Some drainage enterprises and landowners have used oil burners to control vegetation by regular burning during the growing season. Usually the first burn will kill the green vegetation and stunt the growth. A second burning about 2 weeks later will get rid of the dry material left after the first burning. Fire must be used carefully, especially when crops and structures are nearby.

CHEMICALS, such as 2,4-D and 2,4,5-T, are widely used to control unwanted vegetation. Farmers who have not used them will do well to test them before undertaking extensive operations so as to estimate costs and the amounts required for effective control. Care should be taken in applying them lest the chemicals damage adjoining crops. Broadleaf crops and some truck crops are particularly susceptible to damage. Esters of 2,4-D can drift a half mile or more and kill cotton. Chemical companies have prepared informative bulletins about using their products.

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The Use of Pumps for Drainage

John G. Sutton

The use of pumps for drainage has made possible many large drainage projects, one of which is the Zuider Zee project, undertaken by the Government of the Netherlands.

For centuries the Dutch have been reclaiming lands from the sea and draining lakes by constructing dikes, pumping plants, and drainage systems. The new lands have added greatly to the agricultural production and general prosperity of the Netherlands.

Their first efforts to reclaim land began shortly after A. D. 1200. About 80,000 acres were reclaimed before A. D. 1300. Reclamation has continued steadily since then, despite setbacks when storms broke the dikes and caused great loss of life and property and when dikes were breached in war, causing flows that destroyed buildings and structures, filled ditches with sediment, and let ruinous salt water cover the land. The Dutch made repairs each time. They always rebuild their dikes.

In the 750 years that the Dutch have been at this work, they have reclaimed about 1,453,000 acres, of which the Zuider Zee project has contributed 168,000 acres.

The first projects depended on tide gates and gravity drainage. An important advance was the introduction about 400 years ago of windmills for pump drainage; in the 16th and 17th centuries they drained several hundred thousand acres. Some of the lands are more than 12 feet below sea level. During the past century the picturesque windmills have been replaced largely by steam and internal-combustion engines and electric motors, which drive the pumps.

THE UNITED STATES surpasses the Netherlands in area drained by pumps.

Many American projects embrace 3,000 to 20,000 acres. River bottoms, lake and coastal plains, peat land, and irrigated lands are the main types of land reclaimed by pump drainage. Interest in small pumping plants for draining individual farms has grown because of the increase in available electricity, tractors, and internal-combustion engines to drive pumps.

Drainage pumping plants that serve large acreages in the United States are located principally in Illinois, Iowa, Missouri, Louisiana, Florida, and California. In the 1950 census, 378 drainage enterprises reported the use of pumps, which served 1,696,586 acres. That does not include pumping plants in States listed as county-drain States, nor does it include data from irrigation enterprises that had installed their own drainage pumping plants.

The area served by pumps in 1950 in California was 694,023 acres; in Illinois, 315,363 acres; Florida, 293,124; Louisiana, 179,266; Missouri, 67,217. In Iowa, a county-drain State, 81,754 acres were served by pumps in 1940. Drainage pumping plants, which drain smaller acreages, have been installed by drainage enterprises in Indiana, Michigan, Wisconsin, Minnesota, Nebraska, Georgia, Arkansas, Texas, Arizona, Idaho, Oregon, and Washington.

The projects have reclaimed swamp and overflow land which otherwise would be of little value for farming. The fertility of the drained soil has justified the cost. Many of the lands are among the most fertile in the country. They are mostly flat and low and therefore are easy to irrigate.

Examples of benefits from pump drainage are typified by the drainage pumping districts in the upper Mississippi Valley. The higher land in the bottoms was farmed in the early days, but the farmers often lost crops because of flooding by the river. The landowners in 1900 or so began the intensive development of the area by building levees and pumping plants.

Many of the early attempts at drainage meant only failures. The breaching of levees during floods destroyed crops and damaged roads and buildings. When levees break, a lake several miles long may be formed. High and constant wave wash, because of the long distances over which the wind sweeps, often ruins a levee. Each time the levees broke they were built higher. The Federal and State Governments provided financial help for reconstructing the dikes after the bad flood of 1927.

Costly mistakes were made in installing the early pumping plants. Often too little attention was paid to getting efficient equipment. The pumps were not adapted to the head against which they would be required to operate. Sometimes no provisions were made for varying the speed of the pumps in accordance with lift requirements. Because many of the discharge pipes were not submerged, it was necessary to pump against the maximum lift to the top of the levee. Little attention was given to designing pumps along sound hydraulic principles. Plants frequently were neglected. Equipment was ruined by lack of oiling and repair work. Many operators failed to adjust the speed of pumps, even when they could. Many pumps were operated at capacity so the operator could finish his work quickly, regardless of wear on equipment or cost of operation.

After costly experience, principles of efficient design and operation were developed.

Many of the drainage districts were just getting well underway when the agricultural depressions of the 1920's and 1930's occurred. Drainage taxes were high, and many could not meet payments on their bonded indebtedness. Many were refinanced by the Reconstruction Finance Corporation, the bondholders accepting reduced payments.

Very likely the bondholders and original landowners would have come out all right financially had they been able to hold on to their investments during the depression. Much of the land is now valued at several hundred dollars an acre. It can produce up to 125 bushels of corn an acre.

The total drainage costs in the upper Mississippi Valley, including levees, drains, and pumping plants, originally averaged 40 to 100 dollars an acre. Prewar cost of pumping was 1 to 3 dollars an acre, including interest, depreciation, and operating expenses. Costs in 1955 would be double that, or more.

In planning effective pump drainage, it is highly important to select pumps, motors, or engines and construct the pumping plant so that it will have adequate capacity at the maximum lift. Crop losses may be large during periods of heavy rainfall if the pumping plant is too small. Many of the original pumping plants were too small.

Descriptions of present equipment in use in drainage enterprises and recommendations for required capacity are given in the following paragraphs for the principal pumping locations. Many drainage pumps are required in other areas, but pumping capacities may be determined by comparison with one of the areas described.

THE BOTTOM LANDS along the upper Mississippi and Illinois Rivers include 450,000 acres served by drainage pumps in Illinois, Iowa, and Missouri. The lands lie along the Illinois River south of Hennepin, Ill., and along the upper Mississippi River between Savanna, Ill., and St. Louis, Mo.

About 70 pumping districts, which range from 1,500 to 20,000 acres, are in the area. Most of them extend 5 to 10 miles along the river and cover the bottom lands, which are ordinarily 2 to 4 miles wide from the bank of the river to the bluffs. Levees were built to protect the districts from overflow from the rivers. Diversion channels divert hill water from the bottom land. Open ditches and tile collect the drainage water and conduct it to the lower ends of the districts. There the pumping plants lift the water over the levees into the rivers. Many of the drainage districts used to have gravity drainage through sluiceways. The building of dams for navigation, however, has largely ended the use of sluiceways, and the runoff water must be pumped.

The 1950 census of drainage listed 47 enterprises in Illinois. Their pumping plants had a rated plant capacity of 21,020 horsepower and served 315,363 acres. The pumps had an average rated capacity of 10.6 gallons a minute per acre.

The power for 23 drainage enterprises was supplied by 9,800 horsepower of internal-combustion engines. Diesel-type engines comprised most of the power units. Power for 16 enterprises was supplied by electric motors with a total rated capacity of 5,122 horsepower. There were 76 centrifugal pumps with an average capacity of 28,200 gallons a minute each. They were used so widely because of the high lift—15 to 25 feet—against which the pumps operate. Eleven mixed-flow pumps had an average capacity of 40,000 gallons a minute. Ten axial-flow, or propeller, pumps had an average capacity of 18,100 gallons.

In 17 plants in the upper Mississippi Valley in Illinois, Iowa, and Missouri, large pumping plants provided adequate drainage when the capacity ranged from 0.33 to 0.55 inch in depth from the watershed in 24 hours. That equals an approximate range of 6 to 10 gallons a minute per acre of drainage capacity. One inch of runoff for 24 hours is equivalent of 18.86 gallons a minute per acre. The capacities were adequate for drainage pumping from tracts of about 3,000 to 20,000 acres. The districts were along the Illinois River below Peoria and along the upper Mississippi Valley between Alton, Ill., and Burlington, Iowa. Variations in capacity in those areas were related to the amount of seepage. A formula for determining the runoff was developed.

For areas smaller than 3,000 acres in the upper Mississippi Valley, the required pump capacities are determined by estimating the required capacity of open ditches to obtain adequate drainage, adding the estimated seepage, and deducting storage.

THE PUMPING ENTERPRISES of Louisiana are located in the Mississippi delta and coastal areas. Dikes and the pumping lifts are lower than in the upper Mississippi Valley. The land served by pumps in Louisiana increased 46 percent between 1940 and 1950. Thirty drainage pumping enterprises in Louisiana in 1950 had 15,041-horsepower rated capacity and 4,282,000 gallons a minute pump capacity. The plants served 179,266 acres—equivalent to 23.9 gallons a minute per acre, or a depth of 1.27 inches in 24 hours from the land drained. Design standards of the Department of Agriculture provide for a higher plant capacity. There were 37 centrifugal, 32 axial-flow, 1 mixed-flow, and 32 unclassified pumps. Because the lifts are lower, axial-flow pumps are used more extensively than in the upper Mississippi Valley. Power to operate the pumps was supplied chiefly by internal-combustion engines, but some electric and steam power units were in use.

The required plant capacities for Louisiana and Texas are considerably higher than required in the upper Mississippi Valley.

A run-off capacity of 3 inches in 24 hours, including pumping capacity and the storage capacity, is recommended along the gulf coast—on flat tracts smaller than 3,000 acres. Storage is computed as storage available in areas below the elevation of the lowest cultivated land and normal water level. The small ditch storage can be disregarded. If a reservoir storage in a pumping district is 1 inch per 24 hours, the pumping plant should be designed for not less than 2 inches per 24 hours. The combined capacity figure of 3 inches per 24 hours applies to land used mainly for growing sugarcane. A greater capacity is usually advisable for special or truck crops or if property requires better protection. The recommended combined pumping and reservoir capacities may be 2 inches per 24 hours if the main crop is rice or pasture. These rates apply to the area along the gulf coast of Louisiana and Texas south of a line from Natchez, Miss., to Natchitoches, La., then roughly parallel to the gulf coast to Victoria, Tex.

North of that line and in Arkansas, the total pumping capacity and storage capacities may be reduced by 20 percent to 2.4 inches per 24 hours for land used principally for cotton and to 1.6 inches per 24 hours for rice or pastureland.

Many of the successful districts started out with smaller capacity but have increased them.

IN FLORIDA, most of the land served by pumps is in the Lake Okeechobee-Everglades area of southern Florida, which is nearly all peat lands. The average fall of the large outlet canals is approximately 0.2 foot a mile. About 60 percent of the annual rainfall of 55 inches occurs from June through September, when farming activities are slow and pumping can be greatly reduced on truck lands.

Many of the pumps can pump to or from the land served, and thus keep the water tables at a fairly uniform depth. The term "water control" is commonly used to include either raising or lowering the water table as conditions may require. Most pumping, however, is required for drainage. Pumping onto the land usually is done in February or March when the rainfall is light and spring crops are planted.

Nearly all the pumps are of the axial-flow or propeller type. Some are large screw pumps; the smaller propeller pumps commonly pump 10,000 to 30,000 gallons a minute. The maximum pumping lifts are 5 to 9 feet; the average lifts are 4 to 5 feet. Very little or no pumping is needed for drainage when the rainfall is light and Lake Okeechobee is at a low level.

The land served by pumps in Florida increased from 185,693 acres in 1940 to 293,124 acres in 1950. The reported pump capacities average 28.6 gallons a minute per acre, or a depth of 1.53 inches in 24 hours. The average pump capacity in 1940 was 18.2 gallons a minute per acre, or a depth of 0.96 inch in 24 hours.

The 99 enterprises in Florida in 1950 had 28,129-horsepower engine capacity. Nearly all the pumping enterprises were driven by diesel-type engines. Of the 354 pumps listed in 1950, there are 341 axial-flow or propeller pumps and 5 mixed-flow pumps.

For open-ditch drainage of the Florida Everglades the engineering board of review developed and recommended the following formula:

$$Q=\frac{69.1}{M}+9.6$$

in which Q is runoff in cubic feet a second per square mile of drainage area, and M is drainage area in square miles.

This formula has been used by L. A. Jones, of the Department of Agriculture, in preparing plans for water control of organic soils of the region. The formula provides 1-inch runoff depth per 24 hours from 16 square miles, 0.75 inch from 43 square miles, and 0.5 inch from 322 square miles. The formula assumes that the land will be overflowed for short periods after heavy rainfall. It is not intended to provide complete protection from flooding.

Many of the northern Everglades pumping districts serve 5 to 13 sections of land, on much of which sugarcane is grown. Most of the pumping plants were designed to remove 1-inch runoff per 24 hours. The 1-inch rate is generally ample for growing sugarcane on the organic soils of the area—even for areas smaller than the formula indicates.

Truck crops have suffered losses, however, when the capacity was only 1 inch per 24 hours. The following rates are recommended by B. S. Clayton, of the Department of Agriculture, for land used for truck crops in organic soils: 3.0 inches for 1 section of land or less, 2.0 inches for 2 to 3 sections of land, 1.4 inches for 4 to 9 sections, and 1.0 inch for 10 to 16 sections. Those rates are approximately those given by the runoff formula quoted earlier. A long pumping record at the Everglades experiment station at Belle Glade, Fla., indicated that a runoff of 3 inches per 24 hours was needed to protect crops on areas of 1 square mile or less.

Many pumping plants have been installed to serve pastureland. The plants usually drain 2 to 4 sections of land. A runoff of 1 to 2 inches, commonly provided for these grazing areas, has seemed adequate.

IN CALIFORNIA, low-lift drainage pumps drain river bottoms, and high-lift pumps in drainage wells drain irrigated land. Typical of low-lift drainage pumping is the reclamation of delta lands along the San Joaquin River, where large acreages of organic and mineral soil have been reclaimed by diking and pumping.

Pumping lifts vary considerably with the maximum lift, often 10 to 20 feet. In many of the pumping districts, water is admitted through pipes in the levees for irrigation. Seepage and excess irrigation water affect the amounts of water that must be pumped. In 1940 in California, 135 drainage and irrigation enterprises operated drainage pumps, which served 1,220,062 acres and had a total capacity of 5,727,787 gallons a minute. Nearly all were operated by electric power.

Low-lift pumping is done chiefly by means of propeller and centrifugal pumps. The 68 propeller-type pumps served 122,947 acres and had an average capacity of 5.5 gallons a minute per acre. The 168 centrifugal pumps served 456,688 acres and had an average capacity of 6.7 gallons a minute.

California also had many deep-well drainage pumps for irrigated land. These are classified as turbine pumps; 334 such pumps served 377,760 acres in 1940. The average capacity reported was 1.1 gallons a minute per acre.

Many deep-well turbine pumps have a low capacity per acre, but the average capacity reported was unusually low. Many drainage wells pump 2 to 4 gallons a minute per acre.

Investigations are needed to determine the feasibility of draining irrigated lands by pumping. Usually it is cheaper to drain by ditches or tile if permeable layers of soil are within 8 to 12 feet of the surface.

Pump drainage of irrigated lands may be feasible if water-bearing gravel or sand layers are encountered at depths from 20 to 100 feet and surface drains are not effective. Pumping tests usually are needed to determine the yield of water and the drawdown from wells. If results are favorable, pump designs are based on results from the test well. Most deep-well turbine pumps used for drainage have a capacity of 300 to 1,500 gallons a minute and serve 100 to 640 acres.

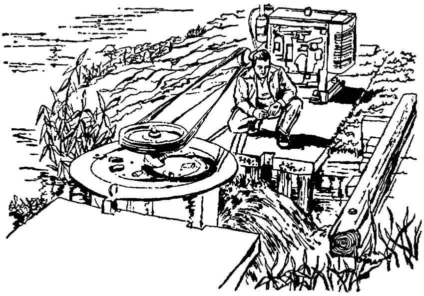
If water is used for irrigation, much of the cost of pumping may be allocated to irrigation. Irrigation enterprises often install dual-purpose pumps to lower a high water table and obtain additional water for irrigation.

Good operating efficiency of plants is obtained by selecting pumps based on the amount of pumping to be done. If a plant operates a large part of the time, it is well to choose more efficient pumps at added initial cost. If a high capacity is required but the total annual amounts of pumping will be small, it may be more economical to obtain less expensive pumps with high capacity but lower operating efficiency. Small farm pumping units that operate only a small part of the time may be quite simple.

Types of pumps used for drainage include propeller or axial-flow, mixed-flow pumps, centrifugal pumps, and turbine pumps.

The axial-flow, screw, or propeller pump, is especially adapted for low-head drainage pumping. The impeller has several blades, like those of a ship propeller. Blades are set on the shaft at angles determined according to the head and speed. The direction of flow through the pump does not change, as in a centrifugal pump. A spiral motion of the water results from the screw action but may be corrected by diffusion vanes. The type has been used extensively where the maximum static lift is less than 10 feet. One disadvantage is that the discharge falls rapidly at heads above that for which the pump is designed. The horsepower required tends to rise at higher heads, so adequate power must be provided to drive the pump at the maximum lift. The maximum static lift and the maximum total head against which this type of pump will operate should be determined accurately.

This type of pump can be built so the flow can be reversed if pumping is needed for both irrigation and drainage—an advantage, especially if control of the water table is important.



A cheap propeller-type pump has been made with a propeller like a boat propeller inside a casing, a straight piece of welded steel pipe. Many have been installed by farmers for draining tracts smaller than 200 acres. Little is known about the efficiency of such pumps. A few have been built with such light outside casings that blocks of wood passing the screen have broken through the casing.

The mixed-flow pump has an open vane, curved-blade impeller, which combines the screw and centrifugal principles in building up the pressure head. It operates efficiently against higher heads than the propeller pump. With one change in speed, a typical mixed-flow pump operated in tests at 70 to 80 percent efficiency at all heads from 6.5 to 26 feet. The discharge did not go down very much at the higher heads. An open-type impeller lets trash pass through quite easily.

The double-suction volute centrifugal pump was used widely in early drainage plants. The Francis-type impeller, with curved vanes, is particularly efficient for lifts of 15 to 25 feet. Centrifugal pumps have a long life and are dependable. Usually they have a greater capacity than the same size screw or mixed-flow pumps, especially against the higher heads.

The deep-well turbine pump is used in irrigation. Most wells are 30 to 100 feet deep. This pump has three parts, the head, the pump bowl, and the discharge column. A shaft from the head to the pump bowl drives the impeller. It has a screen to keep coarse sand and gravel from entering the pump. The impeller is set near the bottom of the well. It forces water up through the discharge column to the surface. Most pumps of this type range in capacity from 300 to 1,500 gallons a minute.

SPEED ADJUSTMENT should be obtained for pumps that operate under variable lifts to obtain highest efficiency. Drainage pumps should be slowed down when operating against lower heads. Most small electric installations do not justify speed adjustments because the first cost of the necessary equipment is high. For pumps used a great deal, however, a speed adjustment is desirable for efficient operation at lower lifts. Sometimes two electric motors are set on the same shaft and operate at different speeds to provide speed regulation. Belt-connected units may have pulleys of different sizes for pump and motor to adjust the speed. Internal-combustion engines may be slowed down at low lifts and provide satisfactory speed regulations.

Direct-connected pumping units have an advantage over belt-connected units because the power losses due to transmission of the power are eliminated. The direct-connected unit is more compact. Transmission equipment is required if the engine or motor and the pump operate at different normal speeds. V-shaped belts and leather belts are the usual types. Chain and gear drives are sometimes installed. Proper alinement of the pump and engine is important. Properly adjusted belts have an efficiency of 95 to 98 percent if the alinement is correct.

In the larger drainage plants, it is wise to have two or more pumps for protection if a breakdown or emergency occurs. A variable rate of pumping is highly desirable in large plants, particularly when the runoff is low. A desirable range of pumping rates is obtained by having one pump half the capacity of the other unit. In large plants that drain several thousand acres, three units of equal size provide a desirable range.

The size of the pump may be computed in a preliminary way on the basis that the water will discharge at the rate of 8 to 10 feet a second through the pump discharge. Then the maximum daily runoff to be pumped needs to be determined. A considerable difference exists in the capacity of plants for the different localities. The required size is determined best by observing the conditions under which pumps are operating satisfactorily and furnishing the desired drainage.

The static lift is the difference of elevation between the water in the suction bay and the water in the discharge bay if the discharge pipe is submerged. If the discharge pipe is not submerged, the static lift is the difference in elevation between the center line of the water in the discharge pipe at the high point of discharge and the elevation of water in the suction bay.

The total head on the pump is the equivalent in feet of water of the total pressure the pump is acting against. It is equal to the static lift plus friction and other losses in the piping system.

Such losses include the entrance loss where the water enters the suction pipe, the friction losses through the suction and discharge pipes, losses due to trash or obstructions in the pipes, losses caused by air entering the discharge pipe where it is under vacuum, and the loss of velocity head at the end of the discharge pipe.

In planning pumping plants to operate efficiently and in estimating costs, it is especially important to determine the maximum, minimum, and average static lifts for the pumps. The pump manufacturer will need that information in order to supply efficient equipment. The static lifts will control the selection of the type of pump. The axial-flow, or propeller, pump is adapted for total heads ordinarily less than 10 feet. Mixed-flow pumps can operate efficiently at heads from 6 to 26 feet. Centrifugal pumps may be designed for efficient pumping against total heads exceeding 12 feet.

The range in lifts that will be encountered is of primary importance in determining the maximum size of the motor or engine. The maximum horsepower required to drive a pump varies according to the pumping lift. The horsepower for the centrifugal pump is generally at a peak at a lower lift and tends to fall off at higher lifts. For a propeller pump, on the other hand, the brake horsepower required tends to increase as the lift increases. A survey to determine the required lifts under the whole range of pumping conditions is essential in order to plan efficient pumping equipment.

CHARACTERISTIC CURVES are the usual means of showing pump performance. Such curves generally show discharge expressed in gallons per minute (g. p. m.) plotted against total head (feet); brake horsepower (b. hp.), plotted against discharge; and pump efficiency (in percentage), plotted against discharge. The three curves are shown for each speed if the pump operates at more than one speed.

The discharge of drainage pumps declines as the total head increases if the speed is constant. The discharge increases as the speed increases if the total head is constant. Impellers are designed to obtain maximum efficiency at a specified head and speed. The efficiency drops off at both higher and lower heads than specified if the speed is held constant. The brake horsepower required to drive the pump depends upon the design and efficiency of the pump.

Drainage pumps usually may be furnished with the maximum efficiency at somewhat more than 80 percent. A well-designed pump should have an efficiency above 70 percent over a wide range of operating lifts. Pump installations sometimes are supplied by a manufacturer according to the purchaser's specifications as to the requirements at maximum and other operating lifts. The manufacturer generally supplies a set of characteristic curves. Most manufacturers base such curves on factory tests of the pump or on the tests of a similar pump.

Pump efficiency is computed by this formula:

$$e = \frac{\text{g. p. m.} \times H_t}{\text{b. hp.} \times 3960 \times e_t}$$

In the equation: e is pump efficiency, g. p. m. is gallons per minute, H_t is total head on pump (feet), b. hp. is brake horsepower (output of motor or engine), and e_t is transmission efficiency of belt or gear connecting engine or motor and pump (ratio, i. e., 97 percent equals 0.97).

For units in which the pump is connected directly to the motor or engine, e_t is 100 percent, and b. hp. equals the horsepower input into pump shaft. For belt-connected units, e_t varies from 95 to 98 percent, and only a small loss of power results.

DISCHARGE PIPES in most large drainage pumping installations should go over the levee near the high water level. If the pump is not submerged, the end of the discharge pipe should be below the low water stage of the discharge bay so that the pump may be primed easily. This arrangement of the discharge pipe permits a siphon action in the discharge pipe, which reduces the total head on the pump. The siphon action has the effect of reducing the power used for pumping. It is important to obtain full benefit from the siphon action if a pump operates a high percentage of time. If the discharge pipe is submerged, it is desirable to install an automatic flap gate on the end of the pipe to prevent backflow through the pump when it stops.

An alternate arrangement is to have the discharge pipe above high water in the discharge bay. Such an arrangement is less efficient, but it is ordinarily used in small plants in combination with a submerged pump. The need for priming equipment thus is avoided, and it is a safe and practical arrangement for automatic operation; no backflow occurs through the pipe when the pump stops.

The friction losses in the suction pipe should be reduced by expanding the pipe so that the entrance area of the pipe will be 2 to 4 times the area of the pump flange. A rounded entrance of the suction pipe is recommended. The expansion of the suction permits the suction bay to be pumped low without causing the pump to lose its prime.

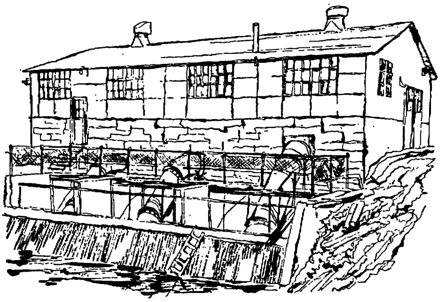
The discharge pipes of larger pumps usually should be 2 to 6 inches larger than the pump flange. The transition should be made by a short expanding section. Expanding a submerged discharge pipe at the end will improve the plant efficiency at small cost.

The friction loss measured in tests of suction and discharge pipes was 1.9 to 4.3 feet, based on 10 feet per second per velocity at the pump flange. The friction loss is a substantial proportion of the average static lift of pumping plants.

THE LOCATION of the pumping plant depends largely on the topography of the area and the location of the outlet in which the pump is to discharge. If several locations are possible, foundation conditions, construction of drainage ditches, and nearness of roads, living quarters, and powerlines may determine the site.

A site should be selected where stable foundation material— as shown by soil borings—is located. The foundation soil should be good because of the vibration set up by large pumping plants. A good foundation is a safety factor during flood conditions. Some large pumping plants have been destroyed by levee breaks because of quicksand or other unstable material near the plants.

The buildings for the pumping vary according to the type of installation, size, type of power, soils and foundation conditions, and the owners' desires. Many drainage districts have attractive, fireproof buildings of masonry and steel, resting on piling. Some landowners have set pumping units on skids on the ditchbank with little or no housing. Because of the large volume of water that passes through drainage pumping plants at high velocity, a substantial foundation and well designed suction bay are necessary to prevent undermining of large plants. The smaller the plant, the greater is the choice in such construction, because erosive forces are less. A small, substantial, fire-resistant building is a good investment even for farm pumping plants—it protects equipment and keeps children and trespassers away from the pumps.



In most mineral and organic soils, piles are recommended for large installations. If the foundation is in clay or other stable material, spread footings may be used for small units and the construction costs will be considerably less than if piles are used.

The piling should support the walls

of the suction bay, wing walls, foundations of engines and motors, and building walls.

The suction bay is often used as the foundation for the pump or the pump and motor. It often consists of a rectangular pit enclosed on three sides by concrete walls. The pump may rest on a steel beam with a vertical suction pipe extending down in the suction bay the necessary distance below low water. This arrangement is satisfactory for vertical-type submerged pumps and for pumps which are set above water and require priming. Another arrangement is to set the pump at the side of the suction bay. Ordinarily the suction pipe enters the pump horizontally and curves downward into the suction bay. Electric motors may be set with the pump on the beams spanning the bay. Diesel engines should rest on a substantial foundation, which adjoins the suction bay.

The pump or suction pipe should be submerged an adequate depth in order for the pump to operate efficiently. In the preliminary plans, a submergence of 3 feet below normal low water pumping level may be assumed for sea-level pumping. If the pump is at 1,000 feet above sea level, the minimum submergence should be increased to 4 feet. Those figures should be modified on the manufacturer's advice, based on requirements of the pump.

The minimum clearance between the pump and side walls or suction pipe and side walls may be computed as 1.5 times the pump size. For example, a 10-inch pump requires a minimum of 15-inch clearance from the side walls, but here, too, the manufacturer's recommendations should be followed. The minimum clearance between the suction edge of the pump and the floor of the intake bay may be designed equal to the pump size if the manufacturer's recommendations do not specify otherwise. For example, a 10-inch pump requires a 10-inch clearance between the bottom of the pump or suction pipe and the floor of the suction bay.

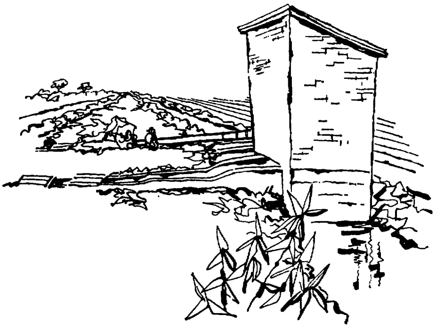
Water storage at the suction bay is advantageous. The suction bay should be controlled within small limits to provide a more constant operating condition. If the storage available at the suction bay is quite small, the pumping plant will draw the water down rapidly under ordinary conditions and pumps will take air and operate less efficiently. The pumping lift would be increased, and frequent starting and stopping of the pumps will be required. A large storage at the suction bay will frequently make it possible to eliminate night operations and may result in lower labor costs.

A special consideration may also be off-peak pumping rates, which lower costs if pumping is done at slack hours. A large storage helps users to take advantage of them. If large areas are to be drained, it is often desirable to leave a few low sloughs undrained in order to provide storage. Usually it is wise to excavate the main ditch leading to the pumping plant deeper and wider than necessary to provide the storage.

Automatic operation is feasible if electric power is used—particularly in the operation of small plants to save expenses. A float starts the motor when the water in the suction bay rises to a predetermined elevation. The pump then starts and gradually lowers the water and float. The water is pumped down to a level; the float trips a switch and cuts off the motor. Another way is to use an upper and lower electrode, which activate switches that start and stop the pump.

If the suction bay is likely to freeze, special precautions are needed. A vertical pipe filled with oil in which the float operates may be connected so as to reflect the stage of the suction bay. The float may operate in oil in below-freezing weather. Usually in very cold weather not much pumping is required, and manual operation of a plant is satisfactory with the float or electrode removed from the water.

Pumping tests should be obtained if the purchaser buys equipment on the basis of guaranteed efficiency. Most manufacturers can test pumps at the factory before shipment. Field tests are costly but may measure efficiency of the completed plant, including the effectiveness of pipes and the pump.



Well-planned farm drainage pumping plant with pump discharging into concrete chute.

PUMPING PLANTS on small farms usually are installed with first cost as a main consideration. Inexpensive foundations and a minimum of equipment are installed.

In many places farmers can drain fields economically by pumping. The outlet ditches in many drainage enterprises are not deep enough to provide adequate drainage for low fields; it often is more economical to install small pumping units to drain the low areas than to construct deeper outlet ditches. Another example is the low land near the Great Lakes. High lake levels often impair outlets and crop losses result from poor drainage, and low dikes and small pumping plants have given many farmers good drainage.

Such pumping plants usually are simple and not overly expensive. Most of them cost less than 5 dollars an acre a year to operate, including interest and depreciation. The volume of water they handle is small, and large erosive forces are not set up in the suction and discharge bay, as with the large plant. Small pumps often are set on a sloping bank or suspended from beams across a ditch and have no permanent foundation and wood housing. Tractors may be used to drive them.

Farm pumping plants consisting of one vertical submerged pump with a free discharge are used extensively. They do not require priming equipment and can operate automatically if electric power is available. Many powerlines can handle motors up to 7.5 horsepower. That limits low-lift pumps to about 2,000 gallons a minute.

The capacity of farm pumping plants may be computed as follows: Required pump capacity equals required capacity of open ditch plus seepage minus storage.

The required capacity of open ditches is given by curves showing drainage coefficients for various crops and land areas, and may be obtained from the soil conservation district. Seepage may be an important factor if open ditches touch sand or gravel layer near lakes or rivers. Under such conditions seepage may be 0.1 to 0.5 inch each 24 hours over the entire watershed area. Seepage generally may be disregarded if the ditches are in clay or silt soils. Storage is the capacity of the suction bay, sloughs, ponds, and ditches to store water between normal water level and high water level. It is assumed that this storage will be effective in a 24-hour period.

Most drainage plants in the upper Mississippi Valley draining agricultural land are used for field crops and plants draining fewer than 3,000 acres have been designed from 0.75 to 1.5 inches runoff. In places where truck crops or high-value crops or property are to be protected, a higher capacity—even up to 4 inches from the watershed in 24 hours—should be provided. Greater capacities are required for small areas in Louisiana and Florida.

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