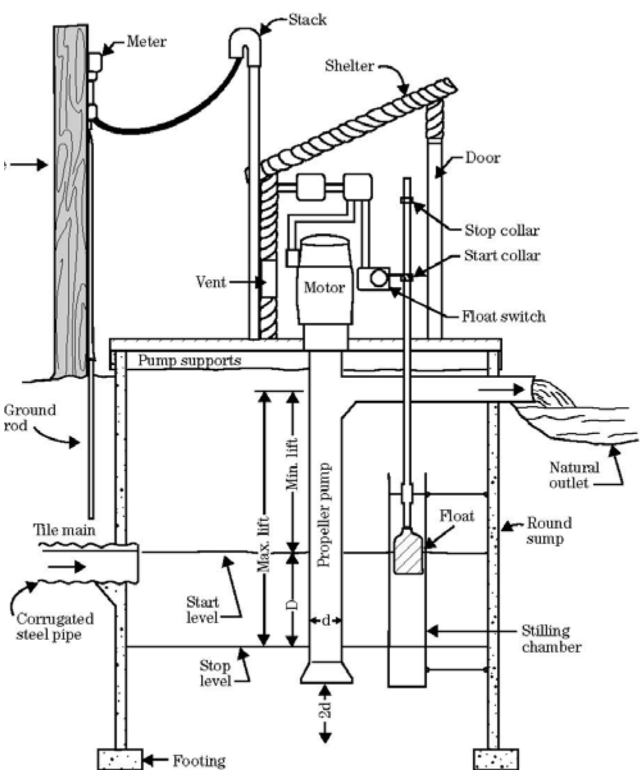
NJ650.1406 Pump Drainage

a) General

Drainage pumping plants remove excess surface or ground water where it is impossible or economically infeasible to obtain gravity outlets for drainage. They are also used on sites that have adequate outlets except during periods of prolonged high water. Figure 6-1 shows a typical installation of a pumping plant. A much more detailed description of drainage pumping is in NEH, Section 16, Drainage of Agricultural Lands.

Figure 6-1 Typical pumping plant



b) Surface drainage pumping conditions

Pumping for surface drainage may be feasible on the following landforms:

Bottom lands or flatlands protected from flooding by dikes, where gravity drainage is restricted because of periodic high stages in the outlet, or where the outlet has inadequate capacity. Floodgates are installed to permit the maximum gravity drainage possible while preventing the inflow of floodwater. The amount of pumping required can vary from a small percentage of the drainage flow to practically all of it.

Coastal plains that do not afford enough slope to the water surface for gravity drainage. Here, the land to be drained is diked, and pumping is done from a sump. The amount of the drainage water that must be pumped depends on the elevation of the land above tidewater. In some situations, the entire runoff must be pumped.

Areas in which the runoff water is to be used for irrigation. The area may or may not be diked, depending on the outlet situation for gravity drainage. Water control structures are necessary.

Areas in which the soil requires a high degree of water table control, such as in areas of organic soils. Pumping is sometimes required to lower water levels during wet periods and raise water levels during dry periods.

c) Subsurface drainage pumping conditions

Conditions under which pumping for subsurface drainage may be feasible:

- Where it is desired to add the drainage water to the irrigation water.
- Where the outlet is at an elevation that does not permit gravity flow from drains located at depths required for adequate drainage.
- Where the indicated method of drainage is to pump the water from an underlying aquifer, which may or may not be under artesian pressure.

d) Relation of pumping plant to drainage system

The pumping plant should be planned and designed as an integral part of the drainage system. The reconnaissance or preliminary survey determines the condition of the drainage outlet and whether pumping is required. A drainage system in which the pumping plant is designed into the system generally functions much more efficiently than one in which the pumping facilities are added after the system is installed because the outlet is inadequate.

Features that require coordination

The pumping plant must be designed to pump the amount of water necessary to give adequate drainage against the total head expected. In determining this, disposing of all the runoff possible by diversion around the area and providing for all possible gravity flow through floodgates should be considered.

The plant should be located where it best serves the intended purposes. Condition of the foundation, access for servicing, proximity to sources of power, and locations that might be susceptible to vandalism should be considered. Where significant sump storage is available, the pumping plant should be located to take maximum advantage of the storage provided. The location should permit safe discharge into the outlet with a minimum of construction outside the diked area.

If possible, the plant should be easily accessible. Ordinarily, the dike can be widened to accommodate vehicular traffic. An all-weather access road is desirable.
The requirements for a stable foundation often conflict with the other requirements of location. Borings should be made and the location selected that has the best foundation conditions consistent with other site requirements. An unstable foundation material can considerably increase the cost of a pumping plant. A more intensive investigation before selecting the plant location often yields big dividends in reduced costs.

Sump storage

Careful consideration should be given to providing storage for runoff within the diked area. The effective storage is that capacity in sump areas and ditches between the lowest elevation at which drainage is by gravity, or the cutoff elevation for the pumps, and the elevation at which flooding of the land to be protected begins. This is determined largely by the topography of the project area and the type of drainage system. A sump for a subsurface drainage system may be only a circular well 8 feet or less in diameter that has 2 feet of effective storage.

A sizeable area near the surface drainage system outlet that is lower than the area to be drained can be used for storage without crop loss. Borrow pits of appreciable size for dike construction and drainage ditches that have sufficient storage capacity can also be used.

All of the storage capacity available should be used to reduce the required pumping capacity, considering the economics of the project. For high-value, highly developed cultivated land, the only storage capacity that may be available is that in open ditches. For watersheds used for low-value crops and that may contain appreciable areas of undeveloped land, a rather large area of low-lying land may be devoted to sump storage. This will result in a less expensive pumping plant. Where the area needs to be developed to more intensive use, the pumping capacity can be increased and some of the area otherwise devoted to sump storage can be developed.

The ditches supplying runoff to the pumps must be capable of delivering water at the maximum pumping rate. The highest roughness factor considered likely to occur should be used to determine the ditch size for this requirement.

Sumps designed to collect and store large volumes of water generally collect runoff as well as subsurface drainage discharge. These sumps can be used where a uniform rate of discharge is desirable in the drainage outlet or where the discharge is desirable only during specified times.

The following formula helps determine sump storage requirements for continuous pumping operations over a specified time period:

$$S = V\,[\,1 - I/P\,]$$

where:
V = Total volume of drain water to be stored over a specified time period
S = Sump storage (gallons)
I = Inflow rate (gallons per minute)
P = Pumping rate (gallons per minute)

The total time during which the pump will operate continuously is defined by:

$$T = V / 60P$$

where:
T = Pumping time (hr)

Example:
If a continuous flow of 600 gpm is desired and an inflow of 250 gpm occurs for 12 hours, then the storage volume needed in the sump will be:

$$S = 250 \times 12 \times 60 \times [\,1 - 250 / 600\,]$$
$$= 104{,}994\ gal$$

To convert this to cubic feet, divide the 104,994 gallons by 7.48. S = 14,037 cubic feet.

The continuous flow of 600 gpm would occur for a time of:

$$t = \frac{250 \text{ x } 12 \text{ x } 60}{60 \text{ x } 600}$$

$$= 5 \text{ hrs}$$

Thus sump and pumps can be selected for individual farm needs or desires.

Concrete sumps are most commonly used for subsurface drainage systems because they are easily equipped with automatic controls and require little space and minimum maintenance.

The sump capacity is based upon the inflow and pumping rate so that the pump cycle is sufficient to allow the pump to operate with an acceptable overall efficiency. A sump should be designed to allow about 10 cycles per hour in the pump system. If it exceeds 15 cycles per hour, pump efficiency and power costs may be undesirable.

The inflow rate, pumping rate, storage capacity, and cycle time for drainage outlets can be determined using the following formula.

$$[\,60 / N\,] = [\,S / I\,] + S / [\,P - I\,]$$

P = Pumping rate (gpm)
I = Inflow rate (gpm)
S = Storage volume (gal) between the on and off stage of the sump
N = Number of complete cycles per hour where the length of the complete cycle equals the standing time plus the running time

The following formula can be used to rearrange and convert storage from gallons to cubic feet:

$$N = \frac{7.48 \text{ x } I \text{ x } [\,P - I\,]}{P} \text{ x } S$$

This formula can also be used to compute the frequency of cycling for given values of S and P and for various rates of inflow.

Sufficient storage capacity needs to be provided in the sump or collection ditch to avoid excessive cycling of the pump in a system using automatic pump controls. Starting an idle pump requires extra energy and also increases maintenance. A reduction in the sump storage capacity can be attained by increasing the cycling frequency of the pump, but the savings may be offset by the increase in operational costs. Similarly, the selection of a pump having a capacity greatly in excess of that required for a given sump should be avoided. This creates a problem with the movement of water being held in more distant storage areas. Often this water is not moved fast enough to maintain continuous pump operation. The maximum S occurs when $I = (1/2)P$. For design purposes the amount of storage required in cubic feet is determined by the following equation:

$$S = [2P] / N$$

where:
N = the maximum or permissible number of cycles per hour
S = the storage in cubic feet

The sump depth between the on and off positions of the pump control and the cross-sectional area of the sump are chosen so that their product is equal to or greater than S. Generally, the S value is used as a minimum sump requirement.

If the number of cycles per hour is set at 5, the last formula may be further simplified as

$$S = 04P$$

The pumping rate P should be equal to or greater than the peak discharge rate from the drain system. For sump depth of more than 15 feet between on and off positions, consideration should be given to a horizontal type sump, which may be more economical

e) Economic justification of pumping plant

Frequently, a decision must be made as to whether areas protected against flooding by dikes and floodgates should be provided with a pumping plant to remove interior drainage during periods when the floodgates are closed. Such a decision cannot be made without a frequency study of precipitation and flood stage records, a determination of the project area that will be flooded without a pumping plant, and an estimate of the resulting damages. The study required for the justification of a pumping plant should be based on a comparison of its cost against the damages expected without it.

f) Pumping from subsurface aquifers

In drainage systems that require pumping from an underlying aquifer, location of the wells and pumps must be based on an extensive subsurface investigation. This investigation must determine the practicability of lowering the water table by pumping the aquifer and also determine the most suitable location for the wells to accomplish the objectives. The drainage water may be discharged either into an irrigation system or through shallow surface ditches to a drainage outlet. In either case, location of the well would be based primarily on requirements for pumping the aquifer instead of conditions for discharge of the effluent.

g) Basic information required for plant design

The amount of data required varies according to specific arrangements. As a general rule, data on the following items are needed:

Location of plant—detailed topography and data on foundation investigations may or may not be provided.

Pump capacity—design removal rate less available storage. The pump capacity can be determined from the drainage coefficient applied to the area served, or by direct hydrologic analysis. The capacity selected should be able to pump the amount of water necessary to provide adequate drainage against the total head anticipated.

Pumping plant capacity for a surface drainage system is usually determined on a daily-rate basis, so that the required capacity can be determined as the runoff from a 24-hour rainfall of a selected frequency of occurrence, plus base flow, less allowances for available surface and groundwater storage.

Pumping plants designed to pump only subsurface water should have a pump capacity equal to the maximum drainage system discharge, plus a 20 percent safety factor.

Pumping plants for both surface and subsurface water should have the capacity to remove from one-half inch to one inch of water in a 24-hour period from the drainage area, for areas of 100 acres or less. For high value crops, the pump capacity should be increased to one and a half to two inches of water per 24 hours.

Maximum, minimum, and average static heads—
based on stage-frequency analysis of the outlet.

The maximum static head is the elevation of the maximum stage in the outlet minus the optimum elevation in the suction bay. Efficiency at this head may be lower than that required at the average head.

The minimum static head is the difference between the mean monthly minimum stage in the outlet and the optimum stage in the suction bay. Where multiple pumping units are required, at least one unit should have a high efficiency at this head.

The average static head is the difference between the average monthly stage in the outlet and the optimum stage in the suction bay, weighted according to the amounts of runoff to be expected for the respective months. The plant should operate at peak efficiency for this stage.

Type, number, and size of pumps—For low heads of up to 15 to 20 feet, the axial flow pump is recommended. For heads of up to 40 to 50 feet, the mixed flow pump is recommended. For large installations, at least two pumps should be recommended with the relative size based on operational requirements. For average conditions, one of the two pumps should have about twice the capacity of the other. A 3-unit plant gives good flexibility of operation. Sizes recommended should be based on holding velocities in the discharge pipe at 8 to 10 feet per second for the design capacity.

Recommended start and stop elevation for each unit.

Schematic layout of the proposed plant-should include suggestions for layout and appurtenant facilities. Such items as the installation of discharge pipes over dikes, trash racks, siphon breakers, equipment for automatic control of operation, and access roads should be indicated.

Pumping plants that pump surface water should be provided with trash racks to screen out trash and debris. Strainers or screens mounted on the pump intake should be avoided as these tend to clog and are difficult to clean. The trash rack should be located across the entrance of the sump and inclined toward the structure in such a manner that flows move evenly through the rack, so floating trash and debris tend to move upward toward the water surface where it can be easily removed with rakes. Bar screens should be used in which the total clear space between bars is in the range of one to three inches. The total clear flow area of the rack should be sufficient to keep flow velocity through the rack under two feet per second.

h) Maintenance

Pumping plants have an estimated service life of 15 years. This can be achieved and prolonged through proper maintenance. Standardized operation and maintenance plans have been developed for pumping plants and can be found in the NRCS New Jersey electronic Field Office Technical Guide.