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Pump Station Design Series

Article 2, Physical Design

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There are many variations in the physical configuration of pump stations. Economics, simplicity of service, site restrictions, and owner experience influence the design for each application.

Wet Well or Dry Well

One of the first decisions is whether to use a traditional design with pumps installed in a dry well or to use a wet well with submersible pumps.

As submersible pump technology has improved and become accepted, submersible pump stations become more common. (Figure 1) They have a small footprint and are less costly. Suction head is not a problem for submersible pumps. Valves and headers may be enclosed in a valve vault for easy access. However, some owners dislike submersible stations because maintenance requires hoisting the pump. Submersible pumps often require factory repair because of specialized components and stringent sealing requirements.

Most large pump stations and many small ones have separate wet and dry wells. (Figure 2) This locates the pumps in an area readily accessible for inspection and service. There is a broader range of pumps available and standard motors can be used. Headers and valves are installed in the dry well.

To avoid damage to motors from flooding, traditional designs installed the motor above grade. A long shaft with intermediate bearings coupled the motor and pump. The extended shafts could develop vibration issues. To eliminate vibration and reduce cost, some owners prefer submersible pumps in a dry well.

Custom Engineered/Factory Built

Both dry well and submersible stations are available as factory built “packaged” lift stations or as custom designs to be constructed on site.

Factory built pump stations are available in a wide variety of configurations. All but the very largest capacities can be accommodated. Most suppliers can provide any type of pump and provide either dry well or submersible designs.

Factory built pump stations are generally less expensive than custom designs and have a smaller footprint. For some owners having the supplier take all responsibility for the station is an advantage. On the other hand, because they are generally steel fabrications, the station life may not be as long as custom built stations.

Custom design obviously allows the owner to insure that the features most important to him are included. Although they are more expensive, the materials of construction for custom design stations mean long life. Space for easy maintenance and future expansion can be incorporated.

Pump Selection

Deciding between submersible or dry well pumps is just the beginning of the pump selection process. The categories and varieties of centrifugal pumps can seem endless. Some types are designed to solve very specific problems and others are designed for broad application. The options include:

- Solids handling dry well and submersible pumps can pass a sphere up to the specified size. They are specified for wastewater service.
- Grinder pumps and vortex impellers
- Self-priming pumps if flooded suction is not feasible
- Double suction pumps - used for large capacity clean water applications
- Stuffing box or mechanical seals
- Horizontal or vertical shafts
- Single or double volute
- Close coupled or extended drive shaft

Selecting the number of pumps and the size (capacity) of each depends on optimizing many factors. Life cycle cost, which includes power and maintenance expense as well as initial cost, is used to guide the selection process. If the pump head is primarily static and the electric billing is for energy only, then a few constant speed pumps may be best. If the energy cost includes time of day and demand charges, then variable speed pumping may be best. If the difference between current capacity and peak or future capacity is large, then using several pumps may be cost effective. The impact of variations in flow on downstream stations or treatment processes should also be considered.

The recommended time between successive starts for constant speed pumps should be more than five minutes and less than thirty minutes. Small pumps and pumps equipped with soft starts or variable frequency drives can operate at the lower end of this range, but large pumps should cycle less frequently. The time between successive starts of a pump can be estimated:

$$t_s = \frac{29.9 \cdot V_{ww}}{q_p}$$

t_s = time between successive pump starts, minutes

V_{ww} = active volume of wet well, cubic feet

q_p = pump capacity, gpm

It should be noted that not all pumps in a station need to be the same size. There are maintenance advantages to having all pumps identical, but these are usually less significant than energy considerations. Installing different diameter impellers in each pump is another possibility. This allows for future capacity increase without jeopardizing current performance.

Piping Systems

Getting the wastewater from the pump discharge to the conveyance system requires piping and related components inside the pump station. There are two principle considerations in the design of the piping system: size and material.

Sizing involves an economic tradeoff. Larger pipe means higher capital cost. This is offset by reduced energy cost because of lower friction losses. Cost increases directly with diameter, and friction decreases with the diameter to the fifth power. By calculating life cycle cost the optimum pipe size can be determined. Water velocities should be between two and eight feet per second. (A velocity of at least two feet per second is required to keep solids from settling in the piping.)

Pipe material selection is a compromise between cost and durability. Steel is typically less expensive but more susceptible to corrosion than ductile iron. Ductile iron pipe is often cement or polyethylene lined for improved durability. Although non-metallic piping is often used for buried service, it is seldom used inside the pump station. The joining method can substantially influence final system cost.

Check valves and isolation valves represent a considerable portion of piping cost. Cast iron bodies with a variety of trim and sealing materials are typical. Suppliers should be consulted for guidance.

Wet Well Design

Determining the wet well configuration can be complex. The wet well may seem a simple tub for holding stormwater or sewage, but poor design can cause problems for operators and damage to pumps. Considerations that influence wastewater wet well size and design include minimizing odors, eliminating air entrainment, and avoiding solids deposition and scum entrapment.

The elevation of the maximum water surface is usually below the invert of the lowest incoming sewer. However, when large fluctuations in flow occur, such as during rain events, the water may be allowed to back up and surcharge the sewer. This provides additional storage capacity. Obviously the level should never exceed the elevation of the lowest customer connection.

The floor elevation and dimensions of the wet well are determined by site constraints and volume requirements. The minimum depth of the water should be sufficiently above the pump intake to avoid the vortices. Submersible pumps should also maintain sufficient submergence to provide motor cooling. The active volume of the water (the difference between high and low level settings) is typically between three and six feet. The height of the pump intake above the floor should be high enough to avoid restrictions but low enough to minimize solids deposition.

Solids in the wet well can become septic and develop odors. To avoid this, the corners of the wet well floor should have fillets. Odor creation is also minimized by keeping the retention time in the wet well under a half hour. Retention time can be calculated:

$$\mathrm{HRT} = \frac{7.48 \cdot V_{ww}}{q_i}$$

HRT = hydraulic retention time, minutes

V_{ww} = active volume of wet well, cubic feet

q_i = influent flow rate, gpm

It is considered good design practice to split the wet well in half and have pump inlets in each. This allows draining one half of the wet well for cleaning and maintenance without taking the station out of service.

Many pump suppliers have extensive experience and detailed design recommendations for wet well and pump station design. They should be consulted for guidance during the design process.

Once the physical design is completed the major design tasks are finished. The final article in the series will cover the additional systems and components required to provide satisfactory operation.

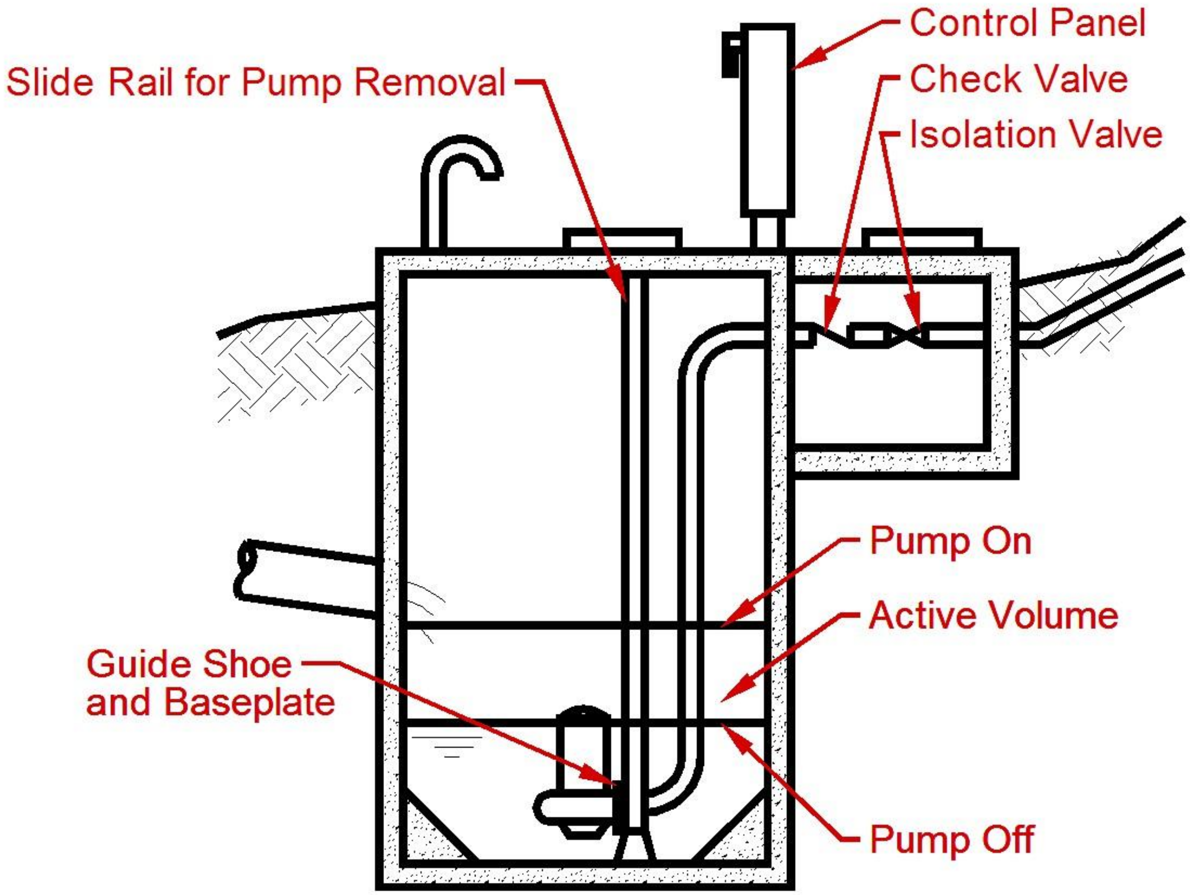

Figure 1: Simplified Diagram of a Submersible Pump Station

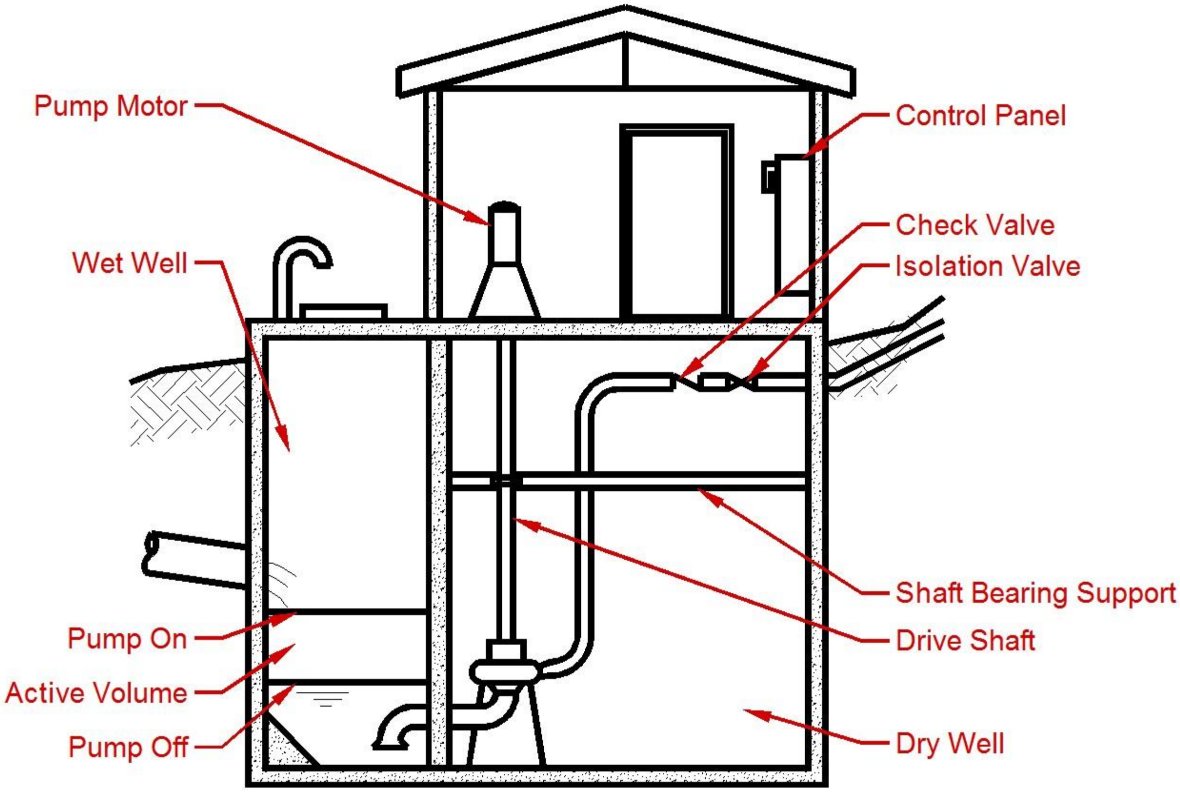

Figure 2: Simplified Diagram of a Conventional Station with Wet Well and Dry Well