Assessment of Factors Contributing to Wastewater Pump Underperformance Using Automatically Monitored Data from Cellular Pump Station Monitors

By: Charles A. Hoffman III

Advisor: Dr. Yen-Chih Chen

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INTRODUCTION

Pump Station Design

Municipal wastewater collection systems use gravity to convey wastewater through the system. When gravity is not sufficient to get the wastewater to its final destination, pumping stations are used to pump the wastewater to the next gravity collection system, to another pumping station, or to a wastewater treatment facility.

When designing a wastewater pumping station, one of the first design considerations is the required flow rate. The flow rate can be estimated based on water usage, or based on gallons per-capita for residential, commercial, or other areas. In addition, the flow estimate must account for inflow and infiltration of groundwater throughout the collection system. Finally, a peaking factor is applied to ensure that the pumping system is sized to handle maximum instantaneous flows (Tchobanoglous, Burton, & Stensel, 2003). The resulting flow rate is the design flow for the pumping station.

Once the design flow rate is established, the total dynamic head (TDH) must be calculated for the piping system. Elevation differentials are calculated to determine the static head, and established formulas such as Hazen-Williams or Darcy-Weisbach are used to calculate dynamic losses in the piping, valves, and fittings at the design flow rate (Jones, Bosserman, Sanks, & Tchobanoglous, 2006). The static head and dynamic losses are added together to determine the TDH.

Using the flow rate and the calculated TDH, pump station designers then turn to pump performance curves to select an appropriate pump. Pump performance curves plot pump performance in relation to flow and TDH to show pump efficiency and power requirements. The designer selects the appropriate pump based on the available curves, and then selects the motor

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Email address(s) CHOFFMAN@ENVIREP.COM

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size appropriate for the application based on the design flow, TDH, and pump efficiency (Jones et al., 2006). Wastewater applications typically use centrifugal pumps, either in a submersible or a suction-lift configuration, depending on the preferences of the owner and the demands of the specific application.

Once the flow and TDH are calculated, and the pump and motor are selected, the pump station designer must select the type of motor starter to use for the system. The three main types of motor starters are across-the-line, reduced voltage, and variable frequency starters. Across-the-line starters, also known as Full Voltage, Non-Reversing (FVNR) starters, are the simplest and lowest-cost starters available. FVNR starters apply full voltage to the motor immediately, resulting in very fast start and stop cycles, but increasing the chances for hydraulic surging, water hammer, and check valve slam. Reduced voltage starters, also known as Reduced Voltage Solid State (RVSS) starters, start and stop the pump gradually over a set time. This "soft start" and "soft stop" functionality reduces the motor inrush current and helps to prevent hydraulic surging and associated issues in the piping system. For these reasons, RVSS starters are often applied on larger motors and on systems with high potential for hydraulic surging. Variable Frequency Drive (VFD) starters have the same soft start/stop capability as RVSS starters, but they can also vary the frequency of the power to the motor, thereby allowing the pump control system to control the pump speed and the resulting flow rate. VFDs are often used in cases where the process requires a variable flow rate, or in pumping systems with a high TDH where power costs can be reduced by pumping at a lower flow rate (Jones et al., 2006).

The design and manufacture of wastewater pumps and pumping systems is subject to numerous regulations and standards. One such standard is the "American National Standard for Rotodynamic Pumps for Hydraulic Performance Acceptance Tests", which is published by the

Hydraulic Institute and outlines the recommended factory testing standards for many different types of pumps. The Hydraulic Institute (HI) is an organization comprised of companies that manufacture and distribute pumping equipment. On its website, HI calls itself a "global authority on pumps and pumping systems" ("Hydraulic Institute", n.d., para. 1). One function of the Hydraulic Institute is to develop standards for the design, manufacture, testing, and operation of pumps and pumping equipment ("Hydraulic Institute", n.d.). For municipal water and wastewater applications such as the pumping stations in this data collection, the Hydraulic Institute recommends testing standard 2B (*American National Standard*, 2011). Standard 2B allows for a pump test to show up to ± 8% flow variation compared to the specified design flow rate (*American National Standard*, 2011). Based on this standard, when the actual observed flow rate for a wastewater pump is within 8% of the design flow, it is considered acceptable by the Hydraulic Institute.

Envirep Database

As part of this study, data were collected on the specific design characteristics of each pumping station from the Envirep equipment database. Envirep, Inc., is a manufacturer's representative of water and wastewater pumping and treatment equipment. They work with consulting engineers and municipal water and wastewater treatment system owners to design, specify, sell, start-up, and maintain the equipment they represent. The Envirep database contains a comprehensive record of the design characteristics and other information from each equipment system sold by Envirep. For pumping stations, the database includes information such as Owner's name and contact information, station installation address, station name, equipment ship date, equipment manufacturer, application type, equipment serial numbers, pump type, pump model number, number of pumps at the station, design flow and TDH, motor size, electrical phase, electrical frequency, electrical voltage, motor starter type, level control type, and other information specific to the application.

<u>Cellular Pump Station Monitors</u>

In addition to the pumps, piping, and associated controls, most pumping stations include a pump station monitor. In the past, these monitors used a conventional telephone landline to alert operators to pump station alarms via a telephone call. Today, modern pump station monitors use cellular networks to alert operators via telephone call, text message, or email. In addition, the cellular monitors have the capability to collect and store much more information that can be useful in evaluating the condition of a pumping system. This study includes collection and analysis of this automatically-monitored data.

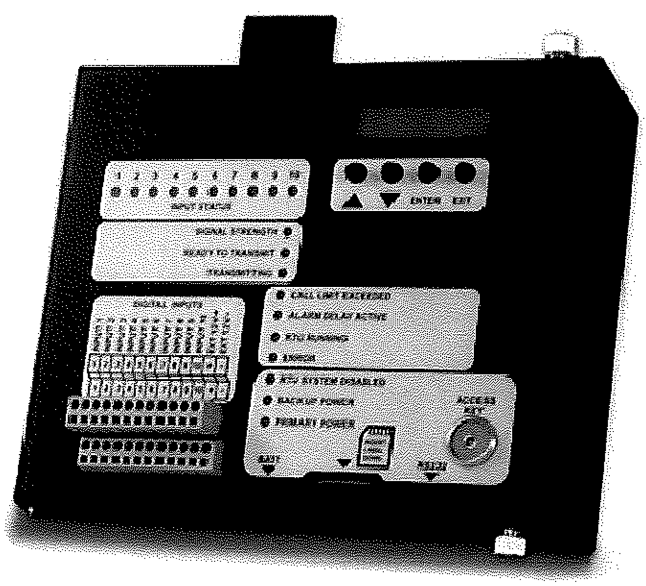

***Figure 1**: OmniSite XR50 cellular pump station monitor.* *https://store.omnisite.com/product_p/s-xr50.htm*

The OmniSite cellular pump station monitor is a modern device which uses cellular networks and a web-based interface to collect, store, and display information. OmniSite's XR50 and Crystal Ball models are designed specifically for monitoring wastewater pumping stations. The XR50 model, shown in Figure 1, includes three (3) pump run inputs and seven (7) universal voltage alarm inputs. Of the seven alarm inputs, two (2) can be used to monitor and record pulse input signals from flow meters and other devices, and one (1) input is compatible with a rain gauge pulse signal to monitor and record rainfall. The XR50 includes a 2 line x 16 character LCD screen and a cellular radio to operate on the Verizon Wireless network ("XR50", n.d.).

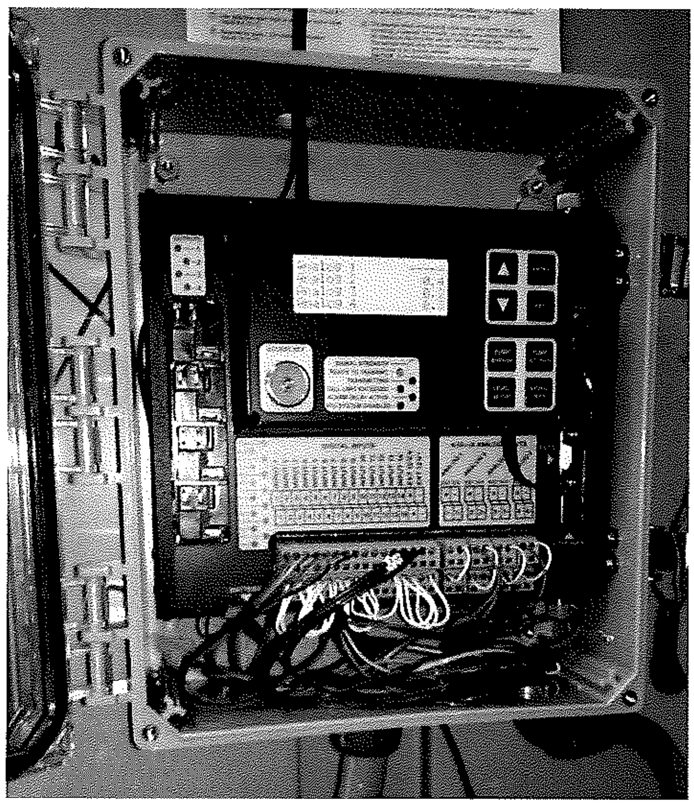

Figure 2: *OmniSite Crystal Ball cellular pump station monitor, installed.*

In addition to the features of the XR50, the Crystal Ball model includes an additional four (4) universal voltage alarm inputs for a total of eleven (11). The Crystal Ball, shown in Figure 2, also includes four (4) 4-20 mA analog inputs, four (4) relay outputs, and a larger 4 line x 20 character LCD display. In addition to functioning as a pump station alarm monitor and data collection device, the Crystal Ball can also function as a backup pump controller. The Crystal Ball can accept a 4-20mA analog level signal from a submersible transducer or other level sensing device, or up to four (4) dry contacts from float switches. The Crystal Ball then uses the relay outputs to start and stop up to three (3) pumps based on the level information provided by the transducer or float switches ("Crystal Ball", n.d.).

The primary purpose of the OmniSite cellular pump station monitor is to notify operators of alarms. However, the OmniSite units monitor and record additional data that is useful for predicting problems and preventing alarms. The pump run inputs allow the OmniSite to track pump run times, pump cycles, and drawdown times. During the initial installation and setup, the unit is programmed with the wet well dimensions and the pump drawdown distance, which allows the drawdown volume to be calculated. The OmniSite uses this drawdown volume, in addition to the pump drawdown times, to calculate the pump flow rate in gallons per minute (GPM). In this way, the OmniSite also monitors and records the pump flow and total station flow per day ("XR50", n.d.).

The OmniSite uses the following volumetric equation to calculate the flow rate of the pumps, where **Q** is the flow in GPM, **t** is the drawdown time in minutes, and **V** is the drawdown volume in gallons:

$$Q = \frac{V}{t} \qquad \text{(Equation 1)}$$

Equation 1 assumes a fixed volume of water is pumped at a constant rate over a measured time period. However, this is not the case with most wastewater pumping stations. Wastewater continues to flow into the wet well during the pumping cycle, which decreases the calculated pump flow rate. To account for the water flowing into the wet well, the OmniSite measures the time required to fill the wet well between pump cycles. Using that time, Equation 1 can be used to approximate the influent flow rate, and adding the calculated influent flow rate to the calculated drawdown pumping rate provides an accurate total flow rate for the pumps.

The information collected by each OmniSite unit is stored locally throughout the day, and then is uploaded to OmniSite's web interface every 24 hours. The web interface is called GuardDog, and is accessible via internet browser or smart phone app from anywhere with an internet connection. Once the data is uploaded to GuardDog, it is stored on an owner's specific password-protected web page for viewing, analyzing, graphing, charting, or exporting to Microsoft Word, Microsoft Excel, or Adobe PDF documents ("GuardDog", n.d.).

Pump Station Problems and SSOs

Failure of a pump or other station component could result in a reduction or loss of flow. Pumps operating at a flow rate that is less than the design flow rate can result in many problems over an extended time, including the following:

- Sanitary sewer overflows, resulting in expensive fines and cleanup fees.
- Increased pump wear, decreased parts life, and increased frequency of mechanical problems, resulting in increased maintenance and life cycle costs.
- Reduced operating efficiency and increased run times, resulting in increased electricity consumption.

Sanitary sewer overflows (SSOs) are one of the most severe problems resulting from reduction or loss of pumped flow. Wastewater contains pathogens that represent a risk to human health, which is one of the primary reasons that wastewater is collected and treated (Tchobanoglous et al., 2003). Wastewater also contains other microorganisms and other hazardous compounds, which can lead to adverse risk to the health of humans and the environment. A 2012 study conducted by Goulding, Jayasuriya, and Horan sought to assess the health risks caused by overflows from a combined sewer system in Melbourne, Australia. In the study, it was shown that the overflows posed a medium risk to primary recreation areas, municipal spaces, and human food crops (Goulding, Jayasuriya, & Horan, 2012). A separate study conducted by Aukidy and Verlicchi in 2017 assessed the effects of sewer overflows on a coastal region of northeast Italy. This study found severe short-term spikes in microbiological concentrations caused by sewer overflows, which in some cases caused beach closures due to health risks (Aukidy & Verlicchi, 2017).

Sanitary sewer overflows have many causes, but a significant contribution to the problem is the aging infrastructure in the United States. A study conducted in 1999 by the American Society of Civil Engineers (ASCE) for the United States Environmental Protection Agency (USEPA) concluded that 57.5% of the sewer infrastructure in the United States was over 21 years old, and that about half the infrastructure in the US would be 50 years or older by 2020 ("Fact Sheet", 2002). Aging sewer pipes and infrastructure increases inflow and infiltration, increasing wet weather flows and increasing the chances of SSOs. A 2005 study by Sier and Lansey recognized the potential health risks and environmental hazards posed by SSOs, and attempted to create a system for monitoring sewer collection systems specifically for the purpose of identifying blockages and SSOs. The approach used in the study showed promise for adapting to other systems to optimize resources and achieve a high level of detection (Sier & Lansey, 2005). Prior to that, a study conducted in 2000 by Samples and Zhang assessed the impact of preventive maintenance on the occurrence of SSOs, and found that maintenance and scheduling at the level implemented at the time was insufficient to significantly impact the incidence of

SSOs. The authors recommended increased maintenance and advanced scheduling techniques to increase the impact of maintenance on the occurrence of SSOs (Samples & Zhang, 2000).

Reporting

The automatically monitored data from pump station monitors is important for diagnosing problems with pumps and other equipment, but there are other reasons to analyze and maintain that data. Many municipalities in Pennsylvania are required by the Pennsylvania Department of Environmental Protection (PADEP) to file a "Chapter 94 Report" every year, which includes information such as the past and projected future hydraulic and nutrient loads for the wastewater system, an analysis of overflows and overloaded system components with a plan for upgrades to address the problems, and an overview of the overall system health ("Chapter 94", 2014). Municipalities in Pennsylvania often use the run time, cycle count, calculated flow rate, and other data from pump station monitors in their Chapter 94 reports to assess pump station health and hydraulic capacity. PADEP evaluates the Chapter 94 reports and requires municipalities with overloaded pump stations to take corrective action, which may include upgrading the pumping station or replacing the sewer infrastructure to address inflow and infiltration issues ("Chapter 94", 2014). These improvements can be very costly, and so it is imperative that the information used for reporting be as accurate and reliable as possible to avoid potentially unnecessary expenses.

IMPORTANCE

Nearly every wastewater pumping system today utilizes one or more pump station monitors. While older telephone units only monitored alarms, the new modern cellular pump station monitors collect and store a wide range of useful data that can be used to evaluate the health of pumping systems. Unfortunately, there has been little effort to collect and analyze this information en masse. The information collected from a single unit can be used to determine if the pumping system is operating at peak efficiency and design capacity. The primary purpose of this study is to use the combined data from dozens of these units to show correlations between design and operating conditions that may be causing stations to operate below design capacity. If such correlations can be shown, the conditions that most often result in reduced flow can be avoided during the design of new pumping stations. In addition, existing pumping systems with these conditions can be earmarked by Owners and Operators for additional scrutiny and maintenance to avoid decreased flow and other problems.

In addition to showing correlations between pump station design parameters and incidence of underperforming pumps, it is important to note that the information collected by the cellular pump station monitors is used for many important purposes. The information is used to assess the health of pumping stations and to monitor changes and trends in performance, and is also used for reporting purposes to satisfy permitting and compliance requirements, such as the Chapter 94 reports required by PADEP. For these reasons, it is important to ensure that the data collected is as accurate and reliable as possible. A secondary purpose of this study is to evaluate the data to make recommendations for OmniSite and for pump station operators to increase the functionality, enhance the usefulness, and improve the accuracy of the equipment and the data that it collects.

METHODOLOGY

Information was gathered from as many wastewater pumping stations as possible to create a spreadsheet of data. The full data set is included at the end of this report in Appendix A. The information was gathered from two main sources: the OmniSite GuardDog web interface, and the Envirep equipment information database. To be included in this data collection, a pumping system must include an OmniSite cellular alarm monitor, and must be listed in the Envirep equipment database. Without information from both sources, the resulting data set would not be sufficient to provide meaningful analysis, so any pumping station found to be missing data from either of the two sources was excluded from this data collection.

An effort was made to select pumping stations with a wide range of design and operating characteristics, such as station age, rated flow, rated head, motor size, starter type, materials of construction, number of cycles per day, average daily run time, etc. This was done to ensure a diverse data set, and to ensure that enough data is available to evaluate possible correlation of different design and operating features with reduced flows. However, since the data collection is limited only to pumping stations with both an OmniSite dialer and an Envirep database entry, the total number of pumping stations is limited by those that fit the criteria.

The following data was collected from the Envirep equipment database:

- Pump station owner name
- Pump station name
- Ship date of pumping system (used to calculate station age)
- Pump type (suction lift or submersible)
- Pump size (diameter of pump discharge connection)
- Materials of construction for the pump wear parts

- Design flow rate (GPM)
- Design total dynamic head (feet of water)
- Motor size (HP)
- Electrical service phase (1 or 3)
- Electrical service voltage (208, 240, or 480)
- Motor starter type (FVNR, RVSS, VFD)

Using the OmniSite cellular alarm monitors, the following data was collected. The data from the OmniSite GuardDog interface was calculated as an average or total value from 06/01/2017 to 08/31/2017.

- Average number of pump cycles per day
- Total pump cycles (06/01/2017 to 08/31/2017)
- Average pump drawdown time
- Average daily pump run time
- Total pump run time (06/01/2017 to 08/31/2017)
- Average calculated flow rate (GPM)
- Average flow pumped per day (GPD)
- Total flow pumped (06/01/2017 to 08/31/2017)

Information was collected from each individual pump in each pumping station. In total, information was collected for 344 individual pumps. Every pumping station with both an OmniSite cellular pump station monitor and an Envirep database entry was included in the data collection provided that the required information above was available.

The collected data was evaluated to determine which pumping systems are not meeting the original design flow rate based on the data collected by the OmniSite alarm monitors. Then, the data was evaluated to determine if there is a correlation of reduced flow conditions with any of the following design / operating conditions:

- Pump station age
- Pump type
- Pump size
- Materials of construction
- Design flow rate
- Design total dynamic head
- Motor size
- Electrical service phase
- Electrical service voltage
- Motor starter type
- Number of cycles per day
- Average drawdown time
- Average daily run time
- Average daily flow pumped

RESULTS & DISCUSSION

The data collection resulted in a comprehensive data spreadsheet for 344 individual pumps at over 150 different pumping stations (see Appendix A). Some pumping stations included two pumps, while others included three. Each pump was analyzed separately, since pump performance often varied between individual pumps in the same pumping station.

The purpose of the data analysis is to determine which pumps are delivering less than the design flow rate, as these represent potential problems that may result in a sanitary sewer overflow. To do this, the flow rate difference was calculated for each pump by subtracting the design flow rate from the actual flow rate. Negative values indicate pumps that are performing below the design flow rate. The resulting difference was then divided by the design flow rate to determine the percent flow difference for each pump. Based on the Hydraulic Institute's 2B testing standard, acceptable pump operation is ± 8% flow variation compared to the specified design flow rate. Therefore, for the purpose of this study, pumps operating at less than -8% of design flow are considered to be underperforming.

Flow Distribution

Figure 3 shows the distribution of flow variations. Of the 344 individual pumps for which data was collected, only 80, or 23.3%, fall within the Hydraulic Institute's acceptable flow range of ± 8%. Of the remaining 264 pumps, 168 are pumping over 8% less than designed. That is, the data shows that 48.8% of all pumps in the data collection are performing below the acceptable flow range set by the Hydraulic Institute.

According to this data, almost half of all the pumps surveyed appear to be operating at a flow rate that is over 8% less than the flow they were designed to provide. This shows a potential widespread problem which must be addressed. Pumps operating at a flow rate that is less than the design flow rate can result in many problems as outlined previously in this paper. For this and other reasons, it is important to maintain wastewater pumps at peak efficiency and design flow. Routine maintenance helps to accomplish this, but problems can occur for reasons that routine maintenance may not handle. Regardless of the reason for a reduction in flow rate, it is imperative that the reduction is identified as soon as possible so that the problem can be diagnosed and addressed before a sanitary sewer overflow or other significant problem can occur.

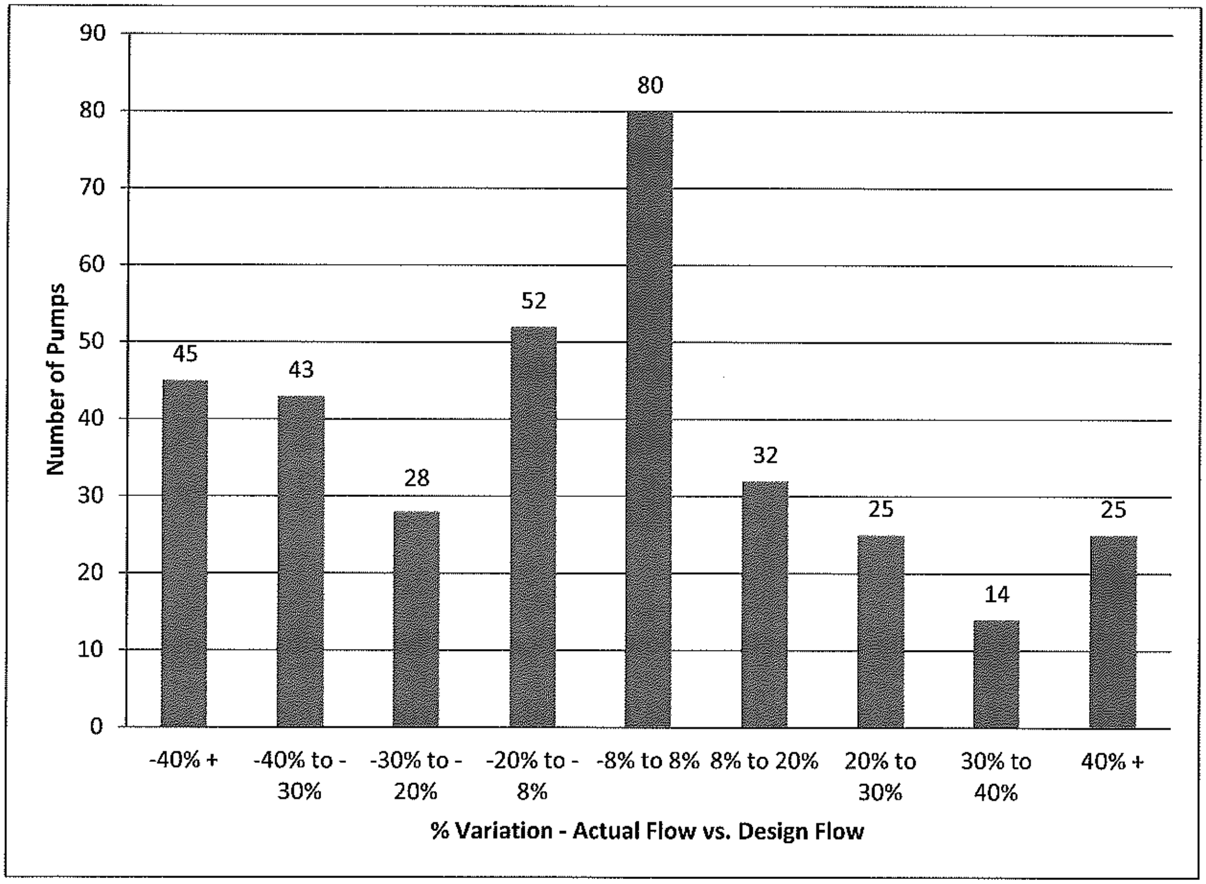

***Figure 3**: Graphical distribution of pump performance, comparing actual flow to the design flow rate. Bars represent the number of pumps that fall within each performance range.*

Pump Age

By identifying and addressing problems as soon as possible, the overall effects of the problems are minimized. However, if the problems can be prevented, the effects of those potential problems are eliminated entirely. The following analysis will examine the design features and operating characteristics of the pumps to determine if any of those characteristics may increase the chances of decreased pump flow rate. If any characteristics are found to correlate with a higher incidence of decreased flow rates, those characteristics can be flagged for further examination to determine the cause of the decreased flow rate and to develop measures to prevent or minimize the occurrence of decreased flow rate in future pump station installations. The first characteristic analyzed is the pump age. The surveyed pumping stations have a wide range of ages, from a low of less than one year, to a high of 34 years. The pump ages were divided into brackets, and for each bracket the number of low-flow pumps was divided by the total pumps in that bracket to produce a percentage. Figure 4 shows the percentage of low-flow pumps in each age bracket.

With the exception of the 10 to 14 year range, all age ranges shown in Figure 4 have a low-flow percentage between 44% and 57%. Furthermore, the two highest brackets are the 0 to 4 year range and the 25+ year range. It is worth noting that the oldest two age ranges were relatively under-represented. The first four age ranges each include at least 50 pumps, but the 20 to 24 and 25+ year ranges only include 36 and 29 pumps, respectively. A two-sample t-test was performed to determine whether there was a significant difference between the 10 to 14 year range and the 0 to 4 year range. The t-statistic was significant at the .05 critical alpha level, $t(138) = 3.095$, $p = 0.0024$. This indicates a significant difference between the 10 to 14 year range and the 0 to 4 year range, though there does not appear to be a clear cause. In addition, it was found that the 10 to 14 year range was significantly different from all other age ranges except the 20 to 24 year range.

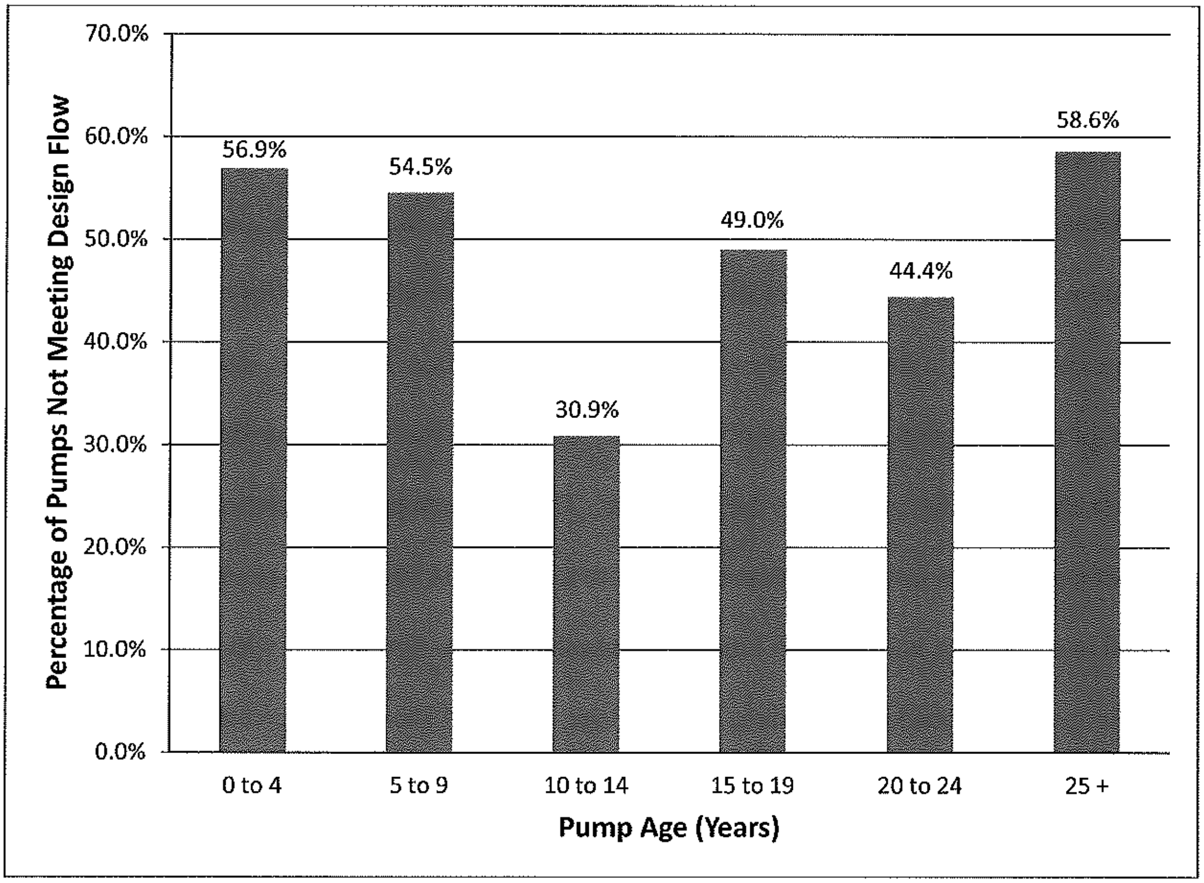

***Figure 4**: Graphical distribution of underperforming pumps based on pump age.*

When condensed into three ranges of 0-9 years, 10-19 years, and 20+ years, the percentage of low flow pumps is 55.6%, 38.7%, and 50.8%, respectively. This shows a higher incidence of low flows in pumps less than 10 years old and greater than 20 years old. It is expected that older pumps would have a higher incidence of low flows, as older equipment tends to develop more wear as it nears the end of its useful life. However, new equipment should have very little wear, which indicates there must be some other factor causing the high incidence of low flows for newer pumping stations, such as newer manufacturing or design standards for the pumps and/or the control components.

Pump Type

There are two main types of wastewater pumps, suction-lift and submersible. Submersible pumps are installed underwater inside the wet well. They require special submersible motors and other components to operate submerged in a hazardous and corrosive environment. Suction-lift pumps are installed outside the wet well, either above-ground or in separate below-ground structures. Suction-lift pumps are designed to lift the wastewater up the pump suction pipe, allowing them to be installed above the water line.

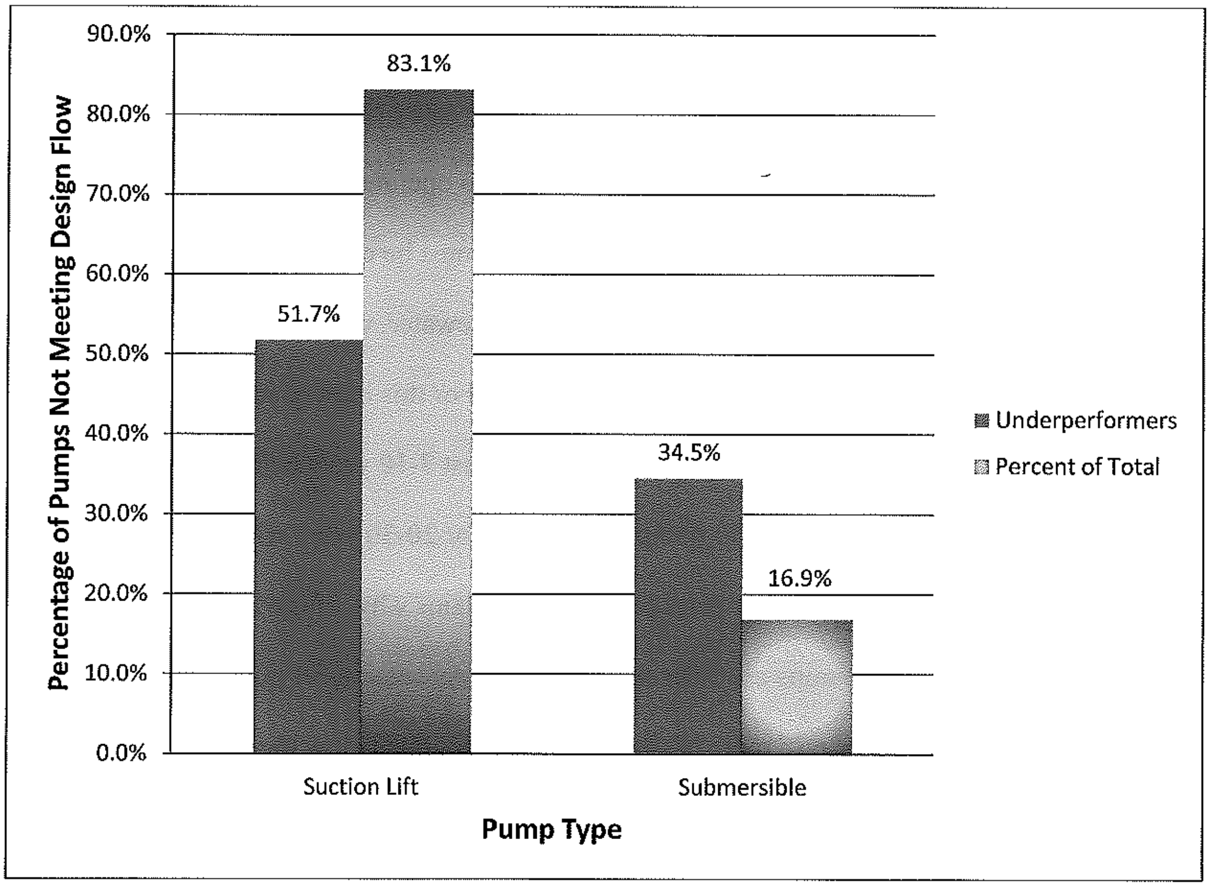

Figure 5: Graphical distribution of underperforming pumps based on pump type. Also shows the number of pumps in each pump type as a percent of the total data set.

Figure 5 shows the incidence of low flow pumps by pump type. 51.7% of all suction-lift pumps surveyed are shown to be operating more than 8% lower than design flow, whereas only

34.5% of submersible pumps are operating at the same low flow condition. Figure 5 also shows the proportion of each pump type in the total data set, with submersible pumps making up 16.9% of the data set, and suction-lift pumps making up 83.1%.

Overall, suction-lift pumps are more represented in this data collection, as 286 of the 344 total pumps are suction-lift. However, the 58 submersible pumps in the data collection still represent a sizeable data set. A two-sample t-test was performed to determine whether there was a significant difference between the suction-lift and submersible pumps. The t-statistic was significant at the .05 critical alpha level, $t(342) = 2.389$, $p = 0.0174$. This indicates that there is a significant difference between the pump types, although the cause of this difference is not clear.

To explain why suction-lift pumps are more likely to operate below design flow, the differences in design and operation of the two pump types must be considered. Submersible pumps spend their entire operating lives submerged in wastewater, whereas suction-lift pumps typically operate in a much more hospitable environment. For this reason, submersible pumps tend to break down sooner. Submersible pumps typically last 7-10 years before they must be replaced entirely, whereas a suction-lift pump can operate for 20-30 years with regular maintenance and replacement of wear parts only. This explains why, of the 20 low-flow submersible pumps, only 4 pumps are older than 10 years. As suction-lift pumps age, the cumulative pump wear may cause more of these pumps to operate below the design flow rate.

Figure 6 is a reproduction of Figure 4, showing the distribution of underperforming pumps based on pump age. However, Figure 6 separates the age brackets by pump type. This data supports the theory that the pump age contributes to the higher incidence of underperforming pumps of the suction-lift type. In the 0-4 year and 5-9 year age brackets, the percentage of underperforming pumps is similar between suction-lift and submersible pumps.

For pumps 10 years and older, the incidence rate varies greatly between the two pump types. However, it is important to note that the data sets for the older brackets of submersible pumps are very small, indicating that additional data may be required for an accurate comparison. The 15 to 19 year age bracket is the only bracket to show a significant difference between the suction-lift and submersible pumps in a two-sample t-test. The t-statistic was significant at the .05 critical alpha level, t(49) = 4.310, p = 0.0001. No other age bracket showed a significant difference.

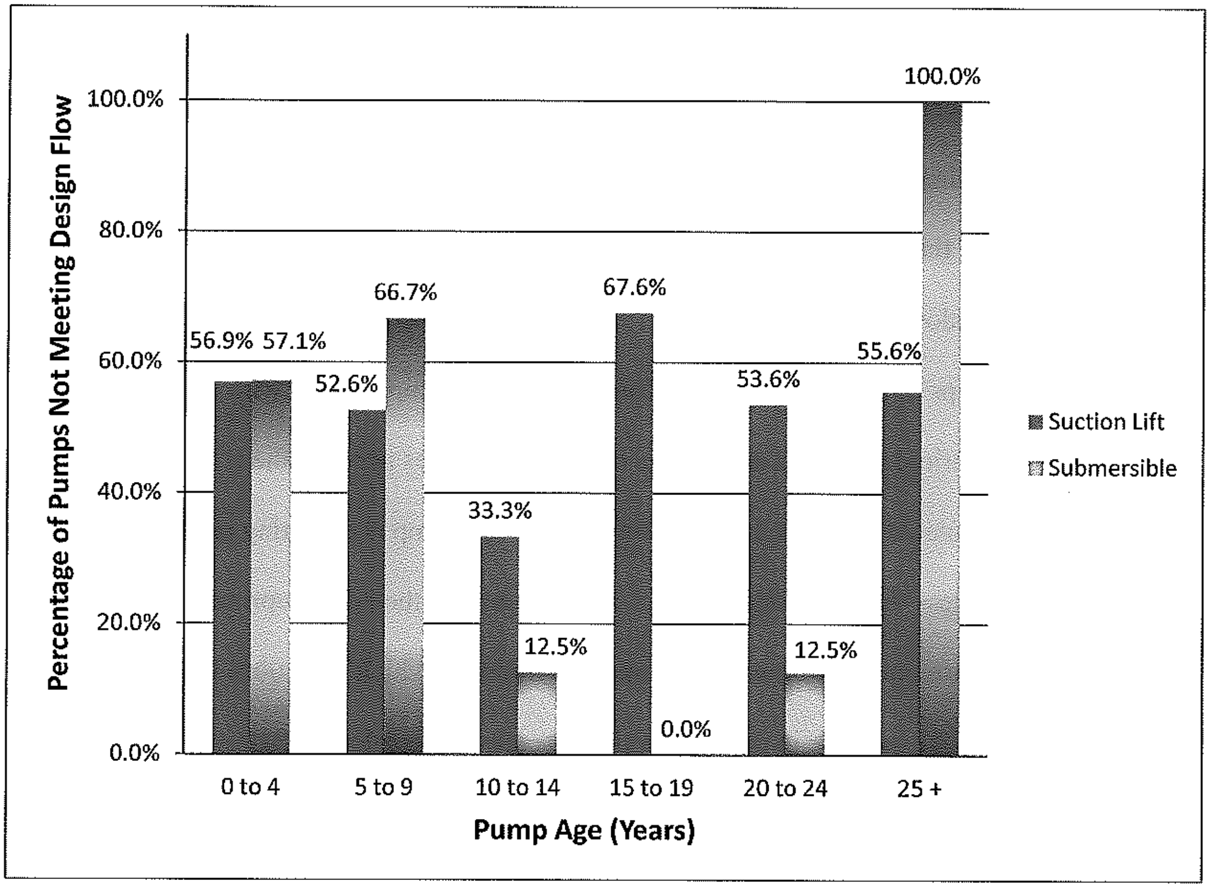

Figure 6: Graphical distribution of underperforming pumps based on age, by pump type.

In addition to the average pump age, the operation of suction-lift pumps may contribute in part to the observed low flow trend. Upon startup, a suction-lift pump must lift the wastewater up the suction pipe. If the suction pipe is full of air when the pump starts, the pump must remove the air before it can begin to pump water. By creating a low-pressure zone at the eye of the impeller, a suction-lift pump evacuates the air from the suction pipe, and atmospheric pressure in the wet well pushes the water up the suction pipe into the pump. This process is called repriming. While the pump is repriming, the OmniSite records the reprime time as part of the drawdown time, even though the pump is not delivering flow. Since the OmniSite calculates flow rate by dividing drawdown volume by drawdown time as shown in Equation 1, the OmniSite will calculate a lower flow for that pump cycle due to the additional reprime time included. It is important to note that suction-lift pumps incorporate a suction flap valve to prevent repriming every cycle, so the pump only needs to reprime on occasion.

Typical reprime times for suction-lift pumps range from 20 seconds to 5 minutes. Average drawdown times for the pumps in the data set range from 33 seconds to over 8 minutes, with a median drawdown time of 2 minutes, 19 seconds. The median number of pump cycles per day for the pumps in the data set is 28. Considering an example pump with a 2 minute cycle time, a 2 minute reprime time, and an average of 30 pump cycles per day, the effect of pump reprime on the calculated flow rate can be estimated. If the pump is operating properly, reprime should be required less than one time per day. If, for example, the pump reprimes one time per day, it would increase one drawdown cycle time to 4 minutes, which is a 100% increase. Based on Equation 1, a 100% increase in drawdown time decreases the calculated flow rate for that pump cycle by 50%. When averaged with the flow rates from 29 other 2-minute cycles for the day, this represents an overall decrease in calculated flow by only 1.67%. When a pump is operating properly, this represents the worst-case scenario for the effect of reprime on the calculated flow rate. The pumps in the data set are not considered to be underperforming until they deviate over 8% from the design flow rate, so while reprime time may be a factor, it should not by itself cause the pump to be considered an underperformer if the equipment is operating properly.

Alternately, consider the above example in the case of a malfunctioning pump. If the suction flap valve has failed, or if the flap valve becomes blocked or clogged, the pump may be required to reprime every cycle. In this case, the 2 minute reprime time would occur every cycle, increasing the average cycle time from 2 minutes to 4 minutes, thereby increasing the average cycle time by 100% and decreasing the calculated flow rate by 50%. In this case, the pump would almost certainly be considered an underperformer. Therefore, while reprime may not be a factor that significantly contributes to the underperformance of suction-lift pumps during normal operation, a problem with the pump or malfunction of the suction flap valve requiring additional reprime cycles may cause the pump to underperform.

Pump Size

The pumps surveyed in this data collection vary in size. Pump size, for the purpose of this analysis, is defined as the diameter of the pump discharge connection. The five pump sizes represented in this data collection are 3", 4", 6", 8", and 10". Figure 7 shows the distribution of low-flow pumps among the five pump sizes. Smaller pumps are over-represented in the data set, while the larger pumps are under-represented. 255 pumps, or 74.1% of the total, are either 3" or 4" pumps. Only twelve 8" pumps and eight 10" pumps were included in the data collection, so these two sizes combined only represent 5.8% of the total pumps in the data set. This indicates that there may not be enough data for the 8" and 10" pumps to draw a conclusion. Even among the smaller pumps, there is no apparent data trend to suggest that pump size correlates with the incidence of low pump flows. In addition, no two pump sizes show a statistically significant difference.

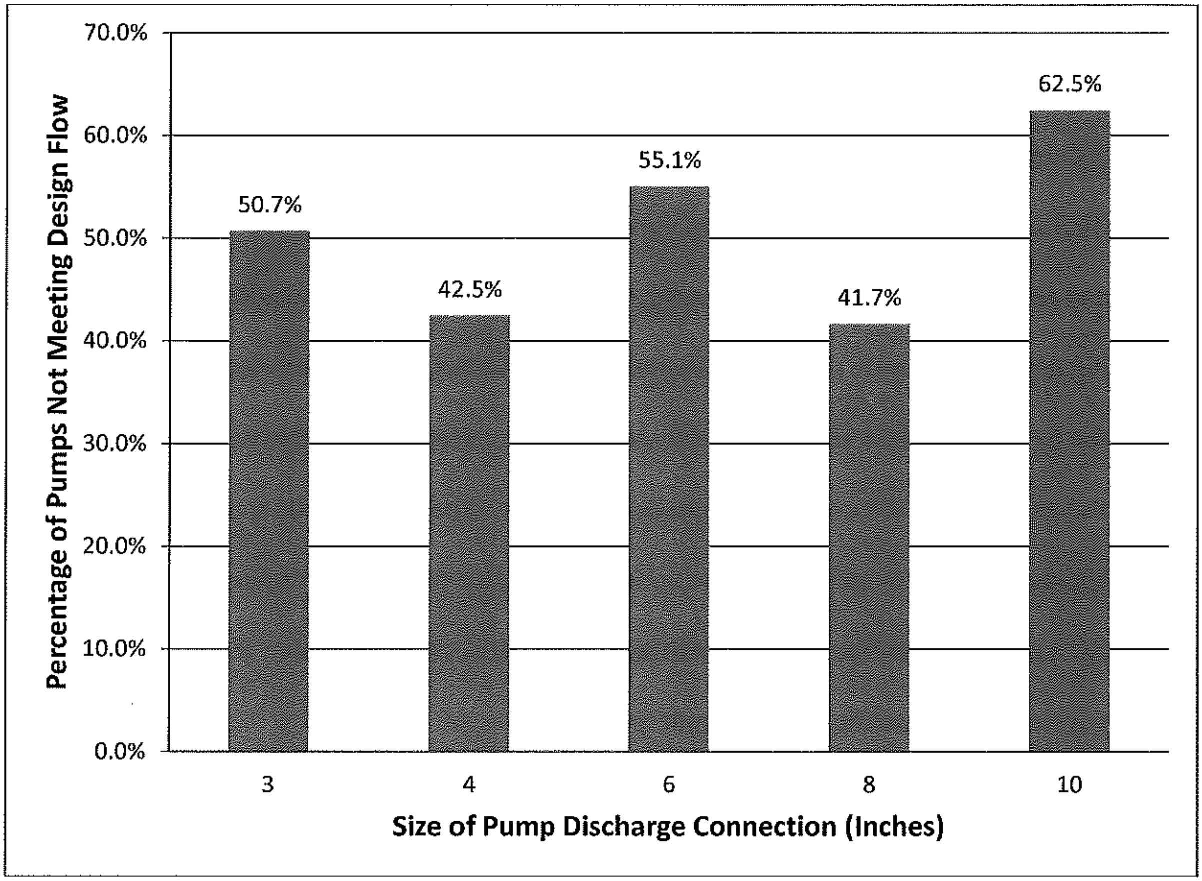

***Figure** 7: Graphical distribution of underperforming pumps based on pump size.*

Materials of Construction

The pumps included in the data set are built with different materials of construction for the wetted wear parts. These materials of construction are Ductile Iron, Austempered Ductile Iron, and 316 Stainless Steel. Ductile Iron, along with similar cast iron alloys, is the standard material for most wastewater pumps. Austempered Ductile Iron is hardened to a Brinell Hardness above 400 to provide resistance to wear from abrasion. Austempered Ductile Iron costs more than standard Ductile Iron, but it increases the useful life of a pump's wear parts, especially in applications with abrasive solids. 316 Stainless Steel is designed to be resistant to chemical attack, and is often used when corrosion is a concern. 316 Stainless Steel has also been observed to provide resistance to cavitation damage, which increases its usefulness in applications where cavitation may occur. 316 Stainless Steel is the most expensive of the three materials listed, so it is reserved for applications where its corrosion or cavitation resistance is required.

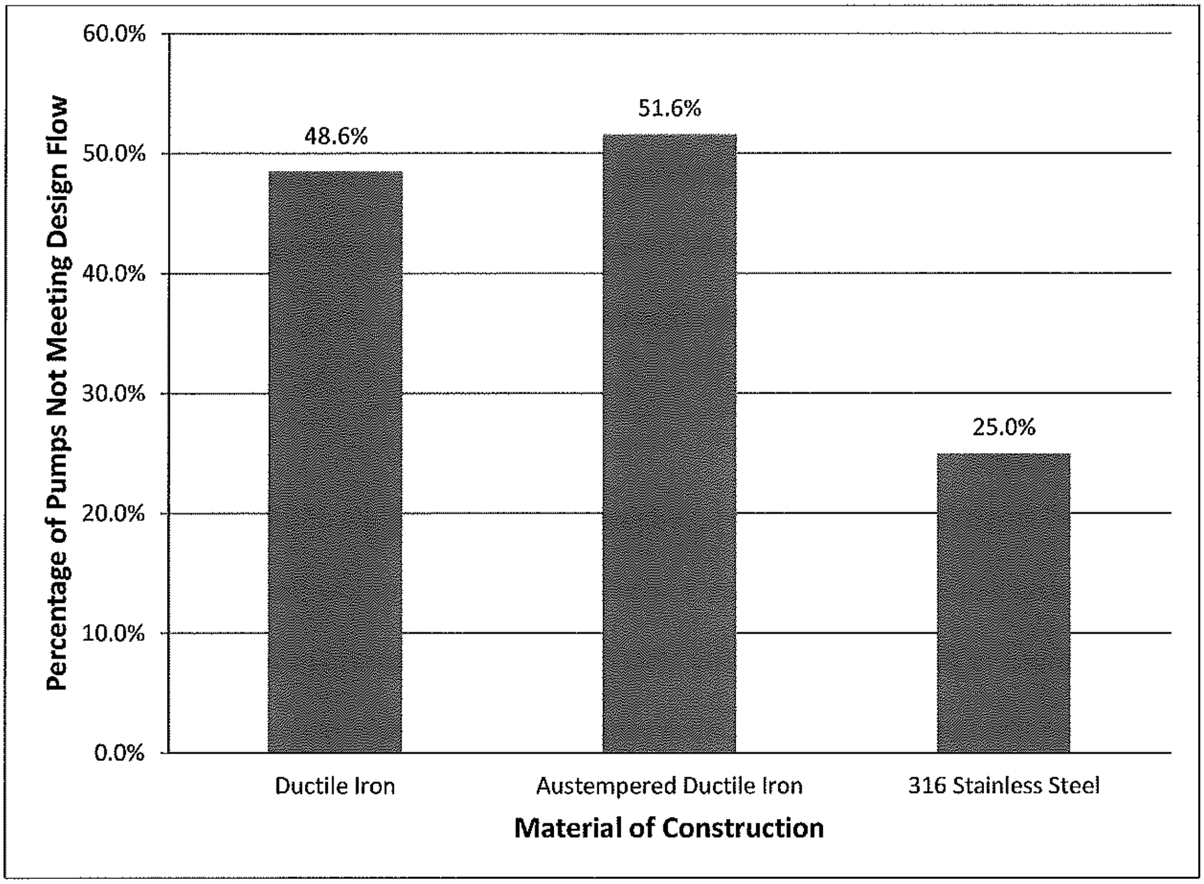

***Figure 8**: Graphical distribution of underperforming pumps based on pump materials of construction.*

Figure 8 shows the percentage of low-flow pumps for each of the three materials of construction. Ductile Iron and Austempered Ductile Iron have similar percentages of low-flow pumps at 48.6% and 51.6% respectively, but the 316 Stainless Steel material is shown to be much less likely to operate lower than the design flow, at only 25.0%. However, since 316 Stainless Steel is not commonly used due to its high cost, only eight pumps of this material are included in the data set. Without a larger data set for 316 Stainless Steel materials, the accuracy of the low-flow incidence is in question. Due to the small sample size for 316 Stainless Steel, the difference shown in Figure 8 was not found to be statistically significant.

It is also worth noting that the Austempered Ductile Iron and 316 Stainless Steel materials have only recently increased in popularity and usage. Of the eight pumps with 316 Stainless Steel wear parts, all are 8 years old or less. Of the 93 pumps fitted with Austempered Ductile Iron wear parts, only five are older than 12 years. Based on the inconclusive data collected, further investigation is required to determine whether the recent trend of upgraded materials results in sufficient benefit to offset the additional cost.

Design Flow Rate

The design flow rate of the surveyed pumps varies from a low of 80 gallons per minute (GPM) to a high of 2,500 GPM. Figure 9 shows the distribution of low flow pumps across 6 different ranges of design flow rate. The 1000+ GPM range appears to have a much higher incidence of low-flow pumps than the other ranges. The higher flow rates are under-represented in the data set, with only 13 pumps in the 800-999 GPM range and 19 pumps in the 1,000+ GPM range. However, the 1000+ GPM flow range was shown to be significantly different from the 0 to 199 GPM range in a two-sample t-test. The t-statistic was significant at the .05 critical alpha level, $t(113) = 2.472$, $p = 0.0149$. The 1000+ GPM range was also found to be significantly different than the 200 to 399 GPM range and the 600 to 799 GPM range. This implies that higher flow rate may correlate with a higher incidence of pump underperformance.

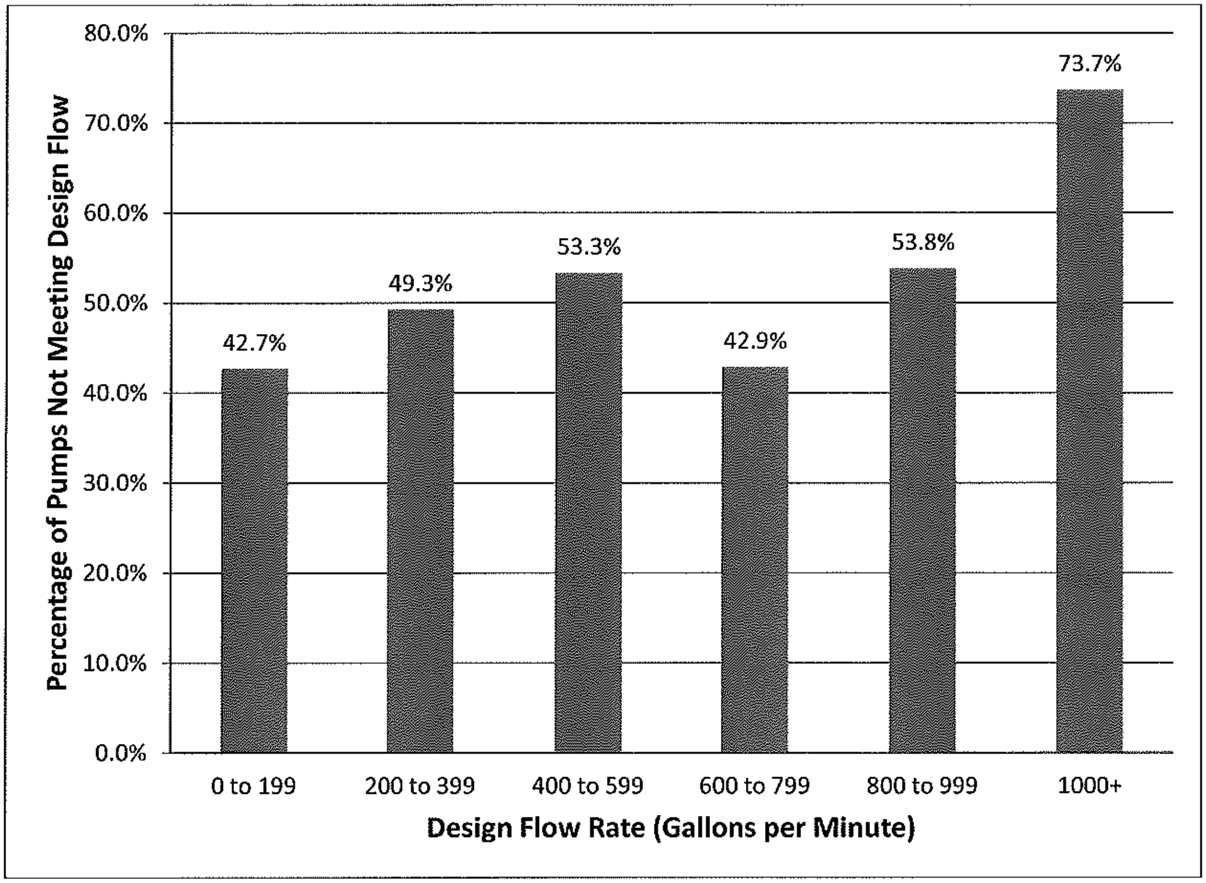

***Figure 9**: Graphical distribution of underperforming pumps based on pump design flow rate.*

<u>Design Total Dynamic Head (TDH)</u>

The pumps in this data set are designed to pump against a wide range of pressures. The design pressure, also known as the design Total Dynamic Head (TDH), is the pressure required to push wastewater through the piping system at the design flow rate. The TDH is calculated by the design engineer based on the job site elevations and the size, length, and fittings of the suction, discharge, and force main piping. In wastewater applications, TDH is typically calculated in feet of water. For this data set, the TDH ranges from a low of 10 feet to a high of 237 feet.

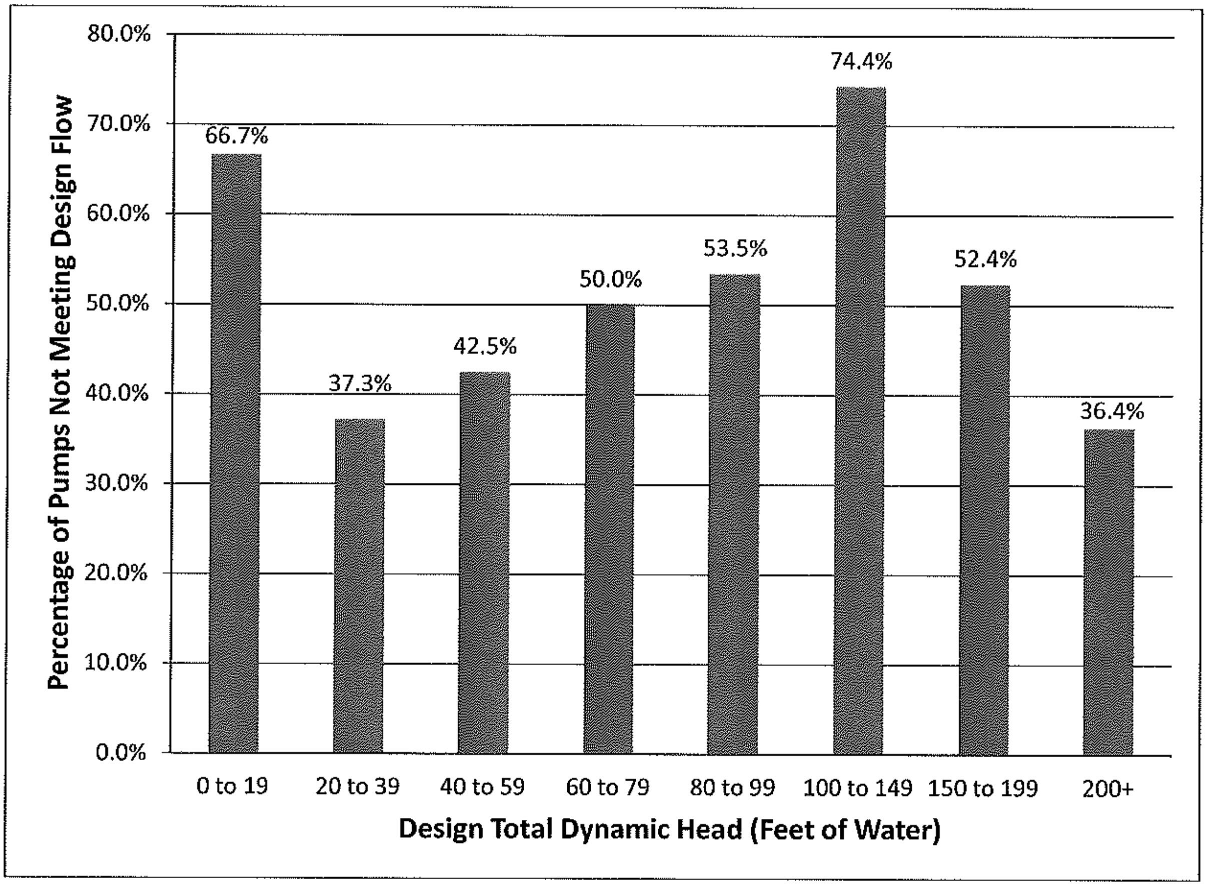

***Figure 10**: Graphical distribution of underperforming pumps based on pump design TDH.*

Figure 10 shows the distribution of low-flow pumps based on design TDH. Based on the data set, the TDH is most commonly between 20 feet and 100 feet, as 77.6% of all pumps in the data set fall within this range. The 0-19, 100-149, 150-199, and 200+ feet ranges contain 6, 39, 21, and 11 pumps, respectively. The 0-19 feet range in particular requires more data for the results to be considered reliable, and this range was not found to be significantly different than the other ranges based on a two-sample t-test. Considering just the TDH ranges that are better represented, there appears to be a clear trend from the 20-39 feet range to the 100-149 feet range showing a correlation between increased design TDH and increased occurrence of under-performing pumps. A two-sample t-test was performed to determine whether there was a significant difference between the 100 to 149 foot range and the 20 to 39 foot range. The t-statistic was significant at the .05 critical alpha level, $t(88) = 3.496$, $p = 0.0007$. This indicates that the 100 to 149 foot range and the 20 to 39 foot range are significantly different, which supports the observed trend. In addition, the 100 to 149 foot range was found to be significantly different than the 40 to 59 foot and the 60 to 79 foot ranges.

Several factors could explain the higher incidence of low flow pumps among higher TDH applications. Primarily, a higher TDH means higher pressures inside the pump, which can lead to increased pump wear. Also, cavitation is more common at higher heads, which may further contribute to increased internal wear on the pump. Finally, high head applications typically include large elevation changes, long force main piping lengths, or both. As the piping system gets more complicated, there is a higher possibility that the TDH design calculations may contain errors that cause the actual TDH to be higher than expected. A higher TDH with a constant pump speed results in reduced flow.

Motor Size

The pumps included in this data set have motor sizes ranging from 2.7 HP up to 150 HP. The required motor size for a pump is a function of the design flow and TDH for the system. During the design of a pumping system, the pump Brake Horsepower (BHP) may be calculated using Equation 2, where Q is the flow in GPM, H is the TDH in feet of water, and n is the pump efficiency at the design flow and TDH. The electric motor is then selected from a list of standard motor sizes based on the calculated BHP.

$$\text{BHP} = \frac{Q * H}{3960 * n} \qquad \text{(Equation 2)}$$

The distribution of low-flow pumps by motor size is shown in Figure 11. As with the design flow and design TDH data sets, the data for motor size is more concentrated on the lower end of the overall range, indicating that the smaller motor sizes are more common for wastewater pumping stations. At 32.8%, almost 1/3 of all the surveyed pumps have a motor size of 10-19 HP. In addition, 73.5% of all the surveyed pumps have motors under 30 HP. While the lower motor size ranges included plenty of data, the higher motor size ranges had to be condensed to provide meaningful data. Even so, there are only 35 pumps in the 50-74 HP range, and only 14 pumps in the 75+ HP range.

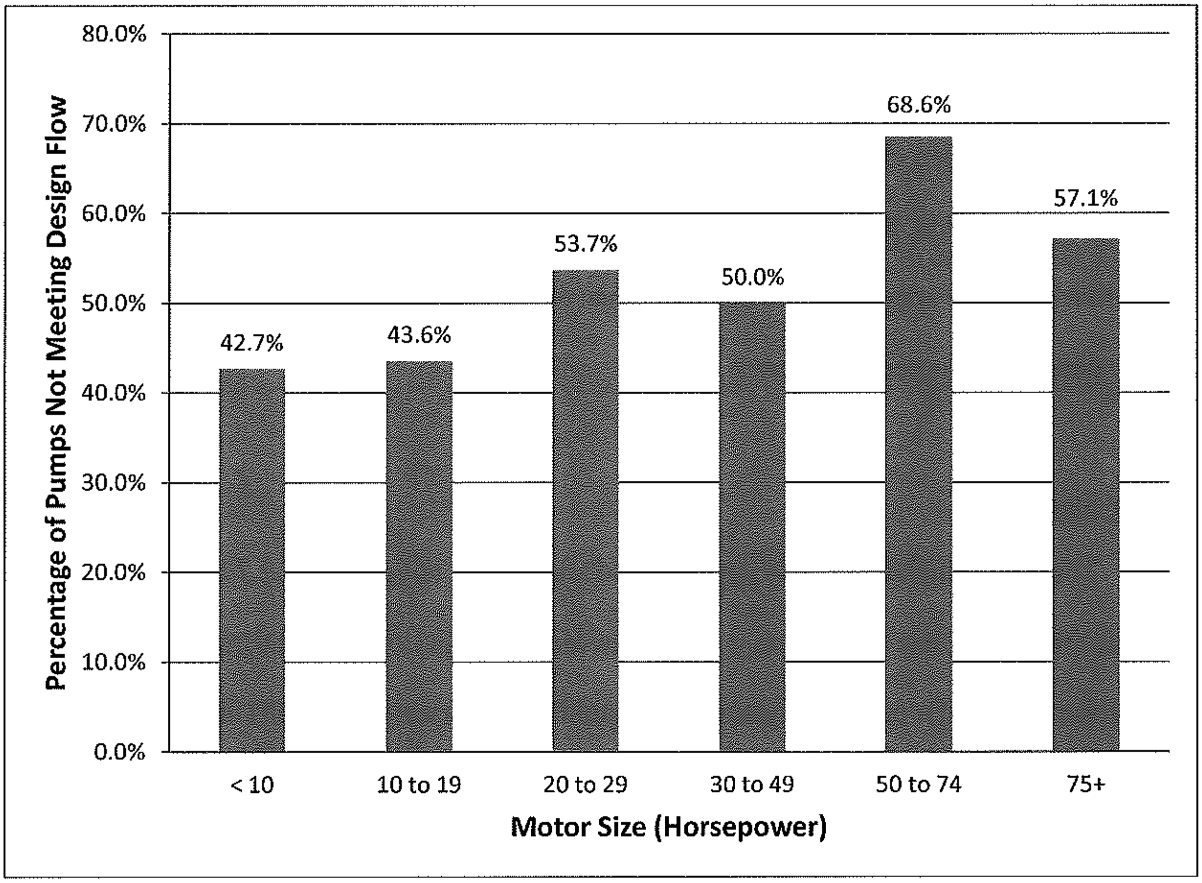

***Figure 11**: Graphical distribution of underperforming pumps based on motor size (HP).*

Overall, the data trend shows an increase in the occurrence of low-flow pumps at larger motor sizes. This trend becomes clearer if the number of motor size ranges is reduced to three. Up to 19 HP, the overall low-flow incidence is 43.2%. From 20 to 49 HP, the incidence rises to 52.1%. Finally, among pumps with motor sizes 50 HP or more, 65.3% were found to be providing over 8% less from than designed. This trend corresponds to the same trend observed with design TDH, in that both larger motor size and higher design TDH appear to correlate with increased incidence of low-flow pumping conditions. Since motor size is related to design TDH based on Equation 2, such that a higher design TDH often results in a larger motor size, it makes sense that the two design characteristics would follow the same trend.

A two-sample t-test was performed to determine whether there was a significant difference between the 50 to 74 HP range and the < 10 HP range. The t-statistic was significant at the .05 critical alpha level, $t(115) = 2.566$, $p = 0.0116$. This indicates that the 50 to 74 HP range and the < 10 HP range are significantly different, which supports the observed trend. In addition, the 50 to 74 HP range was also found to be significantly different than the 10 to 19 HP range.

Electrical Phase

The electrical service at wastewater pump stations is defined by three parameters, which are phase, frequency, and voltage. Low voltage utility power in the United States is always provided at a frequency of 60 Hz, so frequency will be ignored for the purpose of this study, as it does not vary from station to station. Phase and voltage, however, do vary based on the application requirements and the power availability at the site. Electrical service is available in single (1) phase and three (3) phase configurations, and for wastewater pumping stations is typically available in voltages of 208V, 240V, or 480V. Single phase AC power consists of a single waveform, with more pronounced peaks and dips. Three phase power uses three offset waveforms that reduce the peaks and dips in the power and provide a steadier electrical pattern (Jones et al., 2006).

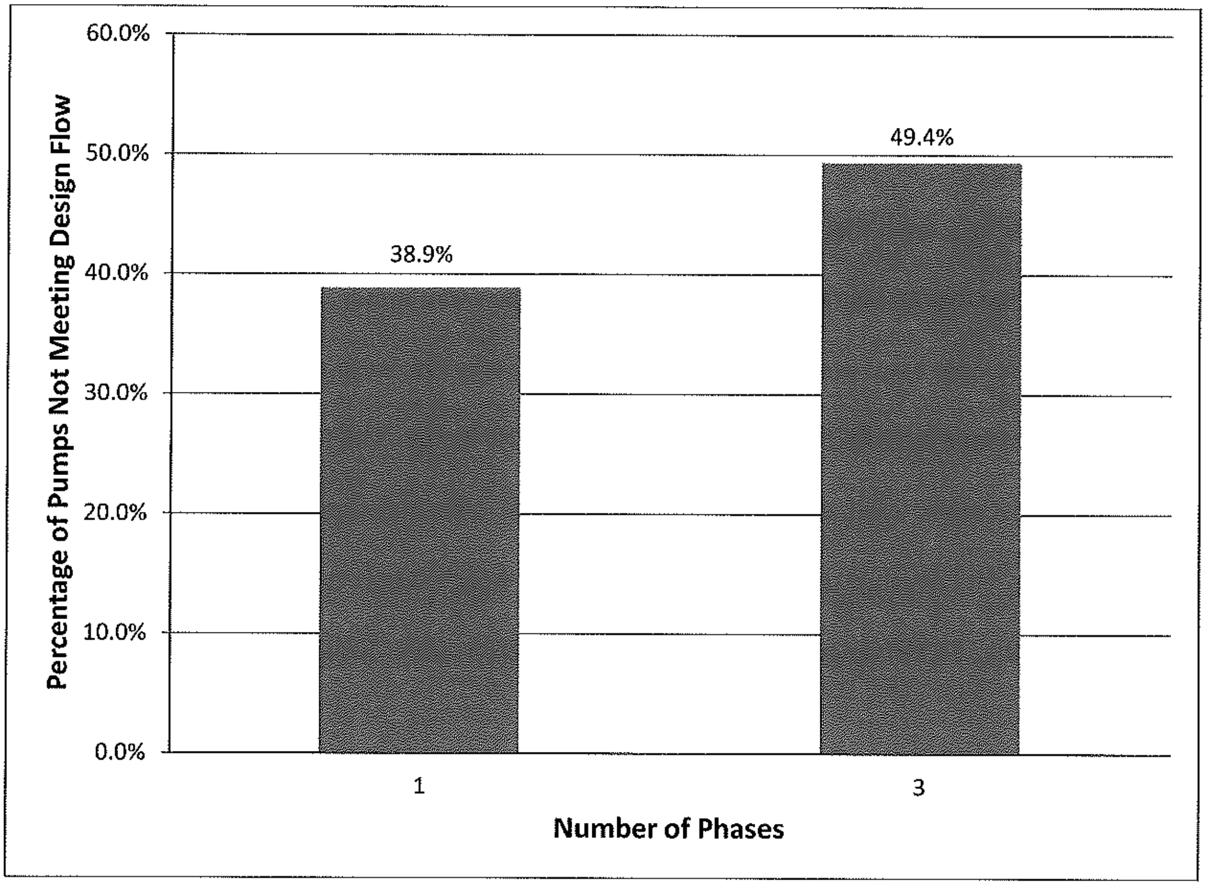

Figure 12: *Graphical distribution of underperforming pumps based on electrical phase.*

Figure 12 shows the distribution of low-flow pumps by electrical phase, either single phase or three phase. The single phase electrical service shows a low-flow incidence of 38.9%, versus 49.4% for the three phase service. However, for wastewater pumping stations, single phase electrical service is relatively rare. Of the 344 pumps in the data set, only 18 use single phase power, and of those, only 7 are considered low-flow pumps for the purpose of this study. Due to the low sample size for the single phase pumps, the data was not shown to be statistically significant. However, it is worth noting that single phase electrical service is only suitable for motor sizes 7.5 HP and smaller, which means that single phase service is only suitable for pumps with relatively small design flows and TDHs. Based on the trends observed with the design TDH and motor size data, it stands to reason that pumps using single phase electrical service would have a lower incidence of low-flow conditions on average. However, the data trends imply that the lower incidence of low-flow pumps on single phase electrical service would be attributable to other factors, and not to the electrical phase directly.

Electrical Voltage

In addition to variations in electrical phase, each pump station varies in the design voltage for the electrical service. Single phase service is always 240V for wastewater applications of this type, but three phase service is available in 208V, 240V, or 480V. On average, the lower voltages of 208V and 240V are more common for wastewater pumping stations, but 480V is often used for applications with larger motor sizes to decrease the required Amperage draw of the motors. For this reason, all pumps in the data set with motor sizes above 60 HP use 480V electrical service.

Figure 13 shows the distribution of low-flow pumps based on the voltage of the electrical service. Unlike some of the other distributions, there are no under-represented categories in this distribution, as each voltage shown represents at least 20% of the data set. Based on the trend observed in the motor size data, and based on the understanding that 480V electrical service is more common with larger motor sizes, it is no surprise that the 480V electrical service has the highest incidence of low-flow pumps, at 55.4%. However, the 208V electrical service is almost as high, at 52.9%. The 240V electrical service shows the lowest incidence of underperforming pumps, at 43.4%, although this difference was not found to be statistically significant.

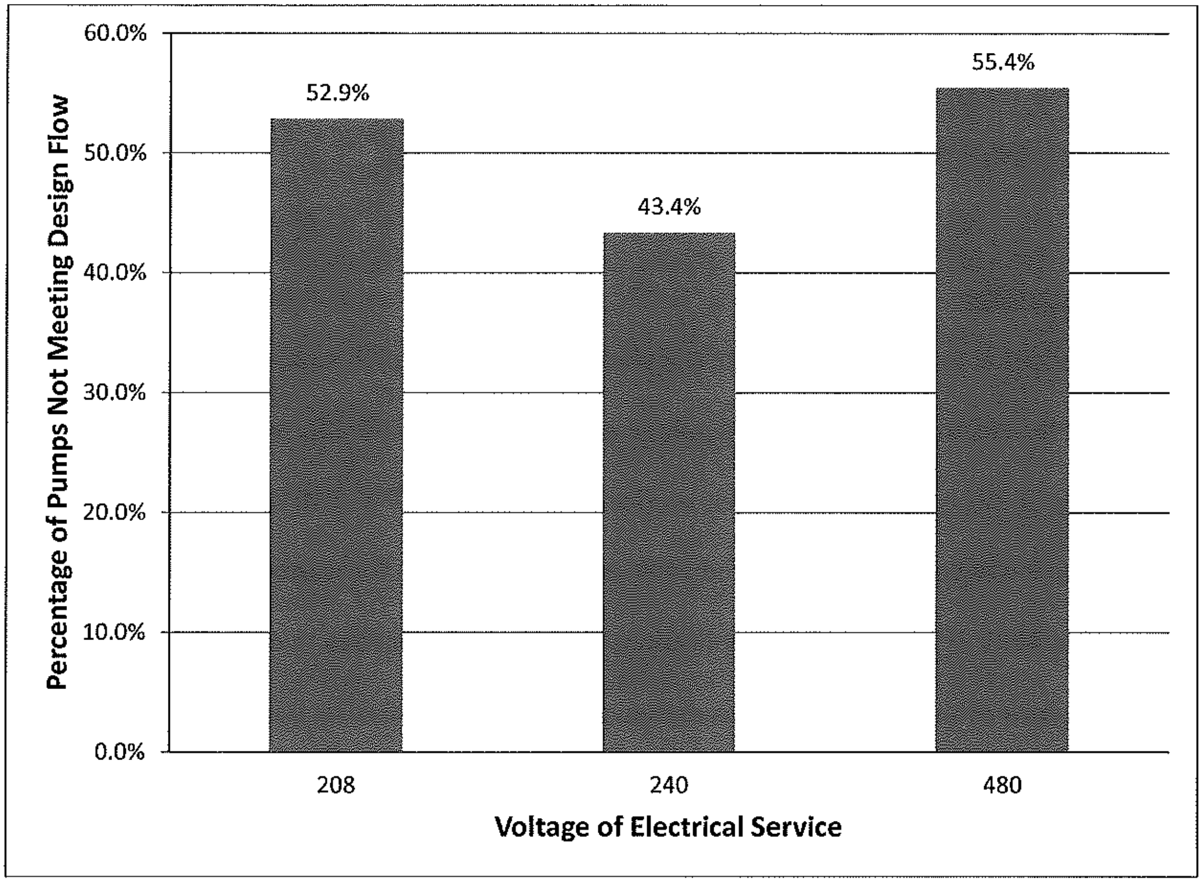

Figure 13: *Graphical distribution of underperforming pumps based on electrical voltage.*

In Figure 12, single phase electrical service is shown to have a lower incidence of underperforming pumps. Since single phase service is only available as 240V, the lower incidence rate of 240V may be explained in part by the inclusion of the single phase data. Figure 14 shows the distribution of low-flow pumps based on the voltage of the electrical service, except in this case the 240V bar is split to show single phase and three phase service separately. Again, the single phase service is shown to have a lower incidence of underperforming pumps, which appears to have slightly affected the combined data for 240V service. However, single phase pumps represent only 10.4% of all 240V pumps, so separating single phase from 3 phase only changed the 3 phase 240V incidence rate from 43.4% to 43.9%. Overall, there appears to be no apparent trend that indicates the electrical voltage has a direct effect on the incidence of low-flow pumps, as none of the differences shown in Figure 14 were found to be statistically significant.

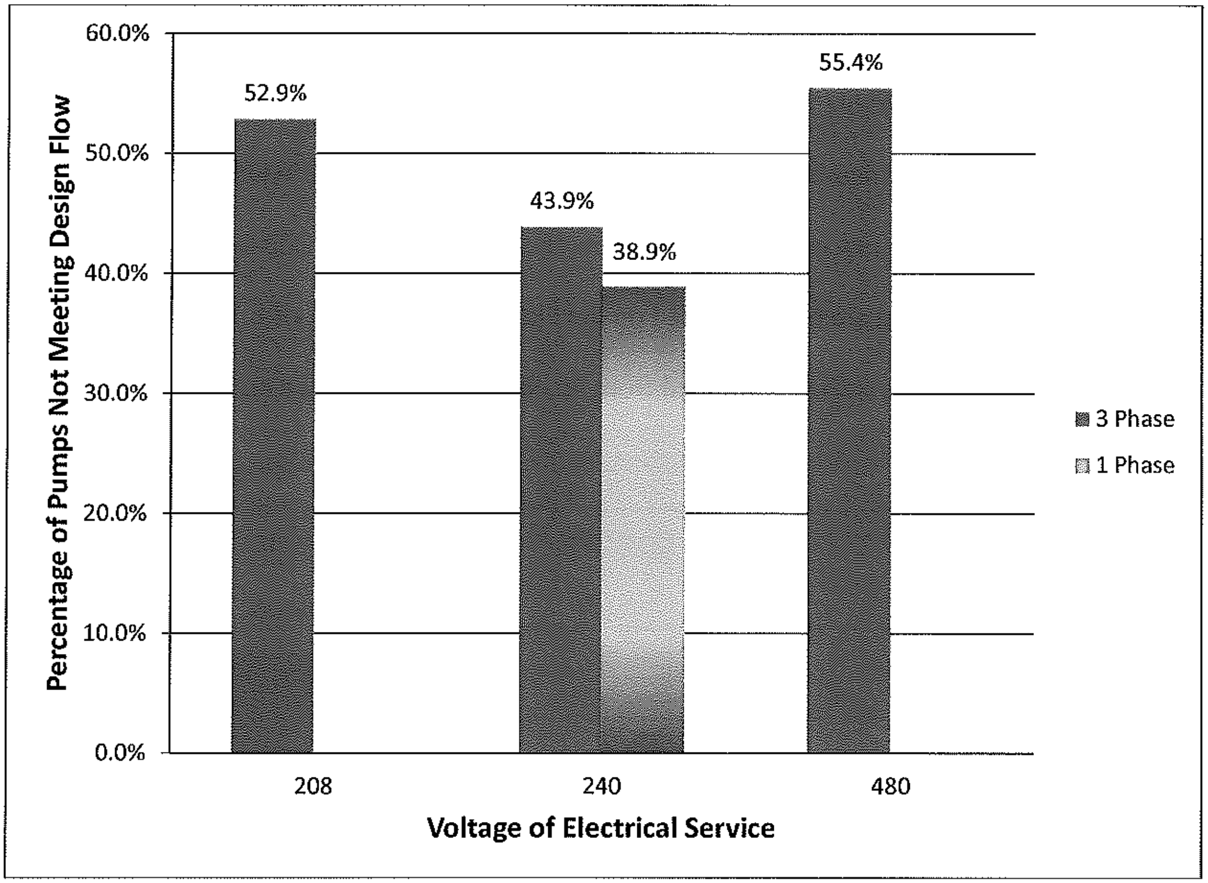

Figure 14: Graphical distribution of underperforming pumps based on electrical voltage, with single-phase 240V separated from 3-phase 240V service.

Motor Starter Type

For wastewater pumping stations, there are three major types of motor starters, which are full voltage, non-reversing (FVNR), reduced voltage, solid state (RVSS), and variable frequency drive (VFD) starters. Figure 15 shows the distribution of low-flow pumps based on the type of motor starter used by the pumps. Only data for FVNR and RVSS starters is shown, since VFD operation does not allow for accurate calculation of flow rate by the OmniSite pump station monitor. VFDs operate by changing the electrical frequency to vary the pump speed and resulting pump flow rate. The design flow rate corresponds to the "full speed" operating condition, and the VFDs vary the flow between the design flow rate and a lower flow rate corresponding to an adjustable "low speed" condition. Since the pump speed varies, at best the OmniSite could only calculate the average flow rate for each pump cycle, which would always be lower than the design flow rate. For this reason, the volumetric flow calculations are considered unreliable, and are often disabled on the OmniSite for pumps with VFDs. Pumps with VFD starters were specifically omitted from this data collection based on the expectation of erroneous flow data.

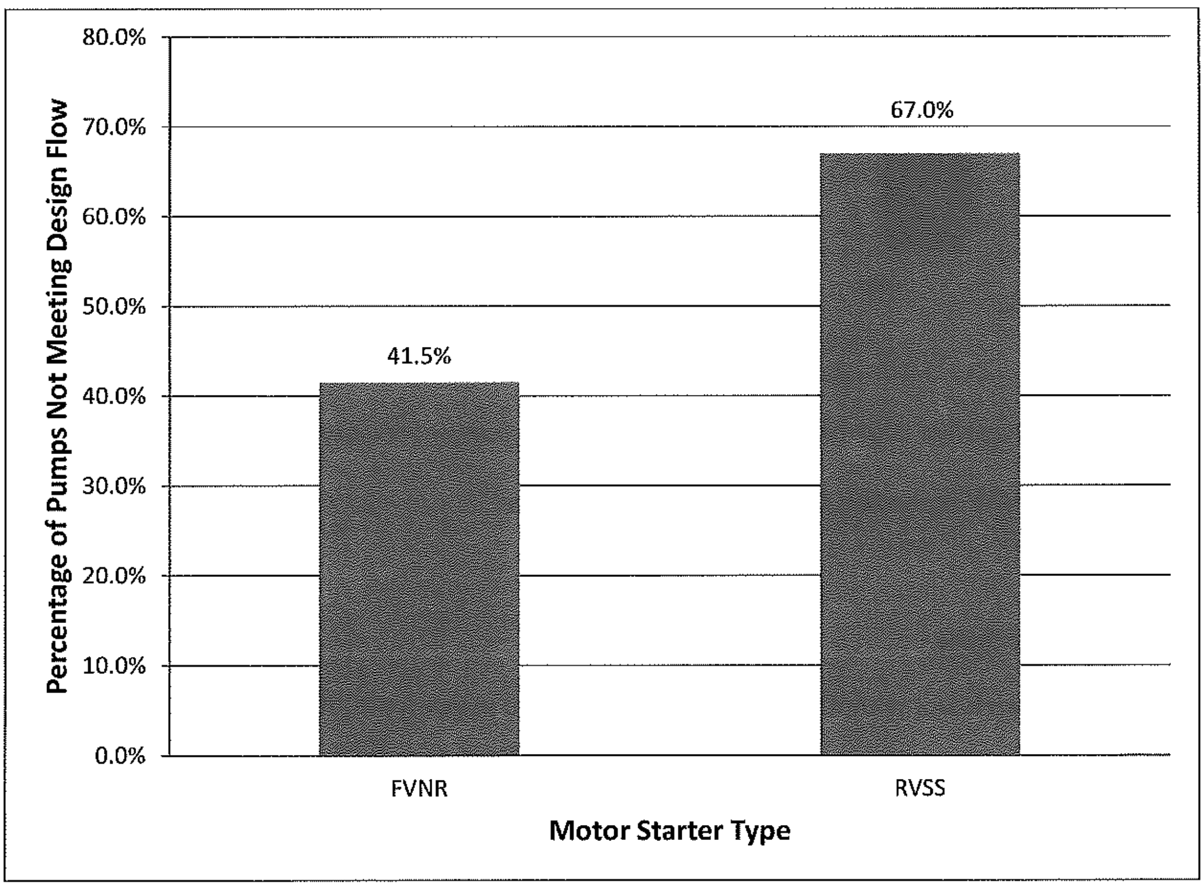

Figure 15: *Graphical distribution of underperforming pumps based on motor starter type.*

Figure 15 shows a stark difference in the incidence of low flow pumps between FVNR and RVSS starters. The incidence for FVNR starters is only 41.5%, compared to 67.0% for the RVSS starters. A two-sample t-test was performed to determine whether there was a significant difference between the motor starter types. The t-statistic was significant at the .05 critical alpha level, $t(340) = 4.213$, $p = 0.0000$. This indicates that the FVNR and RVSS underperformance rates are significantly different.

The most likely explanation for this difference lies in the volumetric drawdown calculation method used by the OmniSite to calculate the pumped flow rate. As previously discussed, the OmniSite's volumetric drawdown equation is based on the drawdown volume and the drawdown time. The drawdown time is defined as the total amount of time that the pump runs during the pump cycle. The primary function of RVSS starters is to provide "soft start" and "soft stop" functionality, which lengthens the start and stop cycle of the pump to reduce motor inrush current and minimize hydraulic surging. Since the pump does not produce much flow during the soft start and stop cycles, the increased drawdown time results in a lower calculated flow rate using the volumetric drawdown method.

Typical soft start/stop cycle times range from 5 seconds to 30 seconds, and the average drawdown times for the pumps in the data set range from 33 seconds to over 8 minutes. For example, a 5 second soft start and 5 second soft stop cycle would increase the total drawdown time by 10 seconds. For an 8 minute drawdown time, this is an increase of only 2.08%, which would decrease the calculated flow rate by 2.04%. Alternately, a 30 second soft start and 30 second soft stop cycle adds 1 minute to the total drawdown time. For a 1 minute cycle time, this is an increase of 100%, which decreases the calculated flow rate by 50%. These examples show

how the overall effect of the soft start and stop functions on the calculated flow rate depends greatly on the length of each soft start/stop cycle and the overall length of the pump cycle.

It is expected that RVSS starters would have a higher incidence of low-flow pumps based on the soft start/stop operation. However, it is also worth noting that RVSS starters have gained in popularity in recent years. Only 11.7% of all pumps with RVSS starters in the data set are older than 15 years, and only 37.2% are older than 10 years. In addition, since RVSS starters are useful for reducing motor inrush current and minimizing hydraulic surging, they are used most often in applications with relatively large motors and relatively high TDHs. Even though 73.5% of all pumps in the data set have motors less than 30 HP, only 27.7% of pumps with RVSS starters have motors that small. This indicates that RVSS starters tend to be heavily represented for pumps less than 10 years old, with a relatively high design TDH, and/or with a relatively large motor, all of which have been shown with higher occurrence of low flow pumps.

Pump Cycles Per Day

The data and trends above are based on pump, motor, and design characteristics collected from the Envirep equipment database. These characteristics are determined during the pump station design process, and they cannot be changed without replacing or modifying some or all of the existing equipment. The data and trends that follow, however, are based on information collected from the OmniSite GuardDog web interface. This information includes operational characteristics such as daily pump cycle counts, drawdown times, daily run times, and daily flows. These parameters are based on the day-to-day operation of the pumping system, and are subject to change based on control settings, influent flow rates, and other factors.

Figure 16 shows the distribution of low-flow pumps based on the average number of pump cycles per day. The majority of the pumps in this data set average less than 60 cycles per day, with only 14 total pumps falling into the 100+ cycles per day range. As shown, the data seems to indicate that the incidence of low-flow pumps decreases with more cycles per day. However, considering that the upper ranges are under-represented, more investigation would be required to determine if that trend holds true.

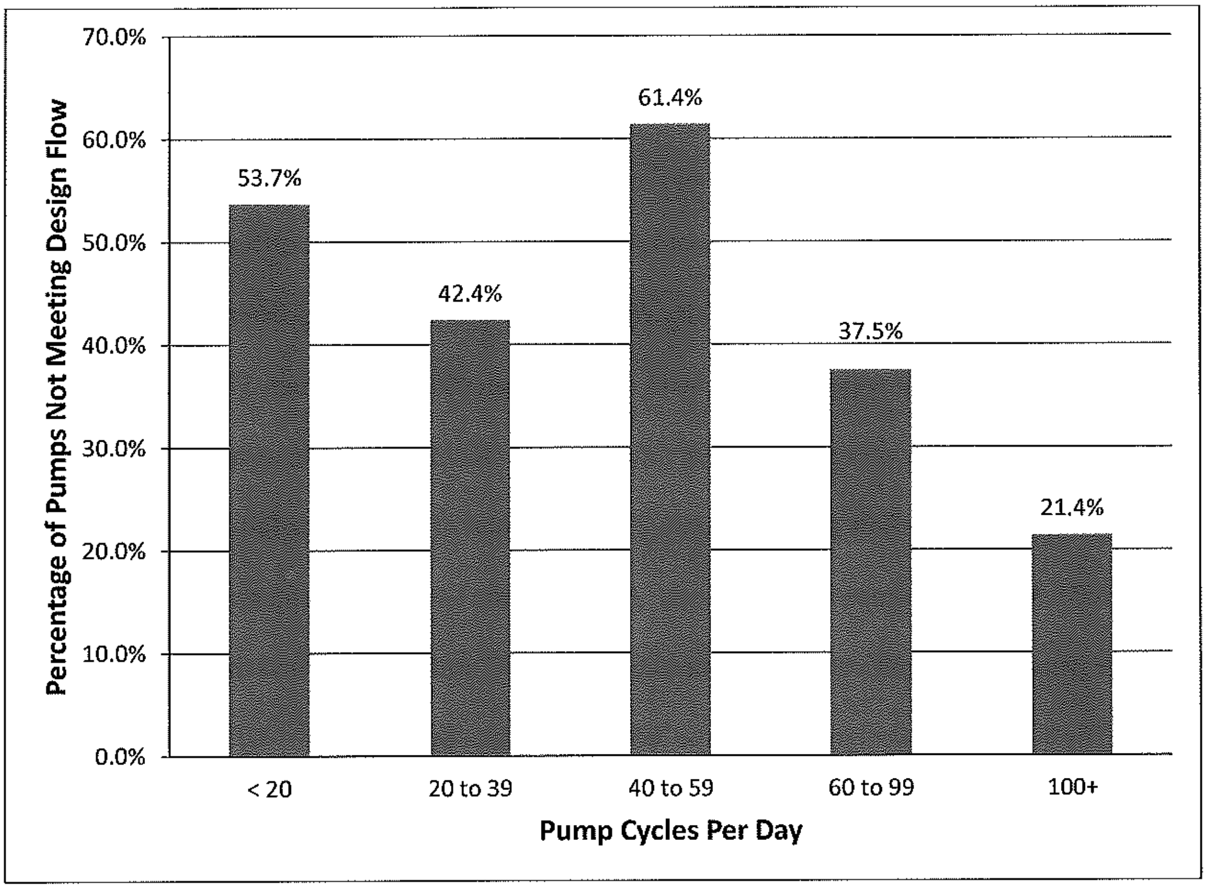

Figure 16: *Graphical distribution of underperforming pumps based on the average number of pump cycles per day.*

A two-sample t-test was performed to determine whether there was a significant difference between the 40 to 59 cycles per day range and the 20 to 39 cycles per day range. The t-statistic was significant at the .05 critical alpha level, $t(167) = 2.433$, $p = 0.0160$. This indicates that the two ranges are significantly different. It was also found that the 40 to 59 cycles per day range was significantly different than the 60 to 99 cycles per day range and the 100+ cycles per day range. In addition, a two-sample t-test was performed to determine whether there was a significant difference between the 100+ cycles per day range and the < 20 cycles per day range. The t-statistic was significant at the .05 critical alpha level, $t(133) = 2.288$, $p = 0.0237$. This indicates that the 100+ cycles per day range is significantly lower, which supports the observed trend.

Average Drawdown Time

Figure 17 shows the percentage of low-flow pumps occurring at different ranges of average drawdown time. The ranges of drawdown times 2 minutes and greater all show relatively similar low-flow percentages, with all four ranges falling between 57% and 69%. However, the range of average drawdown times under 2 minutes is shown as having a much lower incidence of low-flow pumps, at only 27.0%. A total of 122 pumps fall into this range, which is 35.5% of all pumps in the data set. A two-sample t-test was performed to determine whether there was a significant difference between the < 2 minute range and the 2 to 3 minute range. The t-statistic was significant at the .05 critical alpha level, $t(239) = 4.736$, $p = 0.0000$. This indicates that the < 2 minute range and the 2 to 3 minute range are significantly different. The < 2 minute range was also found to be significantly different than all other ranges.

There are several factors that may help to explain why drawdown times less than 2 minutes have a drastically lower incidence of low-flow pumps. One possible explanation is that RVSS starters, which were shown to correlate with a high incidence of low-flow pumps, are rare in this range of drawdown times. Of 122 pumps with an average drawdown time less than 2 minutes, only 19 use RVSS starters. This means that RVSS starters represent only 15.6% of the pumps in this range, although RVSS starters make up 27.3% of all the pumps in this data set. This is due in large part to the soft start/stop operation of RVSS starters, which artificially extends the drawdown time by adding additional run time to the beginning and end of each pump run cycle. This tends to place pumps with RVSS starters in higher drawdown time ranges.

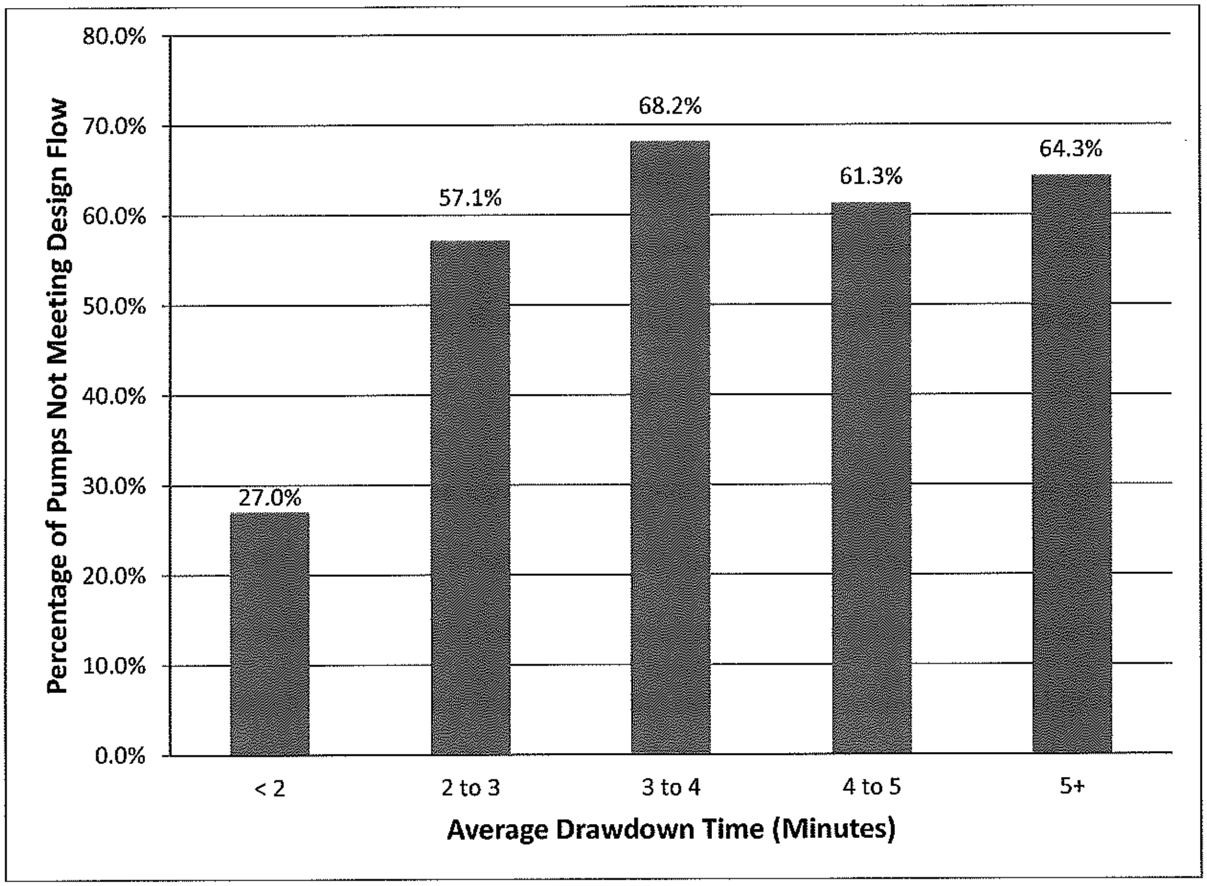

Figure 17: *Graphical distribution of underperforming pumps based on the average drawdown time.*

In general, if the flow rate for a pump decreases for any reason, it will increase the average drawdown time for that pump. Wastewater pumps operate based on the water level in the wet well, so the drawdown volume is fixed unless an operator changes the level settings in the level control system, or adjusts the physical locations of float switches or other level devices. If the drawdown volume stays constant, but the pumped flow rate decreases, the average drawdown time will necessarily increase. Therefore, a greater decrease in flow increases the chance that a pump will be considered a low-flow pump, but the resultant increase in drawdown time increases the chance that the drawdown time will be above 2 minutes.

During the pump station design process, the recommended drawdown volume for a duplex pumping station is calculated using Equation 3. In this equation, V is the recommended minimum drawdown volume, T is the minimum recommended pump cycle time, and Q is the design flow rate. T is based on the recommended maximum starts per hour. For a maximum of 4 starts per hour, T would be 15 minutes. For 6 starts per hour, T is 10 minutes.

$$V = \frac{T*Q}{8} \qquad \text{(Equation 3)}$$

By simplifying equation 3, the recommended drawdown volume can be stated as 1.25 times the design flow for 6 starts per hour, or 1.875 times the design flow for 4 starts per hour. Since these drawdown volumes are expressed as multiples of the design flow, the drawdown times would be 1.25 minutes and 1.875 minutes for 6 starts per hour and 4 starts per hour, respectively. These are the minimum possible drawdown times for these scenarios, as they do not account for the effect of inflow during the pump cycle. As inflow rate increases, the drawdown time will increase as well. Also, as the pumping rate decreases, the drawdown time will increase. An 8% decrease in pumping rate increases the drawdown time by 8.7%. For example, if the minimum drawdown time for a design of 4 starts per hour is 1.875 minutes and the flow rate decreases 8% below the design flow rate, the minimum drawdown time is now 2.04 minutes. In this way, many of the low-flow pumps will have increased drawdown times, placing them in a higher range of drawdown times leading to the results shown above.

Average Daily Run Time

Figure 18 shows the distribution of low-flow pumps based on average daily run time. There appears to be a slight trend indicating that pumps with average daily run times of one hour or less tend to have a lower incidence of low-flow pumping conditions. A two-sample t-test was performed to determine whether there was a significant difference between the 1.5 to 2 hour range and the 0.5 to 1 hour range. The t-statistic was significant at the .05 critical alpha level, $t(117) = 2.349$, $p = 0.0205$. This indicates that the 1.5 to 2 hour range and the 0.5 to 1 hour range are significantly different. It was also found that the 1.5 to 2 hour range was significantly different than the < 0.5 hour range.

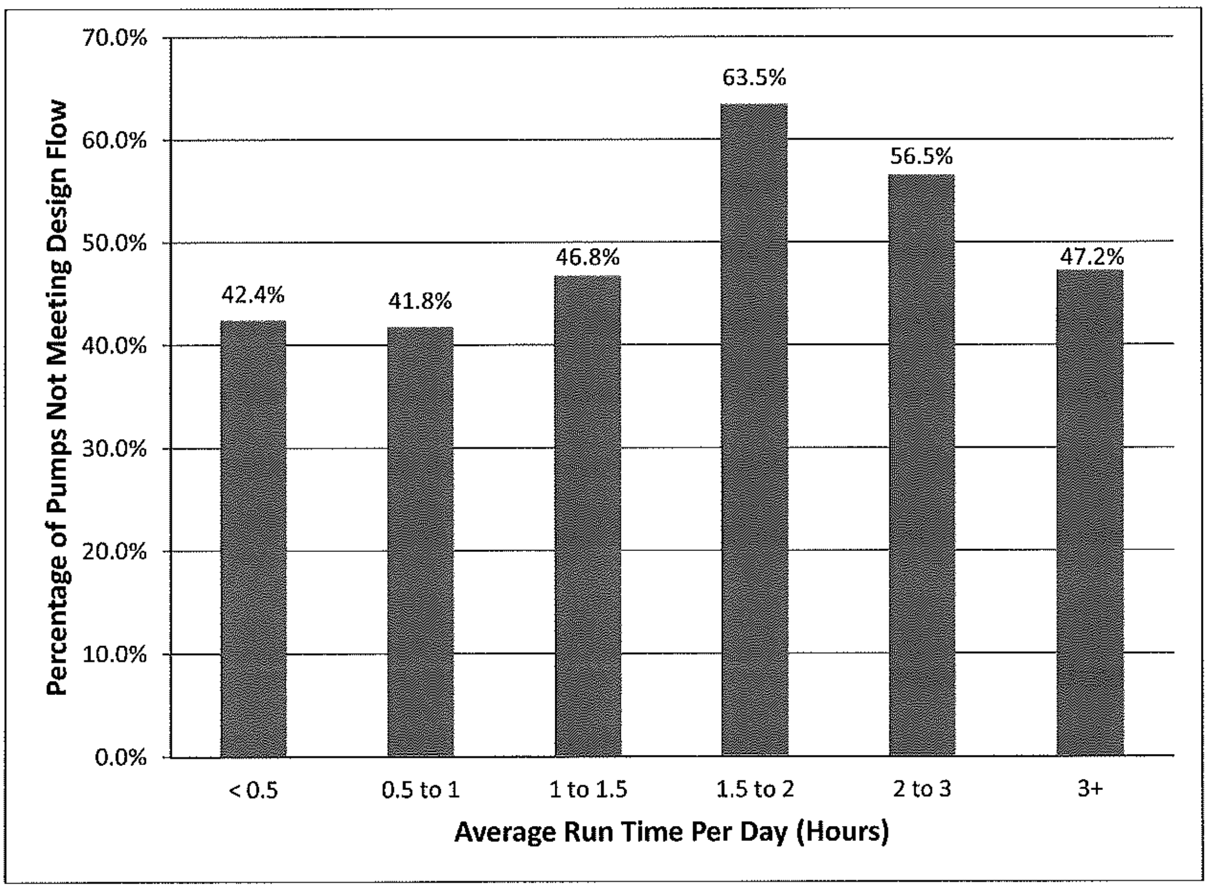

Figure 18: *Graphical distribution of underperforming pumps based on the average pump run time per day.*

These observations can be explained in a similar manner as the drawdown time results above. The average daily run time is based on the inflow into the pump station and the pump flow rate. The inflow is relatively fixed, in that it cannot be changed by modifying the pump station, so a decrease in pump flow rate would necessarily increase the daily run time. By this logic, the lower ranges of average daily run time would be less likely to include pumps operating below their design flow rate, so the incidence of low-flow pumps in those ranges would be lower.

The average daily run time behaves similarly to the average drawdown time, in that a decrease in pump flow rate increases the daily run time or drawdown time, thereby reducing the low-flow pump incidence at lower ranges. However, it is worth noting that while the drawdown time data showed a large drop in low-flow pumps at the lowest range, the daily run time data does not show a drop of the same magnitude. This is likely because daily run time is heavily dependent on and limited by daily inflow, which cannot be changed by modifying the pump station, and which affects the daily run time much more than the pump flow rate does. If the daily inflow is very low, it is unlikely that any decrease in pump flow rate will push the daily run time to a higher range. The drawdown time, however, is much more dependent on the pump flow rate, and mostly independent of the station inflow.

Average Daily Pumped Flow

Figure 19 shows the distribution of low-flow pumps by average daily pumped flow. While the lowest five ranges all have similar percentages of low-flow pumps, the highest range shows a drastic drop. In this range, which is reserved for pumps that deliver over 100,000 gallons each day, only 17.6% of pumps have a flow rate over 8% less than design flow. A two-sample t-test was performed to determine whether there was a significant difference between the

100,000+ gallons per day range and the < 10,000 gallons per day range. The t-statistic was significant at the .05 critical alpha level, $t(138) = 3.596$, $p = 0.0004$. This indicates that the two ranges are significantly different. In addition, it was found that the 100,000+ gallons per day range was significantly different than all other ranges.

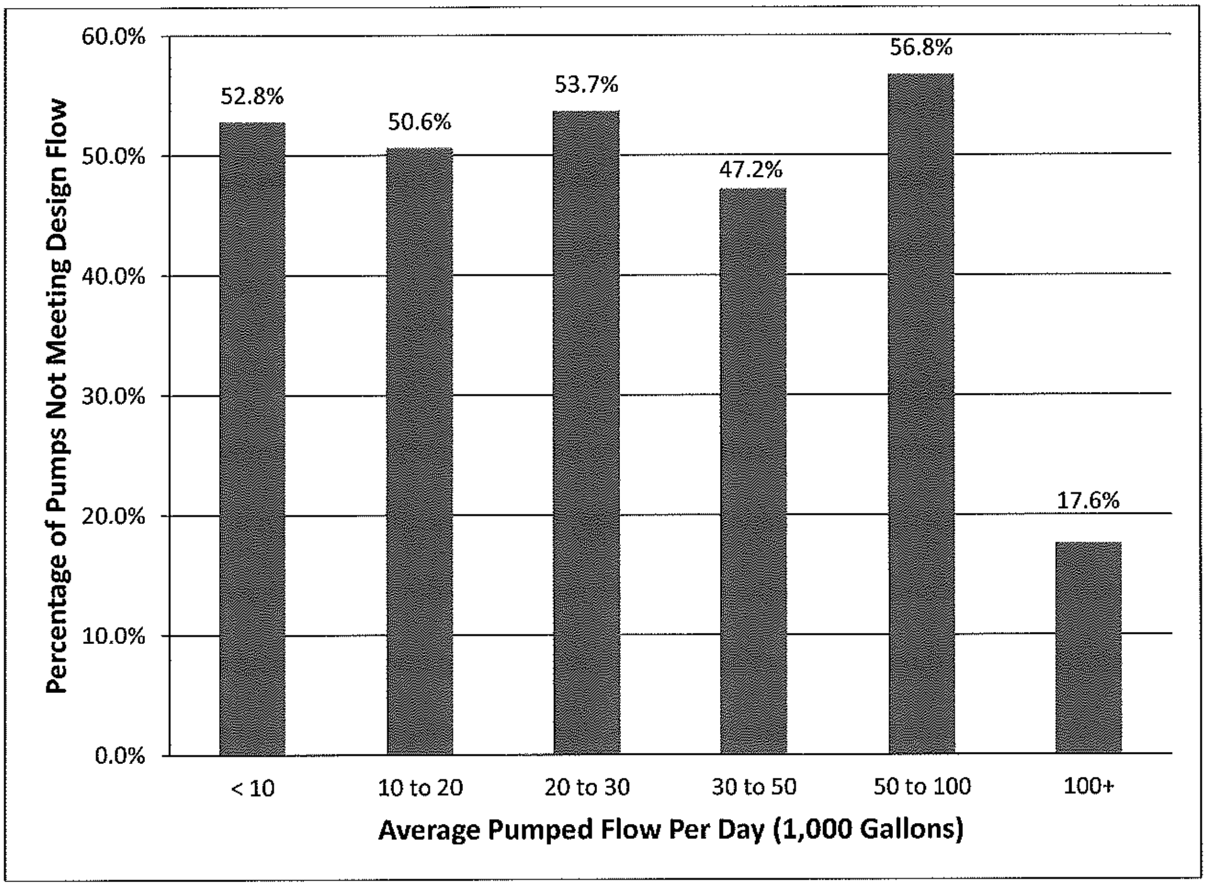

Figure 19: *Graphical distribution of underperforming pumps based on the average pumped flow per day.*

<u>Overperforming Pumps</u>

Although this study focuses on the pumps that are performing below the design flow rate, there are also many pumps in the data set that are shown to be performing above the design flow rate. Overall, a total of 96 pumps, or 27.9% of the total pumps surveyed, are operating at a flow rate 8% or more above the design flow rate. Typically, operation at flows above design is not a problem for wastewater pumps unless there is a hydraulic or process limitation downstream. In most cases, pumping more flow will not cause the operational, hydraulic, mechanical, and overflow problems associated with pumping less flow. For this reason, the over-performing pumps are not typically considered to be a problem. However, when the OmniSite shows a pump to be over-performing, it may be a sign of an underlying problem that should be addressed. Therefore, it is recommended that any deviation over 8% above or below the design flow be investigated to ensure that the pumps are operating as designed.

Causes of Underperformance

This study attempts to find correlations to link under-performing pumps to a component of the pump station design or operation. However, while some of the design or operational characteristics may correlate with the occurrence rate of low-flow pumps, these characteristics are typically not the direct causes of decreased flow. A pump may experience a flow rate less than the design rate due to many factors. Errors during the design process can result in a pumping system that has a higher TDH than designed, which would result in a lower flow rate from the pumps. However, it is worth noting that such errors are typically discovered and resolved during equipment startup. A pump or check valve may develop a full or partial clog, or any of the suction, discharge, or force main piping may become blocked by an obstruction. Flow may decrease over time from air buildup in the force main due to missing or clogged air release valves, or flow may decrease due to solids settling in the force main piping. Worn wear parts may cause clearances inside the pump to open up, causing a loss of efficiency and flow. Troubleshooting the true cause of a reduced flow rate may require extensive testing, but the process cannot begin until the reduced flow is recognized.

In addition to the many causes of flow reduction, there are other conditions that may result in the OmniSite flow data being skewed to show a low flow condition for a pump that is operating properly. As discussed above, the additional pump cycle time caused by RVSS motor starters could cause the calculated flow to be artificially low. In addition, incorrect settings in the OmniSite or the level control system at the pump station could result in erroneous flow calculations. However, it is important to note that the OmniSite units and the pumping stations undergo extensive and thorough startup by a professional, factory-trained service technician before the equipment is placed into service, so all programming should be accurate unless changed by the equipment Owner following startup. Finally, the information in the Envirep equipment database could be incorrect or out of date, due to changes made by the equipment Owner following startup. This means that some of the pumps shown to be under-performing may not actually be experiencing a flow decrease. However, low flow conditions should always be investigated so that the cause of the low flow readings can be addressed and corrected.

Troubleshooting Example

As standard practice, any variation in calculated flow should be investigated to rule out any problems with the pumping system. For example, the data set shows the highest over-performing pumps are Pump 114 and Pump 115, which are both installed at the same pumping station. The OmniSite calculated flow rates for Pump 1 and Pump 2 at 469 GPM and 456 GPM, respectively. The Envirep equipment database showed the design flow rate as only 140 GPM, so the OmniSite calculated flow was more than double the design flow. Upon further investigation, it was determined that the pump station force main was recently replaced, and the new design flow was calculated as 275 GPM. Even considering this change in the design flow, the OmniSite flows were still much higher. Following a day of troubleshooting, it was determined that the level controller was malfunctioning. Once the controller was replaced, the OmniSite re-calculated the flows for Pump 1 and Pump 2 to be 247 GPM and 212 GPM, respectively. Based on this correction, both pumps would now be considered low-flow pumps, as they are more than 8% below the new design flow.

CONCLUSION

In the course of this study, data was collected for 344 individual pumps and was used to determine which pumps were delivering over 8% less than the design flow rate. The data was then analyzed to find trends and correlations between different design and operational characteristics with the incidence of under-performing pumps. The data trends showed the following results:

- Pumps 10-19 years old included fewer under-performing pumps, while pumps both younger and older had more under-performers.
- Submersible pumps had fewer under-performers than suction-lift pumps, but the data set was insufficient for older submersible pumps. Based on most age ranges, the difference between the pump types was not statistically significant.
- Pumps with 316 Stainless Steel wear parts had fewer under-performers than those with Ductile Iron or Austempered Ductile Iron wear parts, but the difference was not statistically significant.
- Pumps with a lower flow rate were less likely to be under-performers.
- Pumps with a lower design TDH were less likely to be under-performers.
- Pumps with smaller motors were less likely to be under-performers.
- Pumps operating on single phase power had fewer under-performers than those operating on 3 phase power, but the difference was not statistically significant.
- Pumps with FNVR starters had fewer under-performers compared to those using RVSS starters.
- Pumps with an average drawdown time under 2 minutes had much fewer under-performers than pumps with drawdown times 2 minutes or more.

From the data presented above, there are several potential warning signs that a pump station may be at a higher than normal risk to have one or more under-performing pumps. RVSS starters, large motors, and a high design flow or TDH correlate with a higher incidence of under-performing pumps, so equipment owners should pay close attention to pumping stations with these characteristics, especially when the pump station also includes suction-lift pumps, a drawdown time over 2 minutes, and /or 3 phase power.

Overall, equipment owners with OmniSite cellular pump station monitors should routinely check the calculated flow rate for each of their pumps to determine if there is a discrepancy or change. Any abnormal flow rates, regardless whether the flow is lower or higher than normal, should be investigated immediately, and the equipment should be returned to working order as soon as possible to avoid potential problems or overflows. Even when a change in the calculated flow rate is not a result of a pump problem, it may indicate a problem with another component of the pumping system which should be corrected if possible.

The OmniSite cellular pump station monitor is a useful tool for monitoring pumping equipment and for diagnosing and preventing potential problems before they escalate. However, it is important to understand the functions and limitations of the OmniSite monitors in order to make better use of them in a wastewater pumping system. By understanding and monitoring the OmniSite units and the data they collect, and by understanding which pump station design and operational characteristics most often lead to flow problems, equipment owners and operators can better control and maintain their wastewater pumping systems.

FUTURE WORK AND RECOMMENDATIONS

As shown above, the calculated flow data can be affected by many different factors. To advance this study, each pump station should be evaluated to confirm proper programming of the OmniSite unit and the pump station controls, and any stations found to have a programming error should be excluded from the data set to minimize the error in the data set. Then, a thorough investigation should be conducted to determine the underlying cause for the under-performance of each pump remaining in the data set. Such a study would provide more insight and detail on the true causes of low calculated flow rates on the OmniSite monitors, and would be very useful to Owners and Operators as a tool for prioritizing troubleshooting efforts.

For Engineers:

Recommendation: Engineers using the OmniSite data to prepare Chapter 94 or similar reports should first evaluate the collected data to determine if the data is reliable. If there is any reason to doubt the data, a pump station evaluation should be conducted to prove or disprove the accuracy of the data.

Best Practice: Engineers should pay close attention to the results of pump station startups to ensure that the startup data matches the engineering calculations and other design characteristics. If there is a discrepancy between design and startup, the issue should be addressed to determine the source of the discrepancy and rule out any potential errors in design.

For Owners/Operators

Recommendations: Owners should not make any changes to the operating levels, or to the pumping system itself, without also making any associated changes to the OmniSite programming to avoid error in the data. Also, Owners should conduct pump station evaluations on a regular basis to ensure that the OmniSite data is accurate and reliable.

Best Practice: Owners and Operators of wastewater pumping systems should regularly check the automatically-monitored data on the OmniSite web site to catch problems early before more serious issues develop. To do this, Owners should compare the station design flow rate to the calculated rate, and investigate any instance where there is more than an 8% discrepancy.

For the Manufacturer

Recommendations: OmniSite monitors should include user-adjustable parameters to enter the ramp-up and ramp-down times for stations with RVSS starters. Since very little flow is produced during the soft start/stop functions, these times should be subtracted from the drawdown time when calculating the flow rate for a more accurate result. Also, it was found that if a pump did not run for a full day, the flow rate for that day was shown as 0 GPM, and that 0 GPM flow was averaged with the flow rates for other days in the 3-month period to get the average calculated flow rate. OmniSite should correct this by omitting the 0 GPM days from the average flow calculations to produce a more accurate average flow rate.

Best Practice: The OmniSite should include a field to enter the design flow rate, with an option to generate an alarm if the calculated flow rate drops a certain percentage below the design rate. This would help to notify equipment owners of a potential problem. The OmniSite should also post the internal setup parameters on the web page, including the drawdown volume, wet well size, and other information. This would assist in the troubleshooting process, as the service technician could confirm that the OmniSite is setup correctly without traveling to the pump station site.

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APPENDIX A

ENVE 594 — OmniSite Pump Station Data Collection — June - August 2017 (6/1/17-8/31/17)

Pump Number	Pump Station	Ship Date	Station Age (yrs)	Pump Type	Pump Discharge Size (Inches)	Materials of Construction	Rated Flow (GPM)	Rated Head (feet H2O)	Motor Size (HP)	Phase (1 or 3)	Voltage	Motor Starter Type	Pump #	Avg. Cycles per Day	Total Cycles	Avg Drawdown Time	Avg Run Time Per Day	Total Run Time (sec)	Avg Flow (GPM)	Avg Effluent Flow (gal/day)	Total Effluent Flow (gal)
1	Lift Station 1	12/7/2001	15	Suction Lift	3	DI	100	46	15	3	208	FVNR	1	8	817	00:04:15	00:37:28	58:04:52	112	4,199	390,511
2	Lift Station 1	12/7/2001	15	Suction Lift	3	DI	100	46	15	3	208	FVNR	2	8	819	00:04:13	00:37:13	57:42:17	113	4,206	391,165
3	Lift Station 10	7/1/2005	12	Suction Lift	4	ADI	400	211	60	3	240	RVSS	1	34	3166	00:02:16	01:17:42	120:26:42	406	31,549	2,934,127
4	Lift Station 10	7/1/2005	12	Suction Lift	4	ADI	400	211	60	3	240	RVSS	2	34	3162	00:02:13	01:15:23	116:50:45	413	31,169	2,898,767
5	Lift Station 15	3/16/2010	7	Suction Lift	3	SST	100	55	7.5	3	208	FVNR	1	51	4817	00:04:46	04:07:36	383:47:24	69	17,334	1,612,153
6	Lift Station 15	3/16/2010	7	Suction Lift	3	SST	100	55	7.5	3	208	FVNR	2	51	4818	00:04:39	04:01:06	373:43:30	72	17,569	1,633,931
7	Lift Station 17	5/15/2001	16	Suction Lift	6	DI	600	49	20	3	240	FVNR	1	24	2269	00:02:45	01:07:20	104:23:09	400	26,996	2,510,670
8	Lift Station 17	5/15/2001	16	Suction Lift	6	DI	600	49	20	3	240	FVNR	2	24	2269	00:02:53	01:10:41	109:34:24	386	27,296	2,538,595
9	Lift Station 19	12/7/2001	15	Suction Lift	3	DI	100	36.5	5	3	240	FVNR	1	36	3359	00:06:29	03:54:14	363:04:16	94	22,069	2,052,447
10	Lift Station 19	12/7/2001	15	Suction Lift	3	DI	100	36.5	5	3	240	FVNR	2	36	3360	00:07:16	04:22:52	407:27:16	87	22,976	2,136,794
11	Lift Station 2	12/7/2001	15	Suction Lift	3	DI	225	96.3	20	3	208	FVNR	1	19	1793	00:04:56	01:36:10	147:28:32	154	14,767	1,358,603
12	Lift Station 2	12/7/2001	15	Suction Lift	3	DI	225	96.3	20	3	208	FVNR	2	16	1497	00:04:44	01:17:10	118:20:00	146	12,117	1,114,765
13	Lift Station 22	5/11/2001	16	Suction Lift	4	DI	350	176	50	3	240	RVSS	1	25	2330	00:05:42	02:23:12	221:57:36	188	26,948	2,506,172
14	Lift Station 22	5/11/2001	16	Suction Lift	4	DI	350	176	50	3	240	RVSS	2	25	2337	00:05:56	02:29:15	231:20:16	182	27,233	2,532,674
15	Lift Station 23	5/15/2001	16	Suction Lift	3	DI	100	38	7.5	3	240	FVNR	1	27	2514	00:03:10	01:25:45	132:56:09	82	6,979	649,047
16	Lift Station 23	5/15/2001	16	Suction Lift	3	DI	100	38	7.5	3	240	FVNR	2	27	2512	00:03:59	01:47:46	167:02:32	67	7,174	667,214
17	Lift Station 24	4/5/2002	15	Suction Lift	3	DI	220	52	10	3	240	FVNR	1	47	4408	00:02:23	01:53:40	176:11:25	191	21,513	2,000,749
18	Lift Station 24	4/5/2002	15	Suction Lift	3	DI	220	52	10	3	240	FVNR	2	47	4405	00:02:09	01:41:53	157:55:49	209	21,124	1,964,615
19	Lift Station 25	8/13/2006	11	Suction Lift	6	ADI	450	83	30	3	208	RVSS	1	3	286	00:02:03	00:06:21	09:51:00	150	952	88,628
20	Lift Station 25	8/13/2006	11	Suction Lift	6	ADI	450	83	30	3	208	RVSS	2	3	283	00:02:08	00:06:31	10:07:29	150	979	91,094
21	Lift Station 3	11/13/2012	4	Submersible	3	DI	100	35	5	3	240	UNKNOWN	1	75	7045	00:02:42	03:25:11	318:03:17	87	17,604	1,637,255
22	Lift Station 3	11/13/2012	4	Submersible	3	DI	100	35	5	3	240	UNKNOWN	2	76	7077	00:03:09	04:00:43	373:07:32	81	18,687	1,737,908
23	Lift Station 6	9/23/2011	6	Suction Lift	3	SST	250	51	10	3	240	FVNR	1	26	2464	00:01:52	00:49:46	77:09:04	251	12,530	1,165,381
24	Lift Station 6	9/23/2011	6	Suction Lift	3	SST	250	51	10	3	240	FVNR	2	26	2473	00:01:57	00:52:10	80:52:10	241	12,601	1,171,903
25	Pump Station 1	12/11/2014	2	Suction Lift	8	ADI	729	51	25	3	240	RVSS	1	34	3188	00:01:52	01:04:26	99:52:53	960	61,869	5,753,895
26	Pump Station 1	12/11/2014	2	Suction Lift	8	ADI	729	51	25	3	240	RVSS	2	34	3188	00:01:54	01:05:26	101:26:31	951	62,270	5,791,160
27	Pump Station 1	12/11/2014	2	Suction Lift	8	ADI	729	51	25	3	240	RVSS	3	34	3187	00:01:49	01:02:27	96:49:22	989	61,793	5,746,818
28	Pump Station 6	1/6/2015	2	Suction Lift	8	ADI	1080	45	30	3	480	RVSS	1	18	1683	00:01:09	00:20:53	32:22:46	800	16,756	1,558,388
29	Pump Station 6	1/6/2015	2	Suction Lift	8	ADI	1080	45	30	3	480	RVSS	2	18	1693	00:01:09	00:21:12	32:51:59	794	16,870	1,568,975
30	Pump Station 2	10/31/2003	14	Suction Lift	4	DI	400	132	40	3	240	RVSS	1	32	3046	00:02:44	01:29:36	138:52:50	322	29,246	2,719,953
31	Pump Station 2	10/31/2003	14	Suction Lift	4	DI	400	132	40	3	240	RVSS	2	32	3048	00:02:41	01:28:22	136:58:58	326	29,343	2,728,929
32	Influent Pump Station	10/19/2001	16	Suction Lift	4	DI	360	30	7.5	3	480	FVNR	1	55	5095	00:02:27	02:17:23	208:23:00	330	45,289	4,121,351
33	Influent Pump Station	10/19/2001	16	Suction Lift	4	DI	360	30	7.5	3	480	FVNR	2	55	5093	00:02:22	02:12:44	201:18:49	331	44,094	4,012,555
34	Pump Station 1	2/15/2002	15	Submersible	4	DI	300	81.3	21	3	240	FVNR	1	23	2213	00:01:13	00:29:05	45:04:54	399	11,629	1,081,586
35	Pump Station 1	2/15/2002	15	Submersible	4	DI	300	81.3	21	3	240	FVNR	2	23	2214	00:01:12	00:28:34	44:17:16	406	11,612	1,079,929
36	Pump Station 2	2/15/2002	15	Submersible	4	DI	260	48	8.7	3	240	FVNR	1	70	6551	00:01:28	01:44:08	161:25:23	368	42,162	3,921,110
37	Pump Station 2	2/15/2002	15	Submersible	4	DI	260	48	8.7	3	240	FVNR	2	67	6234	00:01:19	01:28:47	137:37:44	372	37,334	3,472,089
38	Pump Station 3	2/15/2002	15	Submersible	4	DI	260	48	10	3	240	FVNR	1	67	6318	00:01:19	01:30:02	139:34:30	246	22,173	2,062,114
39	Pump Station 3	2/15/2002	15	Submersible	4	DI	260	48	10	3	240	FVNR	2	67	6318	00:01:08	01:17:42	120:26:58	284	22,059	2,051,555
40	Pump Station 4	2/15/2002	15	Submersible	3	DI	150	25	2.7	3	240	FVNR	1	3	346	00:01:23	00:05:09	07:59:42	152	789	73,429
41	Pump Station 4	2/15/2002	15	Submersible	3	DI	150	25	2.7	3	240	FVNR	2	3	346	00:01:18	00:04:51	07:31:25	162	789	73,442
42	Galyn Manor PS	10/10/2003	14	Suction Lift	4	DI	300	162	40	3	480	RVSS	1	38	3607	00:02:11	01:24:57	131:40:25	446	37,925	3,527,072
43	Galyn Manor PS	10/10/2003	14	Suction Lift	4	DI	300	162	40	3	480	RVSS	2	38	3603	00:02:17	01:28:28	137:08:48	430	38,093	3,542,660
44	Chesterfield PS 5	4/22/1998	19	Suction Lift	3	DI	200	63	10	3	208	FVNR	1	25	2364	00:01:49	00:46:26	71:58:58	245	11,414	1,061,584
45	Chesterfield PS 5	4/22/1998	19	Suction Lift	3	DI	200	63	10	3	208	FVNR	2	25	2359	00:01:51	00:47:11	73:09:20	242	11,424	1,062,466
46	Ridge Street PS 2	2/21/2003	14	Suction Lift	6	DI	700	78	30	3	240	FVNR	1	78	7211	00:02:21	03:04:55	283:33:44	949	188,508	17,342,812
47	Ridge Street PS 2	2/21/2003	14	Suction Lift	6	DI	700	78	30	3	240	FVNR	2	90	8307	00:02:40	04:02:04	371:10:31	1010	244,175	22,464,169
48	Shearer Drive PS 4	4/30/1991	26	Suction Lift	6	DI	400	41	10	3	480	FVNR	1	25	2391	00:03:05	01:19:19	122:56:58	154	12,264	1,140,576
49	Shearer Drive PS 4	4/30/1991	26	Suction Lift	6	DI	400	41	10	3	480	FVNR	2	25	2384	00:03:18	01:24:40	131:14:22	146	12,251	1,139,360
50	Spring Garden St PS 3	2/16/2009	8	Suction Lift	6	DI	1000	59	30	3	240	FVNR	1	51	4761	00:02:30	02:08:48	199:39:54	956	122,822	11,422,514
51	Spring Garden St PS 3	2/16/2009	8	Suction Lift	6	DI	1000	59	30	3	240	FVNR	2	51	4754	00:02:07	01:48:35	168:19:29	1098	118,252	10,997,447
52	Waggoners Gap PS 1	8/1/1988	29	Suction Lift	8	DI	700	140	60	3	480	FVNR	1	104	9672	00:02:08	03:43:16	346:05:15	886	199,923	18,592,879
53	Waggoners Gap PS 1	8/1/1988	29	Suction Lift	8	DI	700	140	60	3	480	FVNR	2	104	9678	00:02:09	03:44:58	348:42:14	885	200,700	18,665,192
54	Pine Hill PS	2/20/2009	8	Suction Lift	3	ADI	204	71.5	15	3	480	FVNR	1	55	5204	00:02:20	02:10:56	202:57:00	136	17,880	1,662,841
55	Pine Hill PS	2/20/2009	8	Suction Lift	3	ADI	204	71.5	15	3	480	FVNR	2	55	5200	00:02:55	02:43:30	253:26:24	123	20,225	1,880,987
56	Shiloh PS	6/20/2008	9	Suction Lift	4	ADI	500	160	50	3	480	RVSS	1	44	4123	00:03:41	02:43:47	253:52:13	445	73,003	6,789,355
57	Shiloh PS	6/20/2008	9	Suction Lift	4	ADI	500	160	50	3	480	RVSS	2	44	4121	00:04:06	03:01:41	281:37:05	405	73,726	6,856,560
58	Shiloh PS	6/20/2008	9	Suction Lift	4	ADI	500	160	50	3	480	RVSS	3	44	4111	00:04:17	03:09:37	293:54:37	385	73,074	6,795,893
59	Snowdens Run PS	12/31/2007	9	Submersible	6	DI	1200	125	64	3	480	RVSS	1	48	4468	00:01:26	01:09:10	107:13:08	1079	74,579	6,935,885
60	Snowdens Run PS	12/31/2007	9	Submersible	6	DI	1200	125	64	3	480	RVSS	2	46	4365	00:01:31	01:11:51	111:22:25	1021	73,307	6,817,622
61	Sykesville PS	11/9/2004	13	Suction Lift	6	ADI	500	175	40	3	480	FVNR	1	44	4100	00:02:42	01:59:23	185:02:51	960	114,604	10,658,198
62	Sykesville PS	11/9/2004	13	Suction Lift	6	ADI	500	175	40	3	480	FVNR	2	44	4100	00:02:50	02:05:04	193:52:30	921	115,261	10,719,283
63	Ashford Manor PS	6/10/2005	12	Suction Lift	3	DI	110	37	5	3	208	FVNR	1	8	819	00:01:50	00:16:10	25:03:44	117	1,896	176,353
64	Ashford Manor PS	6/10/2005	12	Suction Lift	3	DI	110	37	5	3	208	FVNR	2	8	801	00:01:53	00:16:21	25:21:22	113	1,861	173,115
65	Allwood Manor PS	3/12/2010	7	Suction Lift	4	DI	350	67	20	3	208	RVSS	1	16	1512	00:06:49	01:50:57	171:59:45	233	25,865	2,405,530
66	Allwood Manor PS	3/12/2010	7	Suction Lift	4	DI	350	67	20	3	208	RVSS	2	15	1480	00:07:06	01:53:06	175:19:46	224	25,137	2,337,756
67	Chapel View PS	1/31/2013	4	Suction Lift	3	DI	125	40	10	3	240	FVNR	1	24	2304	00:00:33	00:13:59	21:41:26	190	2,669	248,220
68	Chapel View PS	1/31/2013	4	Suction Lift	3	DI	125	40	10	3	240	FVNR	2	25	2343	00:00:57	00:24:15	37:35:41	150	3,564	331,498
69	Chestnut Hill PS	3/16/2007	10	Suction Lift	3	ADI	200	79.5	15	3	480	FVNR	1	24	2319	00:02:16	00:56:54	88:12:53	207	11,802	1,097,587
70	Chestnut Hill PS	3/16/2007	10	Suction Lift	3	ADI	200	79.5	15	3	480	FVNR	2	24	2319	00:02:09	00:53:43	83:15:53	218	11,661	1,084,506

ENVE 594 — **OmniSite Pump Station Data Collection** — June - August 2017 (6/1/17-8/31/17)

Pump Number	Pump Station	Ship Date	Station Age (yrs)	Pump Type	Pump Discharge Size (Inches)	Materials of Construction	Rated Flow (GPM)	Rated Head (feet H2O)	Motor Size (HP)	Phase (1 or 3)	Voltage	Motor Starter Type	Pump #	Avg. Cycles per Day	Total Cycles	Avg Drawdown Time	Avg Run Time Per Day	Total Run Time (sec)	Avg Flow (GPM)	Avg Effluent Flow (gal/day)	Total Effluent Flow (gal)
71	Canal Street PS	7/27/2007	10	Suction Lift	4	ADI	400	44	15	3	480	FVNR	1	13	1260	00:01:04	00:14:38	22:41:13	172	7,202	669,868
72	Canal Street PS	7/27/2007	10	Suction Lift	4	ADI	400	44	15	3	480	FVNR	2	51	4777	00:01:30	01:17:49	120:37:50	520	38,860	3,614,037
73	Electric Avenue PS	10/14/2010	7	Suction Lift	10	DI	1275	27	15	3	240	FVNR	1	39	3566	00:01:46	01:09:39	105:39:01	1500	104,489	9,508,521
74	Electric Avenue PS	10/14/2010	7	Suction Lift	10	DI	1275	27	15	3	240	FVNR	2	38	3530	00:01:47	01:09:43	105:44:50	1500	104,585	9,517,247
75	Electric Avenue PS	10/14/2010	7	Suction Lift	10	DI	1275	27	15	3	240	FVNR	3	36	3366	00:01:52	01:09:29	105:23:11	1500	104,269	9,488,534
76	Hibridge PS	10/2/2009	8	Suction Lift	6	ADI	500	78	30	3	208	RVSS	1	41	3845	00:02:35	01:48:26	166:16:17	202	22,093	2,032,604
77	Hibridge PS	10/2/2009	8	Suction Lift	6	ADI	500	78	30	3	208	RVSS	2	42	3937	00:02:58	02:07:29	195:29:32	179	23,020	2,117,841
78	Maitland PS	10/2/2009	8	Suction Lift	6	ADI	420	48	15	3	208	RVSS	1	43	4051	00:01:58	01:25:41	132:49:28	334	28,564	2,656,463
79	Maitland PS	10/2/2009	8	Suction Lift	6	ADI	420	48	15	3	208	RVSS	2	40	3723	00:01:56	01:17:49	120:37:55	330	26,331	2,448,803
80	Carroll Drive PS	1/3/2014	3	Suction Lift	6	DI	630	105	60	3	480	RVSS	1	53	4971	00:01:36	01:26:21	133:51:02	448	38,666	3,595,991
81	Carroll Drive PS	1/3/2014	3	Suction Lift	6	DI	630	105	60	3	480	RVSS	2	53	4971	00:01:29	01:19:22	123:02:36	487	38,701	3,599,266
82	Monroe Acres PS	4/20/2009	8	Suction Lift	3	ADI	125	78	15	3	240	FVNR	1	7	657	00:04:16	00:30:09	46:45:03	96	2,910	270,686
83	Monroe Acres PS	4/20/2009	8	Suction Lift	3	ADI	125	78	15	3	240	FVNR	2	7	655	00:03:56	00:27:46	43:02:43	104	2,890	268,800
84	Ore Bank Road PS	3/17/2006	11	Suction Lift	6	ADI	700	136	80	3	480	RVSS	1	18	1676	00:07:12	02:09:52	201:18:54	648	84,157	7,826,685
85	Ore Bank Road PS	3/17/2006	11	Suction Lift	6	ADI	700	136	80	3	480	RVSS	2	17	1661	00:08:11	02:26:18	266:46:47	586	85,753	7,975,105
86	Stonebridge Crossing PS	8/28/2005	12	Suction Lift	3	ADI	130	78	15	3	240	FVNR	1	10	996	00:07:04	01:15:48	117:29:45	118	9,010	838,007
87	Stonebridge Crossing PS	8/28/2005	12	Suction Lift	3	ADI	130	78	15	3	240	FVNR	2	10	993	00:07:42	01:22:13	127:27:16	112	9,101	846,435
88	Yellow Breeches PS	3/17/2006	11	Suction Lift	6	ADI	500	172	80	3	480	RVSS	1	16	1515	00:02:08	00:35:08	53:53:13	491	17,294	1,591,136
89	Yellow Breeches PS	3/17/2006	11	Suction Lift	6	ADI	500	172	80	3	480	RVSS	2	16	1493	00:02:05	00:33:59	52:06:50	501	17,031	1,566,919
90	Pump Station 3	9/3/2000	17	Submersible	4	DI	425	32.7	11	3	480	FVNR	1	40	3790	00:01:51	01:15:37	117:12:56	461	34,882	3,244,054
91	Pump Station 3	9/3/2000	17	Submersible	4	DI	425	32.7	11	3	480	FVNR	2	40	3789	00:01:35	01:04:51	100:31:24	528	34,274	3,187,558
92	Beaver Avenue PS 11	4/28/2009	8	Suction Lift	4	ADI	140	38	7.5	3	240	FVNR	1	26	2438	00:04:24	01:55:33	179:07:26	114	13,238	1,231,188
93	Beaver Avenue PS 11	4/28/2009	8	Suction Lift	4	ADI	140	38	7.5	3	240	FVNR	2	25	2397	00:04:17	01:50:49	171:46:53	115	12,817	1,192,016
94	Kayo PS 5	12/11/1998	18	Suction Lift	3	DI	200	72	15	3	240	FVNR	1	10	1004	00:03:57	00:42:46	66:18:02	168	7,047	655,419
95	Kayo PS 5	12/11/1998	18	Suction Lift	3	DI	200	72	15	3	240	FVNR	2	9	857	00:04:29	00:41:23	64:08:59	137	6,070	564,573
96	Southeast PS 6	12/11/1998	18	Suction Lift	4	DI	300	86	20	3	240	FVNR	1	57	5388	00:03:25	03:18:12	307:13:20	284	56,445	5,249,413
97	Southeast PS 6	12/11/1998	18	Suction Lift	4	DI	300	86	20	3	240	FVNR	2	57	5388	00:03:19	03:12:18	298:05:07	290	55,972	5,205,472
98	Super Thrift PS 3	12/11/1998	18	Suction Lift	4	DI	300	78	20	3	240	FVNR	1	67	6303	00:01:52	02:07:08	197:03:28	382	48,647	4,524,257
99	Super Thrift PS 3	12/11/1998	18	Suction Lift	4	DI	300	78	20	3	240	FVNR	2	67	6303	00:01:54	02:08:51	199:44:10	379	49,078	4,564,316
100	Walmart PS	10/27/2006	11	Suction Lift	3	ADI	180	58	15	3	240	FVNR	1	19	1767	00:01:25	00:27:21	41:57:34	217	5,948	547,294
101	Walmart PS	10/27/2006	11	Suction Lift	3	ADI	180	58	15	3	240	FVNR	2	19	1761	00:01:26	00:27:32	42:13:46	214	5,906	543,410
102	Brethren PS	6/28/1990	27	Submersible	3	DI	525	10	6.2	3	240	FVNR	1	8	748	00:03:38	00:29:20	42:28:45	106	3,089	287,307
103	Brethren PS	6/28/1990	27	Submersible	3	DI	525	10	6.2	3	240	FVNR	2	8	752	00:03:34	00:28:52	44:45:59	106	3,031	281,941
104	Clearview Gardens PS	7/16/2004	13	Suction Lift	3	DI	210	55.7	10	3	240	FVNR	1	42	3935	00:01:25	01:00:48	93:14:11	239	14,258	1,336,581
105	Clearview Gardens PS	7/16/2004	13	Suction Lift	3	DI	210	55.7	10	3	240	FVNR	2	42	3915	00:01:51	01:19:05	121:16:25	189	14,890	1,369,932
106	Mission PS	2/1/1991	26	Suction Lift	8	ADI	2000	57	50	3	240	FVNR	1	55	5140	00:01:28	01:21:36	126:29:50	637	53,554	4,980,537
107	Mission PS	2/1/1991	26	Suction Lift	8	ADI	2000	57	50	3	240	FVNR	2	55	5191	00:01:54	01:46:44	165:27:20	567	61,033	5,676,082
108	Mission PS	2/1/1991	26	Suction Lift	8	ADI	2000	57	50	3	240	FVNR	3	52	4857	00:01:48	01:34:21	146:14:59	546	55,986	5,206,727
109	Frost Hollow PS	11/1/2004	13	Suction Lift	6	DI	600	208	100	3	480	RVSS	1	29	2720	00:02:45	01:20:40	125:03:25	740	61,026	5,675,490
110	Frost Hollow PS	11/1/2004	13	Suction Lift	6	DI	600	208	100	3	480	RVSS	2	30	2855	00:02:43	01:23:42	129:44:24	764	63,957	5,948,082
111	Frost Hollow PS	11/1/2004	13	Suction Lift	6	DI	600	208	100	3	480	RVSS	3	29	2776	00:02:38	01:18:43	122:01:01	775	61,742	5,742,017
112	Area 14 PS	7/31/2008	9	Suction Lift	6	ADI	500	70	40	3	480	RVSS	1	30	2796	00:02:27	01:13:45	114:19:38	295	22,471	2,089,874
113	Area 14 PS	7/31/2008	9	Suction Lift	6	ADI	500	70	40	3	480	RVSS	2	30	2800	00:02:05	01:02:47	97:19:58	325	20,997	1,952,739
114	East Main Street PS	4/11/2000	17	Submersible	3	DI	140	58	6.2	3	480	FVNR	1	212	19731	00:01:37	05:43:04	531:45:36	469	160,678	14,943,105
115	East Main Street PS	4/11/2000	17	Submersible	3	DI	140	58	6.2	3	480	FVNR	2	212	19738	00:01:36	05:40:14	527:22:21	456	154,643	14,381,835
116	Little Swatara Influent PS	5/21/2013	4	Suction Lift	6	ADI	700	45	25	3	480	RVSS	1	33	3111	00:04:33	02:32:23	236:11:57	828	126,240	11,740,407
117	Little Swatara Influent PS	5/21/2013	4	Suction Lift	6	ADI	700	45	25	3	480	RVSS	2	32	3026	00:04:29	02:26:09	226:32:16	850	124,960	11,621,292
118	Little Swatara Influent PS	5/21/2013	4	Suction Lift	6	ADI	700	45	25	3	480	RVSS	3	31	2963	00:04:21	02:18:52	215:14:49	828	118,167	10,989,555
119	Sewage PS	6/24/2008	9	Submersible	4	DI	280	59	13	3	480	FVNR	1	56	5242	00:02:06	01:58:28	183:38:17	253	29,983	2,788,473
120	Sewage PS	6/24/2008	9	Submersible	4	DI	280	59	13	3	480	FVNR	2	56	5249	00:02:08	02:00:28	186:44:27	249	30,107	2,800,006
121	Museum Sewage PS	8/25/2006	11	Submersible	4	DI	80	87	17	3	208	FVNR	1	36	3361	00:00:57	00:34:45	53:52:43	200	6,952	646,544
122	Museum Sewage PS	8/25/2006	11	Submersible	4	DI	80	87	17	3	208	FVNR	2	36	3362	00:02:44	01:39:03	153:32:48	111	10,861	1,010,123
123	Pump Station 1	9/5/2014	3	Suction Lift	4	DI	330	87	25	3	240	FVNR	1	11	1057	00:05:04	00:57:44	89:30:40	148	8,889	826,692
124	Pump Station 1	9/5/2014	3	Suction Lift	4	DI	330	87	25	3	240	FVNR	2	11	1054	00:05:19	01:00:15	93:24:44	146	9,086	845,063
125	Pump Station 10	10/18/1991	26	Suction Lift	3	DI	210	52	10	3	240	FVNR	1	21	1953	00:04:27	01:33:32	144:58:53	84	7,876	732,471
126	Pump Station 10	10/18/1991	26	Suction Lift	3	DI	210	52	10	3	240	FVNR	2	21	1954	00:03:05	01:04:59	100:44:51	114	7,464	694,160
127	Pump Station 3	9/5/2014	3	Suction Lift	4	DI	250	57	15	3	480	FVNR	1	19	1847	00:01:51	00:36:52	57:08:52	271	10,437	970,706
128	Pump Station 3	9/5/2014	3	Suction Lift	4	DI	250	57	15	3	480	FVNR	2	21	1982	00:01:52	00:39:51	61:46:35	277	11,182	1,039,983
129	Pump Station 5	1/15/1992	25	Suction Lift	4	DI	380	39	10	3	240	FVNR	1	16	1516	00:04:32	01:13:59	114:40:49	156	11,228	1,044,286
130	Pump Station 5	1/15/1992	25	Suction Lift	4	DI	380	39	10	3	240	FVNR	2	17	1595	00:03:59	01:08:28	106:08:10	169	11,367	1,057,156
131	Pump Station 6	10/18/1991	26	Suction Lift	4	DI	335	74	20	3	240	FVNR	1	4	447	00:01:34	00:07:32	11:40:39	244	1,843	171,399
132	Pump Station 6	10/18/1991	26	Suction Lift	4	DI	335	74	20	3	240	FVNR	2	4	448	00:01:37	00:07:49	12:08:03	234	1,835	170,746
133	Pump Station 7	12/12/1991	25	Suction Lift	4	DI	465	59	20	3	240	FVNR	1	42	3974	00:01:09	00:49:10	76:12:59	557	26,351	2,450,686
134	Pump Station 7	12/12/1991	25	Suction Lift	4	DI	465	59	20	3	240	FVNR	2	42	3976	00:01:01	00:43:34	67:32:31	598	26,108	2,428,100
135	Pump Station 8	4/22/1991	26	Suction Lift	6	DI	955	73	40	3	480	FVNR	1	98	9174	00:01:06	01:48:34	168:17:47	1374	149,340	13,888,631
136	Pump Station 8	4/22/1991	26	Suction Lift	6	DI	955	73	40	3	480	FVNR	2	98	9170	00:01:05	01:47:50	167:10:02	1407	151,523	14,091,692
137	Pump Station 9	9/2/2016	1	Suction Lift	4	DI	620	210	75	3	480	RVSS	1	37	3529	00:02:39	01:40:48	156:15:49	333	33,679	3,132,150
138	Pump Station 9	9/2/2016	1	Suction Lift	4	DI	620	210	75	3	480	RVSS	2	37	3530	00:02:38	01:40:13	155:20:33	334	33,645	3,129,063
139	Strodes Mill PS	5/26/1995	22	Suction Lift	4	DI	175	32	7.5	3	208	FVNR	1	30	2839	00:03:32	01:48:02	167:28:38	190	19,858	1,846,870
140	Strodes Mill PS	5/26/1995	22	Suction Lift	4	DI	175	32	7.5	3	208	FVNR	2	31	2916	00:03:14	01:41:29	157:18:53	192	19,585	1,821,445

ENVE 594 — OmniSite Pump Station Data Collection — June - August 2017 (6/1/17-8/31/17)

Pump Number	Pump Station	Ship Date	Station Age (yrs)	Pump Type	Pump Discharge Size (Inches)	Materials of Construction	Rated Flow (GPM)	Rated Head (feet H2O)	Motor Size (HP)	Phase (1 or 3)	Voltage	Motor Starter Type	Pump #	Avg. Cycles per Day	Total Cycles	Avg Drawdown Time	Avg Run Time Per Day	Total Run Time (sec)	Avg Flow (GPM)	Avg Effluent Flow (gal/day)	Total Effluent Flow (gal)
141	Carlisle Street PS	1/9/1993	24	Suction Lift	4	DI	300	50	15	3	240	FVNR	1	37	3467	00:02:21	01:27:47	136:04:58	533	46,660	4,339,424
142	Carlisle Street PS	1/9/1993	24	Suction Lift	4	DI	300	50	15	3	240	FVNR	2	35	3325	00:02:14	01:19:52	123:48:27	543	44,182	4,109,003
143	Colonial Drive PS	3/6/2002	15	Suction Lift	4	DI	300	115	25	3	240	FVNR	1	39	3678	00:02:36	01:43:20	160:10:57	256	26,495	2,464,058
144	Colonial Drive PS	3/6/2002	15	Suction Lift	4	DI	300	115	25	3	240	FVNR	2	39	3677	00:02:33	01:41:14	156:55:55	262	26,595	2,473,421
145	Washington Street PS	7/2/2013	4	Suction Lift	3	DI	135	31	5	3	480	FVNR	1	1	74	00:04:22	00:03:28	05:23:49	78	393	36,627
146	Washington Street PS	7/2/2013	4	Suction Lift	3	DI	135	31	5	3	480	FVNR	2	1	71	00:06:17	00:04:48	07:27:02	52	374	34,818
147	Wayburn Street PS	6/3/2009	8	Suction Lift	3	DI	140	25	5	3	240	FVNR	1	6	585	00:03:36	00:22:43	35:13:16	137	2,890	268,852
148	Wayburn Street PS	6/3/2009	8	Suction Lift	3	DI	140	25	5	3	240	FVNR	2	6	585	00:02:55	00:18:24	28:31:46	162	2,920	271,643
149	Pump Station 14	7/3/2008	9	Suction Lift	4	DI	450	27	7.5	1	240	FVNR	1	64	5971	00:03:19	03:36:17	331:39:04	485	114,833	9,186,693
150	Pump Station 14	7/3/2008	9	Suction Lift	4	DI	450	27	7.5	1	240	FVNR	2	64	5961	00:04:04	04:24:19	405:18:18	462	121,737	11,078,103
151	Pump Station 20	8/2/2012	5	Suction Lift	4	ADI	210	21	7.5	3	240	FVNR	1	14	1380	00:02:37	00:38:58	60:25:10	200	7,650	711,538
152	Pump Station 20	8/2/2012	5	Suction Lift	4	ADI	210	21	7.5	3	240	FVNR	2	14	1385	00:02:04	00:31:00	48:03:15	217	6,737	626,551
153	Pump Station 21	9/17/1999	18	Suction Lift	3	DI	210	86.5	15	3	240	FVNR	1	50	4676	00:02:22	01:59:07	184:38:42	171	20,499	1,906,424
154	Pump Station 21	9/17/1999	18	Suction Lift	3	DI	210	86.5	15	3	240	FVNR	2	50	4676	00:02:14	01:52:40	174:38:56	180	20,313	1,889,169
155	Pump Station 8	2/11/2005	12	Suction Lift	10	ADI	2500	90	100	3	480	RVSS	1	52	4855	00:03:59	03:28:08	322:36:42	983	208,851	19,423,235
156	Pump Station 8	2/11/2005	12	Suction Lift	10	ADI	2500	90	100	3	480	RVSS	2	52	4860	00:01:42	01:28:55	137:50:46	1633	142,332	13,236,952
157	Pump Station 8	2/11/2005	12	Suction Lift	10	ADI	2500	90	100	3	480	RVSS	3	52	4858	00:02:45	02:24:22	223:46:17	1450	225,340	20,956,661
158	Pump Station 9	7/3/2008	9	Suction Lift	4	ADI	250	50	10	3	240	FVNR	1	71	6561	00:01:03	01:15:01	115:02:17	321	23,932	2,201,745
159	Pump Station 9	7/3/2008	9	Suction Lift	4	ADI	250	50	10	3	240	FVNR	2	71	6560	00:01:08	01:21:39	125:13:07	320	25,354	2,332,638
160	Flintville PS	1/23/2013	4	Suction Lift	3	DI	115	43	7.5	1	240	FVNR	1	10	971	00:02:16	00:23:43	36:46:01	109	2,359	219,439
161	Flintville PS	1/23/2013	4	Suction Lift	3	DI	115	43	7.5	1	240	FVNR	2	10	965	00:01:51	00:19:12	29:45:52	117	2,256	209,900
162	Kleinfeltersville PS	2/14/2013	4	Suction Lift	3	DI	200	117	25	3	208	RVSS	1	10	973	00:02:06	00:22:03	34:11:41	183	4,035	375,277
163	Kleinfeltersville PS	2/14/2013	4	Suction Lift	3	DI	200	117	25	3	208	RVSS	2	10	978	00:02:11	00:22:58	35:36:30	177	4,065	378,129
164	Prescott PS	1/23/2013	4	Suction Lift	3	DI	135	46	7.5	1	240	FVNR	1	24	2317	00:02:01	00:50:32	78:21:04	116	5,909	549,590
165	Prescott PS	1/23/2013	4	Suction Lift	3	DI	135	46	7.5	1	240	FVNR	2	24	2313	00:01:47	00:44:26	68:53:22	132	5,892	548,002
166	East PS	5/20/2013	4	Suction Lift	6	DI	800	66	30	3	480	RVSS	1	19	1806	00:03:23	01:05:49	102:01:41	505	33,493	3,114,849
167	East PS	5/20/2013	4	Suction Lift	6	DI	800	66	30	3	480	RVSS	2	19	1796	00:03:34	01:08:58	106:53:56	500	34,646	3,222,137
168	West PS	5/20/2013	4	Suction Lift	3	DI	120	49	7.5	3	240	FVNR	1	50	4682	00:02:07	01:47:09	166:05:41	80	8,625	802,150
169	West PS	5/20/2013	4	Suction Lift	3	DI	120	49	7.5	3	240	FVNR	2	50	4676	00:02:03	01:43:08	159:52:55	82	8,538	794,048
170	Education Center PS	6/27/2003	14	Submersible	4	DI	135	121	17	3	480	FVNR	1	2	189	00:01:39	00:03:21	05:12:34	248	764	71,081
171	Education Center PS	6/27/2003	14	Submersible	4	DI	135	121	17	3	480	FVNR	2	1	96	00:01:43	00:01:47	02:45:54	75	311	28,995
172	Codorus Lane PS	7/12/2010	7	Suction Lift	3	DI	180	95	20	3	208	RVSS	1	21	2012	00:02:51	01:01:55	95:58:41	166	10,306	958,546
173	Codorus Lane PS	7/12/2010	7	Suction Lift	3	DI	180	95	20	3	208	RVSS	2	21	2007	00:02:55	01:03:03	97:44:35	163	10,282	956,258
174	Pump Station 1A	6/8/2007	10	Suction Lift	4	ADI	325	69	15	3	240	FVNR	1	59	2309	00:01:20	01:19:44	51:49:53	321	25,719	1,003,064
175	Pump Station 1A	6/8/2007	10	Suction Lift	4	ADI	325	69	15	3	240	FVNR	2	59	2307	00:01:20	01:19:07	51:26:09	327	25,896	1,009,959
176	Pump Station 3	9/20/2016	1	Suction Lift	3	DI	200	126	25	3	240	RVSS	1	79	7419	00:02:11	02:54:52	271:03:54	95	16,745	1,557,328
177	Pump Station 3	9/20/2016	1	Suction Lift	3	DI	200	126	25	3	240	RVSS	2	79	7417	00:02:10	02:52:54	268:00:40	96	16,764	1,559,099
178	Noble Street PS	5/11/2001	16	Suction Lift	6	DI	900	121	60	3	480	RVSS	1	69	5941	00:02:12	02:34:25	218:46:46	592	92,152	7,832,954
179	Noble Street PS	5/11/2001	16	Suction Lift	6	DI	900	121	60	3	480	RVSS	2	70	5955	00:02:13	02:35:34	220:24:17	584	91,617	7,787,526
180	Noble Street PS	5/11/2001	16	Suction Lift	6	DI	900	121	60	3	480	RVSS	3	70	5957	00:02:13	02:36:03	221:05:20	583	91,657	7,790,918
181	Butternut Drive PS	8/11/1997	20	Suction Lift	6	DI	450	62	20	3	208	FVNR	1	2	254	00:03:44	00:10:13	15:50:28	14	1,133	105,392
182	Butternut Drive PS	8/11/1997	20	Suction Lift	6	DI	450	62	20	3	208	FVNR	2	130	12135	00:01:11	02:35:50	241:33:45	325	58,450	5,435,873
183	Elm Drive PS	4/11/1997	20	Suction Lift	4	ADI	350	76	20	3	208	FVNR	1	43	4015	00:01:37	01:09:51	108:16:06	232	18,075	1,681,053
184	Elm Drive PS	4/11/1997	20	Suction Lift	4	ADI	350	76	20	3	208	FVNR	2	48	4468	00:01:08	00:55:07	85:25:54	317	18,102	1,683,521
185	Pennsville PS	4/11/1997	20	Suction Lift	4	DI	225	31	7.5	3	208	FVNR	1	18	1723	00:01:53	00:35:29	54:24:30	223	7,903	727,127
186	Pennsville PS	4/11/1997	20	Suction Lift	4	DI	225	31	7.5	3	208	FVNR	2	18	1724	00:01:56	00:36:15	55:35:13	217	7,899	726,789
187	Wood Drive PS	4/11/1997	20	Suction Lift	6	DI	600	88	40	3	480	FVNR	1	61	5742	00:04:19	04:27:06	414:01:41	540	154,805	14,396,877
188	Wood Drive PS	4/11/1997	20	Suction Lift	6	DI	600	88	40	3	480	FVNR	2	76	7101	00:02:08	02:43:58	254:09:40	561	92,051	8,560,754
189	North Side Pump Station	2/1/2010	7	Suction Lift	3	DI	217	160	40	3	480	RVSS	1	23	2182	00:07:37	02:58:53	277:16:10	137	24,285	2,258,530
190	North Side Pump Station	2/1/2010	7	Suction Lift	3	DI	217	160	40	3	480	RVSS	2	21	2026	00:06:04	02:12:19	205:05:52	163	21,786	2,026,101
191	Warwick Woodlands PS	11/2/2016	1	Submersible	3	DI	140	50	7	3	208	FVNR	1	25	2380	00:01:19	00:33:46	52:20:44	225	9,642	896,779
192	Warwick Woodlands PS	11/2/2016	1	Submersible	3	DI	140	50	7	3	208	FVNR	2	25	2372	00:00:54	00:23:15	36:02:38	231	7,774	723,021
193	Jamesway Plaza PS	11/4/2011	6	Suction Lift	4	DI	310	106	25	3	208	FVNR	1	37	3457	00:02:31	01:34:05	145:50:41	200	18,870	1,754,980
194	Jamesway Plaza PS	11/4/2011	6	Suction Lift	4	DI	310	106	25	3	208	FVNR	2	36	3369	00:02:30	01:30:59	141:01:31	202	18,820	1,750,273
195	Middletown School PS	6/2/2006	11	Suction Lift	3	DI	120	40.7	7.5	1	240	FVNR	1	1	133	00:01:17	00:01:51	02:50:49	92	251	23,121
196	Middletown School PS	6/2/2006	11	Suction Lift	3	DI	120	40.7	7.5	1	240	FVNR	2	1	135	00:01:18	00:01:55	02:57:05	92	254	23,388
197	Alison Avenue PS	7/16/2010	7	Submersible	3	DI	225	41	6.2	3	240	FVNR	1	48	4471	00:02:01	01:37:07	150:32:47	158	15,419	1,433,990
198	Alison Avenue PS	7/16/2010	7	Submersible	3	DI	225	41	6.2	3	240	FVNR	2	48	4472	00:01:53	01:31:05	141:11:22	168	15,347	1,427,344
199	Apple Drive PS	7/15/1991	26	Suction Lift	4	DI	250	51	10	3	240	FVNR	1	19	1842	00:06:31	02:09:07	200:08:42	167	21,631	2,011,761
200	Apple Drive PS	7/15/1991	26	Suction Lift	4	DI	250	51	10	3	240	FVNR	2	19	1773	00:06:48	02:09:54	201:20:58	161	21,122	1,964,365
201	Edgewood Drive PS	10/9/2010	7	Suction Lift	3	DI	160	55	10	3	240	FVNR	1	74	6921	00:01:32	01:55:10	178:30:49	165	18,802	1,748,652
202	Edgewood Drive PS	10/9/2010	7	Suction Lift	3	DI	160	55	10	3	240	FVNR	2	74	6918	00:01:30	01:52:06	173:45:41	167	18,637	1,733,324
203	Eric Avenue PS	10/9/2010	7	Suction Lift	3	DI	150	32	7.5	1	240	FVNR	1	18	1691	00:02:13	00:40:30	62:46:57	96	3,873	360,202
204	Eric Avenue PS	10/9/2010	7	Suction Lift	3	DI	150	32	7.5	1	240	FVNR	2	18	1687	00:02:26	00:44:24	68:49:28	95	4,194	390,082
205	Market Street PS	10/9/2010	7	Suction Lift	3	DI	250	41	10	3	240	FVNR	1	60	5651	00:01:24	01:25:44	132:54:31	260	22,274	2,071,486
206	Market Street PS	10/9/2010	7	Suction Lift	3	DI	250	41	10	3	240	FVNR	2	60	5650	00:01:25	01:27:00	134:51:20	255	22,138	2,058,895
207	Messic Avenue PS	10/9/2010	7	Submersible	3	DI	110	29	2.7	1	240	FVNR	1	29	2753	00:00:49	00:24:29	37:58:28	134	3,189	296,605
208	Messic Avenue PS	10/9/2010	7	Submersible	3	DI	110	29	2.7	1	240	FVNR	2	27	2564	00:00:50	00:23:07	35:50:49	118	2,795	260,027
209	Blue Ridge PS	5/26/1993	24	Suction Lift	3	DI	200	50	7.5	3	208	FVNR	1	23	2148	00:02:38	01:00:53	94:22:41	230	13,554	1,260,555
210	Blue Ridge PS	5/26/1993	24	Suction Lift	3	DI	200	50	7.5	3	208	FVNR	2	23	2142	00:01:51	00:42:48	66:21:48	249	10,696	994,780

ENVE 594 — OmniSite Pump Station Data Collection — June - August 2017 (6/1/17-8/31/17)

Pump Number	Pump Station	Ship Date	Station Age (yrs)	Pump Type	Pump Discharge Size (Inches)	Materials of Construction	Rated Flow (GPM)	Rated Head (feet H2O)	Motor Size (HP)	Phase (1 or 3)	Voltage	Motor Starter Type	Pump #	Avg. Cycles per Day	Total Cycles	Avg Drawdown Time	Avg Run Time Per Day	Total Run Time (sec)	Avg Flow (GPM)	Avg Effluent Flow (gal/day)	Total Effluent Flow (gal)
211	Coe Drive PS	8/5/2015	2	Suction Lift	3	ADI	85	43	7.5	3	240	FVNR	1	11	1112	00:04:50	00:57:58	89:51:17	49	2,892	269,004
212	Coe Drive PS	8/5/2015	2	Suction Lift	3	ADI	85	43	7.5	3	240	FVNR	2	11	1112	00:04:54	00:58:37	90:52:19	48	2,895	269,245
213	Main Street PS	8/5/2015	2	Suction Lift	3	ADI	180	37	7.5	3	240	FVNR	1	37	3512	00:02:16	01:26:04	133:25:29	200	17,063	1,586,939
214	Main Street PS	8/5/2015	2	Suction Lift	3	ADI	180	37	7.5	3	240	FVNR	2	34	3223	00:02:08	01:14:18	115:10:46	199	15,497	1,441,222
215	North Newton Hills PS	7/29/2005	12	Suction Lift	3	DI	100	40	5	1	240	FVNR	1	9	875	00:03:41	00:34:45	53:52:49	100	3,622	336,897
216	North Newton Hills PS	7/29/2005	12	Suction Lift	3	DI	100	40	5	1	240	FVNR	2	12	1190	00:03:00	00:38:28	59:38:08	112	4,515	419,987
217	Penn Twp PS 3	5/18/2008	9	Suction Lift	3	ADI	200	35	7.5	3	240	FVNR	1	9	919	00:01:32	00:15:10	23:31:28	184	2,804	260,845
218	Penn Twp PS 3	5/18/2008	9	Suction Lift	3	ADI	200	35	7.5	3	240	FVNR	2	9	920	00:01:28	00:14:34	22:35:17	192	2,793	259,794
219	Rockwood PS	3/19/2013	4	Suction Lift	3	DI	200	178	40	3	480	RVSS	1	14	1353	00:01:22	00:20:05	31:09:13	210	4,247	395,063
220	Rockwood PS	3/19/2013	4	Suction Lift	3	DI	200	178	40	3	480	RVSS	2	14	1354	00:01:21	00:19:40	30:30:21	215	4,243	394,635
221	Pump Station 6	7/29/2015	2	Submersible	3	DI	300	72	15	3	480	FVNR	1	28	2630	00:02:24	01:08:11	105:41:50	298	20,366	1,894,090
222	Pump Station 6	7/29/2015	2	Submersible	3	DI	300	72	15	3	480	FVNR	2	28	2624	00:02:18	01:05:18	101:13:03	310	20,221	1,880,573
223	Pump Station 8	4/6/2017	0	Submersible	3	DI	104	88	15	3	208	FVNR	1	21	2031	00:07:12	02:37:20	243:53:18	80	12,625	1,174,203
224	Pump Station 8	4/6/2017	0	Submersible	3	DI	104	88	15	3	208	FVNR	2	21	2031	00:06:24	02:19:48	216:42:18	87	12,253	1,139,613
225	Smith Lane PS	12/15/2014	2	Suction Lift	3	DI	125	38	7.5	3	240	FVNR	1	3	309	00:03:21	00:11:10	17:19:48	142	1,668	155,177
226	Smith Lane PS	12/15/2014	2	Suction Lift	3	DI	125	38	7.5	3	240	FVNR	2	3	319	00:03:42	00:12:42	19:41:36	122	1,695	157,720
227	Washington Avenue PS	7/18/2008	9	Suction Lift	6	ADI	500	79	40	3	480	FVNR	1	81	7602	00:04:03	05:31:29	513:49:11	467	154,941	14,409,541
228	Washington Avenue PS	7/18/2008	9	Suction Lift	6	ADI	500	79	40	3	480	FVNR	2	81	7601	00:04:07	05:37:49	523:37:25	464	157,053	14,605,971
229	Pump Station 1	6/10/2005	12	Suction Lift	3	ADI	200	98	20	3	208	RVSS	1	20	1947	00:01:32	00:32:07	49:46:58	195	6,281	584,159
230	Pump Station 1	6/10/2005	12	Suction Lift	3	ADI	200	98	20	3	208	RVSS	2	20	1949	00:01:33	00:32:43	50:42:46	194	6,344	590,006
231	Pump Station 2	6/10/2005	12	Suction Lift	3	ADI	225	70	15	3	208	FVNR	1	34	3186	00:02:17	01:18:28	121:38:46	155	12,160	1,130,934
232	Pump Station 2	6/10/2005	12	Suction Lift	3	ADI	225	70	15	3	208	FVNR	2	33	3110	00:02:02	01:08:01	105:26:08	165	11,185	1,040,215
233	Pump Station 3	6/10/2005	12	Suction Lift	4	ADI	360	55.5	15	3	208	RVSS	1	22	2073	00:02:50	01:03:25	98:18:58	189	12,014	1,117,304
234	Pump Station 3	6/10/2005	12	Suction Lift	4	ADI	360	55.5	15	3	208	RVSS	2	22	2056	00:02:54	01:04:21	99:44:35	185	11,954	1,111,764
235	Pump Station 4	11/5/2004	13	Suction Lift	6	ADI	500	43	20	3	208	FVNR	1	27	2520	00:03:18	01:29:44	139:06:15	499	44,763	4,163,040
236	Pump Station 4	11/5/2004	13	Suction Lift	6	ADI	500	43	20	3	208	FVNR	2	27	2517	00:03:18	01:29:23	138:34:10	499	44,654	4,152,849
237	Pump Station 6	9/9/2005	12	Suction Lift	4	ADI	345	50	15	3	208	FVNR	1	27	2539	00:01:27	00:39:49	61:44:02	269	10,720	997,040
238	Pump Station 6	9/9/2005	12	Suction Lift	4	ADI	345	50	15	3	208	FVNR	2	26	2504	00:01:28	00:39:49	61:43:49	260	10,352	962,752
239	Pump Station 7	11/5/2004	13	Suction Lift	3	ADI	110	56	7.5	3	208	FVNR	1	29	2713	00:03:49	01:51:30	172:49:42	147	16,512	1,535,617
240	Pump Station 7	11/5/2004	13	Suction Lift	3	ADI	110	56	7.5	3	208	FVNR	2	29	2705	00:03:28	01:40:57	156:29:27	148	15,144	1,408,396
241	Pump Station 2	6/1/2011	6	Suction Lift	3	ADI	200	80.6	20	3	240	FVNR	1	13	1249	00:03:43	00:50:02	77:33:42	89	5,751	534,877
242	Pump Station 2	6/1/2011	6	Suction Lift	3	ADI	200	80.6	20	3	240	FVNR	2	13	1232	00:03:17	00:43:32	67:28:58	91	5,475	509,191
243	Mullertown PS	11/2/2016	1	Suction Lift	4	DI	500	149	50	3	240	RVSS	1	16	1509	00:02:15	00:36:37	56:45:37	441	16,224	1,508,851
244	Mullertown PS	11/2/2016	1	Suction Lift	4	DI	500	149	50	3	240	RVSS	2	16	1511	00:02:11	00:35:40	55:17:28	455	16,306	1,516,543
245	Meadows PS	7/16/2010	7	Submersible	3	DI	170	48	6.2	3	208	FVNR	1	12	1134	00:02:22	00:29:03	45:01:44	112	3,255	302,726
246	Meadows PS	7/16/2010	7	Submersible	3	DI	170	48	6.2	3	208	FVNR	2	12	1127	00:02:21	00:28:32	44:14:15	113	3,209	298,447
247	Quigley Cove PS	6/13/2007	10	Suction Lift	3	ADI	137	54	7.5	3	240	FVNR	1	13	1200	00:00:43	00:09:49	14:34:12	137	1,345	119,725
248	Quigley Cove PS	6/13/2007	10	Suction Lift	3	ADI	137	54	7.5	3	240	FVNR	2	13	1204	00:00:47	00:10:47	15:59:56	137	1,477	131,470
249	Pump Station 1	1/12/2007	10	Suction Lift	4	ADI	284	51	15	3	480	FVNR	1	17	1611	00:02:16	00:39:29	61:13:10	352	13,933	1,295,800
250	Pump Station 1	1/12/2007	10	Suction Lift	4	ADI	284	51	15	3	480	FVNR	2	17	1611	00:02:12	00:38:14	59:16:33	364	13,930	1,295,581
251	Pump Station 2	2/19/2007	10	Submersible	3	DI	80	19.3	2.7	3	208	FVNR	1	7	690	00:02:31	00:18:44	29:02:12	85	1,603	149,096
252	Pump Station 2	2/19/2007	10	Submersible	3	DI	80	19.3	2.7	3	208	FVNR	2	7	689	00:02:34	00:19:03	29:32:52	83	1,598	148,645
253	Virginville PS	4/8/2013	4	Submersible	3	DI	110	54	7	3	208	FVNR	1	14	1390	00:02:07	00:31:38	49:02:21	106	3,323	309,099
254	Virginville PS	4/8/2013	4	Submersible	3	DI	110	54	7	3	208	FVNR	2	14	1390	00:02:33	00:38:13	59:15:04	89	3,368	313,242
255	Gordon Street PS	6/6/2008	9	Submersible	4	DI	325	96	23	3	240	FVNR	1	16	1572	00:07:32	02:07:25	197:30:40	314	40,035	3,723,284
256	Gordon Street PS	6/6/2008	9	Submersible	4	DI	325	96	23	3	240	FVNR	2	16	1572	00:07:27	02:05:51	195:04:05	317	39,901	3,710,878
257	Avalon PS	5/9/2008	9	Suction Lift	3	DI	220	80	15	3	240	FVNR	1	56	5300	00:01:35	01:30:38	140:29:45	224	20,197	1,878,353
258	Avalon PS	5/9/2008	9	Suction Lift	3	DI	220	80	15	3	240	FVNR	2	52	4863	00:01:28	01:17:00	119:21:56	227	18,228	1,695,288
259	Delta Point PS	4/30/2009	8	Suction Lift	4	DI	200	44	10	3	240	FVNR	1	14	1305	00:00:52	00:12:12	18:54:44	300	3,660	340,417
260	Delta Point PS	4/30/2009	8	Suction Lift	4	DI	200	44	10	3	240	FVNR	2	13	1301	00:00:53	00:12:34	19:29:53	296	3,773	350,960
261	Golden Triangle PS	2/3/2009	8	Suction Lift	8	DI	900	67	40	3	480	RVSS	1	111	10234	00:01:26	02:40:57	246:48:11	1006	162,226	14,924,851
262	Golden Triangle PS	2/3/2009	8	Suction Lift	8	DI	900	67	40	3	480	RVSS	2	111	10235	00:01:24	02:37:26	241:25:11	1020	160,726	14,786,837
263	Sporting Green PS	9/26/2016	1	Suction Lift	6	ADI	900	58	30	3	480	RVSS	1	75	7026	00:02:19	02:55:19	271:44:39	499	87,317	8,120,493
264	Sporting Green PS	9/26/2016	1	Suction Lift	6	ADI	900	58	30	3	480	RVSS	2	75	7029	00:02:18	02:54:06	269:51:59	494	36,087	8,006,136
265	Walden PS	5/25/2007	10	Suction Lift	6	ADI	645	80	30	3	240	FVNR	1	79	7430	00:02:17	03:02:27	282:48:21	656	119,758	11,137,544
266	Walden PS	5/25/2007	10	Suction Lift	6	ADI	645	80	30	3	240	FVNR	2	79	7426	00:02:10	02:54:20	270:13:15	675	117,714	10,947,408
267	Eastern Land PS	1/13/2017	0	Suction Lift	3	DI	200	76	15	3	480	RVSS	1	1	67	00:02:55	00:02:06	03:16:20	136	404	37,609
268	Eastern Land PS	1/13/2017	0	Suction Lift	3	DI	200	76	15	3	480	RVSS	2	1	65	00:03:00	00:02:06	03:15:46	130	398	37,084
269	Locust Road PS	10/24/2008	9	Suction Lift	6	DI	650	114	50	3	480	FVNR	1	21	1993	00:02:16	00:48:50	75:42:11	605	29,496	2,743,132
270	Locust Road PS	10/24/2008	9	Suction Lift	6	DI	650	114	50	3	480	FVNR	2	20	1935	00:02:44	00:57:10	88:36:49	459	26,553	2,469,450
271	Mayapple Woods PS	11/30/2011	5	Suction Lift	3	ADI	230	59.5	10	3	208	RVSS	1	19	1775	00:01:10	00:22:46	34:55:32	132	2,986	274,691
272	Mayapple Woods PS	11/30/2011	5	Suction Lift	3	ADI	230	59.5	10	3	208	RVSS	2	1	60	00:03:26	00:02:14	03:26:25	9	310	28,525
273	Reigerts Lane PS	10/24/2008	9	Suction Lift	6	DI	650	119	50	3	480	RVSS	1	12	1177	00:02:41	00:34:27	52:50:37	475	16,408	1,509,548
274	Reigerts Lane PS	10/24/2008	9	Suction Lift	6	DI	650	119	50	3	480	RVSS	2	12	1177	00:02:38	00:33:47	51:49:15	485	16,401	1,508,932
275	Kellock Run PS	8/8/2013	4	Suction Lift	3	DI	350	237	60	3	480	RVSS	1	37	3532	00:02:54	01:50:30	171:17:59	131	14,265	1,326,714
276	Kellock Run PS	8/8/2013	4	Suction Lift	3	DI	350	237	60	3	480	RVSS	2	37	3532	00:02:55	01:51:12	172:22:53	131	14,312	1,331,098
277	Fox Ridge PS	1/20/2014	3	Suction Lift	3	ADI	140	72	10	3	208	FVNR	1	22	2115	00:02:47	01:03:29	98:24:44	85	5,423	504,410
278	Fox Ridge PS	1/20/2014	3	Suction Lift	3	ADI	140	72	10	3	208	FVNR	2	22	2115	00:01:52	00:42:44	66:14:28	122	5,214	484,911
279	Towanda PS 10	11/1/1987	30	Suction Lift	4	DI	300	102	15	3	240	FVNR	1	47	4404	00:05:22	04:14:31	394:30:38	230	58,123	5,405,501
280	Towanda PS 10	11/1/1987	30	Suction Lift	4	DI	300	102	15	3	240	FVNR	2	43	4076	00:04:40	03:25:13	318:05:42	259	52,986	4,927,759

ENVE 594 | OmniSite Pump Station Data Collection | June - August 2017 (6/1/17-8/31/17)

Pump Number	Pump Station	Ship Date	Station Age (yrs)	Pump Type	Pump Discharge Size (Inches)	Materials of Construction	Rated Flow (GPM)	Rated Head (feet H2O)	Motor Size (HP)	Phase (1 or 3)	Voltage	Motor Starter Type	Pump #	Avg. Cycles per Day	Total Cycles	Avg Drawdown Time	Avg Run Time Per Day	Total Run Time (sec)	Avg Flow (GPM)	Avg Effluent Flow (gal/day)	Total Effluent Flow (gal)
281	Towanda PS 8	3/1/1983	34	Suction Lift	4	DI	125	30.5	5	1	240	FVNR	1	142	13243	00:01:13	02:53:34	269:02:52	164	28,513	2,651,724
282	Towanda PS 8	3/1/1983	34	Suction Lift	4	DI	125	30.5	5	1	240	FVNR	2	142	13245	00:01:06	02:38:56	246:21:48	175	27,802	2,585,590
283	Towanda PS 9	1/24/2012	5	Suction Lift	4	ADI	210	44.4	10	3	208	FVNR	1	63	5860	00:00:59	01:03:20	97:08:09	231	14,702	1,352,624
284	Towanda PS 9	1/24/2012	5	Suction Lift	4	ADI	210	44.4	10	3	208	FVNR	2	63	5858	00:01:12	01:16:38	117:30:43	209	15,449	1,421,309
285	Wysox PS 1	9/13/1988	29	Suction Lift	6	DI	220	63	15	3	240	FVNR	1	128	9265	00:01:40	03:35:56	259:07:50	425	92,088	6,630,389
286	Wysox PS 1	9/13/1988	29	Suction Lift	6	DI	220	63	15	3	240	FVNR	2	128	9257	00:01:45	03:46:13	271:27:44	410	92,937	6,691,505
287	Wysox PS 2	1/24/2012	5	Suction Lift	4	DI	220	80	15	3	240	FVNR	1	127	11876	00:01:51	03:56:38	366:47:42	175	41,448	3,854,700
288	Wysox PS 2	1/24/2012	5	Suction Lift	4	DI	220	80	15	3	240	FVNR	2	127	11880	00:01:37	03:26:30	320:06:00	189	39,219	3,647,446
289	Heidlersburg PS	7/3/2014	3	Submersible	3	DI	110	14.5	3	1	240	FVNR	1	15	1450	00:02:31	00:39:20	60:58:25	95	3,727	346,678
290	Heidlersburg PS	7/3/2014	3	Submersible	3	DI	110	14.5	3	1	240	FVNR	2	15	1447	00:02:49	00:43:54	68:03:08	87	3,728	346,705
291	Rutters PS	11/17/2015	1	Submersible	3	DI	110	30	3	3	208	FVNR	1	10	946	00:03:07	00:31:42	49:09:05	77	2,378	221,156
292	Rutters PS	11/17/2015	1	Submersible	3	DI	110	30	3	3	208	FVNR	2	9	911	00:02:07	00:20:47	32:13:37	105	2,188	203,565
293	Pump Station 3	11/20/2012	4	Suction Lift	3	DI	199	53	15	3	240	FVNR	1	1	132	00:02:20	00:03:19	05:08:52	208	795	73,973
294	Pump Station 3	11/20/2012	4	Suction Lift	3	DI	199	53	15	3	240	FVNR	2	1	101	00:02:43	00:02:57	04:35:39	188	690	64,243
295	Country Estates PS	8/17/2011	6	Suction Lift	4	DI	200	58	10	3	240	RVSS	1	9	919	00:03:58	00:39:13	60:47:12	129	5,076	472,094
296	Country Estates PS	8/17/2011	6	Suction Lift	4	DI	200	58	10	3	240	RVSS	2	9	913	00:03:33	00:34:53	54:05:16	143	4,965	461,757
297	Pump Station 1	5/9/2016	1	Suction Lift	3	SST	500	184	50	3	240	RVSS	1	48	4517	00:02:43	02:11:58	204:34:09	547	72,442	6,737,141
298	Pump Station 1	5/9/2016	1	Suction Lift	3	SST	500	184	50	3	240	RVSS	2	48	4518	00:02:42	02:11:31	203:52:10	544	71,839	6,681,073
299	Wegmans PS	11/28/2003	13	Suction Lift	4	DI	210	24	5	3	208	FVNR	1	15	1441	00:01:50	00:28:37	44:21:49	270	7,575	704,554
300	Wegmans PS	11/28/2003	13	Suction Lift	4	DI	210	24	5	3	208	FVNR	2	15	1453	00:01:47	00:28:04	43:31:23	273	7,665	712,884
301	State Route 117 PS	3/1/2012	5	Suction Lift	3	DI	175	157	30	3	480	RVSS	1	8	749	00:03:59	00:32:25	49:43:50	94	3,055	281,071
302	State Route 117 PS	3/1/2012	5	Suction Lift	3	DI	175	157	30	3	480	RVSS	2	8	745	00:03:24	00:27:35	42:18:23	111	3,023	278,119
303	Pump Station 10	11/16/2001	15	Submersible	4	DI	240	82	17	3	240	FVNR	1	55	5116	00:02:22	02:10:47	202:44:01	228	29,855	2,776,521
304	Pump Station 10	11/16/2001	15	Submersible	4	DI	240	82	17	3	240	FVNR	2	55	5168	00:01:43	01:36:12	149:07:42	291	28,004	2,604,459
305	Pump Station 11	1/17/2003	14	Submersible	4	DI	450	90	21	3	240	FVNR	1	50	4732	00:01:00	00:51:28	79:46:43	436	23,774	2,211,025
306	Pump Station 11	1/17/2003	14	Submersible	4	DI	450	90	21	3	240	FVNR	2	57	5372	00:01:04	01:02:28	96:49:32	446	27,612	2,567,928
307	Pump Station 14	10/12/2015	2	Suction Lift	3	DI	120	39	7.5	3	240	FVNR	1	1	129	00:02:37	00:03:37	05:37:34	98	381	35,493
308	Pump Station 14	10/12/2015	2	Suction Lift	3	DI	120	39	7.5	3	240	FVNR	2	1	130	00:02:34	00:03:36	05:35:24	105	389	36,222
309	Pump Station 2	2/2/1996	21	Submersible	4	DI	100	130	17	3	240	FVNR	1	164	15262	00:01:32	04:12:10	390:51:58	99	25,116	2,335,850
310	Pump Station 2	2/2/1996	21	Submersible	4	DI	100	130	17	3	240	FVNR	2	40	3734	00:01:31	01:01:07	94:45:04	40	6,110	568,239
311	Pump Station 3	7/11/1997	20	Suction Lift	6	DI	790	93	40	3	480	FVNR	1	44	4097	00:02:35	01:54:13	177:03:34	538	62,159	5,780,818
312	Pump Station 3	7/11/1997	20	Suction Lift	6	DI	790	93	40	3	480	FVNR	2	44	4094	00:02:31	01:51:27	172:45:33	545	61,183	5,690,092
313	Pump Station 5	2/2/1996	21	Submersible	4	DI	170	72	14	3	240	FVNR	1	10	994	00:01:46	00:18:53	29:17:18	170	3,211	298,700
314	Pump Station 5	2/2/1996	21	Submersible	4	DI	170	72	14	3	240	FVNR	2	10	997	00:02:22	00:25:24	39:22:30	170	4,264	396,626
315	Pump Station 6	2/2/1996	21	Suction Lift	6	DI	500	73	25	3	240	FVNR	1	28	2686	00:03:21	01:36:56	150:15:26	422	40,181	3,736,894
316	Pump Station 6	2/2/1996	21	Suction Lift	6	DI	500	73	25	3	240	FVNR	2	28	2691	00:03:21	01:37:23	150:57:55	419	40,178	3,736,587
317	Pump Station 7	2/2/1996	21	Submersible	4	DI	260	57	11	3	240	FVNR	1	21	2025	00:02:26	00:53:19	82:38:42	266	14,205	1,321,066
318	Pump Station 7	2/2/1996	21	Submersible	4	DI	260	57	11	3	240	FVNR	2	21	2023	00:02:27	00:53:29	82:54:00	266	14,216	1,322,126
319	Pump Station 8	2/2/1996	21	Suction Lift	4	DI	250	66	15	3	240	FVNR	1	48	4551	00:00:58	00:47:32	73:42:01	286	13,224	1,229,847
320	Pump Station 8	2/2/1996	21	Suction Lift	4	DI	250	66	15	3	240	FVNR	2	43	4039	00:00:59	00:43:21	67:12:09	254	11,832	1,100,461
321	West Pennsboro PS	4/4/2008	9	Suction Lift	4	ADI	300	51.2	15	3	240	FVNR	1	10	950	00:01:09	00:11:54	18:27:20	315	3,745	348,316
322	West Pennsboro PS	4/4/2008	9	Suction Lift	4	ADI	300	51.2	15	3	240	FVNR	2	10	947	00:01:10	00:11:53	18:25:46	318	3,776	351,247
323	Pump Station 05	11/1/1995	22	Suction Lift	10	DI	2400	154	150	3	480	RVSS	1	79	7404	00:03:30	04:39:37	433:25:07	1972	553,875	51,510,444
324	Pump Station 05	11/1/1995	22	Suction Lift	10	DI	2400	154	150	3	480	RVSS	2	55	5143	00:03:29	03:13:31	299:57:20	1628	379,926	35,333,203
325	Pump Station 06	8/13/2013	4	Suction Lift	3	DI	360	115	30	3	480	RVSS	1	16	1506	00:05:10	01:23:44	129:47:28	566	47,391	4,407,452
326	Pump Station 06	8/13/2013	4	Suction Lift	3	DI	360	115	30	3	480	RVSS	2	16	1506	00:05:07	01:22:54	128:30:55	569	47,218	4,391,279
327	Pump Station 08	7/6/1993	24	Suction Lift	4	DI	300	46	10	3	240	FVNR	1	75	1888	00:01:17	01:37:56	40:48:36	263	25,800	645,007
328	Pump Station 08	7/6/1993	24	Suction Lift	4	DI	300	46	10	3	240	FVNR	2	75	1892	00:01:12	01:31:08	37:58:35	274	25,047	626,193
329	Pump Station 13	9/11/1997	20	Suction Lift	6	DI	1000	46	25	3	480	FVNR	1	18	1729	00:02:32	00:47:13	73:11:39	857	40,887	3,802,513
330	Pump Station 13	9/11/1997	20	Suction Lift	6	DI	1000	46	25	3	480	FVNR	2	18	1728	00:04:31	01:24:00	130:12:50	802	67,233	6,252,740
331	Pump Station 14	11/16/2001	15	Suction Lift	6	DI	800	142	60	3	480	RVSS	1	58	5484	00:04:16	04:12:02	390:40:30	806	203,375	18,913,897
332	Pump Station 14	11/16/2001	15	Suction Lift	6	DI	800	142	60	3	480	RVSS	2	59	5488	00:04:26	04:22:11	406:23:43	840	220,433	20,500,361
333	Northwest PS	7/8/2009	8	Suction Lift	3	SST	150	62	10	3	240	FVNR	1	28	2666	00:01:46	00:50:52	78:50:55	200	10,173	946,147
334	Northwest PS	7/8/2009	8	Suction Lift	3	SST	150	62	10	3	240	FVNR	2	28	2675	00:01:46	00:51:05	79:10:54	200	10,216	950,148
335	West PS	9/29/1987	30	Suction Lift	3	DI	120	74	10	3	208	FVNR	1	18	1737	00:06:12	01:55:48	179:29:30	148	17,180	1,597,770
336	West PS	9/29/1987	30	Suction Lift	3	DI	120	74	10	3	208	FVNR	2	18	1720	00:06:37	02:02:27	189:48:57	141	17,267	1,605,865
337	South Street PS	11/24/1992	24	Suction Lift	4	DI	375	68	20	3	240	FVNR	1	11	1087	00:04:26	00:51:55	80:29:35	478	24,881	2,314,018
338	South Street PS	11/24/1992	24	Suction Lift	4	DI	375	68	20	3	240	FVNR	2	11	1085	00:04:18	00:50:17	77:57:44	484	24,362	2,265,750
339	4th & Oley PS	7/13/2001	16	Suction Lift	6	DI	600	135	50	3	480	RVSS	1	45	4196	00:02:52	02:09:50	201:15:58	498	63,385	5,894,894
340	4th & Oley PS	7/13/2001	16	Suction Lift	6	DI	600	135	50	3	480	RVSS	2	40	3775	00:02:48	01:53:45	176:20:06	469	55,253	5,138,609
341	Berkshire Blvd PS	5/26/1995	22	Submersible	6	DI	675	211	72	3	480	RVSS	1	16	1490	00:06:40	01:46:48	165:33:29	689	73,697	6,853,857
342	Berkshire Blvd PS	5/26/1995	22	Submersible	6	DI	675	211	72	3	480	RVSS	2	16	1488	00:07:14	01:55:45	179:24:55	651	75,371	7,009,526
343	Wynnewood PS	3/9/2000	17	Suction Lift	3	DI	250	83	15	3	240	FVNR	1	63	5409	00:03:39	03:53:07	330:15:46	170	39,725	3,376,654
344	Wynnewood PS	3/9/2000	17	Suction Lift	3	DI	250	83	15	3	240	FVNR	2	61	5265	00:04:12	04:20:43	369:22:13	159	41,396	3,518,688