Chapter 4
Construction Drainage

4.1 Summary

In the process called open pumping, water can be allowed to flow into the excavation as it is advanced. The water is collected in ditches and sumps and pumped away. Open pumping from sumps and ditches is usually the least expensive method from the standpoint of direct dewatering cost. Under favorable conditions, it is a satisfactory procedure. But if conditions are not conducive, attempts to handle the water by open pumping can result in delays, cost overruns, and occasionally catastrophic failure. The key is to identify those conditions that are or are not favorable for open pumping, and to recognize which conditions predominate in a given job situation. Generally, the main sump is placed in the middle of the excavation, with the result that the entire subgrade was turned into a quagmire because the water had to travel across subgrade to enter the sump. The condition is exacerbated by the presence of stratified or fine-grained soils at or near excavation subgrade that inhibit vertical drainage. This method suits in dense sands, coarse sands, graded sands, hard fissured rock and clay with surface runoff drainage. But in loose sand, soft soil or rock, problems of slope stability and boiling of the bottom must be anticipated. Tables 4.1 and 4.2 tabulate the conditions that, in authors' experience, may affect whether open pumping is viable on a given project.

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Table 4.1 Conditions favorable to open pumping

Condition	Explanation
Soil characteristics	
Dense, well-graded granular soils, especially those with some degree of cementation or cohesive binder	Such soils are low in hydraulic conductivity and seepage is likely to be how to moderate in volume. Slopes can bleed reasonable quantities of water without becoming unstable. Lateral seepage and boils in the bottom of an excavation will often clear in a short time, avoiding the transport of excessive fines from soils so that foundation properties are not impaired
Stiff clay with no more than a few lenses of sand, which are not connected to a significant water source	Only small quantities of water can be expected from the sand lenses, and it should diminish quickly to a negligible value. No water is expected from the clay
Hard fissured rock	If the rock is hard, even moderate-to-large quantities of water can be controlled by open pumping. As in typical quarry operations (for soft rock and rock with blocked fissures, see Table 4.2)
Hydraulic characteristics	
Low to moderate dewatering head	These characteristics indicate that groundwater seepage will be low, minimizing problems with slope stability and subgrade deterioration, and facilitating the construction and maintenance of sumps and ditches
Remote source of recharge	
Low to moderate hydraulic conductivity	
Minor storage depletion	
Excavation methods	
Dragline, clamshell, and backhoe (if operated from ground surface or elevated bench above excavation subgrade)	These methods do not depend on traction within the excavation, and the unavoidable temporarily wet condition due to open pumping does not hamper progress
Excavation support	
Relatively flat slopes	Flat slopes, appropriate to the soils involved, can support moderate seepage without becoming unstable
Steel sheeting, slurry diaphragm walls or other cutoff structures	These methods cut off lateral flow, and assuming there are no problems at the subgrade, open pumping is satisfactory
Miscellaneous	
Open, unobstructed site	If there are no existing structures nearby, so that minor slides are only a nuisance, some degree of risk can be taken
Large excavation	In a large excavation the time necessary to move the earth is sometimes such that the slow process of lowing water with sumps and ditches does not seriously affect the schedule

(continued)

Table 4.1 (continued)

Condition	Explanation
Light foundation loads	When the structure being built puts little or no load on the foundation soils (for example, a sewage pump station) slight disturbance of the subsoil may not be harmful

Table 4.2 Conditions unfavorable to open pumping (predrainage or cutoff usually advisable)

Condition	Explanation
Soil characteristics	
Loose, uniform granular soils without plastic fines	Suck soils have moderate-to-high hydraulic conductivity and are very sensitive to seepage pressure. Slope instability and loss of strength at subgrade are likely when open pumping
Cohesive less silts, and soft clays or cohesive silts with moisture contents near or above the liquid limit	Such soils are inherently unstable. And slight seepage pressures in permeable lenses can trigger massive slides
Soft rock; rock with large fissures filled with granular soft soils, erodible materials or soluble precipitates, sandstone with uncemented sand layers	If substantial quantities of water are open pumped, soft rock may erode. Soft materials in the fissures of hard rock may be leached out. Uncemented sand layers can wash away. The quantity of water may progressively increase, and massive blocks of rock may shift
Hydrology characteristics	
Moderate to high dewatering head	These characteristics indicate the potential for high water quantities. Even well-graded gravels can become quick if the seepage gradient is high enough. Problems with construction and maintenance of ditches and sumps are aggravated
Proximate source of recharge	
Moderate to high hydraulic conductivity	
Large quantities of storage water	If the aquifer to be dewatered is high in hydraulic conductivity and porosity, large quantities of water from aquifer storage must be expected during the early phase of lowering the water table. This higher flow can greatly aggravate problems with open pumping. With predrainage, pumping can be started some weeks or months before excavation, the pumping rate will decrease and the problem can be mitigated
Artesian pressure below subgrade	Open pumping cannot cope with pressure from below subgrade since, if water reaches the excavation, damage from heave or piping has already occurred. Predrainage with relief well is advisable

(continued)

Table 4.2 (continued)

Condition	Explanation
Excavation methods	
Scrapers, loaders and trucks	These methods require good traction for efficient operation. Unavoidable temporarily wet conditions due to open pumping can seriously hamper progress. If horizontal drains and sumps can be prepared well in advance with drainage or backhoe, mass excavation with scrapers may be feasible
Excavation support	
Steep slopes	Steep slopes are sensitive to erosion and sloughing from seepage, and can also suffer rotary slides unless the water table is lowered sufficiently in advance of excavation
Soldier beams and lagging	Excavating a vertical face to place lagging boards is costly and sometimes dangerous under lateral flow conditions
Miscellaneous	
Adjacent structures	When existing structures would be endangered by slides or loss of fines from the slopes, open pumping cannot be tolerated
Small excavation	In small excavation, delays due to open pumping can seriously delay the work
Heavy foundation loads	When the structure being built bears heavily on the subsoils, even minor disturbance must be avoided
Excavating to clay or rock subgrade	Conditions will improve with extended pumping time. Extra pumping time is usually not available when open pumping

4.2 Open Pumping Methods

4.2.1 Open Ditches and Sump Pumps

4.2.1.1 Stage Excavation Drainage

Shown as Fig. 4.1, the final sump must be deep enough so that when it is pumped out the entire excavation will be drained. This is an obvious point but surprisingly it is often violated. Digging the sump down that extra several feet, or meters, is difficult and sometimes risky; there is a tendency to give up too soon. If necessary, a temporary sump at a shallower level should be constructed and pumped long enough to improve conditions so that the final sump can be safely constructed to the proper depth. Generally, the ditches are stratified dug at one/two sides or in the middle of foundation pit. And the sumps are placed at each 20.00–30.00 m distance

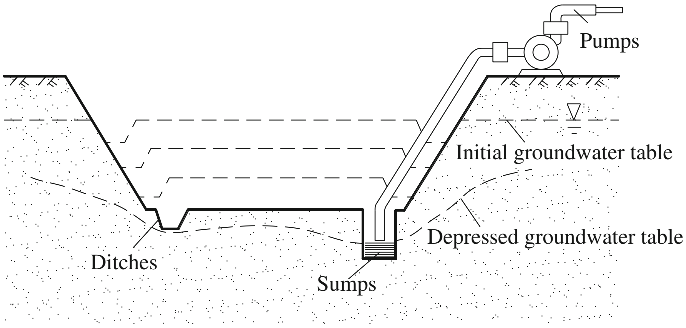


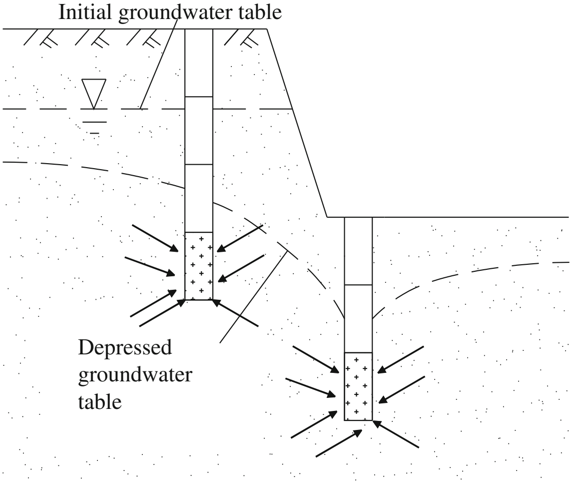
Fig. 4.1 Stage excavation drainage

for the water to be collected and pumped out. The depth of ditches and sumps can be deepened as the excavation advances. The bottom of ditches should be always kept 0.30–0.60 m lower than the pit bottom elevation. Usually in small excavations, depth of ditches can be 0.30–0.6 m with the width of 0.40 m and slope ratio of 1:1–1:1.5. And small slope of 0.2–0.5 % can be set in the ditches bottom for the drainage. The sectional area of sumps should be 0.60 × 0.60–0.80 × 0.80 m. And the bottom elevation should be kept 0.40–1.00 m lower than the ditches. The sump walls can be reinforced by bamboo cages and wood plates. The pumping should be continuously conducted until the backfill is completed.

4.2.1.2 Double Well-Point Drainage

Shown as in Fig. 4.2, the cement concrete pipes with diameter around 80–100 cm are driven into the earth section by section. The water table outside or in the bottom of foundation pit is lowered by a centrifugal pump. Usually, single well is sufficient for construction requirement. Double system is just for the very deep drawdown.

Fig. 4.2 Double well-point drainage



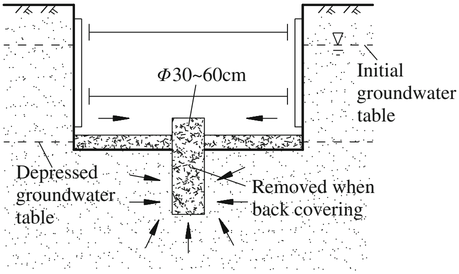


Fig. 4.3 Main central sump pumps

The last section of the well is the filter, which is drilled as quincunx holes in 15–20 cm space for better inflowing of water. The diameter of the quincunx hole is set large out and small in, which is filled by sackcloth. Sand filter material is employed in the filter to block the soil particle flowing through with water.

4.2.1.3 Main Central Sump Pumps

Shown as Fig. 4.3, in the condition that there are no sheet piles surrounding, or slope excavation and no drilled-in supporting, could not meet the construction requirement; some failures would happen, such as slope collapse. Thus, a main seepage well is established for the sump-pump system in the center of foundation pit. This system can be set during the whole construction period. Until the foundation is completed, it is sealed to prevent water seepage.

4.2.1.4 Range of Application

The above three methods are generally applicable for the water drainage in the common foundation, medium area group foundations, or building foundation pit. Easily constructed, simple equipments, low costs, they are mostly used.

4.2.2 Multilayer Open Pumping from Ditches and Sumps

4.2.2.1 Method

Shown as Fig. 4.4, along the slope of foundation pit, 2–3 ditches and sumps system is set to collect the groundwater and to block the water out of excavation area. The distribution and specific sizes of ditches and sumps are almost the same with those in the above common ditches and sumps. It should be paid attentions that to prevent the water in the upper ditches flowing down to the lower ditches. If so it is probable that the slope of foundation pit may collapse by the water seepage.

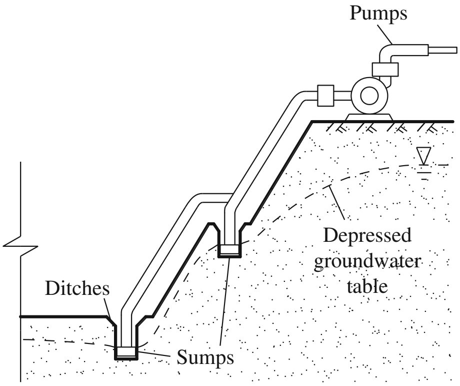


Fig. 4.4 Multilayer open pumping from ditches and sumps

4.2.2.2 Range for Application

This method is used in the very deep foundation pit project, in which the initial groundwater table is relatively high and multilayer permeable soils. Establishing multilayer ditches and sumps can effectively prevent the slope collapse when the groundwater in the upper layers scours the underlying layers. The single pumping head and slope height can be shortened but the excavation area and earthwork volume are both increased.

4.2.3 Deep Ditches Pumping

4.2.3.1 Method

In appropriate locations or upstream of groundwater in the construction site, a longitudinal deep ditch is dug as a main collector, in which the groundwater flows away or is pumped out (Fig. 4.5). Sub-ditches are connected to the main ditch and equipped all round to induce the water directions. The main ditch should be deepest and the depth is lower than the bottom of the foundation pit 1.00–2.00 m. Sub-ditches must be set to be shallower than the main ditch by 0.50–0.70 m. At the locations through the foundation, blind ditches should be set by gravels and sands. Before foundation pit backfilling, they are blocked by clays to prevent the groundwater flowing in the ditches to cause the failure of the subgrade. The deep ditches can also be set in the permanent drainage places in or surrounding the buildings.

4.2.3.2 Range for Application

This method is suitable for dewatering of large-area deep basement, caisson foundation, and group foundations.

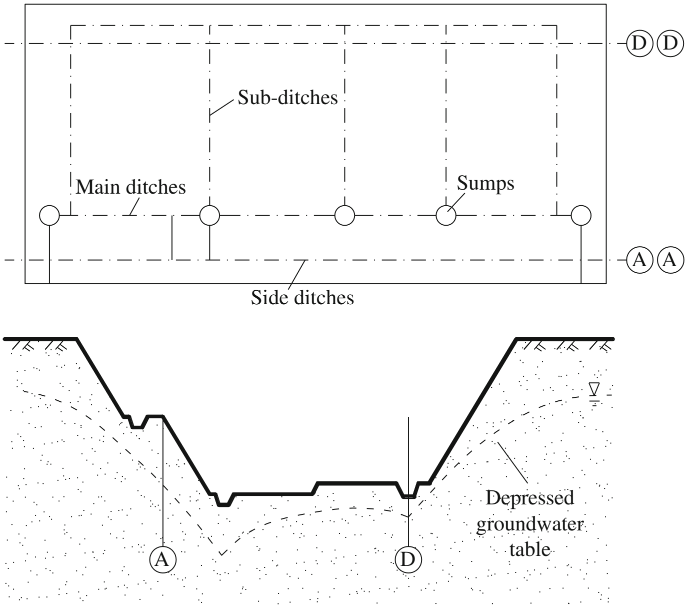


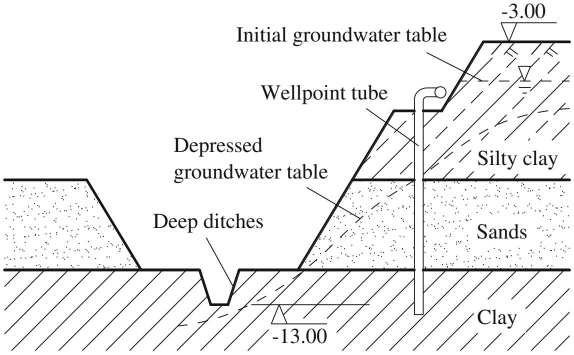
Fig. 4.5 Deep ditches pumping

4.2.4 Combined Pumping

4.2.4.1 Method (Fig. 4.6)

Based on deep ditches pumping, combined the multilayer ditches and sumps pumping, or light well-point dewatering in the upper soil layers, this combined pumping method is employed to drain large amount of underground water.

Fig. 4.6 Combined pumping



4.2.4.2 Range for Application

This method is used in the very uniform soil condition and deep foundation pit, or large amount of water discharge in large-area foundation excavation. The effectiveness is very good by this method but the cost is relatively high.

4.2.5 Dewatering by Infrastructure

4.2.5.1 Method (Fig. 4.7)

In this method, the deep foundation of the plant is constructed firstly, which is set to be the total water collecting site; or the surrounding drainage and sewer system is built previously, so that open sump pumps or blind seepage ditches are established in one/two sides along the foundation pit to induce the water into the main drainage and sewer system.

4.2.5.2 Range for Application

It is specially employed in group foundation dewatering of the large scale infrastructure construction (such as underground garage, oil depot).

4.2.6 Open Pumping in Sheet Pile Supporting System

Shown as Fig. 4.8, when sheet piles are constructed for the support of foundation pit excavation, small scale side ditches are set in the foundation pit edge beside the sheet piles, which is also called collecting ditches. Groundwater flows into the ditches and is pumped away immediately. Gravels and sands are filled in the ditches as filter. The depth of the ditch depends on the water amount. Generally, it is 0.60–1.00 m. Sometimes it can be set outside the foundation pit just beside the outer edge for convenient manipulation.

Fig. 4.7 Dewatering by infrastructure

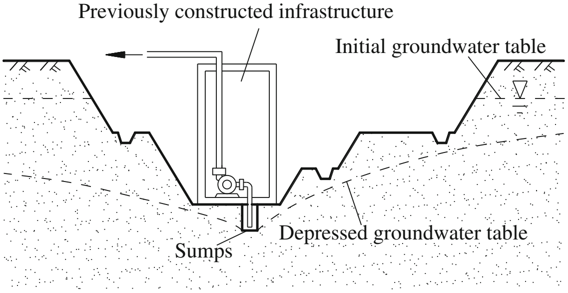
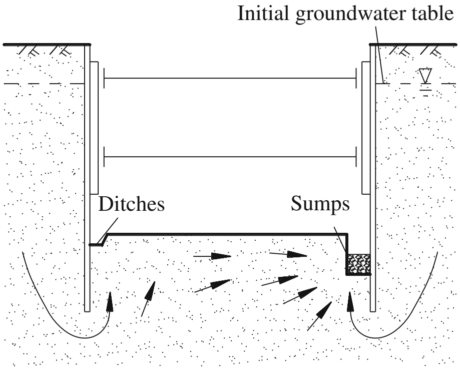


Fig. 4.8 Open pumping in sheet pile supporting system



4.3 Calculation on Open Pumping Amount

4.3.1 Formulas

In industrial and civil engineering construction, very high groundwater table is usually encountered, which is much adverse to the excavation of foundation pit. Thus it is necessary to take some dewatering measures to depress the groundwater table. The dewatering mode and size can be hardly unified. Generally, some simplification is employed to estimate the rate of groundwater flow.

4.3.1.1 Long and Narrow Foundation Pit

Long and narrow foundation pit is defined as the ratio of foundation pit length B to the width C is larger than 10:

$$\frac{B}{C} > 10 \tag{4.1}$$

When groundwater flows into a long and narrow foundation pit, it can be regarded that the groundwater laterally infiltrates in from two sides. According to Dupuit's equation:

Unconfined aquifer:

$$Q = KB\frac{H_0^2 - H_\mathrm{w}^2}{R} \tag{4.2}$$

More specifically, the flow rate of groundwater in two ends along width should be considered. So the calculation mode is divided into two parts (Fig. 4.9). The lateral flow rate can be estimated just by Eq. (4.2). As for the two ends, each can be approximate as a half of well with radius of $C/2$, which is sum up as an entire dewatering well. Thus,

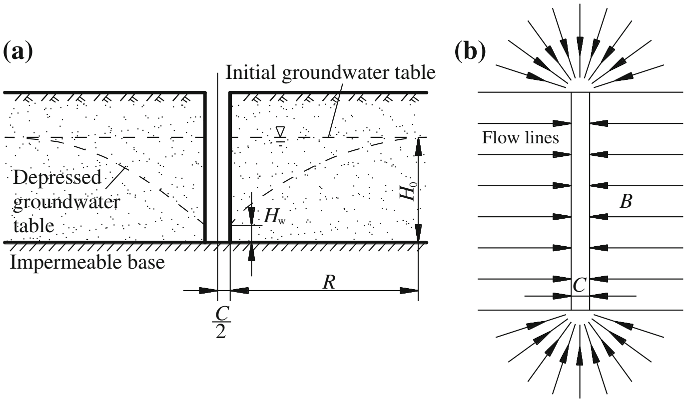


Fig. 4.9 Long and narrow foundation pit. **a** Cross sectional profile. **b** Plane view

Unconfined aquifer:

$$Q = KB\frac{H_0^2 - H_w^2}{R} + \frac{\pi \cdot K(H_0^2 - H_w^2)}{\ln R - \ln\frac{C}{2}} \tag{4.3}$$

Confined aquifer:

$$Q = 2KBM\frac{H_0 - H_w}{R} + \frac{2\pi \cdot K \cdot M(H_0 - H_w)}{\ln R - \ln\frac{C}{2}} \tag{4.4}$$

where C is the width of the foundation pit, m; B is the length of the foundation pit, m; Q it the flow rate, m^3/d; K is the hydraulic conductivity, m/d; H_0 is the initial groundwater table, m; H_w is the water table in the well, m; R is influence radius, m; M is the thickness of confined aquifer, m.

When the lateral recharge conditions in two ends of the foundation pit are different, the calculations should be correspondingly various. Then the total flow rate must be summation of the two parts, i.e., $Q = Q_1 + Q_2$. This circumstance mostly occurs in unconfined aquifer, shown as Fig. 4.10.

Unconfined aquifer:

$$Q_1 = KB\frac{H_1^2 - H_{w1}^2}{2 \cdot l_1} \tag{4.5}$$

$$Q_2 = KB\frac{H_2^2 - H_{w2}^2}{2 \cdot l_2} \tag{4.6}$$

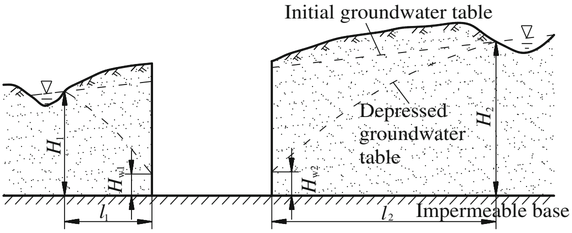


Fig. 4.10 Different lateral recharge boundaries to the foundation pit

where l_1, l_2 are the distances from the recharge boundaries to the foundation pit, m; H_{w1} and H_{w2} are the water tables on the lateral walls of the foundation pit. Others are same as previous equations.

In the case of two paralleling fully drainage channels (Fig. 4.11), the calculation can be considered as the combination of Channel I and Channel II.

Channel I:

$$Q_{\mathrm{I}} = KB\frac{H_1^2 - H_{\mathrm{w}}^2}{2l_1} \tag{4.7}$$

Channel II:

$$Q_{\mathrm{II}} = KB\frac{H_2^2 - H_{\mathrm{w}}^2}{2l_2} \tag{4.8}$$

where B is the length of the foundation pit. H_{w} is much smaller than the thickness of aquifer, then it can be neglected, so the calculation can be largely simplified.

$$\frac{B}{C} < 10 \tag{4.9}$$

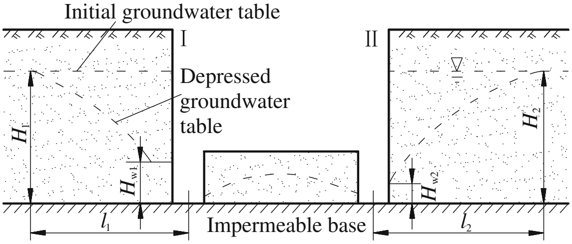


Fig. 4.11 Two paralleling fully penetrated drainage channels

Table 4.3 The value of η

C/B	0	0.2	0.4	0.6	0.8	1.0
η	1.0	1.12	1.16	1.18	1.18	1.18

The flow rate can be estimated as large well method regardless of the shape is rectangle, square, or some others. The reference radius of the hypothesized large well can be calculated as follows.

In the case of square foundation pit, it is

$$R_0 = \eta \frac{C + B}{4} \tag{4.10}$$

where the value of η can be selected from Table 4.3 based on the ratio of width over length of the foundation pit.

In the case of irregular shape foundation pit, the reference radius can be estimated by Eq. (4.11).

$$R_0 = \sqrt{\frac{F}{\pi}} \tag{4.11}$$

where F is the area of the foundation pit, m^2; R_0 is the reference radius in the calculation of large well method, m.

4.3.1.2 The Fully Penetrated Large Well Method in Horizontal Impermeable Base

In the case of the foundation pit fully penetrating an unconfined aquifer, shown as Fig. 4.12a, the calculation formula is as follows as Eq. (4.12).

$$Q = \frac{\pi \cdot K(H_0^2 - H_w^2)}{\ln \dfrac{R + R_0}{R_0}} \tag{4.12}$$

In the case of the foundation pit fully penetrating a confined aquifer, shown as Fig. 4.12b, the dewatering of groundwater must depress the water table down into the confined aquifer. The groundwater farer than the distance of a is the confined

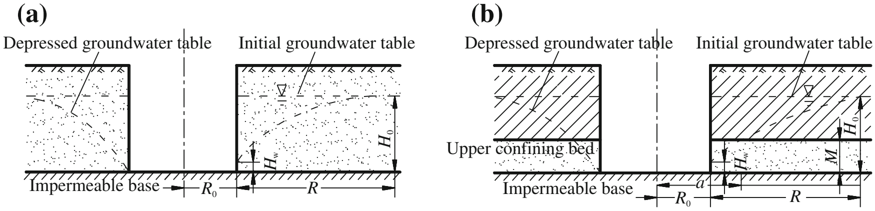


Fig. 4.12 A foundation pit fully penetrating an aquifer. **a** Unconfined aquifer, **b** Confined aquifer

groundwater, while it is the free-surface flow within the range of a. According to the principle of continuity, under the condition of steady flow, it has the relationship of $Q_{\text{unconfined}} = Q_{\text{confined}}$.

$$Q_{\text{unconfined}} = \frac{\pi \cdot K(M^2 - H_{\text{w}}^2)}{\ln \dfrac{a}{R_0}} \tag{4.13}$$

$$Q_{\text{confined}} = \frac{2\pi \cdot K \cdot M(H_0 - M)}{\ln \dfrac{R + R_0}{a}} \tag{4.14}$$

In conjunction with Eq. (4.13) and (4.14), eliminating ln$a$, it has:

$$Q = \frac{\pi \cdot K(2MH_0 - M^2 - H_{\text{w}}^2)}{\ln \dfrac{R + R_0}{R_0}} \tag{4.15}$$

Assuming $H_{\text{w}} = 0$, $s = H_0$ when dewatering for the foundation pit, the flow rate can be deduced as Eq. (4.16).

$$Q = \frac{\pi \cdot K \cdot M(2s - M)}{\ln \dfrac{R + R_0}{R_0}} \tag{4.16}$$

where s is the groundwater drawdown, m; others in the equation are the same as above.

In the case of the foundation pit partially penetrating the unconfined aquifer, shown as Fig. 4.13a, the flow rate per unit width can be estimated as Eq. (4.17).

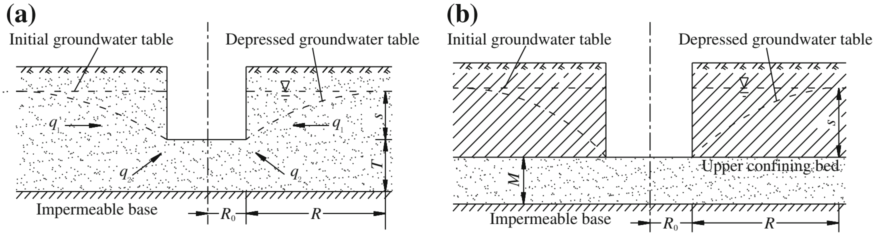


Fig. 4.13 A foundation pit partially penetrating an aquifer. **a** Unconfined aquifer, **b** Confined aquifer

$$q = q_1 + q_2 = \frac{\pi \cdot K \cdot s^2}{\ln \frac{R + R_0}{R_0}} + \frac{2\pi K s R_0}{\frac{\pi}{2} + 2\text{arcsh} \frac{R_0}{T + \sqrt{T^2 + R_0^2}} + 0.515 \frac{R_0}{T} \ln \frac{R + R_0}{4T}} \tag{4.17}$$

where q_1 is the flow rate per unit width from lateral seepage of the foundation pit, m^2/d; q_2 is the flow rate per unit width from the foundation pit bottom, m^2d; T is the thickness from the impermeable base to the bottom of foundation pit, m; arcsh is the inverse hyperbolic cosine function.

So the entire flow rate of the foundation pit in this circumstance is:

$$Q = q \cdot B = B(q_1 + q_2) \tag{4.18}$$

where B is the width of the foundation pit, m.

In the case of the foundation pit partially penetrating the confined aquifer, shown as Fig. 4.13b, the foundation pit bottom just penetrates the upper confining bed, it has

$$Q = \frac{2\pi K s R_0}{\frac{\pi}{2} + 2\text{arcsh} \frac{R_0}{M + \sqrt{M^2 + R_0^2}} + 0.515 \frac{R_0}{M} \ln \frac{R + R_0}{4M}} \tag{4.19}$$

4.3.2 Empirical Method

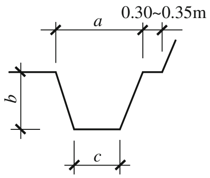
If the project scale is not large, under the moderate groundwater head, an empirical method of unit area seepage amount can be employed. Table 4.4 provides the empirical values of seepage amount under different conditions.

Table 4.4 Seepage amount on unit area in foundation pit

Soil condition	Seepage amount per area (m^3/d)	Soil condition	Seepage amount per area (m^3/d)
Fine sands	0.16	Coarse sands	0.30–3.0
Medium sands	0.24	Fissured rock	0.15–0.25

Note 1. If the construction is in the cofferdam, the seepage from the cofferdam should be taken into consideration. Specifically, the value in the table should be multiplied by a factor of 1.1–1.3
2. The number of pumps should be consider a certain safe factor based on the estimation value in this table

Table 4.5 The section of the drainage ditch

Graphical schematic	Area of foundation pit (m^2)	Section symbol	Silt clay			Clay		
			Depth beneath groundwater level (m)					
			4	4–8	8–12	4	4–8	8–12
	<1000	*a*	0.5	0.7	0.9	0.4	0.5	0.6
		b	0.5	0.7	0.9	0.4	0.5	0.6
		c	0.3	0.3	0.3	0.2	0.3	0.3
	5000–10,000	*a*	0.8	1.0	1.2	0.5	0.7	0.9
		b	0.8	1.0	1.2	0.5	0.7	0.9
		c	0.3	0.4	0.4	0.3	0.3	0.3
	>10,000	*a*	1.0	1.2	1.5	0.6	0.8	1.0
		b	1.0	1.5	1.5	0.6	0.8	1.0
		c	0.4	0.4	0.5	0.3	0.3	0.4

4.4 The Common Section of the Ditches in Foundation Pit

The section of the drainage ditch is generally as Table 4.5.

4.5 The Calculation of the Power of Pumps in Requirement

The power in requirement can be calculated by Eq. (4.20).

$$N = \frac{K_s \cdot Q \cdot H}{102 \cdot \eta_1 \cdot \eta_2} \tag{4.20}$$

where H is the total water head, including pumping head, suction head, and head loss generated by various resistance; K_s is the safe factor, generally $K_s = 2$; η_1 is the pump efficiency, 0.4–0.5; η_2 is the dynamic mechanical efficiency, 0.75–0.85.

To ensure the successful construction, there are always emergency pumps in preparation in case of the accident mechanical failure.

4.6 The Performance of Common Pumps

The performance of common pumps is presented in Table 4.6.

Table 4.6 Performance of general pumps

Type		Flow rate (m³/h)	Total pumping head (m)	Suction head (m)	Motor power (kW)	Weight (kg)	
B	BA					B	BA
1.5B17	1.5BA-6	6–14	20.3–14.0	6.6–6.0	1.7	17	30
2B31	2BA-6	10–30	34.5–24.0	8.7–5.7	4.5	37	35
2B19	2BA-9	11–25	34.5–24.0	8.0–6.0	2.8	19	36
3B33	3BA-9	30–5	35.5–28.8	7.0–3.0	7.0	40	50
3B19	3BA-13	32.4–52.2	21.5–15.6	6.5–5.0	4.5	23	41
4B20	4BA-18	65–110	22.6–17.1	5	10.0	51.6	50

Note 2B19 represents the inlet diameter is 2 in. (50 mm); the total pumping head is 19 m by a single pump

4.7 Case Study

Calculate the hydraulic parameter of aquifer by sensitivity analysis method

1. Compile the sensitivity analysis method program by any available software, adding instruction by block diagram;
2. Use pumping test data to calculate the parameter of aquifer by the above designed program. The pumping test data is shown in the following table.

Pumping test data

Radius of pumping well *r* (mm)	20		Discharge *Q* (m³/d)	2592	
Time *t* (min)	Drawdown *s* (m)	Time *t* (min)	Drawdown *s* (m)	Time *t* (min)	Drawdown *s* (m)
1	0.160	300	0.566	930	0.617
2	0.228	330	0.569	960	0.617
3	0.285	360	0.575	990	0.619
4	0.293	390	0.580	1020	0.622
6	0.321	420	0.583	1050	0.624
8	0.341	450	0.585	1080	0.626
10	0.370	480	0.591	1110	0.627
15	0.387	510	0.595	1140	0.627
20	0.410	540	0.596	1170	0.625
25	0.422	570	0.597	1200	0.624
30	0.443	600	0.598	1230	0.625
40	0.454	630	0.598	1260	0.623
50	0.471	660	0.600	1290	0.624

(continued)

(continued)

Radius of pumping well r (mm)	20		Discharge Q (m^3/d)	2592	
Time t (min)	Drawdown s (m)	Time t (min)	Drawdown s (m)	Time t (min)	Drawdown s (m)
60	0.484	690	0.602	1320	0.624
90	0.515	720	0.603	1350	0.625
120	0.531	750	0.605	1380	0.625
150	0.541	780	0.608	1410	0.626
180	0.547	810	0.610	1440	0.629
210	0.556	840	0.610	1470	0.629
240	0.560	870	0.613	1500	0.631
270	0.563	900	0.615	1530	0.632

4.8 Exercises

1. What kinds of open pumping method are commonly used? What are application conditions?
2. How to estimate the open pumping water discharge in foundation pit?