Yeomans
Chicago
Corporation

P.O. Box 6620
3905 Enterprise Court
Aurora, IL 60598-0620
(630) 236-5500
Fax (630) 236-5511

Sump Mixing and Flushing
An Alternative to Pump-Mounted Mix Flush Valves

A common problem in the operation and maintenance of sewage and wastewater pumping stations is the build-up of solids at the bottom of the sump or wet-well. For submersible pump installations, one popular method for dealing with this problem has been to specify pump-mounted mix-flush valves that are designed to by-pass a portion of the pump discharge flow to create a mixing/flushing action near the bottom of the sump. The most common mix flush valve is a costly and proprietary device only available from the pump manufacturer as an accessory with their submersible pump units.

The purpose of this document is to evaluate this proprietary device and offer recommendations for an alternative system that is less costly, more effective and can easily be assembled and installed using standard commercial components readily available from numerous sources.

We have included excerpts from Pumping Station Design, Second Edition by Robert L. Sanks (Editor-in-Chief), one of our industries leading pump station design experts. These excerpts provide independent third-party support for our recommendations.

Prepared by D. W. Page
Manager – Marketing Services
Yeomans Chicago Corporation
Rev. Aug. 22, 2008

Pump-Mounted Mixing / Flush Valves

Description:

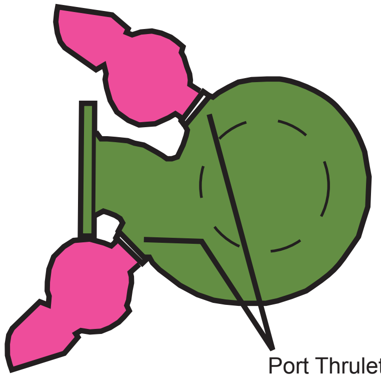
Pump-mounted mixing / flush valves are a proprietary product accessory designed to provide by-pass flow of the sewage/wastewater with the purpose of creating a mixing / flushing action in the wet-well. The valve is operated by means of an internal oil-pot arrangement designed to close slowly when it is pressurized by the pump discharge flow. The valve is mounted directly onto the exterior surface of the pump volute casing. The thrulet port size is 46mm (1.8").

Deficiencies and Potential Problems:

1: Proprietary Design - Single Source of Supply

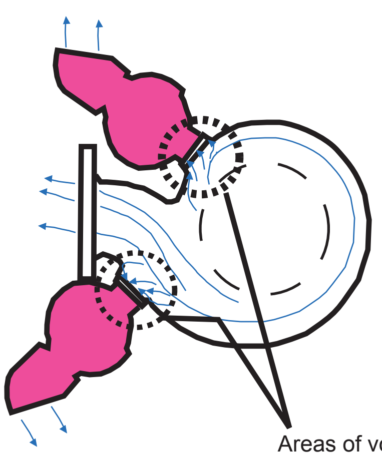
The pump-mounted mixing / flush valve is a proprietary product and is typically not available on the open market from sources other than the pump manufacturer. Therefore, the product is typically very costly, both initially and at a later date when replacement units or replacement parts are required.

2: The valve thrulet port is small, typically 48mm in size. This does not provide adequate room for passage of large solids typically found in raw sewage and wastewater.



When the valve becomes clogged the pump must be removed from the wet-well for cleaning and servicing. This is time consuming, messy and costly.

3: The mounting of the valve on the volute casing creates an unusual interruption to the normally smooth contoured surface of the casing interior wall. This, combined with the by-pass of discharge flow through the small port area creates unusual flow paths and turbulence at the port locations. This can result in casing damage and premature failure due to wear from abrasion / erosion.

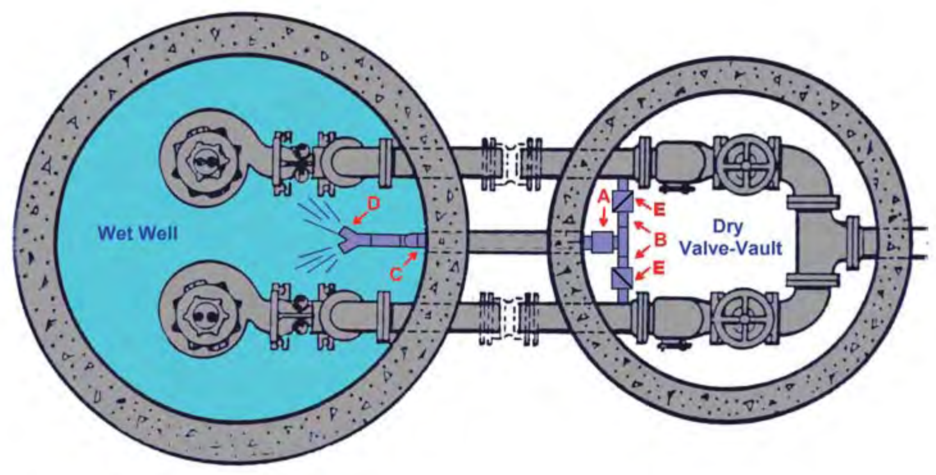


In areas of high sand / grit contents, the abrasive / erosive action is greatly increased, thereby shortening the casing life even more quickly.

Alternative Mixing / Flush Arrangement

Description:

The following sketch illustrates a superior non-proprietary mixing / flush system design utilizing standard low-cost commercial components:



A. Standard commercially available motor-operated ball valve of a port size to meet customer's preferences. The valve is powered and controlled by a timed circuit in the pump control panel. Utilizing an adjustable timing device, the valve can be set to open upon operation of the lead pump unit and close after a predetermined time period according to the customer's preferences. Unlike the pump-mounted valves, this system provides great flexibility to adjust the time duration of the mixing / flushing action. Location of the motor-operated valves in the dry valve-vault provides easy, safe access for servicing. There is no need to remove the pumps from the wet-well !

B. By-pass piping from the main pump discharge pipes. This can be low cost PVC or other materials to meet customer's preferences.

C. The by-pass line (mixing / flushing pipe) enters the wet-well adjacent to the main pump discharge pipes. The line is directed to the bottom of the wet-well.

D. Using standard commercial pipe fittings a "nozzle" arrangement is created at one or more locations to meet the customer's preferences. This method provides great flexibility as to the quantity and locations of the nozzles to meet the unique mixing / flushing requirements of each individual application. Low cost PVC pipe and fittings permits easy reconfiguration should the customer's needs or preferences change.

E. Standard commercial check valves prevent by-pass flush from flowing into discharge pipe of the opposite pump.

Summary:

This alternative system arrangement provides the following key advantages:

- Low cost non-proprietary system components available from numerous sources of supply
- Low cost PVC pipe and fittings provide for highly flexible system design and easy reconfiguration
- Design flexibility regarding size of mixing / flush pipes and nozzles; superior non-clogging design
- Adjustable timing of the mixing / flush sequence
- Location of valves in safe, dry valve-vault area

Cost Estimate For Alternate Sump Mix/Flush System

NOTE: One (1) system can be utlized for each individual pump, in which case the valve is mounted on the individual pump discharge pipe. Alternatively, for redcued overall cost, a single system can be utilized, in which case the valve is mounted on main discharge pipe.

Qty	Description	Estimated Cost
1	Hayward Series EA Automated True Union PVC Ball Valve, full, port design, size 2", 115 VAC (or equivalent)	$375
1	Modifications to pump control panel, including upgrade to standard 120VAC control transformer to supply power to the valve actuator; including timer circuit (adjustable) interfaced with pump RUN circuit; including terminal connections for valve actuator	$350
1	Lot misc. PVC pipe and fittings (2") for by-pass and flush to sump (wet-well)	$75
	Estimated Total Cost:	$800

Source:
Pumping Station Design, Second Edition
Robert L. Sanks (Editor-in-Chief)
Butterworth Heinemann, Woburn, MA (1998
ISBN 0-7506-9483-1

26-1. Redesigned Clyde Wastewater Pumping Station

The Clyde Wastewater Pumping Station in Contra Costa County, California, was rebuilt in 1991 to feature a self-cleaning sump. It is cleaned by pumping the water level down while vigorously mixing the contents with water from the force main. In the as-built plans, shown in Figure 17-22, eccentric plug valves in the valve vault can be regulated to take water from either the force main or from either of the two pumps. The water is discharged under considerable pressure at the surface of the lowered water level in the sump while a pump discharges the mixed liquid to the force main. The system works well for removing both scum and sludge and leaves the wet well remarkably clean.

In this section, the station is described as it might be designed in 1997 with the technology developed since the original plans were drawn. These changes consist of (1) steeper slopes to allow sludge to slide down to the pump intakes so that sludge is removed with every motor start and (2) a sloping approach pipe for introducing the inflow without a cascade and for supplying added storage to reduce the size of the wet well. In other respects, the design approach closely follows that of the existing Clyde pumping station except that fewer valves are used in the valve vault.

The actual design was carried out in U.S. customary units, so those are the units used in this example. The original sewer design studies, surveys, and discussions with operating and maintenance staff established the following general requirements for this sewage lift station:

- *General:* submersible pumps were preferred because of overall low cost, low maintenance, simplicity in operation, and minimizing visual impact on the neighborhood.
- *Flowrates:* Present average dry-weather flow: 30 gal/min.
  Present peak wet-weather flow: 236 gal/min.
  Future peak wet-weather flow: 410 gal/min (equals the capacity of one pump).
- *Ground elevation:* 13.2 ft. Pumping station site is relatively flat.
- *Force main:* An existing 8-in. cement-lined ductile iron pipe 2750 ft long was available.
  Invert elevation: 6.6 ft at the pumping station and 20.6 ft at the discharge.
  Slope: constant.
- *Reliability:* ability to pump future peak wet-weather flow with either of the two pumps out of service.
  Hook-up for portable engine-generator due to lack of space for permanent engine-generator.
  High wet well power-failure and intrusion alarm hooked up to an auto-dialer.
- *Location:* on shoulder of narrow residential street.
  Considerations include space, visibility, odors, noise, and security.

Station Siting

Station siting is established by the low point in the tributary area as well as access, availability of property, proximity to residents (i.e., farther is better), and the cost of piping to and from the site. The low point in the tributary area usually dictates the general location. Access is important because operation and maintenance staff must be able to visit the facility at any hour of the day and under adverse conditions. Access by public roads (paved, if possible) without the need to traverse private property or move parked automobiles is required. It is also preferable to provide room for maintaining the station without obstructing traffic or endangering workers.

Property and easement acquisition begins immediately after selecting the preferred site and before design on the pump station begins. Many projects have been delayed and/or designs changed because the site acquisition process did not begin soon enough. Such delays and changes will result in significant costs to the owner of the facility.

Hydraulic Design

Hydraulic design includes sizing the force main and developing the system curves, which are then used to select the number and size of the pumps. The rest of the facility is designed around the pumps. The force main invert elevation at the pumping station should, if possible, be set to allow for a constantly rising slope. High spots (knees) in a wastewater force main are to be avoided if at all possible, because knees require air release valves, which clog with grease and require constant maintenance. (Some utilities regularly replace all working parts with shop-cleaned parts every month.) Force main installation costs increase with depth, so it is best to keep the pipe as shallow as possible. The discharge end of the force main is susceptible to hydrogen sulfide corrosion and should be protected by using corrosion resistant piping (PVC, HDPE, VCP) where exposed to air or else be submerged to prevent corrosion. Corrosion resistant piping, as shown in Figure 26-1, should begin 10 ft before the point where the static water level contacts the soffit of the force main.

Force mains should be sized to provide a minimum velocity of 2.5 ft/s at present flows and a maximum velocity of 6 to 8 ft/s at future peak wet weather flows. The minimum velocity ensures that most solids will be moved through the force main. The maximum velocity is set to minimize headless and reduce surge pressures in long force mains. A 6-in. force main would meet this criteria for the stated flow conditions. However, an 8-in. mortar-lined ductile iron pipe was already in place and was, therefore, used. The velocity in the force main for this pumping station with its one duty pump is 2.5 ft/s (see Table B-2 for the cross-sectional area).

System curves are developed to define the design operating point and extreme operating conditions for the pumps. Computations for these conditions at the future peak wet weather flowrate are given in Table 26-1. Note that K-values are not absolutes. Different engineers may elect to use different values. Those in Table 26-1 differ somewhat from those in Table B-6. Minimum losses are given for a pipe roughness corresponding to C = 145, and the maximum is for C = 120. The results are shown graphically in Figure 26-2. Point A is the normal flow and head condition, and Point B is the extreme flow and head condition at which the pump may operate.

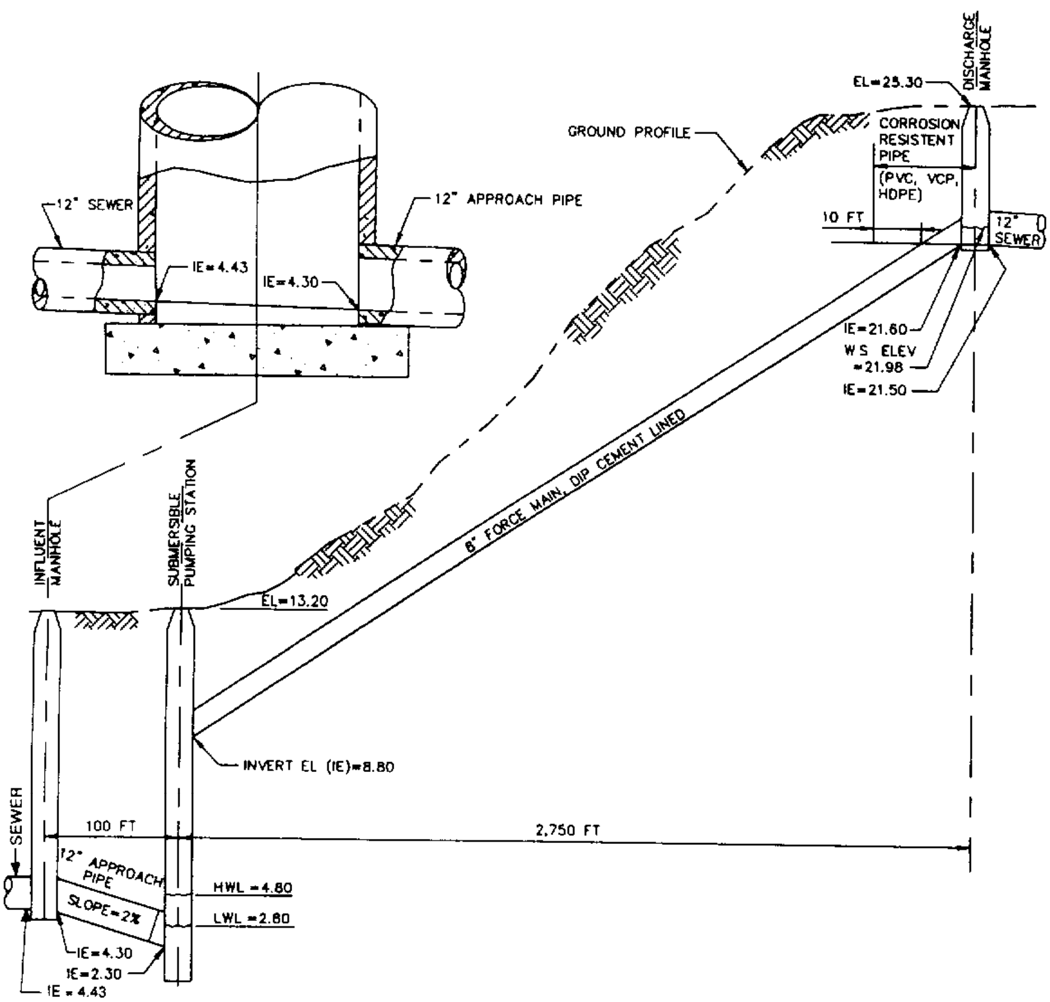


Figure 26-1. Piping profile.

Table 26-1. Total Dynamic Head Losses for Q = 410 gal/min (0.91 ft³/s)

Description		Head losses, ft	
		C = 145	C = 120
		Minimum	Maximum
Station losses (4-in. DIP, v = 10.3 ft/s)	K-value		
Entrance	0.50	0.82	0.82
90° bends, 2 at 0.25	0.50	0.82	0.82
45° bend	0.20	0.33	0.33
Ball check valve	1.35	2.22	2.22
Eccentric plug valve	0.50	0.82	0.82
Tee, line flow	0.30	—	0.49
90° bend 4 to 8-in. expanding	0.50	0.82	0.82
Tee, branch flow, v = 2.49 ft/s	0.75	0.07	0.07
Force main losses			
2750 ft 8–9 in. DIP, lined (v = 2.49)		6.93	9.83
Minor losses, valves, discharge. ΣK = 2.5		0.24	0.24
Static lift		8.78[a]	19.18
Total design head		21.93 (≈22)	35.75 (≈36)

[a] Wet well is assumed to be filled to ground level

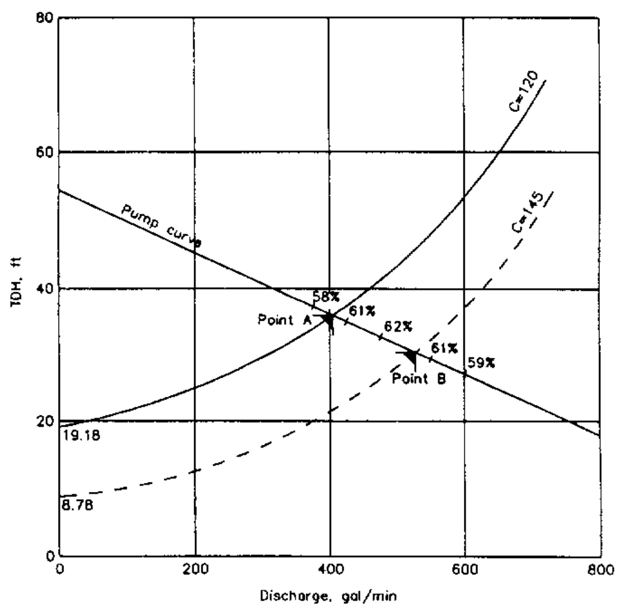


Figure 26-2. Pump and system head-capacity curves.

Not all submersible pump manufacturers include the entrance and discharge elbow losses in their pump curves. The specified design point should be clear on what has been included for losses. The minor losses are not very important for pumping stations with long force mains, but they could be significant for a lift station with low head requirements.

Pump Selection

Operating and maintenance personnel prefer equipment with which they are familiar. They do not like "experimental" applications. Pump selection starts by soliciting input from the people who operate them. Identical pumps are used for multiple pump applications whenever possible to simplify maintenance and provide interchangeability of parts. It is advantageous to have service and parts available from a nearby source.

The selected pump curve and impeller diameter should meet the design point near the best efficiency point. The selected pump should also operate at the low head and high head extremes without cavitating or vibrating. Pump curves with steep slopes are better than those with flat slopes, because there is less variation in capacity with varying head conditions. (Flat spots or dips in the pump curve are therefore undesirable.) Wherever possible choose impellers of intermediate size so that a larger impeller can be substituted for larger future flows. The motor is sized for the worst possible operating point (which is often the low head extreme with one pump operating). For multiple pumps, the best pump efficiency should be at normal operating conditions and not at the ultimate peak flows. However, the emphasis should be on finding pumps that can operate without vibration or cavitation at *all* anticipated service conditions.

Wet Well

The wet well is designed to (1) provide adequate space for the pumps; (2) facilitate cleaning; (3) contain sufficient storage volume; (4) limit pump starts; and (5) minimize installation costs. For a small duplex submersible pump station the most economical wet well is often a reinforced concrete pipe 1.8 or 2.4 m (6 or 8 ft) in diameter standing on a cast concrete bottom.

To improve solids removal, the pumps are confined by close-fitting, nearly conical, smooth walls sloping at 45° to 60° (preferably the latter). Sludge and grit slide down the walls to the pump suction. If the floor is a minimum size (about 0.6 × 1.2 m or 2 × 4 ft), the sludge is so confined that most of it is pumped out on each pump cycle.

The sloping walls may be constructed by placing a custom form in the wet well and injecting concrete behind the form. Fiberglass reinforced plastic or stainless steel can be used as the form and can then remain in place as a liner to provide a smooth, corrosion-resistant surface to facilitate cleaning. Holes are required in the form for the pump discharge elbows, which are cast into the walls. If a disposable form is used, the concrete should be covered with a protective liner such as PVC. The vertical walls above the "cone" should also be protected with a PVC liner.

Active Volume

The active or working volume of wet well and approach pipe must be adequate to limit the frequency of pump starts to a safe value. Conical bottoms reduce the volume available in the wet well, but the addition of an approach pipe laid on a 2% gradient, as described in Section 12-7, supplies additional volume.

The normal LWL is set above the invert of the inlet so that there will be no free fall into the wet well. Consult the manufacturer about the minimum submergence for the motor and the maximum frequency of pump starts. Typically, the motor should be about half submerged at LWL, although under some circumstances the allowable submergence might be less. Starting frequency for small to medium-size submersible pumps may be expected to vary between 6 and 15 starts/h. Using an alternator in stations with multiple pumps to switch lead pumps after each pump cycle reduces the starting frequency. However, one pump may be out of service, so duplex stations must be operable without alternation. Nevertheless, when both pumps are serviceable, alternation could be used to extend the life of the starters and motors.

Calculate the required active volume from Equation 12-3. If the allowable starting frequency for one pump is 10 cycles/h, each cycle takes 6 min and the required volume is

$$V = \frac{TQ}{4} = \frac{(6\text{ min})(410\text{ gal/min})}{4} = 615\text{ gal} = 61.8\text{ ft}^3$$

The wet well and approach pipe are laid out so that the working volume is 615 gal. The existing wet well has limited volume, which requires an approach pipe 100 ft long by 12 in. in diameter. It is laid on a 2% slope with its invert elevation at the wet well at 2.30 ft. The LWL is set at 2.80 ft to force the hydraulic jump to occur in the pipe and not in the wet well. The HWL is set at 4.80 ft. The wet well furnishes about 490 gal of active storage and the approach pipe supplies another 380 gal of storage. The total is 41%% over the requirement.

At the upstream manhole, the invert elevation of the approach pipe is 4.30 ft. On a rising grade of 2%, the invert on the upstream side of a 48-in. manhole would be 0.08 ft higher, but there is some form and friction loss in the transition from half-filled sewer to quarter-filled approach pipe, so an increase of 0.05 ft brings the sewer invert to an elevation of 4.43, as shown in Figure 26-1.

Standby Power

The site cannot accommodate the installation of a permanent engine-generator for standby power. The operator has chosen to store a portable engine-generator at a site about a mile from this facility. A power failure and high water alarm provide indication of potential overflow at the station. During dry weather flow, more than one hour is available to transport and connect the portable engine-generator. However, during wet weather periods, there may be less than 10 min available for that task. Wastewater pumping stations should normally be provided with permanent, on-site standby power to reduce the exposure to wastewater overflows.

Station Piping

Station piping within the wet well is limited to the two pump discharge lines and a force main drain line. Piping within the wet well is as simple as possible with few fittings and no valves. All flange bolts within the wet well are 316 stainless steel, as are the pipe supports and hardware. The piping design within the wet well minimizes items that corrode, that require regular maintenance, or that may catch floating debris. Valves and fittings are contained in a separate valve pit next to the wet well.

The valve pit contains the pump isolation and check valves on the two pump discharge lines and their connection to the force main. A valved force main drain line that discharges back into the wet well is also included. It can be used to agitate the contents of the wet well vigorously so that scum, mixed into the contents, is ejected with the wastewater. Such mixing eliminates the need to pump the water level down to the pump volute to develop vortices for engulfing the scum—an operation that subjects the pump to vibration, stress and wear of the mechanical seals, and possible air binding. Valve stems and nuts are extended nearly to grade to permit operation without the need to enter the vault. The plans are shown in Figure 26-3.

By-pass flush line

An alternative is the use of a pump that ejects part of its discharge into the wet well during the first minute or two after the pump is switched on. The water ejected through a flush valve mixes the solids so that most are discharged to the force main during each pump cycle. The advantage is that the wet well is kept continuously clean automatically. The disadvantages are a small loss of efficiency and the added mechanical device located in the wet well.

Controls and Alarms

The pumps are set up in a lead/lag arrangement with automatic alternation after each pump cycle to balance run times and minimize starts per hour. HAND/OFF/AUTO operator selector switches are provided for each pump at the control panel located with a view of the wet well. Pumps are operated by the wet well water level indicated by a pressure transducer/transmitter hanging in a PVC pipe in the wet well. Key pad controllers are generally preferred because they are easy to operate, do not have pins (easy to lose), and can be programmed with a security code. The high water level alarm consists of a float switch connected to an auto-dialer that pages the on-call operator. A stainless-steel chain supported by the hatch frame is connected to the float switch so the operator can periodically test the switch. A nylon cord would serve the same purpose at less cost.

Operation and Maintenance

Double-leaf, spring-loaded aluminum hatches rated for an H-20 loading are installed over the wet well for access to the pumps. Similar hatches are installed over the valve vault. Safety chains are provided to create a barrier when the hatch is open. Hatches are equipped with padlocks for protection against vandalism.

Telescoping stainless-steel tubes are used for guide rails for installing the pumps. Except during times needed, they are lifted out of the water and hence do not collect debris. Stainless steel cables are attached to the pumps for removal and installation. The owner uses a truck-mounted boom and winch for this service, but, alternatively, a fixed crane or hoist could be provided on site. Winches are equipped with ratchets for use in both directions.

The site is equipped with overhead lights with electric power supplied from a nearby power service pole. Lights are also provided within the outer door of the control panel. A weather guard extending 18 in. in front of the panel is installed at the top front of the control panel. A hook-up with a manual transfer switch makes it easy to use the owner's trailer-mounted engine-generator.

Wash-down water is obtained on-site from the potable water supply. The equipment consists of an air-gap tank, water pump, and hose bibb contained in a locked steel cabinet. The wash-water pump, equipped with a preset timer for automatic shutoff, also has an automatic recirculation line with a pressure regulating valve. Steel traffic bollards are placed around the water and electrical control cabinets. No fencing is provided around the site.

Final Check

After completing the pump selection and piping layouts, the system hydraulics are checked again to see

NOTE:

Special design of wet-well. Includes sloped walls (recommended at 45~60 deg. slope).
System includes by-pass flush pipline from valve-vault to wet-well.
This combination of wet-well design and by-pass flushing provides for an effective "self-cleaning" wet-well system without the need for proprietary "Mix-Flush" valves or motor operated mixing devices.

that the pump selected is the best fit, and that the motor and electrical gear are sized adequately. The drawings and specifications are reviewed by the owner, and the operators are walked through the design system by system. Final revisions are made before bidding the project.

Critique

Compare Figures 26-3, 17-21, and 17-22. The choice of pumping station configuration for each site should be based on sound judgment in which first cost is balanced against cleanliness and

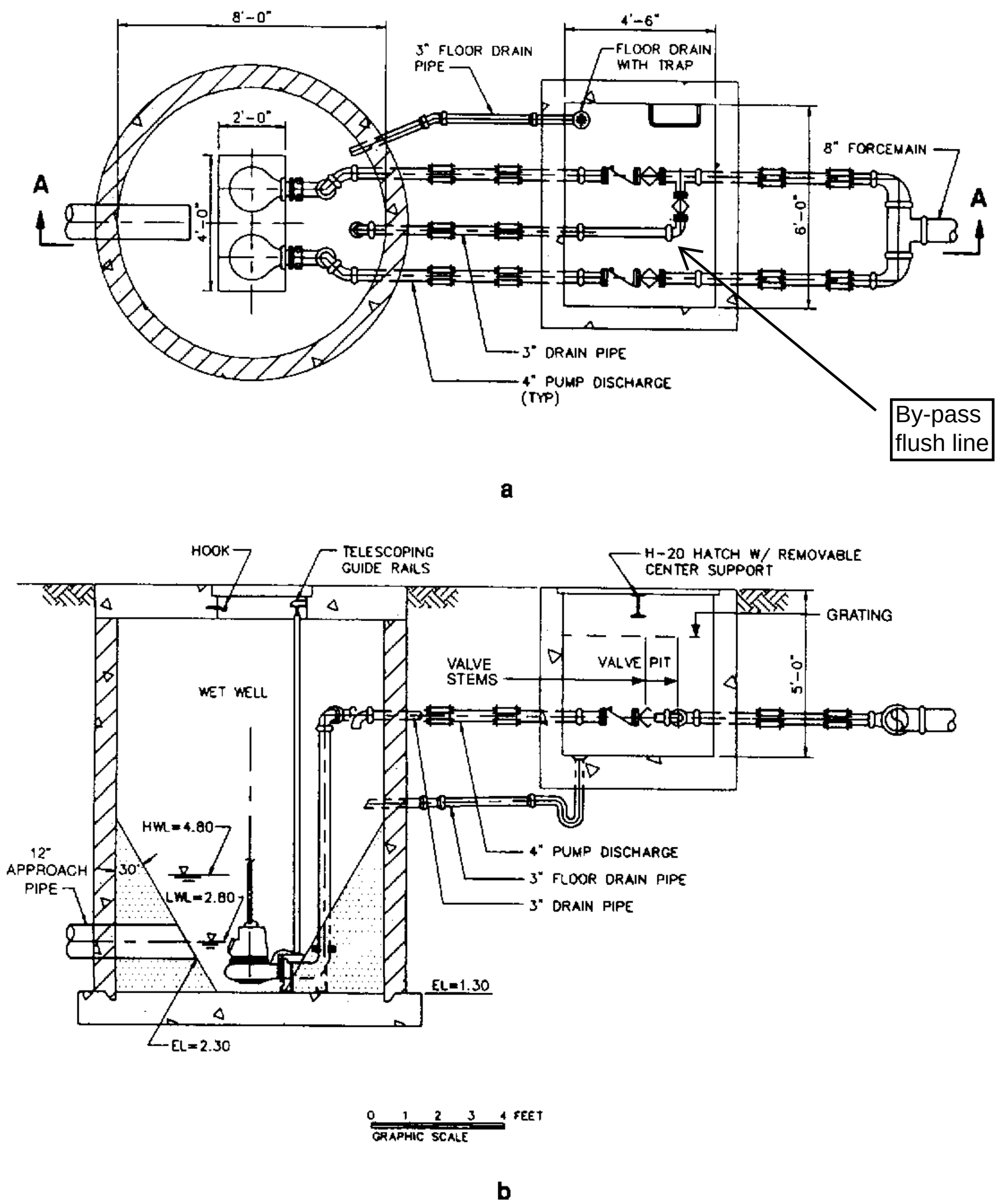


Figure 26-3. Layout of redesigned Clyde pumping station. (a) Plan view; (b) Section A–A.

desired control of odors and the ease and cost of maintenance.

Some operators prefer that the pump discharge lines be cross-connected with each other upstream from the check valves (with a valve on each branch) and connected to the force main drain line, as in Figure 17-22. Although such piping increases the number of valves, the size of the valve vault and the project cost, it allows the operator to agitate the wet well contents with one pump before pumping to the force main with the other. It also allows the operator to backflow one pump with the other to remove clogs without removing the pump.

The pumps could be equipped with nozzles as in Figure 12-58c, but these pumps are so small that such refinements are of debatable value.

The plans in Figure 26-3 indicate a pyramid-shaped hopper bottom. To keep the water surface area as small as possible so that scum will be readily drawn into the pump intakes at pump-down, the sides of the sump should hug the pump volutes with no more than 4 in. of clearance. Instead of being a 2-ft-by-4-ft rectangle, the hopper bottom would be improved if rounded ends were used and if the clearance between pump volutes were reduced to 4 in.

26-2. Redesigned Kirkland Wastewater Pumping Station

Designed originally in 1965, the Kirkland Pumping Station is shown in U.S. customary units in Figures 17-13 and 17-14, so the same units are used in this section. The station has been in continuous operation since 1967. The following example is a revised version of the existing station, modified to reflect: (1) wet well design developments that provide the self-cleaning features described in Chapter 12; (2) the best in current technology; and (3) more recent and stringent reliability standards. The station consists of three 2.5 Mgal/d pumps operating against a total dynamic head of 189 feet.

The top of the influent sewer is no more than 6 ft below finished grade. For such a shallow site, horizontal pumps were selected for both the 1965 and the current designs. Because they are less prone to vibration, horizontal pumps are preferred when they can be justified by little increase in structure cost. Instead of the eddy-current couplings used in the original station, the revised design has 125 hp adjustable-frequency drives. A 300 kW standby generator is provided for protection against power outages.

The force main terminates at an interceptor sewer 3150 ft from the pumping station site at an elevation 123 ft above the soffit of the influent sewer. Calculations were performed by using PUMPGRAF© [1], a computer spreadsheet program configured specifically for pumping station design work.

Individual Hydraulic Losses

Calculations for individual hydraulic losses from the pump inlet to the connection with the discharge manifold were performed first and are shown in Table 26-2. The pump inlet bell diameter in the wet well was selected on the basis of a conservative limiting velocity of 4.5 ft/s even though the HI Standards [2] proposed in 1997 allows 5.5 ft/s. Maximum velocities in pump connecting piping were considered acceptable for a variable speed station, where higher losses are only realized when the equipment operates at full speed. Upon completion of these calculations, they were automatically loaded into the program for the calculation of station system losses.

Station System Losses

Station system head losses in the force main (including static lift) were calculated from the manifold to the point of discharge and are shown in Table 26-3. Instead of the asbestos cement pipe used in the original project, HDPE was the material selected for the force main. Losses were initially calculated for a Hazen–Williams C of 140 and then recalculated for a C of 120. Individual losses for the pump inlet and discharge piping in Table 26-2 were not included in these calculations.

Pump Selection

Station system losses were then transferred through the program to the pump selection program (see Table 26-4), and a pump was selected from a previously entered library of pump manufacturers' catalog information. A plot of the selected performance curves against station system curves is shown in Figures 26-4 and 26-5. The pump performance curves plotted on the figure have been adjusted for individual pump inlet and discharge piping losses of 9.2 ft at 2.5 Mgal/d. These values must be added to the information on the plot to arrive at the correct rating for the pump. In this example, the pumps are to be rated at 2.5 Mgal/d at a total head of 180 ft. The pump selection is considered acceptable, because the intersection between the pump performance curve and the expected range of operating conditions lies well within the manufacturer's published data. Note that the intersection between the manufacturer's curve and the station system curves