WATER PUMPING STATIONS

Robert L. Sanks
Professor Emeritus, Montana State University, Bozeman, MT, USA

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Contents

Summary

Pumping from wells, lagoons, reservoirs, and rivers is described. General types of pumps, pump drivers, and valves are described with respect to types of intake structures and pumping heads. Examples of typical pumping systems are given with elements of reasons involved in decision making. An elementary discussion of water hammer and means for control is included.

1. Introduction

There is more variety in the facilities for pumping water than for pumping other substances such as, for example, storm water or sewage. The design and configuration of pumping stations for transporting water depend on many things such as: the source of the water, flow rate, head, land available, water quality, client's preferences, fish, and even climate to mention a few. A drilled well requires a pump that must be small in diameter to permit its insertion into the well. A pumping station at a riverbank must be large enough to contain (1) trash racks (or fine screens for keeping out fish), (2) pumps, and (3) the associated electrical gear, valves and other control room hardware. Standby engines to ensure uninterrupted power might be required. A close-coupled pump and motor might serve for small flows whereas large flows usually require massive support structures for separated pumps and motors and may also require large areas to house appurtenant facilities. A single impeller can generate low heads, but high heads may require two pumps in tandem or a turbine in which several impellers are mounted on a single shaft. Extremely high heads require positive displacement pumps. If enough land is available, an expensive riverbank pumping station may be supplanted by a short channel leading to a lagoon with a simple concrete slab at the end supporting several pump intakes in unconfined water. Solids-laden waters usually require wet wells that can be cleaned periodically. In some locations, for example northwestern USA and Canada, a mandate to conserve fish is the overriding factor that dictates the design. In mild or tropical climates, pumps can be exposed, but in cold climates pumps and piping must be protected from freezing.

2. Helpful Organizations

Public health and safety all over the world owes much to the American Water Works Association (AWWA). With 54,000 members in 130 countries and more than 400 books, videos and software programs available, it is the leading non-profit technical and education association in the water supply industry. Through its volunteer committees, it publishes in excess of 119 standards for topics ranging from hardware (e.g. pipes and valves) to water treatment and analytical laboratory procedures. It plays a vital role in source water management, treatment plant operations, distribution, and regulation. Its Water for People, organized in 1991 for developing nations, has the goal of ensuring access to safe, clean drinking water for every individual. The Internet address for AWWA is http://www.awwa.org.

The Hydraulic Institute (HI) was founded in 1917 to provide product standards and a forum for information exchange. The HI is now supported by nearly 100 member companies that manufacture pumping equipment. Their standards include nomenclature, definitions, design, application, and operation and testing procedures. From time to time the standards are revised, and all, either new or revised, must be approved by the American National Standards Institute (ANSI) using the canvass method in which the public has ample opportunity to critique new regulations before adoption. Some of these standards, extensively revised and published in 1997 and 1998, are now required for the design of pumping stations in the USA, because they represent a new criterion of care for designers to follow. The Internet address of the HI is http://www.pumps.org.

3. Typical Well Pumping System

Small towns and cities at considerable distances from a surface water source usually get their water from drilled wells. The advantages are proximity and usually uncontaminated water. The disadvantages often include high concentrations of dissolved minerals, high pumping heads and therefore high-energy usage, limited water quantity from a single well, and sometimes sand and/or silt.

Wells can be drilled in almost any strata even solid granite. The most difficult material to drill consists of boulders in sand. A well usually has a steel casing that is perforated in the desired aquifers. For limited water needs, the hole may be only 250 mm in diameter. If large quantities are needed, the hole may be 1000 mm in diameter and filled with gravel between the hole and the casing. The space between the hole and the casing is sealed with grout above the desired aquifer to keep surface water from contaminating the well.

Pumps must be (1) small in diameter (to fit into the well) and (2) must develop high heads. Turbine pumps meet both requirements. Adding more bowls and impellers (see Figure 1) produces higher heads. The drivers are usually electric motors either (1) of small diameter mounted below and directly coupled to the pumps and therefore submerged in the water or (2) of standard size set above ground level with a long lineshaft to the impellers. Submersible motors are especially useful for wells deeper than 180 m and for crooked wells. Otherwise, lineshaft pumps are often preferred. After the well is drilled, it is “developed” by pumping at high rates to create pores that allow larger quantities of water to be pumped. Even solid granite can be made to yield water by shattering the rock with explosives or very high-pressure water.

Figure 1: A two-stage submersible turbine pump for a submerged motor. The motor (not shown) is bolted to the bottom of the pump. Water enters through the screen just below the lower bell.
Courtesy of Crown Pump Corp., De Leon, TX, USA

A schematic diagram of a typical system in which water is pumped to an elevated storage tank is shown in Figure 2. The pump suction is screened to prevent the entrance of coarse sand. At the wellhead, an air-vacuum valve is needed to discharge air when the pump starts. To inhibit pressure surges, the check valve may be either cushioned or spring-loaded to close an instant before flow reverses. A butterfly valve might be used instead of the gate valve for shut-off. For long pipelines, the shut-off valve might be replaced by an electrical or pneumatically actuated control valve that opens slowly to prevent surges as the pump starts and closed slowly when the pump stops. A pump control valve also acts as a check valve when a power failure occurs. The control valve should be used only for lineshafts shorter than 15 m because longer shafts stretch too much with the increased axial thrust while the pump operates against a closed valve. That problem is avoided with submersible motors. Electric power is never 100 per cent reliable. Failure will always occur at some time, and then the equipment must be protected from damage. In some systems, a surge anticipation valve feeding into a bypass to the well is added between the control valve and the shut-off valve, or the control valve itself may be modified to a surge anticipation valve with a pipeline to the well or to waste. Surge is anticipated by means of a small pipe to the pump discharge. When the pump loses power, the pressure drops, and the bypass valve begins to open so that a surge traveling toward the pump encounters an open pipe and therefore cannot develop a destructive pressure. The isolating or shut-off valve is closed only when the upstream (against the flow of water) equipment must be dismantled.

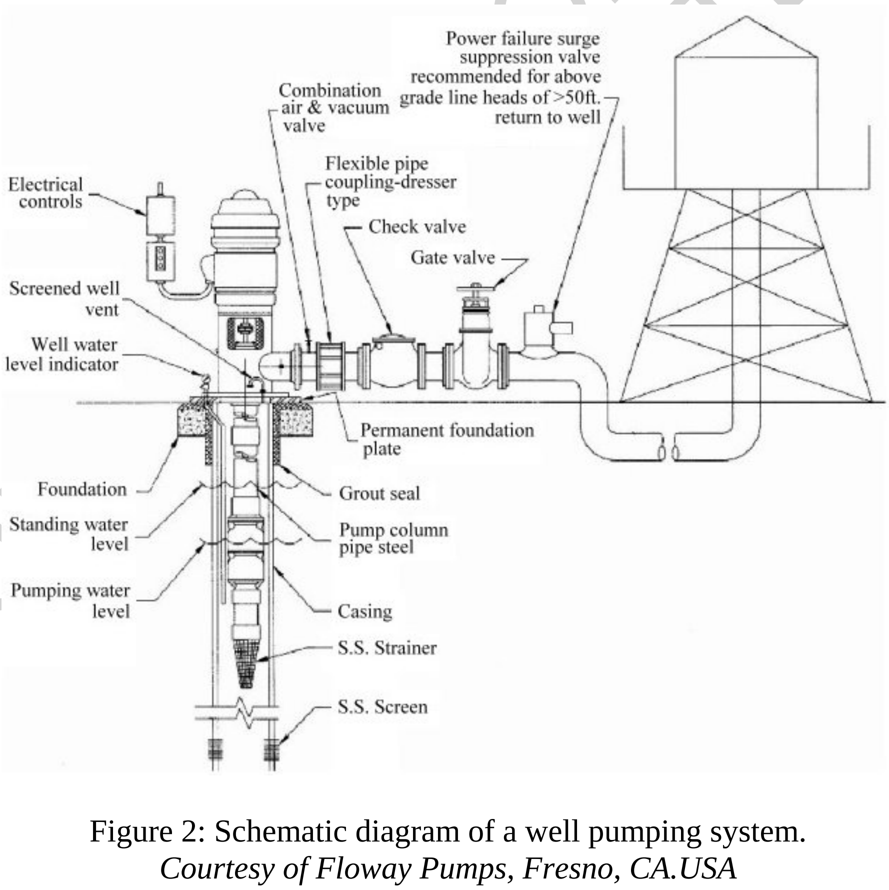

Figure 2: Schematic diagram of a well pumping system.
Courtesy of Floway Pumps, Fresno, CA.USA

Where loss of power for more than a short time would be catastrophic, auxiliary power might be required. It can be furnished with an engine-generator set or by direct connection through right-angle gears and a clutch to the shaft of an engine.

A chlorinating system (not shown) must be added to protect public health. Even if the well system is devoid of living organisms, a water supply can become contaminated. Every potable water supply must carry a small residual dose of chlorine, chlorine dioxide, or chloramine to kill any bacteria that might enter the piping system. Furthermore, there should always be pressure in the potable supply. A vacuum could suck contaminated ground water into the system.

Water supply to a distribution system with adequate service pressure is best obtained from an elevated storage tank. Instead of the tank, however, pumps can be used with any storage basin. Storage basins must have adequate volume to meet both high demand and fire protection.

4. River Pumping System

There are so many variations that it seems unlikely any could be designated as "typical". Enough alternatives are, however, discussed herein to illustrate considerable universality. Consider a river pumping system located on a large river with adequate flows to supply a small (100,000 people) city at all times and with a high water stage no more than about 5 or 6 m above low flow. It is assumed that (1) ice floes and frazil ice occur in winter, (2) some channel migration may wash trees downstream, (3) water is heavy with silt in the spring runoff and after heavy storms, and (4) fish are to be protected.

4.1 Sites

Before design can begin, surveys must be made to find alternative sites, and to determine maximum flood and minimum flow elevations, stability of banks and susceptibility to scour, channel migration, seasonal suspended sediment loads, trash, leaves, and other debris, ice jams, and frazil ice. The conditions may favor (1) an infiltration gallery, (2) a bed intake, (3) a bank intake, or (4) a channel to a pump basin or lagoon.

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Biographical Sketch

Robert L. Sanks, Ph.D., P.E, is Professor Emeritus, Montana State University at Bozeman and a consulting engineer. He has B.S. and Ph.D. degrees from the University of California at Berkeley and the M.S. degree from Iowa State University. He established the graduate environmental engineering program at Montana State University, directed it, and taught the subject for many years. He conceived and directed the Conference on Pumping Station Design for the Practicing Engineer and was Editor-in-Chief for the first (Award of Excellence, Association of American Publishers) and second editions of Pumping Station Design published by Butterworth-Heinemann. He has studied hydraulic models of pump intake basins for many years and has consulted on the design of several medium to large pumping stations. He has written five books and many papers and monographs. He is a Life member in American Society of Civil Engineers and a member of American Water Works Association and Water Environment Federation.