean drinking water for significantly less than the cost for the small town to treat the water on its own. Sometimes, however, there is a large initial cost to connect the small town to the large town.

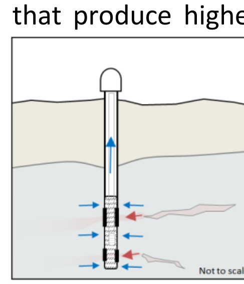


- Abandoning or destroying a contaminated well – when a groundwater well is contaminated, one option is to abandon or destroy the well. This requires adequate capacity from other sources. If it is possible that the groundwater in the well may not be contaminated in the future, or that the water might be treated in the future, the well could be abandoned/inactivated, rather than destroyed. Then, if the contaminant levels change in the future or treatment is installed, the well can be used again. If it is unlikely that the well will ever be used again, the well should be properly destroyed. Properly destroying a well entails covering, sealing, and plugging the well to prevent contaminations and hazardous conditions.



- Building a new well – in some cases, a new groundwater well can be built that will not have the contaminants found in the old well. Careful consideration should be given to the different layers of groundwater found in the new well to reduce contaminant loads in the new well.

- Modifying (partially abandoning) a well – in some cases, a groundwater well can be modified to reduce contaminant loads into the well. This is typically done by capping sections of the well that produce higher contaminant loads. The capacity of the well may be reduced in the process, but the cost can be significantly less than building a new well. See **Fact Sheet Q3** for more information on partially abandoning a well.



Application

Non-treatment options may be applicable if it is possible to find or create a water source that is below the MCLs. If there is not an available source that is below the MCL, treatment options may be necessary to bring water quality to drinking water standards.

Considerations

Blending – if non-compliant groundwater can be blended with surface water to meet MCLs, the added treatment needed for surface water sources should be considered.

Costs

The actual cost of each method varies significantly depending on site conditions (depth of well, distance to nearby town, quality of water, drinking water quality requirements, etc). The Case Study Table on the following page lists a couple example costs. However, these may not be representative of actual cost due to differing conditions.

Resources

[121]Davis, J. 2005. Arsenic in Arizona: Assessing the Economic Cost and Hydrogeologic Feasibility of Nontreatment Options.

[128]Jensen, A., V.B., Darby, J.L., Seidel, C. & Gorman, C. 2012. Drinking Water Treatment for Nitrate. Technical Report 6 in: Addressing Nitrate in California's Drinking Water with a Focus on Tulare Lake Basin and Salinas Valley Groundwater: Chapter 2 – Non-Treatment Options for Nitrate Contaminated Potable Water. Report for the State Water Resources Control Board Report to the Legislature. Center for Watershed Sciences, University of California, Davis. Available online at: http://groundwaternitrate.ucdavis.edu/files/139107.pdf

[135]U.S. EPA. Radionuclides Compliance Help: Learn. Available online at: http://www.epa.gov/ogwdw/radionuclides/pdfs/learn.pdf.

Q2

CASE STUDIES

POTABLE WATER NON-TREATMENT OPTIONS

Method	Contaminant(s)	Cost	Location	Source	Implemented*
Destruction of well	Nitrate	$15,000 (300-400' well)	California	128	E
Construction of new well	Arsenic	$6,800 - $483,300 (6" diameter, 250' deep – 16" diameter, 1500' deep, basin fill aquifer)	Arizona	121	S
Partial abandonment	Arsenic	$2,500 – $6,200 (6" casing for 400-500' – 20" casing 500-600')	Arizona	121	S

*E = Example Value, S = Survey of Contractors and Drillers

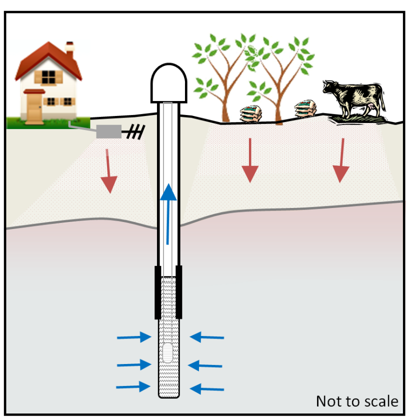
FACT SHEET

PARTIAL ABANDONMENT OF A WELL

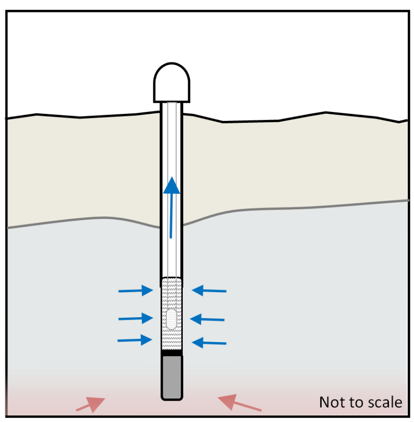
Overview

Partial abandonment of a well (also known as selective sealing or well rehabilitation) is a method that can be used on wells to minimize the introduction of contaminants into the well water. Contaminants are typically found in certain regions of the water table. For example:

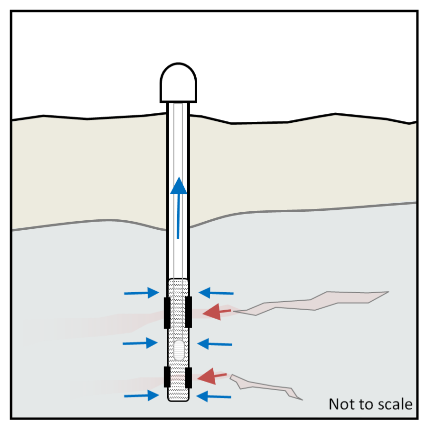
- Nitrate – a nutrient that is the result of fertilizers applied to the land surface, leaching from septic tanks, and sewage – is typically found at higher concentrations near the water table. Further, denitrification (conversion from nitrate to nitrogen gas) occurs in anoxic (deep) aquifers.
- Arsenic – a trace element that is usually the result of erosion from natural deposits – is typically found in deeper groundwater aquifers. In some cases, the concentration may increase with depth. On other cases, there may be a "pocket" source, causing a higher concentration around the "pocket".
- Uranium – a radionuclide that is usually the result of erosion of natural deposits – is sometimes found at higher concentrations near the water table. This is because bicarbonates, which can be introduced from agricultural activities, leach uranium from sediments and move it downward to the water table.
- Radium, – a radionuclide that is usually the result of erosion of natural deposits – is typically found in "pockets" from shaley layers in the groundwater, causing higher concentrations around the "pocket".



Issue: Contaminants near water table
Solution: Line and seal upper portion of well



Issue: Contaminants deep in groundwater
Solution: Plug lower portion of well; raise pump

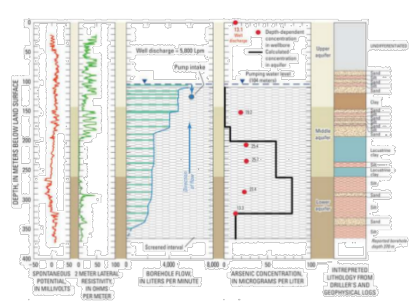


Issue: Contaminants in certain "pockets"
Solution: Cap well around "pocket" regions

Q3

Application

Successful partial abandonment requires a full understanding of the current conditions of the well and groundwater. Driller wells logs should be consulted and video of the well should be considered. The U.S. Geological Survey (USGS) has developed a combined well-bore flow and depth-dependent water sample collection tool to analyze an existing well (see Resource 127). An example output from such a test is shown to the right.



Example USGS report

Considerations

The applicability of partial abandonment will not be known until there is a full understanding of the current conditions of the well and aquifer. However, the structural modification phase of partial well abandonment represents approximately 70% of the total cost. Therefore, a majority of the cost is not committed until the likely result is known[122].

Partial abandonment may reduce the capacity of the well. In some cases, the well can be rehabilitated in the remaining operable regions, reducing the loss in capacity.

An analysis of the dynamic conditions of the well must be performed. Increasing the depth of the lining will increase the drawdown, and the new lining depth should be below the new pumping water level.

Longevity of the contaminant reduction depends on a variety of factors, including type and source of the contaminant, geophysical properties of the aquifer, changes in the water table, as well as the regions of the well that are sealed. When partial abandonment is done properly, it is possible for the reduced contaminant levels to remain for 20 years or more. When done incorrectly, the levels may return to the original values quickly.

Q3 Costs

A hydrogeologist with experience in partial well abandonment as well as other groundwater contaminant remediation options estimated that the cost for partial well abandonment was about one third of the cost of a new well and about 1/14th the cost of a treatment option (reverse osmosis)[122].

As was mentioned above, the applicability of partial abandonment will not be known until there is a full understanding of the current conditions of the well and aquifer. This requires testing and analysis before any structural modifications are made. However, the structural modification phase of partial well abandonment represents approximately 70% of the total cost. Therefore, a majority of the cost is not committed until the likely result is known[122].

Resources

[121] Davis, J. 2005. Arsenic in Arizona: Assessing the Economic Cost and Hydrogeologic Feasibility of Nontreatment Options.

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CASE STUDIES

PARTIAL ABANDONMENT OF A WELL

Technologies	Contam-inant(s)	No. of Wells	Cost	Capacity Loss	Original Contaminant Concentration	Contaminant Reduction	Name	Location	Source	Imple-mented*
Inflatable packer and grout (seal bottom of well)	Arsenic	5	$608,500 (920'sealed, unknown casing diameter)	30%	15-25 ppm	55-85%	LA County Waterworks District No. 40, Antelope Valley	Antelope Valley, CA	131, 125	I
Bentonite grout with sand cap (seal bottom of well)	Arsenic	1		45%	Above 10 ppm	Reduced to 7 ppm	City of Stockton, CA Municipal Utilities Department	Stockton, CA	126	I
Backfilled (seal bottom of well)	Arsenic	1		46%	10 ppm	80%		Near Stockton, CA	129	I
Well liner (steel pipe and cement)	Nitrate	Multiple	1/3 cost of a new well; 1/14 cost of RO treatment			30-90%		Greater Phoenix, AZ Area	122	I
Well liner (steel pipe and cement) and well rehab	Nitrate EDB DBCP	1		Negligible	16.6 ppm (as N) 186 ppt 57 ppt	92% 100% 100%		Salt River Valley, AZ	123	I
Well liner (steel pipe and cement)	Nitrate	1		Unknown	18.1 ppm (as N)	52%		Salt River Valley, AZ	123	I
Well screen sealing	Arsenic	1	$2,500 (400-500' of 6" casing sealed) to $6,200 (500-600' of 16" casing sealed)					Arizona	121	S

*I = Implemented, S = Survey of Contractors and Drillers

FACT SHEET

CONGENERATION/CHP

Overview

At wastewater treatment plants, sludge can be anaerobically digested to create biogas. Biogas can be used in a generator (engine, turbine, or fuel cell) to create thermal energy (heat) and electricity. The production of multiple types of energy from a single fuel source is referred to as “cogeneration” or “combined heat and power” (CHP), and can greatly improve the efficiency and economic feasibility of on-site power generation versus the production of only one type of energy.

Quick Reference: *Typically, biogas-to-electricity systems are cost effective for wastewater treatment plants with anaerobic digesters and average inflows above **5 MGD**. About 100 kW of electricity and 12.5 MMBtu of thermal energy can be created from each 4.4 MGD of influent.*

Considerations

Digester gas usually contains a significant amount of water, hydrogen sulfide, siloxanes, and other contaminants. These compounds must be reduced/removed from feed gas prior to use. Some contaminants are regulated by the Air Resource Control Board, and some are detrimental to the generator (efficiency, corrosion, etc).

Burning biogas to power a device can be 10-15% more efficient than converting the biogas to electricity [37].

Costs

See Case studies for example cost and payback of CHP systems.

The maintenance cost of the cogeneration system is greatly affected by the digester gas quality (contaminants present).

Additional Benefits

Converting biogas to energy reduces venting and flaring, which contributes to greenhouse gas emissions without any beneficial use.

Facilities that are near landfills may be able to use landfill gas (LFG) to supplement their fuel supply.

Many anaerobic digestion units have excess capacity due to overestimation of future development. This excess capacity could be used to co-digest food, fats/oils/grease (FOG), or other biological wastes and increase biogas production.

Generators can be used specifically during peak hours to reduce peak power costs and peak demand.

WW1

Resources

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[37] Electric Power Research Institute (EPRI) for the California Energy Commission (CEC). 1999. Report CR-104300. Energy Audit Manual for Water/Wastewater Facilities.

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WWI

CASE STUDIES

COGENERATION/CHP

Technologies	Energy Savings (of process, unless indicated)	Simple Payback (years)	Name	Location	Plant Capacity (MGD)*	Average Daily Flow (MGD)	Source	Implemented**
CHP system	$37,000/yr	7	Village of Essex Junction Wastewater Treatment Facility	Essex Junction, VT	3.3 (4.7)	2.0	34	I
CHP system	20% of total plant electric requirement ($100,000/yr)	7.5-8.5	Burlingame Wastewater Treatment Facility	Burlingame, CA	5.5 (16)	3.4	117	I
Replace existing CHP unit	210,240 kWh/yr	6.0	Ithaca Sewage Treatment Plant	Ithaca, NY	10	6.5	64	R
CHP system	$1.26M/yr		Ina Road Water Pollution Control Facility	Tucson, AZ	25		96/117	I
CHP system	50-60% of total plant electric requirement (4,000-4,800 MWh/yr, $808,000/yr)	5.7	Kailua WWTP	Kailua, Hawaii	30	12	90	R
CHP system	8M kWh/yr ($300,000/yr)		Encina Wastewater Authority	San Diego, CA	36	25	15	I
CHP system	1.2-1.4 MW (40-50% of total plant power requirement	9.6	South Columbus Water Resource Facility	Columbus , GA		35	28	I
CHP with landfill gas	75% of plant's electric requirement ($4M/yr)		San Jose/Santa Clara Water Pollution Control Plant	San Jose, CA	167 (271)		117	I
CHP system	40-50% of total plant electric requirement ($1.7 million/yr)	6-8	East Bay Municipal Utility District Special District 1, Wastewater Treatment	Oakland, CA	168 (415)	63	14/117	I

Bio-powered engine		4-4.5					41	G
CHP system	1,613 MWh/yr ($129,000/yr)	8			10		56	G

*Values in parentheses indicated storm flows (retention basins and/or reduced treatment)

**I = Implemented, R = Recommended, G = General Value

CHP = combined heating and power

FACT SHEET

RECYCLED WATER

Overview

Using recycled water saves energy and reduces the water needed by a system when it is used in place of fresh water that would be more energy-intensive to extract, treat, and convey than the process of recycling water.

Applications

Recycled water can be used internally in the wastewater treatment plant, or can be exported to landscaping systems, agriculture, groundwater recharge, industrial uses, etc. The following table is adapted from DWR's "Water Facts Number 23: Water Recycling" [11] and shows the level of treatment required for different recycled water uses.

Type of Use	Treatment Level		
	Disinfected Tertiary	Disinfected Secondary	Undisinfected Secondary
Urban Uses and Landscape Irrigation			
Fire protection	✓		
Toilet and urinal flushing	✓		
Irrigation of parks, schoolyards, residential landscaping	✓		
Irrigation of cemeteries, highway landscaping		✓	
Irrigation of nurseries		✓	
Landscape impoundments	✓	✓*	
Agricultural Irrigation			
Pasture for milk animals		✓	
Fodder and fiber crops			✓
Orchards (no contact between fruit and recycled water)			✓
Vineyards (no contact between fruit and recycled water)			✓
Non-food bearing trees			✓
Food crops eaten after processing		✓	
Food crops eaten raw	✓		
Commercial/Industrial			
Cooling and air conditioning – with cooling towers	✓	✓*	
Structural fire fighting	✓		
Commercial car washes	✓		
Commercial laundries	✓		
Artificial snow making	✓		
Soil compaction, concrete mixing		✓	

WW2

Type of Use	Treatment Level		
	Disinfected Tertiary	Disinfected Secondary	Undisinfected Secondary
Environmental and Other Uses			
Recreational ponds with body contact (swimming)	✓		
Wildlife habitat/wetland		✓	
Aquaculture	✓	✓*	
Groundwater Recharge			
Seawater intrusion barrier	✓*		
Replenishment of potable aquifer	✓*		

**Restrictions may apply*

Considerations

Treated wastewater distribution systems typically have to be piped separately from potable water and the pipes must be labeled.

Additional Benefits

Recycled water can reduce the need for new water sources.

Resources

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FACT SHEET

DEEP WELL OIL LUBRICATION

Overview

Perhaps 70% of sudden failures of deep well vertical turbine pumps are caused by improper lubrication of motor bearings and of the lineshaft. This is one if the simplest problems to fix, yet there are three issues:

1. Most people do not know the proper drip rate.
2. The oil reservoirs are too small, so they run out of oil before they are refilled.
3. Hardware that is sold does not provide for a constant drip rate over time.

Application

Proper Oil Drip Rate

Christensen (a divisions of Layne Christensen Co.) provides the following advice in its Deep Well Turbine Pumps manual:

Oil Drip Rate

(from Christensen Pumps *O&M Manual Deep Well Turbine Pumps*)

Shaft Diameter (inches)	Basic Drops/ Minute	Add'l Drops/Minute/ 100' Setting
0.75-1.19	5	2
1.50-1.68	7	3
1.94-2.43	10	4
2.68 and higher	12	5

Size of Oil Reservoir

A gallon of oil (size of many standard oil reservoirs) holds about 150,000 drops. This corresponds to about a 2 day to 2 week supply of oil in a typical one gallon oil reservoir. It is recommended to use a reservoir holding about 4 gallons, minimum.

Maintaining a Constant Oil Drip Rate

Oil drip rates change over time for three reasons:

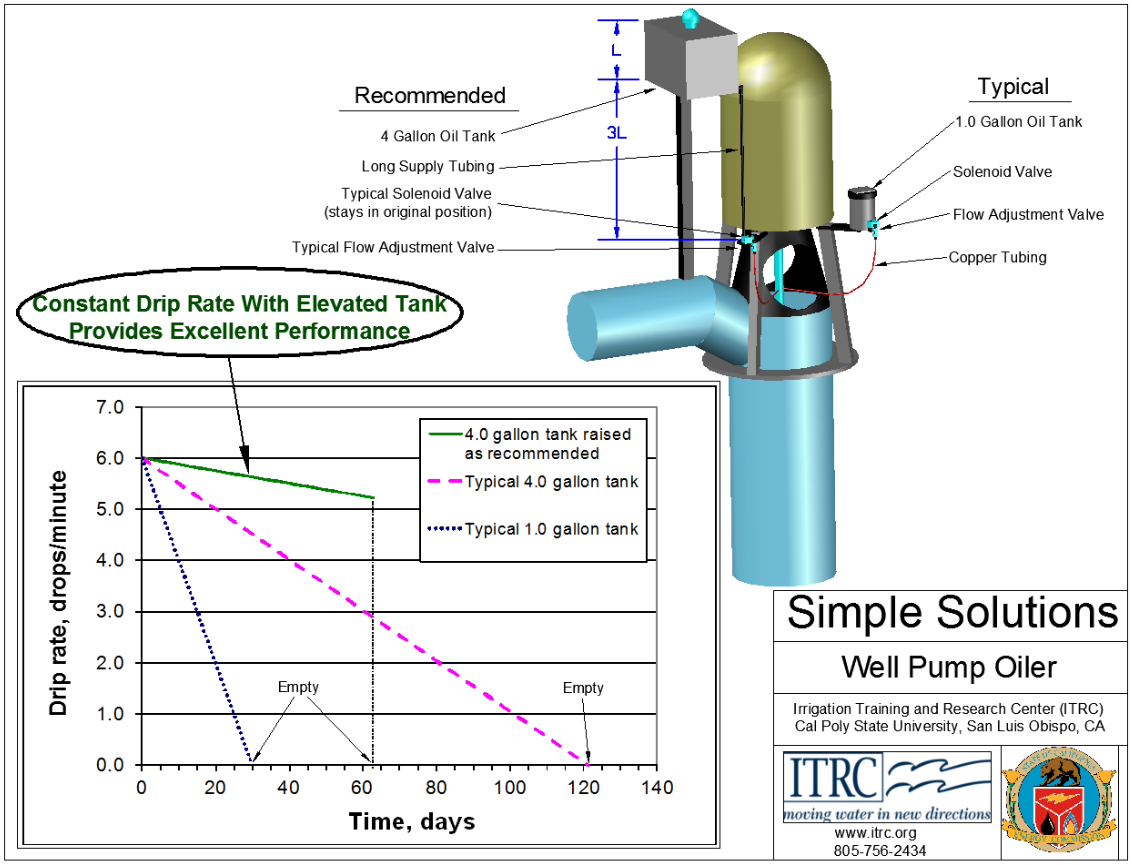
1. The level of the oil in the reservoir drops, decreasing the pressure on the adjusting valve.
2. The temperature of the oil changes, which changes the viscosity.
3. The adjusting valve, or its entrance, becomes plugged.

Summary

The design shown in the following figure overcomes these problems by:

- Raising the oil reservoir several feet above the adjusting valve. Therefore, a change in the oil level in the reservoir itself only represents a small percentage change in the total pressure on the valve
- Some of the pumped water is circulated around the oil tube, immediately above the adjusting valve. This maintains a fairly constant oil temperature, regardless of air temperatures.
- The size of the oil reservoir is 4-5 gallons, so it does not need to be refilled as frequently as conventional oil reservoirs
- The bottom of the oil reservoir is drainage, so sludge and contaminants and water can be removed easily
- The intake pipe to the flow adjusting valve is located several inches above the floor of the reservoir, to minimize the chance of contaminants entering the adjusting valve.

W1



Costs

The costs associated with installation of a larger, raised tank are minimal.

Resources

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W1

Resources

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