United States
Environmental Protection
Agency

Collection Systems Technology Fact Sheet
Sewers, Conventional Gravity

DESCRIPTION

Sewers are hydraulic conveyance structures that carry wastewater to a treatment plant or other authorized point of discharge. A typical method of conveyance used in sewer systems is to transport wastewater by gravity along a downward-sloping pipe gradient. These sewers, known as conventional gravity sewers, are designed so that the slope and size of the pipe is adequate to maintain flow towards the discharge point without surcharging manholes or pressurizing the pipe.

Sewers are commonly referred to according to the type of wastewater that each transports. For example, storm sewers carry stormwater; industrial sewers carry industrial wastes; sanitary sewers carry both domestic sewage and industrial wastes. Another type of sewer, known as a combined sewer, is prevalent in older communities, but such systems are no longer constructed. Combined sewers carry domestic sewage, industrial waste, and stormwater. This fact sheet focuses on sanitary sewer systems.

APPLICABILITY

Conventional gravity sewers are typically used in urban areas with consistently sloping ground because excessively hilly or flat areas result in deep excavations and drive up construction costs. Conventional gravity sewers remain the most common technology used to collect and transport domestic wastewater.

ADVANTAGES AND DISADVANTAGES

Advantages

Conventional gravity sewer systems have been used for many years and procedures for their design are well-established. When properly designed and constructed, conventional gravity systems perform reliably. Properly designed and constructed conventional gravity sewers provide the following advantages:

- Can handle grit and solids in sanitary sewage.
- Can maintain a minimum velocity (at design flow), reducing the production of hydrogen sulfide and methane. This in turn reduces odors, blockages, pipe corrosion, and the potential for explosion (Qasim 1994).

Disadvantages

- The slope requirements to maintain gravity flow can require deep excavations in hilly or flat terrain, driving up construction costs.
- Sewage pumping or lift stations may be necessary as a result of the slope requirements for conventional gravity sewers, which result in a system terminus (i.e., low spot) at the tail of the sewer, where sewage collects and must be pumped or lifted to a collection system. Pumping and lift stations substantially increase the cost of the collection system.
- Manholes associated with conventional gravity sewers are a source of inflow and infiltration, increasing the volume of wastewater to be carried, as well as the size of pipes and lift/pumping stations, and, ultimately, increasing costs.

DESIGN CRITERIA

The design of conventional gravity sewers is based on the following design criteria:

- Long-term serviceability.
- Design flow (average and peak).

- Minimum pipe diameter.
- Velocity.
- Slope.
- Depth of bury and loads on buried conduits.
- Appurtenances.
- Site conditions.

Long-Term Serviceability. The design of long-lived sewer infrastructure should consider serviceability factors, such as ease of installation, design period, useful life of the conduit, resistance to infiltration and corrosion, and maintenance requirements. The design period should be based on the ultimate tributary population and usually ranges from 25 to 50 years (Qasim 1994).

Design Flow. Sanitary sewers are designed to carry peak residential, commercial, institutional, and industrial flows, as well as infiltration and inflow. Gravity sewers are designed to flow full at the design peak flow. Design flows are based on various types of developments. Table 1 provides a list of design flow for various development types.

TABLE 1 AVERAGE DESIGN FLOWS FOR DEVELOPMENT TYPES

Type of Development	Design Flow (GPD)
Residential:	
general	100/person
single family	370/residence
townhouse unit	300/unit
apartment unit	300/unit
Commercial:	
general	2,000/acre
motel	130/unit
office	20/employee
	0.20/net sq.ft.
Industrial (varies with type of industry):	
general	10,000/acre
warehouse	600/acre
School site (general)	16/student

Source: Darby, 1995.

Minimum Pipe Size. A minimum pipe size is dictated in gravity sewer design to reduce the possibility of clogging. The minimum pipe diameter recommended by the Ten State Standards is 200 mm (8 inches). Though the Ten State Standards are adopted by ten specific states (Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, New York, Ohio, Pennsylvania, and Wisconsin) and the Province of Ontario, they often provide the basis for other state standards.

Velocity. The velocity of wastewater is an important parameter in a sewer design. A minimum velocity must be maintained to reduce solids deposition in the sewer, and most states specify a minimum velocity that must be maintained under low flow conditions. The typical design velocity for low flow conditions is 0.3 m/s (1 foot/second). During peak dry weather conditions the sewer lines must attain a velocity greater than 0.6 m/s (2 feet/second) to ensure that the lines will be self-cleaning (i.e., they will be flushed out once or twice a day by a higher velocity). Velocities higher than 3.0 m/s (10 feet/second) should be avoided because they may cause erosion and damage to sewers and manholes (Qasim 1994).

Slope. Sewer pipes must be adequately sloped to reduce solids deposition and production of hydrogen sulfide and methane. Table 2 presents a list of minimum slopes for various pipe sizes.

If a sewer slope of less than the recommended value must be provided, the responsible review agencies may require depth and velocity computations at minimum, average, and peak flow conditions. The size of the pipe may change if the slope of the pipe is increased or decreased to ensure a proper depth below grade. Velocity and flow depth may also be affected if the slope of the pipe changes. This parameter must receive careful consideration when designing a sewer.

Depth of Bury. Depth of bury affects many aspects of sewer design. Slope requirements may drive the pipe deep into the ground, increasing the amount of excavation required to install the pipe. Sewer depth averages 1 to 2 m (3 to 6.5 feet) below ground

TABLE 2 MIMIMUM SLOPES[1] FOR VARIOUS PIPE LENGTHS

Diameter		Pipe Length	
Inches	Millimeters	Up to 5'	6' or More
8	200	0.47	0.42
10	250	0.34	0.31
12	310	0.26	0.24
14	360	0.23	0.22
24	610	0.08	0.088
30	760	0.07	0.07

[1]Slopes in feet per 100'
Source: Fairfax County, VA 1995.

surface. The proper depth of bury depends on the water table, the lowest point to be served (such as a ground floor or basement), the topography of the ground in the service area, and the depth of the frost line below grade.

Appurtenances. Appurtenances include manholes, building connections, junction chambers or boxes, and terminal cleanouts, among others. Regulations for using appurtenances in sewer systems are well documented in municipal design standards and/or public facility manuals. Manholes for small sewers (610 mm [24 inches] in diameter or less) are typically 1.2 m (4 feet) in diameter. Larger sewers require larger manhole bases, but the 1.2 m (4 foot) barrel may still be used. Manhole spacing depends on regulations established by the local municipality. Manholes are typically required when there is a change of sewer direction. However, certain minimum standards are typically required to ensure access to the sewer for maintenance. Typical manhole spacing ranges between 90 to 180 m (300 to 600 feet) depending on the size of the sewer and available sewer cleaning equipment. For example, one municipality requires that the maximum manhole spacing be at intervals not to exceed 120 m (400 feet) on all sewers 380 mm (15 inches) or less, and not exceeding 150 m (500 feet) on all sewers larger than 380 mm (15 inches) in diameter (Fairfax County PFM 1995). Figure 1 shows a typical manhole profile.

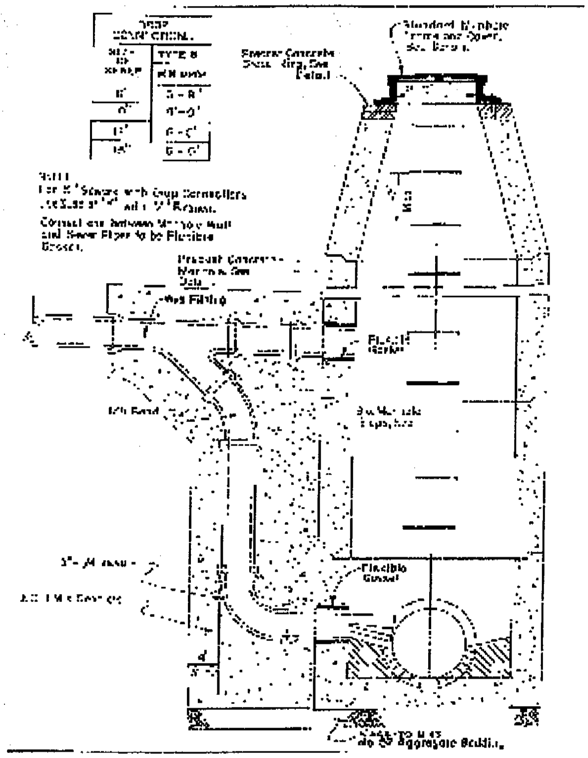
PERFORMANCE

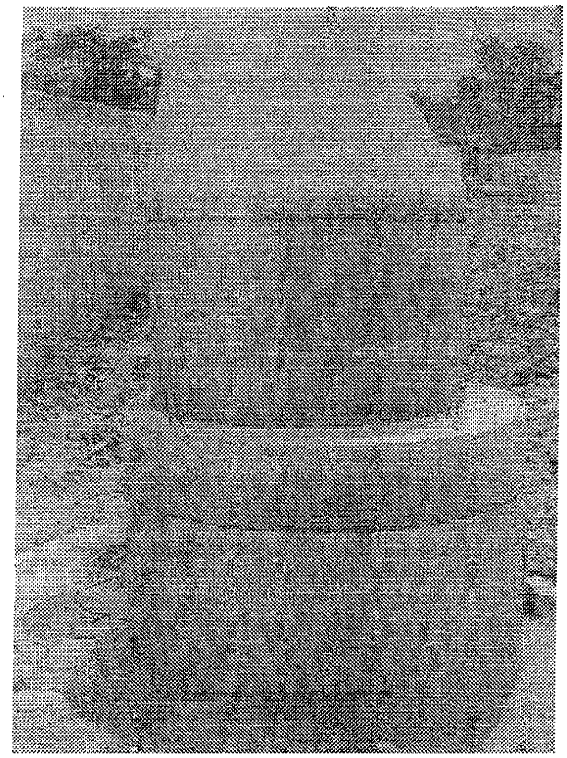
City of Alton, Texas

Alton is a small residential community of about 1,300 homes in Hidalgo County, Texas. Before 1997, all 45 subdivisions in the city used on-site septic tanks, privies, or cesspools for wastewater disposal. These methods did not meet state or county standards primarily because of unsuitable soil conditions, small lot sizes, and density of development. To rectify this situation, a conventional gravity sewer collection system was installed, consisting of 142,600 feet of 8-inch gravity sewer, 5,300 feet of 15-inch gravity sewer, 11,600 feet of 18-inch gravity sewer, 2,600 feet of 6-inch force main, and two lift stations. The system includes 453 manholes and more than 2,000 service connections to convey flow to a nearby interceptor pipeline, which then conveys flow to a nearby wastewater treatment plant in McAllen, Texas. This gravity sewer system has provided reliable performance, while eliminating unsuitable wastewater technologies.

OPERATION AND MAINTENANCE

Interruptions in sewer service may be avoided by strict enforcement of sewer ordinances and timely maintenance of sewer systems. Regular inspection and maintenance minimizes the possibility of damage to private property by sewer stoppages as well as the legal responsibility of the sewer authority for any damages. An operation and maintenance program is necessary and should be developed to ensure the most trouble-free operation of a sanitary sewer system. An effective maintenance program includes enforcement of sewer ordinances, timely sewer cleaning and inspection, and preventive maintenance and repairs. Inspection programs often use closed-circuit television (CCTV) cameras and lamping to assess sewer conditions. Sewer cleaning clears blockages and serves as a preventive maintenance tool. Common sewer cleaning methods include rodding, flushing, jetting, and bailing. Education and pollution prevention can enhance operation and maintenance programs by informing the public of proper grease disposal methods.





Source: Anne Arundel County Std. Details, 1997. Source: Concrete Pipes and Products, Inc., 1992.

FIGURE 1 PROFILE AND PHOTOGRAPH OF MANHOLE

Effective operation of a conventional gravity sewer begins with proper design and construction. Serious problems may develop without an effective preventative maintenance program. Occasionally, factors beyond the control of the maintenance crew can cause problems. Potential problems include:

- Explosions or severe corrosion due to discharge of uncontrolled industrial wastes.
- Odors.
- Corrosion of sewer lines and manholes due to generation of hydrogen sulfide gas.
- Collapse of the sewer due to overburden or corrosion.
- Poor construction, workmanship, or earth shifts may cause pipes to break or joints to open up. Excessive infiltration/exfiltration may occur.
- Protruding taps in the sewers caused by improper workmanship (known as plumber taps or hammer taps) These taps substantially reduce line capacity and contribute to frequent blockages.
- Excessive settling of solids in the manhole and sewer line may lead to obstruction, blockage, or generation of undesired gases.
- The diameter of the sewer line may be reduced by accumulation of slime, grease, and viscous materials on the pipe walls, leading to blockage of the line.
- Faulty, loose, or improperly fit manhole covers can be a source of noise as well as inflow. Ground shifting may cause cracks in manhole walls or pipe joints at the manhole, which become a source of infiltration or exfiltration. Debris (i.e., rags, sand, gravel, sticks, etc.) may collect in the manhole and block the lines.

Tree roots may enter manholes through the cracks, joints, or a faulty cover, and cause serious blockages.

COSTS

The cost of a conventional gravity sewer system varies, based on many factors, including the depth and difficulty of excavation, the cost of labor, availability of pipe, geologic conditions, hydraulic grade line, and construction sequencing. As such, it is difficult to quantify the cost per linear foot for a particular sewer pipe size. Table 3 summarizes unit costs for various items and quantities.

TABLE 3 UNIT COSTS FOR SANITARY SEWER

Item	Cost [1]/Unit
PVC Pipe (not including excavation and backfill):	
8" Diameter	$3.77/linear foot (lf)
10" Diameter	$5.84/lf
15" Diameter	$11.85/lf
Catch Basins or Manholes (including footing and excavation, not including frame or cover):	
Brick, 4' inside diameter, 4' deep	$710 each
Concrete, cast in place, 4'x4', 8" thick, 4' deep	$643 each
Trenching: 4' wide, 6' deep, ½ cubic yard bucket	$18.05/lf
Pipe Bedding: side slope 0 to 1, 4' wide	$3.39/lf
Fill: spread dumped material by dozer, no compaction	$1.23/cubic yard

[1] Source: Means Mechanical Cost Data, 1991.

REFERENCES

Other Related Fact Sheets

Sewer Cleaning and Inspection
EPA 832-F-99-031
September 1999

Sewers, Pressure
EPA 832-F-02-006
September 2002

Other EPA Fact Sheets can be found at the following web address:

http://www.epa.gov/owm/mtb/mtbfact.htm

1. Anne Arundel County, Maryland, 1997. Standard Details for Construction.

2. Border Environmental Cooperation Commission, 1997. Step II Form (Full Proposal). City of Alton, Texas.

3. Concrete Pipe and Products Company, Inc., 1992. Technical Manual. Manassas, Virginia.

4. Crites, R. and G. Tchobanoglous, 1998. Small and Decentralized Wastewater Management Systems. The McGraw-Hill Companies. New York, New York.

5. Darby, J., 1995.

6. Fairfax County, Virginia, 1995. Public Facilities Manual.

7. Lindeburg, M. R., 1986. Civil Engineering Reference Manual. Professional Publications, Inc. Belmont, California.

8. Means Mechanical Cost Data, 1991. Construction Consultants and Publishers. Kingston, Massachusetts.

9. Qasim, S. R., 1994. Wastewater Treatment Plants. Technomic Publishing Company, Inc. Lancaster, Pennsylvania.

10. Urquhart, L. C., 1962. Civil Engineering Handbook. McGraw-Hill Book Company. New York, New York.

11. U. S. EPA, 1986. Design Manual: Municipal Wastewater Disinfection. EPA Office of Research and Development. Cincinnati, Ohio. EPA/625/1-86/021.

12. U. S. EPA, 1991. Manual: Alternative Wastewater Collection Systems. EPA Office of Research and Development. Cincinnati, Ohio. Office of Water. Washington, D. C. EPA/625/1-91/024.

13. U. S. EPA, 1992. Manual: Wastewater Treatment/Disposal for Small Communities. EPA Office of Research and Development. Cincinnati, Ohio. Office of Water. Washington, D. C. EPA/625/R-92/005.

ADDITIONAL INFORMATION

Alton Community Development
5 Mile Line W
Alton, TX 78572

Illinois Rural Community Assistance Program
Illinois Community Action Association
P. O. Box 1090
Springfield, IL 62705

National Small Flows Clearinghouse
at West Virginia University
P. O. Box 6064
Morgantown, WV 26506

David Venhuizen, P.E.
5803 Gateshead Drive
Austin, TX 78745

Walker Baker & Associates, Ltd.
Bill Walker
102 North Gum Street
Harrisburg, IL 62946

Office of Water
EPA 832-F-02-007
September 2002

For more information contact:

Municipal Technology Branch
U.S. EPA
1200 Pennsylvania Avenue, NW
Mail Code 4204M
Washington, D.C. 20460

★ 2002 ★
THE YEAR OF
CLEAN WATER
Celebration & Recommitment

OWM MTB
Excellence in compliance through optimal technical solutions
MUNICIPAL TECHNOLOGY BRANCH

United States Environmental Protection Agency
Office of Water Washington, D.C.
EPA 832-F-00-073
September 2000

EPA

Collection Systems Technology Fact Sheet
Sewers, Lift Station

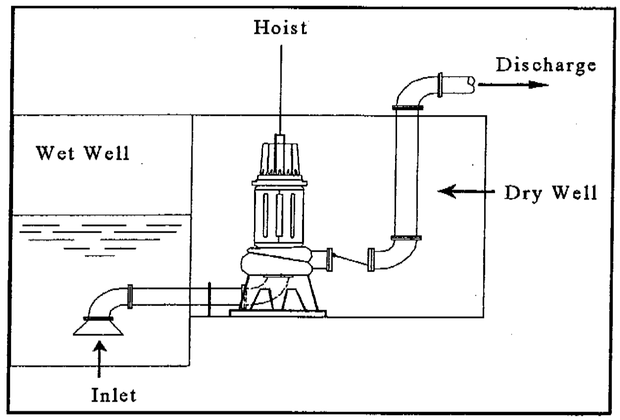
DESCRIPTION

Wastewater lift stations are facilities designed to move wastewater from lower to higher elevation through pipes. Key elements of lift stations include a wastewater receiving well (wet-well), often equipped with a screen or grinding to remove coarse materials; pumps and piping with associated valves; motors; a power supply system; an equipment control and alarm system; and an odor control system and ventilation system.

Lift station equipment and systems are often installed in an enclosed structure. They can be constructed on-site (custom-designed) or pre-fabricated. Lift station capacities range from 76 liters per minute (20 gallons per minute) to more than 378,500 liters per minute (100,000 gallons per minute). Pre-fabricated lift stations generally have capacities of up to 38,000 liters per minute (10,000 gallons per minute). Centrifugal pumps are commonly used in lift stations. A trapped air column, or bubbler system, that senses pressure and level is commonly used for pump station control. Other control alternatives include electrodes placed at cut-off levels, floats, mechanical clutches, and floating mercury switches. A more sophisticated control operation involves the use of variable speed drives.

Lift stations are typically provided with equipment for easy pump removal. Floor access hatches or openings above the pump room and an overhead monorail beam, bridge crane, or portable hoist are commonly used.

The two most common types of lift stations are the dry-pit or dry-well and submersible lift stations. In dry-well lift stations, pumps and valves are housed in a pump room (dry pit or dry-well), that is easily accessible. The wet-well is a separate chamber attached or located adjacent to the dry-well (pump room) structure. Figures 1 and 2 illustrate the two types of pumps.

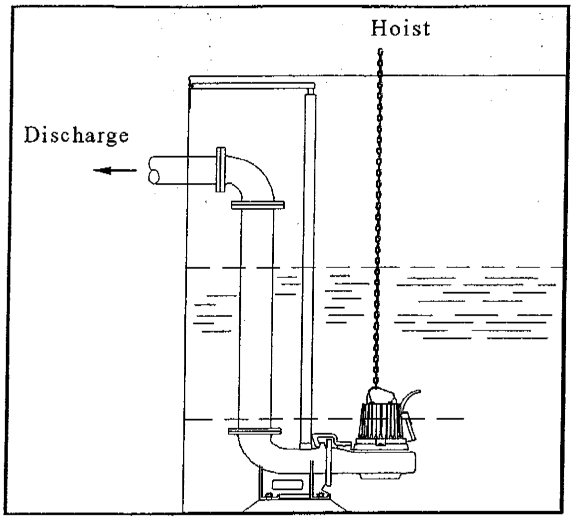


Source: Qasim, 1994.

FIGURE 1 DRY-WELL PUMP

Submersible lift stations do not have a separate pump room; the lift station header piping, associated valves, and flow meters are located in a separate dry vault at grade for easy access. Submersible lift stations include sealed pumps that operate submerged in the wet-well. These are removed to the surface periodically and reinstalled using guide rails and a hoist. A key advantage of dry-well lift stations is that they allow easy access for routine visual inspection and maintenance. In general, they are easier to repair than submersible pumps. An advantage of submersible lift stations is that they typically cost less than dry-well stations and operate without frequent pump maintenance. Submersible lift stations do not usually include

(18)



Source: Qasim, 1994.

FIGURE 2 WET-WELL SUBMERSIBLE

large aboveground structures and tend to blend in with their surrounding environment in residential areas. They require less space and are easier and less expensive to construct for wastewater flow capacities of 38,000 liters per minute (10,000 gallons per minute) or less.

APPLICABILITY

Lift stations are used to move wastewater from lower to higher elevation, particularly where the elevation of the source is not sufficient for gravity flow and/or when the use of gravity conveyance will result in excessive excavation depths and high sewer construction costs.

Current Status

Lift stations are widely used in wastewater conveyance systems. Dry-well lift stations have been used in the industry for many years. However, the current industry-wide trend is to replace dry-well lift stations of small and medium size (typically less than 24,000 liters per minute or 6,350 gallons per minute) with submersible lift stations mainly because of lower costs, a smaller footprint, and simplified operation and maintenance.

Variable speed pumping is often used to optimize pump performance and minimize power use. Several types of variable-speed pumping equipment are available, including variable voltage and frequency drives, eddy current couplings, and mechanical variable-speed drives. Variable-speed pumping can reduce the size and cost of the wet-well and allows the pumps to operate at maximum efficiency under a variety of flow conditions. Because variable-speed pumping allows lift station discharge to match inflow, only nominal wet-well storage volume is required and the well water level is maintained at a near constant elevation. Variable-speed pumping may allow a given flow range to be achieved with fewer pumps than a constant-speed alternative. Variable-speed stations also minimize the number of pump starts and stops, reducing mechanical wear. Although there is significant energy saving potential for stations with large friction losses, it may not justify the additional capital costs unless the cost of power is relatively high. Variable speed equipment also requires more room within the lift station and may produce more noise and heat than constant speed pumps.

Lift stations are complex facilities with many auxiliary systems. Therefore, they are less reliable than gravity wastewater conveyance. However, lift station reliability can be significantly improved by providing stand-by equipment (pumps and controls) and emergency power supply systems. In addition, lift station reliability is improved by using non-clog pumps suitable for the particular wastewater quality and by applying emergency alarm and automatic control systems.

ADVANTAGES AND DISADVANTAGES

Advantages

Lift stations are used to reduce the capital cost of sewer system construction. When gravity sewers are installed in trenches deeper than three meters (10 feet), the cost of sewer line installation increases significantly because of the more complex and costly excavation equipment and trench shoring techniques required. The size of the gravity sewer lines is dependent on the minimum pipe slope and flow. Pumping wastewater can convey the same flow using smaller pipeline size at shallower depth, and thereby, reducing pipeline costs.

Disadvantages

Compared to sewer lines where gravity drives wastewater flow, lift stations require a source of electric power. If the power supply is interrupted, flow conveyance is discontinued and can result in flooding upstream of the lift station, It can also interrupt the normal operation of the downstream wastewater conveyance and treatment facilities. This limitation is typically addressed by providing an emergency power supply.

Key disadvantages of lift stations include the high cost to construct and maintain and the potential for odors and noise. Lift stations also require a significant amount of power, are sometimes expensive to upgrade, and may create public concerns and negative public reaction.

The low cost of gravity wastewater conveyance and the higher costs of building, operating, and maintaining lift stations means that wastewater pumping should be avoided, if possible and technically feasible. Wastewater pumping can be eliminated or reduced by selecting alternative sewer routes or extending a gravity sewer using direction drilling or other state-of-the-art deep excavation methods. If such alternatives are viable, a cost-benefit analysis can determine if a lift station is the most viable choice.

DESIGN CRITERIA

Cost effective lift stations are designed to: (1) match pump capacity, type, and configuration with wastewater quantity and quality; (2) provide reliable and uninterruptible operation; (3) allow for easy operation and maintenance of the installed equipment; (4) accommodate future capacity expansion; (5) avoid septic conditions and excessive release of odors in the collection system and at the lift station; (6) minimize environmental and landscape impacts on the surrounding residential and commercial developments; and (7) avoid flooding of the lift station and the surrounding areas.

Wet-well

Wet-well design depends on the type of lift station configuration (submersible or dry-well) and the type of pump controls (constant or variable speed). Wet-wells are typically designed large enough to prevent rapid pump cycling but small enough to prevent a long detention time and associated odor release.

Wet-well maximum detention time in constant speed pumps is typically 20 to 30 minutes. Use of variable frequency drives for pump speed control allows wet-well detention time reduction to 5 to 15 minutes. The minimum recommended wet-well bottom slope is to 2:1 to allow self-cleaning and minimum deposit of debris. Effective volume of the wet-well may include sewer pipelines, especially when variable speed drives are used. Wet-wells should always hold some level of sewage to minimize odor release. Bar screens or grinders are often installed in or upstream of the wet-well to minimize pump clogging problems.

Wastewater Pumps

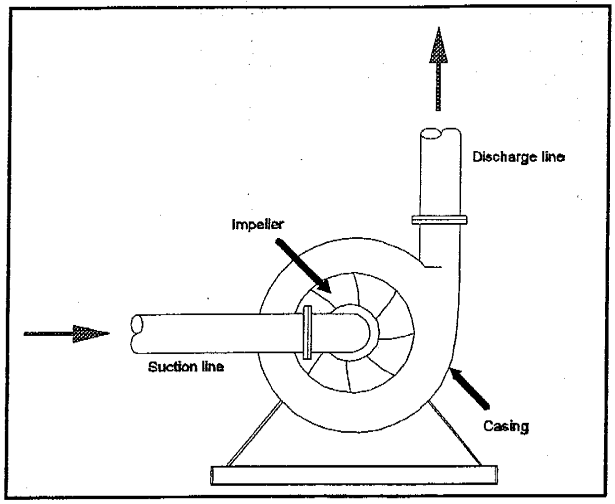
The number of wastewater pumps and associated capacity should be selected to provide head-capacity characteristics that correspond as nearly as possible to wastewater quantity fluctuations. This can be accomplished by preparing pump/pipeline system head-capacity curves showing all conditions of head (elevation of a free surface of water) and capacity under which the pumps will be required to operate.

The number of pumps to be installed in a lift station depends on the station capacity, the range of flow and the regulations. In small stations, with maximum inflows of less than 2,640 liters per minute (700 gallons per minute), two pumps are customarily installed, with each unit able to meet the maximum influent rate. For larger lift stations, the size and number of pumps should be selected so that the range of influent flow rates can be met without starting and stopping pumps too frequently and without excessive wet-well storage.

Depending on the system, the pumps are designed to run at a reduced rate. The pumps may also alternate to equalize wear and tear. Additional pumps may provide intermediate capacities better matched to typical daily flows. An alternative option is to provide flow flexibility with variable-speed pumps.

For pump stations with high head-losses, the single-pump flow approach is usually the most suitable. Parallel pumping is not as effective for such stations because two pumps operating together yield only slightly higher flows than one pump. If the peak flow is to be achieved with multiple pumps in parallel, the lift station must be equipped with at least three pumps: two duty pumps that together provide peak flow and one standby pump for emergency backup. Parallel peak pumping is typically used in large lift stations with relatively flat system head curves. Such curves allow multiple pumps to deliver substantially more flow than a single pump. The use of multiple pumps in parallel provides more flexibility.

Several types of centrifugal pumps are used in wastewater lift stations. In the straight-flow centrifugal pumps, wastewater does not change direction as it passes through the pumps and into the discharge pipe. These pumps are well suited for low-flow/high head conditions. In angle-flow pumps, wastewater enters the impeller axially and passes through the volute casing at 90 degrees to its original direction (Figure 3). This type of pump is appropriate for pumping against low or moderate heads. Mixed flow pumps are most viable for pumping large quantities of wastewater at low head. In these pumps, the outside diameter of the impeller is less than an ordinary centrifugal pump, increasing flow volume.



Source: Lindeburg, revised edition 1995.

FIGURE 3 CENTRIFUGAL ANGLE-FLOW PUMP

Ventilation

Ventilation and heating are required if the lift station includes an area routinely entered by personnel. Ventilation is particularly important to prevent the collection of toxic and/or explosive gases. According to the Nation Fire Protection Association (NFPA) Section 820, all continuous ventilation systems should be fitted with flow detection devices connected to alarm systems to indicate ventilation system failure. Dry-well ventilation codes typically require six continuous air changes per hour or 30 intermittent air changes per hour. Wet-wells typically require 12 continuous air changes per hour or 60 intermittent air changes per hour. Motor control center (MCC) rooms should have a ventilation system adequate to provide six air changes per hour and should be air conditioned to between 13 and 32 degrees Celsius (55 to 90 degrees F). If the control room is combined with an MCC room, the temperature should not exceed 30 degrees C or 85 degrees F. All other spaces should be designed for 12 air changes per hour. The minimum temperature should be 13 degrees C (55 degrees F) whenever chemicals are stored or used.

Odor Control

Odor control is frequently required for lift stations. A relatively simple and widely used odor control alternative is minimizing wet-well turbulence. More effective options include collection of odors generated at the lift station and treating them in scrubbers or biofilters or the addition of odor control chemicals to the sewer upstream of the lift station. Chemicals typically used for odor control include chlorine, hydrogen peroxide, metal salts (ferric chloride and ferrous sulfate) oxygen, air, and potassium permanganate. Chemicals should be closely monitored to avoid affecting downstream treatment processes, such as extended aeration.

Power Supply

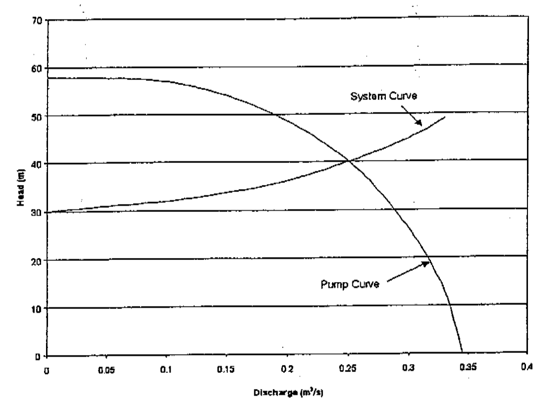
The reliability of power for the pump motor drives is a basic design consideration. Commonly used methods of emergency power supply include electric power feed from two independent power distribution lines; an on-site standby generator; an adequate portable generator with quick connection; a stand-by engine driven pump; ready access to a suitable portable pumping unit and appropriate connections; and availability of an adequate holding facility for wastewater storage upstream of the lift station.

PERFORMANCE

The overall performance of a lift station depends on the performance of the pumps. All pumps have four common performance characteristics: capacity, head, power, and overall efficiency. Capacity (flow rate) is the quantity of liquid pumped per unit of time, typically measured as gallons per minute (gpm) or million gallons per day (mgd). Head is the energy supplied to the wastewater per unit weight, typically expressed as feet of water. Power is the energy consumed by a pump per unit time, typically measured as kilowatt-hours. Overall efficiency is the ratio of useful hydraulic work performed to actual work input. Efficiency reflects the pump relative power losses and is usually measured as a percentage of applied power.

Pump performance curves (Figure 4) are used to define and compare the operating characteristics of a pump and to identify the best combination of performance characteristics under which a lift station pumping system will operate under typical conditions (flows and heads). Pump systems operate at 75 to 85 percent efficiency most of the time, while overall pump efficiency depends on the type of installed pumps, their control system, and the fluctuation of influent wastewater flow.

Performance optimization strategies focus on different ways to match pump operational characteristics with system flow and head requirements. They may include the following



Source: Adapted from Roberson and Crowe, 1993.

FIGURE 4 PUMP PERFORMANCE CURVE

options: adjusting system flow paths installing variable speed drives; using parallel pumps installing pumps of different sizes trimming a pump impeller; or putting a two-speed motor on one or more pumps in a lift station. Optimizing system performance may yield significant electrical energy savings.

OPERATION AND MAINTENANCE

Lift station operation is usually automated and does not require continuous on-site operator presence. However, frequent inspections are recommended to ensure normal functioning and to identify potential problems. Lift station inspection typically includes observation of pumps, motors and drives for unusual noise, vibration, heating and leakage, check of pump suction and discharge lines for valving arrangement and leakage, check of control panel switches for proper position, monitoring of discharge pump rates and pump speed, and monitoring of the pump suction and discharge pressure. Weekly inspections are typically conducted, although the frequency really depends on the size of the lift station.

If a lift station is equipped with grinder bar screens to remove coarse materials from the wastewater, these materials are collected in containers and disposed of to a sanitary landfill site as needed. If the lift station has a scrubber system for odor control, chemicals are supplied and replenished typically every three months. If chemicals are added for odor control ahead of the lift station, the chemical feed stations should be inspected weekly and chemicals replenished as needed.

The most labor-intensive task for lift stations is routine preventive maintenance. A well-planned maintenance program for lift station pumps prevents unnecessary equipment wear and downtime. Lift station operators must maintain an inventory of critical spare parts. The number of spare parts in the inventory depends on the critical needs of the unit, the rate at which the part normally fails, and the availability of the part. The operator should tabulate each pumping element in the system and its recommended spare parts. This information is typically available from the operation and maintenance manuals provided with the lift station.

COSTS

Lift station costs depend on many factors, including (1) wastewater quality, quantity, and projections; (2) zoning and land use planning of the area where the lift station will be located; (3) alternatives for standby power sources; (4) operation and maintenance needs and support; (5) soil properties and underground conditions; (6) required lift to the receiving (discharge) sewer line; (7) the severity of impact of accidental sewage spill upon the local area; and (8) the need for an odor control system. These site and system specific factors must be examined and incorporated in preparing a lift station cost estimate.

Construction Costs

The most important factors influencing cost are the design lift station capacity and the installed pump power. Another cost factor is the lift station complexity. Factors which classify a lift station as complex include two or more of the following: (1) extent of excavation; (2) congested site and/or restricted access; (3) rock excavation; (4) extensive dewatering requirements, such as cofferdams; (5) site conflicts, including modification or removal of existing facilities; (6) special foundations, including piling; (7) dual power supply and on-site switch stations and emergency power generator; and (8) high pumping heads (design heads in excess of 200 ft).

Mechanical, electrical, and control equipment delivered to a pumping station construction site typically account for 15 to 30 percent of total construction costs. Lift station construction has a significant economy-of-scale. Typically, if the capacity of a lift station is increased 100 percent, the construction cost would increase only 50 to 55 percent. An important consideration is that two identical lift stations will cost 25 to 30 percent more than a single station of the same combined capacity. Usually, complex lift stations cost two to three times more than more simple lift stations with no construction complications.

Table 1 provides examples of complex lift stations and associated construction costs in 1999 dollars.

TABLE 1 LIFT STATION CONSTRUCTION COSTS

Lift Station	Design Flowrate (MGD)	Construction Costs (1999 $US)
Cost curve data[1]	0.5	$134,467
Cost curve data[1]	1	$246,524
Cost curve data[1]	3	$392,197
Valencia, California[2]	6	$1,390,000
Sunneymead, California[2]	12	$3,320,000
Sunset/Heahfield, California[2]	14	$2,600,000
Springfield, Oregon Terry Street Pumping Station[2]	20	$5,470,000
Detroit, Michigan[2]	750	$128,800,000

Source: [1]Qasim, 1994 and [2] James M. Montgomery Consulting Engineers, 1998.

Operation and Maintenance Costs

Lift station operation and maintenance costs include power, labor, maintenance, and chemicals (if used for odor control). Usually, the costs for solids disposal are minimal, but are included if the lift station is equipped with bar screens to remove coarse materials from the wastewater. Typically, power costs account for 85 to 95 percent of the total operation and maintenance costs and are directly proportional to the unit cost of power and the actual power used by the lift station pumps. Labor costs average 1 to 2 percent of total costs. Annual maintenance costs vary, depending on the complexity of the equipment and instrumentation.

REFERENCES

Other Related Fact Sheets

Small Diameter Gravity Sewer
EPA 832-F-00-038
September 2000

In-Plant Pump Stations
EPA 832-F-00-069
September 2000

Other EPA Fact Sheets can be found at the following web address:
http://www.epa.gov/owmitnet/mtbfact.htm

1. Casada, Don. *Pump Optimization for Changing Needs*. Operations Forum. Vol. 9, No. 5, 14-18, May 1998.

2. Cavalieri R.R. and G. L. Devin. *Pitfalls in Wet Weather Pumped Facilities Design.* In Proceedings of the Water Environment Federation, 71st Annual Conference, Orlando, Florida, Vol. 2, 719-729, October 1998.

3. Gravette B. R. *Benefits of Dry-pit Submersible Pump Stations.* In Proceedings of the Water Environment Federation, 68th Annual Conference, Miami Beach, Florida, Vol. 3, 187-196, October 1995.

4. Graham B, J., Pinto T.G., and T. Southard. *Backyard Pumping Stations – The Low-pressure Grinder Systems That Call Old Septic Tanks Home.* Operations Forum, Vol. 10, No. 5, 25-29, May 1993.

5. Jackson J. K. Variable Speed Pumping Brings Efficiency to Pump Systems. Operations Forum, Vol. 13, No. 5, 21-24, May 1996.

6. James M. Montgomery Consulting Engineers, 1988. "Sewerage System Preliminary Cost Estimating Curves."

7. Lindeburg, Michael R. *Civil Engineering Reference Manual*, 6th ed., Professional Publications, Inc., revised edition 1995.

8. Makovics J. S. and M. Larkin. *Rehabilitating Existing Pumping Systems: Trips, Traps and Solutions*. Operations Forum, Vol. 9, No. 5, 10-17, May 1992.

9. Metcalf & Eddy Inc., *Wastewater Engineering: Collection and Pumping of Wastewater*, McGraw Hill Book Company, 1981.

10. National Fire Protection Association. *National Fire Codes.* Volume 7, Section 820. Quincy, Massachusetts, 1995.

11. Paschke N.W. *Pump Station Basics – Design Considerations for a Reliable Pump Station.* Operations Forum, Vol. 14, No. 5, 15-20, May 1997.

12. Public Works Journal. *The 1997 Public Works Manual.* April 15, 1997.

13. Qasim, Syed R. *Wastewater Treatment Plants - Planning Design, and Operation.* Technomic Publishing Company, Inc., 1994.

14. Russell Edward. *Screw-Pump Preservation.* Operations Forum, Vol. 9, No. 5, 18-19, May 1992.

15. Sanks R. L., Tchobanoglous G., Newton D., Bosserman, B.E., and Jones, G. M. *Pump Station Design*, Butterworths, Boston, 1998.

16. Schneller T. M. *Pumping it Up? Practical Means For Evaluating Lift Station Fitness*. In Proceedings of the Water Environment Federation, 68th Annual Conference, Miami Beach, Florida, Vol. 3, 155-166 October 1995.

17. Smith E. C. *Don't Lose the Pump Efficiency Game*. Operations Forum, Vol. 11, No. 7, 18-21, July 1994.

18. U.S. Environmental Protection Agency. *Design Manual. Odor and Corrosion Control in Sanitary Sewerage Systems and Treatment Plants*. EPA/625/1-85/018, October 1985.

19. Water Environment Federation. *Existing Sewer Evaluation and Rehabilitation. Manual of Practice No. FD6*, 1994.

20. Water Environment Federation. *Operations and Maintenance of Wastewater Collection Systems. Manual of Practice No. 7*, 1985.

21. Water Environment Federation. *Wastewater Collection Systems Management. Manual of Practice No. 7*, 1992.

22. Workman G. and M.D. Johnson. *Automation Takes Lift Station to New Heights*. Operations Forum, Vol. 11, No. 10, 14-16, October 1994.

ADDITIONAL INFORMATION

Luis Aguiar
Assistant-Director
Miami-Dade Water and Sewer Department
4200 Salzedo Street
Coral Gables, FL 33146

Eileen M. White
East Bay Municipal Utility District
P.O. Box 24055
Oakland, CA 94523

Richard R. Roll
City of Niagara Falls
Department of Wastewater Facilities
P.O. Box 69
Niagara Falls, NY 14302

Gary N. Oradat
City of Houston DPW & Engineering
Utility Maintenance Division
306 McGowen Street
Houston, TX 77006

David Jurgens
City of Fayetteville
113 West Mountain Street
Fayetteville, AR 72701

Bruno Conegliano
Water & Wastewater Utility
City of Austin, P.O. Box 1088
Austin, TX 78767

For more information contact:

Municipal Technology Branch
U.S. EPA
Mail Code 4204
1200 Pennsylvania Avenue, NW
Washington, D.C. 20460

OWM MTB
Excellence in compliance through optimal technical solutions
MUNICIPAL TECHNOLOGY BRANCH