Water Engineering Course

Water Intake

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Water Intakes:

Surface sources of water are subject to wide variation in flow , quality, and temperature ,and structures must be designed so that required flow can be withdrawn despite these natu

.the intake it self normally consist of a (frequently screened in some manner) and a conduit which conveys the flow to a sump from which it may be pumped to the treatment plant .

RAW WATER INTAKES, SCREENING AND AERATION

Intakes are structures constructed in or adjacent to lakes, reservoirs, or rivers for the purpose of withdrawing water. In general, they consist of an opening with a grate or strainer through which the water enters, and a conduit to conduct the water by gravity to a low-lift pumping station. The water is pumped from the low-lift pumping station to the water treatment facility. Schematic diagrams of lake and river intake systems are shown in Figures I-1 and I-2. Also see plates I-1.

The key requirements of the intake structures are that they are:

1. Reliable.
2. Of adequate size to provide the required quantity of water.
3. Located to obtain the best quality water.
4. Protected from objects that may damage or clogging equipment, piping and pumps.
5. Easy to inspect and maintain.
6. Designed to minimize damage to aquatic life.
7. Located to minimize navigational hazards.

Water Intake

Example

A two-cell intake tower located in a cold climate reservoir is being designed for a winter design flow rate of 6000 m^3/d. The tower will have three ports at three different elevations in each cell. Each port must be able to deliver the design flow rate operating alone. Determine the area of each port opening.

Solution.

For a cold climate reservoir, the intake velocity should be limited to less than 0.10 m/s (Table I-2). Using an intake velocity of 0.08 m/s and Equation:

$$Q = VA$$

$$A = \frac{Q}{V} = \frac{6000\ m^3/d}{\left(0.08\frac{m}{s}\right)\left(86400\frac{s}{d}\right)} = 0.868\ m^2\ ,\quad or = \ 0.9\ m^2$$

This area is a preliminary estimate that will have to be enlarged because it does not take into account the area of the screen that has to be installed to prevent debris from entering the tower.

Note that the design flow rate specified was for winter conditions. Summer flow rates generally are higher than winter flow rates, and the velocities will be higher.

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Example

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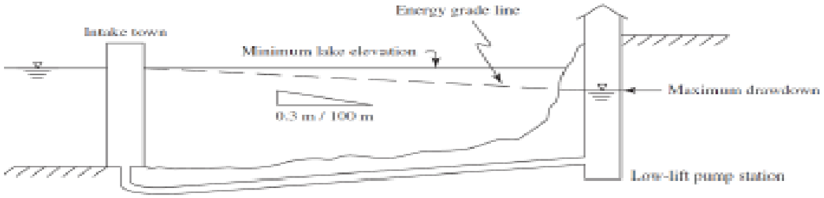
1- Determine the area of each port opening
2- Determine the diameter of a concrete conduit to transport the water from the intake tower to a low-lift pump station on shore. A sketch of the minimum lake elevation and the maximum allowable drawdown in the low-lift pump station is shown below.



Water Intakes

Solution:

(1):

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(2):

From Table I-4 , the maximum flow rate is assumed to be 2.0 (Q), that is, twice the winter design flow rate.

The winter design flow rate is 6000 m^3/d. The maximum flow rate is:

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EXAMPLE:

Design a water intake tower structure for the following requirements:

1- Maximum daily demand = 113500 m^3/day
2- Minimum reservoir elevation = 70 m (mean sea level msl)
3- Maximum reservoir elevation = 90 m (msl)
4- Normal water surface elevation = 85 m (msl)
5- Bottom elevation = 60 m (msl)
6- The velocity through rack screen should be less than 8 cm/s
7- The velocity through the fine screen shall be less than 0.2 m/s
8- Fine screen efficiency factor = 0.56
9- Use two fine screen installed at the pumping station
10- The depth of flow at fine screen chamber = 9.53 m
11- The orifice discharge coefficient = 0.6

Solution:

1- **Select the size of the intake gate**

The gates are sized such that the entire maximum flow of 113500 m3/day can be withdrawn from a single level at a maximum velocity of 0.08 m/s.

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$$Q = 113500 \frac{m^3}{day} = 1.31 \ \frac{m^3}{s}$$

$$area\ of\ gate\ , A = \frac{Q}{v} = \frac{1.31 \frac{m^3}{s}}{0.08\ m/s} = 16.38\ m^2$$

This is too large for a single gate, so select two equal size square gates of area 16.38 /2 = 8.19 m2 each.

$$Width = Heigh = \ (8.19\ \ m^2)^{1/2} = 2.86\ m$$

Select the next larger standard size gate :

$$Width = Heigh = \ 3\ m$$

$$Velocity\ through\ gate = \frac{Q}{A} = \frac{1.31 \frac{m^3}{s}}{3\ m\ x\ 3\ m} = 0.07 \frac{m}{s}$$

2- Determine the layout of the intake gates

Set the highest gate with its top two meters below the normal water surface elevation of 85 m, resulting in a centerline elevation of 81.5 m. likewise, set the lowest gate at a centerline elevation of 65 m, providing 3.5 m of head at the 100-year drought elevation of 70 m. at this elevation, the bottom of the lowest gate is 3.5 m above the reservoir bottom. In order to provide the flexibility to withdraw water from intermediate elevations, provide additional

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gates at two levels equally spaced over the 16.5 m range (81.5 m – 65 m).

$$Spacing = \frac{16.5\ m}{3\ spaces} = 5.5\ m/space$$

Therefore, gates will be provided at centerline elevations of 81.5 , 76 , 70.5 and 65 m.

Locate two gates on each side of the intake tower. Each gate is 3 m wide. So set the width of the tower wall is 8 m. This will provide approximately 0.5 m between the gate and the wall and approximately 1 m between gates. The overall dimension of the tower are 10 m x 10 m with high of about 35 m (above the maximum water level by approximately 5 m).

3- **Design of coarse screen**

The coarse screen will be located at the intake ports (gates). Use 13 mm square edge bars, 4.8 m long, spaced at approximately 8 cm on centers. This provides a clear opening of 6.7 cm (8 cm – 1.3 cm). the bars cover 3.6 m width over the gate. The number of bars required is computed as follow:

$$Number\ of\ spaces = \frac{360\ cm}{8\ cm/space} = 45\ spaces$$

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$$Number\ of\ bars = Number\ of\ spaces - 1 = 45 - 1 = 44\ bars$$

4- **Determine the velocity through the bar rack**

$$Open\ area\ through\ the\ rack = Total\ area\ of\ the\ rack - Area\ of\ the\ bars$$

$$Open\ area\ through\ the\ rack = (3.6\ x\ 4.8\ ) - (44\ \ bars\ x\ 0.013\ m\ x\ 4.8\ m)$$

$$Open\ area\ through\ the\ rack = 17.28\ m^2 - 2.75\ m^2 = 14.53\ m^2 = (4.8\ m\ x\ 3.028\ m)$$

Maximum flow rates through the rack is half of the design flow rate because there are two gates at each level.

$$Flow\ through\ the\ rack\ \frac{1.31\frac{m^3}{s}}{2} = 0.66\frac{m^3}{s}$$

$$Velocity\ through\ the\ bar\ rack = \frac{Q}{A} = 0.66\frac{m^3}{s}\ \ x\ \frac{1}{14.53\ m^2} = 0.0541\ m/s\ (5.41\frac{cm}{s})$$

This is within the acceptable velocity (less than 8 cm/s)

5- **Design of fine screen**

Provide two screens each with a 9.5 mm opening and flow of :

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$$\frac{1.31\,\frac{m^3}{s}}{2} = 0.66\,\frac{m^3}{s}$$

The depth of flow at screen chamber is 9.53 m, and take velocity through screen is 0.2 m/s.

$$Total\ area\ of\ opening = \frac{Q}{v} = \frac{0.66\,\frac{m^3}{s}}{0.2\ m/s} = 3.3\ m^2$$

With screen efficiency factor 0.56,

$$Total\ area\ of\ fine\ screen = \frac{3.3\ m^2}{0.56} = 5.89\ m^2$$
$$= width\ of\ screen\ x\ depth\ of\ flow$$

$$width\ of\ screen = \frac{5.89\ m^2}{9.53\ m} = 0.62\ m$$

6- **Hydraulic calculations**

The approach velocity in the reservoir is assumed to be zero. The head loss through the rack is:

$$h_L = \frac{(v^2 - v_v{}^2)}{2g} x \frac{1}{0.7} = \frac{(0.0451\ m/s)^2 - (0.0\ )^2}{2x\ 9.81} x \frac{1}{0.7}$$
$$= 0.0001\ m$$

The head loss through the intake port can be calculated by the orifice equation:

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$$velocity\ through\ port,\ v = \frac{Q}{A} = \frac{0.66\,\frac{m^3}{s}}{3m\ x\ 3m} = 0.0733\ m/s$$

$$h_L = \frac{1}{2\,g}\left(\frac{v}{C_d}\right)^2 = \frac{1}{2\ x\ 9.81}\left(\frac{0.073\ m/s}{0.6}\right)^2 = 0.0008\ m$$

The head loss through the fine screen will also can be calculated by the orifice equation. The total flow is 1.31 m^3/s (when one screen is out of service and the other screen must pass the entire flow):

$$velocity\ through\ fine\ screen\ ,\ v = \frac{Q}{total\ opening\ area}$$

$$v = \frac{1.31\,\frac{m^3}{s}}{0.62\ m\ x\ 9.53\ m\ x\ 0.56} = 0.396\ m/s$$

$$h_L = \frac{1}{2\,g}\left(\frac{v}{C_d}\right)^2 = \frac{1}{2\ x\ 9.81}\left(\frac{0.396\ m/s}{0.6}\right)^2 = 0.01\ m$$

Total head loss = 0.0001 + 0.0008 + 0.01 = 0.011 m (very small)

7- <u>Check the stability of intake structure</u>

$$The\ weight\ of\ water\ displaced\ by\ tower\ and\ base\ slab$$
$$= Volume\ of\ water\ displaced\ by\ tower\ and\ base\ slab\ x\ density$$

In design of intakes, one must consider the following points :

1-source of water supply (collection basin , river ,or lake) …..etc
2-surroundings characteristics of intake (water depth ,or variation of water level , navigation requirements ,local currents and patterns of sediment deposition and scour , spatial and temporal variation in water quality ,and the quantity of floating debris .
3-the intake must be located at upstream of the water source
4-prevent floating materials like plants to in enter to the intake
5-the entrance of intake must be located in place with no fast currents .
6-the floor near intake must be stable enough .
7-the suction pipe should be locate below water surface in order to convey the cold water and to preventing materials.
8-the entrance of intake should be located at suitable distance offshore of water source to prevent pollution .

Type of in takes :

1-lake intakes :-

Lake intakes should be located as for as possible from sources of pollution , and one should consider wind and current effects on the motion of contaminants . in particular , winds may stir up sediment from the bottom which may carried to the in lake if it is located is shallow water or too close to the bottom. Inlet velocities should be less than 0.15 m/s to avoid trapping excessive quantities of floating material , sediment , ice , or fish. A water depth of (6 to 9 m) is necessary to prevent blocking of the intake by ice jams which may fill the take to the bottom in shallower depths .

2-river intakes

River intakes should be designed , when possible , to withdraw water from slightly below the surface in order to avoid both sediment in suspension at lower levels and floating debris . some large cities have built elaborate river intakes resembling bridge piers with ports at various depth to accommodate variations in water level . small cities may use simple pipe intakes located so that they are sufficiently below the low – water level that river traffic is not impeded . such intakes must also be above the bottom so that materials being carried in traction will not cover them . these requirement often dictate that the intake opening be in the main channel , which may be quite for from the normal bank.

3-collection basins (tanks) intakes .

4-direct intakes (or simple intakes)

Direct intakes are always designed for small cities the conditions of direct intakes selection are :

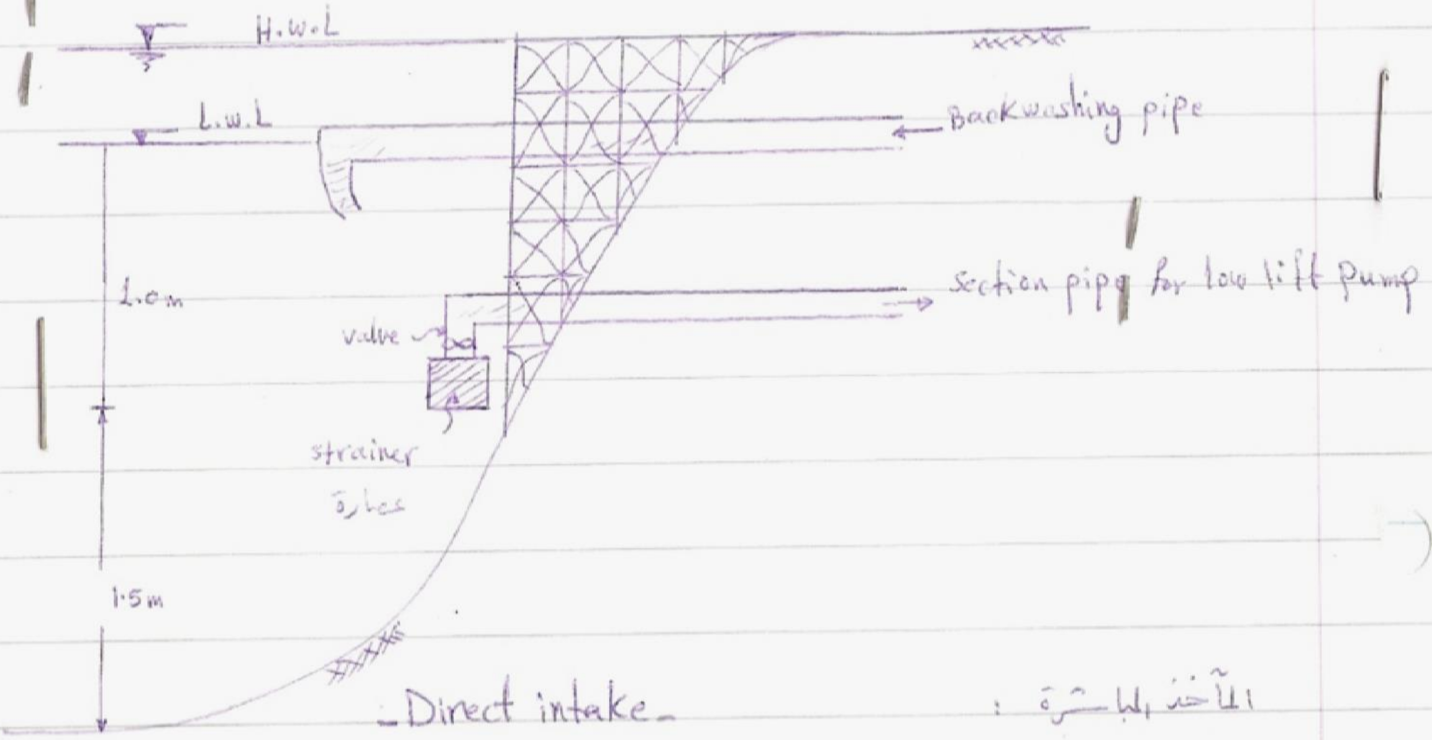
1-deep water source like river ,and takes .

2-the embankment of water source has enough resistance against corrosion and deposition .

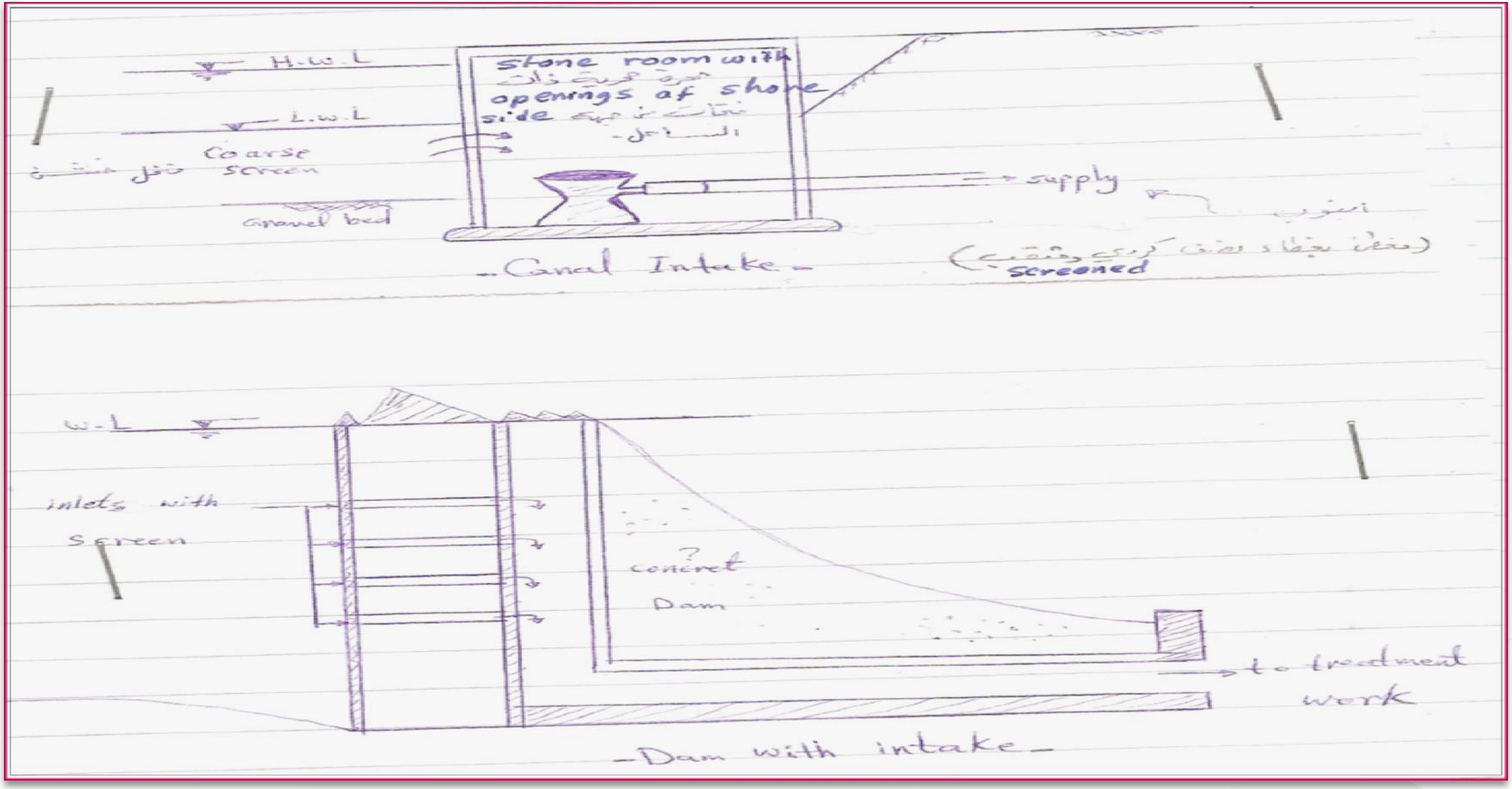
This type of intakes is considered the cheaper type of intakes

3-Intakes of Storage Tanks

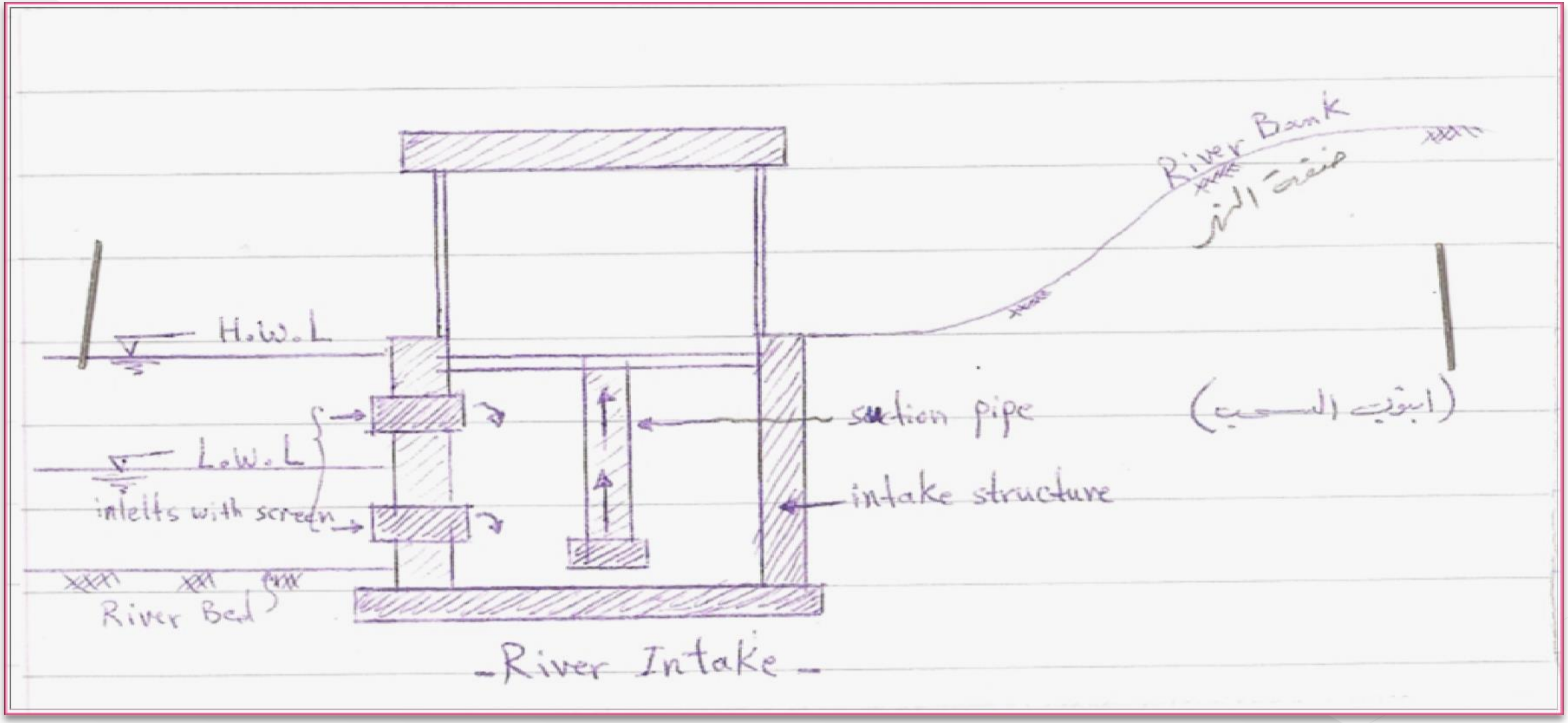
4-Direct Intakes



Direct intake : الآخذ المباشرة



H.W.L
L.W.L
Coarse screen
Gravel bed
Stone room with
openings of shore side
supply
screened
- Canal Intake -
W.L
inlets with screen
concret Dam
to treatment work
- Dam with intake -


River Bank
ضفة النهر
H.W.L
L.W.L
inlets with screen
suction pipe
(ابوبت السحب)
intake structure
River Bed
-River Intake-

Ex: design a direct intake of water treatment plant which has 3000 m^3/hr max . flow rate .

Solution :-

Limitation

F the permissible velocity of pipes of intake is between (60-100) cm/s

$$Q = \text{flow rate} = 3000\ m^3/hr = \frac{3000}{3600} = 0.83\ m^3/s$$

use 6 delivery pipes plus one pipe as stand – by and each pie is mounted with one pump.

$Q_{\text{one pipe}} = \frac{0.83}{6}$ $M^3/s = 0.138\ m^3/s$

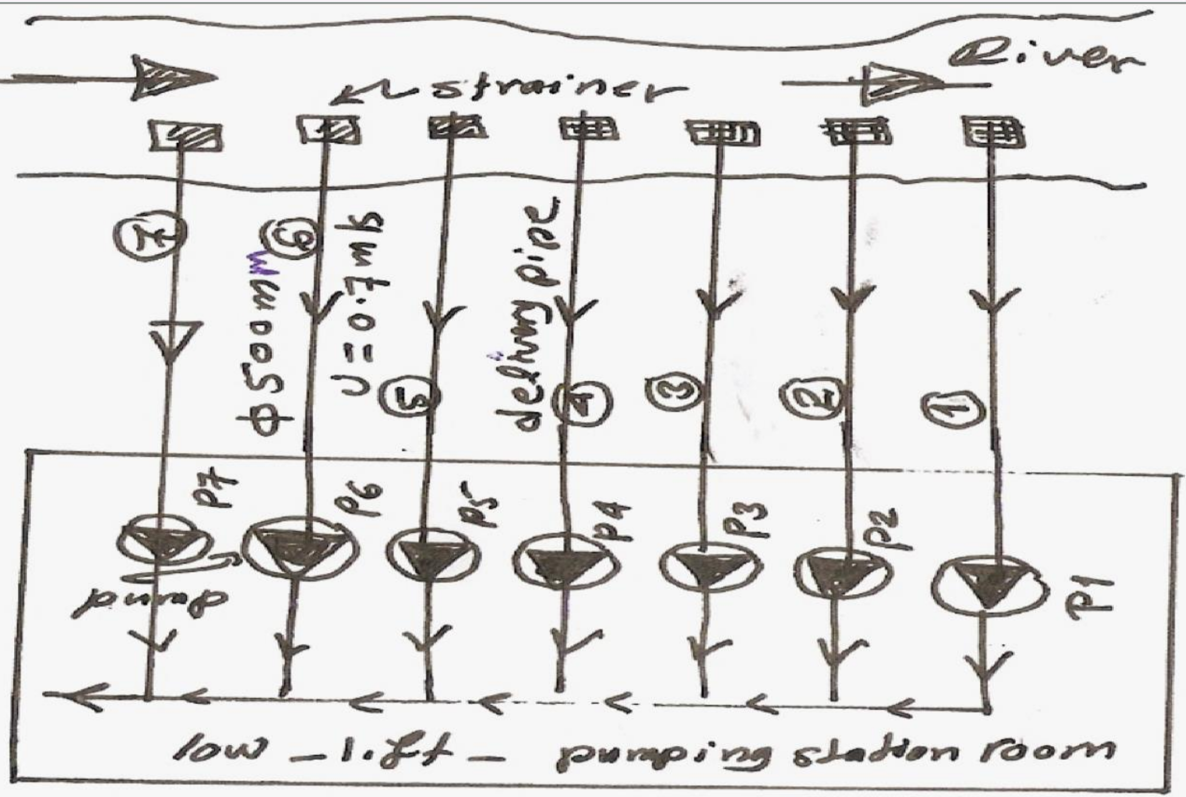
D= 0.469 USE D = 0.50M = 500 MM

Use 0.80 m/s velocity $Q = V \cdot \frac{(\pi D^2)}{4}$ *$0.8 = 0.138$*

Check the actual velocity $V = \frac{0.138\ m^3/s}{\frac{\pi}{4}(0.50)^2}$ =0.7 m/s, satisfactory

$0.6\ m/s < V < 1\ m/s$

Use 6 pipe plus one pipe as :



Determination of

Power of pumps

Determine of power of pumps ?
Use 7 pumps (6 pumps are working (and one pump is stand – by therefore

Q $_{\text{one pump}}$ $\frac{0.83}{6}$ = 0.138

The pumps used of low – lift pumps ,so the head of pump should not exceed 30 m .

Water pipes

Use head of pump of 20 m

$$P = \frac{\gamma . Q . H}{\mu_m \mu_E}$$

power of (kw) pump

α= water density ≈(10 kn/m^3)

H= head of pump (m).

$\mu_m \mu_E$= mechanical and electrical efficiencies respectively

$$\therefore P = \frac{10*0.130*20}{0.75*0.75} = 49 \text{ kw}$$


QUESTIONS

Any Questions?