Selection Criteria for Wastewater Pumps

By Bayard Bosserman, P.E. and Paul Behnke, P.E.

Editor's Note: This is the final section of the three-part article. The first two sections appeared in the September and October issues of the magazine. This portion of the article further describes different types of pumping stations and summarizes the criteria for selecting pumps for specific applications.

Submersible Pumps in the Dry Well

Figure 6 depicts the concept of using submersible pumps that can operate in a dry well in lieu of the conventional dry pit vertical sewage pumps. A "standard" submersible pump cannot operate in a dry well because it must be submerged in order to cool the motor.

The construction costs associated with this alternative are shown in Table 6 and compared with the construction costs for the conventional wet well/dry well design previously described.

Table 6 — Probable Construction Costs for Submersible Pumps in Dry Well*

Pumping Station Capacity (mgd)	Probable Construction Costs of Station Using Submersible Pumps in the Dry Well	Probable Construction Costs of Station Using Conventional Pumps	Savings
2-mgd	$1,650,000	$1,700,000	$50,000
5-mgd	$2,600,000	$2,700,000	$100,000
15-mgd	$4,700,000	$4,900,000	$200,000

*Assumes no mechanical screening facilities required.

Estimated Life Cycle Costs: There does not appear to be any increase in annual O&M costs associated with equipment maintenance with this design compared to those for a conventional dry pit pump design. The motors are less efficient than conventional motors, as was described above. Table 7 summarizes the resulting life cycle costs of pumping stations using submersible pumps in the dry well.

Table 7 — Estimated Life Cycle Costs of Pumping Stations Using Submersible Pumps in the Dry Well

	Pumping Station Capacity (mgd)		
	2[1]	5[2]	15[3]
Estimated Construction Cost[4]	$1,650,000	$2,600,000	$4,700,000
Present Value of Additional Energy Costs	15,000	40,000	110,000
TOTAL[5]	$1,650,000	$2,650,000	$4,800,000

Notes:
1. Assumes two 50-horsepower pumps (1 operating, 1 standby).
2. Assumes three 60-horsepower pumps (2 operating, 1 standby).
3. Assumes four 125-horsepower pumps (3 operating, 1 standby).
4. Assumes no mechanical screening facilities as part of pumping station.
5. Figures are rounded to the nearest $50,000.

Vertical Turbine-Type Solids Handling Pumping Stations

A typical vertical turbine-type solids handling pumping station is depicted in Figure 7. The design typically features a wet well in which the pump is hung, suspended from a supporting slab over the wet well. A separate building is provided to house the electrical and control systems. Most of the installations investigated did not have on-site cranes. Truck-mounted cranes are used to remove the pumps for maintenance and to reinstall them.

The construction costs for the type of pumping station are similar to those (although a little greater) for a submersible type of station. The vertical turbine-type solids handling type of pump generally is more expensive than either a conventional dry well or submersible pump. The estimated construction costs associated with the design are shown in Table 8 and compared to the construction costs for the other types of stations.

Table 8

Probable Construction Costs* of Vertical Turbine-Type Solids Handling Pumping Stations

Pumping Station Capacity (mgd)	Probable Construction Cost of Conventional Pumping Station Without Screening System (Figure 4)	Probable Construction Cost of Submersible Station Without Screening System (Figure 5)	Probable Construction Cost of Vertical Turbine-Type Solids Handling Station Without Screening System (Figure 6)
2-mgd	$1,700,000	$1,300,000	N/A
5-mgd	$2,700,000	$2,100,000	$2,300,000
15-mgd	$4,900,000	$3,900,000	$4,200,000

* ENR CCI value approximately 4,500. Costs taken from data presented in References [1], [2] and [3].

Capacities: The minimum capacity of this type of pump is about 1,500-gpm with total dynamic head (TDH) in the range of 15 to 30 feet per stage. Thus, there is only a limited use for such pumps in small pump station applications.

The maximum capacity of this type of pump is about 65,000-gpm with TDH in the range of 80 to 90 feet. Such a TDH is attainable with pumps typically having a capacity of 2,500-gpm or more. Thus, vertical turbine-type solids handling pumps are better suited for large pumping station applications.

Figure 8

Comparison of Estimated Life Cycle Costs for Types of Wastewater Pumping Stations

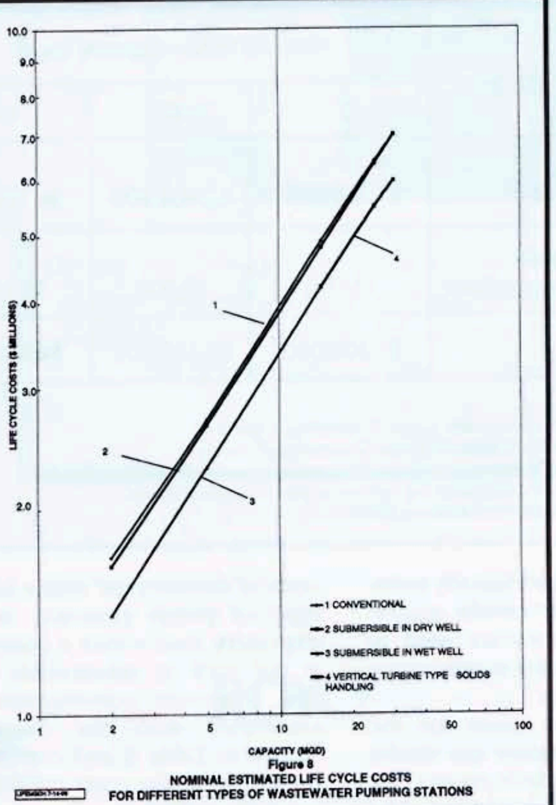

Figure 8
NOMINAL ESTIMATED LIFE CYCLE COSTS FOR DIFFERENT TYPES OF WASTEWATER PUMPING STATIONS

Operation and Maintenance Aspects: All the O&M personnel contacted spoke very favorably of the ease of maintenance and low O&M costs of this type of pump. Generally speaking, the level of effort required for maintenance is about the same as that for conventional dry pit pumps except that a crane is necessary to remove the pump in order to work on the impellers, tail bearings and shaft supports. The following specific comments were made.

- The effort to check and adjust or install packing is the same as that required for conventional dry well pumps.
- The pumps have to be removed approximately every two to four years to have the bearings inspected and, if necessary, replaced. Shaft connectors and supports should also be inspected and repaired or replaced at this time.
- One agency reported that this type of pump is very sensitive to having the impellers become clogged with rags and that a screening system should be installed ahead of the pumps. However, this agency O&M supervisor doubted that any other type of pump could handle their rag load without screens.

The agencies all used truck cranes to remove the pumps for maintenance, and this does take slightly more effort than is the case for handling conventional dry well pumps because the pump columns are long. This characteristic increases the time it takes to remove or reinstall the pumps, but the magnitude of this additional time is not thought to be significant.

The pump and motor efficiencies are the same as for conventional dry well pumps.

Estimated Life Cycle Costs: There does not appear to be any significant increase in annual O&M costs with this design compared to those for a conventional dry pit pump design. Thus, the life cycle costs are the same as the construction costs shown in Table 8.

Submersible Pumps in a Dry Well

A majority of the O&M supervisors in the agencies investigated in the United States prefer the "submersible pumps in a dry well" design for the following reasons.

- Eliminates the line shafts associated with conventional dry well pumps. These line shafts can require a lot of maintenance, especially with the pillow block bearings. When the pillow block bearings fail, it takes a lot of effort to reinstall and realign the line shafts after new pillow blocks are installed.
- Eliminates O&M cost associated with shaft and equipment vibration.
- Eliminates the initial construction cost of catwalks for access to the intermediate bearings, line shaft supports, etc.

Table 9

Comparison of Estimated Life Cycle Costs for Types of Wastewater Pumping Stations
(Assuming No Mechanical Screens)

Type of Station	Comments	Capacity (mgd) 2	5	15
Conventional		$1,700,000	$2,700,000	$4,900,000
Submersible in wet well	6-month repair cycle	$1,750,000	$2,800,000	$4,900,000
	2-year repair cycle	$1,400,000	$2,300,000	$4,200,000
	5-year repair cycle	$1,350,000	$2,200,000	$4,100,000
Submersible in dry well		$1,650,000	$2,650,000	$4,800,000
Vertical turbine-type solids handling		N/A	$2,300,000	$4,200,000

- Allows much better access from the overhead bridge cranes, since there are no interfering line shafts and catwalks in the dry well.

- The submersible pumps are noticeably quieter than the conventional dry well pumps with shafting.

- Allows routine monitoring to be performed without having to remove the pumps from a wet well and transport them to an off-site repair facility.

Unlike the case of pumps in a wet well, it is anticipated that there is no increased O&M costs (other than higher power costs due to the less efficient motors) of using submersible pumps in a dry well compared to using conventional pumps in a dry well.

Summary of Maintenance

In the opinion of the O&M staffs at most of the agencies contacted, the degree of effort required to maintain various types of sewage pumping stations (from easiest to most difficult) is as follows:

1. Submersible pumps in a dry well.

2. Conventional dry well pumps in a dry well or vertical turbine-type solids handling pumps.

3. Submersible pumps in a wet well.

A careful and realistic life cycle cost analysis should be performed before deciding to use submersible pumps, especially if the contemplated pumping station is fairly large (greater than 10- to 15-mgd capacity). Table 9 summarizes and compares the estimated life cycle costs previously given in Tables 1, 5, 7 and 8. These data also are depicted graphically in Figure 8.

Selection Criteria

In light of the concepts presented, it is suggested that the following criteria be used in selecting the type of pump and associated pumping station design for wastewater systems.

- Ability of the owner's staff to obtain high quality pump equipment through its procurement process.
- Familiarity of owner's staff with the pump equipment.
- Ability of the owner's staff to maintain the pump equipment.
- Availability of supporting maintenance equipment such as cranes and trucks.
- Degree of commitment of owner to train and support O&M staff.
- Present value of annual O&M costs.
- Initial construction cost.

These criteria are discussed in more detail in Table 10 for three hypothetical owners or sanitation agencies. In addition, Chapter 25 in Reference [1] presents a thorough comparison of the advantages and disadvantages of the various typical wastewater pumping stations.

Recommended Types of Wastewater Pumping Stations

Recommendations to use various types of pumping stations under various design conditions are summarized in Table 11. Actual selection should be done on a project-specific basis and considering the owner's preferences and experiences, but the following recommendations are offered. These recommendations are based on a combination of life-cycle costs in conjunction with the other criteria given in Table 10. It should be emphasized that all these factors need to be considered in selecting the type of wastewater pump for a given project. Where alternatives are shown in Table 11, they are listed in order of best life-cycle costs.

REFERENCES

1. Robert L. Sanks, et al, *Pumping Station Design*, second edition, Butterworths-Heinmans, 1998.
2. DG-04 Value Engineering Study, Report of Value Analysis, Contract 95MM1279A, Washington Suburban Sanitary Commission, prepared by Boyle Engineering Corporation, July 1996.
3. B. Bosserman, S. Collins, A. Will, "Current Concepts in Wastewater Pumping Station Design," presented at the 28th Joint Annual Conference of the Chesapeake Water Environment Association and the Water and Waste Operators Association of Maryland, Delaware, and District of Columbia, Ocean City, Maryland (July 9–11, 1997).

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Table 10 — Criteria for Hypothetical Owners

Issue or Criteria	Hypothetical Owner No. 1	Hypothetical Owner No. 2	Hypothetical Owner No. 3	Reader Self Assessment
Ability of owner to obtain high quality equipment through its procurement process.	Procurement process allows for specification and purchase of high quality, durable equipment. Some difficulties occasionally encountered.	Procurement process generally allows for specification and purchase of high quality, durable equipment.	Difficult to obtain high quality, durable equipment.	
Ability of owner's staff to maintain the pump equipment and availability of supporting maintenance equipment.	Owner's staff can maintain equipment or qualified pump repair companies are readily available.	Owner's staff can maintain conventional equipment and qualified private repair companies are usually available to maintain specialized equipment.	Owner's staff has difficulty maintaining specialized equipment and qualified private pump repair companies are not readily available.	
Familiarity of owner's staff with the type of pump equipment selected and with the size or capacity to be used.	Owner's staff is very familiar with the type and size of pump equipment to be provided and is aware of its limitations or special requirements.	Owner's staff is generally familiar with the type and size of pump equipment to be provided and is somewhat aware of its limitations or special requirements.	Owner's staff is unfamiliar with pump equipment to be provided, or is familiar with equipment in much smaller capacities and sizes.	
Adequacy of owner's annual O&M and training budget.	Owner understands budget needed for effective O&M and training, and sufficient budget is available.	Owner understands budget needed for effective O&M, but sufficient O&M budget may be difficult to obtain.	Owner has difficulty obtaining sufficient annual O&M budget and is sensitive to O&M costs.	

Recommendations for Wastewater Pumping Station Selections
(Alternates Where Shown are Listed in Order of Best Life-Cycle Costs)

Table 11

		Types of Pumping Station		
Maximum Station Capacity (mgd)	**Comments**	**Hypothetical Owner No. 1**	**Hypothetical Owner No. 2**	**Hypothetical Owner No. 3**
2[1]		Submersible in wet well.	Submersible in wet well.	1. Conventional. 2. Submersible in wet well.
10[1]	Maximum pump size of 150-horsepower for submersible pump in a wet well.	Submersible in wet well.	Submersible in wet well.	1. Vertical turbine-type solids handling. 2. Submersible in dry well. 3. Conventional.
	Pump size greater than 150-horsepower.	1. Vertical turbine-type solids handling. 2. Submersible in dry well.	1. Vertical turbine-type solids handling. 2. Submersible in dry well.	1. Vertical turbine-type solids handling. 2. Submersible in dry well. 3. Conventional.
	Wet well depth greater than 40 feet.	Submersible in dry well.	Submersible in dry well.	1. Submersible in dry well. 2. Conventional.
30[1]	Maximum pump size of 150-horsepower for submersible pump in a wet well.	1. Vertical turbine-type solids handling. 2. Submersible in dry well. 3. Submersible in wet well.	1. Vertical turbine-type solids handling. 2. Submersible in dry well. 3. Submersible in wet well. 4. Conventional.	1. Vertical turbine-type solids handling. 2. Submersible in dry well. 3. Conventional.
	Pump size greater than 150-horsepower.	1. Vertical turbine-type solids handling. 2. Submersible in dry well.	1. Vertical turbine-type solids handling. 2. Submersible in dry well. 3. Conventional.	1. Vertical turbine-type solids handling. 2. Submersible in dry well. 3. Conventional.
	Wet well depth greater than 40 feet.	Submersible in dry well.	Submersible in dry well.	1. Submersible in dry well. 2. Conventional.
Larger than 30[1]		1. Vertical turbine-type solids handling. 2. Submersible in dry well. 3. Conventional.	1. Vertical turbine-type solids handling. 2. Submersible in dry well. 3. Conventional.	1. Vertical turbine-type solids handling. 2. Submersible in dry well. 3. Conventional.
Any	Pumping station TDH greater than approximately 90 feet but less than approximately 180 feet.	1. Submersible in dry well. 2. Two-stage vertical turbine-type solids handling.	1. Submersible in dry well. 2. Two-stage vertical turbine-type solids handling. 3. Conventional.	1. Submersible in dry well. 2. Two-stage vertical turbine-type solids handling. 3. Conventional.
Any	Pumping station TDH greater than approximately 180 feet.	Conventional[2] with tandem pumps.	Conventional[2] with tandem pumps.	Conventional[2] with tandem pumps.

1. Maximum pump speed of 1,800-rpm for pumps 100-horsepower and smaller and 1,200-rpm for larger pumps. Maximum 1,200-rpm preferred.
2. Maximum speed of 1,200-rpm is preferred regardless of pump size.