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Study and Design of Detention Ponds for the City of Baghdad

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Abstract:

Detention ponds are probably the most common management practice for the control of storm water runoff quality. If properly designed, constructed, and maintained, they can be very effective in controlling a wide range of pollutants and peak runoff flow rates. There is probably more information concerning the design and performance of detention ponds in the literature than for any other storm water control device. Detention ponds are a very robust method for reducing storm water pollutants. They typically show significant pollutant reductions as long as a few design-related attributes are met. Many details are available to enhance performance, and safety, that should be followed. Many processes are responsible for the pollutant removals observed in detention ponds. Physical sedimentation is the most significant removal mechanism. However, biological and chemical processes can also contribute important pollutant reductions. The extensive use of aquatic plants, in a controlled manner, can provide additional pollutant removals. Detention ponds are also suitable for enhancement with chemical and advanced physical processes.

1. Introduction:

Peak flow control generally involves the use of a detention structure to temporarily store excess runoff and gradually release it over a period of time to the receiving watercourse.

Typically, a detention facility is designed to control outflow at a rate no greater than the pre-development peak discharge rate.

Generally, detention facilities will not significantly reduce the total volume of runoff, but will redistribute the rate of runoff over a period of time by providing temporary "live" storage of a certain amount of storm water. The purpose is to reduce downstream flooding and erosion problems. The most common detention structure is the dry detention basin, although wet ponds can also be used for peak flow control. A dry detention basin is normally designed for quantity control or peak flow control and pollutant removal is only a minimal benefit. Although detention basins are effective at controlling peak discharge rates leaving a site, they may do little to limit increases in flow rates further downstream and, in some cases, may actually increase the peak flows at some points. In this project we study the dry detention pond to find the required volume and area in relative with rainfall flow and to design the detention pond in the appropriate location in Baghdad city.

2. Area of Study

Baghdad city is the capital of Iraq located at latitude 33° 20' 19" North and longitude 44° 23' 38" East. The mean maximum monthly air temperature is 44.4 C° and occurs in July, while the mean minimum monthly air temperature is 4.2 C° and occurs in January. The city gets about 280 mm as annual rainfall. The maximum relative humidity occurs in January and is about 71.7%, while the minimum relative humidity occurs in July and is 25.3%

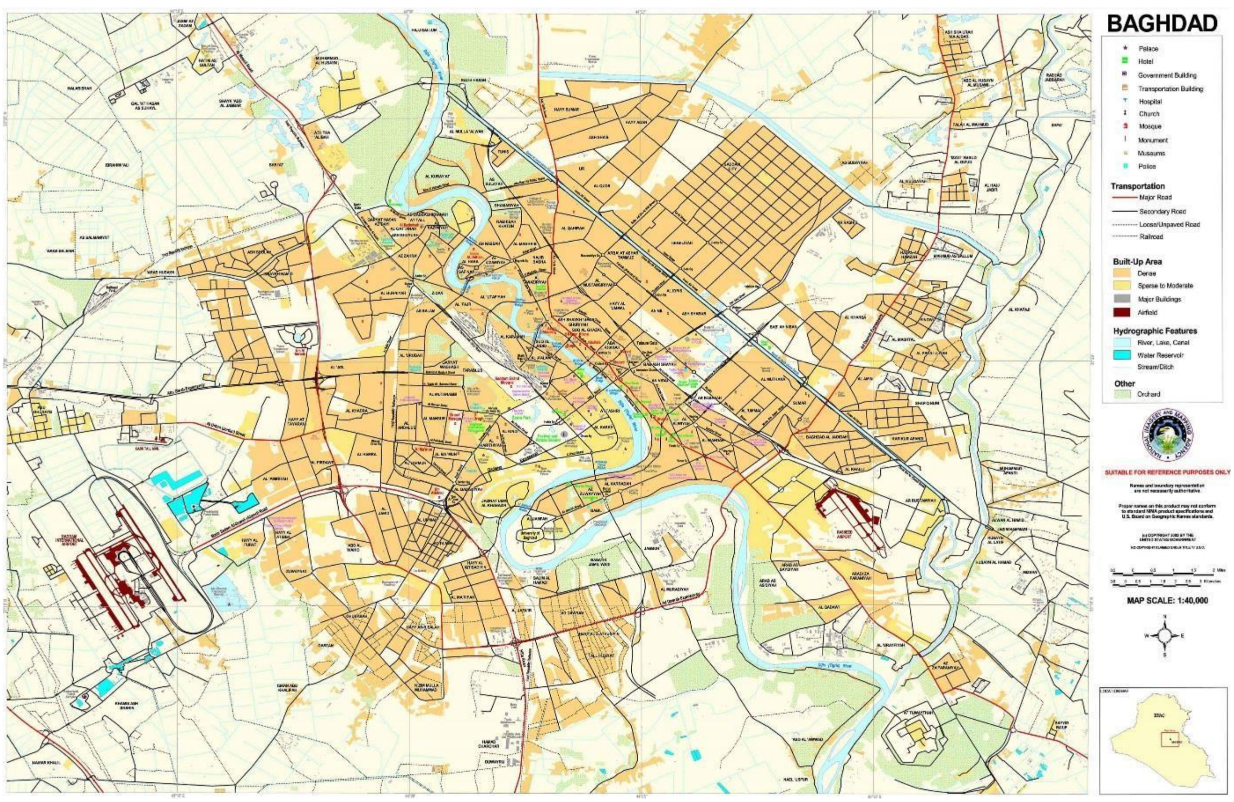


Figure (1) Baghdad city

3. Hydrology of Baghdad

Tigris river water is considered the only source of potable water for the city of Baghdad, and Tigris River within Baghdad city about 38 Km in length, the river divides the city into right (Karkh) and left (Risafa) sides with a flow direction from north to south. Three periods in the annual cycle of the Tigris river water regime: flood period (February- June) connected with snow thawing in the mountains, summer low water period (July- October) and a period of rain flooding (November- February) within the flood period the Tigris river conveys about 75% of annual flow, in the dry period about 10% and in the period of autumn- winter floods about 15%. There are two channels (Al-Jeish channel & Al- Shorta channel) was created to provide service in the rescue Baghdad of the flood. Will be regard the place to design detention pond in this project to basin of these three streams.

Figure (2) Tigris River

4. Topography of Baghdad

Baghdad is a flat land and does not contain clear terrain, the difference in elevation is only visible in the river basin. The range of elevation is from 25-40 and this variation for whole the city, from map the flattest slope appears near the river and channels basin.

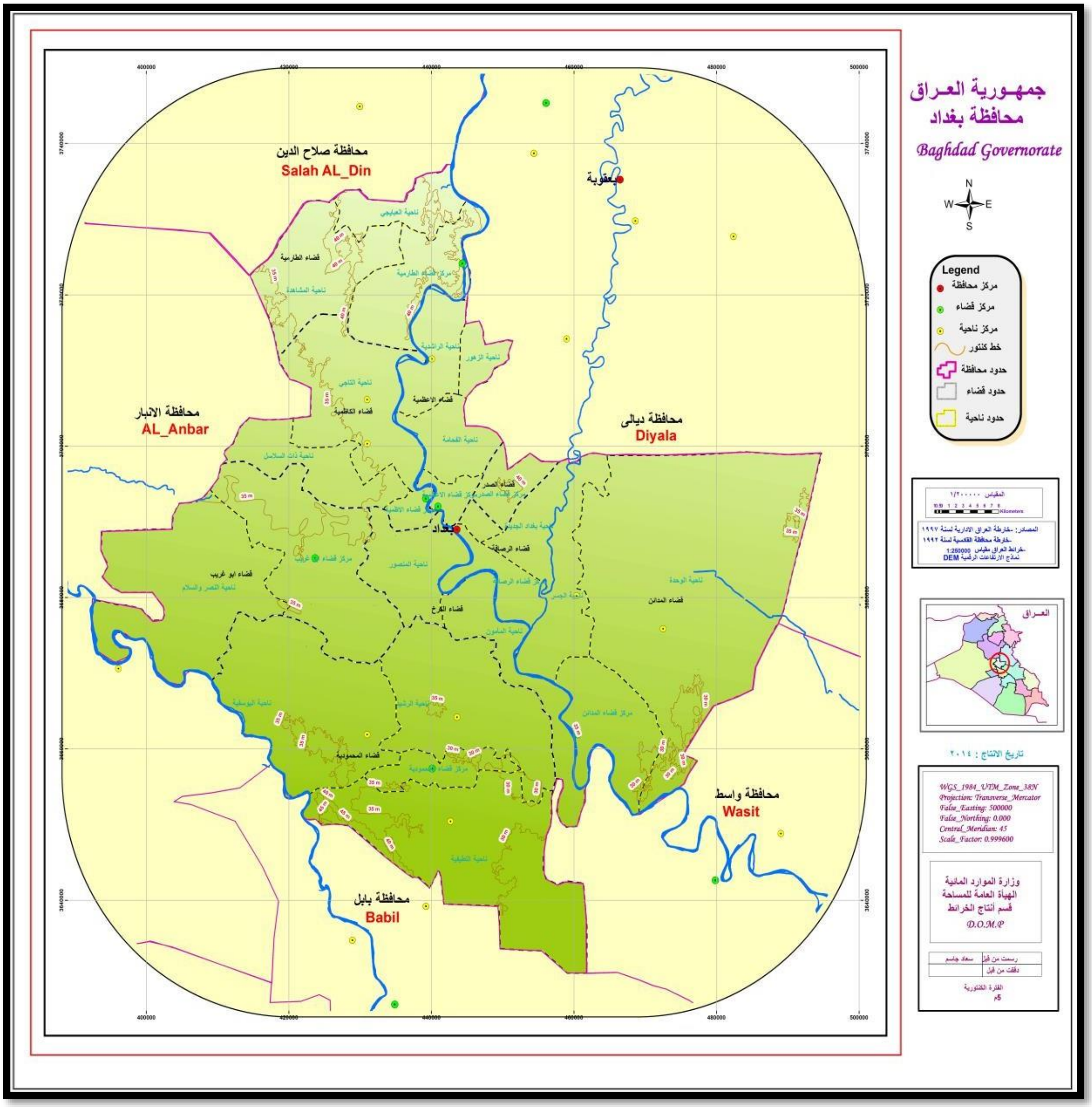


Figure (3) contour lines for the Baghdad city

5. Detention Pond

Detention ponds are open basins that provide live storage volume to enable reduction of stormwater runoff flow rates and allow matching of predeveloped flow durations discharged from a project site. Detention ponds are commonly used for flow control in locations where space is available for above ground facility but where infiltration of runoff is infeasible.

Figure (5) Detention pond

Advantages

- Surrounding areas have vegetative buffer that can withstand dry or wet conditions.
- May cost less to implement than a wet retention pond because the size is generally smaller.

Disadvantages

- Requires a large amount of space.
- Does not improve water quality.
- Can become a mosquito breeding ground.
- Can detract from property value, whereas retention ponds may add value.

6. Retention Ponds

Wet retention ponds are a stormwater control structure that provides retention and treatment of contaminated stormwater runoff. By capturing and retaining stormwater runoff, wet retention ponds control stormwater quantity and quality. The ponds natural processes then work to remove pollutants. Retention ponds should be surrounded by natural vegetation to improve bank stability and improve aesthetic benefits.

Water is diverted to a wet retention pond by a network of underground pipes connecting storm drains to the pond. The system allows for large amounts of water to enter the pond, and the outlet lets out small amounts of water as needed to maintain the desired water level.

From a health standpoint, there is always a concern with standing water. This can be a drowning hazard, particularly with children. Ponds can also draw mosquitoes, which may contribute to the transmission of some diseases.

Figure (6) Retention pond

Advantages

- Retention ponds are simple if space is provided.
- Collects and improves water quality.
- Naturally processes water without additional equipment.
- Improved stormwater collection and flood control.
- New habitats are created.
- Can be used for recreational purposes.

Disadvantages

- Can be a drowning hazard.
- Large areas of land are needed.
- Negative water quality impacts if not properly designed.

7. Maintenance Considerations

One of the most important maintenance needed for either of these basins is to ensure that the orifice does not become blocked or clogged. Keeping the pipes clear of debris will ensure the ponds and basins are functioning properly. Keeping up with maintenance can reduce costly repairs in the future. Other maintenance includes:

- Identifying and repairing areas of erosion - A few times a year and after major storms, check for gullies and other disturbances on the bank.
- Removing sediment and debris - Keeping pipes clear of debris and removing sediment ensures proper function. Remove debris around and in ponds before it reaches the outlets to prevent problems.

- Maintaining vegetation - The amount of maintenance depends on the type of vegetation surrounding the basin. Some grasses need weekly mowing, and others can be maintained a couple of times a year.

8. The Difference Between Detention and Retention Ponds

The main difference between a detention basin or retention basin, is the presence or absence of a permanent pool of water, or pond. The water level is controlled by a low flow orifice. In most cases, the orifice is part of a metal or concrete structure called a riser. A detention, or dry, pond has an orifice level at the bottom of the basin and does not have a permanent pool of water. All the water runs out between storms and it usually remains dry. A retention basin or pond has a riser and orifice at a higher point and therefore retains a permanent pool of water. A retention pond looks like a regular pond, but plays an important role in controlling stormwater runoff.

The basins are important for storing and slowing stormwater runoff from nearby areas, especially areas with asphalt or concrete development. Stormwater runoff flows much faster from these surfaces than naturally occurring areas and needs to be diverted to ensure the runoff occurs at the desired rate. The amount of cleaning and treatment of the water is limited. Dry basins, or detention basins, only control flood flows. A retention pond can also provide some water quality benefits by reducing pollutants and sediments.

9. General Criteria

Storage may be concentrated in large basin-wide or regional facilities or distributed throughout an urban drainage system. Dispersed or on-site storage may be developed in depressed areas in parking lots, road embankments and freeway interchanges, recreation areas, small lakes, ponds and depressions within urban developments. The utility of any storage facility depends on the amount of available storage, its location within the system, and its operational characteristics. An analysis of such storage facilities should consist of comparing the design flow at a point or points downstream of the proposed storage site with and without storage.

In addition to the design flow, the effect of larger flows expected to pass through the storage facility should be included in the analysis. For most cases ensuring that the 100-year flood is adequately accommodated is sufficient, but in critical situations where there is the possibility of loss of life or significant property damage, the probable maximum flood (PMF) should be evaluated.

The design criteria for storage facilities should include:

- Release rate;
- Storage volume;
- Grading and depth limitations;
- Outlet works;
- Location and aesthetics; and
- Provisions to ensure public safety.

10. Release Rate

Storage facility release rates shall ensure that the 100-year post- developed flood is detained to the 100-year pre-developed peak runoff rate. Where ever possible multistage outlet works shall be provided to ensure that runoff is detained to historic rates for the conventional design frequency of the downstream drainage system. Some municipalities have specific design storms for which developments must design storage facility release rates. The local requirements are typically adhered to if the downstream drainage system capacity will not be exceeded.

Emergency overflow capacity is required to handle flows exceeding the post-development 100-year discharge. Design calculations are required to demonstrate that runoff from the design storms are controlled.

11. Storage Volume

Storage volume shall be adequate to attenuate the post-development peak discharge rates to pre-developed discharge rates for the 100-year storm and the conventional design frequency of the downstream drainage system.

Routing calculations should be used to demonstrate that the storage volume is adequate. If sedimentation during or after construction causes loss of detention volume, design dimensions shall be restored before completion of the project and through regular maintenance. For detention basins, all detention volume shall be drained within 72 hours to prevent excessive saturation of embankment material.

12. Grading and Depth

Following is a discussion of the general grading and depth criteria for storage facilities followed by criteria related to detention and retention facilities.

General

Grading is important to ensuring adequate storage volume and an aesthetic appearance is provided in the storage facility. It is critical though, to the safety of people who might live near the facility or utilize the facility for recreational purposes. As a general rule, slopes should be as flat and depths as shallow as site conditions and safety considerations allow. If a person were to fall into the facility, slopes should be flat enough that they can easily climb out. Slope terracing is sometimes effective. Slope stabilization should be with vegetation or other materials which are traversable when wet. The following is a discussion of the general grading and depth criteria for storage facilities:

- The construction of storage facilities usually requires excavation or placement of earthen embankments to obtain sufficient storage volume.
- Vegetated embankments shall be less than 20 feet in height and shall have side slopes no steeper than 3:1 (horizontal to vertical). Slopes flatter than 4:1 are preferred.
- Riprap protected embankments shall be no steeper than 2:1. Geotechnical slope stability analysis is recommended for embankments greater than 10 feet in height and is mandatory for embankment slopes steeper than those given above.
- A minimum freeboard of one foot above the 100-year design storm high water elevation shall be provided for impoundment depths of less than 10 feet.
- Impoundment depths greater than 10 feet are subject to the requirements of the Safe Dams Act unless the facility is excavated to this depth.

Detention Pond Depth and Grading

Detention facilities should be provided only where they are shown to be beneficial by hydrologic, hydraulic, and cost analysis. Areas above the normal high-water elevations of storage facilities should be sloped at a minimum of 5% toward the facilities to allow drainage and to prevent standing water. Careful finish grading is required to avoid creation of upland surface depressions that may retain runoff. Areas within storage facilities should be sloped at a minimum of 2% toward the outlet works to allow drainage and to prevent standing water. A small paved apron should be provided around the outlet works to allow for maintenance access and prevent vegetation from clogging the release structure. A low flow or trickle channel constructed across the facility bottom from the inlet to the outlet is recommended to convey low flows, and prevent standing water conditions.

13. Outlet Works

Outlet works selected for storage facilities typically include a principal spillway and an emergency spillway. Outlet works can take the form of combinations of drop inlets, culvert pipes, overflow weirs, stand pipes and orifices.

Perforated riser pipes are discouraged for use as principal spillways but are well suited for water quality release structures. Curb openings may be used for parking lot storage. The principal spillway is intended to convey the design storm without allowing flow to enter an emergency outlet. For large storage facilities, selecting a flood magnitude for sizing the emergency outlet should be consistent with the potential threat to downstream life and property if the basin embankment were to fail. The minimum flood to be used to size the emergency outlet is the 100-year flood. The sizing of a particular outlet works shall be based on results of reservoir routing calculations.

Location

In addition to controlling the peak discharge from the outlet works, storage facilities will change the timing of the entire hydrograph. If several storage facilities are located within a particular basin, it is important to determine what effects a particular facility may have on combined hydrographs in downstream locations. For all storage facilities, channel routing calculations shall proceed downstream to a confluence point where the drainage area being analyzed represents 10% of the total drainage area. At this point, the effect of the hydrograph routed through the proposed storage facility on the downstream hydrograph shall be assessed for detrimental effects on downstream areas.

14. Outlet Hydraulics Outlets

Sharp-crested weir flow equations for no end contractions, two end contractions, and submerged discharge conditions are presented below, followed by equations for broad-crested weirs, v-notch weirs, proportional weirs, and orifices, or combinations of these facilities. If culverts are used as outlets works, procedures presented in the Culvert Chapter should be used to develop stage-discharge data.

Sharp-Crested Weirs

A sharp-crested weir with no end contractions is illustrated below. This discharge equation for this configuration is (Chow, 1959):

$$Q = [(3.27 + 0.4(H/Hc)]\ LH^{1.5}$$

Where: Q = discharge, cfs

H = head above weir crest excluding velocity head, ft Hc = height of weir crest above channel bottom, ft

L = horizontal weir length, ft

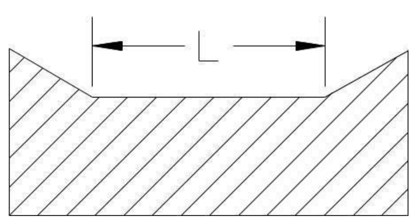


Figure 7 Sharp-Crested Weir No End Contractions

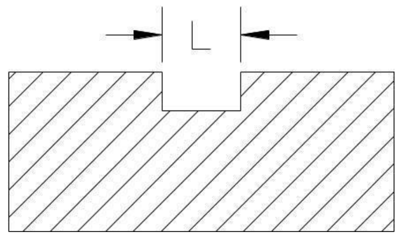


Figure 8 Sharp-Crested Weir and Head

A sharp-crested weir with two end contractions is illustrated below. The discharge equation for this configuration is (Chow, 1959):

$$Q = [(3.27 + .04(H/Hc)] (L – 0.2H) H^{1.5}$$

Where: Variables are the same as equation 6.4.

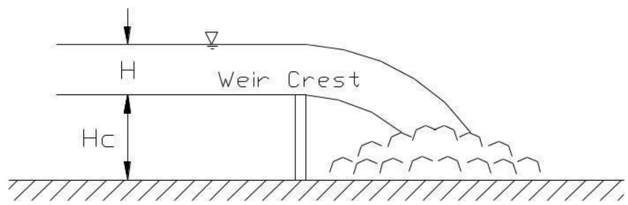


Figure 9 Sharp-Crested Weir, Two End Contractions

A sharp-crested weir will be affected by submergence when the tail water rises above the weir crest elevation. The result will be that the discharge over the weir will be reduced. The discharge equation for a sharp-crested submerged weir is (Brater and King, 1976):

$$Qs = Qf(1 – (H2/H1)^{1.5})^{0.385}$$

Where: Qs = submergence flow, cfs Qf = free flow, cfs

H1 = upstream head above crest, ft

H2 = downstream head above crest, ft

Broad-Crest Weirs

The equation for the broad-crested weir is (Brater and King, 1976):

$$Q = CLH^{1.5}$$

Where:

Q = discharge, cfs

C= broad-crested weir coefficient L = broad-crested weir length, ft H = head above weir crest, ft If the upstream edge of a broad-crested weir is so rounded as to prevent contraction and if the slope of the crest is as great as the loss of head due to friction, flow will pass through critical depth at the weir crest; this gives the maximum C value of 3.087. For sharp corners on the broad- crested weir, a minimum C value of 2.6 should be used. Information on C values as a function of weir crest breadth and head is given in Table 6-2

V-Notch Weirs

The discharge through a v-notch weir can be calculated from the following equation (Brater and King, 1976):

***Q* =2.5 tan(ş/2)$H^{2.5}$**

Where: Q = discharge, cfs

ş = angle of v-notch, degrees H = head on apex of notch, ft

Proportional Weirs

Although more complex to design and construct, a proportional weir may significantly reduce the required storage volume for a given site. The proportional weir is distinguished from other control devices by having a linear head-discharged relationship achieved by allowing the discharge area to vary nonlinearly with head.

Design equations for proportional weirs are (Sandvic, 1985):

$$Q = 4.97\, a^{0.5}\, b(H - a/3)$$

$$x/b = 1 - (1/3.17)\,(\text{arc tan } (y/a)^{0.5})$$

Where: Q = discharge, cfs

Dimensions a, b, h, x, and y are shown below

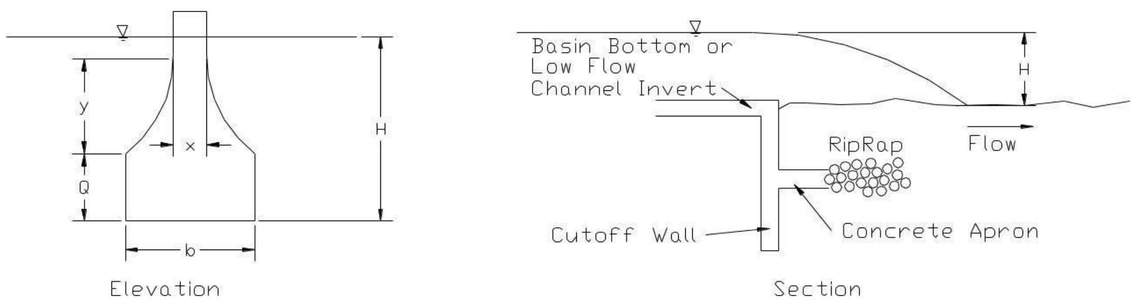


Figure 10 Proportional Weir Dimensions

Orifices

Pipes smaller that 12" may be analyzed as a submerged orifice if H/D is greater than 1.5. For square-edged entrance conditions,

$$Q = 0.6A(2gH)^{0.5} = 3.78D^2H^{0.5}$$

Where: Q = discharge, cfs

A = cross-section area of pipe, ft^2

g = acceleration due to gravity, 32.2 ft/s^2 D = diameter of pipe, ft

head on pipe, from the center of pipe to the water

H = surface

Combination Outlets

Combinations of weirs, pipes and orifices can be put together to provide a variable control stage-discharge curve suitable for control of multiple storm flows. They are generally of two types: shared outlet control and separate outlet controls. Shared outlet control is typically a number of individual outlet openings, weirs or drops at different elevations on a riser pipe or box that all flow to a common larger conduit or pipe.

Separate outlet controls are less common and normally consist of a single opening through the dam of a detention facility in combination with an overflow spillway for emergency use. For a complete discussion of outlets and combination outlets see Municipal Stormwater Management by Debo and Reese

15. PRELIMINARY DETENTION CALCULATIONS

Storage Volume

A preliminary estimate of the storage volume required for peak-flow attenuation may be obtained from a simplified design procedure that replaces the actual inflow and outflow hydrographs with the standard triangular shapes shown in Figure

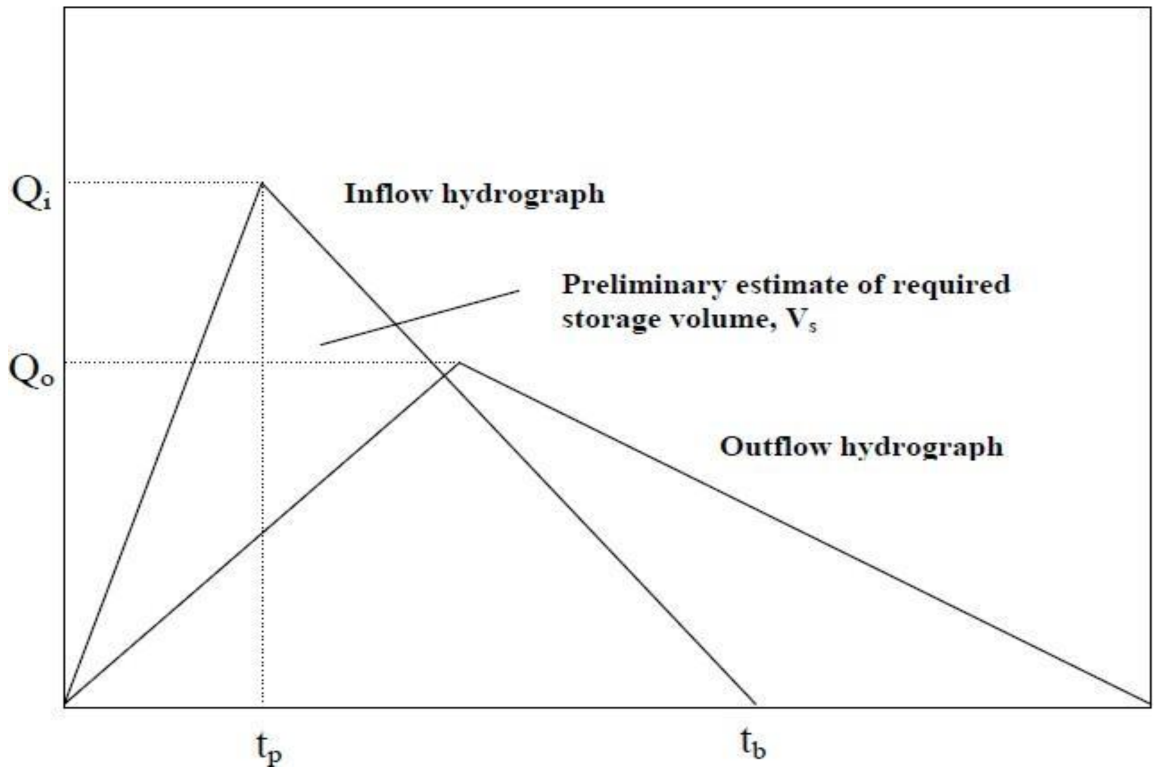


Figure (11) Triangular Shaped Hydrographs (For Preliminary Estimate of Required Storage Volume).

The required storage volume may be estimated from the area above the outflow hydrograph and inside the inflow hydrograph, expressed as:

$$VS = 0.5Ti(Qi - Qo)$$

where: VS = storage volume estimate, ft3; Qi = peak inflow rate, ft3/s; Qo = peak outflow rate, ft3/s; Ti = duration of basin inflow, s.

16. CONSTRUCTION AND MAINTENANCE CONSIDERATIONS

General

An important step in the design process is identifying whether special provisions are warranted to properly construct or maintain proposed storage facilities. To assure acceptable performance and function, storage facilities that require extensive maintenance are discouraged. The following maintenance problems are typical with urban detention facilities, and facilities shall be designed to minimize problems:

- Weed growth,
- Grass and vegetation maintenance,
- Sedimentation control,
- Bank deterioration,
- Standing water or soggy surfaces,
- Mosquito control,
- Blockage of outlet structures,
- Litter accumulation, and
- Maintenance of fences and perimeter plantings.

Proper design should focus on the elimination or reduction of maintenance requirements by addressing the potential for problems to develop:

- Both weed growth and grass maintenance may be addressed by constructing side slopes that can be maintained using available power- driven equipment (e.g., tractor mowers).
- Sedimentation may be controlled by constructing traps to contain sediment for easy removal or low-flow channels to reduce erosion and sediment transport.
- Bank deterioration can be controlled with protective lining or by limiting bank slopes.
- Standing water or soggy surfaces may be eliminated by sloping basin bottoms toward the outlet, constructing low-flow pilot channels across basin bottoms from the inlet to the outlet, or constructing underdrain facilities to lower water tables.
- In general, when the above problems are addressed, mosquito control will not be a major problem.
- Outlet structures should be selected to minimize the possibility of blockage (i.e., very small pipes tend to block quite easily and should be avoided).
- Finally, one way to address the maintenance associated with litter and damage to fences and perimeter plantings is to locate the facility for easy access where maintenance can be conducted on a regular basis.

17. Sediment Basins

Often detention facilities are used as temporary sediment basins. To control the maintenance of these facilities, some criteria must be established to determine when these facilities should be cleaned and how much of the available storage can be used for sediment storage.

18. PROTECTIVE TREATMENT

Protective treatment may be required to prevent entry to facilities that present a hazard to children and, to a lesser extent, all persons. Fences may be required for detention areas where one or more of the following conditions exist:

- Rapid-stage increases would make escape practically impossible where small children frequent the area.
- Water depths either exceed 2.5 ft for more than 24 h or are permanently wet and have side slopes steeper than 1V:4H.
- A low-flow watercourse or ditch passing through the detention area has a depth greater than 3 ft or a flow velocity greater than 3 ft/s.

➢ Side slopes equal or exceed 1V:2H.

Guards or grates may be appropriate for other conditions but, in all circumstances, heavy debris must be transported through the detention area. In some cases, it may be advisable to fence the watercourse or ditch rather than the detention area.

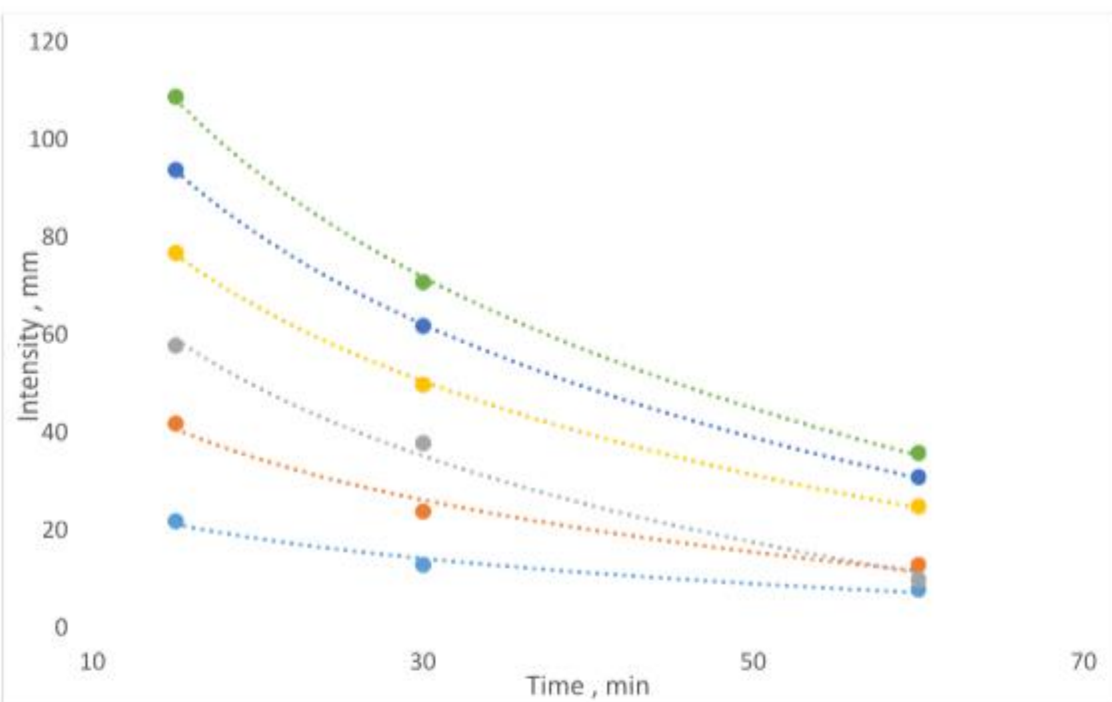
Fencing should be considered for dry retention areas with design depths in excess of 3 ft for 24 h, unless the area is within a fenced, limited- access facility.

19. IDF curve

An IDF curve or graph is produced from an extreme value statistical analysis of at least 10 years of rate 0f rainfall observations. The basic IDF curve information is provided in files containing the IDF tables and graphs. It includes the frequency of extreme rainfall rates and amounts corresponding to the following durations: 5,10,15,30 and 60 minutes and 2,6,12 and 24 hours. Return period are used as the measure of frequency of occurrence and are expressed in years. Estimates of the rates and amounts for the durations noted above and their confidence intervals for the rates are provided for return periods of 2,5,10,25,50 and 100 years.

20. Return period

Return period is defined as the reciprocal of the annual probability that an event occurs or is exceeded. So a 50 year return period event has a 1/50 or 2% probability of being equaled or exceeded in any given year. Return period is sometimes known as recurrences of a rainfall event of a given magnitude. The rainfall amounts and rates for various return periods are calculated by fitting a series of annual maximum rainfall rates for the corresponding durations to a given statistical distribution.



		100-year 50-year 25-year
		10-year 5-year 2-year

Figure (12) IDF curve for Baghdad city

21. Case of study

I take Al-Sadder city as an example to calculate the volume required for detention pond and the available area for designing this pond. The elevation in Al-Sadder city is at range 30-40 m and is variable for whole city but in general the elevation in center of city is high and in the sides be low. So we can divide the area for many sections depending on the slope and assume the volume of detention pond for each section.

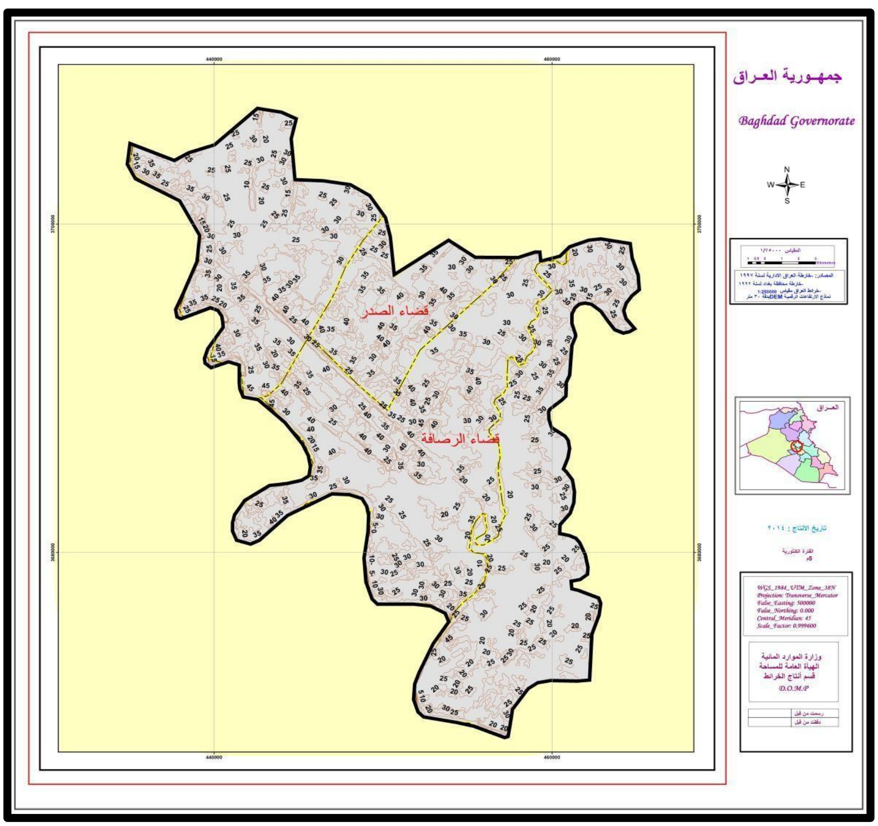


Figure (13) contour lines for the east of Tigris River

I will take section where is in the end of city

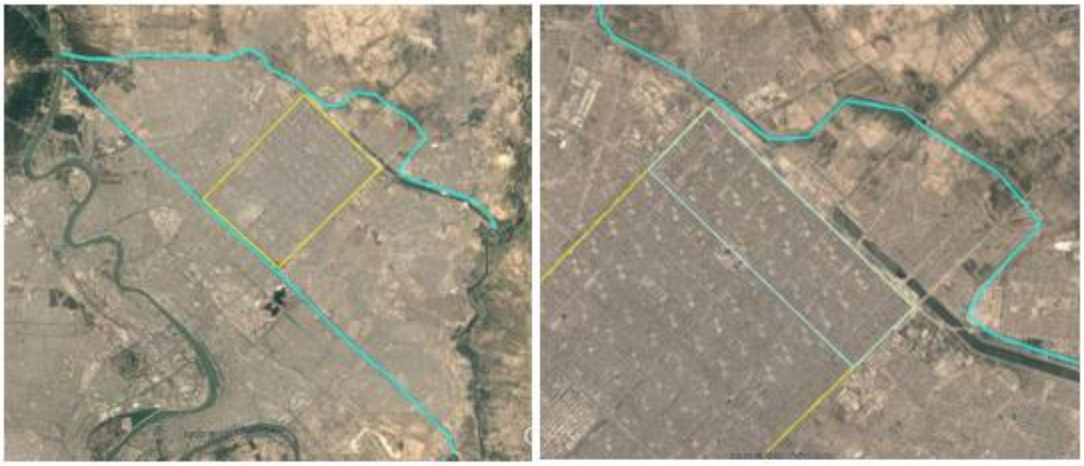


Figure (14) Al-Sadder city

this area facing major flood and the storm water accumulative in the streets for many days and we can discharge the water from detention pond to Al-Jiesh channel so from google earth the area of this section is approximately 6 km2 and from IDF curve I take the intensity 71 mm for 100 years and coefficient 0.85 and duration of storm is 3 hour

Volume of rainfall =6000000*0.071 = 426000 m3

Discharge = 426000 / (3*3600) = 39.4 m3/s * 0.85 = 33.5 m3/s

Let the discharge capacity from sewage plant is 3 m3/s and the outlet flow from the detention is 1.5 m3/s

Q = 33.5-3-1.5 = 29 m3/s

Take the duration of basin inflow is 5hr Vs = 0.5(5*3600(29)) = 261000 m3

Let the depth of pond is 3 m Area = 261000/3 = 87000 m2

Figure (15) location the pond

For other sections in this city the place of pond will relative to one of two ways, the first the outflow from pond discharge to the near channel (Al-Jiesh or Al-Shorta) I take this option because we want to usefulness from this water to increase the discharge of channels and then the river. The second way the outflow of pond discharge to near sewage plant that take to get rid of the flood as possible.

22. Storm water management and road tunnel

In urban cities we face big problem is the empty spaces we can see it in Baghdad for example. In Malaysia they work for another solution to solve this problem, they use 13.2m diameter tunnel consists of a 9.7 km storm water bypass tunnel and is the first multi-functioning tunnel in the world

Figure (16) Storm water management and road tunnel Main purpose to:

Divert floodwaters

Reduces traffic congestion during rush hour Motorists reduce travel times So if we use it in the highway of Al-jiesh channel, in the storm duration the flow enters the tunnel and in other side discharged the water to the Al-Jiesh channel in this situation we get rid from the storm water and in other time we get the other benefit reduces traffic congestion.

Conclusions:

1. The annual rainfall rate for Baghdad is 147 mm.
2. The monthly rainfall occurs during the six months of rain is 25 mm per month, which can be drainage by the networks in the case of completion of strategic transport lines (Khansa line in the side of Rusafa and the western line and the south west side of Karkh) where not completed.
3. The overall capacity for the lines of rainwater drainage networks for the city of Baghdad can absorb rain up to 17 mm and incase of increasing the amount of rainfall from the above and causes the loss of water outside the network.
4. The area of the city of Baghdad (900 km2) divided into three main sites are:

- East of the canal area 233 km2
- West of the canal to the Tigris river (Rusafa) 145 km2
- West of the Tigris river (Karkh) 504 km2

1. Through the previous seasons the amount of time needed to pass the water falling on the city of Baghdad, it appears that an increase of 1 mm requires about 6 hours to pass through the network.
2. The Municipality of Baghdad is not used IDF curve in design stage, but using estimate the quantities of water falling on 60% from the city of Baghdad area as this method is not accurate and lead to major problems, as happened in 2015.
3. The lack of empty spaces in the in inside the districts make design detention pond in required space is major problem.

Recommendations:

1. The use of IDF curve is required when designing any projects (related to storm water) specially a sewer network for any area within the city of Baghdad.
2. Use storm water management solution and road tunnel to get rid from empty spaces problem if we want design detention pond.

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