CHAPTER 14
PUMP STATIONS

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14.1 INTRODUCTION

Stormwater pump stations are used to remove stormwater from highway sections that can not be drained by gravity. Due to high costs and the potential problems associated with pump stations, their use is recommended only where other systems are not feasible. When operation and maintenance costs are evaluated, a considerable expenditure can be justified for a gravity system. Alternatives to pump stations include deep tunnels, siphons and recharge basins. General guidance and information on all aspects of pump stations can be found in FHWA's, "Manual for Highway Storm Water Pumping Stations".

14.2 DESIGN CONSIDERATIONS

14.2.1 Location

Economic and design considerations dictate that the pump station be located relatively near the low point of the highway. Easy access to the station is desirable. The station and access road should be located on high ground so that access can be obtained if the highway becomes flooded. Architectural and landscaping decisions should be made in the location phase for above-ground stations so the station will be compatible with the surroundings and community.

14.2.2 Hydrology

The pump stations serving expressways must be designed for the same flood frequency as the storm drains (2 to 5 years). Also, the drainage system should be checked for the 100-year storm to determine the extent of flooding and the associated risk. The maximum ponding depth for the 100-year storm should not exceed two feet for safety reasons. No inundation of travel lanes should be permitted for the 50-year storm on interstate highways. Every attempt should be made to keep the drainage area draining to the station as small as possible. This may include crest vertical curve on approach roadways, dikes and inlets above the sump. The resulting design should by-pass all possible drainage to reduce pumping requirements. Avoid future increases in pumping by isolating the drainage area, i.e.; prevent off-site drainage from possibly being diverted to the pump station.

14.2.3 Collection Systems

Storm drains leading to the pumping station are usually designed on flat grades to minimize depth and cost. Minimum cover or local head requirements should govern the depth of the uppermost inlets. The inlet pipe should enter the station perpendicular to the line of pumps. The inflow should distribute itself equally to all pumps. Baffles may be required to ensure that this is achieved. Using grate inlets as screens to prevent large objects from entering the system and possibly damaging the pumps is recommended.

14.2.4 Station Types

Basically, there are two types of stations: wet-pit and dry-pit.

Wet-Pit Stations - In the wet-pit station, the pumps are submerged in a wet well involving the use of submersible pumps. The submersible pumps handle storm water very well and they allow for convenient maintenance in wet-pit stations because of easy pump removal. Submersible pumps are available in large sizes and should be considered for use in all station designs.

Dry-Pit Stations - Dry pit stations consist of two separate elements: the storage box or wet well and the dry well. Storm water is stored in the wet well, which is connected to the dry well by horizontal suction piping. Dry-pit stations are more expensive than the wet-pit stations. CDOT has only used wet-pit stations. At dry-pit stations, centrifugal pumps are usually used. The main advantage of the dry-pit station is the availability of a dry area for personnel to perform routine and emergency pump and pipe maintenance.

14.2.5 Pump Types

The most common types of stormwater pumps are axial flow (propeller), radial flow (impeller) and mixed flow (combination of the two).

Axial Flow Pumps - Axial flow pumps lift the water up a vertical riser pipe; flow is parallel to the pump axis and drive shaft. They are commonly used for low head, high discharge applications. Axial flow pumps do not handle debris well because the propellers will bend or possibly break if they strike a relatively large, hard object.

Radial Flow Pumps - Radial flow pumps utilize centrifugal force to move water up the riser pipe. They are typically used in dry-pit stations and/or for high head applications.

Mixed Flow Pumps - Mixed flow pumps are very similar to axial flow except they create head by a combination of lift and centrifugal action. These pumps can be driven by motors or engines housed in a dry well or by submersible motors located in a wet well. Submersible pumps frequently provide special advantages in simplifying the design, construction, and maintenance and, therefore, cost of the pumping station.

14.2.6 Submergence

Submergence is the depth of water above the pump inlet necessary to prevent cavitation and vortexing. It varies significantly with pump type, speed and atmospheric pressure.

14.2.7 Water-Level Sensors

The water-level sensors activate the pumps. There are a number of different types of sensors that can be used. Types include the float switch, electronic probes, ultrasonic devices, mercury switch, and air pressure switch. Presently, only air pressure sensors are used at CDOT's pump stations.

14.2.8 Discharge System

The discharge piping should be kept as simple as possible. Pumping systems that lift the stormwater vertically and discharge it through individual lines to a gravity storm drain as quickly as possible are preferred. Individual pump discharge lines are the most cost-effective system for short outfall lengths. The effect of stormwater returning to the sump after pumping stops should be considered. Individual lines may exit the pumping station either above or below grade. The back flow head should allow enough water to flow back for back flushing of each pump, but not more than that.

14.2.9 Flap Gates

The purpose of a flap gate is to restrict water from flowing back into the discharge pipe and to discourage entry into the outfall line. Experience in Colorado has shown that debris can clog the opening of flap gates, thus preventing the closure of the gates.

14.2.10 Trash Racks And Grit Chambers

Trash racks should be provided at the entrance to the wet well. For stormwater pumping stations, simple steel bar racks are adequate. Preferably the bar racks are inclined on a 3:1 slope. The bar spacing varies depending on pump size, with the minimum of 3.5 centimeters (1.5 inches). Constructing the racks in modules facilitate removal for maintenance. If the rack is relatively small, an emergency overflow should be provided to protect against clogging and subsequent surcharging of the collection system. The open area of the trash rack should be four times the area of the delivery system. A sediment chamber should be provided to catch solids that are expected to settle out. This will minimize wear on the pumps and limit deposits in the wet well.

14.2.11 Ventilation

Ventilation of dry and wet wells is necessary to ensure a safe working environment for maintenance personnel. Wet wells commonly have dual fan systems, although some can be designed to solely use natural ventilation. The intake fan forces fresh air down the ducts to the lower areas of the well while the exhaust fan pulls the stale air or any potentially explosive gases from the opposite side of the sump. If mechanical ventilation is required to prevent buildup of potentially explosive gasses, the pump motors or any spark producing equipment should be rated explosion proof or the fans run continuously. Enough ventilation should be provided to prevent condensation from damaging electrical components.

14.2.12 Monitoring

Pump stations are vulnerable to a wide range of operational problems from malfunction of the equipment to loss of power. Monitoring systems such as on-site warning lights and remote alarms can help minimize such failures and their consequences.

14.2.13 Maintenance

Maintenance personnel should provide input in the design and selection of each element in the station. A comprehensive program should be developed for maintaining and testing the equipment so that it will function properly when needed. Input from maintenance forces should be a continuous process so that each new generation of stations will be an improvement. Annual inspection by mechanical and electrical engineers can provide valuable information to the maintenance personnel regarding items that need attention. They will often identify deficiencies not noted by regular maintenance personnel. Detailed records of the maintenance activities should be kept for every pump station so that follow-up personnel will know the status of the station. These records will also help in determining or tracing the costs of operating the station.

14.3 RECOMMENDED DESIGN CRITERIA

14.3.1 Station Type And Depth

CDOT has only used wet wells with separate sediment pits, for its pump stations. The station depth should be minimized. No more depth than that required for pump submergence and clearance below the inlet invert is necessary.

14.3.2 Power

CDOT Regions decide what type of power source to use. The need for backup power is dependent upon the consequences of failure and secondary power sources should be considered.

14.3.3 Discharge Head

Since stormwater pumps are extremely sensitive to changes in head, the head demand on the pumps should be calculated as accurately as possible. All valve and bend losses should be considered in the computations. The total dynamic head (TDH) should be based on the maximum static head (i.e., the lowest pump-off elevation). This will allow rising water levels in the wet well to somewhat compensate for loss of capacity due to pump wear and oxidation or mineral deposits in the discharge system. The TDH is computed as follows:

$$TDH = H_s + H_f + H_v + H_1 \qquad (14.1)$$

Where: TDH == total dynamic head, ft; H_s = max. static head (at lowest pump-off elevation), ft; H_f = friction head, ft; H_v = velocity head, ft; H_l = losses through fittings, valves, etc., ft

14.3.4 Main Pumps

Number And Capacity:

A minimum of 3 pumps are recommended. If the total discharge to be pumped is very small and the area draining to the station has little chance of increasing substantially, the use of a two pump station may be considered. However, for this configuration each pump should be sized to handle 66 – 100 percent of the required discharge. The resulting damage caused by the loss of one pump could be used as a basis for deciding the size of the pumps. If constant water flow is evident, a smaller pump should be used to minimize the use of the larger and more expensive pumps.

It is recommended that equal size pumps be used. Identical size and type enables all pumps to be freely alternated into service. This equalizes wear and reduces needed cycling storage. It also simplifies scheduling maintenance and allows pump parts to be interchangeable. Hour meters should be provided to aid in scheduling needed maintenance.

Final Selection:

Manufacturer’s information will likely dictate the type required. However, knowing the operating RPM's, a computation can be made to check the appropriateness of the pump type. The type of existing pumps, the inventory of the spare parts and the availability of parts for any specific pump in Colorado should be considered before ordering any specific brand of pump.

14.3.5 Spare Pumps

Spare pumps are not warranted in stormwater applications. If the consequences of a malfunction are particularly critical, it is more appropriate to add another main pump and reduce their size accordingly. In CDOT's existing pump stations, spare pumps are the same model and size as the main pumps.

14.3.6 Pump On-Off Settings

Pump on-off settings which control the starting and stopping of pump motors correspond to rising and receding water levels in the sump. These settings must be carefully established so that the pumps can handle the design peak flow and all lesser flow rates and durations, and so that the motors will not experience rapid starting cycles. The first pump on-off setting is extremely important since it establishes the most frequent cycle time. To prolong the life of the motors, sufficient volume must be provided in this cycle to meet the minimum cycle time required by the pump motors. Other pump settings are then established so that there is sufficient volume of storage to provide an acceptable cycle time for all remaining pumps. Rotating pumps in starting cycle will prolong pump life. The combination of the pump settings and pump capabilities establish the stage-discharge relationship for the pumping station.

Allowable High Water Elevation:

The allowable high water (AHW) elevation in the station should be set such that the water surface elevation at the lowest inlet in the collection system provides one to two feet of freeboard below the roadway grate.

Clearances:

Pump to pump, pump to backwall, and pump to sidewall clearances should be the minimum possible to minimize the potential for sedimentation problems. Consult manufacturer or a dimensioning guide. The pump inlet to floor clearance plus the pump submergence requirement constitutes the distance from the lowest pump off elevation to the wet well floor. The final elevation may have to be adjusted if the type of pump to be installed is different than anticipated.

Design Examples:

For design example, refer to AASHTO Model Drainage Manual, 1991.

REFERENCES

AASHTO, "*Model Drainage Manual,*" 2003.

Federal Highway Administration, "*Manual for Highway Storm Water Pumping Stations, Volumes 1 & 2,*" FHWA-IP-82-17 and PB 84-152727 and 152735, 1982 and 1984.