University of Al Mustansiriyah
Faculty of Engineering
Civil Engineering Department
Third Stage

IRRIGATION AND DRAINAGE ENGINEERING

Asst. Prof. Dr. Rasul M. Khalaf

2016 - 2017

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2016-2017

Civil Engineering Department
THIRD YEAR / CURRICULUM
2016 - 2017

Subject: **Irrigation & Drainage Engineering**

ABET Code	Units	First Semester			Second Semester		
		Theo.	Tut.	Prac.	Theo.	Tut.	Prac.
50601305	4	2	-	-	2	-	-

50601305 Irrigation and Drainage Engineering

Irrigation: ***Introduction, definition, purposes, necessity, soil – water - plant relations, land grading, computation, design slope calculations, earth works calculations, Infiltration, infiltration equations, field measurements. Surface irrigation, efficiency, adequacy, uniformity, water balance concept, water front advance. Consumptive use and water requirements, net and gross depth, continuous and intermitted discharge, Irrigation scheduling, water duty.***

Irrigation Canals: ***Classification, general layout, numbering, canal design methods.***

Drainage: ***Definition, drainage coefficient, Darcy's Law, closed and open drains, filters, cross sectional design of open and closed drains, design of drain spacing, vertical drainage system .***

Reference

1. *Punmia, Pande Lal, Ashok Kumar , Arun Kumar ,* Irrigation and Water Power Engineering, *16th ed. , 2009.*
2. *A. M. Michael* ,Irrigation Theory and Practice – *2nd ed.-2008.*
3. *Varshney ,Gupta ,Gupta,* Theory & Design of Irrigation Structures: Canal and storage works, *1977.*
4. *G.L. Asawa* , Irrigation and Water Resources Engineering,*2005*
5. *Iqbal Ali* , Irrigation and Hydraulic Structures: Theory, Design , 2008.
6. *Santosh Kumar Garg*, Irrigation Engineering and Hydraulic Structures, *12th ed. or latest .*
7. *James N. Luthin* ,Drainage Engineering ,*1973*
8. هندسة البزل ، عبدالستار الدباغ
9. هندسة نظم الري الحقلي ، أحمد يوسف حاجم
10. *-Lecture notes and other handouts as well as tutorial sheets.*

Rasul M. Khalaf

Asst. Prof.

Dr. Rasul M. Khalaf

2016 - 2017

Table of Contents

Rasul M. Khalaf

Asst. Prof. Dr. Rasul M. Khalaf

2016-2017

Conversion of units

Length

1 inch = 2.54 cm

1 mile = 1.6093 km

1 ft = 0.3048 m

1 yard = 3 ft = 0.9144 m

cm = 0.394 inch

1 Km = 0.6214 mile

1 m = 3.281 ft

1 m = 1.094 yard

Areas

1 acre = 4047 m^2

1 acre = 43560 ft^2

1 acre = 0.001563 $mile^2$

or 1 $mile^2$ = 640 acre

1 hectar (ha) = 10000 m^2

1 ha = 10^4 m^2

1 Km^2 = 10^6 m^2

1 Km^2 = 100 ha

Donum = 2500 m^2

1 haetar = 4 Donums.

1 hectar = 2.471 acre

convert 1 $mile^2$ to hec?

Volume & Discharge

gallon = 3.785 Lit.

ft^3/sec = Cfs = 0.0283 m^3/sec

m^3/sec = 35.315 Cfs

$$1\,mile^2 * \frac{640\,acre}{mile^2}$$

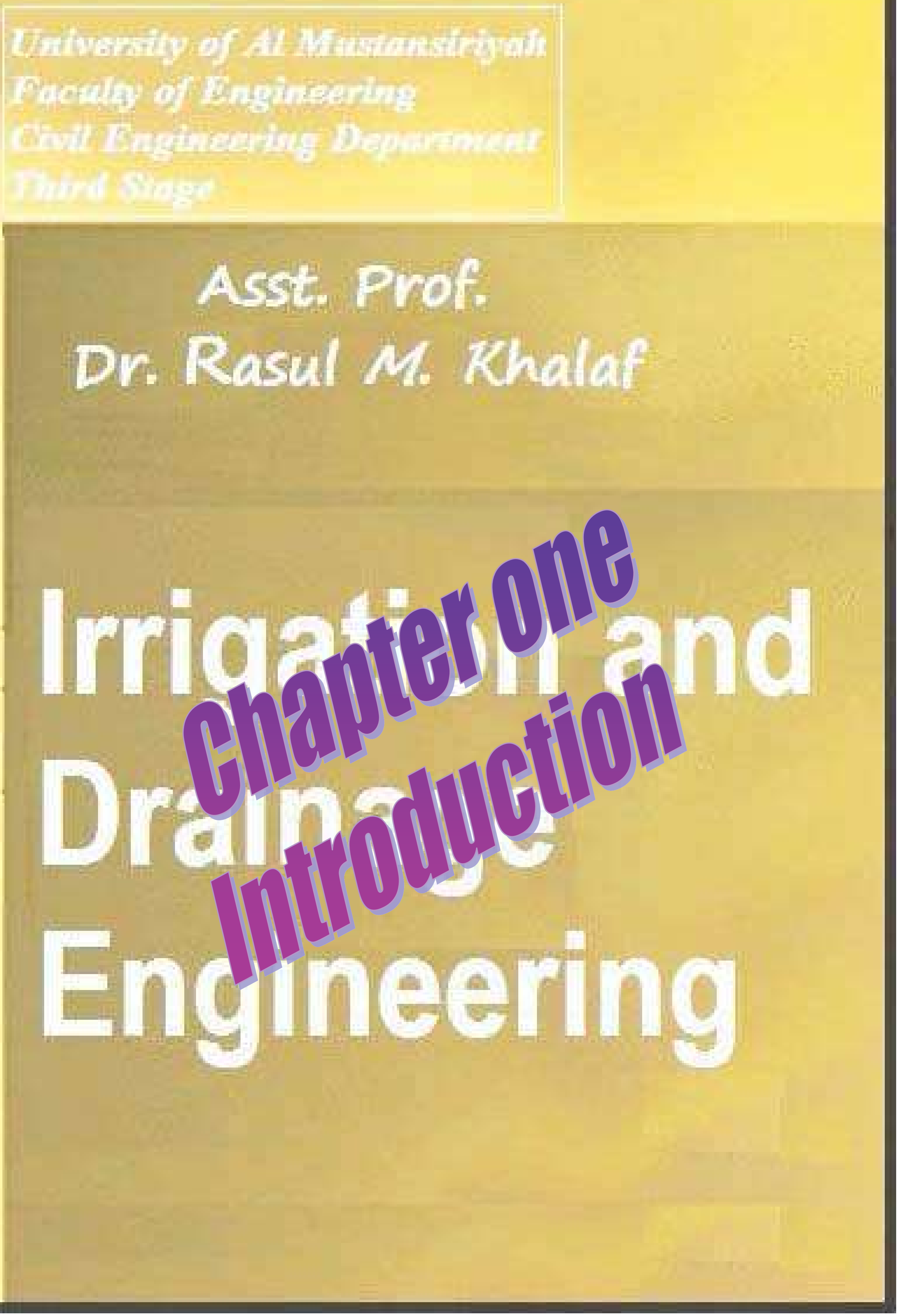
$$= 640\,\cancel{acre}\;\frac{hect}{2.471\,\cancel{acre}}$$

2 acre-ft = 1 Cfs.day   volume

acre-ft = 43560 ft^3

ha - m = 10^4 m^3

} volume



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Irrigation and Drainage Engineering

Chapter one
Introduction

د. رسول محي
٢٠١٧-٢٠١٢

Chapter one
Introduction

What is the irrigation? ما هو الري

Irrigation: is the application of water to the soil for purpose of supplying the moisture essential for plant growth
هو تزويد التربة بالماء لغرض توفير رطوبة اساسية لنمو النبات .

Purposes: الغرض من الري

1. add water to soil for supplying moisture for plant growth.
2. provide crop insurance against duration drought.
3. cool the soil and atmosphere to get bestenvironment.
4. Wash out the salt from soil
5. Reduce soil errosion.
6. use it as injection of fertilizers.

Necessity of irrigation ضرورة الري

1. Less rainfall
2. Non-uniform rainfall
3. Commercial crops with additional water.
4. Controlled water Supply.

Types of irrigation: انواع الري

1. Total irrigation: for areas of no rainfall
2. Supplementary irrigation: in area with rainfall for a part of a season Per year.

for both types one can use
1. surface irrigation system (Border, Basin, forrows...)
2. ground water irrigation. (by well resources)

Irrigation water resources:

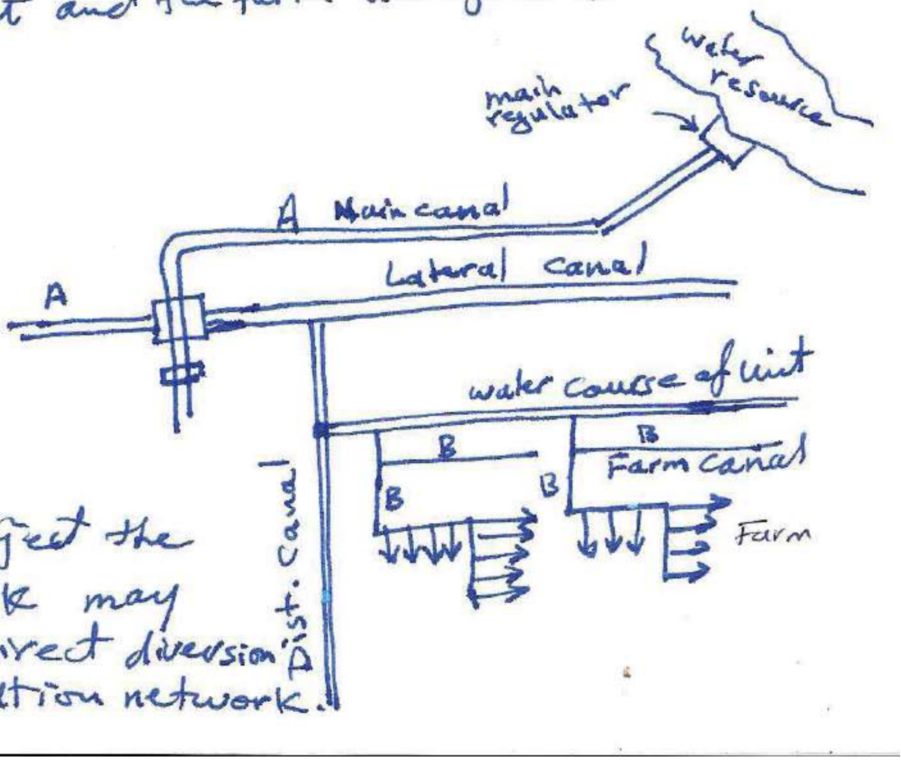
1. rainfall
2. surface water
3. Subsurface (gramd water)
4. Springs (temporarly)
5. Softting of sea water (high cost)
6. waste water (should be treated)

Irrigation Network شبكة الري

The irrigation network for any large project can be divided into two parts: شبكة التوزيع الرئيسية

① Major Distribution network
② Minor Distribution network شبكة التوزيع الثانوية

The MDN included water diversion تحويل الماء from main resources such as D in the figure, and then conveyance نقل الماء of water by main conveyance lines assigned by A, whereas the MIDS is almost located in the irrigation unit and the farm assigned B.



A : شبكة توزيع رئيسية
B : شبكة توزيع ثانوية
(الحقلية)

For small irrigation project the main irrigation network may not included just direct diversion will occur to minor irrigation network.

Irrigation Project:

Define as: the irrigated area specified for Corps production. It consists water resource or(s) such as river, Lake, well, etc..., main irrigation Network, minor irrigation Network, Drainage system of open and closed drains Networks as well as The all required structures which are called hydraulic structures.

Benefits of Irrigation projects

1. Employment & income. التوظيف والعائد
2. Security against impoverishment الامن الغذائي ضد الافقار
3. Reducing migration الحد من الهجرة
4. Quality of life تحسين نوعية الحالة المعيشية (تقليل الامراض).

Irrigation Unit [water course] الوحدة الاروائية

In modern designs, the irrigation unit consits of number of Farms supplied by water through one watercourse (مسقى) which consequetly supplied by water from Distributed cancal (مجرى موزع). The rectangular shape is preferable for simple operation & maintenance.

Farm المزرعة

The area of the farm depends on type and nature of mangement, there were an individual farm other is cooperative one. The convient area of farm depends on Agr. density and Agr. mechanization. المقتصرة على كثافة الزراعة والمكننة الزراعية

Feild الحقل

It is a part of farm planted by one type of crop and usually there will be more than one field planted at same time in each farm

surface gravity Irrigation: الري السطحي بالجاذبية

It is an old irrigation method since 4000 years in Iraq, Egypt and India, and it is still used in most countries. It required to land grading تسوية الارض to get slopes less than 6%. It is suitable for loamy - Medium - soil التربة المزيجية المتوسطة and fine - Heavy - soil والتربة الناعمة الثقيلة. The types of surface irrigation can be divided into:

① Border irrigation الري الشريطي
② Basin irrigation ري الاحواض
③ Furrow irrigation ري المروز
④ Sprinkler irrigation الري بالرش
⑤ Trickle (Drip) irrigation الري بالتنقيط

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Irrigation and Drainage Engineering

Chapter Two
Soil-Water-Plant Relations

د. رسول محمد خلف
٢٠١٧-٢-١٢

Chapter-2

Soil-water-plant relations

علاقة الترب - الماء - النبات

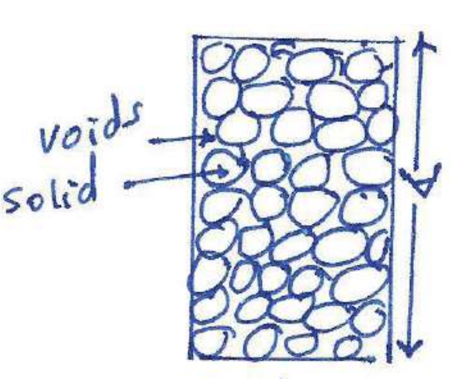
Soil classification تصنيف الترب

gravely soil > 2 mm
Sandy soil 0.05 - 2.0 mm
Silty soil 0.002 - 0.05 mm
clayey soil < 0.002

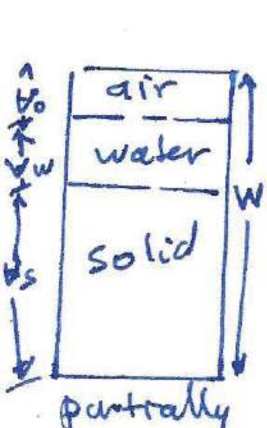
According to USDA classification.

Soil-water relations

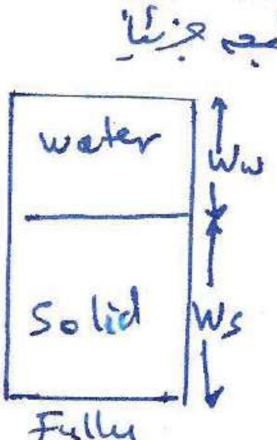
- Soil compositions
  - solid
  - water
  - air
- soil phases
  - dry
  - saturated
    - partially saturated مشبع جزئياً
    - fully Saturated مشبع كلياً



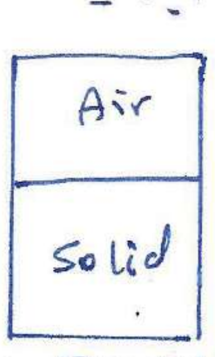
Soil skeleton



partially Saturated



Fully Saturated



Dry soil

Volumetric relations

Void ration نسبة الفراغات (e)

$$e = \frac{\text{Volume of voids}}{\text{Volume of solid}} = \frac{\forall_v}{\forall_s}$$

Porosity المسامية (η)

$$\eta = \frac{\text{Volume of voids}}{\text{Total Volume}} = \frac{\forall_v}{\forall}$$

Volumetric moisture content "ω"

$$\omega = \frac{\text{Volume of water}}{\text{Total volume}} = \frac{\forall_w}{\forall}$$

Degree of saturation S

$$S = \frac{\text{Volume of water}}{\text{Volume of Void}} = \frac{\forall_w}{\forall_v}$$

for fully saturated soil $\forall_w = \forall_v$ (no air)

thus ; $S = 1 = 100\,\%$.

Note that ; $\omega = \frac{\forall_w}{\forall} = \frac{\forall_w}{\forall_v} \cdot \frac{\forall_v}{\forall}$

$$\Rightarrow \boxed{w = S \cdot \eta}$$

and $\eta = \frac{e}{1+e}$, $e = \frac{\eta}{1-\eta}$

moisture by weight

$W_c = \frac{W_w}{W_s}$ (water content by weight)

γ is measured by weight per volume; if the weight measured by Newton $\Rightarrow \gamma$ (N/m³) otherwise γ (g/cm³) if weight is measured by gram

Dry-

G_s ; specific gravity (relative density)

$G_s = \frac{\gamma_s}{\gamma_w}$, γ_s = solid density $= \frac{W_s}{\forall_s}$

wet-

G_b ; bulk specific gravity $\gamma_b = \gamma_{dry}$

$G_b = \frac{\gamma_b}{\gamma_w}$; $\gamma_b = \frac{W_s}{\forall} = \frac{\gamma_t}{1+W}$ ← المحتوى الرطوبي الوزني

γ_t = total density $= \frac{W}{\forall} = \frac{G_s + Se}{1+e}\gamma_w$

γ(buoyant (submerged)) $= \gamma_{buoy} = \gamma_t - \gamma_w$

γ_{buoy} for saturated soil $= \frac{G_s - 1}{1+e}\gamma_w$

γ_{buoy} for partially Statured soil $= \frac{G_s - 1 - e(1-S)}{1+e}\gamma_w$

من التعريف . $\boxed{G_b \gamma_w = \frac{W_s}{\forall}}$

Example 1

Determine moisture content (وزنيا) available in a soil sample, if the wet weight of soil is 10 g and oven dried soil mass is 6.5 g

W by weight $= \frac{\text{weight of water}}{\text{wight of solid}} = \frac{10-6.5}{6.5} = 53.85\%$

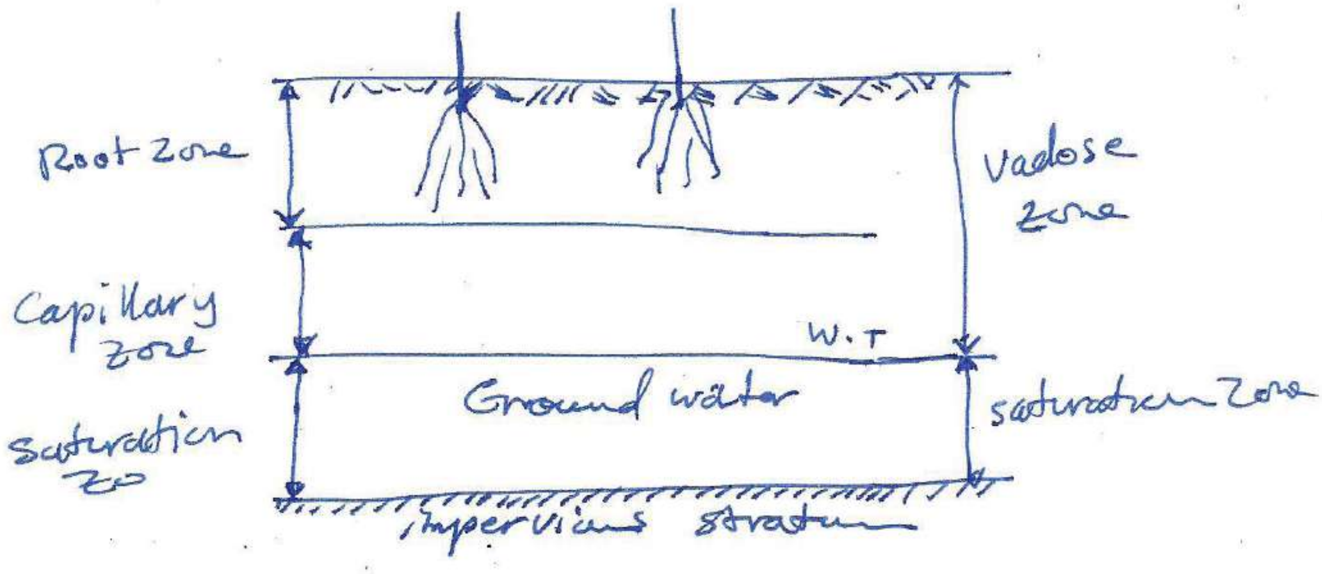
Example 2 : $\gamma_s = 4.8\ g/cm^3$, $\gamma_b = 2.5\ g/cm^3$ find η

$1-\eta = 1 - \frac{\forall_v}{\forall} = \frac{\forall - \forall_w}{\forall} = \frac{\forall_s}{\forall} = \frac{\forall_s / W_s}{\forall / W_s} = \frac{1/\gamma_s}{1/\gamma_b}$

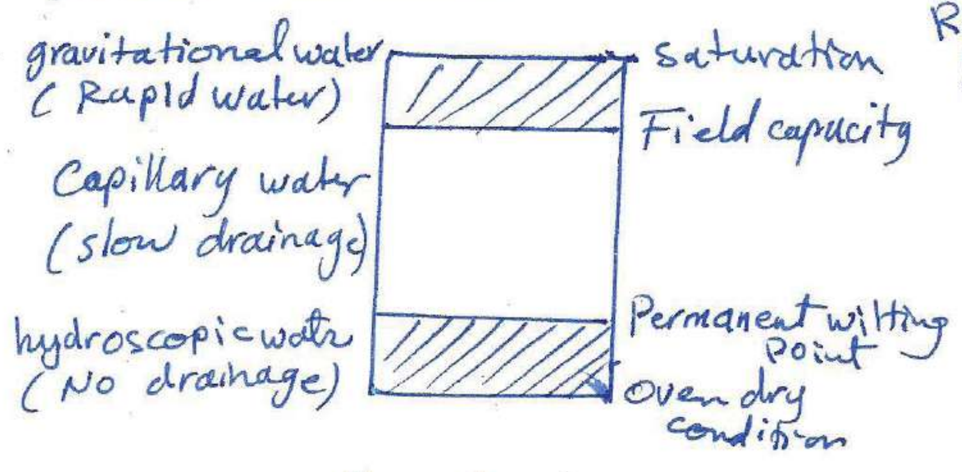
$\boxed{G_b = (1-\eta) G_s}$ ← $1-\eta = \frac{\gamma_b}{\gamma_s} \Rightarrow \eta = 1 - \frac{2.5}{4.8} \approx 48\%$

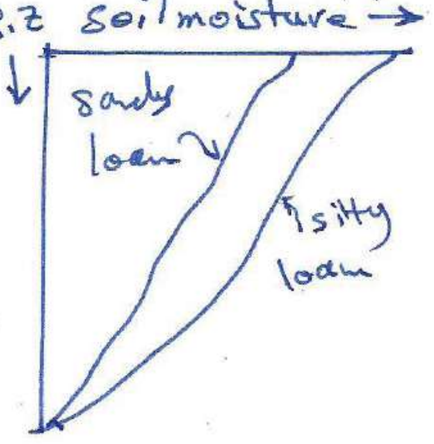
Subsurface water

Zone of areation   Zone of saturation



Root Zone water





Gravitational water: the water that moves in orant of the soil by gravity.

Capillary water; is the water that remains in the soil after draining of gravitational water. It permits plants to servive through draughts.

hydroscapic water: is the water held very tightly by the soil particles. It is unavailable to plant.

Field capacity (Fc): the water remaining in the soil after excess water (gravity water) was drained away and the rate of downward movement has decreased, after 2-3 days (after irrigation depending on texture & strutural of soil).

السعة الحقلية .

هي كمية الرطوبة (الماء) التي تحتفظ في التربة بعد التخلص من الماء الزائد اي بعد توقف حركة المياه النازلة نحو الاسفل بفعل الجاذبية حيث يقل المحتوى الرطوبي لحد السعة الحقلية بعد ٢-٣ ايام من الارواء وحسب طبيعة التربة .

Permanent wilting point: نقطة الذبول الدائمة (PMP) is the moisture content beyond which the plants can no longer extract enough moisture and remains wilted unless water is added to the soil.

هي كمية الرطوبة التي عندها يصل النبات الى حالة الذبول ما لم يتم اضافة الماء مجدداً الى التربة حيث يتعذر على النبات امتصاص هذه الرطوبة ويتطلب ذلك تسليط شد رطوبي عالي جداً على النبات يصل 1500 Kpa .

في الترب الناعمة تكون السعة الحقلية ما بين 10-20 ٪ ماء وتصل نقطة الذبول الدائمة عند 4٪ . اما الترب المزيجية loam فتكون السعة الحقلية عند 25 ٪ تقريباً ماء و pwp عند 8٪ في حين ان الترب الثقيلة تحتوي 38٪ 50 و pwp عند 18٪

moisture tension at pwp (15 * atm)

moisture tension at Fc (1/3 atm)

pwp → Fc. (1/3 - 15) atm pressure.

or (30 kpa - 1500 kpa)

Available water (capillary water) الماء المتوفر

$AW = FC - PWP$

Readily available water RAW is the water which can be removed from the soil with minimal energy required.

RAW = Percent of AW (الماء المتاح (الماء الميسر

$RAW = (\%) AW$

بالرغم من أن AW هو الماء المتوفر (أي قابل للامتصاص) من قبل النبات
إلا أن RAW يمتص بسهولة في النبات بدون جهد حيث بعد حد
RAW سيبذل النبات جهداً أكبر يزداد كلما اقتربنا من PWW.

Allowable Depletion نسبة الاستنزاف الرطوبي المسموح
(AD)

is the allowable amount of water that can be withdrawn from the soil between two successive irrigations without stressing the plant

نسبة الاستنزاف الرطوبي المسموح لكي يبقى
دائماً جزء من المياه يحتاج النبات إليه في أوقات انقطاع الري أو
الصيانة أو لأسباب فنية أخرى. وهكذا فإن

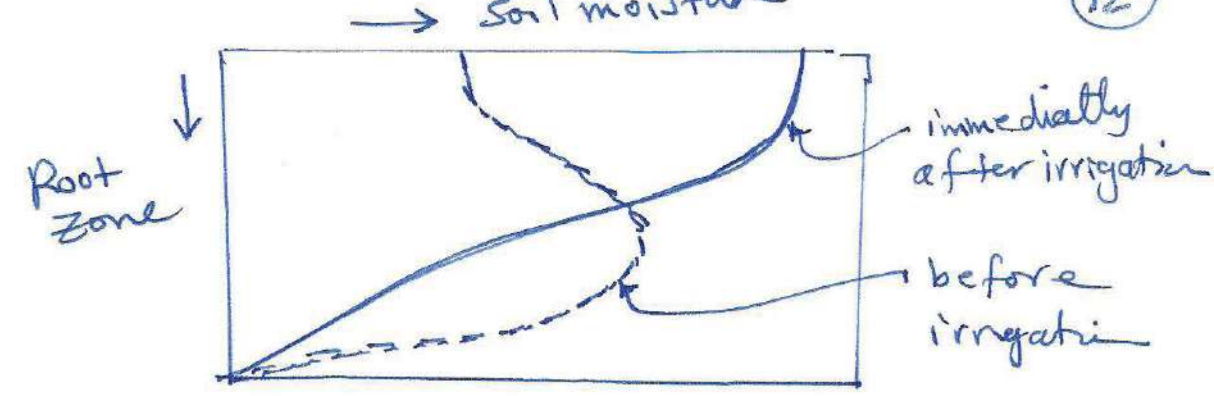
$RAW = AD * AW$

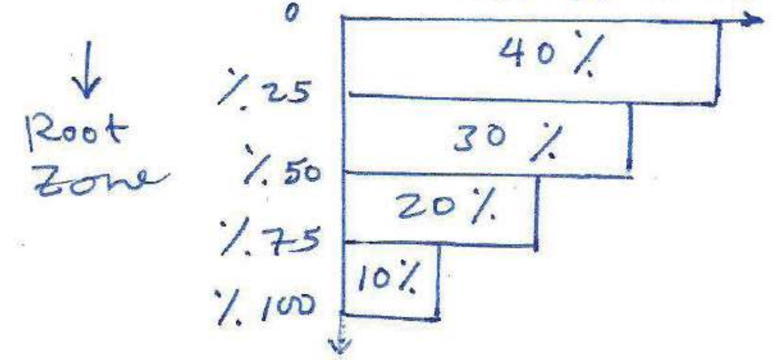
تتراوح نسبة الاستنزاف الرطوبي من (40 - 60) في المئة
الماء المتوفر (AW).

Soil Moisture deficit (SMD) العجز في رطوبة التربة (النقص)
is the amount of water required to recover the soil moisture at field capacity.

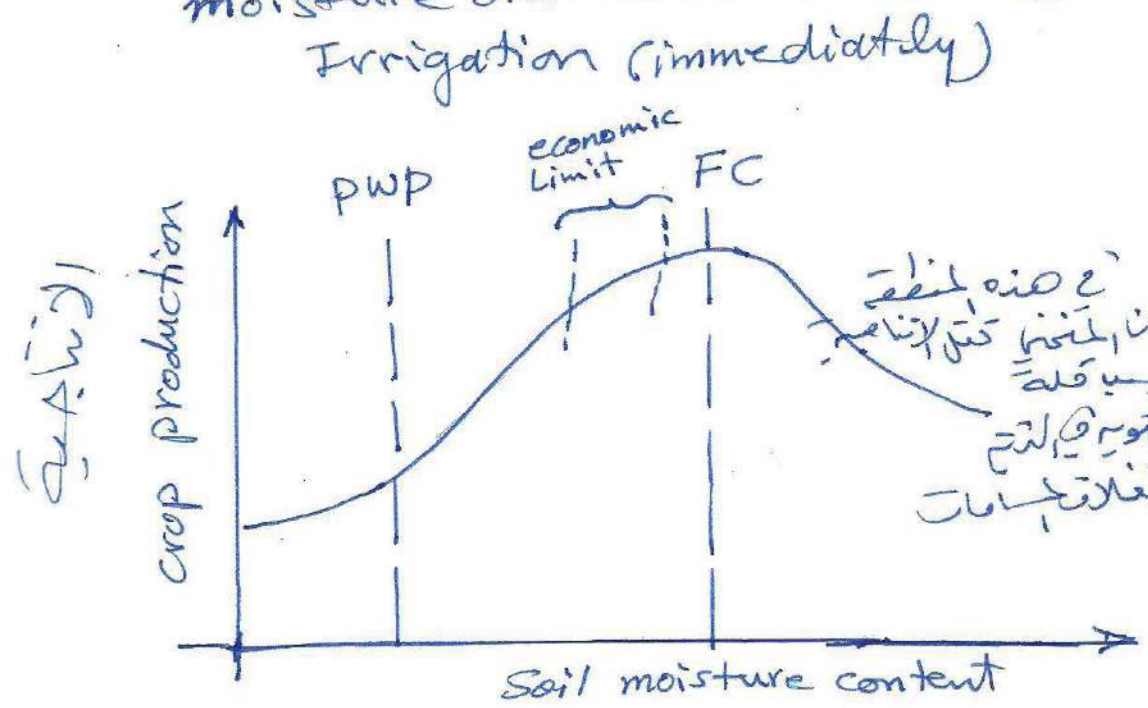
$SMD_{max} = RAW \quad (SMD \leq RAW)$

if $SMD = 0$ then water content is at F.C.





moisture distribution after Irrigation (immediatly)



relation between water content and the crop production

Ex: For a soil ; FC = 28% by dry weight
PWP = 18% by volume
AD = 50% , find Readily available water by volume , $G_b = 1.35$
and Readily AW by weight.

Sol. RAW = AD * AW
= AD * (FC − PWP)

$$w \text{ by volume} = \frac{V_w}{V}$$

by V in terms of Gb's ; $V = \frac{W_s}{G_b \gamma_w}$

$$\Rightarrow w)\text{by volume} = \frac{V_w}{W_s / G_b \gamma_w} = \frac{V_w \gamma_w}{W_s} G_b$$

$$= \frac{W_w}{W_s} G_b$$

$$\Rightarrow \boxed{w \text{ by volume} = w \text{ by weight} * G_b}$$

$$RAW = \frac{50}{100} * (28 * 1.35 - 18)\% = 9.9\% \text{ by vol.}$$

$$RAW = 9.9/1.35 = 7.33\% \text{ by weight.}$$

Ex: For given soil ; $G_s = 2.46$ weight = 184 g
dry weight = 153 g , find Gb ?

Sol: $G_b = \frac{W_s}{V \gamma_w}$, $G_s = \frac{W_s}{V_s \gamma_w} \Rightarrow V_s = \frac{153}{2.46 \times 1} = 62.5 \text{ cm}^3$

$W_w = 184 - 153 = 31 g$

$V_w = \frac{31}{\gamma_w} = 31 \text{ cm}^3$

$V = 62.5 + 31 = 93.5 \text{ cm}^3$

$$G_b = \frac{153}{93.5 * 1} = 1.64$$

Ex: A layered soil has the following:

Top layer $F.C. = 40\%$, $PWP = 18\%$] depth of soil = 50 cm

initial water content = 26% by volume AD = 35%

Bottom layer: $F.C. = 38\%$, $PWP = 20\%$] depth of soil D = 60 cm

actual water content = 30% by vol., AD = 55%

Find the required depth of irrigation "dn".

Sol.

top layer; SMD = (F.C − initial content) * Depth

$$= \left(\frac{40-26}{100}\right) * 50 = 7 \text{ cm}$$

RAW = (F.C − PWP) . AD * Depth

$$= \left(\frac{40-18}{100}\right) * 50 * 0.35 = 3.85 \text{ cm}$$

⇒ SMD > RAW ?

but SMD should be less or equal to RAW

معنا ذلك أن الارض عطشانة جداً حيث تجاوزت حد الخزين الداخلي للتربة -

Bottom layer

$$SMD = \left(\frac{38-30}{100}\right) * 60 = 4.8 \text{ cm}$$

$$RAW = \left(\frac{38-20}{100}\right) * 60 * 0.55 = 5.94$$

SMD < RAW o.K

$dn = 7 + 4.8 = 11.8$ cm

$dn_{max} = 3.85 + 5.94 = 9.79$ cm

HW

For a soil ; F.C. = 20% , PWP = 12% (all by weight) Gb = 1.2 , R.Z = 80 cm , AD = 50% if SMD>RAW by 20% . If 40 mm of water is added to the soil immediately, Find SMD after adding the water ?

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Irrigation and Drainage Engineering

Chapter Three
Land Grading

أ.م.د. رسول جميل

Chapter-3

Land Grading تدريج الارض

Land grading: is the process of forming the surface to a predetermined grades sothat the water easily flow to irrigate and to drain. It is involving cutting and fill.

The land grading permits uniform and efficient application of irrigation water without excessive erosion and at same time provides adquate surface drainage.

تدريج الارض: هو اعادة تشكيل سطح الارض باتجاه معين لاغراض الري والبزل. وتدريج الارض يسمح بجعل الري منتظم وكفوء فضلاً عن ذلك يمنع تعرية وتآكل التربة مع سهولة اداء البزل السطحي.

Some time Land grading includes Land planning which is the process of smoothing the Land surface with a land planner to eliminate minor dipressions and irregularities with changing the general topograph.

تسوية الارض: هو عمليات تجرى بالالة لغرض تنعيم (تنعيم السطحي) لازالة اي منخفضات صغيرة أو عدم انتظامية بدون تغيير رئيسي في طوبوغرافية الارض وقد تعد احدى فقرات تدريج الارض.

The land grading is very important in saving the water resources in an optimum way, however it caused a destroy and demolition (هدم وتخريب) in soil structure and fertility. This was due to the cutt and fill process. Thus, Some land grading criteria must be considered :-

1. soil profile condition

- make survey → information about thickness of the soil suitable for planting (the datum layer) الطبقة الأم الانتية
- disadvantage of soil damage can be reduce by removing the fertile surface and placing it away, thenafter spreading it again through Land grading process. Although it is conservative step, but it is still of high cost process.

2. Land slope

ميل حاد

For land of steep slope or has complex topography or the planting depth is small, It cannot be able to make the surface of uniform slope, this type of slope or soil is preferable to leave without land grading, otherwise the dividing of the land into subareas each one has a certain slope to reduce the cutt and fill works. The limitations of the slopes in the direction of irrigation are specified the range of the slope from $\frac{1}{20}$ % to ½ % with min = $\frac{1}{20}$ % but for drainage requirement the more convient slope is (0.1 – 0.2) %. For Furrow slope, it is less than 2%.

Type of soil	Slope in Irrigation direction
Heavy soil	0.05 % – 0.25 %
Loam soil	0.2 % – 0.4 %
Light soil	0.25 % – 0.65 %

3- Plot size for grading ، مقياس التسوية

It may be considered as unit, farm or even field depending on topography of the land and the method of irrigation. In IRAQ the land grading is preferable at farm level and rarely at field level.

4. Crop type نوع المحصول

Valuable crop → high degree of accuracy for L.G.
Other crop → has no need for this type of L.G.
(i.e fodder)

5. Irrigation methods طرق الري

For each method there will be limitation concerned for irrigation slope and transverse slope. If more than one type of irrigation used in same field, it will expected to be also more restrictions for L.G.

6. Other requirement اعتبارات أخرى

Cutt & fill works from drainage canals construction Can be used for fill works i.e, Canals, dikes, حواجز قنوات
سداد صغيرة Levees, and field ways since the drainage system is constructed during L. G.

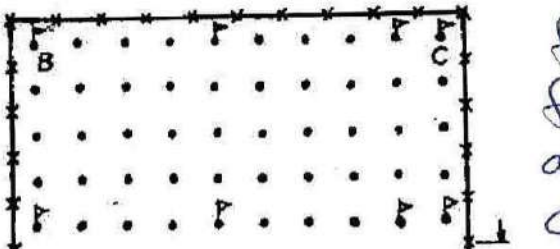
Preparatory steps الخطوات التمهيدية

The first steps of L.G. is:
1: define the plot size of grading.
2 - Staking. use stake (1cm x 1cm x 4cm)
3 - Dertermination of elevation at each stak point. close to 1 cm, All structures, electric lines, drains roads, water resourse, must be assigned.

Staking التوتيد

The natural ground surface elevations and the values of cutt and fill works must be found at a certain points where the stacks are fixed at equal spacing ranged from 15 to 30m from station to station, thus a network of squeare or rectangles are created as shown in the following illustration.

توضع اعلام عند النقاط
A, B, C and D
فضلاً عن ذلك توضع
اعلام كل 4 أوتاد
الاطوال أي كل
4x15 = 60m



for nonuniform field, the stacks are extended to cover any ared within a dimension of 15m or greater.

Typical layout for staking area required to grade

Land Grading computations:

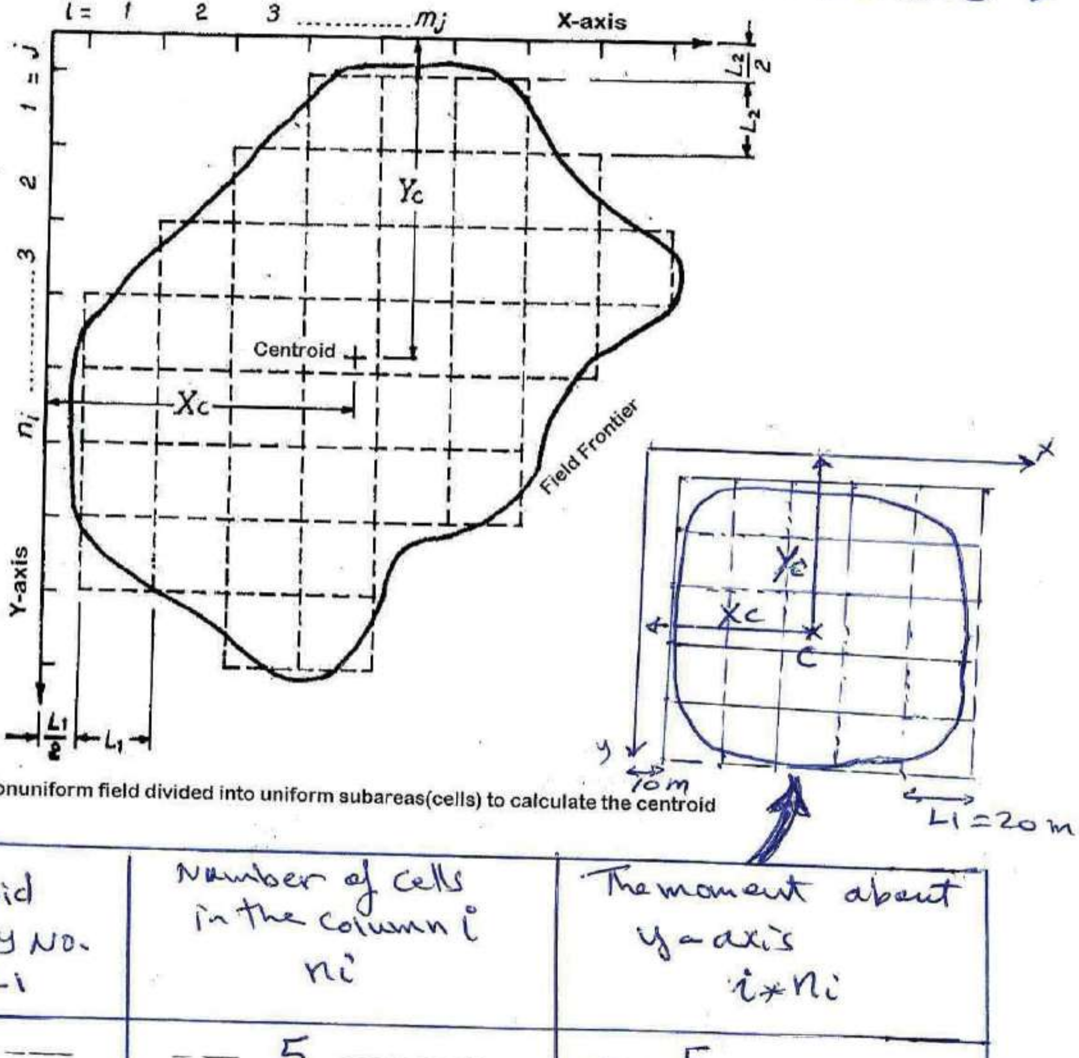
(1-) Locating the centroid تحديد مركز الشكل

For uniform shape (rectangles, triangles, ...etc) it is easy to locate the centroid, while the nonuniform (irregular) shapes are posed a problem. The area, hence, divided into uniform shape of known centroid and calculate it as:

$$X_c = \frac{\Sigma a_i x_i}{\Sigma a_i} \quad \text{———} \quad (3.1)$$

Same formula was held for y_c -

For more accuracy, it is recommended to divide the farm into small areas as in network of land elevations with neglecting the parts of cell (if it exists), see figure below. Also the procedure shown in a table below -



Nonuniform field divided into uniform subareas(cells) to calculate the centroid

Distance for column centroid from y-axis by No. of interval L_i	Number of cells in the column i n_i	The moment about y-axis $i * n_i$
1	5	5
2	5	10
3	5	15
4	5	20
5	5	25

$\Sigma n_i = 25$ $\Sigma(i * n_i) = 75$

$X_c = \frac{75}{25} = 3 L_1$

or $X_c = 3(20) = 60$ m [say $L_1 = 20$ m]

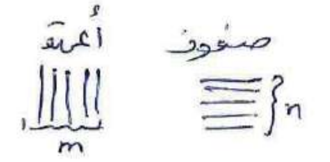
In general:

(i) عمود : تتحرك الحركة باتجاه x

$$X_c = \left[\sum_{i=1}^{m} (n_i * i) \Big/ \sum_{i=1}^{m} n_i \right] * L_1 \text{ ------ } (3.2)$$

(j) صف : تتحرك صفوف باتجاه y

$$Y_c = \left[\sum_{j=1}^{n} (m_j * j) \Big/ \sum_{j=1}^{n} m_j \right] * L_2 \text{ ---- } (3.2)$$



② Determination of average field Levels

إيجاد معدل مناسيب الحقل $(\bar{H})$

The average of field levels $(\bar{H})$ can be found by dividing the sum of levels in the center of cells (i.e, $\Sigma H_{i,j}$) by the total number of cells $\left(\sum_{i=1}^{m} \sum_{j=1}^{n} N_{i,j} \right)$; Thus

$$\bar{H} = \sum_{i=1}^{m} \sum_{j=1}^{n} (H_{i,j}) \Big/ \sum_{i=1}^{m} \sum_{j=1}^{n} N_{i,j} \text{ ---- } (3.3)$$

$$\text{where } \underbrace{\sum_{i=1}^{m} \sum_{j=1}^{n} N_{i,j}}_{\text{مجموع كل الخلايا}} = \underbrace{\sum_{i=1}^{m} n_i}_{\text{مجموع الخلايا في الأعمدة}} = \underbrace{\sum_{j=1}^{n} m_j}_{\text{مجموع الخلايا في الصفوف}}$$

③ Calculation of Design plane slope

حساب ميل المستوى التصميمي

Three methods are discussed herièn to calculate the design plane slopes in irrigation direction, and the transverse direction.

ⓐ The plane of best fit

This method fulfills a minimum earth works, such that cutt are equal fill works. Infinite planes passing through the centroid give cutt = fill but one plane gives min(cutt) = min(fill). This is

So-called best plane (optimum plane) having slopes Sx in x-direction and Sy in y-direction.

مجموع خلايا في العمود i

$$S_x = \frac{\sum_{i=1}^{m}\left[\left(\sum_{j=1}^{m} H_j\right) * i\right] - X_c * \left[\sum_{j=1}^{n}\sum_{i=1}^{m} H_{i,j}\right]}{\sum_{i=1}^{m}\left[N_i * i^2\right] - \left[\sum_{i=1}^{m}\sum_{j=1}^{n} N_{i,j}\right] * X_c^2} \quad \text{---} (3.4)$$

عدد الخلايا في العمود i

مجموع خلايا السطر j

مجموع مناسيب الحقل

$$S_y = \frac{\sum_{j=1}^{n}\left[\left(\sum_{i=1}^{m} H_i\right) * j\right] - Y_c * \left[\sum_{j=1}^{n}\sum_{i=1}^{m} H_{i,j}\right]}{\sum_{j=1}^{n}\left[N_j * j^2\right] - \left[\sum_{i=1}^{m}\sum_{j=1}^{n} N_{i,j}\right] * Y_c^2} \quad \text{---} (3.5)$$

عدد الخلايا في السطر j

المجموع الكلي للخلايا

for example consider the field below!

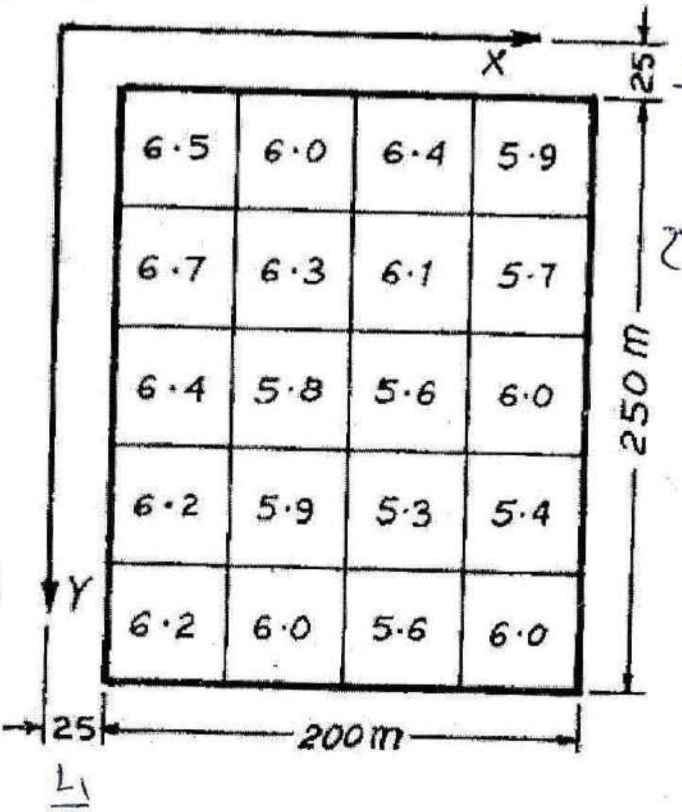
$X_c = 2.5\ L_1$

$Y_c = 3\ L_2$

or $X_c = 125$ m

$Y_c = 150$ m

Sx and Sy were determined in next table (page 8).



6.5	6.0	6.4	5.9
6.7	6.3	6.1	5.7
6.4	5.8	5.6	6.0
6.2	5.9	5.3	5.4
6.2	6.0	5.6	6.0

i: تتحرك اعمدة وتشكل بذلك صف كامل بالجمع

j: تتحرك صفوف وبذلك تشكل عمود عند الجمع

Natural Levels for small field (Network 50x50m)

$\sum_{i=1}^{m=4}$ colum تترك أعمدة (over row)

$\sum_{j=1}^{n=5}$ row تترك صفوف (over calume)

$i = 1 \longrightarrow m$ (No. of column)

$j = 1 \longrightarrow n$ (No. of rows)

$$\sum_{i=1}^{m=4} \sum_{j=1}^{n=5} H_{i,j} = 120$$

$$\sum_{i=1}^{m} \sum_{j=1}^{n} N_{i,j} = 20$$

جمع لكل الأعمدة ، مجموع خلايا عمود i

$$\sum_{i=1}^{m} \left[\left(\sum_{j=1}^{n} H_j \right) * i \right] = 295$$

$$\sum_{i=1}^{m} \left[N_i * i^2 \right] = 150$$

①	②	③	④	
6.5	6.0	6.4	5.9	①
6.7	6.3	6.1	5.7	②
6.4	5.8	5.6	6.0	③
6.2	5.9	5.3	5.4	④
6.2	6.0	5.6	6.0	⑤

j	N_j	$N_j * j^2$	$(\Sigma H_i)_j$	$(\Sigma H_i)_j * j$
1	4	4	24.8	24.8
2	4	16	24.8	49.6
3	4	36	23.8	71.4
4	4	64	22.8	91.2
5	4	100	23.8	119
Σ	20	220	120	356

جمع خلايا الصف لكل j

$$\sum_{j=1}^{n=5} \left(\sum_{i=1}^{m=4} H_i \right) * j = 36$$

تجميع صفوف

i	N_i	$N_i * i^2$	$(\Sigma H_j)_i$	$(\Sigma H_j)_i * i$
1	5	5	32	32
2	5	20	30	60
3	5	45	29	87
4	5	80	29	116
Σ	20	150	120	295

تجميع الأعمدة

وبعد استخدام قيم Xc و Yc علينا تطبيق معادلة 3-5 و 3-4 لإيجاد Sx و Sy

(عدد الخلايا في الصف)

عدد الأعمدة m = 4

عدد الصفوف n = 5

(عدد الخلايا في العمود)

Sample of calculation for the designed slopes by using plane of best fit method

ملاحظة:

لـ Sx

① نجمع خلايا الصف لكل عمود ثم نتحرك على كل الأعمدة أفقياً (أي باتجاه X).

② نجمع خلايا العمود لكل صف ثم نتحرك على كل الصفوف عمودياً (باتجاه Y).

$$S_x = \frac{295 - 2.5 * 120}{150 - 20 (2.5)^2} = -0.2 \; m / L_2$$

أي أن الانحدار في اتجاه المحور X هو 0.2 لكل 50 متر

$$\Rightarrow S_x = -\frac{0.2}{50} * 100 = -0.4\%$$

$$\text{and, } S_y = \frac{356 - 3 * 120}{220 - 20 (3)^2} = -0.1$$

$$\Rightarrow S_y = \frac{-0.1}{50} * 100 = -0.2\%$$

الإشارة السالبة تعني أن ميل المستوى في اتجاه المحور ينحدر نحو الأسفل وعكس ذلك تكون الإشارة الموجبة هو ارتفاع نحو الأعلى.

b) The average profile method طريقة معدل شكل المقطع

1. Calculate average elevations of cells through raw, $\bar{H}_j$ and average elevation of cells through column, $\bar{H}_i$, and cosequently average of all cells, $\bar{H}$

$$\bar{H}_j = \sum_{i=1}^{m} \frac{H_i}{m_j} \quad \text{———} \quad (3.6)$$

$$\bar{H}_i = \sum_{j=1}^{n} \frac{H_j}{n_i} \quad \text{———} \quad (3.7)$$

$\bar{H}$ is calulated previously by eq.(3.3).

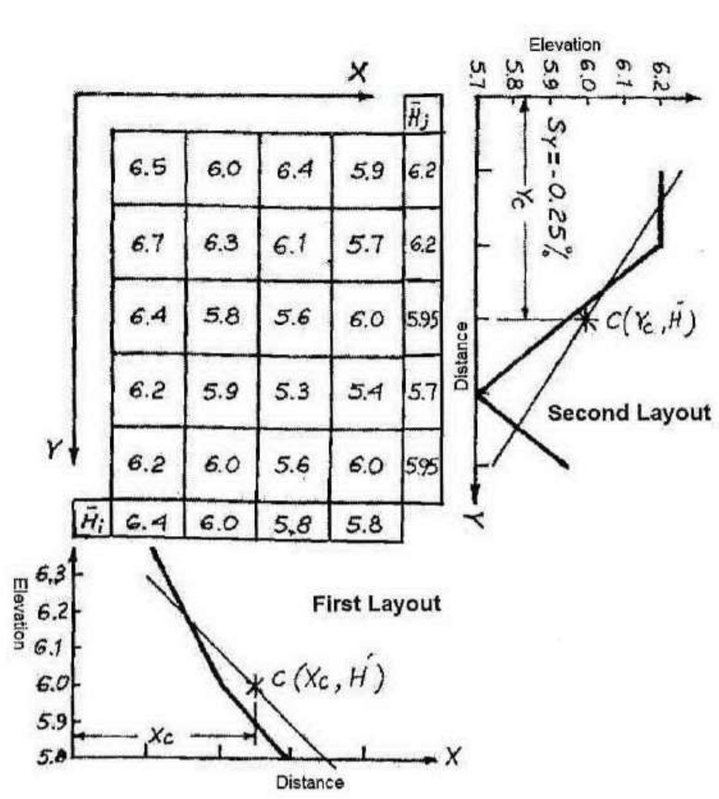
2. define the centroid of the area.

3. Draw a sketch for $\bar{H}_i$ (average columns) with distance of colums from y-axis. Also Draw the $\bar{H}_j$ (average of rows) with distance of rows from x-axis.

4. point out the point $(x_c, \bar{H})$ on first sketch and the point $(y_c, \bar{H})$ on second sketch.

5. A straight line passes through point $(x_c, \bar{H})$ and another straight line passes through point $(y_c, \bar{H})$ should forced to pass through most points of the each sketch to give minimum fill and cutt, checked by eyes.

6. Determine the slope of straight Line from first sketch which equals to S_x and the slope from straight line of the second sketch to give S_y.



				$\bar{H}_j$
6.5	6.0	6.4	5.9	6.2
6.7	6.3	6.1	5.7	6.2
6.4	5.8	5.6	6.0	5.95
6.2	5.9	5.3	5.4	5.7
6.2	6.0	5.6	6.0	5.95
6.4	6.0	5.8	5.8	$\bar{H}_i$

Sample of calculation for the designed slopes by using average profile method

(c) average slope method

طريقة متوسط الميل

It is the simplest one but with Less accuracy It is built on finding the average of ~~all~~ slopes for all rows considering the number of cells in each row, i-e;

$$S_x = \frac{\sum_{j=1}^{n} N_j * S_{xj}}{\sum_{i=1}^{m} \sum_{j=1}^{n} N_{ij}} \quad \text{———} \; (3.8)$$

N_j: عدد الخلايا في السطر.

وفي حالة تساوي الخلايا في جميع الأسطر فإن المعادلة (3.8) تكون

$$S_x = \frac{\sum_{j=1}^{n} S_{xj}}{n} \quad \text{———} \; (3.9)$$

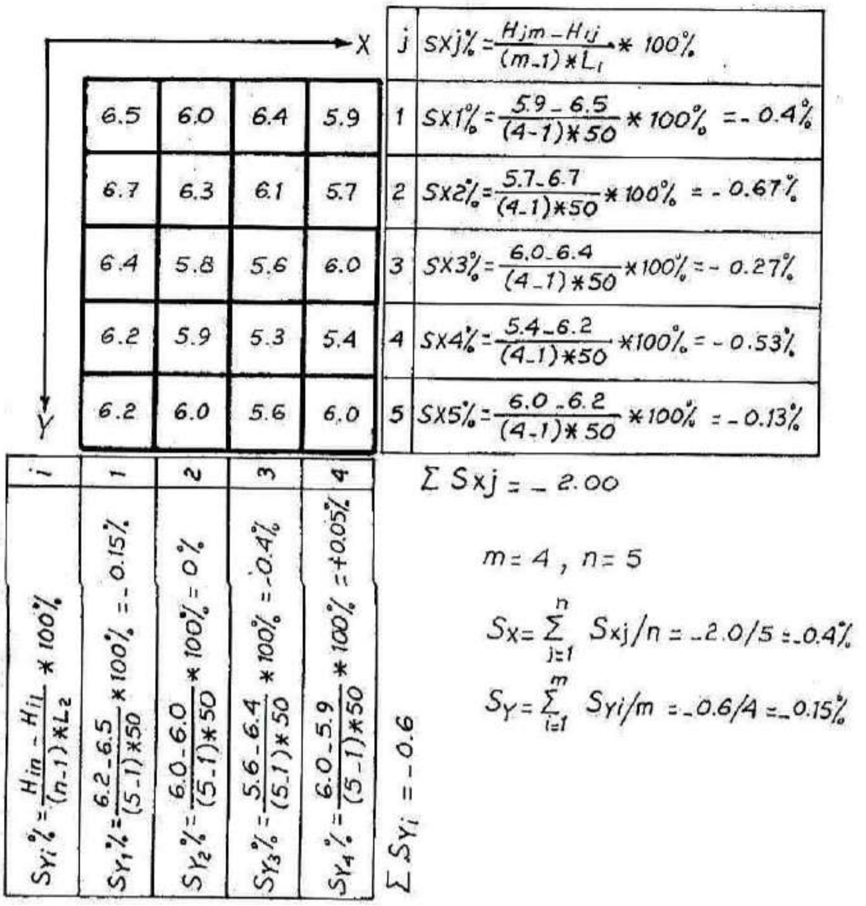
n = عدد الصفوف = عدد الخلايا في كل عمود

ميل الصف j

$$S_{xj} = \frac{H_{mj} - H_{1j}}{(m-1) L_1} \times 100 \quad \text{———} \; (3.10)$$

m: عدد الأعمدة

H_{mj} and H_{1j} represents the elevations of first and last point in the row.



6.5	6.0	6.4	5.9	1
6.7	6.3	6.1	5.7	2
6.4	5.8	5.6	6.0	3
6.2	5.9	5.3	5.4	4
6.2	6.0	5.6	6.0	5
1	2	3	4	i

j $SXj\% = \frac{Hjm - Hij}{(m-1)*L_1} * 100\%$

1 $SX1\% = \frac{5.9 - 6.5}{(4-1)*50} * 100\% = -0.4\%$

2 $SX2\% = \frac{5.7 - 6.7}{(4-1)*50} * 100\% = -0.67\%$

3 $SX3\% = \frac{6.0 - 6.4}{(4-1)*50} * 100\% = -0.27\%$

4 $SX4\% = \frac{5.4 - 6.2}{(4-1)*50} * 100\% = -0.53\%$

5 $SX5\% = \frac{6.0 - 6.2}{(4-1)*50} * 100\% = -0.13\%$

$\Sigma Sxj = -2.00$

i $SYi\% = \frac{Hin - Hi1}{(n-1)*L_2} * 100\%$

1 $SY_1\% = \frac{6.2 - 6.5}{(5-1)*50} * 100\% = -0.15\%$

2 $SY_2\% = \frac{6.0 - 6.0}{(5-1)*50} * 100\% = 0\%$

3 $SY_3\% = \frac{5.6 - 6.4}{(5-1)*50} * 100\% = -0.4\%$

4 $SY_4\% = \frac{6.0 - 5.9}{(5-1)*50} * 100\% = +0.05\%$

$\Sigma SY_i = -0.6$

$m = 4 , n = 5$

$Sx = \sum_{j=1}^{n} Sxj/n = -2.0/5 = -0.4\%$

$S_Y = \sum_{i=1}^{m} SYi/m = -0.6/4 = -0.15\%$

Sample of calculation for average slope method

$$Sy = \frac{\sum_{i=1}^{m} Ni \cdot Syi}{\sum_{i=1}^{m} \sum_{j=1}^{n} Ni,j} \qquad (3-11)$$

Ni عدد الكنتور في العمود i

وفي حالة تساوي خلايا جميع الأعمدة فأن

$$Sy = \frac{\sum_{i=1}^{m} Syi}{m} \qquad (3-12)$$

m = عدد الأعمدة = وهو عدد الخلايا لكل صف

$$Syi = \frac{Hin - Hi1}{(n-1) L_2} \times 100 \qquad (3-13)$$

n: عدد الصفوف

حيث:

Hin, Hi1 represent the elevations of the first and the last point in the Column.

Calculation of Design Levels حساب مناسيب التصميم

With availability of acual Levels and the slopes Sx and Sy in x- and y-direction, one can calculate the levels of design plane. Take into account the previous example and considered the method of best fit (optimum method) to clarify the calculation steps.

$S_x = \bar{0}.2\ m/L_1$

$S_y = \bar{0}.1\ m/L_2$

$\bar{H} = 6.0\ m$

shape example in Page 7

The accuracy used is up to 1cm

بعد الفارزة مرتبتين فقط، اذا كانت المناسيب بالامتار .

$$\left.\begin{array}{l} Y_c = 3L_2 \\ X_c = 2.5L_1 \end{array}\right\} \bar{H} = 6\,m \text{ at } (X_c, Y_c)$$

, i.e, it located at $(2.5L_1, 3L_2)$, thus the centroid is not at center of cell. It must be shiftted to new Location by

$6 + \frac{0.2}{2} = 6.1\,m$ and assigned for cell $i = 2$ and $j = 3$ (او مركز خلية (الصف الثالث مع العمود الثاني)

All Levels should be stated at centers of cells by adding $0.2m/L_1$ to the left or subtracting $\frac{0.2}{L_1}$ to the right. If the row NO.3 is completed, the other elevations can achived easly by considering the 3rd row cell intersection.

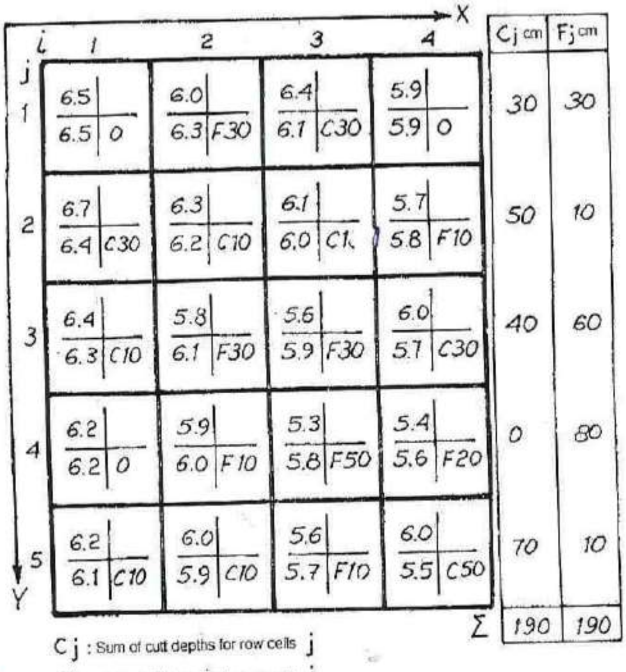
Calaulation of Earth work (Cutt & Fill)

The depths of cutt and fill in the cell of mesh are calculated by comparing the actual levels and the design Levels, and if the actual Levels > design level the depths therefore are cutt, otherwise are fill. The all depths in the cell then became known (in the centers of these cells).

The cutt depth is assigned by "C" whereas the fill is by "F". from previans example, by considering the design levels & the actual levels, the sum of the depths for cutt and fill is equal = 190 cm

ملاحظة: في حالة عدم وجود قطع أو ردم
فيكون العمق = صفر

actual	
design	C or F



i → X j ↓ Y	1	2	3	4	Cj cm	Fj cm
1	6.5 6.5 0	6.0 6.3 F30	6.4 6.1 C30	5.9 5.9 0	30	30
2	6.7 6.4 C30	6.3 6.2 C10	6.1 6.0 C1	5.7 5.8 F10	50	10
3	6.4 6.3 C10	5.8 6.1 F30	5.6 5.9 F30	6.0 5.7 C30	40	60
4	6.2 6.2 0	5.9 6.0 F10	5.3 5.8 F50	5.4 5.6 F20	0	80
5	6.2 6.1 C10	6.0 5.9 C10	5.6 5.7 F10	6.0 5.5 C50	70	10
				Σ	190	190

Cj : Sum of cutt depths for row cells j

Fj : Sum of fill depths for row cells j

Average depth (cm) of cutt and fill in network cells

There are manymethods available for estimating the quantity of earth works. Two of them were disussed below:-

1. Summation method طريقة الجمع

* Quick * simple but gives an overestimation. تعطي احجاماً أكبر من الواقع

$$\forall_{cutt} = \forall_C = \sum C * (L_1 * L_2) \quad \text{———} \quad (3.14)$$

$$\forall_{Fill} = \forall_F = \sum F * (L_1 * L_2) \quad \text{- - - -} \quad (3.15)$$

على فرض أن حجم القطع أو الردم عند مركز الخلية ثابت في كل عموم مساحة الخلية الواقعة في وحدة التشبيك).

2. The Four-point method طريقة النقاط الأربع

This method has more accurate and more complicated Calulation steps. To accomplish the calulation, a new delineation was adopted for the area by passing horizontal and vertical lines through the centers of cells. Three types of areas were obteined

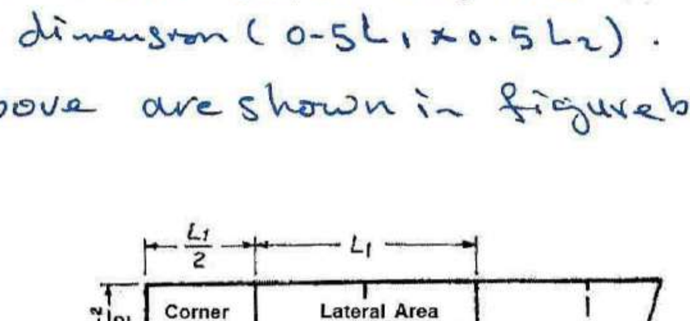
ⓐ internal area: with dimension $(L_1 * L_2)$
ⓑ lateral area: with dimension $(L_1 * 0.5 L_2)$ or $(0.5 L_1 * L_2)$
c) Coner area: with dimension $(0.5 L_1 * 0.5 L_2)$.

The three types above are shown in figure below.

يتم ايجاد احجام القطع V_c
واحجام الردم V_F وفق المعادلات
الآتية :-

$$V_c = \frac{L_1 * L_2}{400}\left[\frac{H_c^2}{H_c + H_F}\right] \quad (3.16)$$

$$V_F = \frac{L_1 * L_2}{400}\left[\frac{H_F^2}{H_c + H_F}\right] \quad (3.17)$$



Partial Layout represents Area re-networking by the four-point method

V_c, V_F in m^3, H_c, H_f in cm, L_1, L_2 in m.

Hc and Hf is calculated according to above types of areas.

ⓐ for internal area
$H_c = C_1 + C_2$, $H_f = f_1 + f_2$

ⓑ for lateral area (Likewise area adjacent to line $C_1 f_2$)
$H_c = C_1$, $H_f = F_2$

ⓒ for Corner area
$H_c = C_1$, $H_f = 0$

The total earth works is equall to sum of earth work of all areas -

Earthwork Balance موازنة الأعمال الترابية

$1\ m^3$ of cutt volume from natural soil → $0.8\ m^3$ fill volume

$$\Rightarrow C/F = \frac{1}{0.8}$$ أي أن أحجام الردم أقل من أحجام القطع

والسبب هو الانتفاخ (Sevelling) في التربة وكما يحدث الانتفاخ
تحدث الانكماش (Shrin-kage) في التربة .

$$C/F = \frac{1}{0.8} \Rightarrow C/F = 1.25$$

Shrinkage factor (SF):

$$SF = (C/F - 1) * 100 = 25\%$$

C/F ratio ranged from <u>1.15 to 1.6</u> depending on * grading of the earth surface *

(عالي C/F)
عند أعماق أقل من 30 سم (ضعيفة)
والأكثر من 30 سم فإن درجة التدرج تكون ضعيفة
نستخدم قيمة أقل نسبياً لـ C/F .

* water content for soil

dry season → use C/F واطئ
low

wet season → use C/F (high) عالي

* Type of equipments used = الماكنات والمعدات

heavy equipment → low C/F

عندما تكون نسبة قطع/ردم ≠ ١ فإنه يجب خفض المناسيب التصميمية بمقدار
ΔH لجعل C/F ≠ ١ ويجب ΔH من المعادلات التالية :-

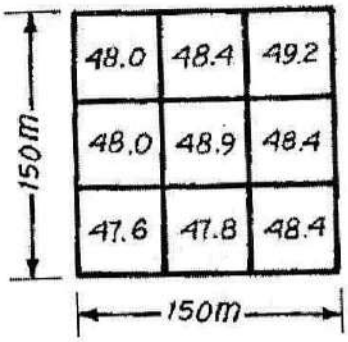
$$\left.\begin{aligned} \Sigma C_b &= \Sigma C + n_c * \Delta H \quad (3.18) \\ \Sigma F_b &= \Sigma F - n_f * \Delta H \quad (3.19) \end{aligned}\right\} \Rightarrow \frac{\Sigma C_b}{\Sigma C_F} = (C/F)$$

$$(C/F) = \frac{\Sigma C + n_c * \Delta H}{\Sigma F - n_f * \Delta H} \; ; \; \Delta H = \frac{(C/F)\Sigma F - \Sigma C}{(C/F)\, n_f + n_c} \quad --- (3.20)$$

Examples For Land Grading

Ex1: *Design the land grading of the field, shown in Figure below, using the plane of best fit to determine the design slopes, summation method for earthwork calculations. Consider a ratio of cut to fill (C/F) ranged from 1.2 to 1.45.The intervals of mesh points is 50x50 m. The design should e reveal the following:*

- ***a)** final design level at center of mesh unit (cells).*
- ***b)** Volumes of cut and fill after performing the earthwork balance.*
- ***c)** Plot the contour line of no cut & no fill (divide line of cut and fill regions).*
- ***d)** If the cost of 1m^3 of cut , transport, and grading soil to use as fill is 9 000 ID, estimate the land grading cost for 1hectar.*



48.0	48.4	49.2
48.0	48.9	48.4
47.6	47.8	48.4

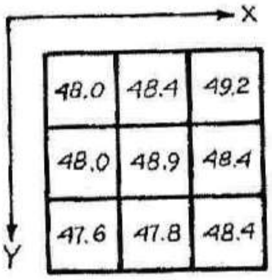
Solution:

***a)** The field is a square shape, therefore the centroid is located at intersection point of both diagonals. Xc =2L$_1$ Yc= 2 L$_2$, Sx and Sy can be calculated from following tables:*

From eq(3.6) and (3.7):-

$$Sx = \frac{871.8 - 2(434.7)}{42 - 9 * 2^2} = 0.4/L_1\ meter$$

$$Sy = \frac{867.6 - 2(434.7)}{42 - 9 * 2^2} = -0.3/L_2\ meter$$



48.0	48.4	49.2
48.0	48.9	48.4
47.6	47.8	48.4

j	N_j	$N_j * j^2$	$(\Sigma H_i)_j$	$(\Sigma H_i)_j * j$
1	3	3	145.6	145.6
2	3	12	145.3	290.6
3	3	27	143.8	431.4
Σ	9	42	434.7	867.6

i	N_i	$N_i * i^2$	$(\Sigma H_j)_i$	$(\Sigma H_j)_i * i$
1	3	3	143.6	143.6
2	3	12	145.1	290.2
3	3	27	146	438
Σ	9	42	434.7	871.8

From eq.(3.3)

$$\overline{H} = \frac{434.7}{9} = 48.3\ m$$

Let the design plane of above slopes pass through the centroid of the field with a level of $\overline{H}$ at this point to get the design levels. Thenafter, calculate the cut and fill at each cell to obtain the total depths of cut and fill over whole field.

48.0 48.2 F20	48.4 48.6 F20	49.2 49.0 C20
48.0 47.9 C10	48.9 48.3 C60	48.4 48.7 F30
47.6 47.6 0	47.8 48.0 F20	48.4 48.4 0

$$\sum C = 20 + 10 + 60 = 90\ cm$$

$$\sum F = 20 + 20 + 30 + 20 = 90\ cm$$

*By considering **eartwork balance**:*

n_c =5 (includeing non-cut points and non-fill points)

n_f =4

From eq.(3.20) with C/F =1.2 :

ΔH = 1.83 cm approximate the result close to 1cm , thus;

ΔH = 2 cm ,now check C/F with this value of ΔH ,however the new value of C/F is within a given range (C/F=1.22).

48.0 48.18 F18.	48.4 4858 F18	49.2 48.98 C22
48.0 47.88 C12	48.9 48.28 C62	48.4 48.68 F28
47.6 47.58 C02	47.8 47.98 F18	48.4 48.38 C02

b) *From eqs.(3.18 &3.19):*

$$\sum C_b = 90 + 5 \times 2 = 1\ m$$

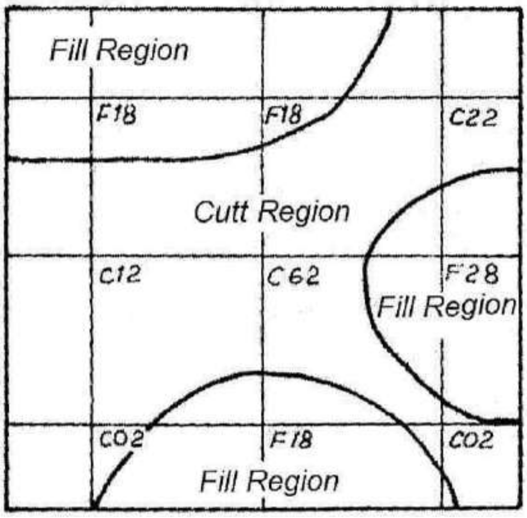
$$\sum F_b = 90 - 4 \times 2 = 0.82\ m$$

From eqs.(3.14 &3.15):

$$\forall C = 1.00\ (50 \times 50) = 2500\ \ m^3$$

$$\forall_F = \ 0.83\ (50 \times 50) = 2050\ \ m^3$$

c) *The contour line between cut & fill regions is plotted after the values of cut and fill are fixed at intersection of a new mesh generated by delineation passing through centers of old cells as shown below:*



d) *Total area of the field =150X150=22500 m^2=2.25 hec*

Volume of cut =2500 m^3

$$Cost = \frac{2500\,m^3 \times 9000\,ID/m^3}{2.25\,hec} = 10\ 000\ 000\ ID\,/\,hec$$

Ex2: *Design the land grading of the small field, shown in Figure, using the average slope method and considering C/F=1.5 . Determine the final design levels at each point and estimate the earthwork .The intervals are 20x20m.*

11.9	12.2
12.1	12.0

Solution:

From eq. (3.9):

$Sx_1 = 12.2 - 11.9 / (2-1)(20) \times 100 = 1.5$

Sx_2={(12.0- 12.1)/[(2-1)x20]} x100= - 0.5%

From eq. (3.9): *Sx = 1.5+(- 0.5)/2 =0.5%=10m/ 20m*

11.9	12.2
12.1	12.0

From eq. (3.13):

Sy_1={(12.1- 11.9)/[(2-1)x20]} x100=1.0 %

Sy_2={(12.0- 12.2)/[(2-1)x20]} x100= - 1.0 %

From eq. (3.12): *Sy = 1.0+(- 1.0)/2 = 0*

From eq.(3.3) : $\overline{H} = \frac{11.9+12.2+12.1+12.0}{4} = 12.05\ m$

Let the design plane of calculated slopes pass through the centroid of the field with a level of $\overline{H}$ at this point to get the design levels. Thenafter, calculate the cut and fill at each cell to obtain the total depths of cut and fill over whole field as shown in figure.

11.9 12.0 F10	12.2 12.1 C10
12.1 12.0 C10	12.0 12.1 F10

$$\sum C = 10 + 10 = 20\ cm$$

$$\sum F = 10 + 10 = 20\ cm$$

*By considering **eartwork balance**:*

n_c =2

n_f =2

From eq.(3.20) with C/F =1.5 : $\Delta H = 2\ cm$

Now lower all levels at centers of cells by 2cm,the final levels are shown in figure.

11.9 11.98 F08	12.2 12.08 C12
12.1 11.98 C12	12.0 12.08 F08

From eqs.(3.18 &3.19):

$$\sum C_b = 20 + 2 \times 2 = 0.24\ m$$

$$\sum F_b = 20 - 2 \times 2 = 0.16\ m$$

From eqs.(3.14 &3.15):

$\forall c = 0.24\ (20 \times 20) = 96\ m^3$

$\forall_F = 0.16\ (20 \times 20) = 64\ m^3$

Ex3: *The values shown in table represent the natural ground levels at center of mesh unit of the land grading. If the design slopes are given as Sx=0.4% and Sy=0 ,while the intervals are 25x25m , find the:*

	7.10	7.00
6.90	6.80	7.30

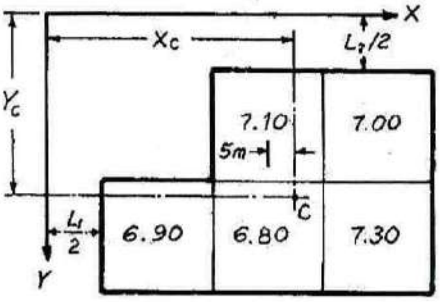
- ***a)*** *by using the summation method ,the volumes of earthwork at (C/F) ratio=1.0*
- ***b)*** *ΔH required to lower the design plane in order to get C/F=1.5*

Solution:

Since the field is unsymmetrical shape, therefore the centroid must determined by using eqs.(3.1&3.2) as follow:

Xc=(1x1+2x2+2x3) / (1+2+2)=2.2 L_1*=55 m*

Yc=(2x1+3x2) / (2+3)=1.6 L_2*=40 m*



From eq.(3.3)

$$\overline{H}=\frac{7.1+7+6.9+6.8+7.30}{5}=7.02\ m$$

Let the design plane of above slopes pass through the centroid of the field with a level of $\overline{H}$ *at this point to get the design levels, as shown in figure.*

Thenafter, calculate the cut and fill at each cell to obtain the total depths of cut and fill over whole field.

	7.10 7.00 C10	7.00 7.10 F10
6.90 6.90 0	6.80 7.00 F20	7.30 7.10 C20

$$\sum C=10+20=0.30\ m$$

$$\sum F=10+20=0.30\ \ cm$$

By considering ***eartwork balance****:*

n_c *=3 (includeing non-cut points and non-fill points)*

n_f *=2*

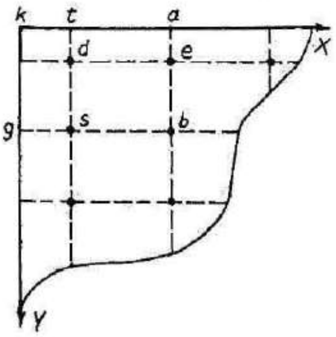
From eqs.(3.14 &3.15):

a) $\forall c=0.3\ (25\times 25)=187\ m^3$

$\forall_F=\ 0.3\ \ (25\times 25)=187\ m^3$

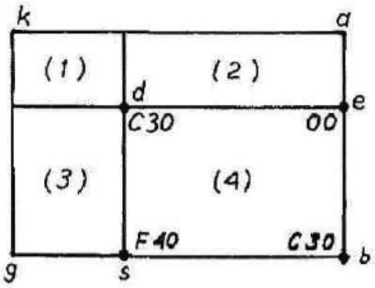
b) *From eq.(3.20) with C/F =1.5 :* $\Delta H=0.025\ m=2.5\ cm$

Ex4: The small area shown in figure was a part of a land grading design for large project whose interval in x-direction L_1=30m and in y-direction L_2=20m.the natural ground levels at points **d,e,b**, and **s** are 48.4 , 48.0 , 48.6, 48.0, respectively , while design levels are 48.1, 48.0, 48.3, 48.4. Calculate the volume of earthwork?



Solution:

From the balance of natural ground levels and the design levels at points **d,e,b**, and **s** ,the depths of cut and fill for the area **kabg** shown in figure are calculated by using Eqs.(3.16&3.17) for subareas **1,2,3**,and **4** .The results are shown in tabble below:



Area No.	H_c (cm)	H_f (cm)	V_c (m^3)	V_f (m^3)
1	30	0	45	0
2	30	0	45	0
3	30	40	19	34
4	60	40	54	24
			Sum=163m^3 for Cut	**Sum=58** m^3 for Fill

Ex5: A survey for small field was carried out in order to implement a land grading of intervals L_1 x L_2 =20x25m .Thus, the mesh consists of 6 rows and 10 columns. The averaged natural ground levels are given below :

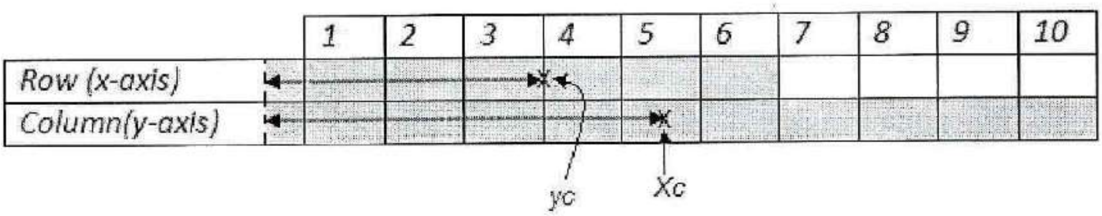
	No. of row or column									
	1	2	3	4	5	6	7	8	9	10
Row (x-axis)	67.0	67.2	67.3	67.3	67.5	67.5				
Column(y-axis)	67.7	67.5	67.4	67.5	67.3	67.2	67.2	67.1	67.0	67.1

Use average rofile method to determine the design slopes in x- and y-direction.show in a lot the rofile of average levels in x- and y-direction associated with slopes as percent with sign.

Solution:

$$\overline{H}\text{=Mean of average levels} = \frac{67{,}0+67.2+67.3+67.3+67.5+67.5}{6} = 67.3\ m$$

Xc= 100m , Yc=75m



Along y-distance

The first point was selected by sight is (12.5,67.05), whereas the second point is (yc, $\overline{H}$). Thus , the slope Sy can be calculated as:

$$Sy = \frac{67.3 - 67.05}{75 - 12.5} \times 100 = 0.4\%$$

Along x-distance

The first point was selected by sight is (10.67.63),whereas the second point is (xc, $\overline{H}$).Thus, the slope Sy can be calculated as:

$$Sx = \frac{67.3 - 67.63}{100 - 10} \times 100 = -0.36\%$$