* هذه الدورة مهمة ؟
تدخل في حساب

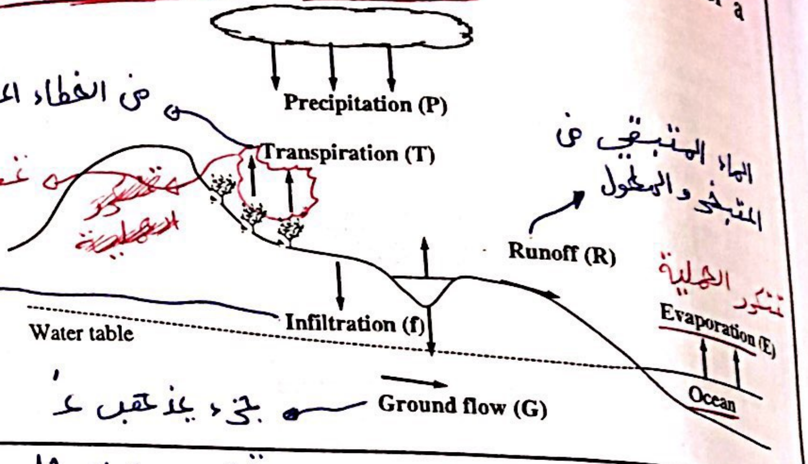
mass balance

Hydrologic cycle "الدورة الهيدرولوجية"

تمثل

It represents the water cycle on the earth or part of it. It is useful to study the mass balance of water over a specified region or the whole earth.

مفيد



تجميع الماء مثل
البحر، ينابيع ومصدره من Insiltration

Hydrologic cycl

For given region, the
over the time appears

$$\Delta S = V_{in} - V_{out}$$

معادلة خطية
مهمة في إدارة
السدود

V_{in}: total water volu
V_{out}: total water vol

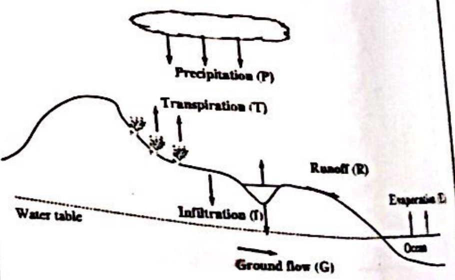
Hydrologic cycle

Water is distributed in the hydrologic cycle as follows: 97.5% as seawater and 2.5% as freshwater (including glaciers and ice caps).

مكونات

Components of the cycle are:

- Precipitation (P), مصدر رئيسي — هطول (مطر، ثلج)
- Evaporation (E), — تبخر
- Transpiration (T), — نتح من الغطاء النباتي
- Infiltration (f), — الرشح
- Surface runoff (R), — جريان سطحي
- Groundwater flow (G)



نهمله في حالة
كان الغطاء النباتي
قليل

Hydrologi

Ex: water bala

A dam lake of
for January
cumulative pr
evaporation fr
infiltration fro
the lake wate

ut
حتى لو
كان منه
لا يؤخذ
عل الكل

Soln:

Runoff

* كتلة الماء ثابتة .

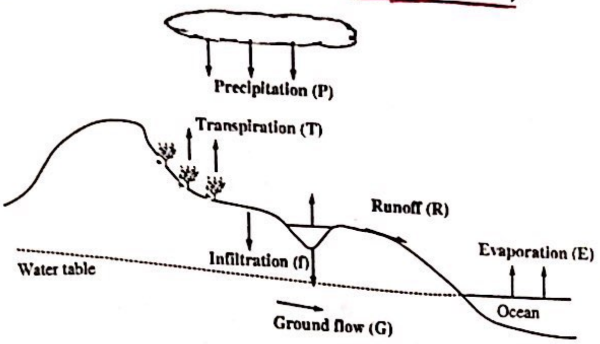
أساس هذه المعادلة من الدورة الهيدرولوجية

Hydrologic cycle: mass balance

For given region, the change in water volumes (mass) over the time appears as a change in the storage (ΔS):

$$\Delta S = V_{in} - V_{out}$$

معادلة خطية مهمة في إدارة السدود



V_{in}: total water volume inters the region (system) ⊕

V_{out}: total water volume leaves the region (system) ⊖

* الحجم و الكتلة للماء نفسه .

* ارتباط الكثافة مع الحرارة شيء بسيط لذلك نعتبرها 1000

ΔS → ⊕ → تعبئة
→ ⊖ → تفريغ

Hydrologic cycle

In

متوسط خلال شهر

شهر ٤ / 30

Ex: water balance application

A dam lake of 40km² receives an average water flow of 0.56m³/s for January while delivers 0.48m³/s as leaving runoff. The cumulative precipitation for January is 45mm. The cumulative evaporation from the lake surface is 125mm and the cumulative infiltration from the lake bottom is 25mm. Calculate the change in the lake water level during January?

out

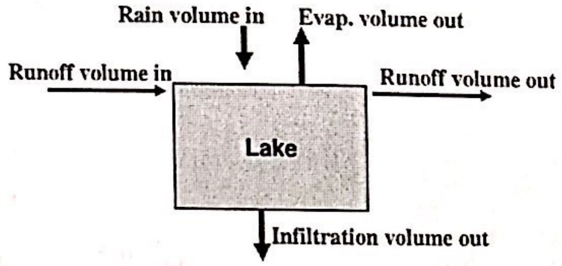
Out

حتى لو
كان متو
لا يؤثر
على الحل

العمق الناتج من المطول In

out

Soln:



* التبخر يتأثر بكثير من العوامل ويحدث طالما T > 0° .

⊛ ملاحظات قبل الحل :-

١- تحويل الوحدات

٢- المطلوب خلال شهر

٣- معرفة In, out

$40Km^2 = 40 * 1000 * 1000$

الشهر 31 يوم واليوم 24 ساعة والساعة
60 دقيقة والدقيقة 60 ثانية .

$\frac{45mm}{1000} = 0.045 m$

Hydrologic cycle

Volume in:

$V_{R\text{-}in} = 0.56 \times 60 \times 60 \times 24 \times 31 = 1,499,904m^3$ → خلال شهر

$V_P = 0.045 \times 40,000,000 = 1,800,000m^3$

Volume out:

$V_{R\text{-}out} = 0.48 \times 60 \times 60 \times 24 \times 31 = 1,285,632m^3$

$V_E = 0.125 \times 40,000,000 = 5,000,000m^3$

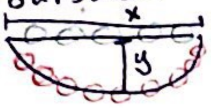
$V_I = 0.025 \times 40,000,000 = 1,000,000m^3$

$$\Delta S = V_{in} - V_{out}$$
$$= (1,499,904+1,800,000) - (1,285,632+5,000,000+1,000,000)$$
$$= \ominus 3,985,728m^3$$

The change in the lake water level is a drop =
$= 3,985,728 / 40,000,000 = 0.1m = 10cm.$

على شكل عمق

المساحة كبيرة
لذلك فرضنا
نفس Area
surface



Watershed definition

* حساب Q لقو المصمم .

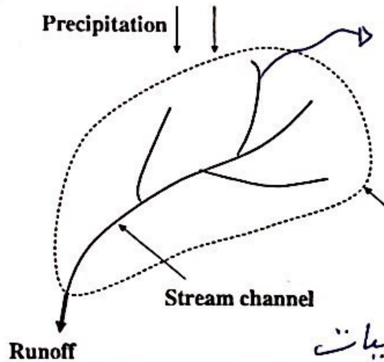
الجابية المطرية

watershed :- فقط للجريان السطحي

catchment :- يأتي لها الهطول

basin :- مساهمة من البرك، ينابيع

The ①watershed is defined as the land area that contributes surface flow. The ②catchment is the land area that receives precipitation. The ③basin is usually large and contributes flow from surface and subsurface (groundwater) sources.



روافد شعرية

حدود تفصل الجابيات المطرية

حفزه أخفض نقطة لتجمع المياه

* إذا كانت المسامية صفر يحدث جريان سطحي .

Watershed delineation

"وضع حدود"

Watershed delineation means to mark the watershed borders where surface flow from precipitation will evolve. → يتخلص

Why it is important to delineate the watershed?

Answer:

To compute Q from the watershed!

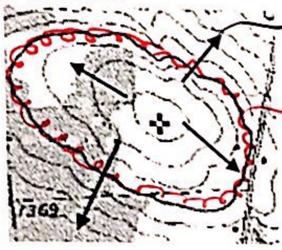
Q α A^n n could be 1.

→ Q والمساحة علاقة طردية

Watershed delineation

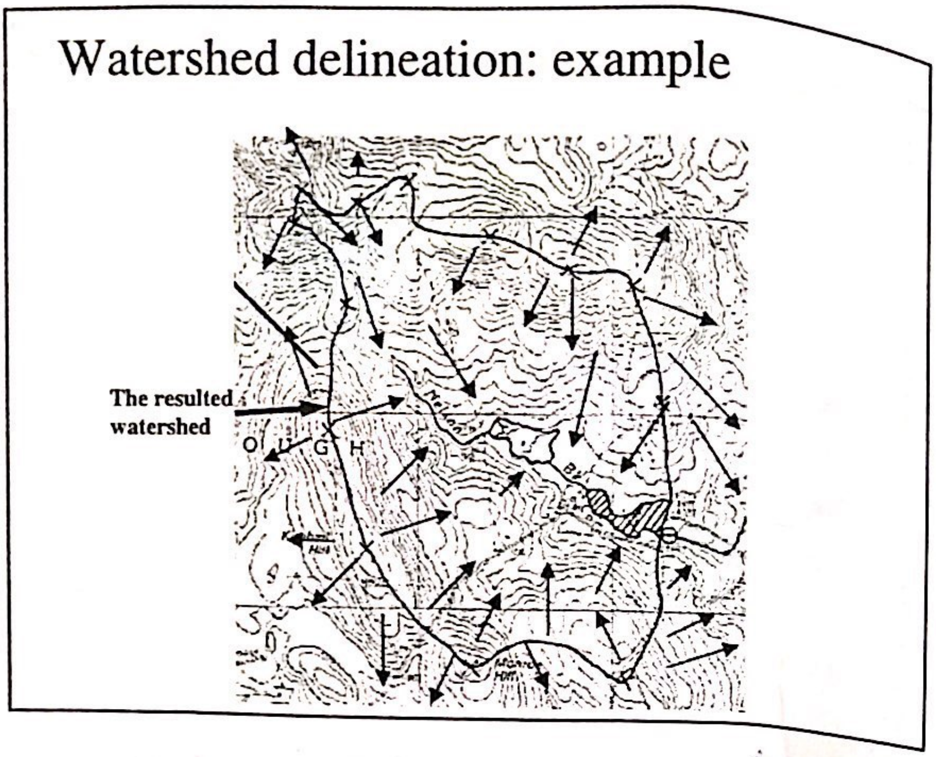
Rules:

1. Locate the major stream, → أقل قيمة لخطوط الكنتور
2. Mark the peaks of surrounding hilltops,
3. Mark flow directions from peaks of hilltops to cross contour lines at right angle, زاوية قائمة
4. Connect the marks at peaks to include the flow direction arrows towards the major stream.

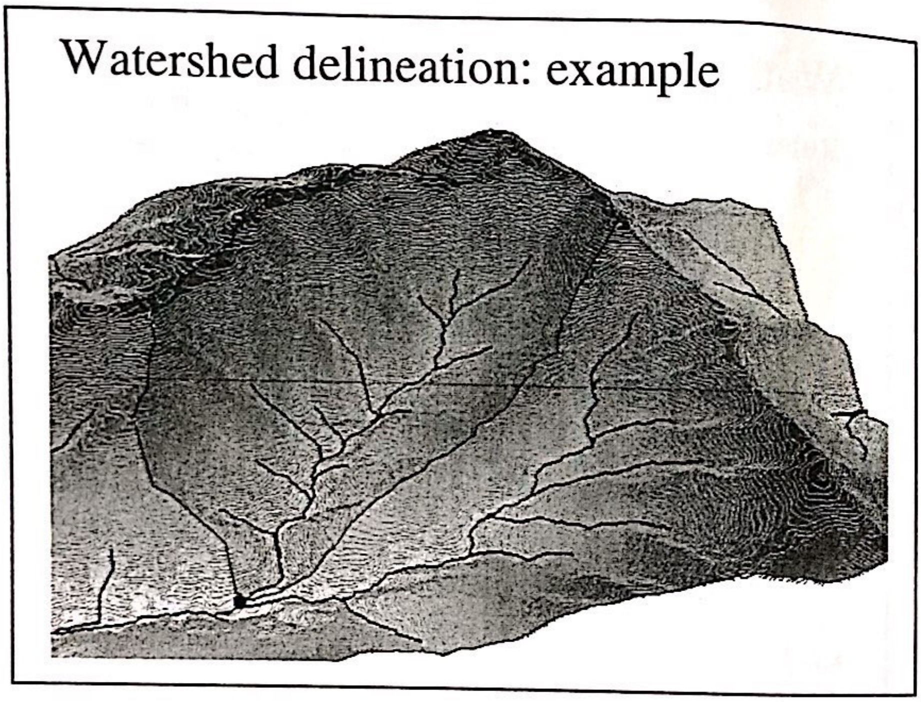


اتجاه
slow

خطوط
كنتور

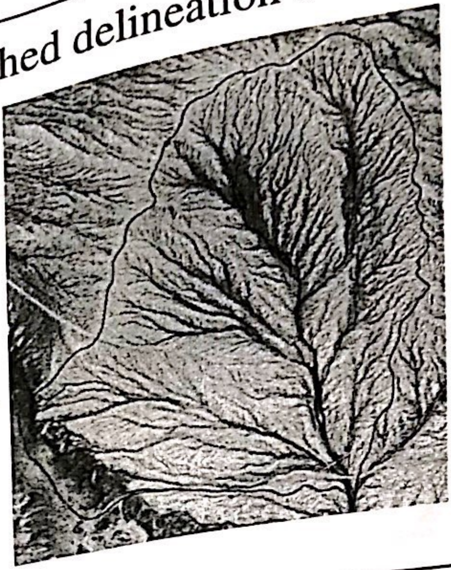


Watershed delineation: example



Watershed delineation: example

Watershed delineation using GIS



Watershed characteristics

كلما زاد الميل زاد Q .

⊛

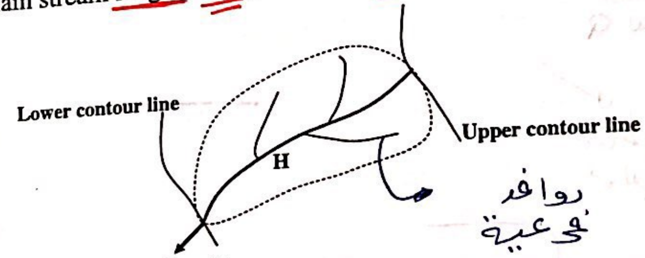
Watershed average slope:

The watershed average slope can be estimated from topographic maps as follows

$$S = \Delta E/H$$

ΔE : elevation difference along the main stream channel,

H : main stream length, map projected distance.



روافد فرعية

* Average weight slope :-

تأثير كل ميل على المجموع الكلي .

⊛ كل منطقة لها ~~Slope~~
ارتفاع لذلك نحسب لكل ارتفاع Slope .

Watershed characteristics

①

Watershed shape:

The watershed shape highly reflects the flow amount (m^3/s) and the time needed to reach the peak flow. The watershed shape is a result of the watershed slope.

In general, two types of watershed shapes are recognized:

شكل الجابية المطحية .

1- Elongated watersheds: results from steep slopes.

حاد

الستطالة

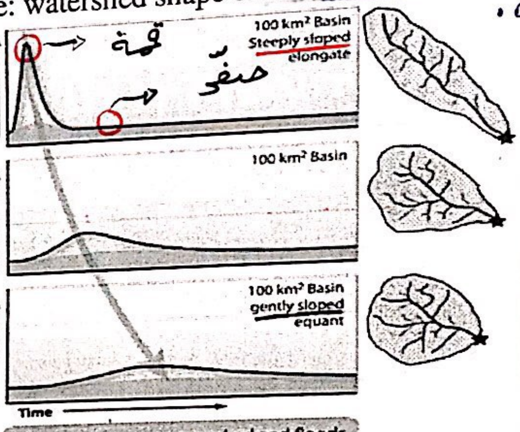
2- Equant watersheds: results from gentle slopes.

أقحب للدائرة
أو ورقة، رغيش

Watershed characteristics

Example: watershed shape effect on the flow.

نفس المساحة والظروف .



Hydrographs are more peaked and floods more abrupt in narrow, steep basins than in equant, gently sloping basins.

قمة مفاجئة
خلال مدة قصيرة
مثل السلطا .
مثل قوة

قمة موزعة
Low Q

مناطق سهلية

*

$Q = \frac{v}{t}$

الحجم والحد

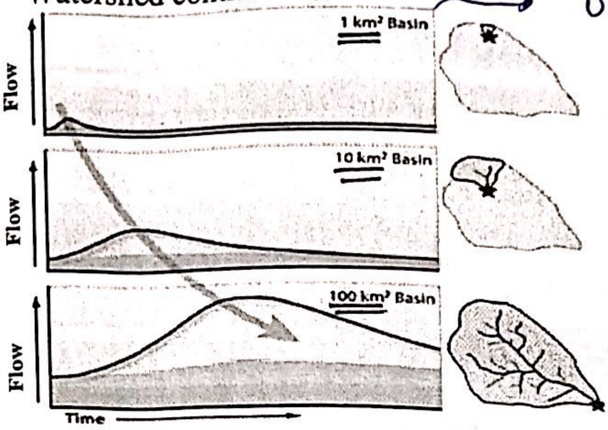
or
water profile

المتدفق قليل ⇐ علان الزمن كبير
و الميل قليل من خلال
Manning معادلة

Watershed characteristics

Watershed contributing area:

Q قليلة لأن
A قليلة

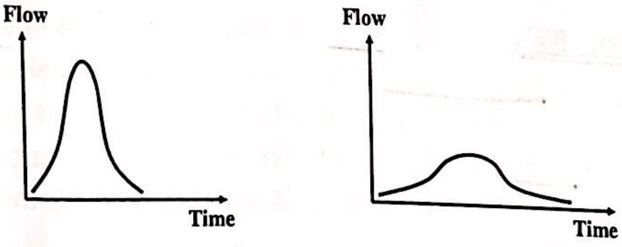


Conclusion:

As area increases, the flow amount increases, i.e. Q α A

⊛المتدفق
والمساحة
علاقة طردية .

Watershed characteristics



Case A

Case B

Steep watershed discharges flow like case .A.

Watershed of rough surface discharges flow like case ..B

سرعة قليلة
الزمن كبير

Watershed characteristics

Drainage density: "كثافة التصريف"

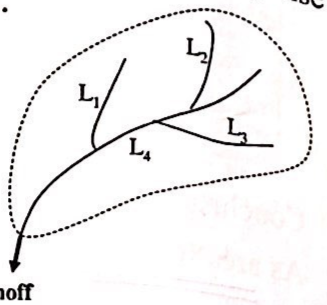
فوائده :-
١- أغراض المقارنة
٢- ,ايجاد Q
اذا وُجدت D

The drainage density (D) is the ratio of the total length of all streams formed to the watershed area. The drainage density reflects the response of the watershed to the rainfall. It can be used to classify watersheds. Usually high D values means high and quick response (flow) of the watershed to rainfall.

⊛ تُعطي الاستجابة الجابية للأمطار من حيث التصريف (سريع، بطئ)

$$\underline{\underline{D}}=\frac{\sum L \rightarrow}{A}$$

طول القنوات



* D = zero

↳ zero slope → $\Sigma L = 0$

لا يوجد ينابيع ، برك

Watershed characteristics

* سؤال مباشر

Ex:

Watershed A of 4.1km^2 area has streams of 11.2km total length and watershed B of 0.58km^2 area has streams of 1.55km total length. If watershed A discharged peak flow of 1m^3/s from 30 minutes storm, estimate the peak flow resulted from watershed B when subjected to the same storm?

Soln:

$D_A = 11.2 / 4.10 = 2.73$

$D_B = 1.55 / 0.58 = 2.67$

Conclusion: $D_A \approx D_B$ (similar watersheds)

↳ الظروف قريبة من بعضها

Watershed characteristics

Soln:

The flow Q is directly proportional to the area A.

$Q \, \alpha \, A$ or $Q = k \times A$, or ratio $k = Q/A$ is constant.

$k_A \approx k_B$ because $D_A \approx D_B$,

$$\begin{cases} Q = U A \\ Q = K A \end{cases}$$

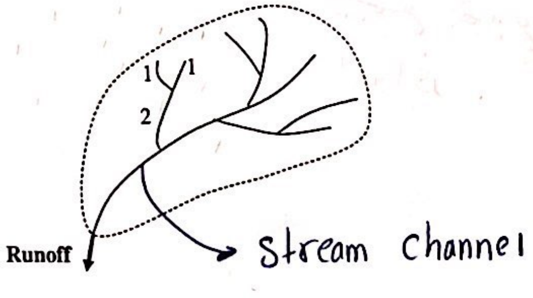
$$\frac{Q_A}{A_A} = \frac{Q_B}{A_B}$$

$Q_B = (0.58 \times 1)/4.1 = 0.141 \mathrm{m}^3/\mathrm{s}$.

Watershed Bifurcation "تفرعات في Strem"

Stream order and Horton laws:

The stream order is used to classify watersheds. The order 1 is assigned to the smallest stream in the watershed, the order 2 is assigned to the next larger stream, and so on. The Horton laws can be used for computational purposes.

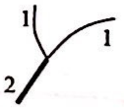


⊛ التفرعات ليست عشوائية , بل لها آلية
محددة وهي متشابهة حتى لو اختلفت
الجابيات .

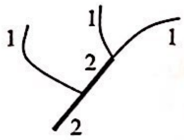
Watershed Bifurcation

Stream ordering rules:

When 2 streams of the same order (order *i*) are joined, the stream formed has the order of *i* + 1.



When a stream of order *i* meets a stream of order *i* + 1, then the stream formed has the order *i* + 1.

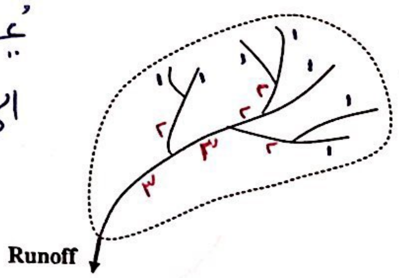


Watershed Bifurcation

Ex:

For the following watershed, order all streams and estimate the principal stream order.

له أعظم
يُجمع جميع
الروافد .

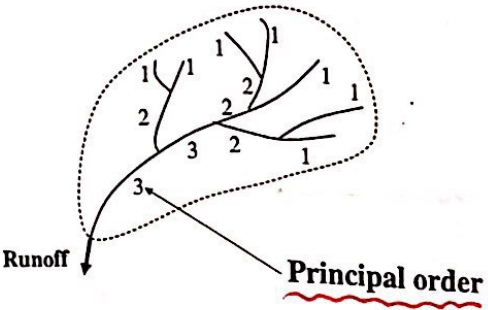


Watershed Bifurcation

Soln:

The first streams are labeled by the order 1, finish the rest using the rules mentioned previously. The principal order (k) = the largest order resulted.

$k = 3$

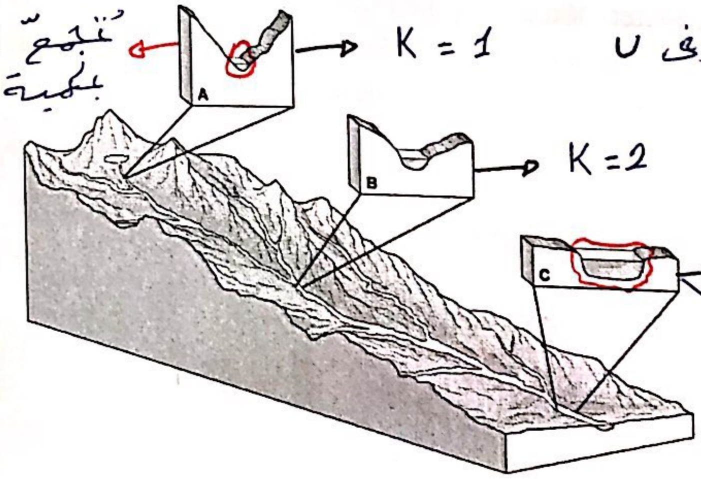


لو تشابه نعرف أنّ الميل والمساحة متساويتان .

Watershed Bifurcation

Changes in the watershed stream properties versus the stream order.

* الشكل مع الرتبة .



تجمّع الماء بكمية قليلة

K = 1

حرف U

K = 2

K=3 □

Q عالي و تجمع الماء بكمية كبيرة...

$\frac{N_3}{N_4} = \frac{N_4}{N_5}$

"دقيقة جداً" لأنها مبنية على الحساب

عدد Stream لـ أي order

كمية ثابتة

Watershed classification

Horton laws of streams:

Law of stream number (Bifurcation ratio):

$$\frac{N_i}{N_{i+1}} = R_n \longrightarrow N_i = R_n^{k-i}$$

أعلى رافد

عدد Stream الذي لهم رتبة i

where *k* is the principal stream order.

$\frac{N_3}{N_5}$ ✗

$\frac{N_3}{N_4}$ ✓

Law of stream length

$$\frac{\sum L_{i+1}}{\sum L_i} = R_L \longrightarrow L_i = \sum L_1 R_L^{i-1}$$

كمية ثابتة

Watershed characteristics

Exercise:

A watershed of 5.71km² area has principal stream order of 4. If streams of orders 3 and 4 have 1.23km and 0.45km total length respectively, compute the watershed drainage density?

What is the length of streams of order 6?

zero

أعلى شيء هو 4

Mean and Variance and probapility of repete

Statistical methods in hydrology

The design of surface water systems depends on natural hydrologic variable parameters like: precipitation, runoff, humidity, wind speed, etc. Such parameters are random variables → كمية متغيرة لا يمكننا معرفتها

To handle such hydrologic random variables, statistical methods like the expectation, the variance, probability distribution functions, and frequency analysis are used. Such useful statistical methods will enable us to obtain the exceedance probability and the return period for design purposes, constructing IDF curves for computing peak flows for sewer sizing. ← مدة الفشل

كل كم يحدث الفشل .

* R.V → مرة عالي ومرة واطي ومن دون انضباط مثل كميات الأمطار .

* التجاوز .

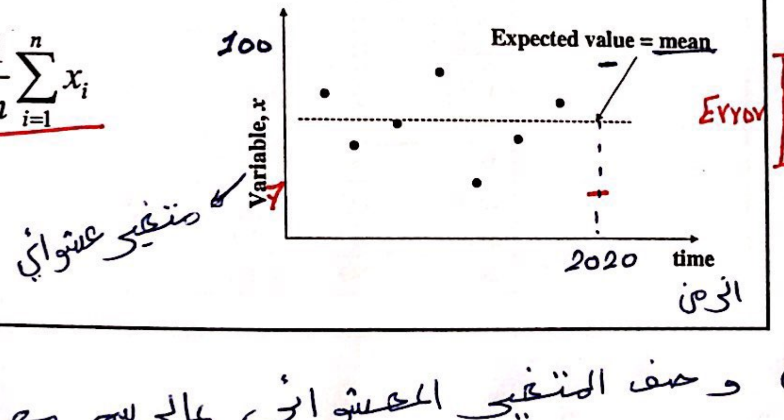
* التصميم يكون على رقم محدد فما احتمال تجاوزه ؟

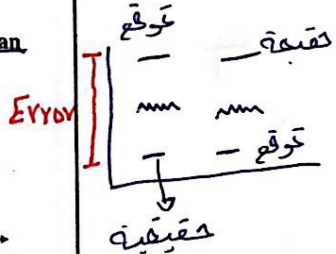
Statistical methods in hydrology

The expected value:

Given a historical record of hydrologic variable (*X*), for example the precipitation over *n* years, then the expected value (mean or average) of the variable is estimated as:

$$\overline{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

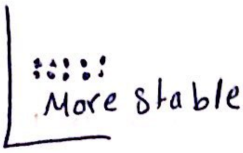


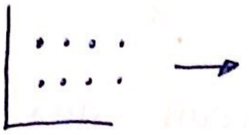


* وصف المتغير العشوائي بالرسم مع الزمن .

* توقع كمية الأمطار عند تاريخ 2020 والأصح توقع mean وليس رقم عشوائي لكي يقل Error .

سو تشتت
القيم قليل وهو
الأفضل .





تشتت
عالي

Error :-
Real - Expected

Statistical methods in hydrology

تباين

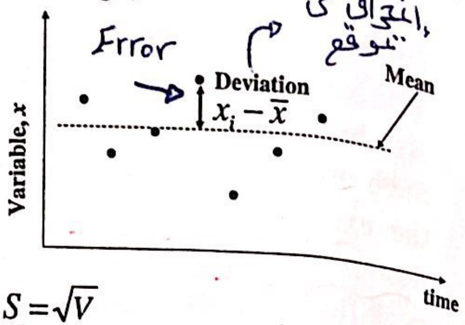
The variance and standard deviation:

Given a historical record of hydrologic variable (*X*), for example the precipitation over *n* years, then the variance is the squared deviation of the variable about its expected value (mean or average):

* كلما كان
Error
أكبر دلّ على
المتغير العشوائي
فيه تشتت
وفيه شدة في
المتغير .

$$V=\frac{1}{n-1}\sum_{i=1}^{n}\left(x_i-\overline{x}\right)^{②}$$

عملنا التربيع عشان
المجموع صفر .



The standard deviation $\underline{\underline{S}}=\sqrt{V}$

معدل Error
تباعد القيم عن توقعها .

* أقل عشوائية تعني
أكثر انضباطية .

Statistical methods in hydrology

Example:

Given a historical record of rainfall depths (*x*) for years 1995 – 2010 at gauging station in Jordan. Estimate the mean and the standard deviation of the rainfall depth?

Year	Rainfall (mm)	Year	Rainfall (mm)
1995	212	2003	188
1996	123	2004	141
1997	156	2005	197
1998	225	2006	180
1999	134	2007	96
2000	175	2008	150
2001	237	2009	207
2002	249	2010	167

Soln: $n = 16$

Year	x_i	Year	x_i
1995	212	2003	188
1996	123	2004	141
1997	156	2005	197
1998	225	2006	180
1999	134	2007	96
2000	175	2008	150
2001	237	2009	207
2002	249	2010	167

The rainfall expected value (mean) =

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i = \frac{1}{16} \times 2837 = 177.3 \text{ mm}$$

Statistical methods in hydrology

Soln: $n = 16$

Year	x_i	$(x_i - \bar{x})^2$	Year	x_i	$(x_i - \bar{x})^2$
1995	212	1203.2	2003	188	114.2
1996	123	2949.8	2004	141	1318.6
1997	156	454.2	2005	197	387.6
1998	225	2274.1	2006	180	7.2
1999	134	1876	2007	96	6611.7
2000	175	5.3	2008	150	746
2001	237	3562.6	2009	207	881.3
2002	249	5139.1	2010	167	106.3

The standard deviation $S = \sqrt{V}$

$$S = \sqrt{V} = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2} = 42.9 \text{ mm}$$

⊛ لو كان في منطقة أخرى وارقم 70

نختار 42.9 لأن التشتت أقل .

Statistical methods in hydrology

Probability analysis of hydrologic variables:

For design of water systems, given the exceedance probability of rainfall or flow random variables, the design rainfall or flow can be obtained. The exceedance probability can be estimated by plotting the cumulative probability distribution.

Examples from CE applications:

- Design flow for culverts,
- Design rain for collection systems (Sewers).

Statistical methods in hydrology

Obtaining the design value:

Assume the task is to design a culvert as shown. The question is: given flow values from weir, what is the value of Q_{design}?

Flow rate (m^3/s)

2.1
1.4
8.8
4.3
0.9
3.9

تم إيجادهم عن طريق Hydrolicks

⊛ الصعوبة في اختيار قيمة Q ، نختارها كبيرة أم صغيرة؟

كبيرة تكلفة عالية

صغيرة خوف من الفشل

Culvert عبّاره

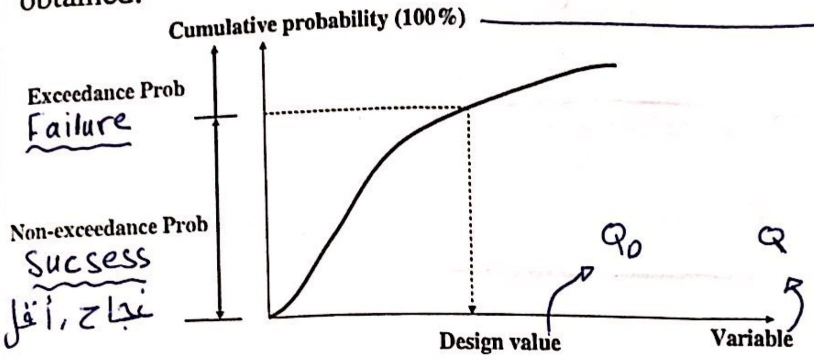
* بإمكاني التصميم على تكلفة أقل لكن حدوث فشل مرة في عمرها .

5%. → لديك 100 قيمة
5 قيم منهم فشلوا

Statistical methods in hydrology

Obtaining the design value:

After drawing the cumulative probability and given the exceedance probability (failure probability: 5% or 10% as provided by the project owner), the design value can be obtained.



أكبر

⊛ تلزمني عند التصميم لـ عباره او أنابيب .

⊛ التمثيل مهم لكي نحدد قيمة التصميم .

⊛ النسبة تعتمد على المكان، اذا توافر فيه أجهزة، كهربائيات .

Design value →

Statistical methods in hydrology

The computation of cumulative probability: طريقة رسم الاحتمالية

The exceedance probability can be estimated by plotting the cumulative probability distribution of the variable (rainfall or flow). Since the exact probability distribution function of the variable is unknown, the plotting position equations can be used to plot the empirical cumulative distribution of the variable.

يجب

One of the common equations to plot the empirical distribution is the **Weibull** plotting position equation.

موقعه فوق، تحت، قريب من التوقع أم بعيد

1) معرفة التوزيع الاحتمالي لهذه prop

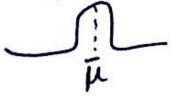
⊛ المشكلة ـ عدم معرفة نوع التوزيع للمتغير لقلة الاعداد

⊛ نماذج رياضية

نعرف كيف توزع المتغير .

مثل التوزيع الطبيعي

Expon, Gamma, ...



Statistical methods in hydrology

The **Weibull** plotting position equation computes the non-exceedance probability $P(X \le x)$ as:

$$\underset{\text{رقم}}{P(\overset{\text{متغير}}{X} \le x)} = \frac{m}{n+1}$$

$P(X \le x)$: probability of observing variable $\le$ specified value x.

m: is data rank (lowest to highest).

n: record length. ← عدد Data point

The probability $P(X > x) = 1 - P(X \le x)$ is the exceedance probability.

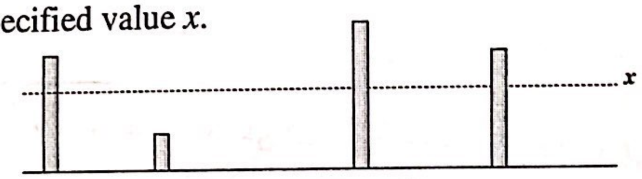
Statistical methods in hydrology

⊛ زمن العودة
متى سيحدث
الفشل ؟

Given the exceedance probability $P(X > x)$, the return period T of the hydrologic variable that exceeds specified value (x) is:

$$T = \frac{1}{P(X > x)}$$

The return period defines on average how frequent or often the variable X will take time to exceed the specified value x.



Q	m
2	1
3	2
3	3
5	4
8	5

2	1
3	2
3	2
5	4
8	5

2	1
3	3
3	3
5	4
8	5

س. لو كان متغير يمثل Q وكان يوجد تكرار ، في الحل الأول يوجد ٢ نفس الحالات أخذت من رتبة واحتمالية وهذا لا يجوز .

الحلول :-

١- أخذ أخفيج

٢- أخذ رتبة أقل

٣- أخذ رتبة أعلى

m = n

Statistical methods in hydrology

Ex:

Annual rainfall at gauging station is recorded for years 1995 – 2010. Plot the distribution of the rainfall. Assuming that the design storm is 210mm, how frequent such rainfall storm is?

لـ القيمة التي تم التصميم عليها

Year	Rainfall (mm)	Year	Rainfall (mm)
1995	212	2003	188
1996	123	2004	141
1997	156	2005	197
1998	225	2006	180
1999	134	2007	96
2000	175	2008	150
2001	237	2009	207
2002	249	2010	167

Statistical methods in hydrology

Soln: Arrange data from the lowest to highest. Rank the arranged data, and use the Weibull equation to calculate probability. $n = 16$.

Sample calculation: for $x = 96$, m = 1, then $P(X \le x) = 1/(16+1) = 0.059$.

$\frac{1}{1+16}$

لا يوجد 1.5

Rank (m)	Rainfall (x)	$P(X \le x)$	Rank (m)	Rainfall (x)	$P(X \le x)$
1	96	0.059	9	180	0.529
2	123	0.118	10	188	0.588
3	134	0.176	11	197	0.647
4	141	0.235	12	207	0.706
5	150	0.294	13	212	0.765
6	156	0.353	14	225	0.824
7	167	0.412	15	237	0.882
8	175	0.471	16	249	0.941

$P(X \le x) \longrightarrow$ احتمال قدوم الأمطار ، أقل من 96 هو 6%

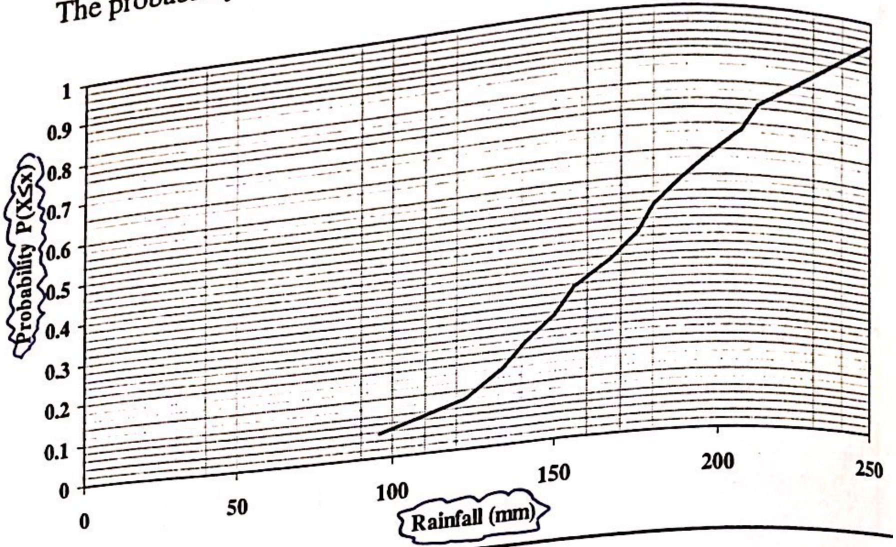
الأصل أن تكون 1 لأن حقنا

⊛ يمثل جميع الحالات لكن لأن n عدد قليل لذلك لم يصل لل 1 .

⊛ يكون
Error
عالي في حال
لما n<30 .

Statistical methods in hydrology

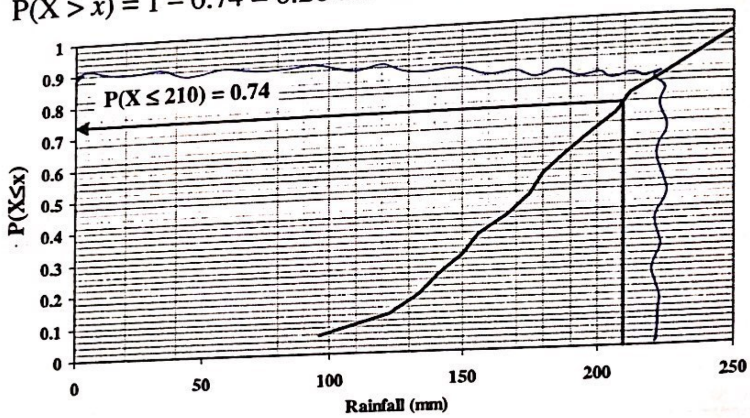
The probability distribution of the annual rainfall.



Statistical methods in hydrology

To find T for the design storm (210mm), then

$P(X > x) = 1 - 0.74 = 0.26$ and $T = 1/0.26 = 3.86 \approx 4$years.



Question: estimate the design storm that being exceeded 40% of time?

س. ما قيمة Design Flow التي لها
نسبة الفشل 10% ؟

$P\ X > 10 = P(X \le 90)$

شدة ، كثافة

Statistical methods in hydrology

Intensity Duration Frequency (IDF) curves

Are set of curves that relate the maximum rainfall intensity (i) of a storm versus the duration (d) and the storm frequency (Return period: T years).

Max Q

التصميم عليه يحمي من الفيضان

مرتبطة مع الزمن و التكرار .

The rainfall intensity is defined as the ratio of the rainfall depth (mm) to the duration (hr),

مثل stress

$$i(mm/hr) = \frac{x(mm)}{d(hr)}$$

عمق ماء

مدة زمنية تساقط عاصفة

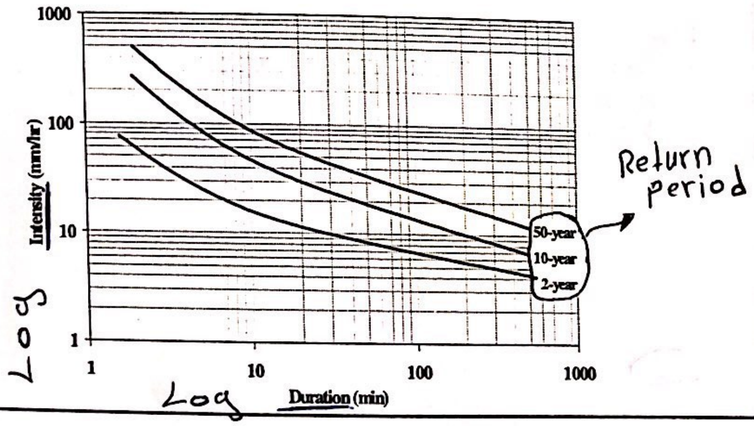
i and d علاقة عكسية

Such curves are useful for computing the peak flow from small watersheds using the rational method.

Statistical methods in hydrology

IDF curves:

Are set of curves that relate the maximum rainfall intensity (i) of a storm versus the duration (d) and the storm frequency (T years).



* هي فريدة وهي دائما تنزل ، اذن علاقة عكسية .

* الشيء المألوف له i أعلى ومعنى مألوف هو تكراره بين فترة وفترة و تكون كبيرة .

Statistical methods in hydrology

To estimate the maximum storm intensity, we need at first to determine the maximum rainfall depth. The theoretical model that fits the distribution of the maximum rainfall depth of a given duration is the extreme value distribution type 1 (Gumbel distribution).

خاص بـ

Max Value

Large

Tall

extreme

$$P(X \le x) = \exp\left[-\exp\left(-\left[\frac{x-u}{\alpha}\right]\right)\right]$$

$$e^{-e^{-\left[\frac{x-u}{\alpha}\right]}}$$

α and u are the model parameters.

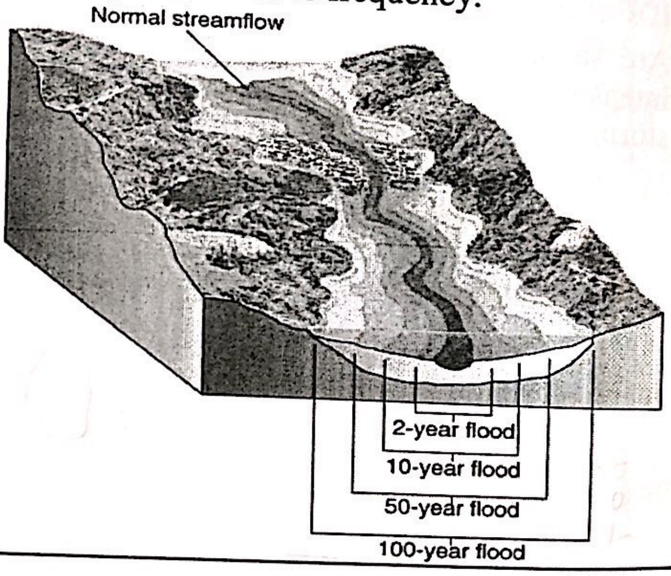
$$\alpha = \frac{\sqrt{6}\,S}{\pi} \qquad u = \bar{x} - 0.5772\alpha$$

Standard devuation

mean

Statistical methods in hydrology

Flow quantity in relation to frequency.



Statistical methods in hydrology

Ex:

Plot the theoretical distribution for the following 15-minute extreme rainfall depths.

Year	15-minute extreme rainfall depth (mm)
2000	12
2001	17
2002	7
2003	14
2004	27
2005	9
2006	13
2007	18
2008	8
2009	15
2010	11

Statistical methods in hydrology

Ex:

$\bar{x} = 13.72mm$ $\qquad$ $S = 5.64mm$

$$\alpha = \frac{\sqrt{6} \times 5.64}{\pi} = 4.4$$

$$u = 13.72 - 0.5772 \times 4.4 = 11.18$$

$$P(X \le x) = \mathbf{exp}\left[-\mathbf{exp}\left(-\left[\frac{x-u}{\alpha}\right]\right)\right]$$

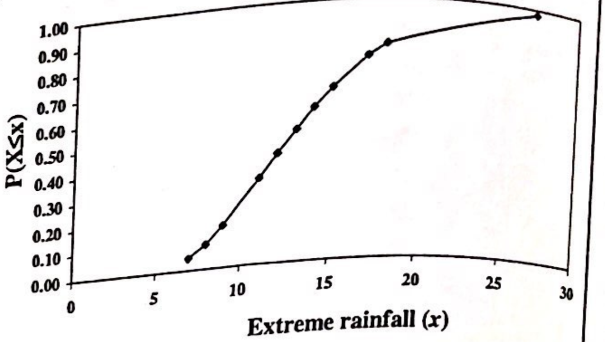
Statistical methods in hydrology

Ex:

$$P(X \le 7mm) = \mathbf{exp}\left[-\mathbf{exp}\left(-\left[\frac{7-11.18}{4.4}\right]\right)\right] = 0.08$$

x	P(X ≤ x)
7	0.08
8	0.13
9	0.19
11	0.35
12	0.44
13	0.52
14	0.59
15	0.66
17	0.77
18	0.81
27	0.97

احتمالية
قدوم أقصى
أمطار في
هذه المنطقة

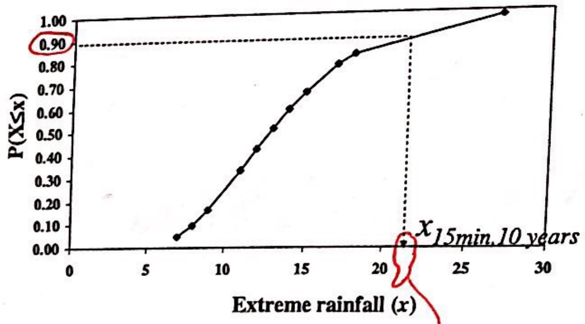


ليست 100%
لقلة Data point

Statistical methods in hydrology

Question: what is the amount of the extreme rainfall depth that is associated to 15 mins duration and return period of 10 years, i.e. $x_{15min,10\,years}$

Answer: use the probability plot



21

يحدث كل
10 سنين

$T = 10$

$P(X \geq x) = 0.1$

$P(X \le x) = 0.9$

Non exceed

⊛

طريقة
أخرى للإجابة
بدل من الرسم .

Statistical methods in hydrology

The past question can be also answered computing the quantile ($x_{d,T}$) using the frequency factor (K_T) of the Gumbel distribution as follows:

$$Q \leftarrow x_{d,T} = \overline{x}_d + K_T S_d \longrightarrow$$

معادلة خاصة
بـ Max

أي متغير

$x_{d,T}$: extreme rainfall depth for storm of duration d and frequency T years.

$\overline{x}_d$ and S_d: mean and standard deviation of the extreme rainfall depths for storm of duration d (from records).

K_T: frequency factor of the Gumbel distribution.

$$K_T = -\frac{\sqrt{6}}{\pi}\left[0.5772 + \ln\left(\ln\left[\frac{T}{T-1}\right]\right)\right]$$

Inverse for p

Inverse for e

⊛
بواسطة
علم الجبر .

Statistical methods in hydrology

Ex:

For the past 15-minute extreme rainfall depths, estimate the amount of the 15-minute rainfall depth associated to the 10-year return period

Year	15-minute extreme rainfall depth (mm)
2000	12
2001	17
2002	7
2003	14
2004	27
2005	9
2006	13
2007	18
2008	8
2009	15
2010	11

Statistical methods in hydrology

Ex:

$$K_T = K_{10} = -\frac{\sqrt{6}}{\pi}\left[0.5772 + \ln\left(\ln\left[\frac{10}{10-1}\right]\right)\right] = 1.3$$

From the historical data

$$\bar{x}_d = \bar{x}_{15} = 13.72mm \qquad S_d = S_{15} = 5.64mm$$

then the amount of 15-min rainfall at T = 10 years is

$$x_{d,T} = \bar{x}_d + K_T\, S_d$$

$$x_{15\min,10year} = \bar{x}_{15} + K_{10}\, S_{15} = 13.72 + 1.3 \times 5.64$$

$$x_{15\min,10year} = \underline{\underline{21mm}}$$

Statistical methods in hydrology

Ex:

A watershed discharges extreme flows of $3m^3/s$ and $4.4m^3/s$ from 30 minutes storm of 10 and 20 years return periods, compute the extreme flow that is associated to the 30 minutes storm but of 50 years return period?

$Q_{10} = 3$ $\qquad T = 10$

$Q_{20} = 4.4$ $\qquad T = 20$

$Q_{50} = ??$

* عمل نسبة وتناسب غلط عشان
العلاقة ليست خطية .

حساب K_{10} و K_{20} وحل
معادلتين ثم حساب $\bar{X}_{10}$
S_{10}
ثم . ايجاد Q_{50}

5 min :- (... عليه)

بينشا

⊛ يُنصح بها لكن ليست
إجبارية .

⊛ رسم IDF
curves .

Statistical methods in hydrology

يخرج

⊕ Steps to construct the IDF curves:

1. From precipitation records, for each year extract the max rainfall depths for durations: 5mins, 10, 15, 30mins, 1hr, 2, 6, and 24hrs.
2. Estimate the mean and standard deviation of max rainfall depths at the durations listed above.
3. Using the extreme value distribution estimate the frequency factor K_T and estimate the amount of rainfall depth ($x_{d,T}$) for durations listed at return periods of 2 years, 5, 10, 25, 50, and 100 years.
4. Correct the rainfall depths at the 2-year and 5-year return period by multiplying with 0.88 for the 2-year and 0.96 for the 5-year return period.

في الأرصاد

بأخذ x
ثم i

عدل

20
لحتى
نكمل عل
100

* ليس
للحفظ .

أقصى هطول
في 5 دقائق
خلال عام 2000

5 10 20
لحتى تكمل عل
60min

هل يجوز
رسم عند
T = 1 ?

يجوز، يمكنه
حدث مُعتاد عليه وكل سنة بيحدث

Statistical methods in hydrology

Steps to construct the IDF curves:

6. Calculate the rainfall intensity (i) in mm/hr units as:

$$i(mm/hr)=\frac{x_{d,T}}{d}$$

7. Plot the IDF curves. Place storm duration (d) at log scale on x-axis. Place the intensity (i) at log scale on the y-axis.

T

Return period

Statistical methods in hydrology

Ex:

Construct the 5-year IDF curve for the following max rainfall depths of 15-min and 60-min duration.

Year	15-min max rainfall	60-min max rainfall
2000	24	45
2001	30	75
2002	20	34

Soln:

for 15-min, $\bar{x}_{15} = 24.7mm$ $S_{15} = 5mm$

for 60-min, $\bar{x}_{60} = 51.3mm$ $S_{60} = 21.2mm$

$$K_5 = -\frac{\sqrt{6}}{\pi}\left[0.5772 + \ln\left(\ln\left[\frac{5}{5-1}\right]\right)\right] = 0.72$$

Statistical methods in hydrology

Ex:

Soln: $x_{d,T} = \bar{x}_d + K_T S_d$

أقصى كمية
هطول تحدث
في منطقة
لمدة 15 min
وكل 5 سنوات
تحدث

For 15-min, $x_{15,5} = 24.7 + 0.72 \times 5 = \boxed{28.3mm}$

The corrected $x_{15,5} = 0.96 \times 28.3 = 27.2mm$,

قيم
نظرية

$$i = \frac{27.2}{(15/60)} = 108.8 mm/hr$$

For 60-min, $x_{60,5} = 51.3 + 0.72 \times 21.2 = 66.6mm$

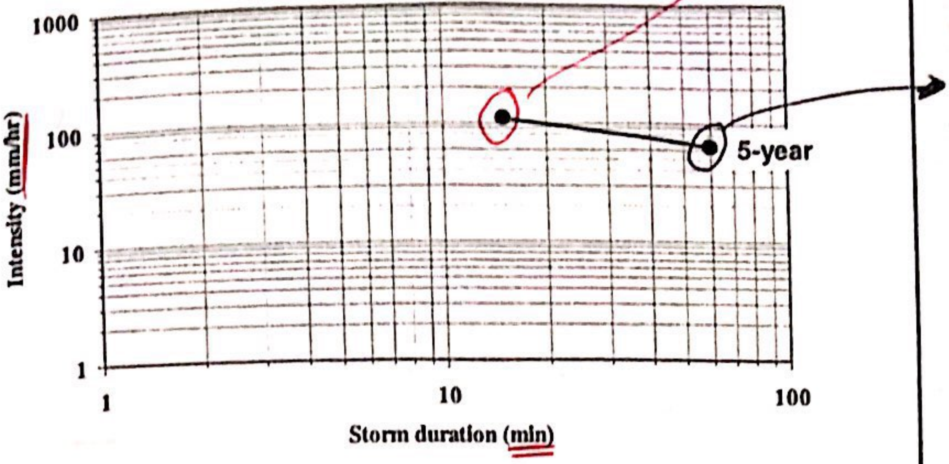
The corrected $x_{60,5} = 0.96 \times 66.6 = 64mm$,

$$i = \frac{64}{(60/60)} = 64 mm/hr$$

لكي
نضرب
km^2
و mm
Depth

Statistical methods in hydrology

Ex: Result IDF for 5 years return period.



⊛ الوحدات بـ min ، $\frac{mm}{hr}$ حكي

نطبق معادلة Q .

Micro-scale basin: computing the runoff

عقلانية

The surface runoff (flow) from small watersheds can be computed using the rational method benefiting of the IDF curves. In urban hydrology, the rational method is used to estimate the peak runoff for storm sewer design. The peak flow (m³/s) is: حساب i عند max

Net flow

$$Q = \boxed{0.278} C i A$$

Q حدودي A

Always < 1

C : runoff coefficient,

i : storm intensity (mm/h) obtained from IDF curves,

A : watershed contributing area (km²).

خاصة بـ منطقة وتعتمد على عناصر المناخ

حكي نخب km² و mm

Depth

⊛ الإستفادة من IDF هي استخدام هذه المعادلة.

مطر قوي يعني i عالي نغرق الدنيا

⊛ بعض الأمطار تذهب تبخر، جورة، ملئ الفراغات أي يعني لا يذهب الماء كله للتصريف .

Sand → مسامي / أقرب لـ 20% / صحراء /
حرارة عالية / تبخر عالي / فلترة عالي .

clay → دائما أعلى

C = 0.8
↳ Flow من 80% يُصرّف .

C = 0
↳ جميع الماء قد تبخر

Land Use or Type	C Value
Agriculture	
Bare Soil	0.20-0.60
Cultivated Fields (sandy soil)	0.20-0.40
Cultivated Fields (clay soil)	0.30-0.50
Grass	
Turf, Meadows	0.10-0.40
Steep Grassed Areas	0.50-0.70
Woodland	
Wooded Areas with Level Ground	0.05-0.25
Forested Areas with Steep Slopes	0.15-0.40
Bare Areas, Steep and Rocky	0.50-0.90
Roads	
Asphalt Pavement	0.80-0.90
Cobblestone or Concrete Pavement	0.60-0.85
Gravel Surface	0.40-0.80
Native Soil Surface	0.30-0.80
Urban Areas	
Residential, Flat	0.40-0.55
Residential, Moderately Steep	0.50-0.65
Commercial or Downtown	0.70-0.95

منطقة ترابية

جميع Soil

لا يحدث Filter

خرسانة جديدة

Micro-scale basin: computing the runoff

The rational method is usually used conditioning to:

⊛- the watershed area is small (< 3km²).

⊛- the watershed is nearly flat. < 5 %

⊛- the storm duration is ≥ the time of concentration.

If the conditions mentioned above are not applicable, then the accuracy of the rational method is questionable. In that case the unit hydrograph, synthetic hydrographs and SCS method are used to estimate the peak runoff (will be discussed later).

⊛ شروط ←
١- مساحة صغيرة
٢- تكون مستوية

ملاحظة :-
لو تم التطبيق والمساحة كبيرة سيكون هناك نسبة خطأ كبيرة .

Flow From Far place come in same time with Flow From Near place. → ط

Micro-scale basin: computing the runoff

The time of concentration t_c:

For a given watershed, the time of concentration is defined as the time needed such that the whole watershed discharges flow. It is the longest time needed for a water drop to travel through the watershed to the final drainage point. Using the Kerby-Kirpich method, t_c in **minutes**: → لمراعاة IDF

تدفق من
أمس تجاوز
مع تدفق
الجديد
عند نفس
المخرج .

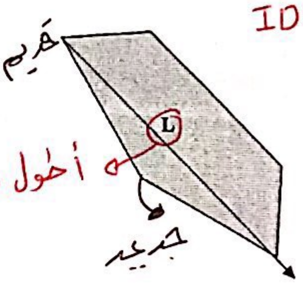
تعريف
أمطار أمس
واليوم
أي مجموع
Area .

خصائص water Shed

$$t_c = \frac{0.828\left(L\times n\right)^{0.467}}{S^{0.235}}$$

Non-Linear

n: Roughness of surface
L: flow path distance (m)
S: surface slope



Longest time → الزمن الحرج
أبعد نقطة ← وصولي
كم الوقت .؟

علاقات ←
١- سرعة ∝ وقت
٢- مسافة ∝ زمن
٣- خشونة ∝ .اعاقة
.اعاقة ∝ سرعة
سرعة ∝ زمن

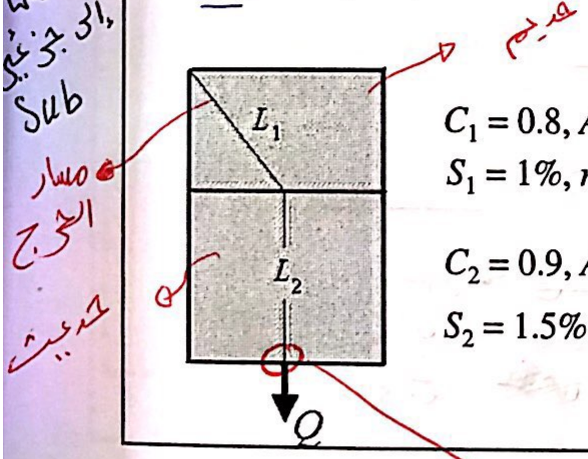
⊗ الأمطار
لا دور لها .
No relation

Micro-scale basin: computing the runoff

Ex:

For the watershed shown below, compute (estimate) the peak flow from a storm of 2 years return period that lasts for 20mins (IDF curves given). → Storm duration

تم تقسيمها الى جزئين Sub



$C_1 = 0.8, A_1 = 40000\ m^2$

$S_1 = 1\%, n_1 = 0.025,\ L_1$=220m

$C_2 = 0.9, A_2 = 50000\ m^2$

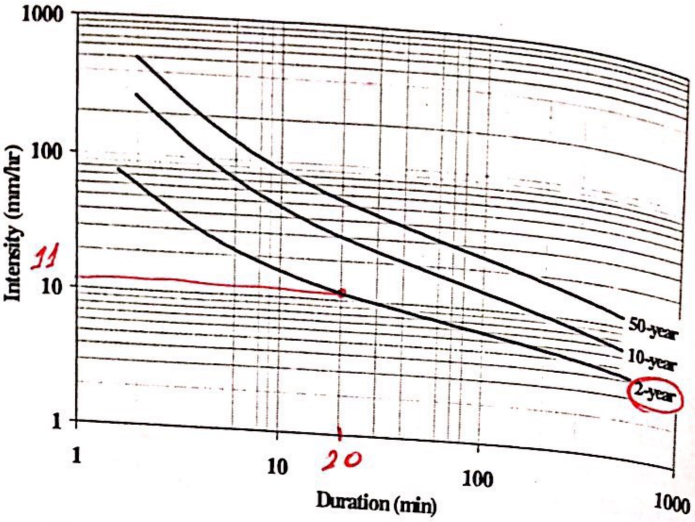
$S_2 = 1.5\%, n_2 = 0.03,\ L_2$=250m

مكان تجاوز Q ، مكان قديم وحديث

* ملاحظة ←
١- لا يمكن جمع Q جمع جبري لاختلاف زمن الوصول

Micro-scale basin: computing the runoff

IDF curves.



شرط
التحقق

Micro-scale basin: computing the runoff

Soln:

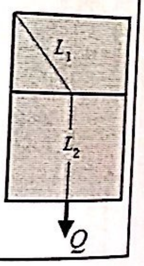
The time of concentration t_{c1} from sub-watershed 1=

$$= 0.828\times(220\times0.025)^{0.467}/0.01^{0.235} = 5.4 \text{ mins.}$$

The time of concentration t_{c2} from sub-watershed 2=

$$= 0.828\times(250\times0.03)^{0.467}/0.015^{0.235} = 5.7 \text{ mins.}$$

The time of concentration from the whole watershed =



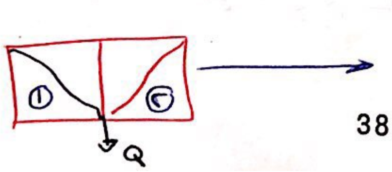
$t_c = 5.4 + 5.7 = 11.1$ mins. → ضمان وصول جميع المياه إلى المخرج

Why both times have been added?

⊛
عمان — زرقاء
زرقاء — هاشمية

عشان من L1 لحتى تصل المياه ,الى نقطة تخرج منها تحتاج للمرور بـ L2

⊛



نأخذ tc الأكبر

Micro-scale basin: computing the runoff

Soln:

The average watershed $C =$

$$C = \frac{(0.8\times40000)+(0.9\times50000)}{90000} = 0.86$$

$\sum A$

⊛ For t_c = 11.1mins < storm duration (20mins), and for T = 2 years then from the IDF-curves the storm intensity i = 11mm/h.

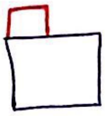
شرط التحقق

The peak flow $Q = 0.278\times0.86\times11\times0.09 = 0.237 m^3/s$

لـ Q الكاملة من watershed

$\frac{90000}{1000\,000}$

⊛ يجوز أخذ أي بيج لكن غير دقيق .



عالشي الأحمر قليل بالنسبة للأزرق

Average weight

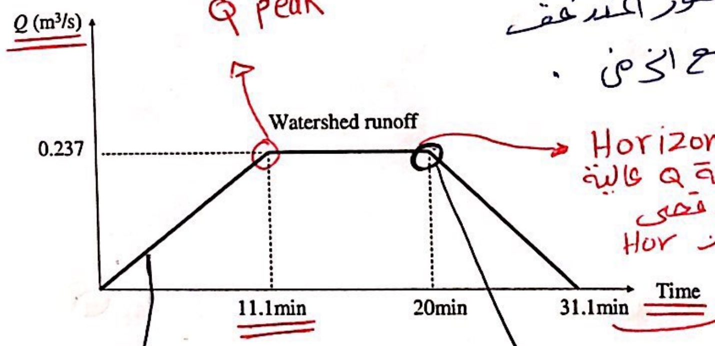
Micro-scale basin: computing the runoff

Soln:

The resulted flow hydrograph (the hydrograph is defined as flow profile over the time).

Flow profile

⊛ تطور التدفق مع الزمن .

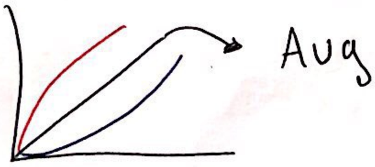


Q peak

Horizontal
قيمة Q عالية
والأقصى
لذلك Hor

$20 \rightarrow$
$+ 11.1 \; t_c$
$= 31.1$

وقف المطر



Avg

مثل Expected لكي تقل

نسبة Error، لا يوجد معلومات كافية لـ Flow

⊛ جاء في تقسيم الهيدروجاف إلى مربعات
ومستطيلات .

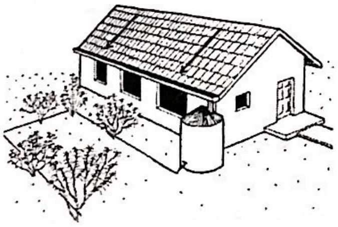
Micro-scale rainwater harvesting

Rainwater falls on small catchments (surfaces) will finally generate clean water runoff (flow) that can be collected as potential water source. Such small catchments can be: house ① rooftop, paved ③ street or ② parking lot. The quality of such collected water is considered acceptable for drinking (give an example from the Jordanian heritage), gardening and cleaning purposes.

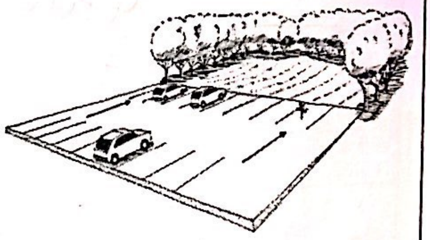
At an average rainy season, each single house rooftop in Jordan is able to collect about 10m^3 of clean water. Just imagine that: if 50% of Jordanian house conduct such technique, what would be the amount of water collected? Do the simple math?

Micro-scale rainwater harvesting

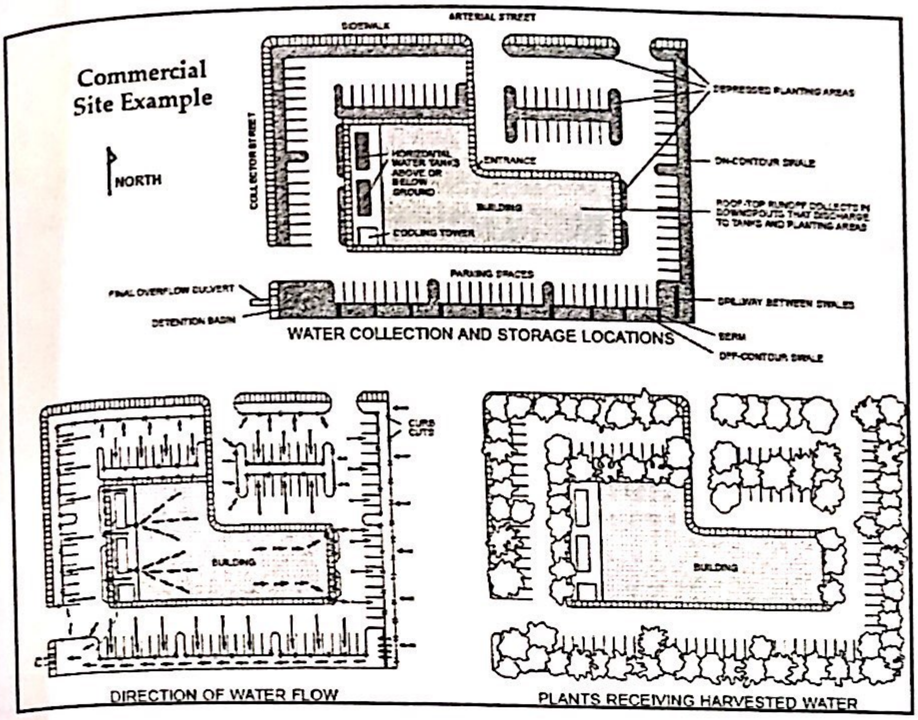
Example: micro-scale rainwater harvesting projects.



House rooftop

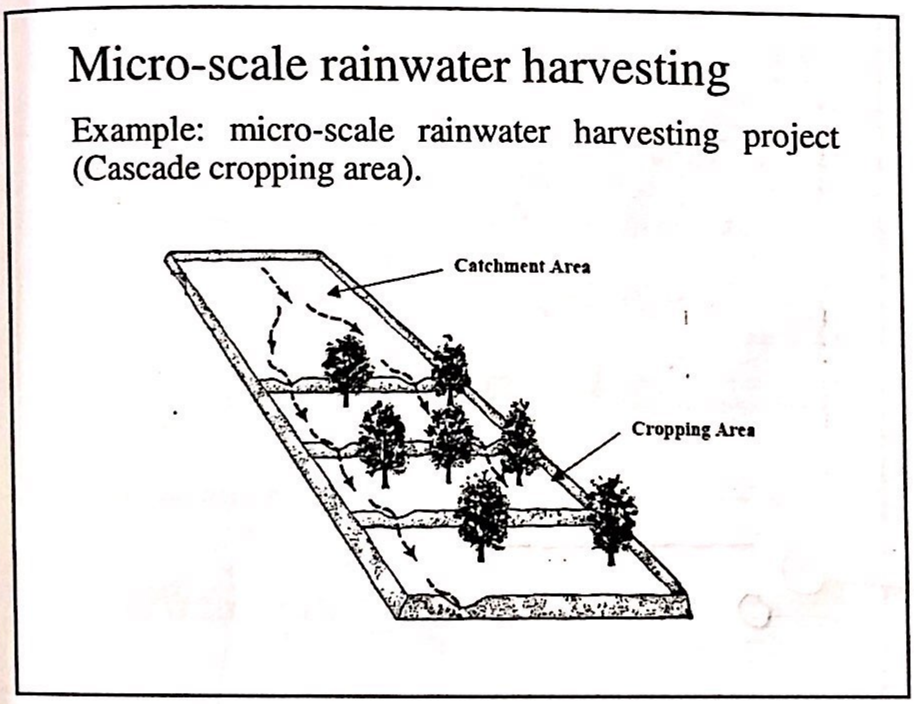


Parking lot



البركة نعتمد عل Shear

$T = kv^{\textcircled{2}}$



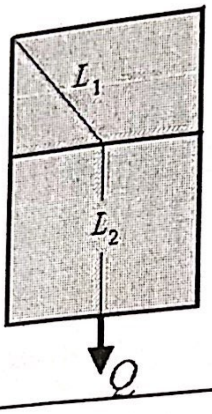
Micro-scale rainwater harvesting

Example: micro-scale rainwater harvesting project (Cascade cropping area).

Micro-scale rainwater harvesting

Ex:

For the watershed shown in the previous example, estimate the maximum potential water volume that can be harvested from the storm given.



$C_1 = 0.8, A_1 = 40000\ \text{m}^2$

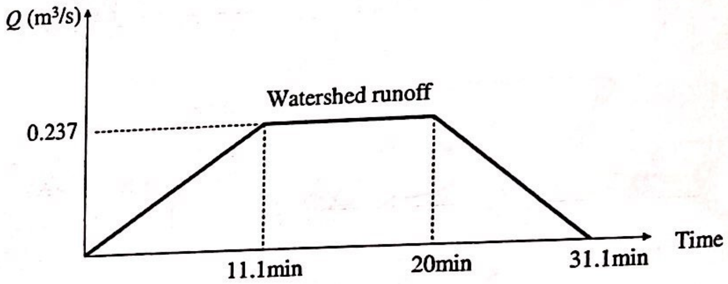
$S_1 = 1\%, n_1 = 0.025,\ L_1$=220m

$C_2 = 0.9, A_2 = 50000\ \text{m}^2$

$S_2 = 1.5\%, n_2 = 0.03,\ L_2$=250m

Micro-scale rainwater harvesting

Soln: given the hydrograph below.



The water volume possibly harvested from such watershed is the area under the runoff curve:

$V = Q \times \text{time}$

$= 2\times(0.5\times11.1\times60\times0.237) + (20 - 11.1)\times60\times0.237$

$= 284\text{m}^3$

نجد الحجم

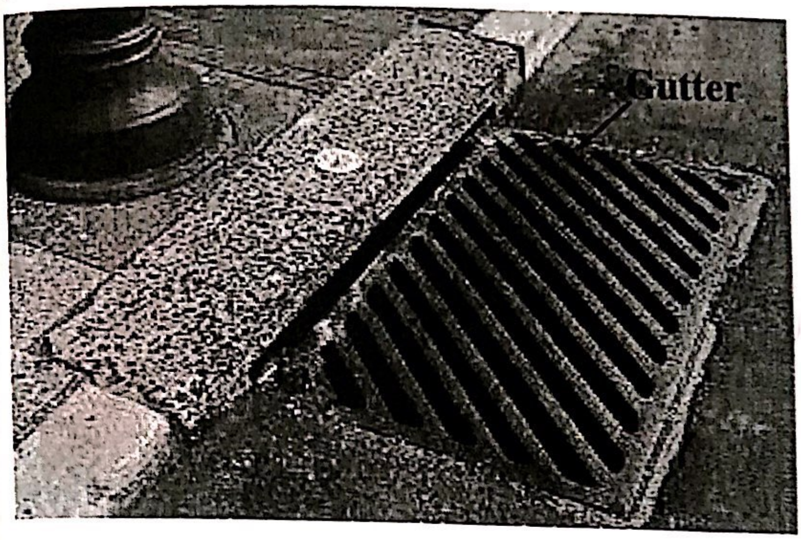
لمعرفة أبعاد الخزان

* معرفة كمية الماء الذي تم تجميعه خلال 20 min

مدخل

Design of storm sewer

Surface flow inlet: gutter.

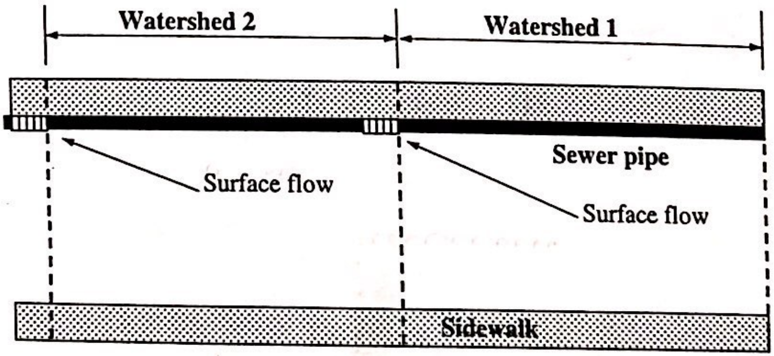


Design of storm sewer

*

أنابيب تصريف مياه الأمطار

The gutter allows the surface runoff to inter the sewer pipe. After computing Q using the rational method, the pipe diameter (D) can be obtained as the best hydraulic section. The minimum distance between the gutters will not be detailed here.



Design of storm sewer

Pipe 1 diameter D_1 = ??

Use Manning $Q = 1/n \times A \times R^{2/3} \times S^{0.5}$

The best section of circular section:

$Q_1 = 0.135m^3/s = (1/0.014) \times (0.77D_1^2) \times (0.286D_1)^{2/3} \times 0.01^{0.5}$

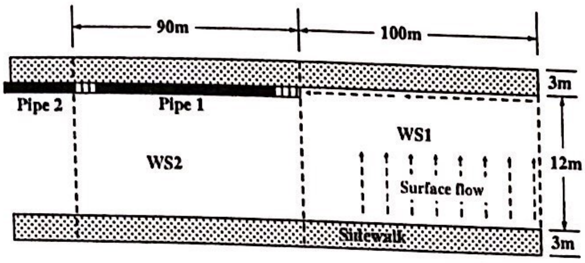
$D_1 = 0.34m$, use $D_1 = 0.35m$ = 350mm.

والآن هيدروليك ⇐

$A = 0.77D^2$

$P = 2.69 D$

$R = 0.286 D$



Design of storm sewer

Flow in pipe 2 from WS1 + WS2:

Surface flow longest path in WS2 is $L_2 = 3 + 12 + 90 = 105m$.

$tc_2 = 0.828\times(105\times0.015)^{0.467}/0.01^{0.235} = 3$ mins.

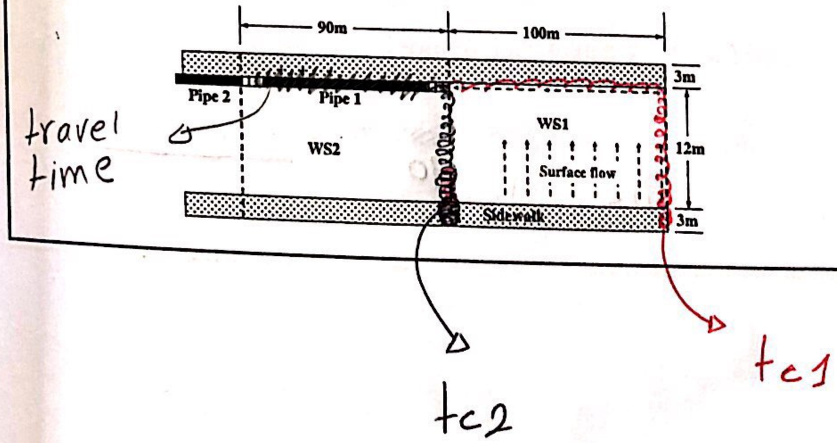
To pipe 2 inlet, the time of concentration is either:

tc_2 or (tc_1 + travel time in pipe 1), why ????.

اختار الأكبر

In pipe 1, the travel time = L_1/V_1

Use the partial flow diagram to find V_1



Q1 →

تم احتسابها

Design of storm sewer

To find V_1 from the partial flow diagram, compute Q_1/Q_{full} = ??

$$Q_{full} = \frac{1}{n}\frac{\pi}{4}D^2\left(\frac{D}{4}\right)^{2/3}\sqrt{S_o} =$$

→ مدفة

$$\frac{1}{0.014}\frac{\pi}{4}(0.35)^2\left(\frac{0.35}{4}\right)^{2/3}\sqrt{0.01} = 0.135\ m^3/s$$

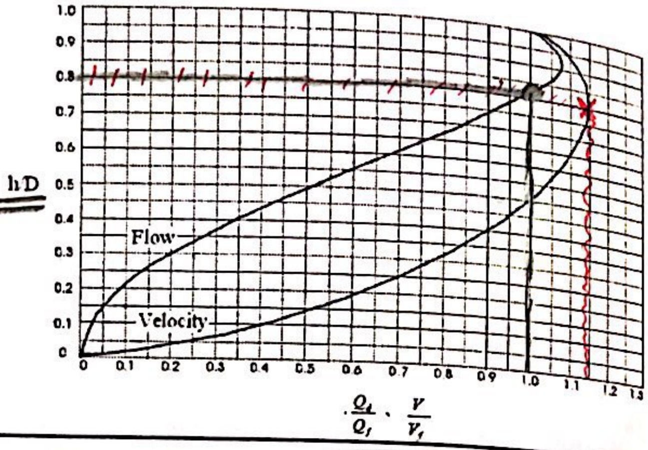
$\frac{h}{d}$ →

Max V → 0.81

Max F → 0.95

➡ $Q_1/Q_{full} = 1$

➡ $V_1/V_{full} = 1.14$



* من $\frac{Q}{Qf}$ نجد $\frac{h}{d}$ ثم من $\frac{h}{d}$ نجد $\frac{V}{Vf}$

Design of storm sewer

Find V_{full} from Manning as:

$$V_{full} = \frac{1}{n}\left(\frac{D}{4}\right)^{2/3}\sqrt{S_o} = \frac{1}{0.014}\left(\frac{0.35}{4}\right)^{2/3}\sqrt{0.01} = 1.41\ m/s$$

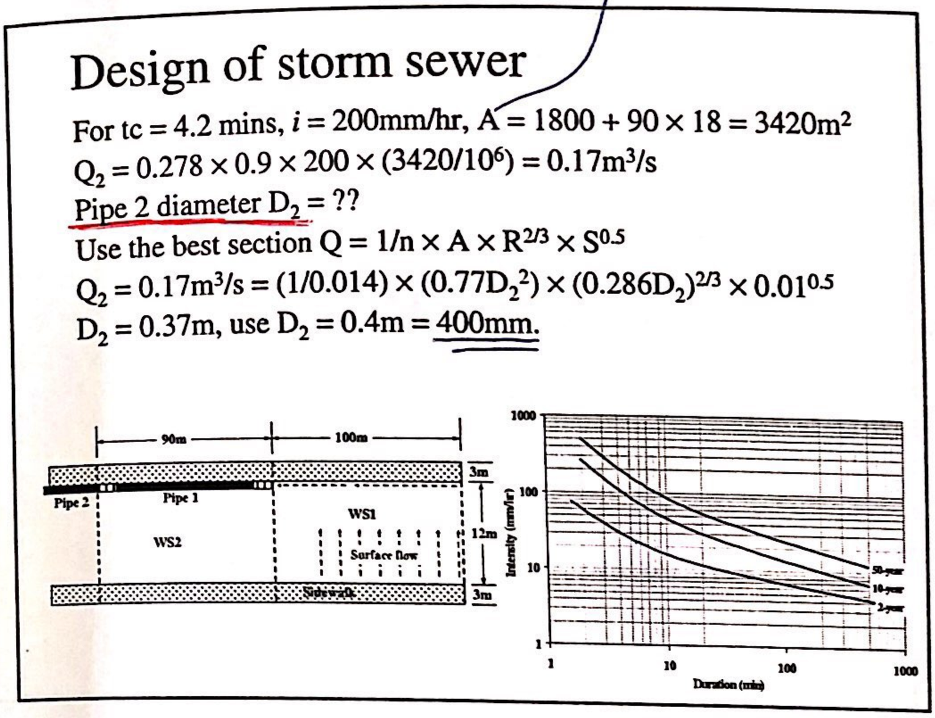
from $V_1/V_{full} = 1.14$ ➡ $V_1 = 1.6$m/s

therefore, tc_1 + travel time in pipe1=

tc = 3.15 + (~~100~~ 90/1.6)/60 = 4.2 mins > tc_2

pipe طول 90

whole shed



Design of storm sewer

For tc = 4.2 mins, i = 200mm/hr, A = 1800 + 90 × 18 = 3420m^2

$Q_2 = 0.278 \times 0.9 \times 200 \times (3420/10^6) = 0.17 m^3/s$

Pipe 2 diameter D_2 = ??

Use the best section $Q = 1/n \times A \times R^{2/3} \times S^{0.5}$

$Q_2 = 0.17 m^3/s = (1/0.014) \times (0.77 D_2^2) \times (0.286 D_2)^{2/3} \times 0.01^{0.5}$

D_2 = 0.37m, use D_2 = 0.4m = 400mm.

تكرار ←

First End

" وإني لآت بما لم يأتي به الأوائل ♡ "