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Enhancement of the Efficiency of Infiltration Basins for Effluent Recharge

(Case Study: Northern Gaza New Infiltration Basins)

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Enhancement of the Efficiency of Infiltration Basins for Effluent Recharge

(Case Study: Northern Gaza New Infiltration Basins)

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نتيجة الحكم على أطروحة ماجستير

بناءً على موافقة الدراسات العليا بالجامعة الإسلامية بغزة على تشكيل لجنة الحكم على أطروحة الباحث/ باسم ابراهيم جمعة سرداح لنيل درجة الماجستير في كلية الهندسة قسم الهندسة المدنية- هندسة مصادر المياه وموضوعها:

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(Case Study: Northern Gaza New Infiltration Basins)

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والله ولي التوفيق،،،

مساعد نائب الرئيس للبحث العلمي والدراسات العليا

أ.د. فؤاد علي العاجز

ABSTRACT

The Agricultural sector in the Gaza Strip on an average consumes around 75-80 MCM of water annually. All amounts of water used for this purpose come from groundwater wells. Wastewater reuse is envisaged primarily as a means to support the agricultural sector in Gaza Strip as addressed by Palestinian Water Authority (PWA). The artificial recharge (AR) of treated wastewater to groundwater can be achieved by means of spreading basins the commonly used methods for infiltration purposes to unconfined aquifers. The problem of the AR is the reduction of infiltration capacity in the infiltration basins resulting from using partially treated wastewater due to accumulation of suspended solids (SS) and the organic load, and the poor maintenance. The goal of this research is enhancement of the efficiency of Infiltration Basins for effluent recharge. Field experiments was performed in order to achieve the required objectives such as the quality of the soil under the infiltration basin, and quality of the effluent water to the basin. Also modeling for the unsaturated zone using the Green-Ampt model (1911) was performed in order to predict the existing and enhanced infiltration rate. The field and lab tests results showed that the soil strata in the infiltration basin IB1 consists of Sand which is non-plastic and has good permeability characteristics, Clayey Sand: which is the wide spreading layer at the top of the basin, and of low to medium plasticity, and of low permeability, and Sandy Silty Clay which is of medium plasticity, and of low permeability. The results showed that the infiltration rate is affected by the soil properties; sandy soils have the highest infiltration rates and clayey soils have the lowest infiltration rates. Also the results showed that the infiltration rate is affected by the quality of the effluent water, operation cycles and maintenance for the top surface. According to the results which have been supported by model; removing the upper 2.0 meters of soil layer at IB1 and replacing it with new sand martial with high permeability introduced an efficient solution for enhancement the infiltration rate. Also penetrating the lower soil layers with 60 piles and filling the piles with gravel fine media with high permeability, will increase the infiltration rate for the whole basin according to the study. Performing 35 cycles of wetting and drying during the year with 2 days of wetting in summer and winter and 7 days of drying in summer and 12 days of drying in winter, will help to reach the optimal infiltration rate. Soil plowing after each drying cycle for the basin is required to maintain good infiltration rate and prevent accumulation of the organic matter (OM) in the top soil layer.

الخلاصة

يستهلك قطاع الزراعة في قطاع غزة في المتوسط حوالي 75-80 مليون متر مكعب من المياه سنويا وجميع كميات المياه المستخدمة لهذا الغرض تأتي من الآبار الجوفية. يرجع إعادة استخدام المياه العادمة في المقام الأول كوسيلة لدعم القطاع الزراعي في غزة كما هو مقرر من قبل سلطة المياه الفلسطينية. التغذية الصناعية للخزان الجوفي باستخدام مياه الصرف الصحي المعالجة يمكن تحقيقها عن طريق استخدام أحواض الترشيح وهي الطرق الأكثر استخداما لأغراض الترشيح للمياه الجوفية الغير المحصورة. مشكلة التغذية الصناعية تأتي من انخفاض كفاءة الترشيح في أحواض الترشيح نتيجة استخدام مياه الصرف الصحي المعالجة جزئيا بسبب تراكم المواد الصلبة والمواد العضوية بالإضافة الى سوء الصيانة. الهدف من هذا البحث هو تحسين كفاءة أحواض الترشيح المعدة لاستخدام مياه الصرف الصحي المعالجة. من أجل تحقيق الأهداف المطلوبة تم إجراء التجارب الميدانية مثل فحص نوعية وجودة التربة تحت حوض الترشيح، ونوعية المياه المتدفقة إلى الحوض. كما تم عمل نمذجة للمنطقة غير المشبعة باستخدام جرين امبت (1911) من أجل التنبؤ بمعدل الترشيح للوضع القائم والوضع بعد التحسين. أظهرت النتائج أن طبقة التربة في حوض الترشيح رقم 1 تتكون من الرمل الغير لدن وله خصائص نفاذية جيدة ، ومن الرمل الطيني وهي الطبقة العلوية الأكثر انتشارا في الحوض وتعتبر طبقة منخفضة إلى متوسطة اللدونة ، مع نفاذية منخفضة، وطبقة من الرمل والطين والطين ذات لدونة متوسطة ، و نفاذية منخفضة . أظهرت النتائج أن معدل التسرب يتأثر بخصائص التربة؛ حيث ان التربة الرملية لديها أعلى معدلات ترشيح والتربة الطينية لديها أدنى معدلات ترشيح . كما أظهرت النتائج أن معدل الترشيح يتأثر بنوعية المياه المتدفقة ، ودورات التشغيل والصيانة للطبقة العلوية . وفقا للنتائج والتي تم تدعيمها بالنموذج تبين ان إزالة الجزء العلوي من التربة في حوض الترشيح رقم 1 وبسمك 2 متر واستبدالها بطبقة رمل جديدة ذات نفاذية عالية حسنت معدل الترشيح. أيضا اختراق طبقات التربة السفلى بعدد 60 بئر مع ملئ هذه الآبار بحصمه ناعمة ذات نفاذية عالية ، سوف يزيد من معدل الترشيح لكل الحوض حسب الدراسة. اجراء عدد 35 دورة من الترتيب والتجفيف خلال السنه بمعدل 2 يوم من الترتيب خلال الصيف والشتاء و 7 ايام تجفيف في الصيف و12 يوم تجفيف في الشتاء سوف يساعد في الوصول الى المعدل الامثل للترشيح. حرث التربة بعد كل دورة تجفيف للحوض يحفاظ على معدل ترشيح جيد ويحد من تراكم المادة العضوية على طبقة التربة السطحية.

QURAN



{ رَبِّ أَوْزِعْنِي أَنْ أَشْكُرَ نِعْمَتَكَ الَّتِي أَنْعَمْتَ عَلَيَّ وَعَلَىٰ وَالِدَيَّ وَأَنْ أَعْمَلَ صَالِحًا تَرْضَاهُ
وَأُدْخِلْنِي بِرَحْمَتِكَ فِي مَجْدِكَ الصَّالِحِينَ } النمل (19).

All praises and glory are due to **ALLAH** for all the bounty and support granted to me.

This work would not be done without **ALLAH** endless guidance and support.

DEDICATION

This research is dedicated:

To My Father and Mother

*To my wife Majda and my daughters, Enaya, Dana,
Rimas, and Sama*

*To all of my brothers, Mohammed and Ahmed and all
of my sisters.*

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LIST OF ACRONYMS AND ABBREVIATIONS

AR	Artificial Recharge
ASTM	American Society for Testing and Material
BH	Bore Hole
BLWWT	Beit Lahia Waste Water Treatment Plant
BOD	Biological Oxygen Demand
BS	British Standard
CA	Calcium
CMWU	Coastal Municipalities Water Utility
COD	Chemical Oxygen Demand
EC	Electrical Conductivity
ERRC	Environmental and Rural Research Center
FC	Fecal Coliform
GA	Green and Ampt
GS	Gaza Strip
H	Hardness
IB	Infiltration Basin
IR	Infiltration Rate
K	Hydraulic Conductivity
Mg	Magnesium
Na	Sodium

NGSWSP	Northern Gaza Storm Water and Sewerage Project
NWP	National Water Plan
OM	Organic Matter
PCBS	Palestinian Central Bureau of Statistics
pH	Hydrogen Ion Concentration
PMU	Project Management Unit
PNA	Palestinian National Authority
PWA	Palestinian Water Authority
SAR	Sodium Adsorption Ratio
SAT	Soil Aquifer Treatment
T	Temperature
TC	Total Coliform
TSS	Total Suspended Solids
TWW	Treated Wastewater
Uc	Uniformity coefficient
USCS	Unified Soil Classification System
WC	Water Content
WW	Wastewater

LIST OF UNITS

°C	Celsius
cm/hr	Centimeter per Hour
Ds/m	Deci Siemens per meter
ft/d	feet per day
Hr	Hour
m/d	Meter per day
m²	Meter square
m³/d	Cubic Meter per day
m³/hr	Cubic Meter per hour
meq/kg	Milli equivalent per kilogram
meq/l	Milli equivalent per liter
mg/l	Milligrams per Liter
m/day	Meter per Day
MCM	Million Cubic Meters

CHAPTER 1 : Introduction

1.1 Background

Water is essential to sustain life, and it is considered a scarce resource in Palestine. Sustainable water management calls not only for careful use of freshwater but also for reuse of treated wastewater (Aish, 2004). Indications of the need for changing the current (and historical) management are seen in the lowering of the water table and the increasing chloride and nitrate concentrations in the groundwater (SWECO, 2003).

The abstraction rates have increased remarkably over the last three decades, due to a combination of inadequate available water imports to Gaza; the expanding population; and the drilling and use of unlicensed wells (especially to provide irrigation for agricultural activities). The over-abstraction has caused saline intrusion (i.e. the entry of sea water to the aquifer from the Mediterranean Sea to the west, and also from deep groundwater in Israel to the south-east of Gaza) (PWA, 2011).

The Gaza Strip suffers from high pressure imposed on its water resources. There is a deficit of about 50 MCM (million cubic meters) every year, which has led to a declination of groundwater level and deterioration of groundwater quality. New water resources are sought to fulfill the water deficit; among them is the artificial recharge of treated wastewater to groundwater (Hamdan, et al., 2011).

The Gaza Strip has high population density accompanied with growing water demands that are met by groundwater as the one and only local resource. The Agricultural sector in the Gaza Strip on an average consumes around 75-80 MCM of water annually. All amounts of water used for this purpose come from groundwater wells (PWA, 2012).

Upon the fact that the entire existing agricultural water demand is taken from the groundwater aquifer, of which a large proportion is brackish, Palestinian Water Authority (PWA) addressed that the long-term target is that only minimal fresh water will be provided for soil flushing and specific high value crops. Other low quality water and conservation practices, including brackish water, storm water harvest, blending of water and conjunctive use of saline and non-saline water, will be utilized to optimal

economic and practical effect in accordance with the following targets. Ultimately, by 2020 the utilization of wastewater is planned to provide 50 % of the total required by agriculture (**PWA, 2012**).

Wastewater reuse is envisaged primarily as a means to support the agricultural sector in Gaza (**PWA, 2011**). The agricultural demand is almost constant since the agricultural areas are limited or even decreasing. However, the domestic demand increases due to the rapid growth of the population. This increases the amount of wastewater produced and the treated effluent becomes a significant resource of water that could improve the water balance in the region (**Hamdan, et al., 2011**).

Artificial recharge is one such idea that has emerged over the past 20 years as a major water management tool for meeting water supply challenges. The concept of artificial recharge is simple: return water to aquifers and increase groundwater supplies (**Arroyo, 2007**). Where sewage effluent is used for ground water recharge, the quality improvement of the sewage water as it moves through the vadose zone and aquifer becomes very significant (**Bouwer, 2002**).

Reclaiming waste water involves management of groundwater recharge by introducing treated waste water into the aquifer and taking advantage of either the raised groundwater levels or the actual water volume or a combination of the two. Artificial recharge is a process by which surface water is directed into the ground to replenish the aquifer either by spreading on the surface in basins, by using recharge wells, or by altering natural conditions to increase infiltration. The objectives of infiltration includes the quantity aspect which aimed at breaking the trend of decreasing groundwater table (and the increasing chloride concentrations connected to that) and allowing for a water abstraction from the aquifer for water supply (**SWECO, 2003**).

1.2 Problem Statement

Water scarcity is likely to become more problematic in the near future due to rapid population growth, increasing per capita water consumption, and the draught conditions of the world. These have forced various countries and communities to look towards alternative water resources to meet the growing needs and to be as long term water supplies. The artificially recharge of the groundwater is one option with extremely good future, since the underground storage is becoming a major alternative for overcoming

short-term and long-term seasonal differences between water supply and demand (Abushbak, 2004).

Artificial recharge facilities or projects are constructed to control the movement and rate of infiltration, with the purpose of adding water to the aquifer. Constructed recharge projects require maintenance to maintain infiltration rates and ensure smooth operations (Arroyo, 2007).

The problem of the artificial recharge is the reduction of infiltration capacity in the infiltration basins resulting from using partially treated wastewater due to accumulation of suspended solids and biological oxygen demand loading (BOD) in addition to poor maintenance. The current infiltration system at Northern Gaza Storm Water and Sewerage Project consists of nine basins distributed from (1-9). The infiltration rate for all the basins began to deteriorate significantly since December, 2011, and infiltration basin (1) mainly has the lowest infiltration rate since the operation of the infiltration system. Figure (1-1) shows the average infiltration rate for the all basins with time since July, 2009 up to March, 2013.

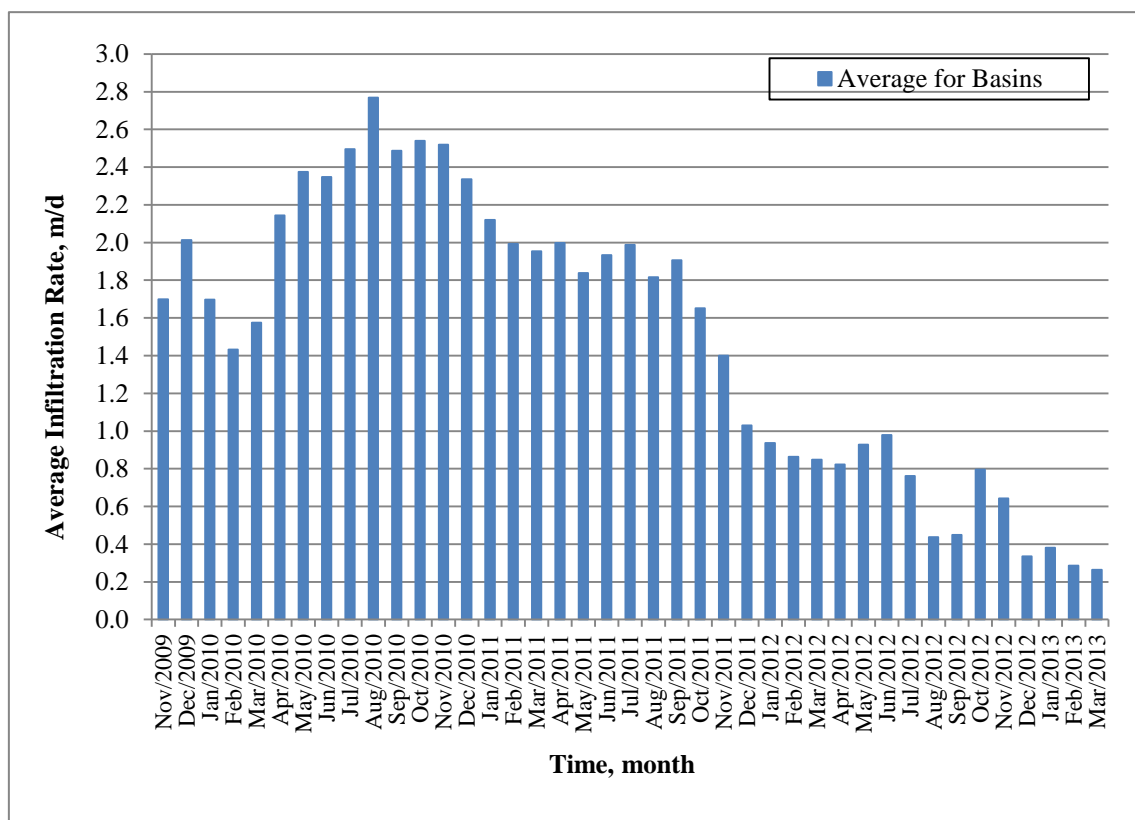


Figure (1-1): Average Infiltration Rate for All Basins with Time

1.3 Goals

The goal of this research is **Enhancement of the Efficiency of Infiltration Basins for Effluent Recharge.**

1.4 Objectives

The main objectives of this research are:

- Study the soil profile underneath the infiltration basin (IB1).
- Study the performance of the infiltration basin (IB1) under different conditions.
- Modeling the flow in the unsaturated zone.
- Propose enhancement methods and assess the impact of each method.

1.5 Methodology

It is intended to achieve the objectives of the study by the following steps:

a. Literature review

Revision of accessible references as books, studies and researches relative to the topic of the research which may include: Artificial Recharge, Quality of soil, Quality of Effluent, ..etc.

b. Data collection

Collecting of relevant data mainly from the Palestinian Water Authority (PWA), and from any relevant authorities where detailed information is needed.

c. Field Experiment

Field experiments were performed at infiltration basin (IB1) in order to achieve the required objectives such as:

- Quality of the soil under the infiltration basins was tested and the following tests were performed:
 - Soil tests for the layers under the basin bed in different locations were tested to a depth of 12m (five boreholes were performed and the soil samples were taken every 30 cm until a depth of 2.10 m, after that from 2.10m to 3.0m and every one meter from the depth 3.0m until reaching the end of borehole). After collecting all the samples, grain size analysis (sieve analysis), water

content(θ_i), and hydraulic conductivity (K) for the different layers of the soil was performed.

- Soil quality tests beneath the basin bed to a depth of 2.10m, and samples were taken each 30cm (from the same five boreholes) to test the effect of Organic Matter (OM), and Sodium Adsorption Ratio (SAR) .
- Quality of the influent to the basin was tested.

d. Modeling for ground water in the unsaturated zone

For the infiltration basin (IB1) a lump-parameter model was developed based on the Green-Ampt Model (1911) in order to predict the model which describing the real infiltration rate, and to introduce the proposed model for infiltration after enhancement.

e. Data analysis, assessment and discussion

Determining the factors that influence the efficiency of the infiltration basins capacity, and how to enhance the capacity of the infiltration after enhancement in order to reach a reasonable infiltration rate.

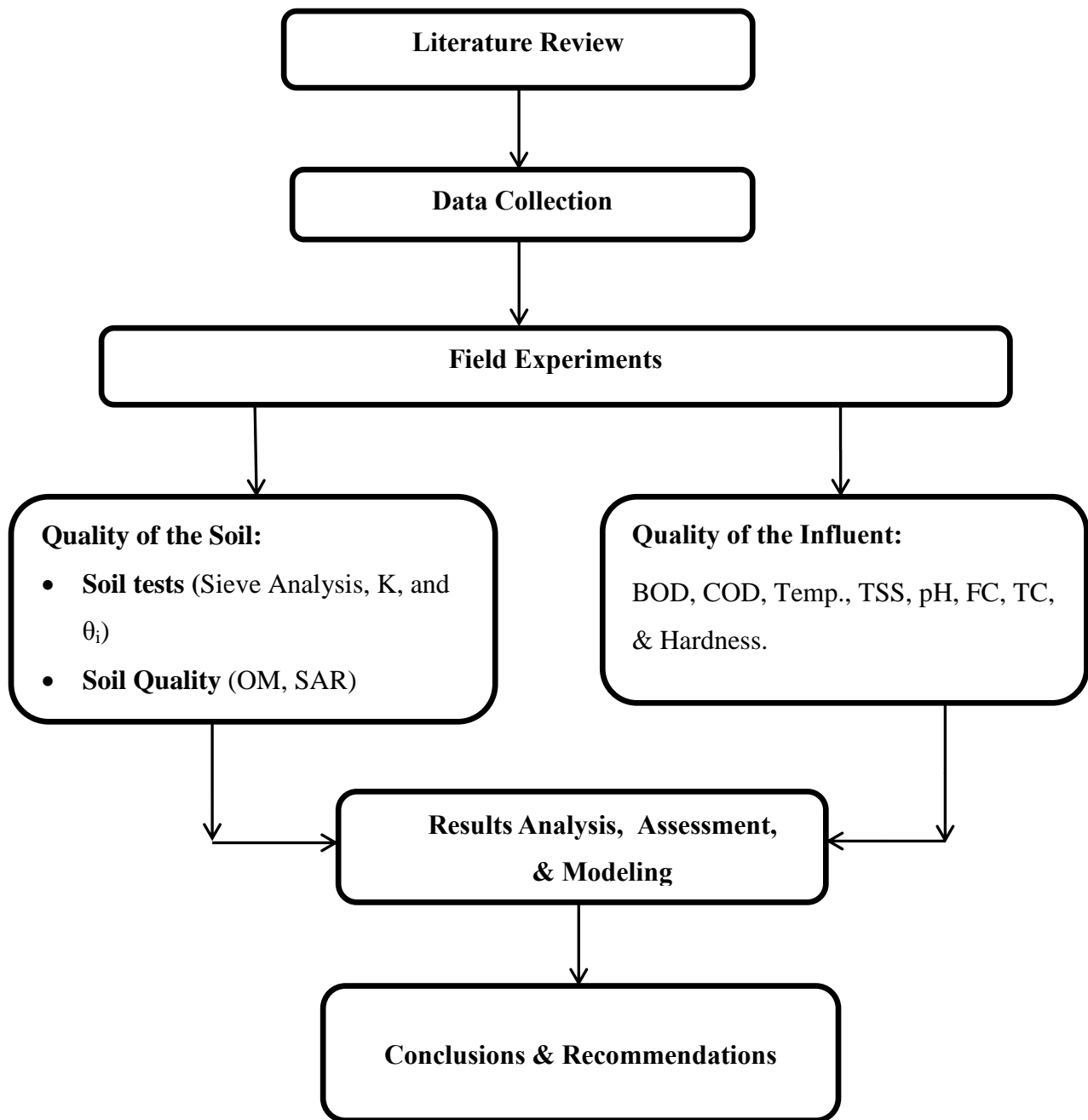


Figure (1-2): Methodology Flow Chart

1.6 Thesis Outline

This study consists of the following seven chapters:

- 1. Chapter One (Introduction):** A general background illustrating the water situation in Gaza Strip (GS) followed by the problem statement, goals and study objectives, methodology used in order to achieve the objectives and finally the thesis outline.

2. **Chapter Two (Literature Review):** It covers a general literature review concerning the artificial recharge, infiltration, methods of enhancement the infiltration rate, and finally the literature review presents modeling of unsaturated zone.
3. **Chapter Three (Study Area):** Chapter three describes the location of the Gaza Strip, climate, rainfall status, geology, study area with respect to its location and topography, the existing situation of the infiltration basins and the related information about the operation.
4. **Chapter Four (Methodology):** Chapter four discusses the methodology of study including data collection, field experiments, data analysis and preparation.
5. **Chapter Five (Results and Discussion):**
Chapter five will presents the field experiments results for the soil profile, the soil quality parameters and the effluent quality parameters of the recharged water, also factors that influence the efficiency of the infiltration basins capacity, behavior of infiltration capacity under different loading conditions, and finally how to enhance the capacity of the infiltration. Also this chapter will presents modeling for the unsaturated zone and its applicability in the field of infiltration basins.
6. **Chapter Six (Conclusions and Recommendations):** The conclusions and recommendations of the study are stated in this chapter.

CHAPTER 2 : Literature Review

2.1 Introduction

Fresh water shortage is becoming an increasingly acute problem facing many nations in the world. Groundwater recharge with treated wastewater is becoming more valuable with time in developing countries because of the scarcity of water resources (**Deepa, and Krishnaveni, 2012**).

Water demand in Palestine, in general and in the Gaza strip, in particular is rapidly increasing (**PWA, 1998**). The Gaza Strip suffers from a disastrous situation due to poor water quality with the Coastal Aquifer as the sole water source shared with Israel. The aquifer is being over pumped with annual quantities that double that of the safe pumping rate (50-60 MCM/ year); this has led to seawater and surrounding saline aquifers intruding into this fresh water source causing salination. The Agricultural sector in the Gaza Strip on an average consumes around 75-80 million cubic meters of water annually. All amounts of water used for this purpose come from groundwater wells (**PWA, 2012**). It is stated in the National Water Plan (NWP) that wastewater investment costs represents about 37% of overall Palestinian investment plan for Gaza Strip overall the period time to achieve strategies and targets outlined in the NWP. Wastewater reuse schemes are indispensable for Palestinian in general and Gaza strip in particular (**Nassar, et al., 2009**). Wastewater (WW) reuse will provide an alternative to groundwater (GW) for irrigation when well treated wastewater (TWW) can be used for irrigation as it is planned in the NWP by year 2000. Reuse of TWW in irrigation is considered a priority in the GS due to a number of factors including the depletion of GW resources and fact that reuse would increase the availability of fresh water resources for domestic and industrial use (**Nassar, et al., 2009**).

The reuse of the effluent could be accomplished in two ways: either by direct irrigation to farms and/or through artificial recharge to groundwater, which is then pumped to irrigate farms with reclaimed wastewater (**Hamdan et al., 2011**).

2.2 Artificial Recharge (AR)

Groundwater recharge with reclaimed municipal wastewater presents a wide spectrum of technical and health challenges that must be carefully evaluated. Natural replenishment of the vast supply of underground water occurs very slowly; therefore, excessive continued exploitation of groundwater at a rate greater than this replenishment causes declining groundwater levels in the long term and if not corrected, leads to eventual mining of groundwater. To increase the natural supply of groundwater, artificial recharge of groundwater basins is becoming increasingly important in groundwater management and particularly in situations where the conjunctive use of surface water and groundwater resources is being considered. **(Asano and Cotruvo, 2004).**

Artificial recharge is one means of conserving water by allowing storage and future use of reclaimed water **(Toze, et al., 2004)**. AR and water reuse are important aspects of integrated water management where water resources management problems are solved by considering all aspects **(Bouwer, 2002)**. Thus moving towards attaining sustainable water management in addition, artificial recharge can significantly contribute to water quality improvement by natural attenuation of contaminants via passage of the water through the aquifer. The ability to obtain an improvement in water quality would be a major benefit of artificial recharge in less arid parts of the world where water scarcity and quality issues are prevalent **(Toze, et al., 2004)**. **Mohammedjema, 2006 R5** stated that artificial recharge can be used for a number of reasons: Integrated water management, seasonal storage and recovery of water, long-term storage or water banking, emergency storage or strategic water reserve, short term storage, enhance well field production, restore groundwater level, replace over draft, raise water levels, reduce pumping cost, stop or reduce rate of land surface subsidence, improve groundwater quality to agriculture or municipal standards.

Artificial recharge of groundwater is achieved by putting surface water in basins (Figure 2-1), furrows, ditches, or other facilities where it infiltrates into the soil and moves downward to recharge aquifers. Artificial recharge is increasingly used for short-or long-term underground storage, where it has several advantages over surface storage, and in water reuse **(Bouwer, 2002)**.

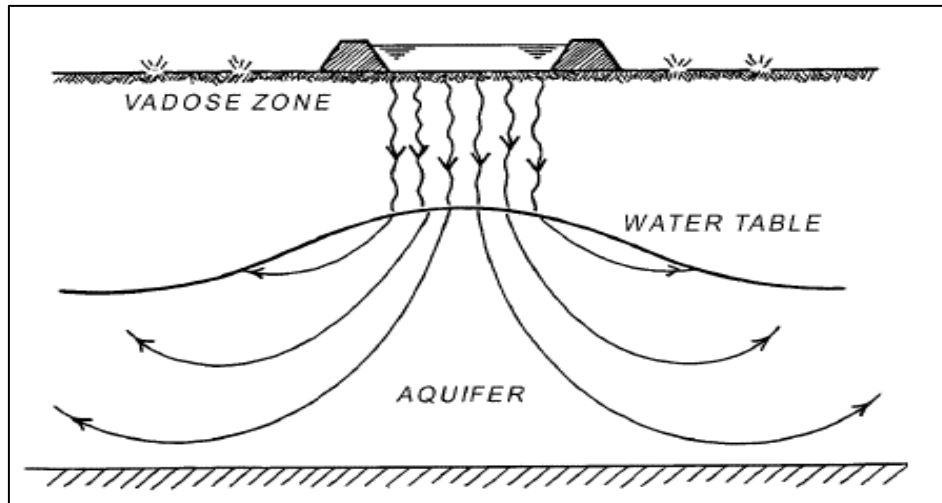


Figure (2-1): Typical groundwater recharge system, (Bouwer, 2002)

2.2.1 Advantages and Disadvantages of Artificial Recharge

Artificial recharge has several potential advantages, namely (Bhattacharya, 2010):

- The use of aquifers for storage and distribution of water and removal of contaminants by natural cleansing processes.
- Groundwater recharge stores water during the wet season for use in the dry season, when demand is the highest.
- Recharge can significantly increase the sustainable yield of an aquifer.
- Recharge methods are environmentally attractive, particularly in arid regions.
- Most aquifer recharge systems are easy to operate.
- Recharge with less-saline surface waters or a treated effluent improves the quality of saline aquifers, facilitating the use of the water for agriculture.

Artificial Recharge has some disadvantages, namely (Bhattacharya, 2010):

- Recharge can degrade the aquifer unless quality control of the injected water is adequate.
- Unless significant volumes of water are injected in an aquifer, groundwater recharge may not be economically feasible.
- The hydrogeology of an aquifer should be investigated and understood before any future full-scale recharge project is implemented.

- There is a potential for contamination of the groundwater from injected surface-water. In most cases, the surface-water is not pre-treated before injection.

2.2.2 Methods of Artificial Recharge

There are two methods of artificial recharge in general: Direct and Indirect (**Mohammedjema1, 2006**).

A. Direct method

Direct methods can be divided into surface recharge techniques and subsurface recharge techniques. In surface recharge, water moves from the land surface to the aquifer by means of infiltration through the soil. The surface is usually excavated and water is added to spreading basins, ditches, pits, and shafts and allowed to infiltrate.

B. Indirect methods

Indirect method include installing groundwater pumping facilities near connected surface water bodies to lower groundwater levels and induce infiltration elsewhere in the drainage basin. Indirect methods include modifying aquifers to enhance groundwater reserves.

Mohammedjema1, 2006 stated that there is a third method for artificial recharge, which is the Combination system. The mixed recharge is the combination of infiltration and recharge wells. The advantage of this system is that the water has been pre filtered through the soil and the perched groundwater zone, so that its clogging potential is significantly reduced. In this way the risk of aquifer obstruction is reduced.

Table (2-1) summaries the major characteristics for various technologies used for artificial_recharge (**El Arabi, 2012**)

2.2.3 Influence of Recharge Factors

Not all aquifers can be artificially recharged. The hydraulic characteristics of the aquifer, the nature of the existing groundwater, and the characteristics of the recharge water can have a major influence on the outcome of a recharge operation (**Spandre R., 1999**).

Table 2-1: Characteristics for Various Technologies Used for Artificial Recharge (El Arabi, 2012).

Parameter	Recharge Basin	Vadose Zone Injection Wells	Direct Injection Wells
Aquifer Type	Unconfined	Unconfined	Confined/Unconfined
Pre-Treatment Requirements	Low Technology	Removal of Solids	High Technology
Capacity	1000-20,000 m ³ /ha/day	1000-2000 m ³ /ha/day	2000-6000 m ³ /ha/day
Maintenance Requirements	Drying and Scraping	Drying and Disinfection	Disinfection and Flow Recovery
Soil-Aquifer Treatment	Vadose Zone and Saturated Zone	Vadose Zone and Saturated Zone	Saturated Zone

2.2.3.1 Geological and Hydrogeological Factors

The receiving aquifer must be homogeneous and isotropic as possible. One of the main factors affecting recharge is aquifer porosity. Porosity must be as high as possible, and this factor depends on a uniformity coefficient: where the coefficient is small, porosity is high. Another factor is the hydraulic conductivity of an aquifer: when the hydraulic conductivity is high, recharge is very quick. Hydraulic conductivity values tend to be high when the aquifer grain size is large. The artificial recharge depends on transmissivity and porosity values, and the uniformity of these parameters is very important.

2.2.3.2 Physical and Chemical Factors

The chemical and physical characteristics of groundwater and recharge water have a great effect on the results of artificial recharge. (Spandre R., 1999).

2.3 Infiltration Basins (IB)

One artificial recharge method commonly used is infiltration to unconfined aquifers via pond infiltration or surface spreading (Toze, et al., 2004). Recharging basins are still the most common method of recharge and provide excellent versatility for water

resources planning (**El Arabi, 2012**). Infiltration basins require a substantial amount of land area with a suitable geology, allowing the water to infiltrate into the aquifer and percolate to the groundwater table. Infiltration basins (Figure 2-2) allows for natural, quality improving processes to take place in the surface of the infiltration ponds and subsoil (**SWECO, 2003**). The spreading basins should excavated in areas of high permeable soils, where the infiltration is most effective (**Guttman, 2012**) Construction is normally comparatively simple and low cost.

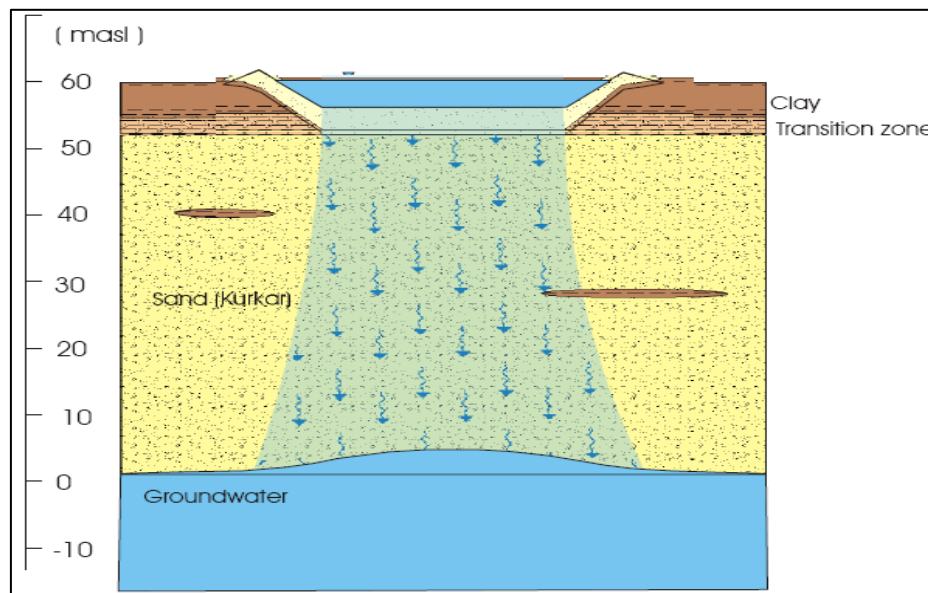


Figure (2-2): Principle for basin infiltration, (**SWECO, 2003**).

2.3.1 Infiltration Rate (IR)

Infiltration rates are expressed as volume of water moving into the soil or aquifer per unit infiltration area and per unit time. The dimension of infiltration rate thus is length/time, for example, cm/h or in/h, or m/day or ft/day. For IB, this rate can be visualized as the rate of fall of the water surface in the basin if there is no inflow to or outflow from the basin. IR for surface infiltration recharge systems typically range from 0.3 to 3 m/day (1–10 ft/day) (**Bouwer, 2002**).

For surface infiltration systems in uniform soils without surface clogging, infiltration rates will be about equal to the vertical hydraulic conductivity of the soil which has the following approximate orders of magnitude:

Clay soils	<0.1 m/day
Loams	0.2 m/day
Sandy loams	0.3 m/day
Loamy sands	0.5 m/day
Fine sands	1 m /day
Medium sands	5 m /day
Coarse sands	>10 m/day

These values can be used for preliminary site evaluation and system selection (**Bouwer, 2002**).

2.3.2 Factors Affecting Infiltration Rate

The infiltration rate of a natural porous body depends on its porosity and saturated hydraulic conductivity, which in turn is a function of the intrinsic permeability of the medium and the fluidity of the penetrating liquid (**Lin, et al., 2003**). Initially, soil sorptivity is the primary factor affecting infiltration rate; but as infiltration time increases, the hydraulic conductivity becomes the controlling factor (**Lin et al., 2003**). The following factors is also affecting the IR:

2.3.3 Temperature

The infiltration rate into a soil will decrease as temperature of the system decreases, most likely due to the increased viscosity of the percolating water. Water viscosity changes by approximately 2% per degree Celsius in the relevant environmental temperature range of 15-35°C. This leads to an estimated 40% change of infiltration rate between the summer and winter months in arid regions The increase in hydraulic conductivity with increase in temperature is commonly attributed to the decrease in viscosity of the water (**M. Braga, 2005**).

Because infiltration rates vary inversely with water viscosity, temperature also affects infiltration rates. In areas with large differences between winter and summer temperatures, viscosity effects alone cause winter infiltration rates to be as low as about half of those in summer (**Bouwer, 2002**).

2.3.4 Basin Water Depth

Achieving a maximum infiltration rate for recharge basins is essential, especially in urban settings where land is limited. The depth of water in recharge basins must be selected to achieve maximum infiltration rates (**M. Braga, 2005**).

2.3.5 Clogged Basin Layer

Clogging is one of the most critical factors affecting infiltration performance. Clogging may be defined as the reduction of the available pore volume of a porous media due to a range of physical, biological and chemical processes (**Nadee et al., 2010**).

Physical processes are accumulation of inorganic and organic suspended solids in the recharge water, such as clay and silt particles, algae cells, microorganism cells and fragments, and sludge flocks in sewage effluent. Another physical process is downward movement of fine particles in the soil that were in the applied water or in the soil itself, and accumulation of these fine particles at some depth where the soil is denser or finer, and where they form a thin subsurface clogging layer. The depth of this layer ranges from a few mm to a few cm or more (**Bouwer, 2002**).

Biological clogging processes include: accumulation of algae and bacterial flocks in the water on the infiltrating surface; and growth of micro-organisms on and in the soil to form biofilms and biomass (including polysaccharides and other metabolic end products) that block pores and/or reduce pore sizes (**Bouwer, 2002**).

Chemical processes include: precipitation of calcium carbonate, gypsum, phosphate, and other chemicals on and in the soil. Sometimes, these precipitations are induced by pH increases caused by algae as they remove dissolved CO₂ from the water for photosynthesis. Bacteria also produce gases (nitrogen, methane) that block pores and accumulate below clogging layers to create vapor barriers to infiltration (**Bouwer, 2002**).

Consequently, the immediate effect of clogging is to reduce the intrinsic permeability of a system, leading to a drop in infiltration rates in the case of surface ponding. The poorer the source water quality, the faster and more extensive the reduction in infiltration rate, as illustrated in Figure (2-3) (**Nadee et al., 2010**).

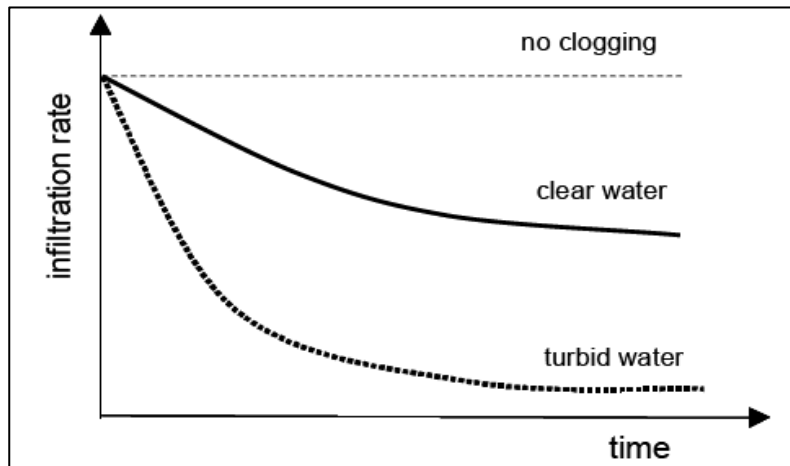


Figure (2-3): Illustration of Infiltration and clogging, (Nadee et al., 2010)

Over time, the bottom of the infiltration basin can become clogged by a layer of inorganic and/or organic deposits creating a barrier between the basin and the wetted perimeter as cleared on figure (2-4). As fine particles settle out and biological activity on the bottom continues, the thickness of the clogging layer can increase until infiltration rates eventually become so small that the function of the infiltration basin ends. (M. Braga, 2005).

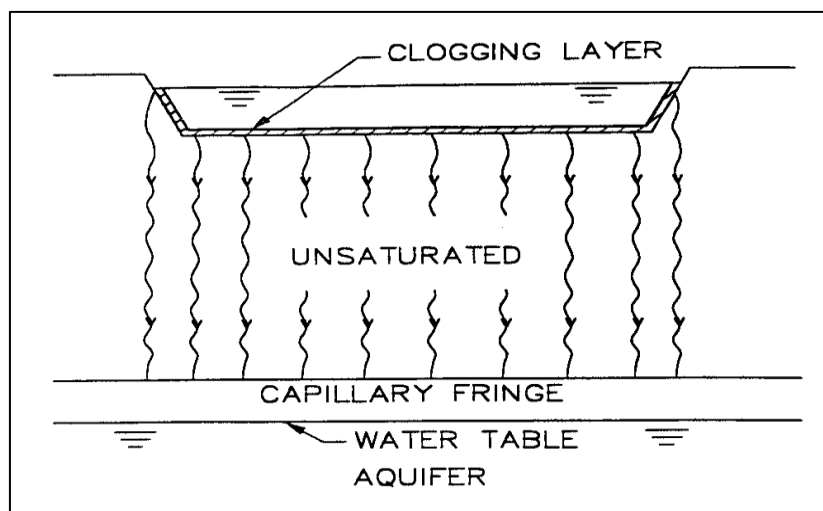


Figure (2-4): Illustration of clogging layer, (Bouwer, 1999)

2.3.6 Sodium Adsorption Rate (SAR)

Sodic soil, or soil with excessive levels of sodium ions (Na^+) relative to divalent ions calcium (Ca^{2+}) and magnesium (Mg^{2+}), can alter soil structure and reduce soil permeability. The sodium adsorption rate (SAR) is an indicator of sodicity. To calculate the SAR of a waste or soil, determine the (Na^+), (Ca^{2+}), and (Mg^{2+}) concentrations in

milliequivalents per liters for use in the Gapon equation which is commonly used to determine the ratio of sodium to calcium and magnesium:

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}} \quad 2.1$$

The term milliequivalents per liter (meq/l) expresses the concentration of a dissolved substance in terms of its combining weight. Milliequivalents are calculated for elemental ions such as Na^+ , Ca^{2+} , and Mg^{2+} by multiplying the concentration in mg/l by the valence number (1 for Na^+ , 2 for Ca^{2+} and Mg^{2+}) and dividing by the atomic weight (22.99 for Na^+ , 40.08 for Ca^{2+} , and 24.31 for Mg^{2+}). (EPA, 2013)

Too much sodium causes problems related to soil structure. As sodium percentage increases, so does the risk of dispersion of soil aggregates, Figure (2-5).

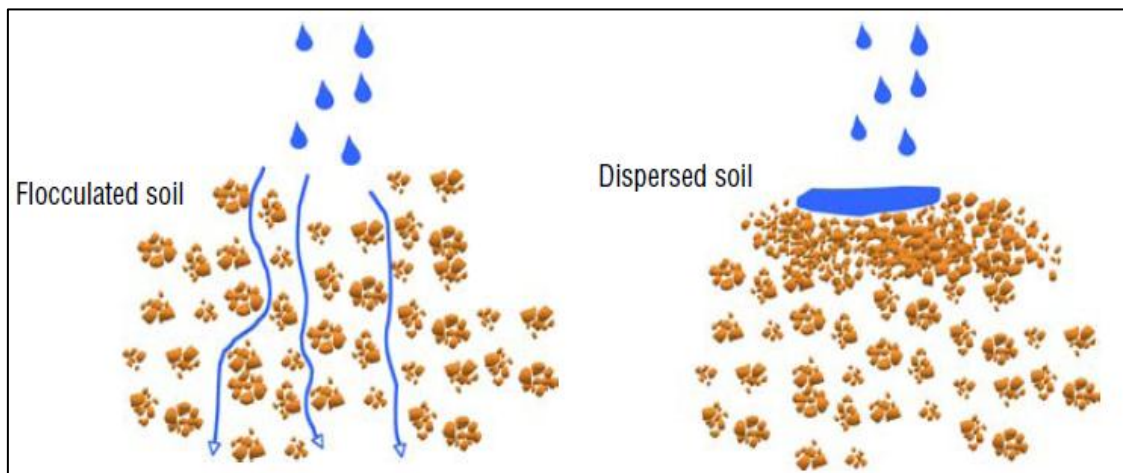


Figure (2-5): The difference between flocculated (aggregated) and dispersed soil structure (Horneck, et al., 2007).

Flocculation soil is important because water moves through large pores. Dispersed soil plug soil pores and impede water movement and soil drainage in all but the sandiest soil (Horneck, et al., 2007).

Figure (2-6) shows sodium adsorption ratio (SAR). SAR is a ratio of bad (Na^+) to good (Ca^{2+} and Mg^{2+}) flocculators. When (Na^+) dominates (high SAR), soil pores clog (soil disperses), limiting water infiltration (Horneck, et al., 2007)

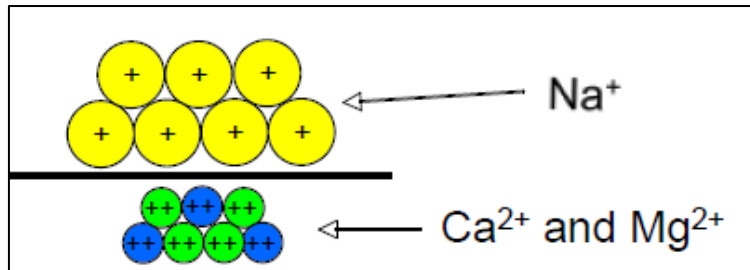


Figure (2-6): Representation of Sodium adsorption ratio (SAR) (Horneck, et al., 2007)

According to (Waskom, et al., 2012) the following terms mean:

- Saline related to high salt content,
- Sodic related to high sodium content, and
- Saline/sodic related to high salt and high sodium content.

The following Table 2-2 shows the general classification of salt-affected soils.

Table 2-2: General classification of salt-affected soils (Waskom, et al., 2012)

Classification	Electrical Conductivity (EC) (ds/m)	Soil pH	Sodium adsorption ratio (SAR)	Soil physical condition
Slightly Sline	2-4	<8.5	<13	Normal
Saline	>4.0	<8.5	<13	Normal
Sodic	<4.0	>8.5	>13	Poor
Saline-Sodic	>4.0	<8.5	>13	Varies
High pH	<4.0	>7.5	<13	Varies

2.4 Maintenance and Monitoring Artificial Recharge System

Managed for optimum performance for artificial recharge system depend entirely on local conditions of soil, hydrogeology, topography, water availability (quality, continuous, or interrupted supply), and climate. Key factors in the design and management of successful artificial recharge systems are site and system selection, maintenance of adequate infiltration rates, hydraulic continuity between the recharge system and the aquifer (no clay layers in the vadose zone), and groundwater control for effective water recovery and prevention of undue groundwater rises in the recharge area **(Bouwer, 2002)**. As stated by **(Guttman, 2012)** recharge is most effective when there are no clay layers between the land surface and the aquifer. Another important factor in the selection of the type of recharge system is the pretreatment of the water required before recharge to minimize physical, chemical, or biological clogging of the infiltrating surface (bottom in basins and walls in trenches, shafts, and wells) **(Bouwer, 2002)**.

Periodic maintenance of artificial recharge structures is essential because infiltration capacity is rapidly reduced because of silting, chemical precipitation, and accumulation of organic matter **(Bhattacharya, 2010)**.

Infiltration rates of water through the soil can decrease as a result organic matter (OM) accumulation and the consequential water repellency. OM accumulation in the topsoil layer was found to be the main factor adversely affecting soil permeability, the OM originating from the TWW has water-repellent characteristics that alter soil hydraulic properties. The chemical nature and composition of the OM may have stronger effects on soil water repellency than its quantity **(Nadav et al., 2011)**.

Organic matter (OM) in the top soil layer is the main factor determining treated waste water (TWW) infiltration into the soil. Soil plowing reduced OM content in the top soil layer and consequently, reduced the effect of OM on the soil hydraulic properties and restricted the reduction in TWW infiltration that occurs mainly during the winter. Soil plowing was found to be an efficient procedure that can be employed to reduce OM content in the top layer and maintain high infiltration rates of TWW into the soil **(Nadav et al., 2012)**.

(Guttman, 2012) emphasized that the proper monitoring and maintenance is the key factor in long term operating of the artificial recharge plant.

In order to maintain sufficient infiltration rate to satisfactory values, the clogging layer should control periodically by drying the basins or other infiltration facility, and letting the layer decompose, shrink, crack, and curl up (Bouwer, 2004). Rates of infiltration are maintained mainly by ploughing (plowing) or disking of the ground between or at the end the recharge events (Guttman, 2012).

If clogging materials continue to accumulate, they must be periodically removed at the end of a drying period. This can be done mechanically with scrapers, front-end loaders, graders, or manually with rakes (Bouwer, 2004).

2.5 Modeling of the Unsaturated Zone

2.5.1 The Green - Ampt Model (GA), 1911

Water infiltration is an important component of hydrological cycles. It serves an important role on many phenomena such as irrigation, runoff generation, soil erosion, and nutrient and contaminant transport (Ma, et al., 2011). There always has been a great interest in the modeling of the infiltration process (Brevnova, 2001). A large number of infiltration models, including the Green-Ampt model the Richards equation, the Kostiakov model, the Horton model, and the Philip model have been developed in the last century. The formulation of the Green-Ampt model is very simple and the model parameters can be directly obtained from the physical and hydraulic properties of soil (Ma, et al., 2011).

Green-Ampt GA (1911) developed the first physically based model. (Brevnova, 2001). The Green-Ampt equation is one of the most widely used equations for modeling one-dimensional vertical flow of water into soil. It was developed from an integration of Darcy's Law by assuming infiltration from a ponded surface into a deep homogeneous soil of uniform antecedent water content. What makes this model ideal is its reliance on physical parameters, most of which can be evaluated from properties of the soils identified through field-testing (Braga, 2005).

2.5.2 Assumptions of the GA model:

The following assumptions are made according to the Green-Ampt Model (Brikowski, 2007).

- The wetting front advances at the same rate with depth, which produces a well-defined wetting front.
- The volumetric water contents remain constant above and below the wetting front as it advances.
- The soil-water suction immediately below the wetting front remains constant with both time and location as the wetting front advances.

This model employs a simple equation for describing and calculating infiltration. Green - Ampt arrived at their simplified theory of infiltration by considering the wetting front as a precipitous border between wetted and non-wetted soils. Figure (2-7) shows graphical representation of the Green-Ampt infiltration model: the wetting front penetrates to a depth L at time t , separating the saturated soil with hydraulic conductivity K , and porosity η for the soil which has moisture content θ_i below the wetting front. There is ponded water with a depth of h_0 above the surface (Brevnova, 2001).

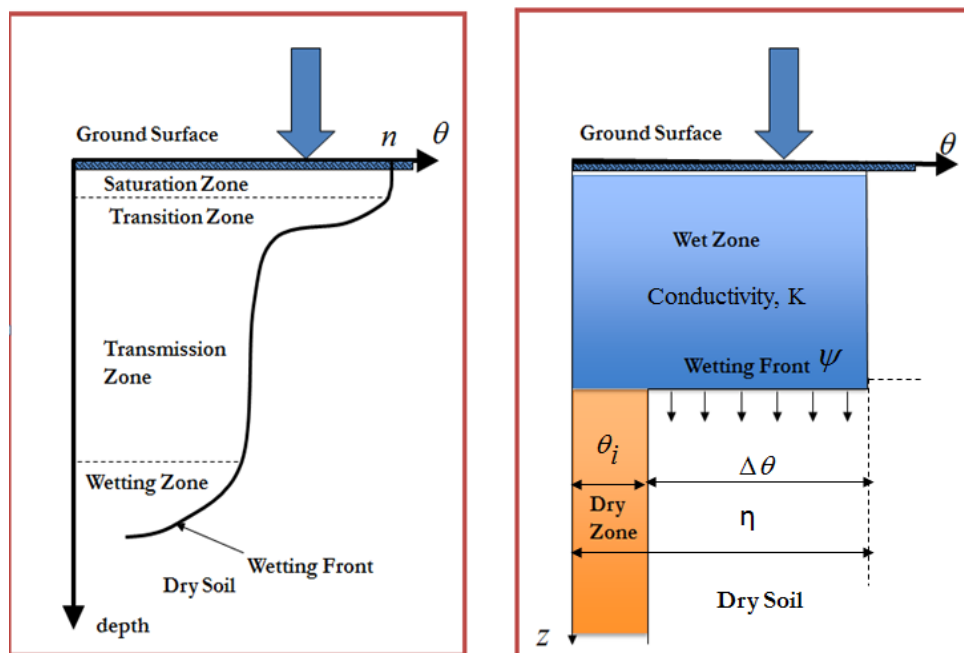


Figure (2-7): Graphical Representation of the GA Infiltration Model (Brevnova, 2001)

By applying Darcy's law to an imaginary vertical column of homogeneous soil with a unit cross-sectional area at the top, and a control volume between soil surface and wetting front boundary, infiltration can be expressed as the total gradient which includes a capillary suction (ψ) effect due to dryness at lower levels (**Brevnova, 2001**).

$$f = K_s \frac{h_0 + \psi + L}{L} \quad 2.2$$

For the ponded depth, h_0 , considerably smaller than capillary suction and wetting front depth, equation 2.1 can be simplified as:

$$f = K_s \frac{\psi + L}{L} \quad 2.3$$

The assumption $h_0 = 0$ is usually appropriate for surface water hydrology problems because it is assumed that ponded water becomes surface runoff.

The Green-Ampt equations for cumulative infiltration $F(t)$ and infiltration rate f with time are (**Todd and Mays, 2005**):

$$F(t) = Kt + \psi \Delta \theta \ln \left(1 + \frac{F(t)}{\psi \Delta \theta} \right) \quad 2.4$$

$$f = K \left(1 + \psi \frac{\Delta \theta}{F} \right) \quad 2.5$$

The Green-Ampt infiltration equation involves parameters (see table 2-3):

1. The infiltration rate, f (cm/hr),
2. Hydraulic conductivity, K (cm/hr),
3. Wetting front capillary pressure head, ψ (cm), and
4. Change in moisture content $\Delta\theta$, which is a difference between porosity η , and initial soil water content, θ_i .
5. Time, t (hr).
6. The cumulative infiltration, $F(t)$ (cm)

Application of the Green-Ampt model requires estimates of the hydraulic conductivity K , the wetting front soil suction head ψ (see table 2-3), and $\Delta\theta$.

The residual moisture content of the soil, denoted by θ_r , is the moisture content after it has been thoroughly drained. The effective saturation (S_e) is the ratio of the available moisture ($\theta - \theta_r$) to the maximum possible available moisture content ($\eta - \theta_r$), given as:

$$S_e = \frac{\theta - \theta_r}{\eta - \theta_r}, \quad 2.6$$

where $\eta - \theta_r$ is called the effective porosity θ_e .

The effective saturation has the range $0 \leq S_e \leq 1.0$, provided $\theta_r \leq \theta \leq \eta$. ((**Todd and Mays, 2005**)).

2.5.3 Estimating of Hydraulic conductivity (K)

A variety of methods are available for estimating saturated hydraulic conductivity values from grain size information. One of the most simple and most commonly used approaches is the Hazen equation (**Massman, 2003**):

$$K_s = Cd_{10}^2 \quad 2.7$$

Where;

K_s : is the saturated hydraulic conductivity,

C : is a conversion coefficient, and

d_{10} : is the grain size for which 10% of the sample is more fine (10% of the soil particles have grain diameters smaller than d_{10}).

For K_s in units of cm/s and for d_{10} in units of mm, the coefficient, C , is approximately (1).

Table 2-4 contains some representative hydraulic conductivity for different soil types.

Table 2-3: Green-Ampt infiltration parameters for various soil classes, (Todd and Mays, 2005)

Soil class	Porosity η	Effective Porosity θ_i	Wetting front soil suction head ψ (cm)	Hydraulic Conductivity K (cm/hr)
Sand	0.437 (0.374-0.500)	0.417 (0.354-0.480)	4.95 (0.97-25.36)	11.78
Loamy sand	0.437 (0.363-0.506)	0.401 (0.329-0.473)	6.13 (1.35-27.94)	2.99

Sandy loam	0.453 (0.351-0.555)	0.412 (0.283-0.541)	11.01 (2.67-45.47)	1.09
Loam	0.463 (0.375-0.551)	0.434 (0.334-0.534)	8.89 (1.33-59.38)	0.34
Silt loam	0.501 (0.420-0.582)	0.486 (0.394-0.578)	16.68 (2.292-95.39)	0.65
Sandy clay	0.398 (0.332-0.464)	0.33 (0.235-0.425)	21.85 (4.42-108.0)	0.15
Clay loam	0.464 (0.409-0.519)	0.309 (0.279-0.501)	20.88 (4.79-91.10)	0.10
Silty clay	0.471 (0.418-0.524)	0.432 (0.347-0.517)	27.3 (5.67-131.50)	0.10
Sandy clay	0.430 (0.370-0.490)	0.321 (0.207-0.435)	23.9 (4.08-140.2)	0.06
Silty clay	0.479 (0.425-0.533)	0.423 (0.334-0.512)	29.22 (6.13-139.4)	0.05
Clay	0.475 (0.427-0.523)	0.385 (0.269-0.501)	31.63 (6.39-156.5)	0.03

Table 2-4: Some Representative Hydraulic Conductivity for Different Soil Types
(Todd and Mays, 2005)

Material	Hydraulic conductivity (m/day)
Gravel, coarse	150
Gravel, medium	270
Gravel, fine	450
Sand, coarse	45
Sand, medium	12
Sand, fine	2.5
Silt	0.08
Clay	0.0002

2.6 Enhancement of the Lower Layers Infiltration Rate

Injection piles are used in order to enhance the infiltration rate for the deep low permeability layers. From the radial flow concept, it is apparent that as ground water converges a well, its velocity increases. If the velocity exceeds a critical limit, finer particles will be transported from the aquifer into the gravel filter, and the filter subsequently plugs, this velocity is the approach velocity (**Williams, 1981**).

The relationship between the velocity and hydraulic conductivity of the aquifer is expressed by Sichardt equation (**Williams, 1981**):

$$V_a < \frac{\sqrt{K}}{15} \quad 2.8$$

where V_a is the approach velocity, m/s, and K is the hydraulic conductivity of the aquifer, m/s with safety factor for design computations of $V_a < \frac{\sqrt{K}}{30}$ (Safety factor of 2 for design considerations).

2.7 Enhancement of the Wetting Drying Cycles for Infiltration basins:

Soil Aquifer Treatment (SAT) basin hydraulics are often controlled by the development of a low-conductivity clogging layer at and near the ground surface. This clogging layer has been found to be subject to compression under seepage forces exerted by infiltrating water with a corresponding reduction in the hydraulic conductivity of the layer, particularly when algae and/or a high concentration of particulate matter is present in the effluent. Limiting the depth of water in the pond can help to prevent excessive compression and a further reduction of hydraulic conductivity of the clogging layer. Additionally, the use of fairly short wetting cycles, designed to cut down on the growth of algae, can be helpful in minimizing the reduction of hydraulic conductivity of the clogging-surface layer (**Sandra et al., 1999**).

As suspended solids, algae growing in the infiltration basin, and microbes growing in the soil or the basin surface components accumulate on the bottom of the basin floor to form the clogging layer, they begin to restrict infiltration. Therefore, management of surface and near surface basin soils through control of wetting and drying cycle times is generally required to ensure adequate infiltration rates. Longer drying time tends to be more effective in reestablishing infiltration rate compared to shorter drying time. Short

drying times did not provide complete nitrification, thus allowing NH_4 to build up in soil. Long enough drying times will promote complete nitrification (NH_4 to NO_3) and will prevent accumulation of NH_4 in the soil (**Abushbak, 2004**).

(**AWWA, 1998**) emphasized that longer drying time tends to be more effective in reestablishing infiltration rates compared with shorter drying time. It is reasonable to expect that a more thorough surface drying with corresponding cracking and breaking up of the surface clogging layer would increase infiltration rates.

2.8 Research Contribution

The main enemy of the infiltration basins is the clogging on the infiltration surface which cause severe reduction in the infiltration rate for the system. The findings of the research will help to identify the constraints affecting the efficiency of the infiltration process, and it will help the responsible local authorities to operate the infiltration basins in a proper way by introducing methods of controlling and enhancement of infiltration rate.

CHAPTER 3 : Study Area Description

3.1 Location of the Gaza Strip

The Gaza Strip is located on the eastern coast of the Mediterranean Sea that borders Egypt on the southwest (11 km) and Israel on the east and north (51 km). It is 41 kilometers long, and from 6 to 12 kilometers wide, with a total area of 365 km² as shown in Figure 3-1 (PCBS, 2013).



Figure (3-1): Map of the Gaza Strip (Wikipedia, 2013)

The Gaza Strip is located between longitudes 34° 20" east, and latitudes 31° 25" north (Wikipedia, 2013).

3.2 Demographical Data

Demographic pressures in the Gaza Strip in terms of population density, growth rate, poverty and unemployment are extraordinarily high compared to neighboring countries

and regions. Based on estimates prepared by Palestinian Central Bureau of Statistics (PCBS) according to the results of the Population, Housing and Establishment Census of 2007, the estimated population of Gaza Strip totaled 1.64 million inhabitants **(PCBS, 2012)**.

3.3 Climate

The Gaza Strip is located at the south-eastern edge of the Mediterranean and has arid to semiarid climate. The Gaza Strip is characterized by short winter season, the first real rain starts from October till March, rains in September and April are occasionally and happened two times in the last decade. Therefore, the average yearly rainfall is only distributed to five months a year. Around 30% of the rains occurs in January **(Al Najjar, 2011)**. The annual rainfall fluctuating from 236 mm in the south to 433 mm in the north **(Hamdan, 2012)**.

The maximum temperature ranges between 18.1 and 29.4°C, while the minimum temperature ranges between 10.7 and 24.6 in winter and summer, respectively. The average humidity is 68.3% indicating high humidity in summer than in winter, as the Gaza Strip located on a coastal zone. **(Al Najjar, 2011)**.

3.4 Geology

The ground surface in the Gaza Strip is formed of elongated ridges and depressions parallel to the Mediterranean coast, and it is composed of sedimentary rocks belong to Quaternary Era and divided into two main formations, Holocene at the top is composed of continental alluvial and aeolian deposits called continental kurkar composed of calcareous sandstone covered by recent calcareous sand dunes accumulation lying in 1-4 km belt along the coast which is suitable for natural water recharge. The lower formation, Pleistocene is composed of near shore deposits and called marine kurkar. The kurkar deposits are porous, and this makes it important as a groundwater aquifer showing high hydraulic conductivity. The thickness of both formations

constituting the Quaternary formation is estimated at 160 meters, where the kurkar formation is subdivided into sub-aquifers by local aquicludes at the first four kilometers parallel to the coast which are composed of clay and marl beds making confined aquifers, Figure 3-2. Black shale of 100m of Pliocene age deposits are found beneath the Quaternary sediments and known locally as Saqiya formation which forms the base of the water bearing layer i.e. the coastal aquifer of the Gaza Strip (**Hamdan, 2012**).

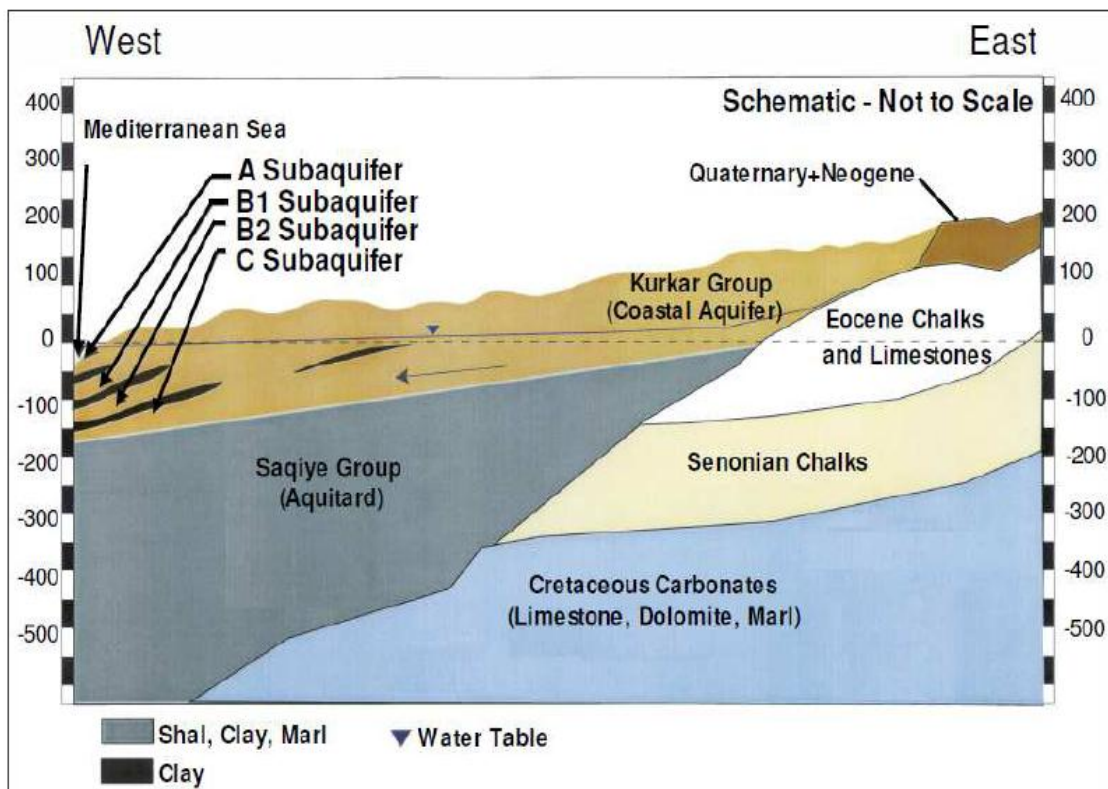


Figure (3-2): Generalized Geological Cross-section of the Coastal Plain (Greitzer, and Dan, 1967)

3.5 Infiltration Basins Location and Topography

The site is located east of Gaza City, next to the border with Israel. The site is located on a slope with the eastern part elevated at 70 meters above sea level (masl) and the western part at 50 masl, Figure 3-3. The land has previously been used for agriculture. The areas north and south of the site are used for orchards and along the western side a cemetery is located (**SWECO, 2003**).



Figure (3-3): The location of the Infiltration Basins

3.6 Situation, and Operation of the Infiltration Basins

3.6.1 Background

The Swedish Government has supported the Palestinian National Authority (PNA) with assistance in funding of the Northern Gaza Storm Water and Sewerage Project (NGSWSP) through the Palestinian Water Authority (PWA). The purpose of the project was to provide a long-term and sustainable solution of the wastewater situation for Northern Gaza (SEWCO, 2003).

The NGSWSP main components as stated by SWECO International:

- Pressure Mains and Gravity Sewers, which already done.
- Pumping Stations consisting of a New Terminal Pumping Station at the existing WWTP and upgrading of the existing Beit Lahia Pumping Station, and the project was implemented.

- New Wastewater Treatment Plant, including inlet works with screening, grit and grease removal, primary and biological treatment, final clarification and sludge treatment facilities. This component is still under construction.
- Effluent Infiltration Basins for aquifer recharge, which is the subject of the study.

The infiltration area divided into nine ponds with a total area of approximately 80.000 m². The area of each pond as per design and after construction is presented in Table 3-1 below.

Table 3-1: Infiltration Basins Area

Infiltration Pond	Area (m²) according to the design (SWECO, 2003)	Area (m²) after construction (PWA, 2009)
1	10700	12328
2	12700	11142
3	6900	6892
4	8900	7845
5	9300	9174
6	7700	6120
7	8400	8386
8	7600	6302
9	7200	7091

The infiltration basins are distributed in three groups. Basin 1,2,3, basin 4,5,7 and basin 6,8,9, Figure 3-4. The water is distributed to one to three basins in each group at a time. After flooding for a certain time, 0.5-2 days, the water is redirected to the next group in order. In between flooding cycles, the basins are allowed to dry for period of 1-4 days or longer. The relatively short flooding period and the drying periods will minimize algae

growth and this will prevent a quick clogging of the ponds. Normally one basin is out of operation for extended drying and cleaning (SWECO, 2003).

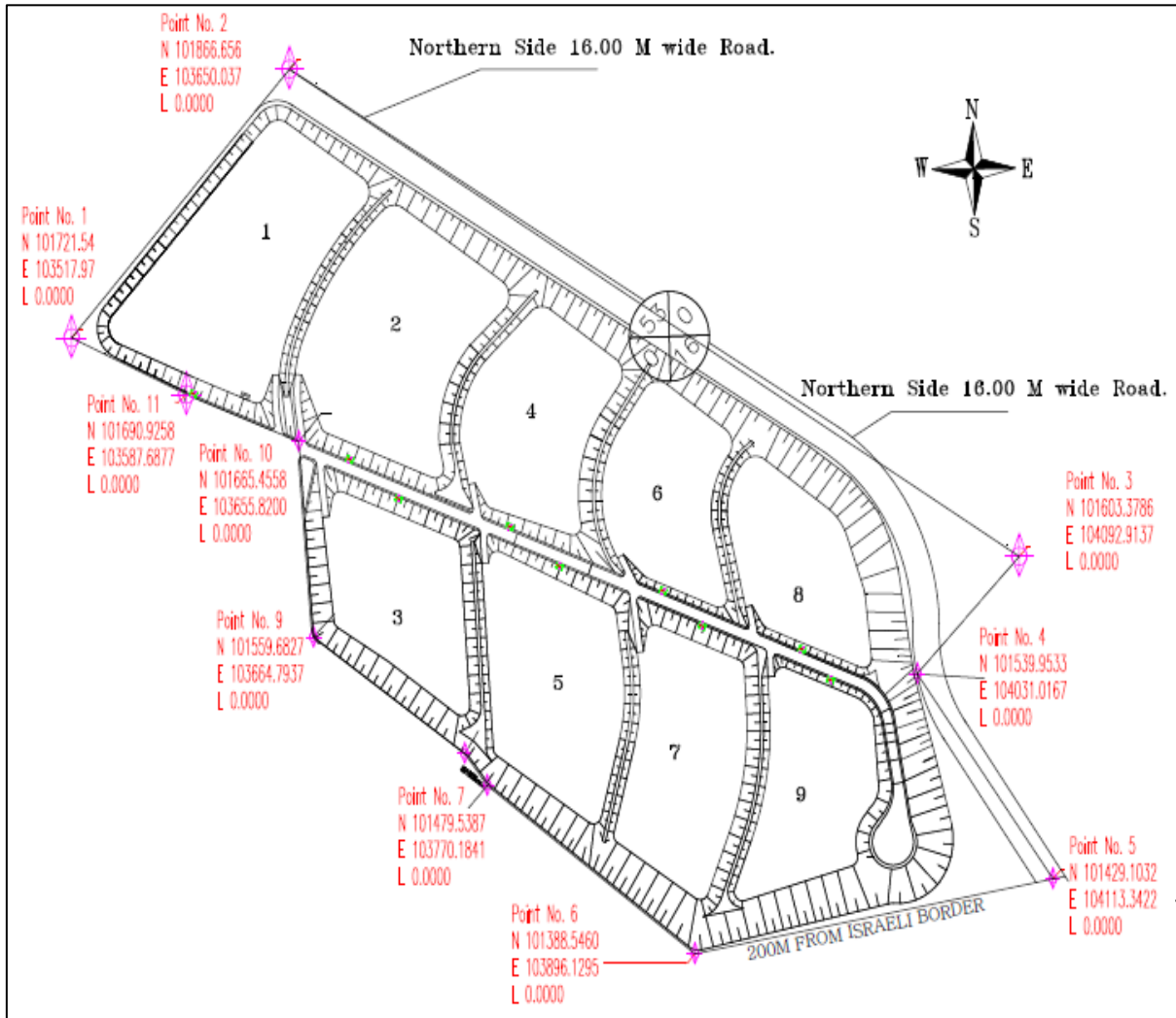


Figure (3-4): Infiltration Site Layout (PWA, 2009)

3.6.2 Effluent Water Flow, and Effluent water Quality

The infiltration basins are designed to accommodate an average design flow of 35,600 m³/d which will be coming out from the wastewater treatment plant (new northern wastewater treatment plant), Table 3-2.

Table 3-2: The Design Flow for the Infiltration Basins (SWECO, 2003)

Design Flow Values	Unit	Values
Flow, population	m ³ /d	33,960
Flow, industrial	m ³ /d	1,640
Total flow, average	m ³ /d	35,600
Design flow	m ³ /h	1,975
Peak flow	m ³ /h	3,600

The Effluent water quality according to the design criteria to be infiltrated and used for unrestricted irrigation is (SWECO, 2003):

- BOD₅ 10-20 mg/l
- SS 15-20 mg/l
- N-tot 10 mg/l
- Helminthes <1 No/l
- Fecal coliform <200 No/100 ml

The effluent water quality according to the periodic (Year 2011, 2012, and 2013) water quality monitoring by the PWA is:

- BOD₅ 60-95 mg/l
- SS 60-130 mg/l
- N-tot 55-75 mg/l
- Fecal coliform >1100 No/100 ml

According to the progress report (Quarter # 33 for the Period from January to March, 2013) prepared by the Projects Management Unit (PMU) at PWA, the total accumulated quantity of the effluent transferred to the new infiltration basins from April, 2009 until March, 2013 is about 19 MCM, with average daily flow discharged to the IB of 8,400 m³.

Due to the partially treated effluent, and to reduce the pollution of the aquifer, both PWA and the Coastal Municipalities Water Utility (CMWU) agreed a maximum pumping rate of 15,000 m³/d from the Terminal pump station to the new IB.

The quantity of effluent is still below the agreed quantity between PWA and CMWU which is 15,000 m³/d. The excess quantities of effluent pumped to two emergency ponds northern to Bait Lahia Waste Water Treatment Plant (BLWWTP).

To improve the performance of the infiltration basins, PWA starting the cleaning activities for ponds one and two at BLWWTP during March, 2013. According to PWA progress report the cleaning will help in decreasing the Suspended Solids (SS) concentration, and thus may improve the quality of effluent reaching the basins and improve the infiltration rate.

3.6.3 Infiltration Basins Efficiency

According to historical records by the PWA, the efficiency of the basins have deteriorated with compared the average infiltration rates for all basins for the years 2010, 2011, 2012 and 2013, Figure 3-5, and the worst one is infiltration basin IB1, Figure 3-6, and Figure 3-7.

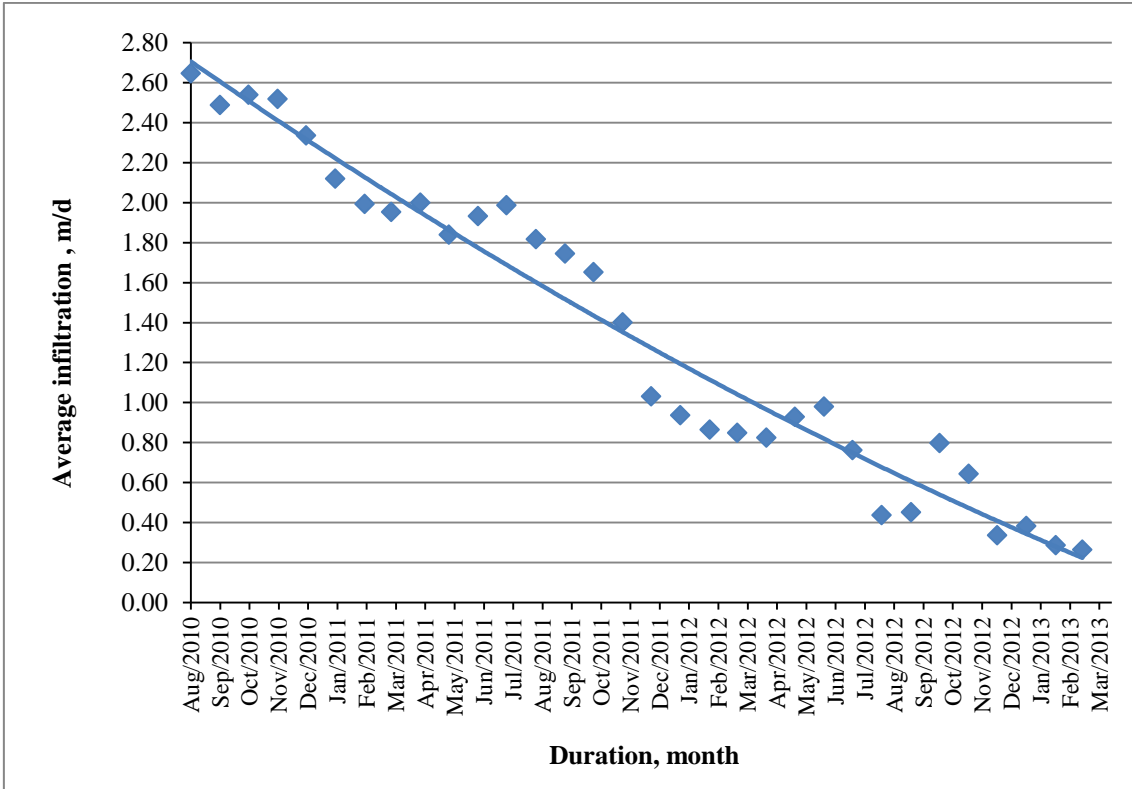


Figure (3-5): Average infiltration record for all basins (1-9) from August 2010 to March 2013 (PWA, 2013)

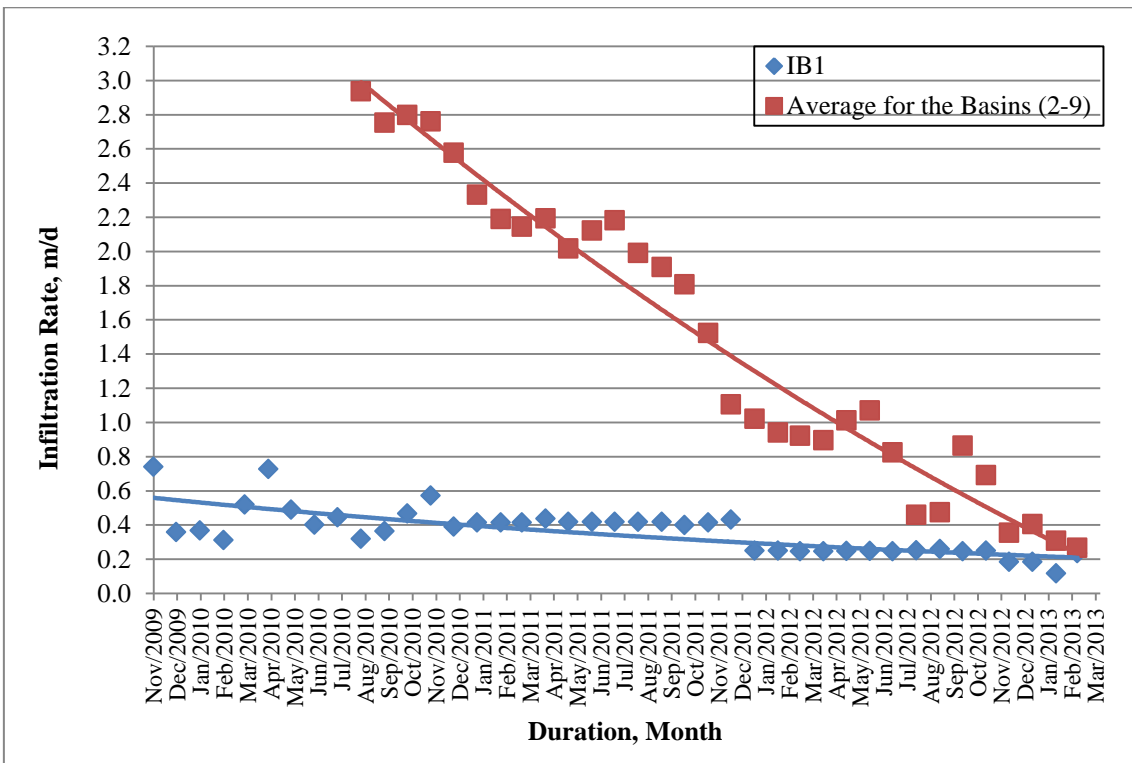


Figure (3-6): Average infiltration Record from November 2009 to March 2013 for IB1 Comparing with Basins (2-9), (PWA, 2013)

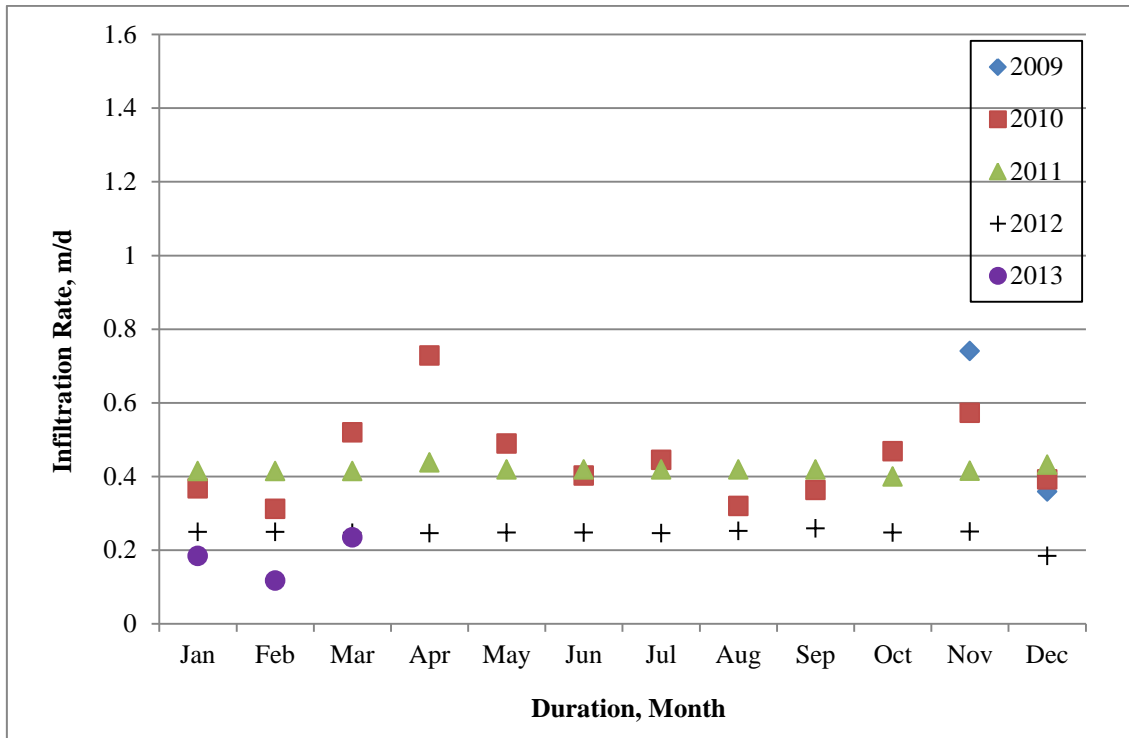


Figure (3-7): Average monthly infiltration rate for IB1 for the Years 2009, 2010, 2011, 2012, and 2013 (PWA, 2013)

The efficiency of infiltration basin IB1 is in deteriorating since the operation of the infiltration system as shown in Figure 3-6, and 3-7 with comparing the rate of infiltration for the basin for the years 2009, 2010, 2011, 2012, and up to March, 2013. The basin takes long time to dry (Figure 3-8) and this is clear from the plowing periods recorded by CMWU, the authority who perform the plowing works. It is concluded that the problem of IB1 is not related to operation, but it may related to geological factors.

Appendix (2) shows the schedule of plowing for the IB1, since 14.09.2011 until 13.05.2013 (the last plowing) before stopping pumping to the basin.



Figure (3-8): General view for infiltration basin IB1(July, 2013)

CHAPTER 4 : Methodology

4.1 Introduction

The methodology followed in this study was based on the objectives of the study as stated in chapter 1, section 1.4. To achieve the objectives; the study was divided into two parts: field investigations and experiment tasks (experimental methods were employed to determine soil classification tests and soil quality) and modeling tasks for the unsaturated zone.

4.2 Soil Classification Tests

The location of Bore holes (5 bore holes) was selected as shown in Figure 4-1, after continuous monitoring for the basin (IB1), at the places which has low infiltration rate. The drilling of bore holes was performed by the method of Rotary Auger, Figure 4-2.

During the drillings, disturbed samples were collected each 30cm until the depth 2.10m and each 1.0 m until the depth of 12.0m (end of bore hole), with a total of 17 samples for each bore hole. Samples were selected in a way representative to the soil strata within the borehole along the depth of 12m for the infiltration basin (IB1). The samples were checked ocular at the site with regards of the soil texture and color, and the soil samples were placed in a clean plastic bags before transported to the laboratory. An identity number, sample location, and depth within the borehole was identified for each sample.

The soil classification tests executed laboratory tests which included: Sieve Analysis; Atterberge Limits; Moisture Content, and Hydraulic Conductivity. Samples were selected in a way representative to the soil strata within the borehole along the depth of 12m for the infiltration basin (IB1).

The tests results are shown in appendix (1). The laboratory analysis of soil samples were carried out in the Consulting Center For Quality and Calibration.

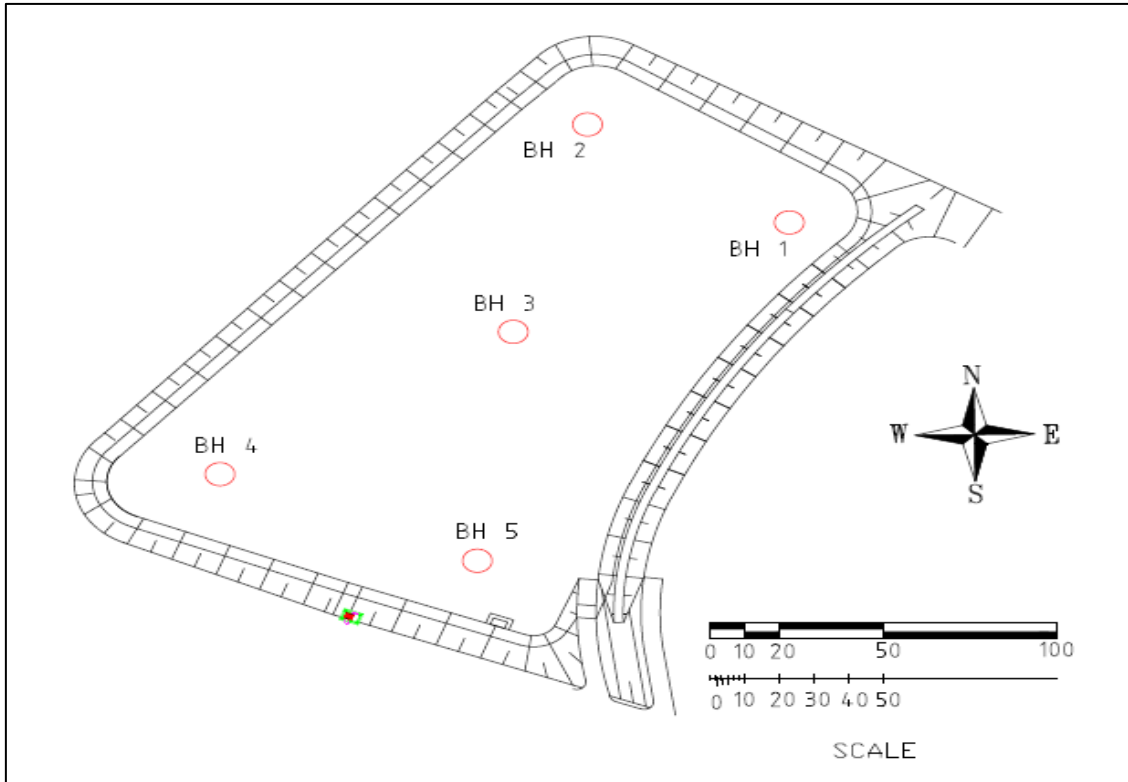


Figure (4-1): Location of Bore Holes at Infiltration Basin (IB1)



Figure (4-2): Drilling method using Rotary Auger

Tests were performed according to the international standards (American Society for Testing and Materials (ASTM) and British Standards (BS)). The soil layers were classified according to the Unified Soil Classification System (USCS). The following tests with their relevant standards were performed at the laboratory, Table 4-1.

Table 4-1: Testing methods and relevant standards

Testing Method	Relevant Standard
Description and Identification of Soils (Visual-Manual Procedure).	ASTM D 2488-93
Particle Size Analysis of Soils.	ASTM D 422-63-Reapproved 1998
Classification of Soils for Engineering Purposes (Unified Soil Classification System).	ASTM D 2487-98
Laboratory Determination of Water (Moisture) Content of Soil.	ASTM D 2216-98
Liquid Limit, Plastic Limit, and Plasticity Index of Soils.	ASTM D 4318-98, BS 1377-1990

4.3 Soil Quality Tests

Soil quality tests was conducted in order to check if soil contains high load of organic matter (OM) and high rate of sodium adsorption ratio (SAR).

The samples from the same bore holes was taken in parallel with the soil classification samples each 30cm until the depth of 2.10m (7 samples from each bore hole). The soil quality samples was placed in a clean plastic bags before delivered to the laboratory. An identity number, sample location, and depth within the borehole was identified for each sample.

Samples were selected in a way representative to the soil depth within the borehole .

The organic matter test was conducted according to the ASTM standards, ASTM D 2974-00 at Consulting Center For Quality and Calibration.

SAR was carried out in Bir Zeit University Testing Laboratory according to Methods of Soli Analysis, Chemical and Microbiological Properties, Ammonium Acetate Method. Figure 4-3, Figure 4-4, and Figure 4-5 showing some procedures during testing of SAR. SAR was calculated according to Gapon equation as stated in Chapter 2, section 2.3.6.

Note: the soil sample for borehole (1) which related to the depth 1.80m was lost during transportation of the samples to the laboratory.



Figure (4-3): Preparation of soil samples



Figure (4-4): Soil samples after digestion

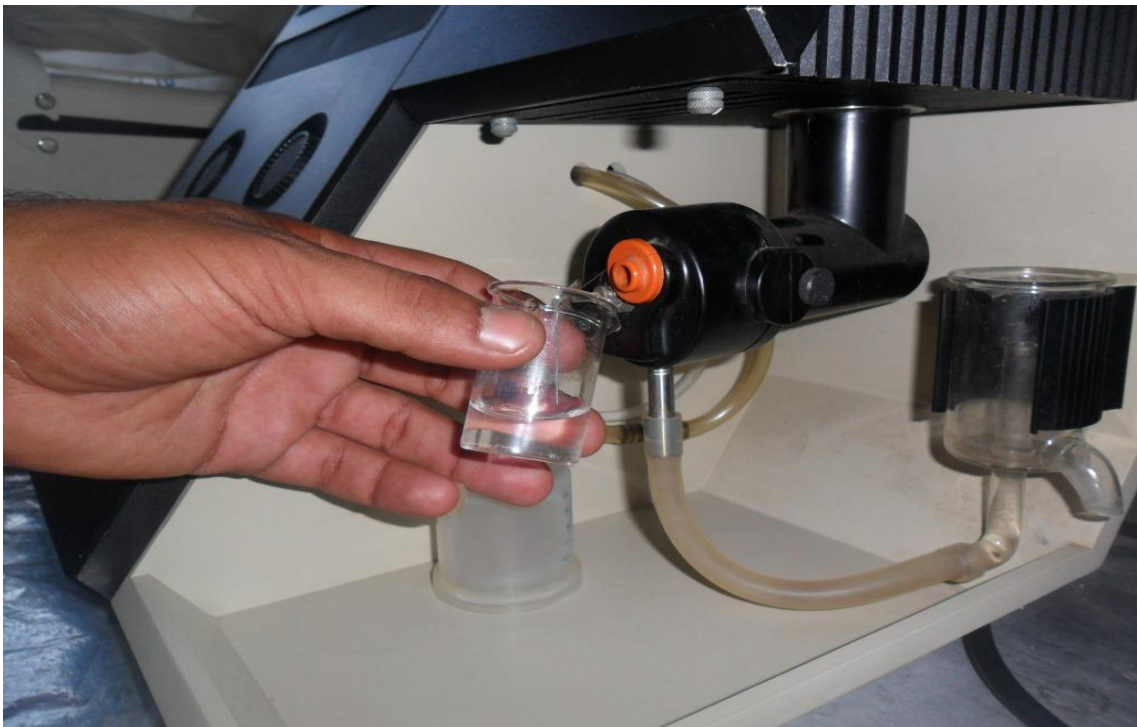


Figure (4-5): Final test of SAR

4.4 Water Quality Tests

Quality of the effluent (partially treated wastewater) was tested in order to determine the parameters: Biochemical Oxygen Demand BOD, Chemical Oxygen Demand COD, Temperature T, Total Suspended Solids TSS, Hydrogen Ion Concentration pH, Total Coliform TC, Fecal Coliform FC, and Hardness H. Tests were carried out at Environmental and Rural Research Center (ERRC) at the Islamic University of Gaza by the Project Management Unit at PWA. Table 4-2 shows adopted methods and used instruments performed by ERRC.

Table 4-2: Adopted Methods and Instruments

No.	Parameter	Procedure	Name of Instrument
1	BOD	OxiTop method	OxiTop
2	COD	Close reflux method	Spectrophotometer & COD reactor
3	TSS	Dry 105 C ^o	Oven
4	TC	Filtration technique	Incubator
5	FC	Filtration technique	Incubator

4.5 Modeling for the Unsaturated Zone

Chapter six will explain and discuss the modeling for the unsaturated zone by using the Green-Ampt model (1911) for infiltration. Modeling for the exiting infiltration regime, and modeling for the enhancement will be performed by using different soil parameters. Also this chapter will introduce method of enhancement the wetting and drying cycles in order to maintain reasonable infiltration rate.

CHAPTER 5 : Results and Discussion

This chapter demonstrates and discusses the results of the collected data and their analysis for IB1, also the modeling for the unsaturated zone.

5.1 Field Experiments Results

USCS classification system introducing the following symbols for the soil:

SP: poorly graded sand, gravelly sand, little or no fines.

SM: Silty sands, sand-silt mixture.

SC: clayey sand, sand- clay mixture.

CL: Inorganic clays of low to medium plasticity, gravel clays, sand clays, silt clays, lean clays.

5.1.1 Results of Soil Classification Tests

5.1.1.1 Grain Size Analysis for Bore Hole BH1

According to the bore hole log for BH1, the top soil from depth 0.0-0.30m is sand: yellowish fine sand with little gravel (Kurkar) and a little fines (14.0%), and it is non-plastic. The percentage of water content WC is 11.0%. The depth from 0.30-0.90m is classified as clayey sand: slightly brown clayey sand with little gravel (Kurkar) and some fines (21.6%-29.6%). The layer is of low to medium plasticity, with WC decreasing from 12.7% to 12.0%. The depth from 0.90m until depth of 12.0m the end of the bore hole is sand: yellowish fine sand with little gravel (Kurkar) and a little fines (2.0%-11.9%). The layer is non-plastic, with WC from 3.80% to 8.70%. Figures 5-1, 5-2, and 5-3 showing the geological cross section for the soil according to bore holes (1-3-4), and (2-3-5). Also summary of the soil classification for BH1 is shown in Table 5-1.

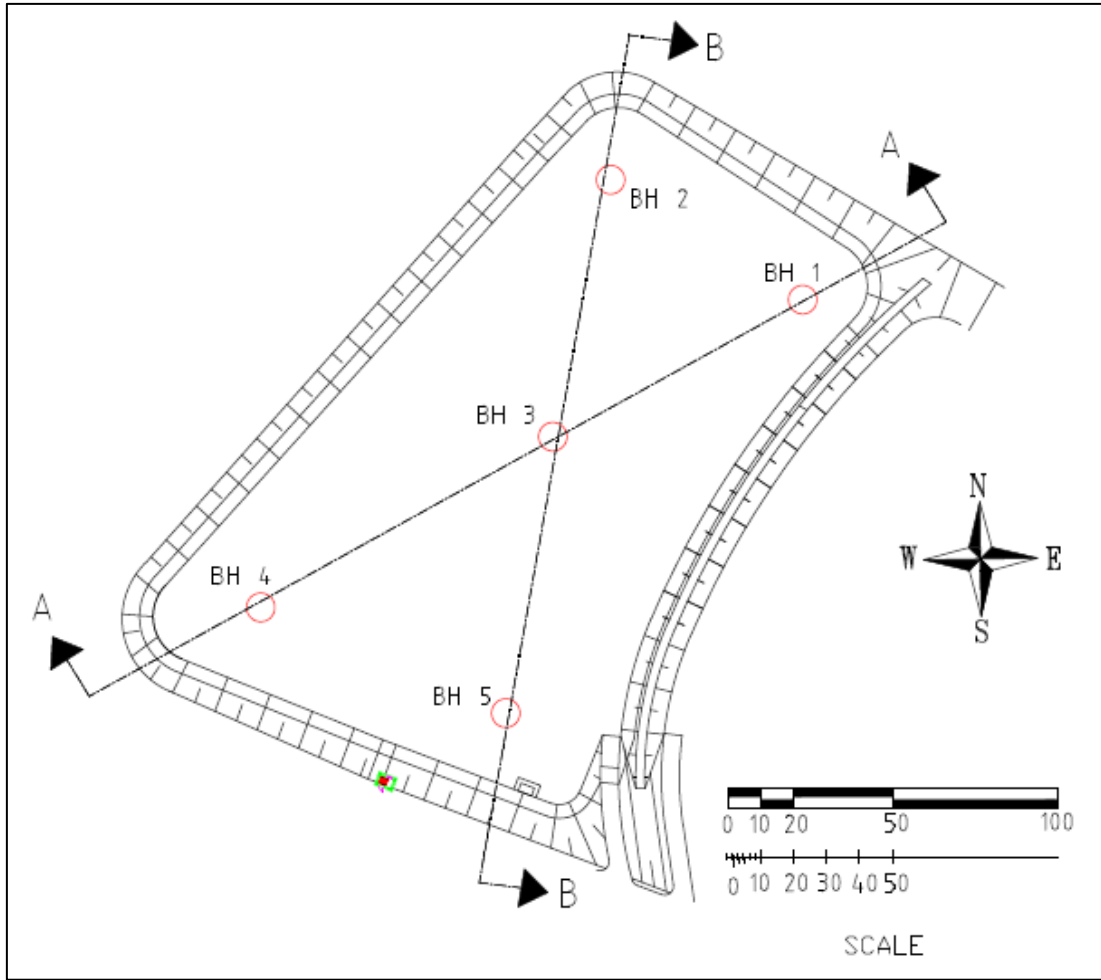


Figure (5-1): Section Plan at the Bore Holes for IB1

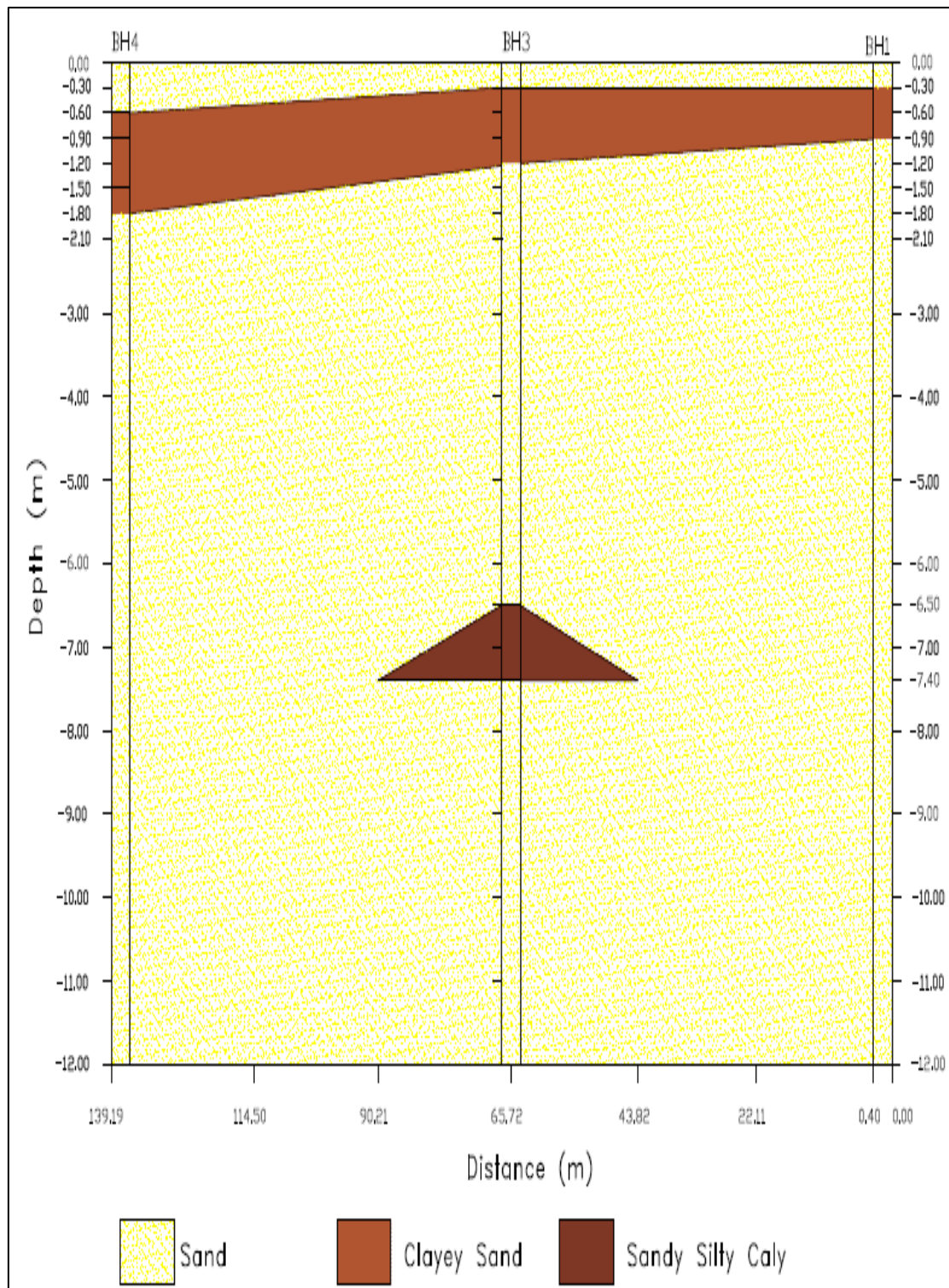


Figure (5-2): Geological Cross Section A-A (BH1-BH3-BH4)

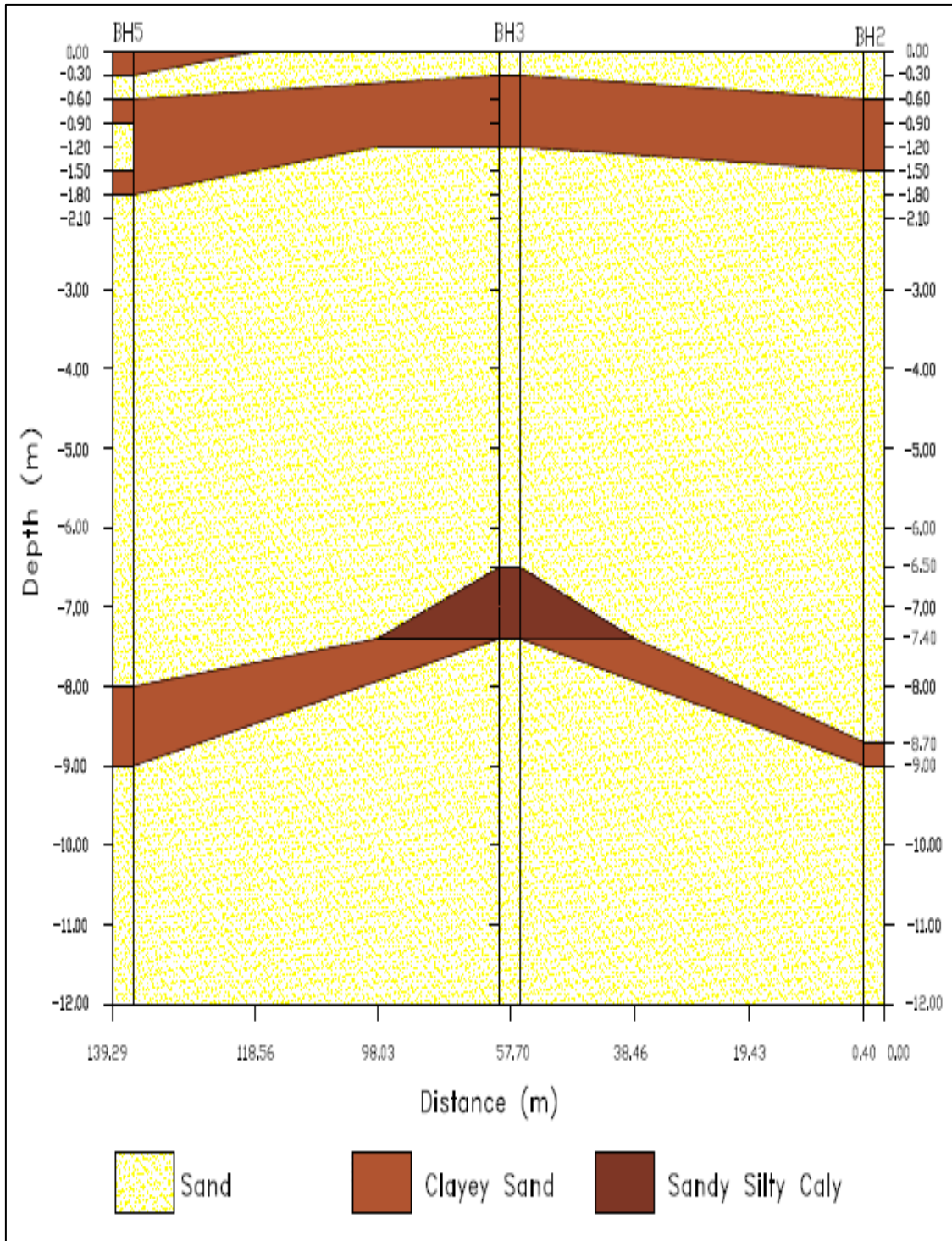


Figure (5-3): Geological Cross Section B-B (BH2-BH3-BH5)

Table 5-1: Soil Classification for BH1

Depth (m)	Soil Description	Soil Classification	Fines Content (%)	WC (%)
0-0.3	Sand: yellowish fine sand with little gravel (Kurkar) and a little fines.	SM	14.0	11.0
0.3-0.9	Clayey Sand: slightly brown clayey sand with little gravel (Kurkar) and some fines.	SC	21.6-29.6	12.0-12.7
0.9-12.0	Sand: yellowish fine sand with little gravel (Kurkar) and a little fines.	SP-SM	2.0-11.9	3.8-8.7

5.1.1.2 Grain Size Analysis for Bore Hole BH2

The bore hole log for BH2 shows that the top soil layer from depth 0.0-0.60m is sand: yellowish fine sand with little gravel (Kurkar) and a little fines (6.3%), the soil layer is non-plastic. The percentage of water content WC is 11.4%. The depth from 0.6-1.5m is classified as clayey sand: slightly brown clayey sand with little gravel (Kurkar) and some fines (18.2%-27.7%). The layer is of low to medium plasticity, with WC decreasing from 15.6% to 14.2%. The depth from 1.5m until the depth of 8.7m is sand: yellowish fine sand with little gravel (Kurkar) and a little fines (4.6%-9.6%). The layer is non-plastic, with WC ranged from 5.60% to 10.5%. The depth from 8.70m up to 9.0m is classified clayey sand: slightly light brown clayey sand with little gravel (Kurkar), with some fines (26.5%). The WC is 10.5%. The layer is of medium plasticity. Depth from 8.70m up to end of BH is sand: yellowish fine sand with little gravel (Kurkar) and a little fines (3.3%), the soil layer is non-plastic, WC ranged from 4.2%-6%. Summary of the soil classification for BH2 is shown in Table 5-2.

Table 5-2: Soil Classification for BH2

Depth (m)	Soil Description	Soil Classification	Fines Content (%)	WC (%)
0-0.6	Sand: yellowish fine sand with little gravel (Kurkar) and a little fines.	SP-SM	6.3	11.4
0.6-1.5	Clayey Sand: slightly brown clayey sand with little gravel (Kurkar) and some fines.	SC	18.2-27.7	14.2-15.6
1.5-8.7	Sand: yellowish fine sand with little gravel (Kurkar) and a little fines.	SP-SM	4.6-9.6	5.6-10.5
8.7-9.0	Clayey Sand: slightly brown clayey sand with little gravel (Kurkar) and some fines.	SC	26.5	10.5
9.0-12.0	Sand: yellowish fine sand with little gravel (Kurkar) and a little fines.	SP	3.3	4.2-6

5.1.1.3 Grain Size Analysis for Bore Hole BH3

The bore hole log for BH3 shows that the top soil layer from depth 0.0-0.30m is sand: yellowish fine sand with little gravel (Kurkar) and a little fines (13.8%), the soil layer is non-plastic. The percentage of water content WC is 12.8%. The depth from 0.30-1.20m is classified as clayey sand: light brown clayey sand with little gravel (Kurkar) and some fines (22.9%-39.9%). The layer is of low to medium plasticity, with WC ranged from 12.1%-15.6%. The depth from 1.2m until the depth of 6.5m is sand: yellowish fine sand with little gravel (Kurkar) and a little fines (9.1%-11.6%). The layer is non-plastic, with WC ranged from 6.8% to 9.0%. The depth from 6.50m up to 7.4m is classified sandy silty clay: dark brown sandy clay with little gravel (Kurkar). The layer is of medium plasticity. Fines content 55.6%, WC is 17.9%. The depth from 7.4m to the end of BH is sand: yellowish fine sand with little gravel (Kurkar) and a little fines (2.3%-6.8%), the soil layer is non-plastic, WC ranged from 3.5%-4.2%. Summary of the soil classification for BH3 is shown in Table 5-3.

Table 5-3: Soil Classification for BH3

Depth (m)	Soil Description	Soil Classification	Fines Content (%)	WC (%)
0-0.3	Sand: yellowish fine sand with little gravel (Kurkar) and a little fines.	SM	13.8	12.8
0.3-1.2	Clayey Sand: light brown clayey sand with little gravel (Kurkar) and some fines.	SM-SC	22.9-39.9	12.1-15.6
1.2-6.5	Sand: yellowish fine sand with little gravel (Kurkar) and a little fines.	SP-SM	9.1-11.6	6.8-9.0
6.5-7.4	Sandy Silty Clay: dark brown sandy clay sand with little gravel (Kurkar) and some fines.	CL	55.6	17.9
7.4-12.0	Sand: yellowish fine sand with little gravel (Kurkar) and a little fines.	SP-SM	2.3-6.8	3.5-4.2

5.1.1.4 Grain Size Analysis for Bore Hole BH4

The bore hole log for BH4 shows that the top soil layer from depth 0.0-0.60m is sand: yellowish fine sand with little gravel (Kurkar) and a little fines (5.4%-8.7%), the soil layer is non-plastic. The percentage of water content WC is ranged from (7.2-9.2%). The depth from 0.60-0.9m is classified as clayey sand: light brown clayey sand with little gravel (Kurkar) and some fines (21.3%). The layer is of low to medium plasticity, with WC of 7.7%. The depth from 0.9-1.5m is sand: yellowish fine sand with little gravel (Kurkar) and a little fines (6.8%-10.8%). The layer is non-plastic, with WC ranged from (6.2% to 7.8%). The depth from 1.50m up to 1.8m is classified clayey sand: slightly light brown clayey sand with little gravel (Kurkar), fines content 20.70%. The layer is of low plasticity, and WC is 5.1%. The depth from 1.8m to the end of BH is sand: yellowish fine sand with little gravel (Kurkar) and a little fines (2.1%-11.4%), the soil layer is non-plastic, WC ranged from (4.7%-7.6%). Summary of the soil classification for BH4 is shown in Table 5-4.

Table 5-4: Soil Classification for BH4

Depth (m)	Soil Description	Soil Classification	Fines Content (%)	WC (%)
0-0.6	Sand: yellowish fine sand with little gravel (Kurkar) and a little fines.	SP-SM	5.4-8.7	7.2-9.2
0.6-0.9	Clayey Sand: light brown clayey sand with little gravel (Kurkar) and some fines.	SC	21.3	7.7
0.9-1.5	Sand: yellowish fine sand with little gravel (Kurkar) and a little fines.	SP-SM	6.8-10.8	6.2-7.8
1.5-1.8	Clayey Sand: slightly light brown clayey sand with little gravel (Kurkar)	SC	20.7	5.1
1.8-12.0	Sand: yellowish fine sand with little gravel (Kurkar) and a little fines.	SP-SM	2.1-11.4	4.7-7.6

5.1.1.5 Grain Size Analysis for Bore Hole BH5

The bore hole log for BH5 shows that the top soil layer from depth 0.0-0.30m is clayey sand: slightly dark brown clayey sand with little gravel (Kurkar), fines content 31.5%. The layer is of medium plasticity, and WC is 12.3%. Depth from 0.3-0.6m is classified as sand: yellowish fine sand with little gravel (Kurkar) and a little fines (6.1%), the soil layer is non-plastic. The percentage of water content WC is 5.8%. The depth from 0.60-0.9m is classified as clayey sand: light brown clayey sand with little gravel (Kurkar) and some fines (26.5%). The layer is of medium plasticity, with WC of 11.0%. The depth from 0.9-1.5m is sand: yellowish fine sand with little gravel (Kurkar) and a little fines (5.3%-6.1%). The layer is non-plastic, with WC ranged from (5.5% to 5.9%). The depth from 1.50m up to 1.8m is classified clayey sand: slightly light brown clayey sand with little gravel (Kurkar), fines content 23.40%. The layer is of medium plasticity, and WC is 9.6%. The depth from 1.8m up to 8.0m is sand: yellowish fine sand with little gravel (Kurkar) and a little fines (2.3%-5.0%), the soil layer is non-plastic, WC ranged from (3.3%-7.5%). The depth from 8.0- 9.0m is clayey sand: slightly light brown clayey sand with little gravel (Kurkar), fines content 20.3%. The layer is of low plasticity, and WC

is 3.4%. Finally, depth from 9.0m up to the end of BH is sand: yellowish fine sand with little gravel (Kurkar) and a little fines (2.1%-3.2%), the soil layer is non-plastic, WC ranged from (3.5%-4.0%).

BH Summary of the soil classification for BH5 is shown in Table 5-5.

Table 5-5: Soil Classification for BH5

Depth (m)	Soil Description	Soil Classification	Fines Content (%)	WC (%)
0-0.3	Clayey Sand: slightly dark brown clayey sand with little gravel (Kurkar).	SC	31.5	12.3
0.3-0.6	Sand: yellowish fine sand with little gravel (Kurkar) and a little fines.	SP-SM	6.1	5.8
0.6-0.9	clayey sand: light brown clayey sand with little gravel (Kurkar) and some fines.	SC	26.5	11.0
0.9-1.50	Sand: yellowish fine sand with little gravel (Kurkar) and a little fines.	SP-SM	5.3-6.1	5.5-5.9
1.5-1.8	clayey sand: slightly light brown clayey sand with little gravel (Kurkar), fines content.	SC	23.4	9.6
1.80-8.0	Sand: yellowish fine sand with little gravel (Kurkar) and a little fines.	SP	2.3-5.0	3.3-7.5
8.0-9.0	clayey sand: slightly light brown clayey sand with little gravel (Kurkar), fines content	SC	20.3	3.4
9.0-12.0	Sand: yellowish fine sand with little gravel (Kurkar) and a little fines.	SP	2.1-3.2	3.5-4.0

5.1.2 Discussion of Grain Size Analysis Test Results for Bore Holes (1-5)

According to the USCS classification system, the bore holes indicated that the soil strata in the infiltration basin IB1 consists the following layers (soil types):

- **Sand:** is a poorly graded Sand, dim yellowish with little gravel (Kurkar) exist at depths as indicated in the soil logs in the appendix (2). It contains (85%-100%) Sand, (1%-19%) % gravel, and a little fines contents (0%-15%). The layer is non-plastic and has good permeability characteristics.
- **Clayey Sand:** is a poorly graded Clayey Sand, Slightly light brown with little gravel (Kurkar) exist at depths as indicated in the soil logs in the appendix (2). The layer is of low to medium plasticity, contains (3%-10%) gravel, (60%-85%) sand, and (15%-40%) fines. This layer is of low permeability.
- **Sandy Silty Clay:** is well graded sandy silty clay, dark brown sandy clay with little gravel (kurkar). The layer is of medium plasticity, and contains (3%) gravel, (1-33%) sand, (12%-28%) silt, and (16%) clay. This layer is of low permeability as shown in Figure 4, and Figure 5.

According to Taylor & Ashcroft, 1972, sandy soils have the highest infiltration rates and clayey soils have the lowest infiltration rates, Figure 5-4 and Figure 5-5 illustrate soil type effects on infiltration rate.

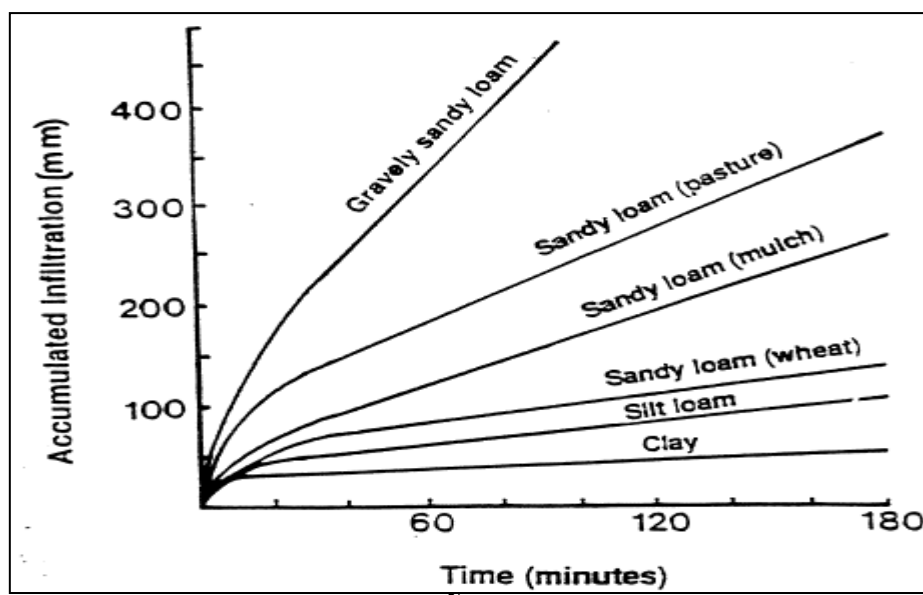


Figure (5-4): Soil type effects on accumulated infiltration (Taylor & Ashcroft, 1972)

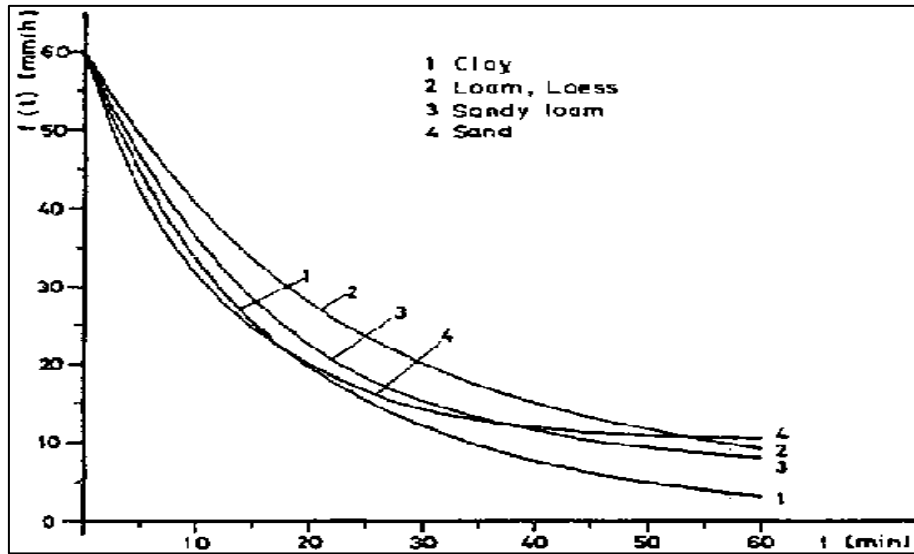


Figure (5-5): Soil type effects on infiltration rate (Taylor & Ashcroft, 1972)

5.1.3 Permeability Test Results for the Bore Holes from (1-5)

The hydraulic conductivity K was estimated according to Hazen equation, as stated previously in Chapter 2, section 2.5.3. Table 5-6 illustrates the estimated hydraulic conductivity K for the different soil types for soil samples which taken from bore holes (1-5).

Table 5-6: Estimated hydraulic conductivity K for the testing soil samples

Estimated hydraulic conductivity (K)					
Depth	BH1	BH2	BH3	BH4	BH5
(m)	(m/d)	(m/d)	(m/d)	(m/d)	(m/d)
0.3	2.68	6.14	2.73	5.18	0.04
0.6	0.26	4.85	0.20	6.86	6.18
0.9	0.09	1.93	0.19	0.29	0.09
1.2	3.46	0.08	0.02	4.03	6.13
1.5	5.59	0.09	4.12	5.81	5.94
1.8	6.92	4.83	4.78	0.34	0.17
2.1	5.44	5.49	4.76	6.57	2.18
3	5.05	5.38	4.96	4.10	7.27

Estimated hydraulic conductivity (K)					
Depth	BH1	BH2	BH3	BH4	BH5
(m)	(m/d)	(m/d)	(m/d)	(m/d)	(m/d)
4	5.24	6.26	2.98	5.35	7.47
5	5.26	5.58	2.35	5.55	7.14
6	6.16	5.76	3.61	6.20	8.15
7	6.59	5.94	0.01	3.71	6.07
8	6.43	6.26	7.10	5.57	6.34
9	6.88	0.92	6.09	6.42	0.38
10	5.61	7.13	6.32	6.09	7.33
11	5.76	6.81	7.19	7.57	7.03
12	7.02	8.99	7.17	7.15	7.12

According to Table 5-6, the values of hydraulic conductivity ranged between 0.01m/d, and 8.99m/d. According to Table 2-4 in Chapter 2, the range of estimated hydraulic conductivity is laid between the classification sand medium and clay.

(Todd and Mays, 2005), stated that the hydraulic conductivity of a soil depends on a variety physical factors, including porosity, particle size and distribution, shape of particles, arrangement of particles, and other factors. In general, for unconsolidated pours media, hydraulic conductivity varies with particle size; clayey material exhibit low values, where sands and gravel display high values. Figure 5-6 showing the variation of hydraulic conductivity with depth.

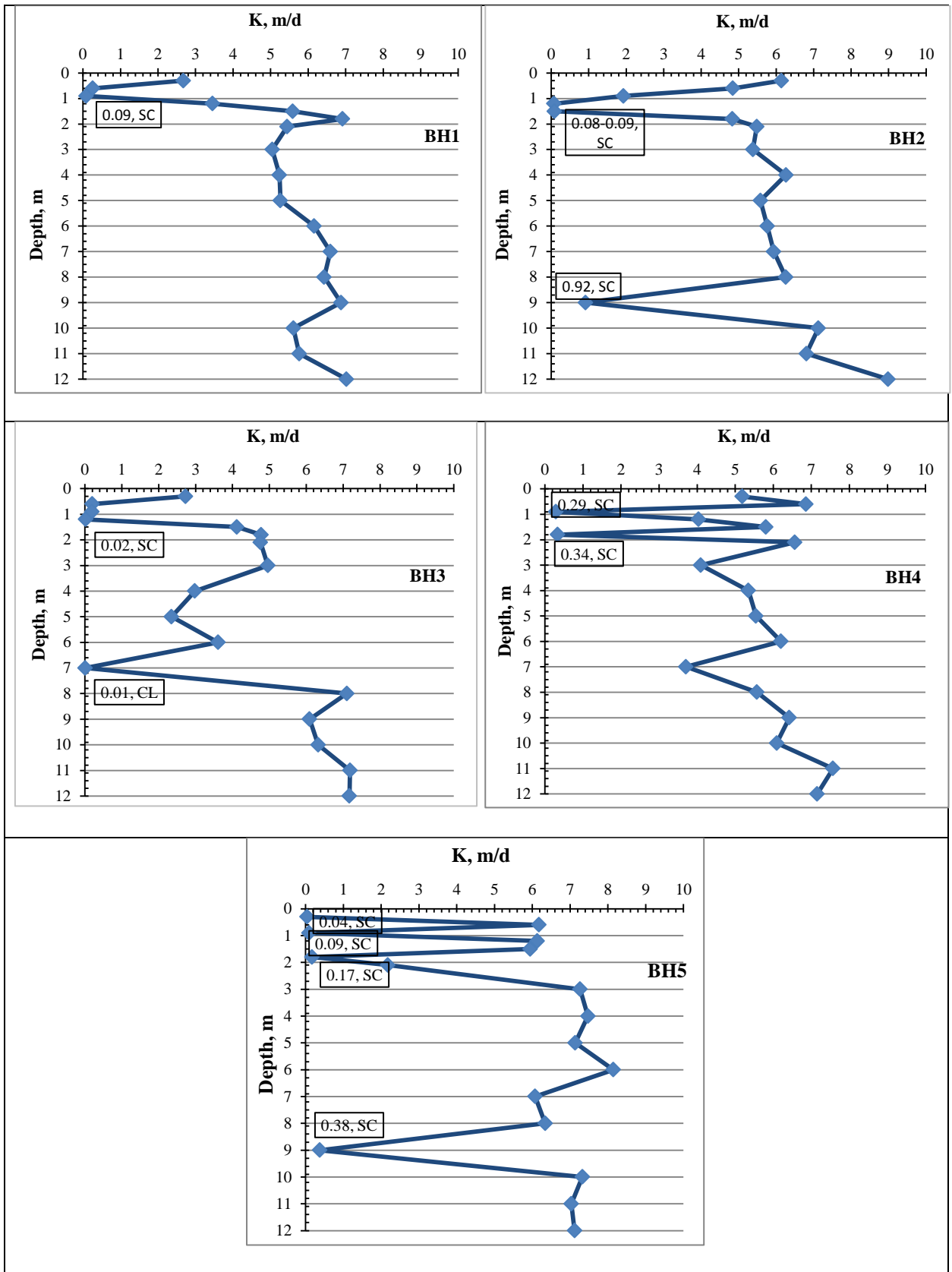


Figure (5-6): Variation of HC (K) according to Soil Depth for Bore Holes (1-5)

5.1.4 Results of Soil Quality Tests

5.1.4.1 Organic Matter Test Results

Organic Matter is the carbonaceous material contained in plants or animals and wastes. Organic matter is oxygen-demanding substances, and BOD is a measure of oxygen consumed in biological processes that break down organic matter (EPA, 2004).

According to the test results, OM was found at variable depths with variable rates, Table 5-7 shows OM test results for bore holes from (1-5). The explanation of the existence of OM in the soil is that the BOD load resulting from the partially treated wastewater still high. The organic loads which are expressed by BOD and COD in the waste water are considered the main problems and pollutants in the recharged water. The organic load causes the following (El Arabi, 2012):

- Increasing the organic matter content in the soil.
- Decreasing the infiltration rate of the soil by time.

Table 5-7: Organic Matter Test Results

Organic Matter (%)					
Depth (m)	BH1	BH2	BH3	BH4	BH5
0.3	0.5	0.5	0.7	0.9	0.9
0.6	0.4	0.3	0.8	0.7	0.7
0.9	0.2	0.7	0.7	0.8	0.8
1.2	0.1	0.6	0.8	0.2	0.5
1.5	0.0	0.4	0.3	0.2	0.4
1.8	0.0	0.4	0.1	0.2	0.5
2.1	0.0	0.4	0.2	0.2	0.6

In general the OM still with low values and will affect soil hydraulic conductivity or the infiltration rate. Figure 5-7 showing the variation of OM with depth.

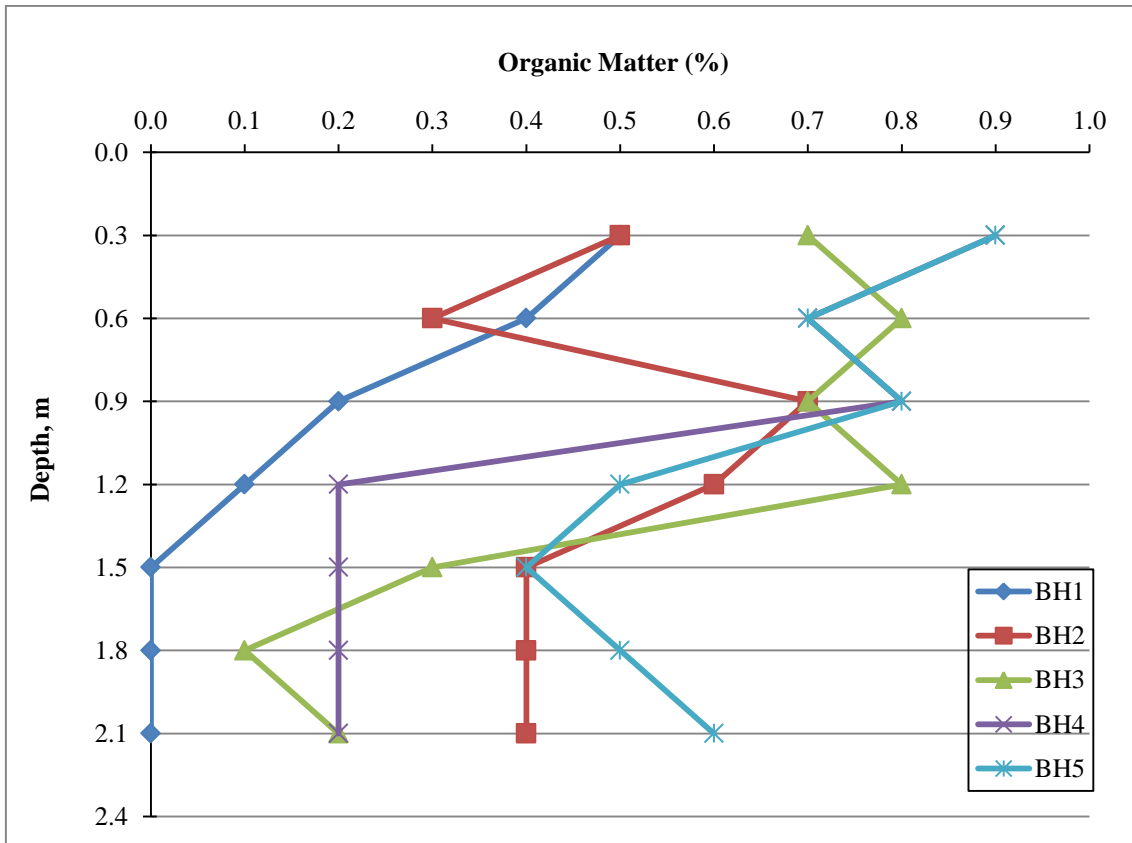


Figure (5-7): Organic Matter Test Results for Bore Holes (1-5)

5.1.4.2 SAR Test Results

SAR Tests results for each bore hole are shown in Tables (5-8 to 5-12).

Table 5-8: SAR, test results for bore hole (1)

Depth M	Ca mg/kg	Mg mg/kg	Na mg/kg	Ca meq/kg	Mg meq/kg	Na meq/kg	SAR
0.30	3607	2067	500	180.35	172.25	21.74	1.64
0.60	3848	2159	300	192.4	179.92	13.04	0.96
0.90	3928	2038	300	196.4	169.83	13.04	0.97
1.20	4329	1732	300	216.45	144.33	13.04	0.97
1.50	3928	1819	150	196.4	151.58	6.52	0.50
2.10	3687	1844	100	184.35	153.67	4.36	0.34

Table 5-9: SAR, test results for bore hole (2)

Depth M	Ca mg/kg	Mg mg/kg	Na mg/kg	Ca meq/kg	Mg meq/kg	Na meq/kg	SAR
0.30	3607	1941	200	180.35	161.75	8.70	0.67
0.60	3848	1722	160	192.4	143.50	6.96	0.54
0.90	3968	1965	300	198.4	163.75	13.04	0.97
1.20	3607	2402	300	180.35	200.17	13.04	0.95
1.50	4008	2329	300	200.4	194.08	13.04	0.93
1.80	3848	1989	180	192.4	165.75	7.83	0.59
2.10	3848	2023	150	192.4	168.58	6.52	0.49

Table 5-10: SAR, test results for bore hole (3)

Depth M	Ca mg/kg	Mg mg/kg	Na mg/kg	Ca meq/kg	Mg meq/kg	Na meq/kg	SAR
0.30	4409	2086	320	220.45	173.83	13.91	0.99
0.60	4569	2183	250	228.45	181.92	10.87	0.76
0.90	4569	2135	280	228.45	177.92	12.17	0.86
1.20	4890	2135	400	244.5	177.92	17.39	1.20
1.50	4168	2086	220	208.4	173.83	9.57	0.69
1.80	4008	2086	160	200.4	173.83	6.96	0.51
2.10	4008	2038	190	200.4	169.83	8.26	0.61

Table 5-11: SAR, tests results for bore hole (4)

Depth M	Ca mg/kg	Mg mg/kg	Na mg/kg	Ca meq/kg	Mg meq/kg	Na meq/kg	SAR
0.30	4008	1989	170	200.4	165.75	7.39	0.55
0.60	4008	1795	160	200.4	149.58	6.96	0.53
0.90	3848	2038	160	192.4	169.83	6.96	0.52
1.20	3367	1941	140	168.35	161.75	6.09	0.48
1.50	3607	1990	100	180.35	165.83	4.35	0.33
1.80	4008	1941	110	200.4	161.75	4.78	0.36
2.10	3928	1989	100	196.4	165.75	4.35	0.32

Table 5-12: SAR, tests results for bore hole (5)

Depth M	Ca mg/kg	Mg mg/kg	Na mg/kg	Ca meq/kg	Mg meq/kg	Na meq/kg	SAR
0.30	4088	2184	400	204.4	182.00	17.39	1.26
0.60	3848	1941	140	192.4	161.75	6.09	0.46
0.90	4409	1892	260	220.45	157.67	11.30	0.82
1.20	4008	1989	300	200.4	165.75	13.04	0.97
1.50	4409	1892	120	220.45	157.67	5.22	0.38
1.80	4409	2329	250	220.45	194.08	10.87	0.76
2.10	4248	2111	250	212.4	175.92	10.87	0.78

SAR test results shows that the rate of SAR is less than 2. According to section 2.3.6, Sodium Absorption Rate (SAR), Chapter 2, Table 2-2, $SAR < 13$, which means that the soil physical condition is normal. Accordingly SAR will not affect the infiltration rate. Figure 5-8 showing the variation of SAR with depth.

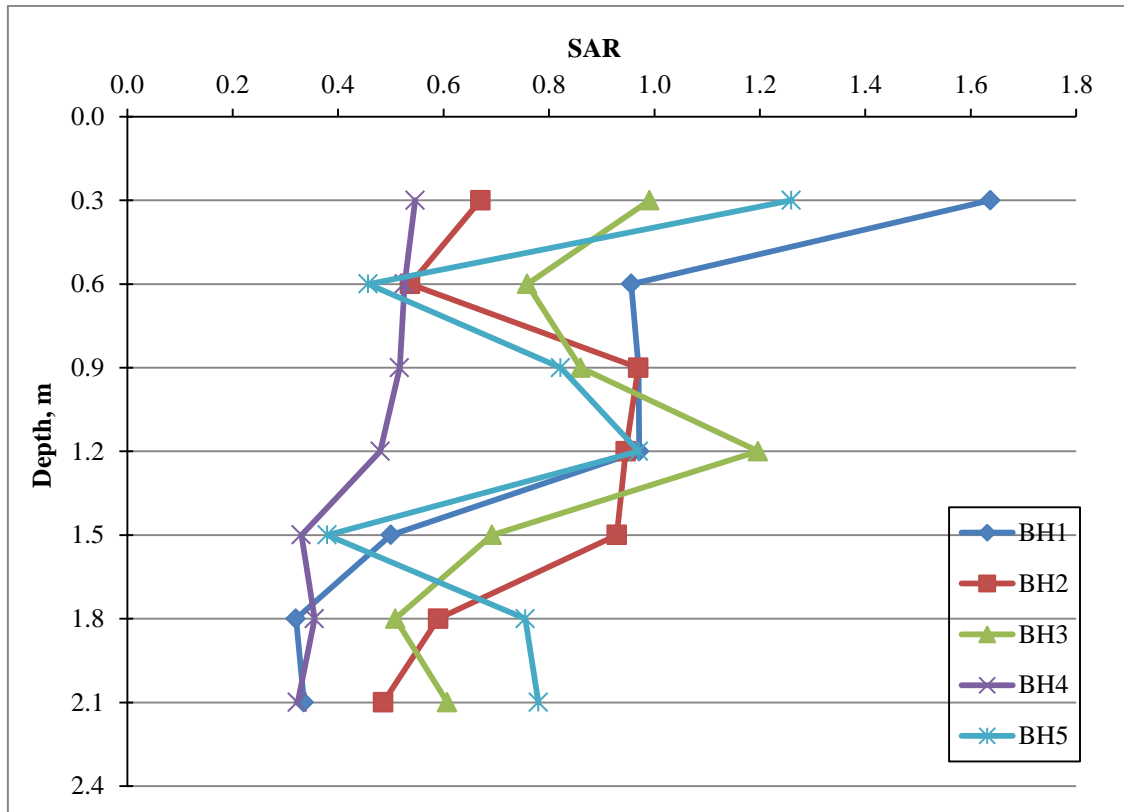


Figure (5-8): Organic Matter Test Results for Bore Holes (1-5)

5.1.5 Results of Water Quality Tests

The historical records of water quality results for the influent to the infiltration basin (Grab samples) for the first round are shown in Table 5-13. Infiltration basin IB4 was empty during the period of collecting samples which began on 30.06.2013 and finished on 24.07.2013. The PH, Temperature, and Hardness were not tested during the first round period.

With comparing contaminant strength among different infiltration basins, the extreme difference of BOD and COD (there are no limits for the COD in the design criteria) concentration values refer to the accumulation of pollutants at the basins which mean that the samples are not representative (wrong sampling), also it may refer to the poor performance of BLWWTP. According to the design criteria done by SWECO international, 2003, the BOD concentration is still out of range (10-20mg/l), and accordingly; the BOD and COD (150mg/l according to the Palestinian Standards for Treated Wastewater) concentration are not suitable for the infiltration purposes.

Figure 5-9 illustrate the variation of BOD, and COD concentration in the influent to the basins.

Table 5-13: Water Quality Tests Results (PWA, 1st Round Report, 2013)

Location	BOD(mg/l)	COD(mg/l)	TSS(mg/l)	TC(n/100ml)
IB1	100	320	78	120
IB2	480	2000	295	1500
IB3	480	2200	145	5
IB4	-	-	-	-
IB5	120	270	255	1900
IB6	310	720	180	5x10 ⁴
IB7	270	540	22	10x10 ⁴
IB8	370	770	170	10x10 ⁴
IB9	200	400	250	45

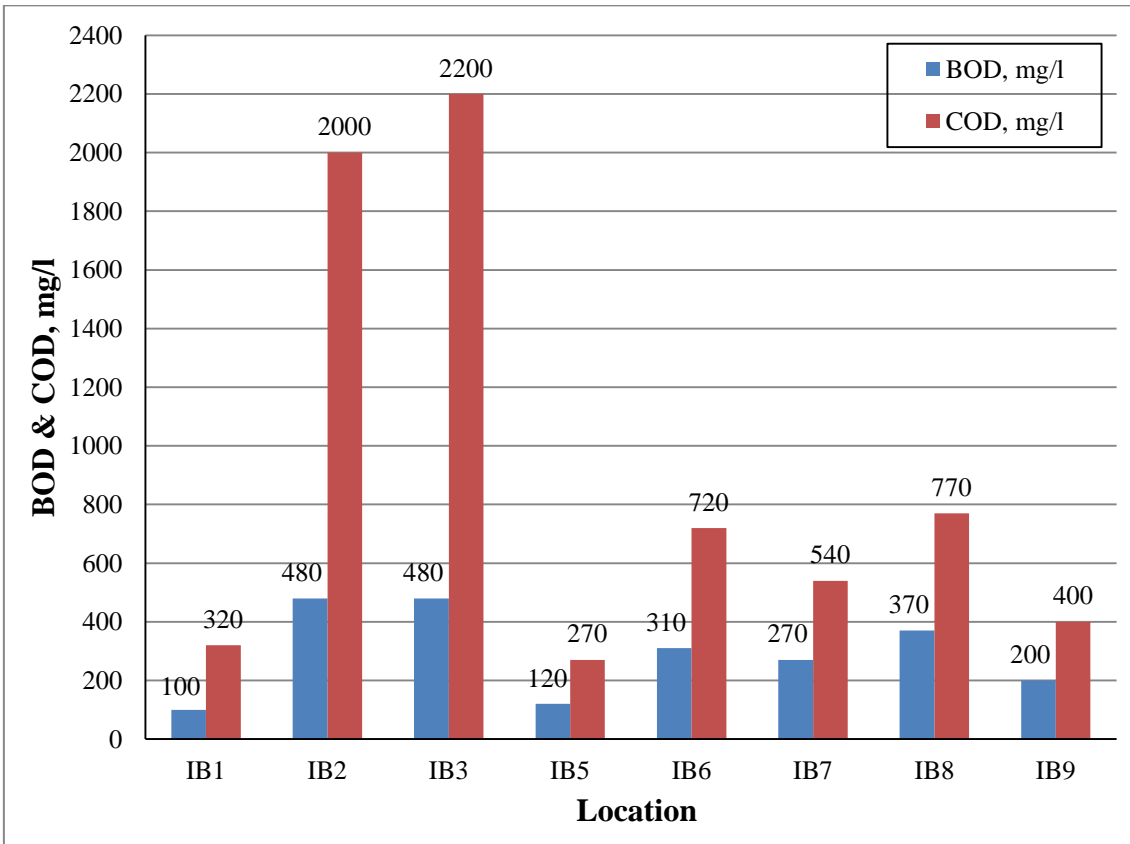


Figure (5-9): Concentration of BOD and COD in the influent to the Basins

As per design criteria the suspended solids ranged 15-20 mg/l (SWECO,2003). The TSS concentration for the basins ranged from 22 at IB7 to 295 mg/l at IB2. The high concentration of TSS may refer to wrong sampling, and to the poor performance of BLWWTP. The TSS concentration still out of the design criteria. Accordingly, the TSS concentration is not suitable for the infiltration process. Figure 5-10 shows the concentration of TSS in the influent to the infiltration basins. Historical utilization of infiltration basins for partially treated effluent with high TSS might have been the reason for diminishing the infiltration capacity of the top soil layer of the basin.

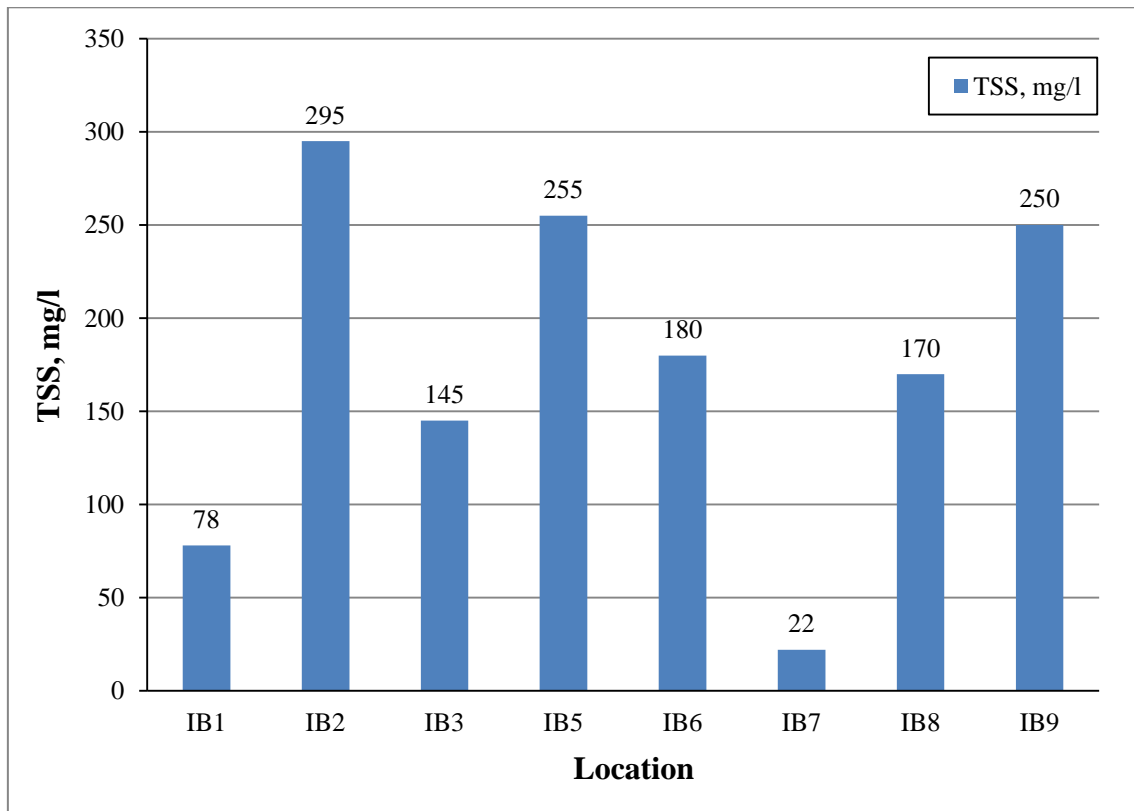


Figure (5-10): Concentration of TSS in the influent to the Basins

The concentration of FC ranged from 0 (No/100 ml) to 1700 (No/100 ml) According to the design criteria the Fecal coliform (FC) should be < 200 No/100 ml (SWECO, 2003). As the treated wastewater will infiltrate to the aquifer; the concentration of FC should be less than the design criteria in all the basins. TC ranged concentration ranged from 5 (No/100 ml) to 100,000 (No/100 ml) and the values still high even though there are some values still less than the FC value as per design criteria. The variation of FC and TC concentration at the basins is refer to different influent batches from BLWWTP, and to the poor treatment efficiency also it may refer to wrong sampling. In

general the values of FC and TC are not good for the infiltration purposes according to the design criteria and to the Palestinian standard (100-1000 No/100 ml). Figure 5-11 and 5-12 showing the values of FC, and TC at the basins.

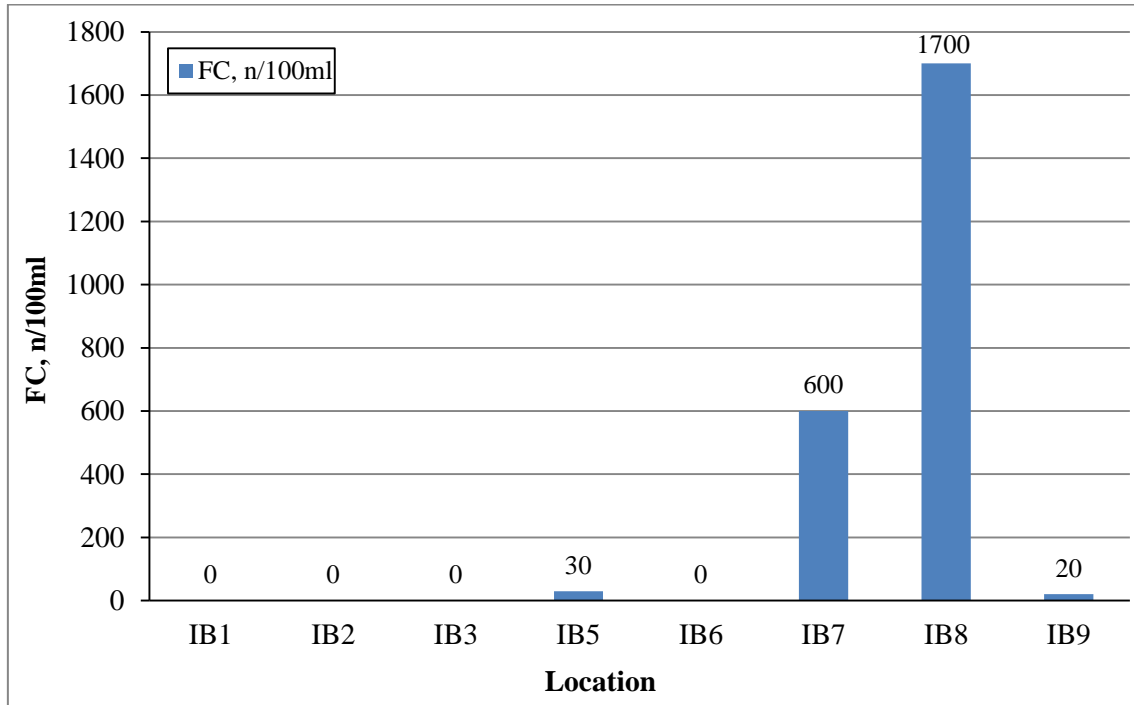


Figure (5-11): Concentration of FC in the Influent to the Basins

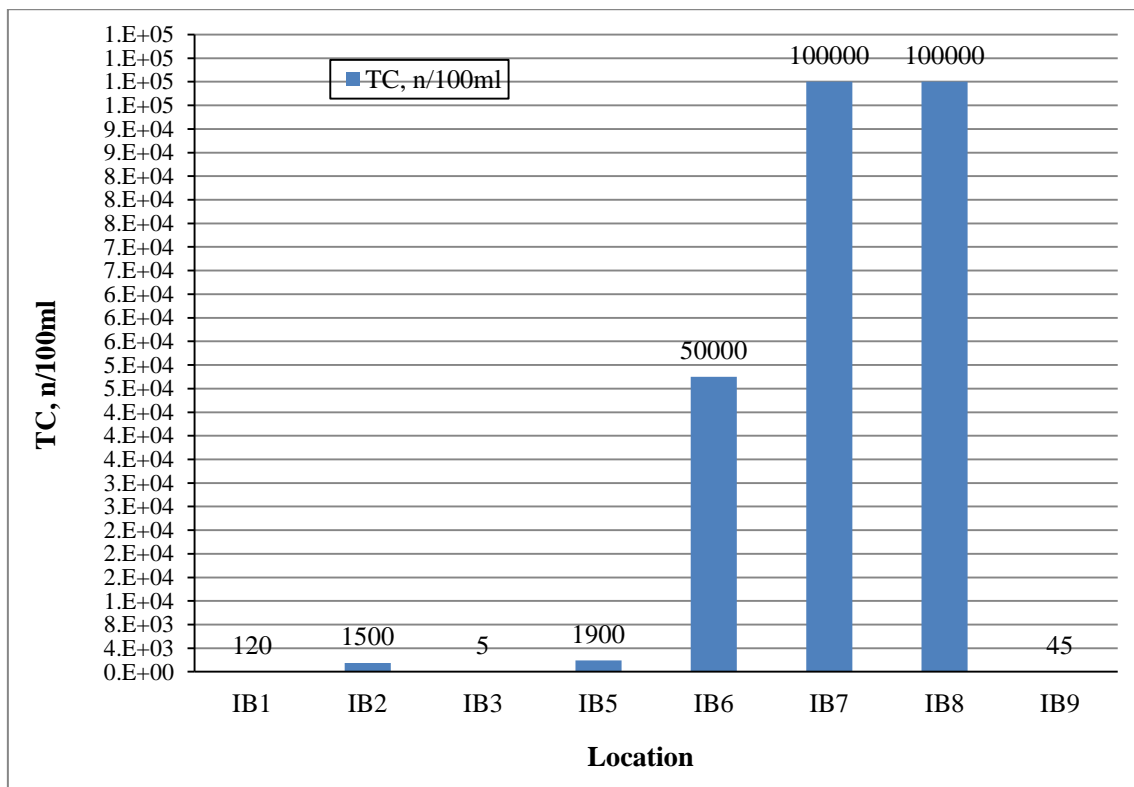


Figure (5-12): Concentration of TC in the Influent to the Basins

Table 5-14 shows comparison between the influent quality to the IB1, the design criteria, and the Palestinina Sandrd (PS) for treated wastewater. Figure 5-13 to Figure 5-15 illustrating the influent quality with referenece to the design criteria and PS.

Table 5-14: Influent Quality with referenc to Desing criteria and PS

Description	BOD(mg/l)	COD(mg/l)	TSS(mg/l)	FC (No/100ml)
IB1	100	320	78	0
Design Criteria	10-20	-	15-20	< 200
PS	40	150	50	1000

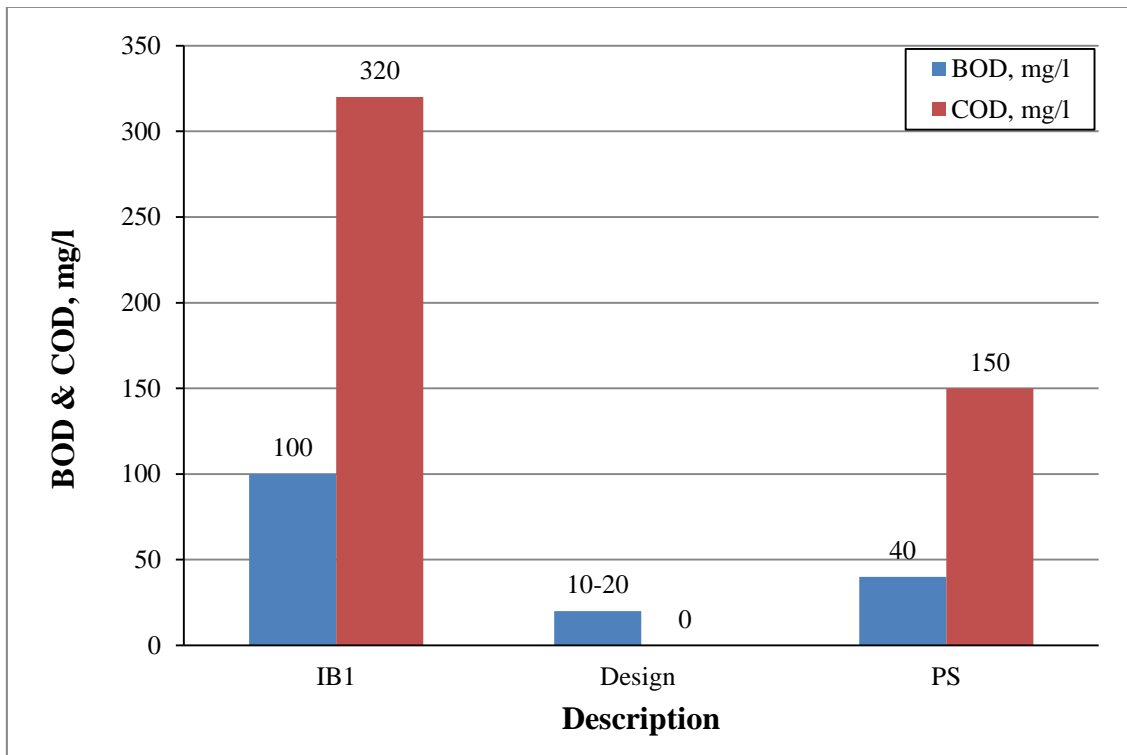


Figure (5-13): BOD & COD concentration with reference to Design Criteria & PS

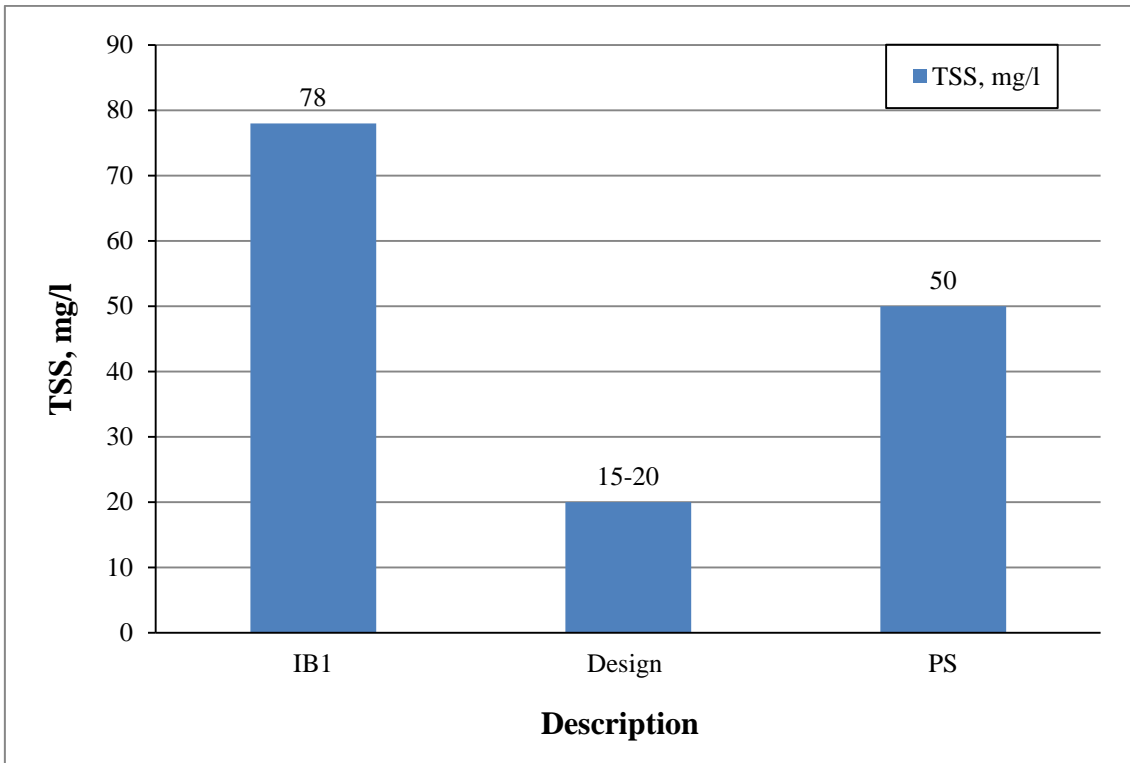


Figure (5-14): TSS concentration with reference to Design Criteria & PS

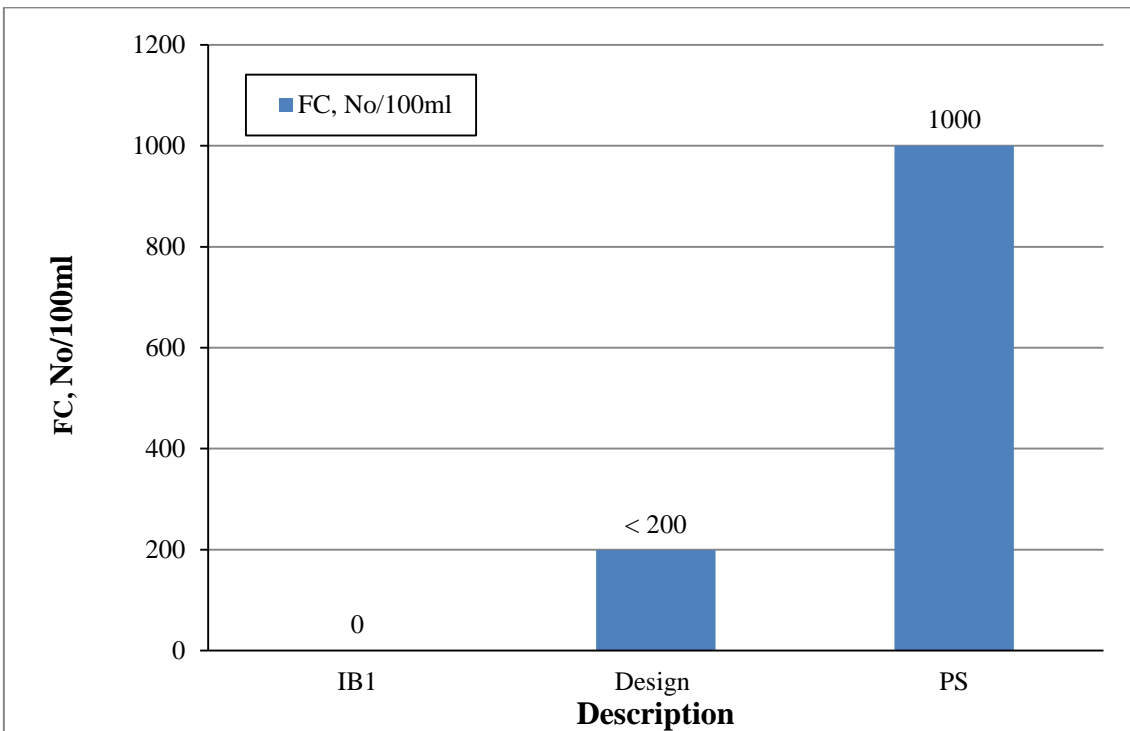


Figure (5-15): FC concentration with reference to Design Criteria & PS

5.2 Modeling of the Unsaturated Zone

5.2.1 Introduction

This chapter represents the modeling of the unsaturated zone for the existing infiltration regime, and modeling for enhancement of the infiltration rate for IB1 by using the Green-Ampt infiltration model (1911). The Green-Ampt model is a more physical approach to computing infiltration losses. It is derived from physical parameters such as hydraulic conductivity, soil moisture, and capillary suction. Because of its simplicity and versatility, the Green-Ampt model is becoming more frequently used in models for determining infiltration (**Smemo, et al., 2003**). The Green-Ampt infiltration model developed from an approximate theory to an exact solution (**Maidment, 2010**).

As explained previously in Chapter 2, section 2.5 the Green- Ampt infiltration equations for cumulative infiltration (equation 2.4), and for infiltration rate (equation 2.5) are:

$$F(t) = Kt + \psi\Delta\theta \ln\left(1 + \frac{F(t)}{\psi\Delta\theta}\right), \text{ cm.}$$

$$f = K\left(1 + \psi \frac{\Delta\theta}{F}\right), \text{ cm/hr.}$$

The modeling domain for the unsaturated zone for the existing infiltration regime, and the modeling domain for enhancement of the infiltration rate for IB1 will be performed for the upper two meters for the soil layer. The soil parameters used in computing the cumulative infiltration and the infiltration rate were taken from the laboratory soil tests results as discussed previously in this Chapter, and from Table (2-3): Green-Ampt infiltration parameters for various soil classes.

Since cumulative infiltration is non-linear equation, which requiring iterative solution to solve it; Excel Solver was used to solve the equation. More details are clear in appendix (3).

5.2.2 Modeling the existing Infiltration Regime for IB1

Many trials was performed using different hydraulic conductivities and different soil parameters to calculate the cumulative infiltration and the infiltration rate for the existing infiltration regime in order to predict the model which describes the real infiltration rate recorded by PWA. Table 5-15 and Table 5-16 showing the behavior of cumulative infiltration and infiltration rate with time for the first and second trials. Figure 5-16, Figure 5-17 and Figure 5-18 are the representation for the infiltration with time for the same trials.

5.2.2.1 First Model with Minimum K (0.042cm/hr) in IB1

Table 5-15: $F(t)$ & f at $K=0.042\text{cm/hr}$

t (hr)	F (cm)	f (cm/hr)	f (m/d)
0.0	0	∞	∞
0.1	0.203	1.073	0.258
0.2	0.289	0.767	0.184
0.3	0.371	0.608	0.146
0.4	0.425	0.535	0.128
0.5	0.474	0.484	0.116
1	0.679	0.351	0.084
1.1	0.712	0.337	0.081
1.2	0.743	0.324	0.078
1.3	0.774	0.313	0.075
1.4	0.803	0.303	0.073
1.5	0.839	0.292	0.070
2	0.970	0.258	0.062
2.5	1.094	0.233	0.056
3	1.207	0.216	0.052
3.5	1.312	0.202	0.048
4	1.411	0.190	0.046
4.5	1.504	0.181	0.043
5	1.589	0.174	0.042
6	1.758	0.161	0.039

t (hr)	F (cm)	f (cm/hr)	f (m/d)
8	2.060	0.144	0.034
10	2.336	0.131	0.032
12	2.589	0.123	0.029
16	3.054	0.110	0.026
20	3.476	0.102	0.024
24	3.872	0.096	0.023

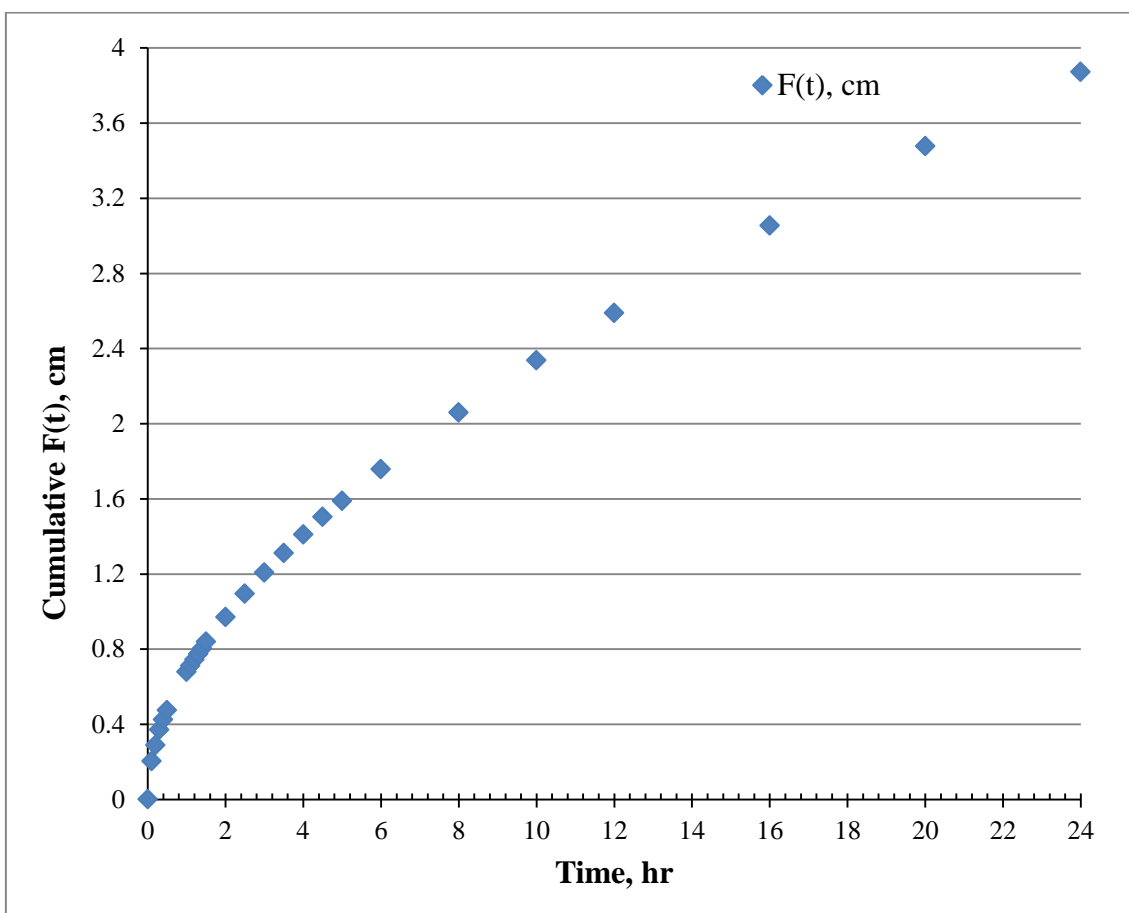


Figure (5-16): Cumulative infiltration with time, 1st Model

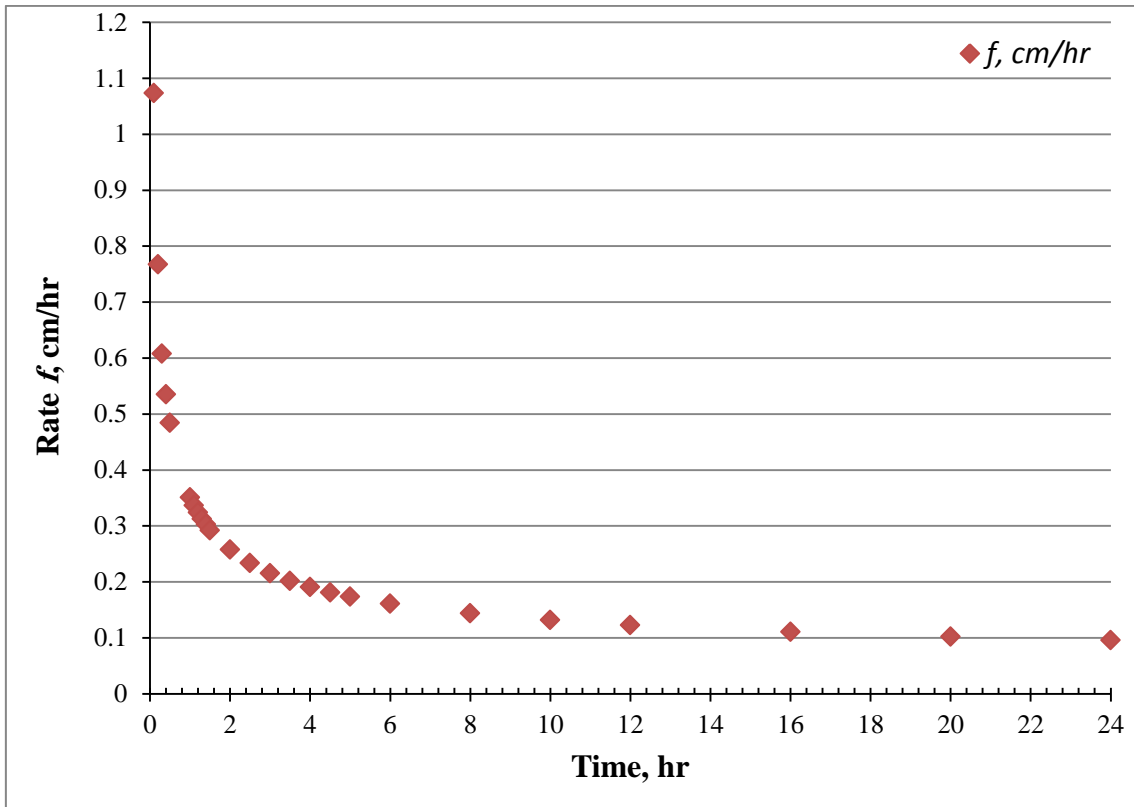


Figure (5-17): Infiltration Rate with Time, 1st Model

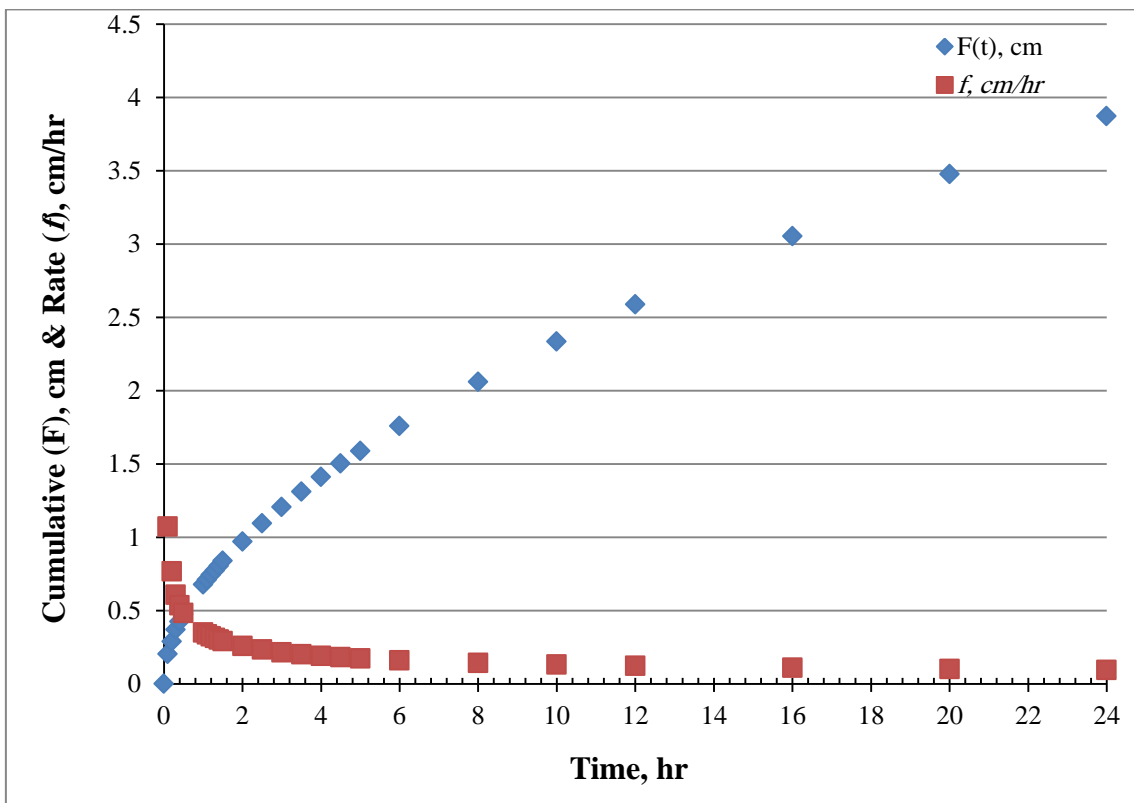


Figure (5-18): Cumulative Infiltration, and Rate with Time, 1st Model

5.2.2.2 Second Model with Maximum K (37.458cm/hr) in IB1

Table 5-16: F (t) & f at K= 37.458cm/hr

<i>t (hr)</i>	F (cm)	<i>f (cm/hr)</i>	<i>f (m/d)</i>
0.0	0	∞	∞
0.1	6.428	47.531	11.408
0.2	10.934	43.380	10.411
0.3	15.180	41.724	10.014
0.4	19.302	40.813	9.795
0.5	22.869	40.290	9.670
1	43.085	38.961	9.351
1.1	46.975	38.837	9.321
1.2	50.853	38.732	9.296
1.3	54.722	38.642	9.274
1.4	58.582	38.564	9.255
1.5	62.435	38.495	9.239
2	81.616	38.252	9.180
2.5	100.702	38.101	9.144
3	119.725	37.999	9.120
3.5	138.705	37.925	9.102
4	157.653	37.869	9.089
4.5	176.577	37.825	9.078
5	195.480	37.790	9.069
6	233.241	37.736	9.057
8	308.639	37.668	9.040
10	383.930	37.627	9.030
12	459.155	37.599	9.024
16	609.476	37.565	9.015
20	759.690	37.544	9.010
24	909.834	37.529	9.007

Figure 5-19, Figure 5-20, and Figure 5-21 are the representation for the infiltration with time for the same trials.

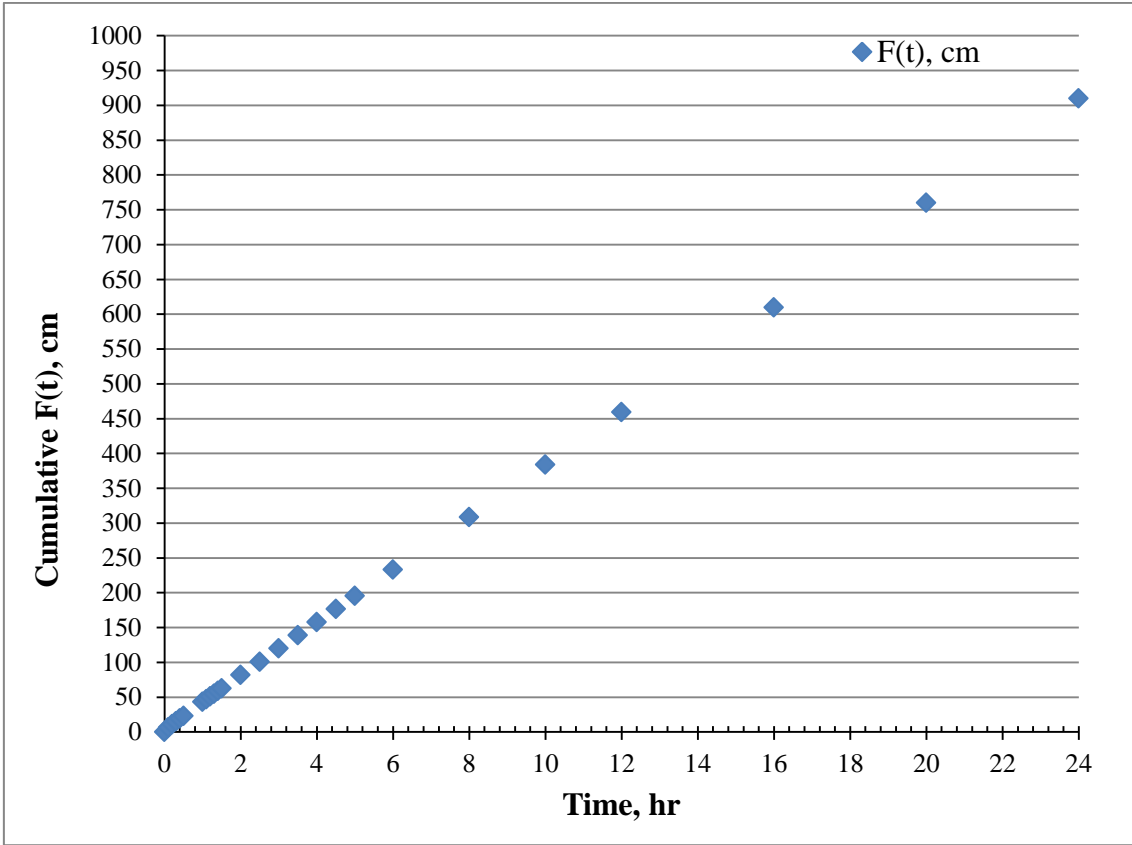


Figure (5-19): Cumulative infiltration with Time, 2nd Model

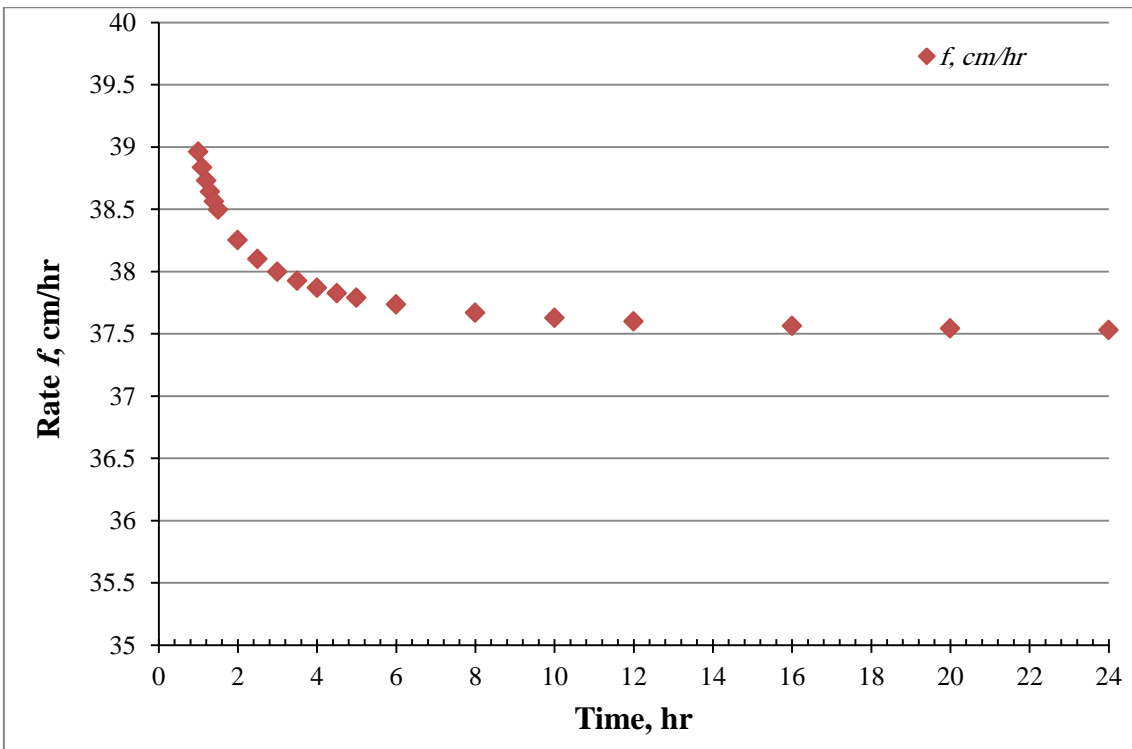


Figure (5-20): Infiltration Rate with Time, 2nd Model

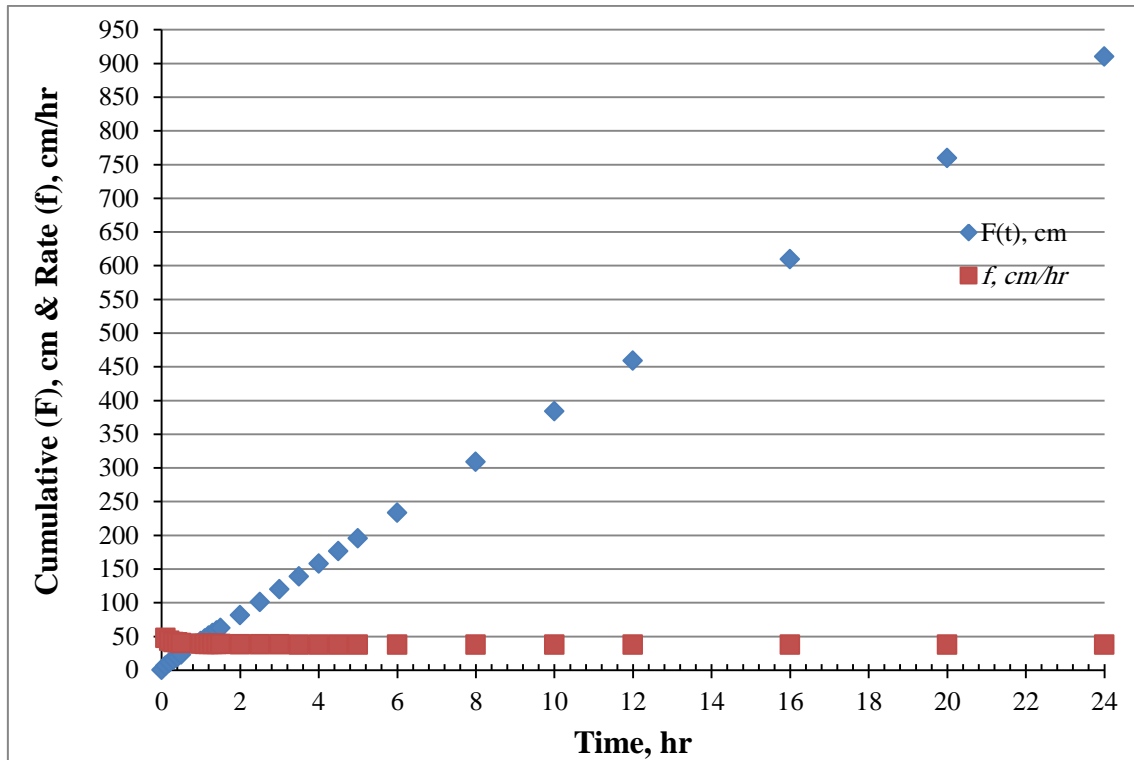


Figure (5-21): Cumulative Infiltration, and Rate with Time, 2nd Model

None of the first or the second model matched the real behavior of infiltration regime for IB1. So the trials continuing with different K's (11.167 cm/hr, 8.042 cm/hr, 1.083 cm/hr, and finally 0.833 cm/hr), and different soil parameters. It was found that the real model for infiltration can achieved when K (0.833 cm/hr), and rate (0.98 cm/hr), and this model approximately representing the data recorded by PWA especially for the year 2013 (rate, 0.96 cm/hr equal to 0.23 m/d) as obvious in Figure 3-7, Chapter 3.

Tables 5-17 shows the results taken from the model which representing the real infiltration regime for IB1, also Figures 5-22, 5-23, and 5-24 representing the real cumulative infiltration and infiltration rate for the same basin from the same model.

Figure 5-25 illustrating the modeled and measured infiltration values for IB. The measured values is approximately closed to the data obtained by the model and with very high correlation coefficient R^2 equal to (0.9951), which is considered as an excellent value. It can be concluded that the model is representing the real infiltration rate for the basin. Figure 5-26 shows the summary for infiltration rate with time for different soil parameters.

Table 5-17: F (t) & f at K= 0.833cm/hr

<i>t (hr)</i>	F (cm)	<i>f (cm/hr)</i>	<i>f (m/d)</i>
0.0	0	∞	∞
0.1	0.995	5.280	1.2672
0.2	1.445	3.895	0.9347
0.3	1.800	3.291	0.7899
0.4	2.109	2.931	0.7035
0.5	2.391	2.684	0.6441
1	3.553	2.078	0.4988
1.1	3.759	2.010	0.4824
1.2	3.957	1.951	0.4684
1.3	4.148	1.900	0.4559
1.4	4.337	1.853	0.4448
1.5	4.520	1.812	0.4349
2	5.384	1.655	0.3972
2.5	6.183	1.549	0.3717
3	6.937	1.471	0.3530
3.5	7.658	1.411	0.3386
4	8.350	1.363	0.3272
4.5	9.022	1.324	0.3177
5	9.676	1.291	0.3097
6	10.938	1.238	0.2971
8	13.336	1.165	0.2796
10	15.614	1.117	0.2680
12	17.811	1.082	0.2596
16	22.035	1.034	0.2482
20	26.105	1.003	0.2407
24	30.069	0.980	0.2353

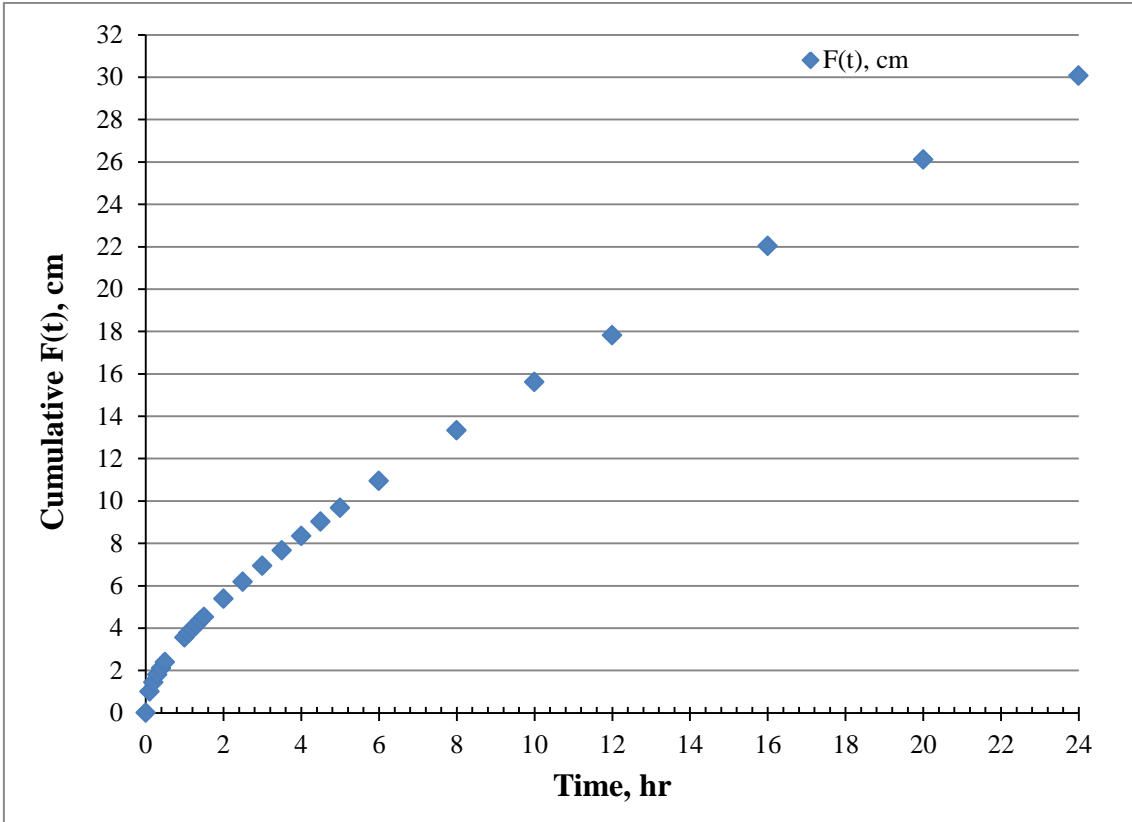


Figure (5-22): Cumulative Infiltration, and Rate with Time, the Real Model

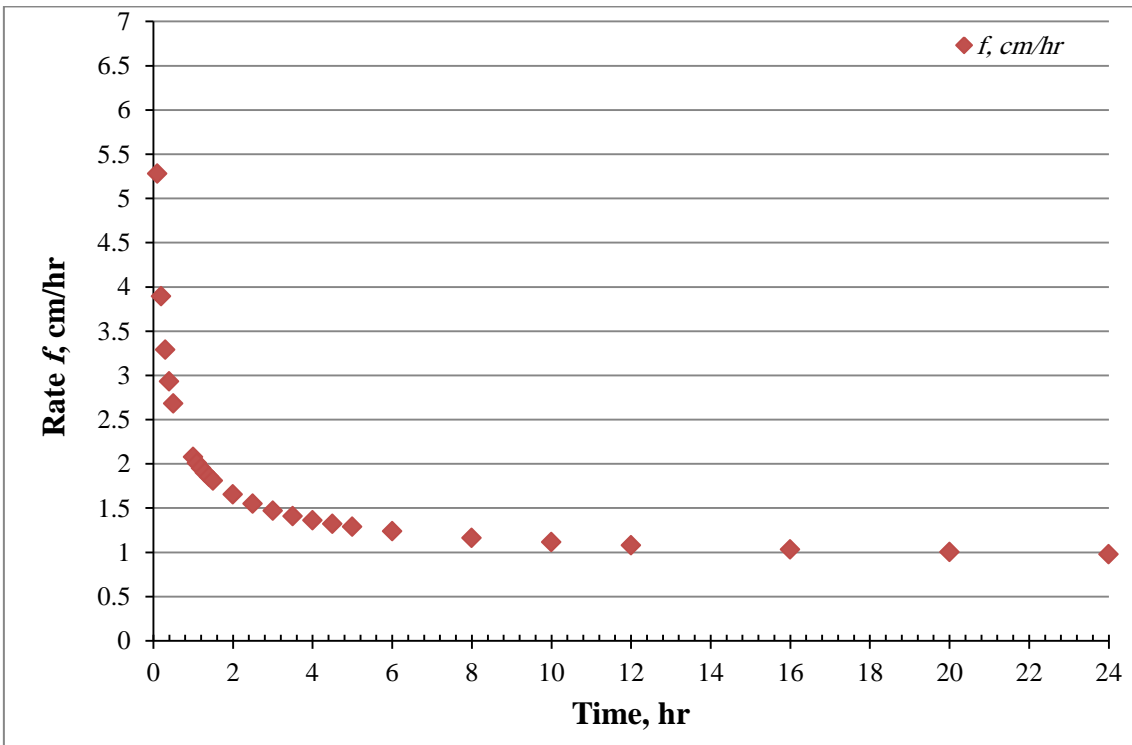


Figure (5-23): Infiltration Rate with Time, the Real Model

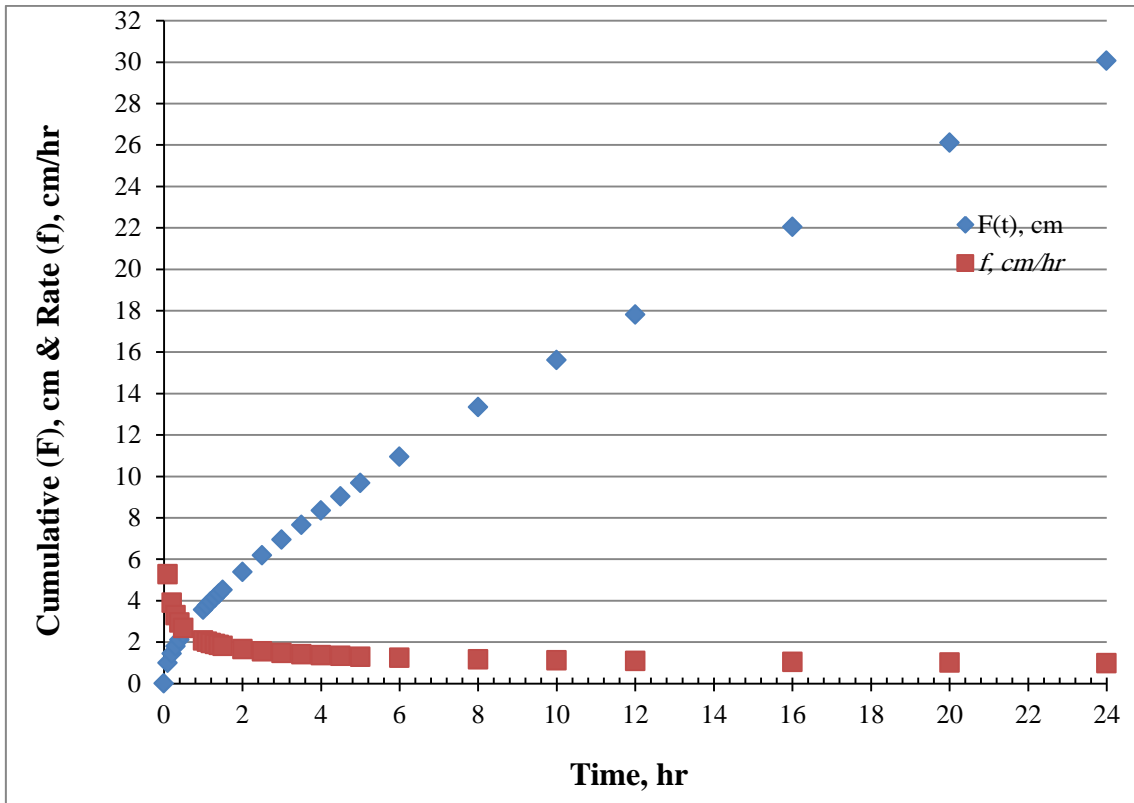


Figure (5-24): Cumulative Infiltration, and Rate with Time, the Real Model

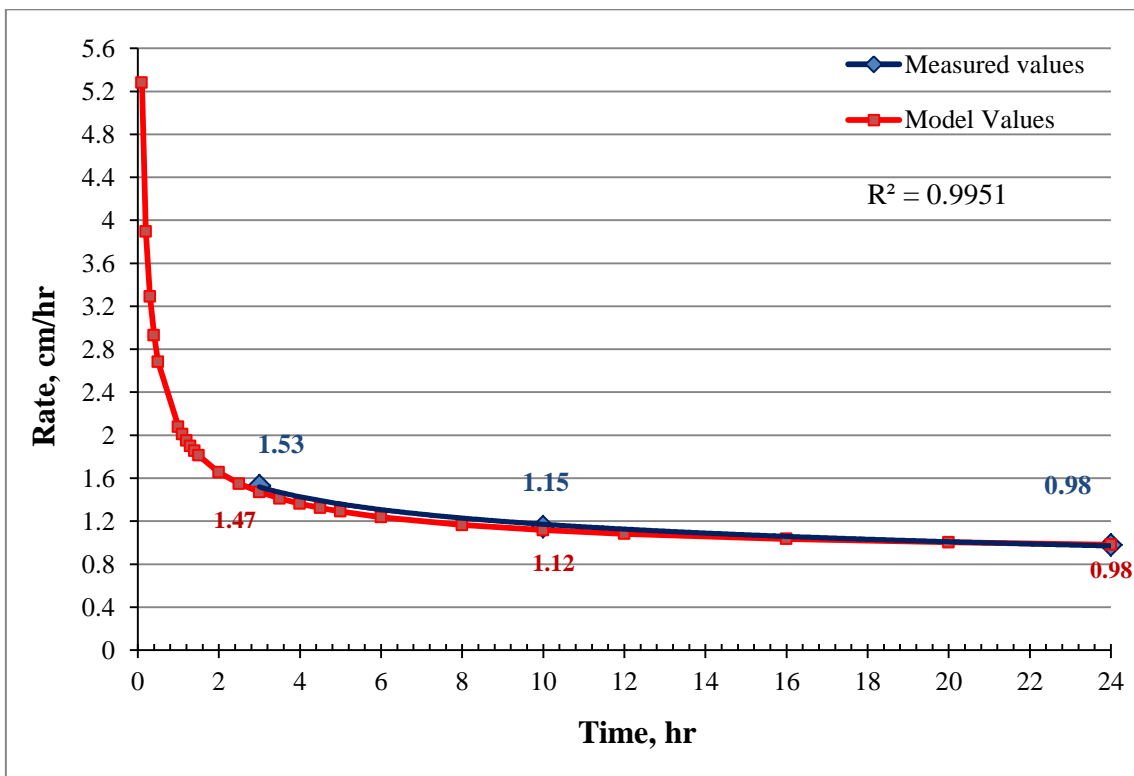


Figure (5-25): Measured and Model Values for Infiltration Rate at IB1

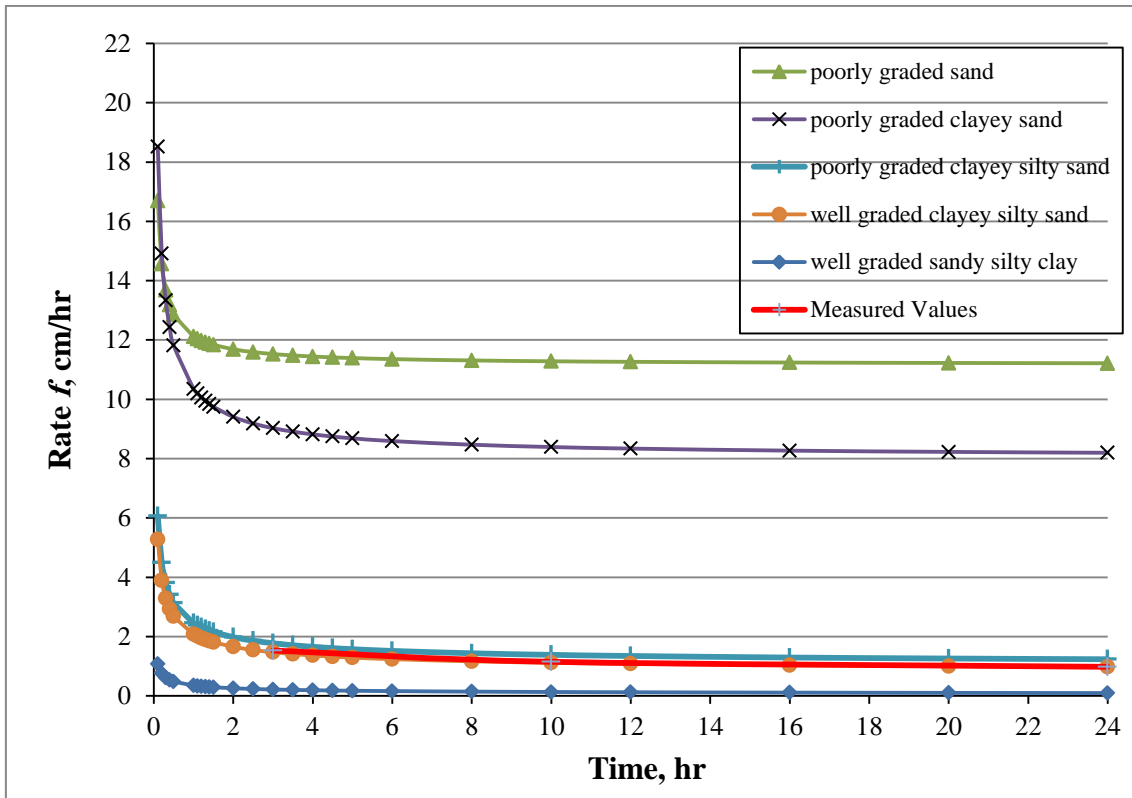


Figure (5-26): Infiltration Rate with Time, for different Soil Parameters.

5.2.3 Enhancement the Infiltration Rate for IB1

5.2.3.1 Enhancement the Upper Soil Layer

According to the geological cross section for the soil (Figures 5-1, and 5-2, Chapter 5), a clayey sand Ia layer, which is a poorly graded clayey sand, slightly light brown with little gravel (Kurkar) exist at variable depths. The layer is of low to medium plasticity, and contains (3.0-10.0)% gravel, (60-85)% sand, and (15-40)% fines, and this layer is of low permeability. The clayey sand layer is spreading widely at the first two meters in the basin. The effect of the clayey sand layer on the infiltration rate was obvious during modeling the existing infiltration regime, as discussed previously. In order to enhance the infiltration rate; this layer should be completely removed and should be replaced by a new sand layer with high permeability.

Todd and Mays, 2005 mentioned that the sand can give permeability of 11.78cm/hr (2.827m/d) as stated in Table 2-3, Chapter 2, Green-Ampt infiltration parameters for various soil classes. A model for describing the infiltration for the proposed sand layer

was performed. The output of the model is shown in Table 5-18, and Figures 5-27, 5-28, and 5-29.

Table 5-18: $F(t)$ & f at $K= 11.78\text{cm/hr}$ for the Proposed Sand Layer

t (hr)	F (cm)	f (cm/hr)	f (m/d)
0.0	0	∞	∞
0.1	3.085	19.909	4.778
0.2	4.898	16.899	4.056
0.3	6.517	15.627	3.751
0.4	8.041	14.898	3.576
0.5	9.505	14.418	3.460
1	16.384	13.310	3.194
1.1	17.709	13.196	3.167
1.2	19.024	13.098	3.144
1.3	20.329	13.013	3.123
1.4	21.627	12.939	3.105
1.5	22.917	12.874	3.090
2	29.290	12.636	3.033
2.5	35.568	12.485	2.996
3	41.782	12.380	2.971
3.5	47.952	12.303	2.953
4	54.088	12.244	2.938
4.5	60.198	12.197	2.927
5	66.286	12.158	2.918
6	78.414	12.100	2.904
8	102.531	12.025	2.886
10	126.531	11.978	2.875
12	150.454	11.947	2.867
16	198.153	11.907	2.858
20	245.726	11.882	2.852
24	293.219	11.866	2.848

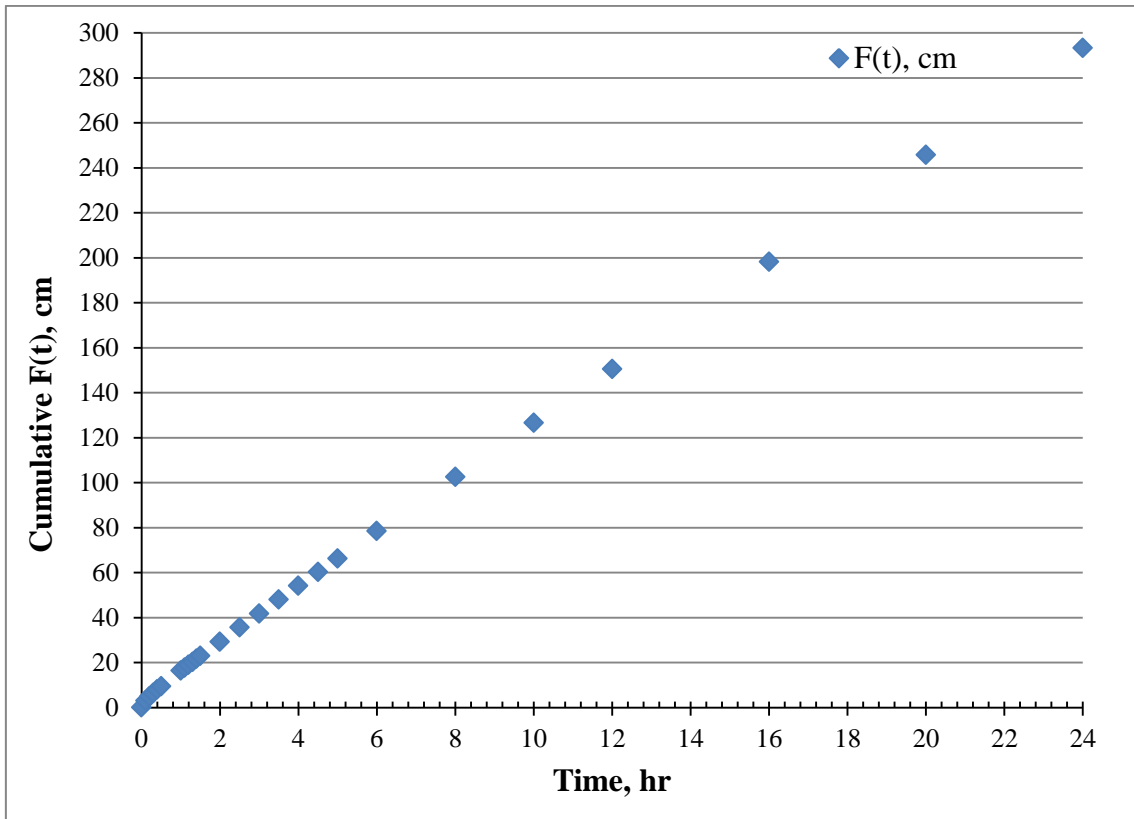


Figure (5-27): Cumulative Infiltration with Time for the Proposed Sand Layer

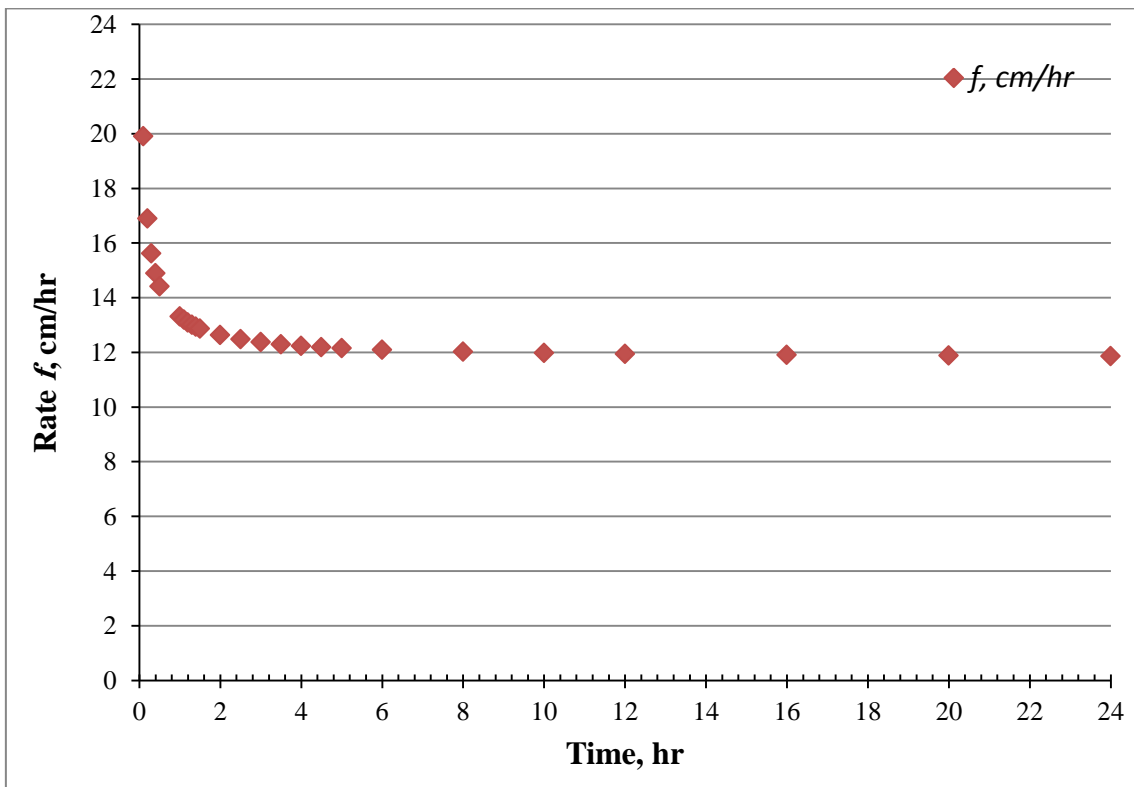


Figure (5-28): Infiltration Rate with Time for the Proposed Sand Layer

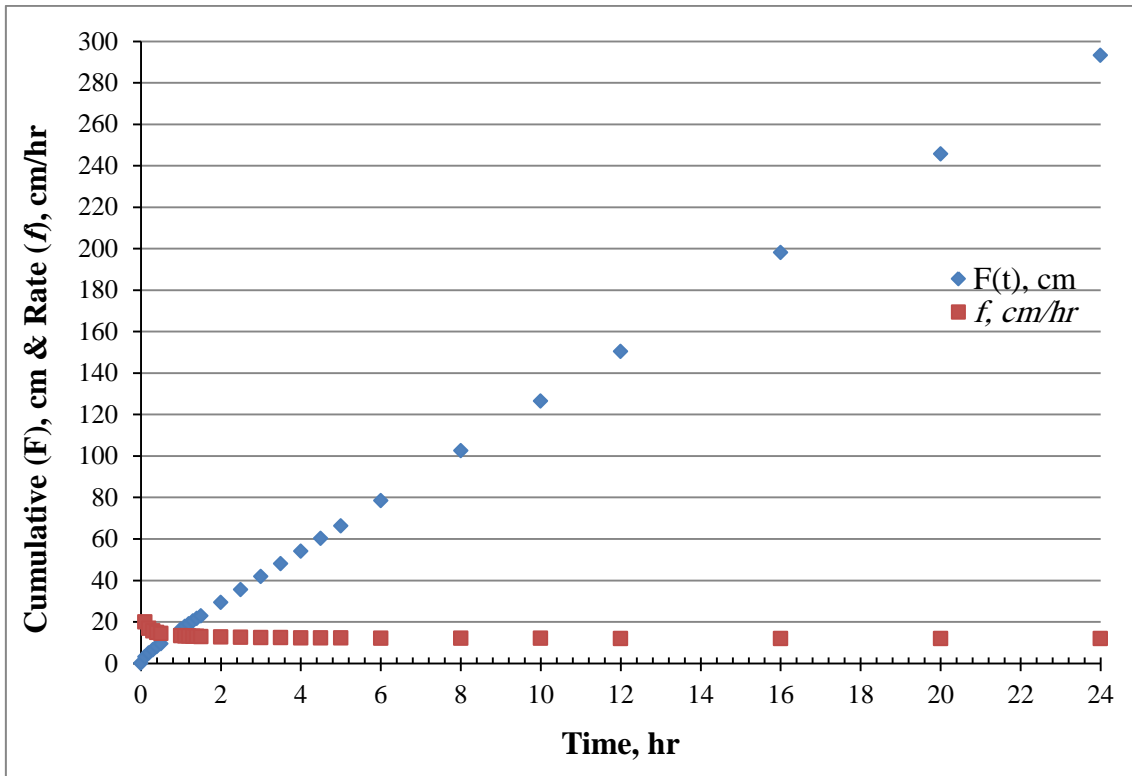


Figure (5-29): Cumulative Infiltration, & Rate with Time for the Proposed Sand Layer

The output of the model illustrating that the infiltration rate will reach 11.866 cm/hr (2.848 m/d) after 24 hours with cumulative infiltration of 293.219 cm, which is approximately closed to the permeability (11.78 cm/hr) stated by (Todd and Mays, 2005).

5.2.3.2 Enhancement the Lower Soil Layers

According to the geological cross section for the soil; a layer of sandy silt clay is exists at depth ranged from 6.40 m to a depth of 7.50 m (0.90 m thick) at the middle of IB1, and the layer appeared only on BH3. This layer is dark brown sandy clay with little gravel (Kurkar), and the layer is of medium plasticity, and of low permeability. The layer contains Fine gravel (3.0)%, sand (41.50)%, silt (39.45)%, and finally clay (16.10)%. The effect of this layer was clear on the infiltration rate during modeling the infiltration, because this layer has the minimum hydraulic conductivity (0.042 cm/hr). Another soil layer was found at depth ranged from 8.0 m to a depth of 9.0 m (1.0 m thick) at BH2, and BH5 only, this layer is same as in the first two meters.

In order to enhance the infiltration rate, a group of piles should be performed and penetrate the soil layers with a depth at least of 14 m , these piles should contain a

media with high permeability. The piles can be implemented after the removal of the first two meters immediately. The numbers of piles and the diameter for each pile, will be designed in the following section.

5.2.3.2.1 Design of the Piles

As illustrated in Chapter 3, Table 3-2, Infiltration area after construction, the area of IB1 is 12,328 m². According to the design criteria, the infiltration basins designed to receive 35,600m³/day of treated wastewater. The amount of treated wastewater will be distributed to three ponds according to the area of each basin. IB1 will take 14,455 m³/d. the rate for IB1 will equal to (14,455 m³/d)/(12,328 m²) = 1.20 m/d.

According to Table 2-4, Some Representative Hydraulic Conductivity for Different Soil Types, the Gravel fine can give hydraulic conductivity of 450 m/d (Todd and Mays, 2005). The total area of the piles will be: (14,455 m³/d)/(450 m/d) = 32 m². A pile diameter of 60cm will be used with surface area of 0.28m², thus lead to number of piles = 32 m²/0.28 m² = 114 pile.

Sichardt equation will be used as stated previously in Chapter 2, section 2.6 in order to calculate the velocity of the aquifer.

K for the aquifer will be equal to 7.20 m/d (0.0001 m/s), which is the average K for layers at depth 11.0 m, and 12.0 m, (Table 5-6, Estimated hydraulic conductivity K for the testing soil samples).

$$V_a < \frac{\sqrt{0.0001}}{30}, V_a < 0.0003 \text{ m/s, take } V_a = 0.00025 \text{ m/s.}$$

The flow inside the pile $Q = 2\pi RLV \text{ m}^3/\text{s}$, where:

R: is the radius of the pile, m

L: is the length of pile below the clay sad layer (6.0 m), and

V: is the approach velocity, m/s.

$$Q = 2 * \pi * 0.3m * 6m * 0.00025 \text{ m/s} = 0.003 \text{ m}^3/\text{s} (244 \text{ m}^3/\text{d}).$$

As the pile will drainage $244 \text{ m}^3/\text{d}$, the number of piles (114 pile) can be reduced as following:

$(14,455 \text{ m}^3/\text{d})/(244 \text{ m}^3/\text{d}) = 60$ pile, these piles will distributed at the middle area of the basin, because the worst permeability ($0.01\text{m}/\text{d}$) was found at BH3 at depth 7.0m.

The piles will distributed at area of $90 \times 50 \text{ m}^2$ from the middle of the basin, with $10 \times 10\text{m}$ grid between piles center to center as shown in Figure 5-30. In order to maintain good drainage for the infiltrated water, it is preferred to use closed UPVC 22" in diameter with total length of 9.0 m in order to prevent clogging of the gravel media due to entrance of the fine particles from the surrounding soil (clayey sand at depth 8-9 m, and sandy silty clay at depth 6.5-7.40 m), also perforated UPVC pipe 22" diameter with total length of 5.0 m below the 9.0 m pipe in order to maintain good infiltrated water to the lower strata as shown in Figure 5-31. The gravel media is designed on the basis of sieve analysis of aquifer sample. If aquifer samples from different depths show considerable variation in gradation, the gravel should be based stable against the finer grade samples. Uniformity coefficient (U_c) of the aquifer is the control in this case (**Boonstra, 1999**).

$U_c = d_{60}/d_{10}$, where the effective particle size is the 10 percent finer than value (d_{10}), and d_{60} is the 60 percent finer than value. A uniform material has a low uniformity coefficient, while a well graded material has a high uniformity coefficient (**Todd and Mays, 2005**).

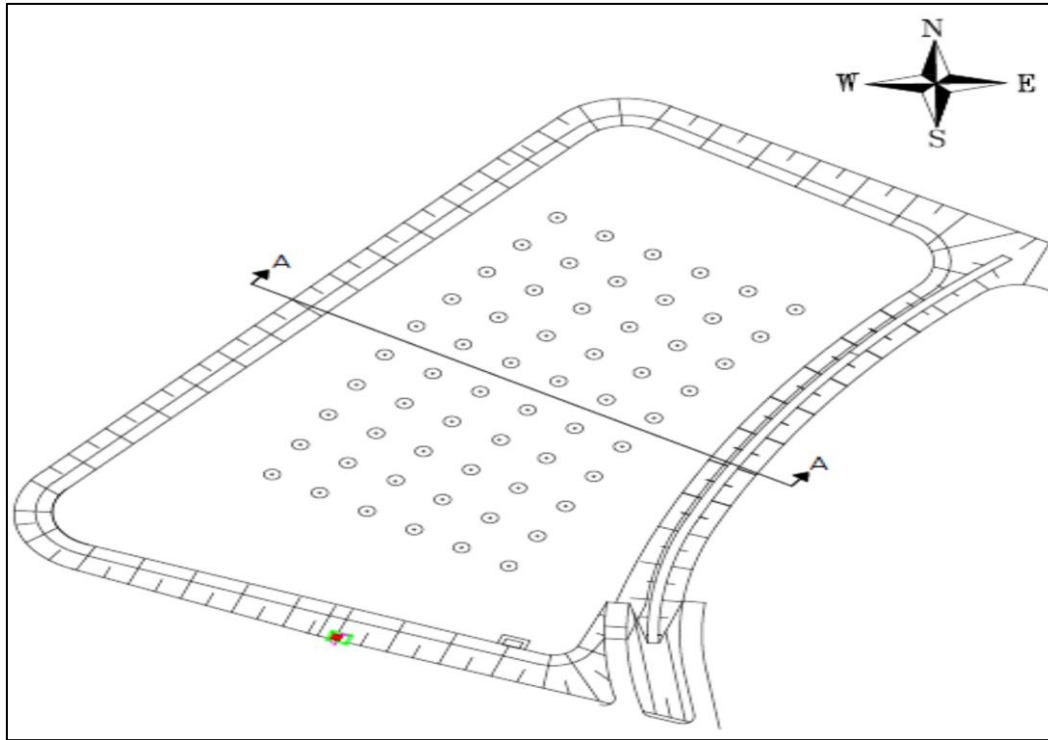


Figure (5-30): Distribution of Piles at IB1

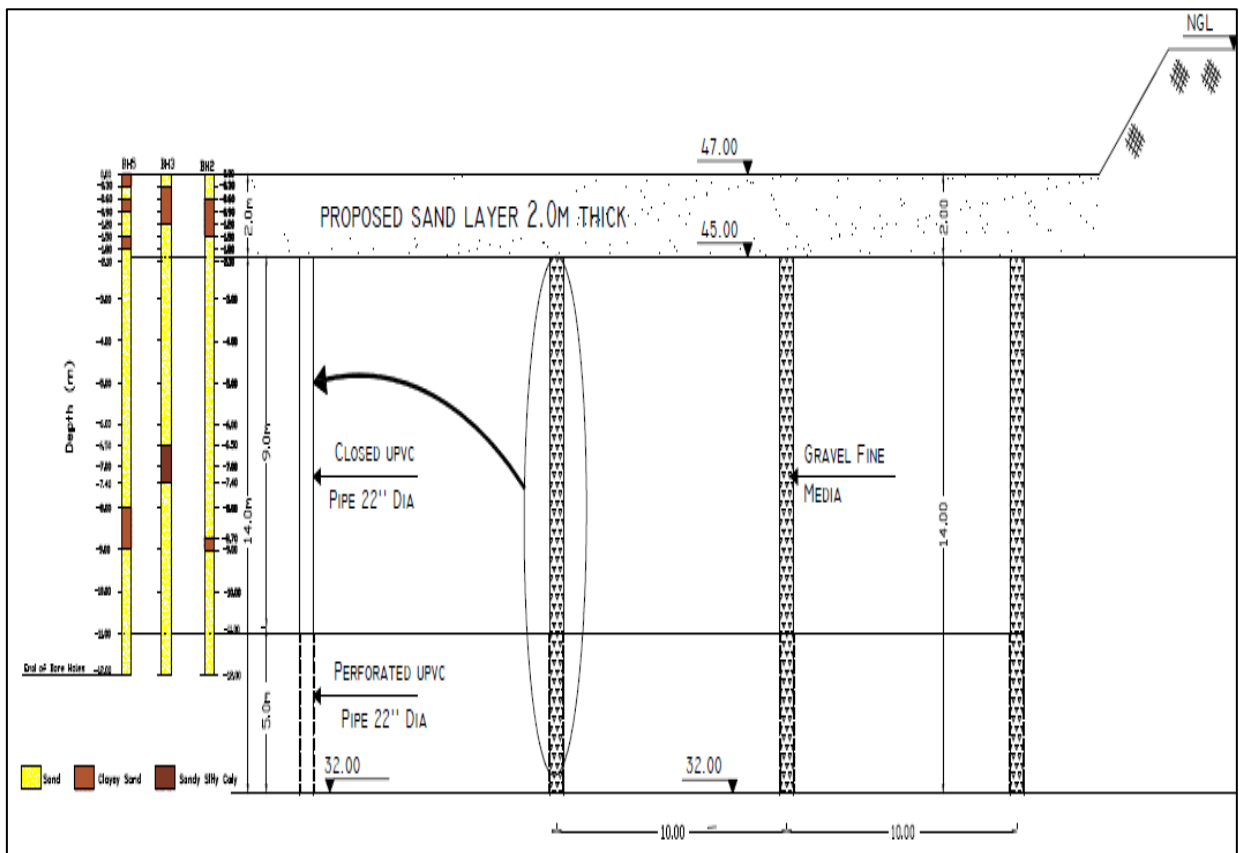


Figure (5-31): Section A-A in the Piles

5.2.3.3 Design of Wetting Drying Cycles

A regular drying period is essential for the successful performance of infiltration system. For primary effluent the ratios of loading to drying periods within a single cycle are generally less than 0.2 to allow for adequate drying, Table 5-19 presents suggested hydraulic loading/drying periods. In all cases, to avoid excessive soil clogging, the hydraulic loading period for primary effluent does not exceed 1-2 days regardless of season or treatment goals (EPA, 1981).

Table 5-19: Suggested Loading Cycles (EPA, 1981)

Loading cycle objective	Applied Wastewater	Season	Application Period D	Drying Period D
Maximize infiltration rates	Primary	Summer	1-2	5-7
		Winter	1-2	7-12
	Secondary	Summer	1-3	4-5
		Winter	1-3	5-10
Maximize nitrogen removal	Primary	Summer	1-2	10-14
		Winter	1-2	12-16
	Secondary	Summer	7-9	10-15
		Winter	9-12	12-16
Maximize nitrification	Primary	Summer	1-2	5-7
		Winter	1-2	7-12
	Secondary	Summer	1-3	4-5
		Winter	1-3	5-10

For treatment goals with primary effluent are to maximize infiltration rates:

Summer period (from April to October, 241d): Wet (2d), Dry (7d), and Total (2+7) = 9d

So, summer period each cycle equal to 9d.

Cycles per season (summer) = $214d/9d = 24$ cycles.

Winter period (from November to March, 151 d): Wet (2d), Dry (12d), and Total (2+12) =14d.

The winter period each cycle equal to 14d.

Cycle per season (winter) = $151/14 = 11$ cycles.

Total cycles per year = $24+11 = 35$ cycles.

Accordingly; 35 cycles of wetting and drying should be performed during the year in order to reach the optimal infiltration rate.

CHAPTER 6 : Conclusions and Recommendations

6.1 Conclusions

1. The results showed that the soil strata in the infiltration basin IB1 consists of Sand which is non-plastic and has good permeability characteristics, Clayey Sand: which is the wide spreading layer at the top of the basin, and of low to medium plasticity, and of low permeability, and Sandy Silty Clay which is of medium plasticity, and of low permeability. The results showed that that the infiltration rate is affected by the soil properties; sandy soils have the highest infiltration rates and clayey soils have the lowest infiltration rates.
2. The hydraulic conductivity of the soil layers ranged between 0.01m/d, and 8.99m/d with the range laid between the classification of sand medium and clayey material. Clayey material exhibit low hydraulic conductivity values, where sandy soil display high values. The effect of hydraulic conductivity was obvious on infiltration rate.
3. OM in the soil still with low values, and will not affect the infiltration rate and soil plowing is efficient procedure that can be employed to reduce OM content in the top layer and maintain high infiltration rates of TWW into the soil.
4. SAR test results shows that the rate of SAR is less than <13, which means that the soil physical condition is normal (not sodic soil) and SAR will not affect the infiltration rate.
5. BOD and COD values are still out of range with comparing with design values, and this refer to the accumulation of pollutants and to the poor performance of BLWWTP. The BOD and COD concentration are not suitable for the infiltration purposes.
6. The TSS concentration still out of the design criteria, which is not suitable for the infiltration process, and it has a direct influence in reducing the IR in IB (2-9).

7. The concentration of FC, and TC is facultative; sometimes less and sometimes high. The variation of FC, and TC concentration is referred to different influent batches from BLWWTP, and to the poor treatment efficiency. In general the value of FC and TC is not suitable for infiltration purposes based on the design criteria and the Palestinian standard for ground water recharge.
8. Different models with different soil properties were developed by using the Green-Ampt infiltration model in order to describe the existing infiltration regime for the IB1, the existing infiltration was reached, and it was compatible with the data recorded by PWA.
9. Penetrating the lower soil layers (after removing the upper 2.0 meters soil layer), with 60 piles and filling the piles with gravel fine media with high permeability, will increase the infiltration rate for hole of the basin.

6.2 Recommendations

6.2.1 Recommendations for Good Operation

1. In order to enhance the infiltration rate; the upper soil layer with thickness of 2.0m should be completely removed and it should be replaced by a new sand layer with high permeability.
2. The quality of the influent water to IB1 depends on the efficiency of BLWWTP, so increasing the performance of BLWWTP (until finishing the Northern Wastewater Treatment Plant) will reducing the concentration of TSS, and the organic load.
3. Field measurements such as temperature, pH, and turbidity for the influent water to the basins should be recoded daily to ensure good water quality for infiltration process.
4. In order to reach the optimal infiltration rate; it is recommended to perform 35 cycles of wetting and drying with 2 days of flooding in winter and summer and 7 days of drying in summer and 12 days of drying in winter.
5. Soil plowing should be performed immediately after each drying cycle for the basins in order to maintain good infiltration rate and to prevent accumulation of the OM in the top soil layer.

6.2.2 Recommendations for the Research

1. It is recommended to perform further bore holes at the middle of IB1 in order to ensure that the sandy silty clay layer is spreading at variable depths before the implementation of the injection piles (60 piles).
2. As the clogging layer is subject to compression under seepage forces exerted by infiltrating water, it is recommended to try variable water depths (for example 0.6-1.0m) in the basin in order to determine the optimal depth which may help to prevent excessive compression and further reduction of hydraulic conductivity.
3. OM accumulation in the topsoil layer is the one of the main factors adversely affecting soil permeability. Up on that; it is recomnded to perfrom additional studies in order to detrmine the chemical nature and composition of the OM and it is effect on the soil.
4. The pumping to the infiltration basins should be stopped until reaching BOD load suitable for infiltration purposes.

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APPENDICES

APPENDIX (1)

Schedule of Plowing for IB1 (CMWU, 2013)

Plowing Date	Tool of Plowing
14.09.2011	PLOW
03.11.2011	PLOW
05.01.2012	PLOW
21.03.2012	PLOW
22.05.2012	PLOW
28.07.2012	PLOW
29.08.2012	PLOW
06.10.2012	PLOW
01.01.2013	PLOW
30.03.2013	PLOW
13.05.2013	PLOW

APPENDIX (2)

Borehole Log (BH1)

SUBSURFACE PROFILE			SAMPLE										
Depth (m)	Graphic Log	Elev.	Soil Description	No.	USCS Classification	Fines Content %	Liquid Limit %	Plastic Limit %	Plasticity Index	Coefficient of Uniformity (Cu)	Coefficient of Gradation (Cc)	Average Size (mm)	Water Content (WC) %
0.0		0.00	Ground Surface										
		-0.30	Sand Yellowish fine Sand with little gravel (Kurkar) and a little fines. Non plastic.	1	SM	14.0			NP	5.974	0.841	0.240	11.0
				2	SM	21.6			NP	14.256	2.15	0.181	12.7
		-0.90	Clayey Sand Light Brown Clayey Sand with little gravel (Kurkar) and some fines. The layer is of low to medium plasticity.	3	SC	26.9				24.788	2.785	0.172	12.0
				4	SP-SM	11.9			NP	5.548	0.797	0.254	8.7
				5	SP-SM	7.1			NP	4.2	0.75	0.250	6.4
			Sand Yellowish fine Sand with little gravel (Kurkar) and a little fines. Non plastic.	6	SP	4.1			NP	4.974	0.733	0.326	4.9
				7	SP-SM	7.6			NP	4.364	0.745	0.258	6.8
				8	SP-SM	9.0			NP	4.864	0.729	0.271	6.8
				9	SP-SM	8.2			NP	4.175	0.751	0.244	7.2
				10	SP-SM	8.1			NP	4.068	0.755	0.240	7.5
				11	SP-SM	5.4			NP	4.15	0.752	0.264	4.4

SUBSURFACE PROFILE				SAMPLE									
Depth (m)	Graphic Log	Elev.	Soil Description	No.	USCS Classification	Fines Content %	Liquid Limit %	Plastic Limit %	Plasticity Index	Coefficient of Uniformity CU	Coefficient of Gradation Co	Average Size D ₆₀	Water Content W _c %
7.0				12	SP	3.6			NP	3.651	0.772	0.246	4.5
8.0				13	SP	3.7			NP	3.4	0.784	0.230	4.4
9.0				14	SP	2.0			NP	3.221	0.791	0.227	4.1
10.0				15	SP-SM	6.7			NP	3.671	0.771	0.228	5.4
11.0				16	SP-SM	6.5			NP	4.12	0.753	0.253	5.0
12.0		-12.00		17	SP	3.1			NP	4.226	0.75	0.286	3.8
			End of Borehole										

Borehole Log (BH2)

SUBSURFACE PROFILE				SAMPLE									
Depth (m)	Graphic Log	Elev.	Soil Description	No.	USCS Classification	Fines Content %	Liquid Limit %	Plastic Limit %	Plasticity Index	Coefficient of Uniformity CU	Coefficient of Gradation Co	Average Size D ₅₀	Water Content W _C %
0.0		0.00	Ground Surface										
			Sand Yellowish fine Sand with little gravel (Kurkar) and a little fines. Non plastic.	1	SP-SM	6.3			NP	5.348	0.766	0.245	11.4
		-0.60		2	SP-SM	9.6			NP	4.915	0.727	0.268	11.3
			Clayey Sand Light Brown Clayey Sand with little gravel (Kurkar) and some fines. The layer is of low to medium plasticity.	3	SM	18.2				7.245	0.803	0.237	15.6
1.0				4	SC	27.7				25.117	2.958	0.164	14.3
		-1.50		5	SC	26.8				21.042	3.169	0.154	14.2
			Sand Yellowish fine Sand with little gravel (Kurkar) and a little fines. Non plastic.	6	SP-SM	9.6			NP	4.01	0.757	0.227	7.6
2.0				7	SP-SM	7.4			NP	4.174	0.751	0.25	7.0
				8	SP-SM	7.8			NP	4.274	0.784	0.252	5.6
3.0				9	SP	4.6			NP	3.703	0.77	0.243	6.2
4.0				10	SP-SM	7.0			NP	3.904	0.762	0.239	7.5
5.0				11	SP-SM	6.2			NP	3.694	0.77	0.232	6.8
6.0													

SUBSURFACE PROFILE				SAMPLE									
Depth (m)	Graphic Log	Elev.	Soil Description	No.	USCS Classification	Fines Content %	Liquid Limit %	Plastic Limit %	Plasticity Index	Coefficient of Uniformity CU	Coefficient of Gradation Cc	Average Size D ₅₀	Water Content WC%
7.0				12	SP-SM	6.6			NP	5.208	0.72	0.311	5.7
8.0				13	SP-SM	5.7			NP	4.981	0.725	0.307	6.0
		-8.70		14	SC	26.5				25.702	2.618	0.181	10.5
9.0		-9.00	Clayey Sand Slightly Light Brown Clayey Sand with little gravel (Kurkar). The layer is of medium plasticity.	15	SP	3.3			NP	4.614	0.737	0.309	6.0
10.0			Sand Yellowish fine Sand with little gravel (Kurkar) and a little fines. Non plastic.	16	SP	3.3			NP	3.893	0.762	0.263	4.6
11.0				17	SP	0.0			NP	4.617	0.788	0.372	4.2
12.0		-12.00	End of Borehole										

Borehole Log (BH3)

SUBSURFACE PROFILE			SAMPLE										
Depth (m)	Graphic Log	Elev.	Soil Description	No.	USCS Classification	Fines Content %	Liquid Limit %	Plastic Limit %	Plasticity Index	Coefficient of Uniformity CU	Coefficient of Gradation Cc	Average Size D ₅₀	Water Content WC%
0.0		0.00	Ground Surface										
		-0.30	Sand Yellowish fine Sand with little gravel (Kurkar) and a little fines. Non plastic.	1	SM	13.8				5.496	0.858	0.227	12.8
				2	SM	22.8				16.126	2.368	0.177	12.1
			Clayey Sand Light Brown Clayey Sand with little gravel (Kurkar) and some fines. The layer is of low to medium plasticity.	3	SM	22.9				16.806	2.348	0.18	12.6
1.0		-1.20		4	SC	39.9				38.485	3.913	0.118	15.6
				5	SP-SM	10.7			NP	4.136	0.798	0.217	7.9
			Sand Yellowish fine Sand with little gravel (Kurkar) and a little fines. Non plastic.	6	SP-SM	9.8			NP	3.882	0.762	0.22	7.0
2.0				7	SP-SM	9.9			NP	4.632	0.736	0.253	7.6
				8	SP-SM	9.1			NP	3.876	0.763	0.224	6.8
3.0													
				9	SM	13.0			NP	6.11	0.813	0.256	6.9
4.0													
				10	SM	15.4			NP	4.619	0.943	0.185	9.0
5.0													
				11	SP-SM	11.6			NP	4.207	0.839	0.208	7.4
6.0													

SUBSURFACE PROFILE				SAMPLE									
Depth (m)	Graphic Log	Elev.	Soil Description	No.	USCS Classification	Fines Content %	Liquid Limit %	Plastic Limit %	Plasticity Index	Coefficient of Uniformity CU	Coefficient of Gradation Cc	Average Size D50	Water Content WC%
		-6.50											
7.0		-7.40	Sandy Silty Clay Dark Brown Sandy Clay with little gravel (Kurkar). The layer is of medium plasticity.	12	CL	55.6				30.861	7.67	0.067	17.9
8.0			Sand Yellowish fine Sand with a little gravel (Kurkar) and a little fines. Non plastic.	13	SP-SM	5.1			NP	6.309	0.828	0.454	3.7
9.0				14	SP-SM	6.8			NP	6.222	0.793	0.414	3.5
10.0				15	SP	4.5			NP	3.745	0.768	0.246	4.2
11.0				16	SP	2.4			NP	3.958	0.759	0.274	4.0
12.0		-12.00		17	SP	2.3			NP	3.881	0.762	0.27	3.7
			End of Borehole										

Borehole Log (BH4)

SUBSURFACE PROFILE			SAMPLE										
Depth (m)	Graphic Log	Elev.	Soil Description	No.	USCS Classification	Fines Content %	Liquid Limit %	Plastic Limit %	Plasticity Index	Coefficient of Uniformity CU	Coefficient of Gradation Cc	Average Size D ₅₀	Water Content WC%
0.0		0.00	Ground Surface										
			Sand Yellowish fine Sand with little gravel (Kurkar) and a little fines. Non plastic.	1	SP-SM	8.7			NP	5.777	0.72	0.322	9.2
		-0.60			2	SP-SM	5.4			NP	6.335	0.806	0.444
			Clayey Sand Light Brown Clayey Sand with little gravel (Kurkar) and some fines. The layer is of low plasticity.	3	SM	21.3				22.278	1.584	0.262	7.7
1.0		-0.90			4	SP-SM	10.8			NP	4.989	0.767	0.252
				5	SP-SM	6.8			NP	5.028	0.724	0.299	6.2
		-1.50		Sand Yellowish fine Sand with little gravel (Kurkar) and a little fines. Non plastic.	6	SM	20.7			NP	15.389	1.776	0.212
				7	SP	4.5			NP	4.455	0.742	0.288	5.4
		-1.80		Clayey Sand Slightly Light Brown Clayey Sand with little gravel (Kurkar). The layer is of low plasticity.	8	SP-SM	10.8			NP	6.379	0.74	0.311
2.0													
			Sand Yellowish fine Sand with little gravel (Kurkar) and a little fines. Non plastic.	9	SP-SM	8.3			NP	5.821	0.733	0.336	6.8
3.0													
				10	SP-SM	7.6			NP	5.209	0.719	0.30	7.6
4.0													
				11	SP-SM	6.1			NP	5.443	0.746	0.344	5.7
5.0													
6.0													

SUBSURFACE PROFILE				SAMPLE									
Depth (m)	Graphic Log	Elev.	Soil Description	No.	USCS Classification	Fines Content %	Liquid Limit %	Plastic Limit %	Plasticity Index	Coefficient of Uniformity CU	Coefficient of Gradation Cc	Average Size D ₅₀	Water Content WC%
7.0				12	SP-SM	11.4			NP	7.273	0.773	0.345	6.8
8.0				13	SP-SM	7.8			NP	5.959	0.784	0.365	6.0
9.0				14	SP-SM	5.4			NP	5.115	0.738	0.328	5.9
10.0				15	SP-SM	6.4			NP	5.443	0.752	0.344	5.8
11.0				16	SP	2.1			NP	4.399	0.744	0.308	5.1
12.0		12.00		17	SP	3.6			NP	4.916	0.743	0.332	4.7
			End of Borehole										

Borehole Log (BH5)

SUBSURFACE PROFILE			SAMPLE										
Depth (m)	Graphic Log	Elev.	Soil Description	No.	USCS Classification	Fines Content %	Liquid Limit %	Plastic Limit %	Plasticity Index	Coefficient of Uniformity CU	Coefficient of Gradation Cc	Average Size D ₅₀	Water Content WC%
0.0		0.00	Ground Surface										
			Clayey Sand Slightly Dark Brown Clayey Sand with little gravel (Kurkar). The layer is of medium plasticity.	1	SC	31.5				31.028	3.176	0.15	12.3
		-0.30	Sand Yellowish fine Sand with little gravel (Kurkar) and a little fines. Non plastic.	2	SP-SM	6.1			NP	5.347	0.731	0.33	5.8
		-0.60	Clayey Sand Light Brown Clayey Sand with little gravel (Kurkar) and some fines. The layer is of medium plasticity.	3	SC	26.5				23.509	2.789	0.171	11.0
		-0.90	Clayey Sand Slightly Light Brown Clayey Sand with little gravel (Kurkar). The layer is of medium plasticity.	4	SP-SM	5.3			NP	4.003	0.758	0.256	5.9
		-1.50	Sand Yellowish fine Sand with little gravel (Kurkar) and a little fines. Non plastic.	5	SP-SM	6.1			NP	4.304	0.747	0.267	5.5
		-1.80	Clayey Sand Slightly Light Brown Clayey Sand with little gravel (Kurkar). The layer is of medium plasticity.	6	SC	23.4				31.796	1.708	0.282	9.6
			Sand Yellowish fine Sand with little gravel (Kurkar) and a little fines. Non plastic.	7	SM	16.4			NP	6.93	0.824	0.244	7.5
				8	SP	4.3			NP	5.453	0.818	0.409	3.8
3.0													

SUBSURFACE PROFILE				SAMPLE									
Depth (m)	Graphic Log	Elev.	Soil Description	No.	USCS Classification	Fines Content %	Liquid Limit %	Plastic Limit %	Plasticity Index	Coefficient of Uniformity CU	Coefficient of Gradation Cc	Average Size D ₅₀	Water Content WC%
4.0				9	SP	2.8			NP	4.811	0.742	0.332	3.8
				10	SP	3.1			NP	4.468	0.741	0.301	4.1
5.0				11	SP	2.3			NP	5.202	0.788	0.398	3.3
6.0													

SUBSURFACE PROFILE				SAMPLE									
Depth (m)	Graphic Log	Elev.	Soil Description	No.	USCS Classification	Fines Content %	Liquid Limit %	Plastic Limit %	Plasticity Index	Coefficient of Uniformity CU	Coefficient of Gradation Cc	Average Size D50	Water Content WC%
				12	SP	5.0			NP	3.447	0.781	0.228	4.1
7.0				13	SP	5.0			NP	4.288	0.747	0.275	5.0
8.0		-8.00		14	SM	20.3				14.263	1.732	0.21	3.4
			<i>Clayey Sand</i> Slightly Light Brown Clayey Sand with little gravel (Kurkar). The layer is of low plasticity.										
9.0		-9.00											

SUBSURFACE PROFILE				SAMPLE										
Depth (m)	Graphic Log	Elev.	Soil Description	No.	USCS Classification	Fines Content %	Liquid Limit %	Plastic Limit %	Plasticity Index	Coefficient of Uniformity CU	Coefficient of Gradation Cc	Average Size D50	Water Content WC%	
			Sand Yellowish fine Sand with little gravel (Kurkar) and a little fines. Non plastic.											
				15	SP	2.1				NP	3.989	0.758	0.279	4.0
10.0														
				16	SP	2.7					NP	3.892	0.762	0.268
11.0														
				17	SP	3.2				NP	4.483	0.741	0.301	3.5
12.0		12.00	End of Borehole											

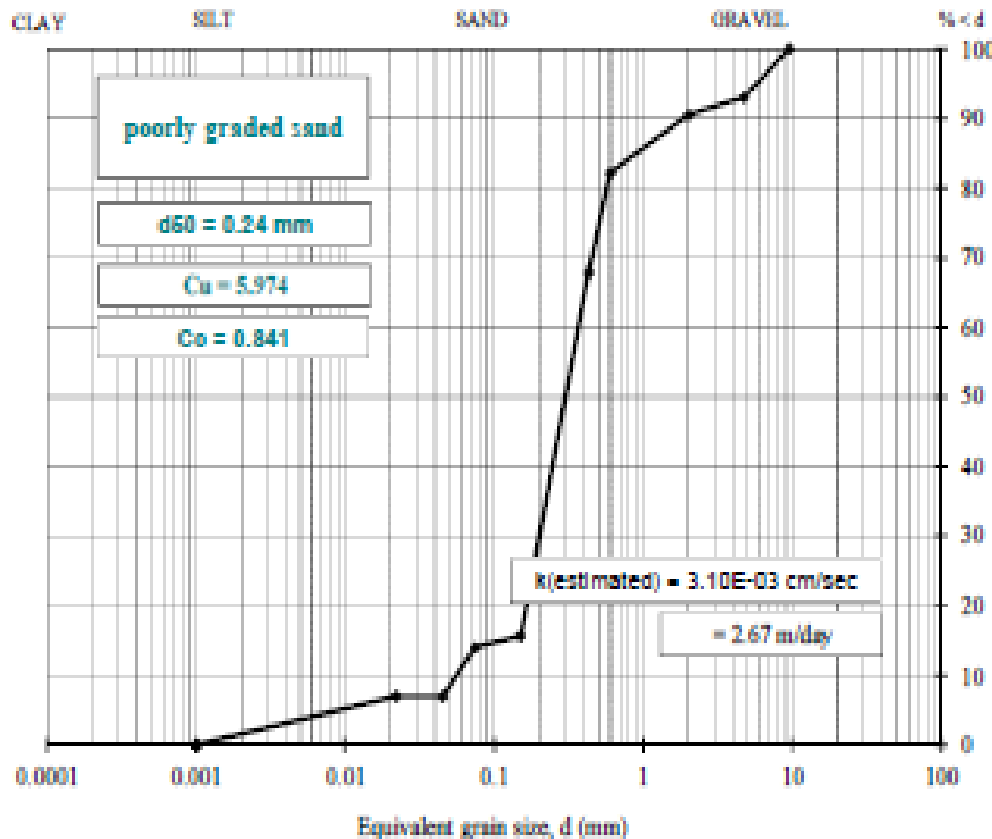
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH1
Depth	0.3 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	7.0
				Medium gravel	0.0	
				Fine gravel	7.0	
3/8"	9.50	90.6	100.0	Coarse sand	2.5	79.0
Nr. 4	4.75	84.3	95.0	Medium sand	22.6	
Nr. 10	2.00	82.0	90.5	Fine sand	53.9	
Nr. 30	0.60	74.5	82.2	Coarse silt	7.01	9.95
Nr. 40	0.43	61.5	67.9	Medium silt	0.00	
Nr. 100	0.15	14.2	15.7	Fine silt	2.95	
Nr. 200	0.07	12.7	14.0	Clay	4.06	
Pan	---	0.0	0.0			4.06

*Percentages relative to entire sample mass



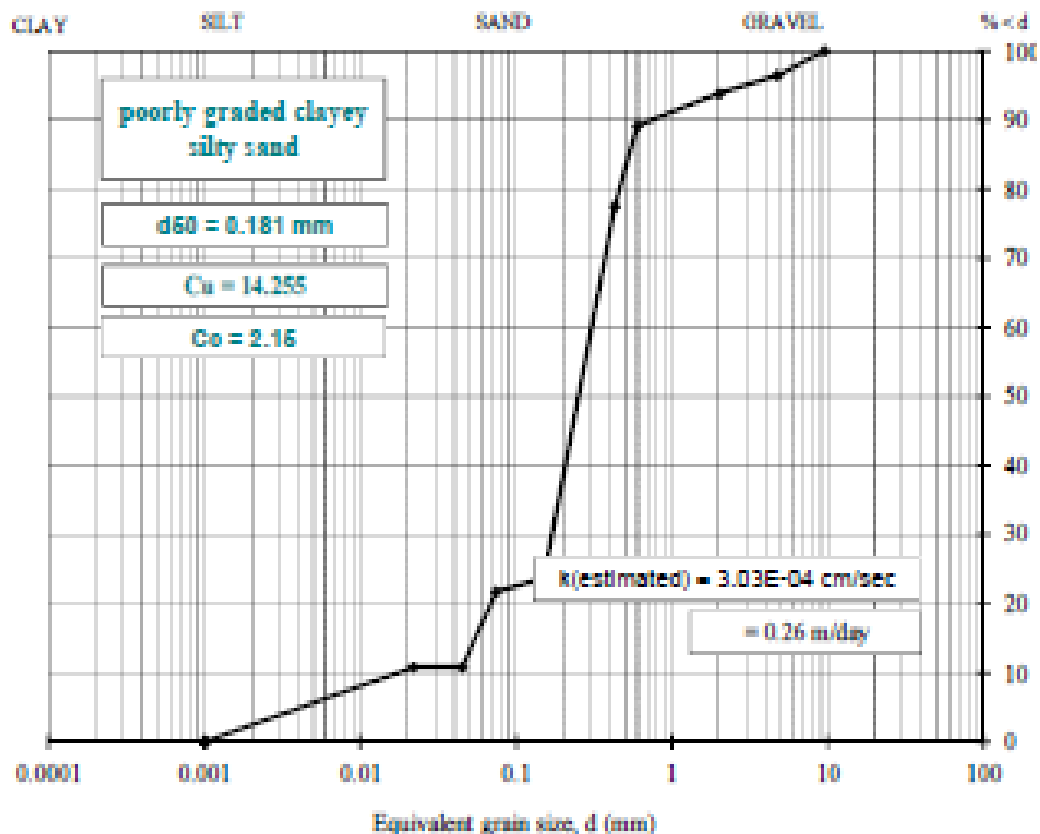
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH1
Depth	0.6 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	3.5
				Medium gravel	0.0	
				Fine gravel	3.5	
3/8"	9.50	158.0	100.0	Coarse sand	2.7	74.9
Nr. 4	4.75	152.5	96.5	Medium sand	16.4	
Nr. 10	2.00	148.3	93.9	Fine sand	55.8	
Nr. 30	0.60	140.9	89.2	Coarse silt	10.82	15.37
Nr. 40	0.43	122.4	77.5	Medium silt	0.00	
Nr. 100	0.15	37.4	23.7	Fine silt	4.55	
Nr. 200	0.07	34.2	21.6	Clay	6.27	
Pan	—	0.0	0.0	Clay	6.27	6.27

*Percentages relative to entire sample mass



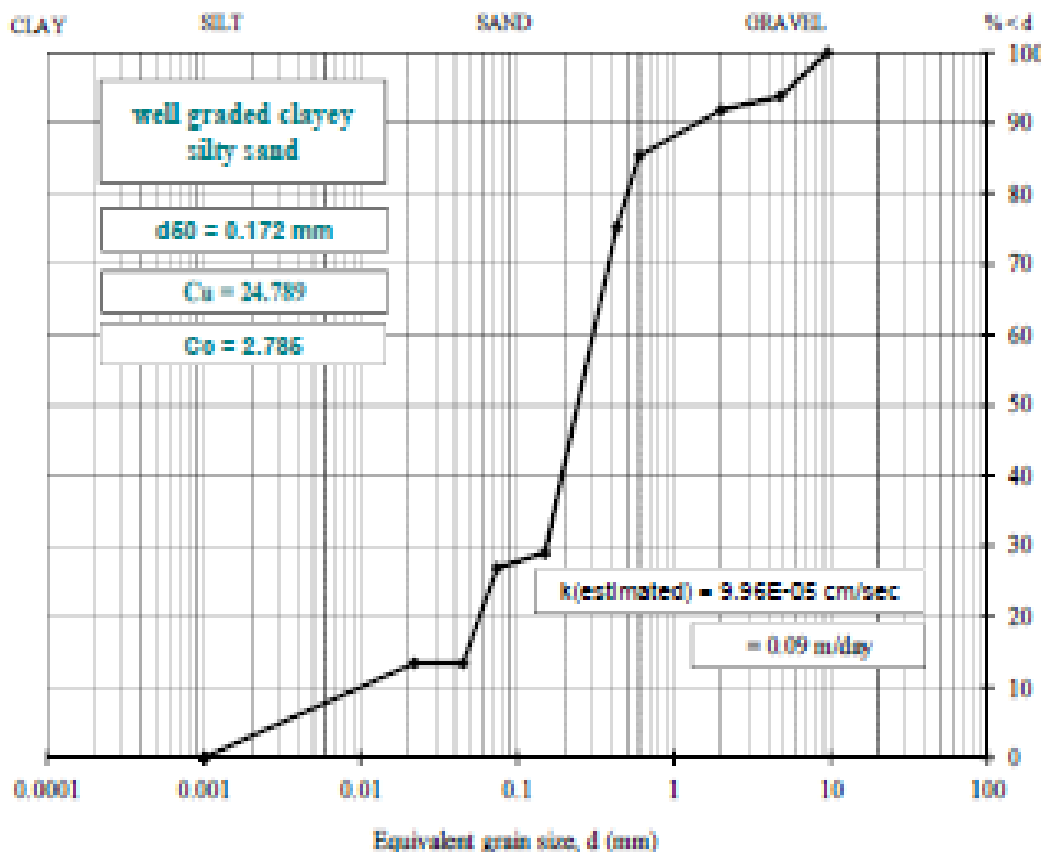
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH1
Depth	0.9 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %			
				Coarse gravel	0.0	6.2
				Medium gravel	0.0	
				Fine gravel	6.2	
3/8"	9.50	88.2	100.0	Coarse sand	1.9	66.9
Nr. 4	4.75	82.7	93.8	Medium sand	16.7	
Nr. 10	2.00	81.0	91.8	Fine sand	48.3	
Nr. 30	0.60	75.3	85.4	Coarse silt	13.44	19.08
Nr. 40	0.43	66.3	75.2	Medium silt	0.00	
Nr. 100	0.15	25.6	29.0	Fine silt	5.65	
Nr. 200	0.07	23.7	26.9	Clay	7.79	
Pan	---	0.0	0.0			1.79

*Percentages relative to entire sample mass



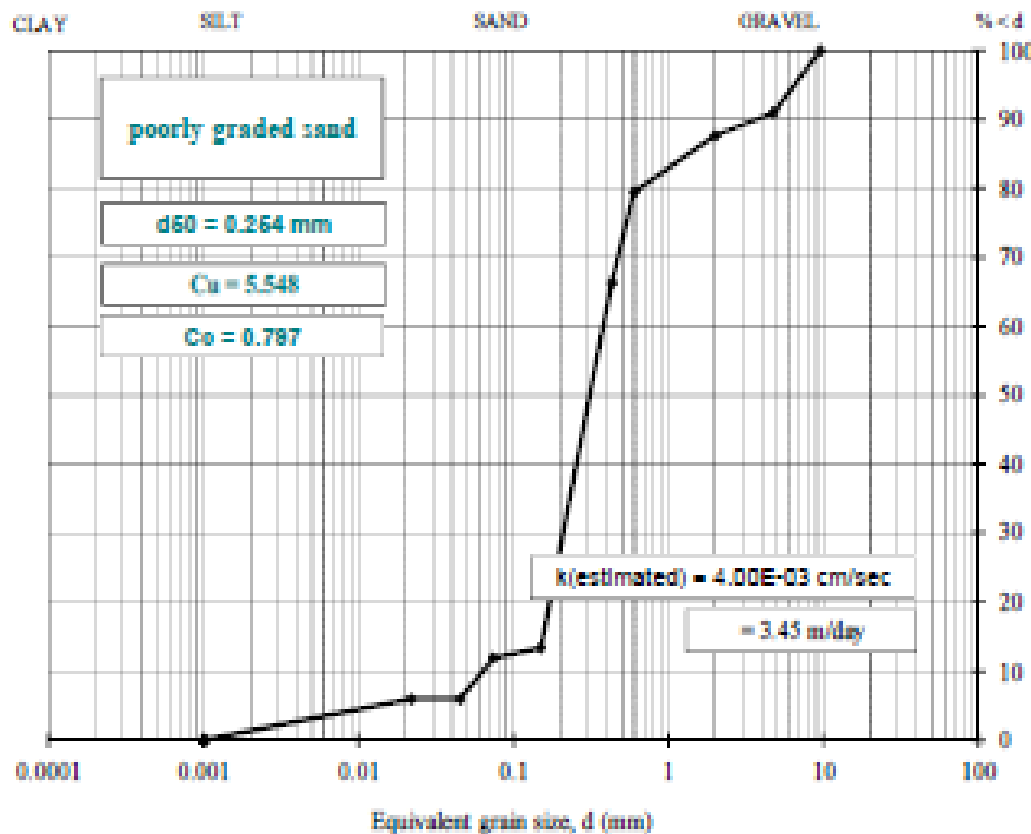
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH1
Depth	1.2 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	9.0
				Medium gravel	0.0	
				Fine gravel	9.0	
3/8"	9.50	108.6	100.0	Coarse sand	3.3	79.1
Nr. 4	4.75	98.8	91.0	Medium sand	21.4	
Nr. 10	2.00	95.2	87.7	Fine sand	54.4	
Nr. 30	0.60	86.3	79.5	Coarse silt	5.94	8.44
Nr. 40	0.43	72.0	66.3	Medium silt	0.00	
Nr. 100	0.15	14.5	13.4	Fine silt	2.50	
Nr. 200	0.07	12.9	11.9	Fine silt	2.50	3.44
Pan	---	0.0	0.0	Clay	3.44	

*Percentages relative to entire sample mass



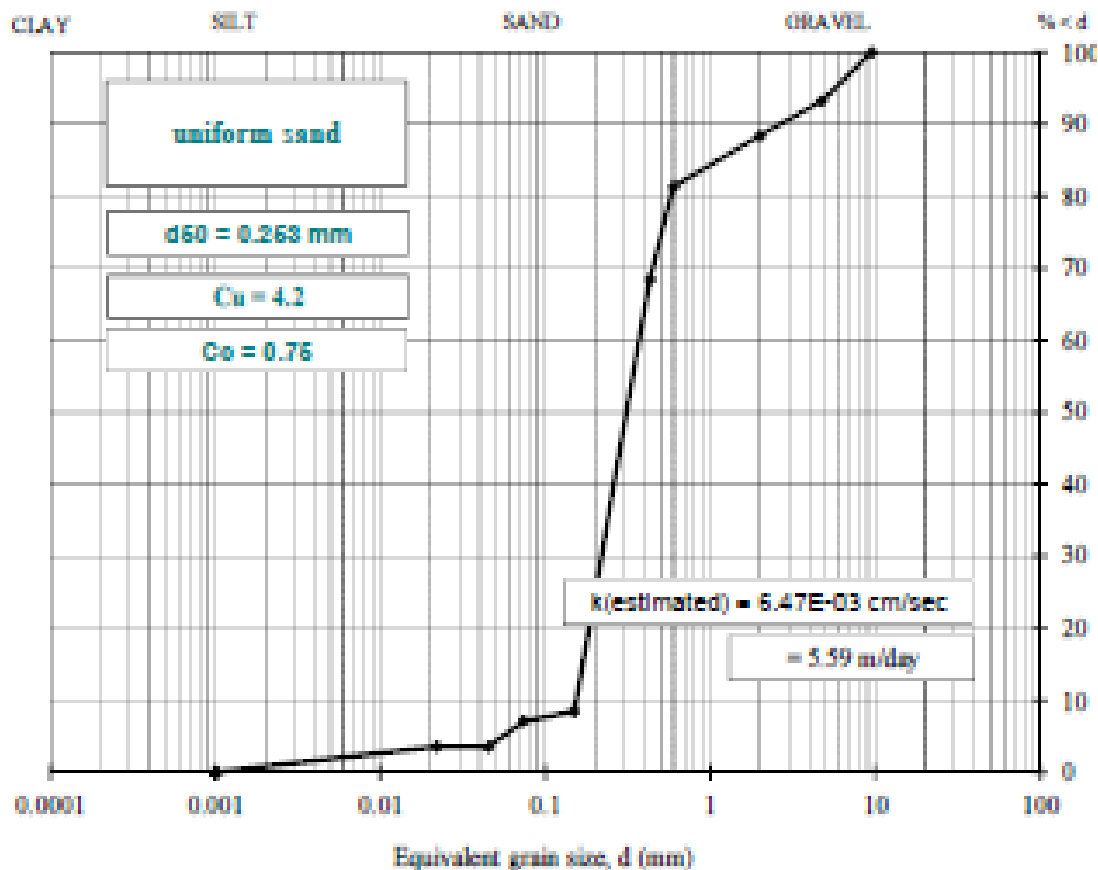
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH1
Depth	1.5 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	6.7
				Medium gravel	0.0	
				Fine gravel	6.7	
3/8"	9.50	107.0	100.0	Coarse sand	4.9	86.2
Nr. 4	4.75	99.8	93.3	Medium sand	20.0	
Nr. 10	2.00	94.6	88.4	Fine sand	61.3	
Nr. 30	0.60	87.0	81.3	Coarse silt	3.55	5.04
Nr. 40	0.43	73.2	68.4	Medium silt	0.00	
Nr. 100	0.15	9.1	8.5	Fine silt	1.49	
Nr. 200	0.07	7.6	7.1	Clay	2.06	
Fin	---	0.0	0.0			2.06

*Percentages relative to entire sample mass



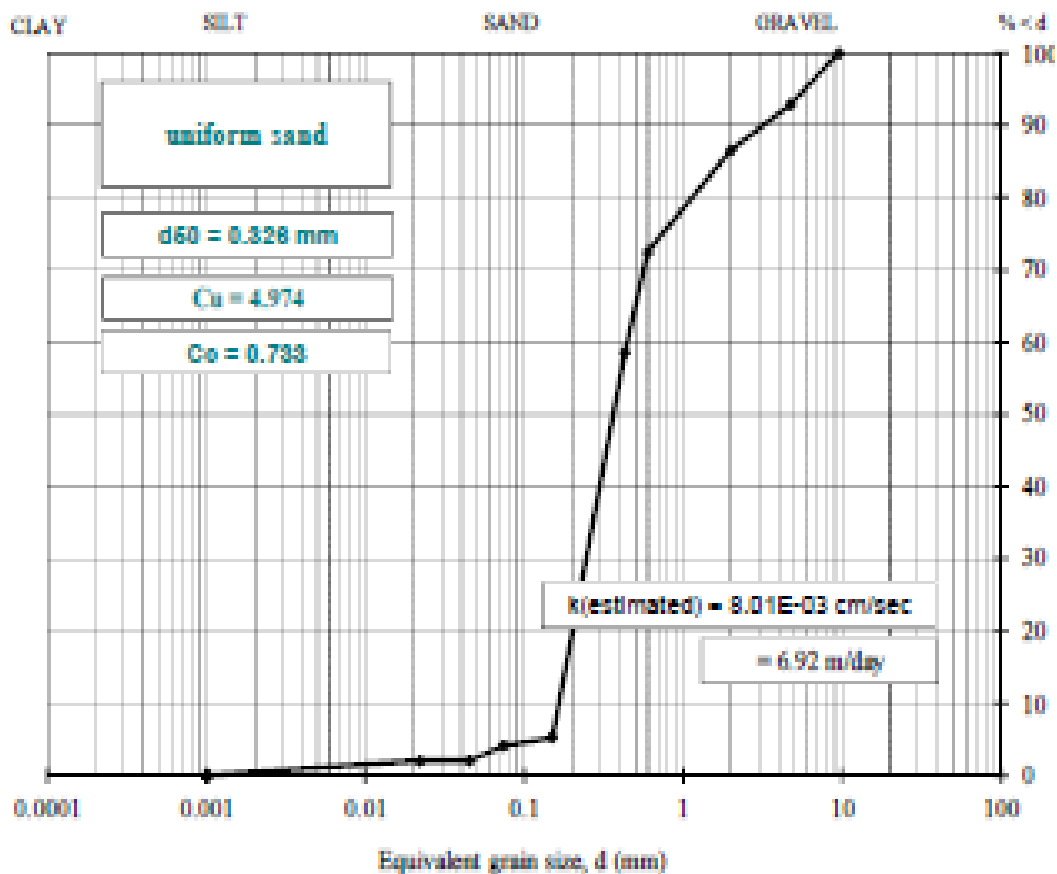
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH1
Depth	1.8 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	7.1
				Medium gravel	0.0	
				Fine gravel	7.1	
3/8"	9.50	97.2	100.0	Coarse sand	6.3	88.8
Nr. 4	4.75	90.3	92.9	Medium sand	28.1	
Nr. 10	2.00	84.2	86.6	Fine sand	34.4	
Nr. 30	0.60	70.5	72.5	Coarse silt	2.06	2.92
Nr. 40	0.43	56.9	58.5	Medium silt	0.00	
Nr. 100	0.15	5.1	5.2			
Nr. 200	0.07	4.0	4.1	Fine silt	0.86	
Pan	---	0.0	0.0	Clay	1.19	1.19

*Percentages relative to entire sample mass



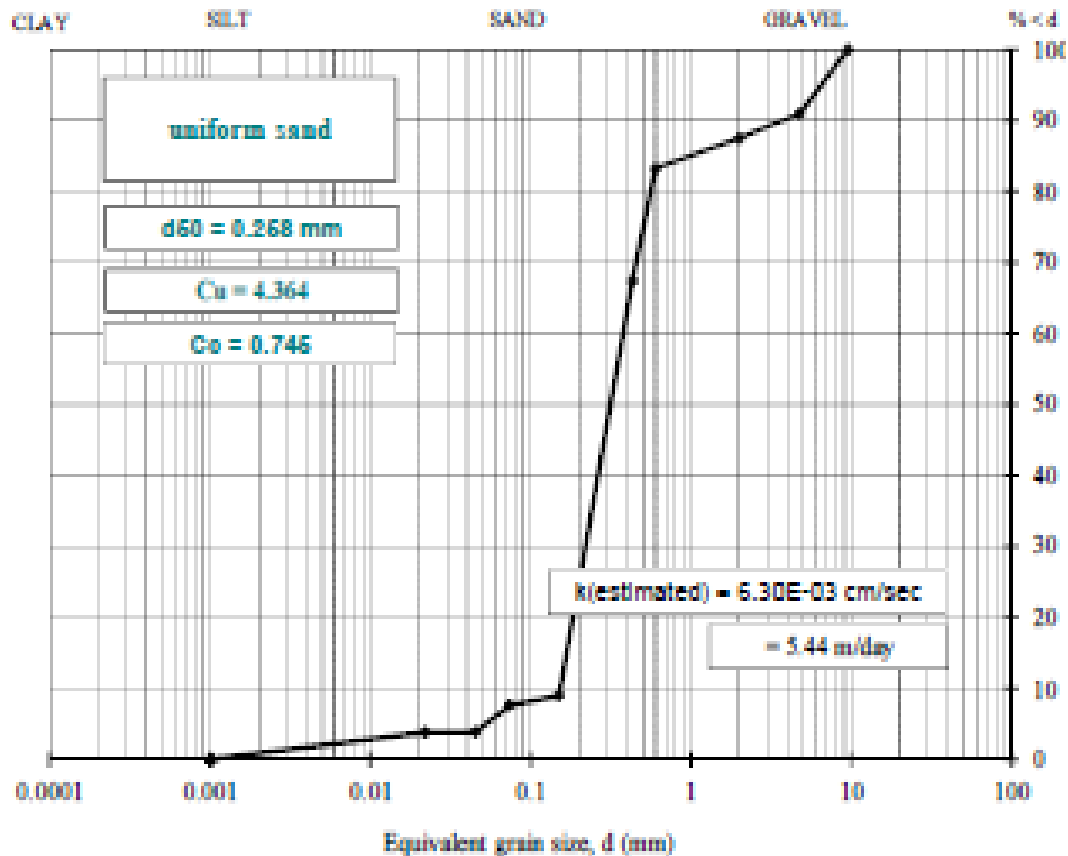
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH1
Depth	2.1 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	9.0
				Medium gravel	0.0	
				Fine gravel	9.0	
3/8"	9.50	119.4	100.0	Coarse sand	3.4	83.3
Nr. 4	4.75	108.6	91.0	Medium sand	20.2	
Nr. 10	2.00	104.5	87.5	Fine sand	59.7	
Nr. 30	0.60	99.4	83.2	Coarse silt	3.81	5.41
Nr. 40	0.43	80.4	67.3	Medium silt	0.00	
Nr. 100	0.15	10.7	9.0	Fine silt	1.60	
Nr. 200	0.07	9.1	7.6	Clay	2.21	
Fin	---	0.0	0.0	Clay	2.21	2.21

*Percentages relative to entire sample mass



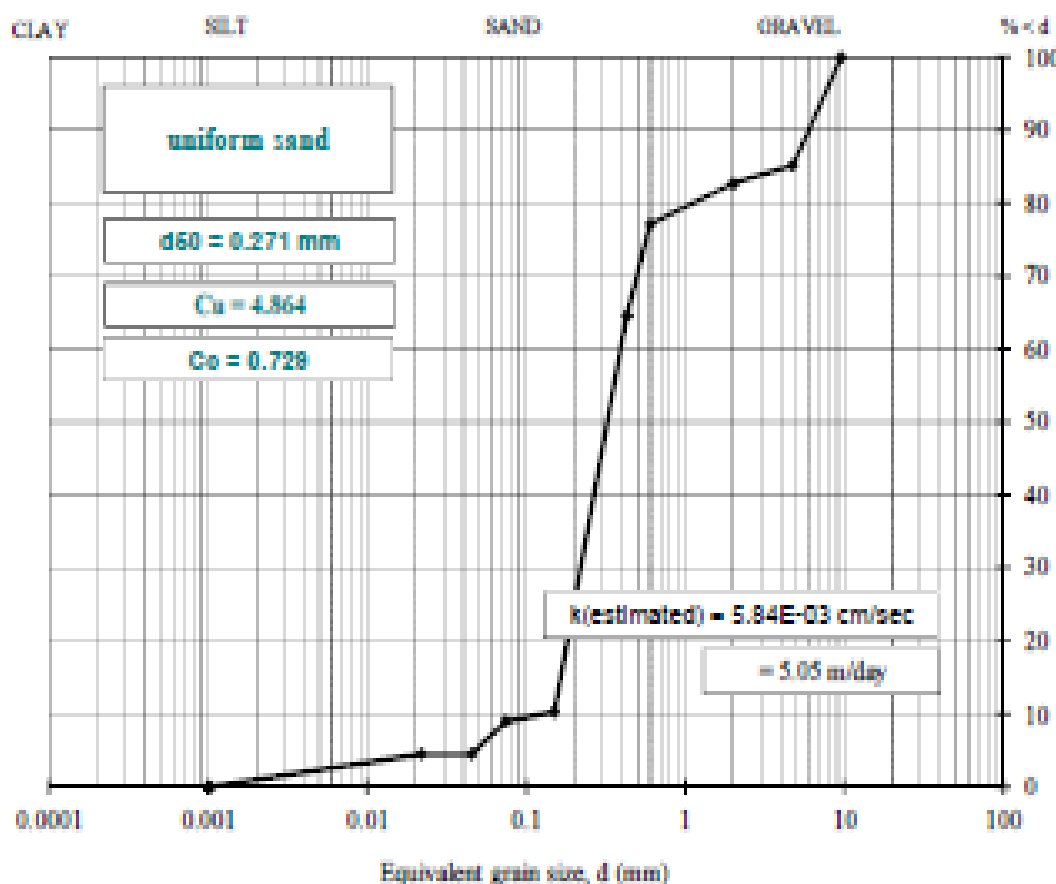
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH1
Depth	3.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	14.8
				Medium gravel	0.0	
				Fine gravel	14.8	
3/8"	9.50	114.7	100.0	Coarse sand	2.5	76.2
Nr. 4	4.75	97.7	85.2	Medium sand	18.0	
Nr. 10	2.00	94.8	82.7	Fine sand	55.6	
Nr. 30	0.60	88.5	77.2	Coarse silt	4.49	6.38
Nr. 40	0.43	74.1	64.6	Medium silt	0.00	
Nr. 100	0.15	11.8	10.3	Fine silt	1.89	
Nr. 200	0.07	10.3	9.0	Clay	2.60	
Pan	---	0.0	0.0	Clay	2.60	2.60

*Percentages relative to entire sample mass



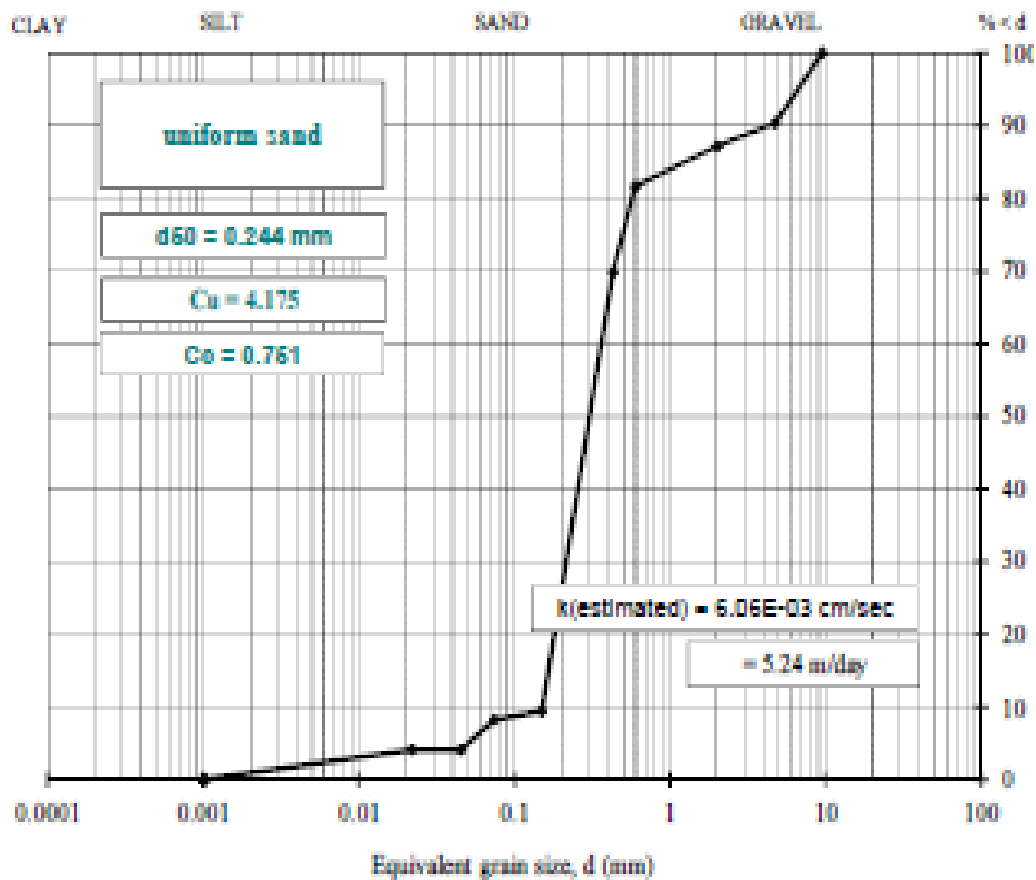
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH1
Depth	4.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Course gravel	0.0	9.7
				Medium gravel	0.0	
				Fine gravel	9.7	
3/8"	9.50	97.3	100.0	Course sand	3.2	82.1
Nr. 4	4.75	87.9	90.3	Medium sand	17.4	
Nr. 10	2.00	84.8	87.2	Fine sand	61.6	
Nr. 30	0.60	79.4	81.6	Course silt	4.11	5.84
Nr. 40	0.43	67.9	69.8	Medium silt	0.00	
Nr. 100	0.15	9.2	9.5	Fine silt	1.73	
Nr. 200	0.07	8.0	8.2	Fine silt	1.73	
Pan	--	0.0	0.0	Clay	2.38	2.38

*Percentages relative to entire sample mass



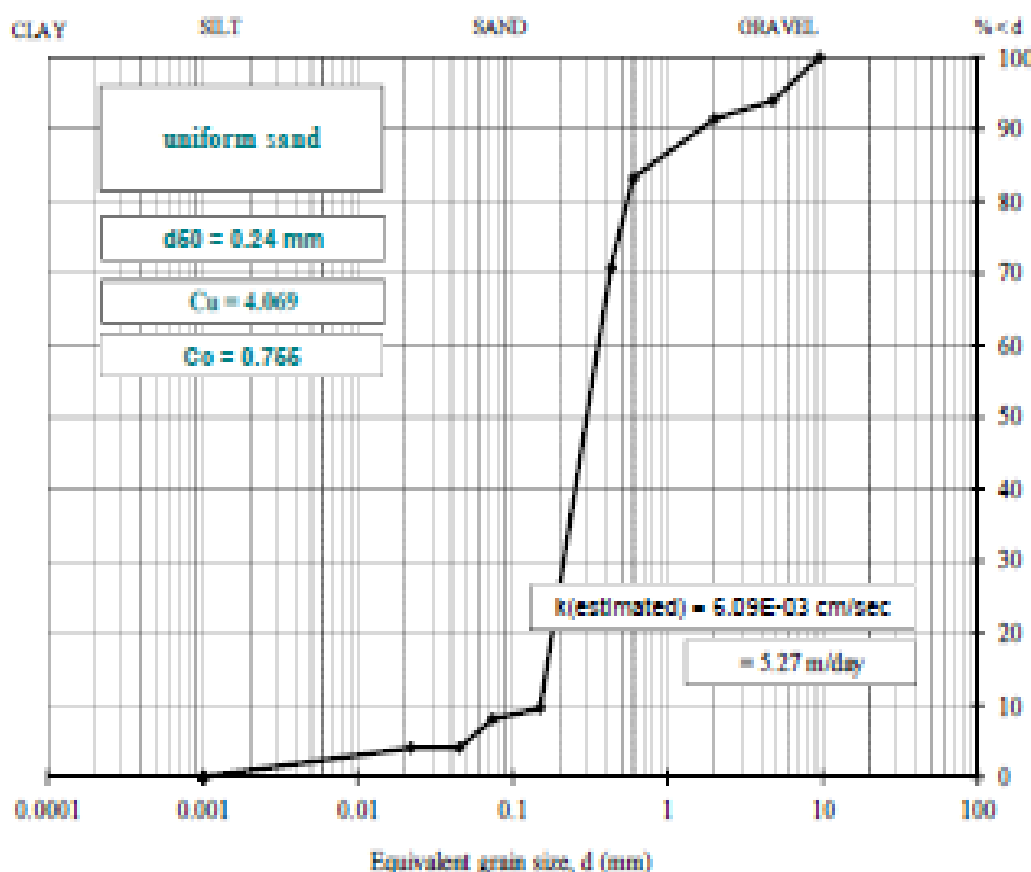
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH1
Depth	5.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	6.0
				Medium gravel	0.0	
				Fine gravel	6.0	
3/8"	9.50	107.5	100.0	Coarse sand	2.5	85.9
Nr. 4	4.75	101.0	94.0	Medium sand	20.7	
Nr. 10	2.00	98.3	91.4	Fine sand	62.7	
Nr. 30	0.60	89.5	83.3	Coarse silt	4.05	5.75
Nr. 40	0.43	76.1	70.8	Medium silt	0.00	
Nr. 100	0.15	10.3	9.6			
Nr. 200	0.07	8.7	8.1	Fine silt	1.70	
Fan	---	0.0	0.0	Clay	2.35	2.35

*Percentages relative to entire sample mass



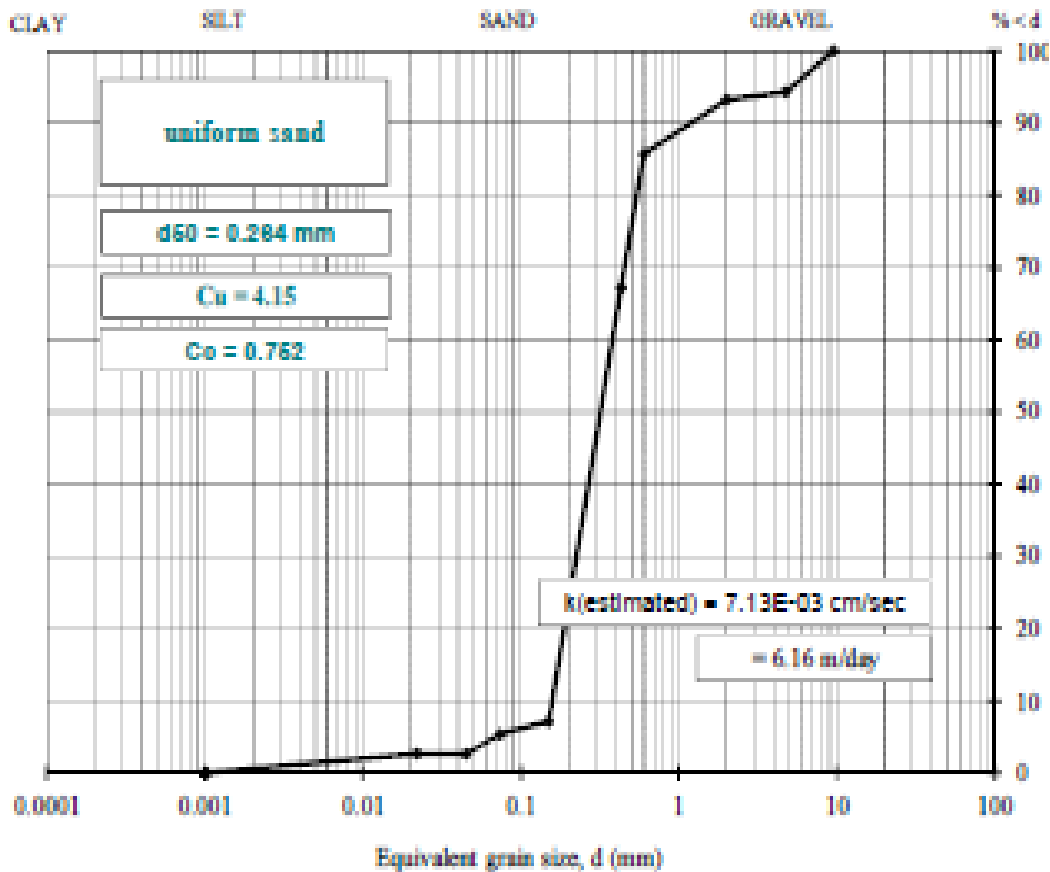
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH1
Depth	6.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	5.7
				Medium gravel	0.0	
				Fine gravel	5.7	
3/8"	9.50	173.7	100.0	Coarse sand	1.1	88.9
Nr. 4	4.75	163.8	94.3	Medium sand	26.0	
Nr. 10	2.00	161.9	93.2	Fine sand	61.8	
Nr. 30	0.60	148.9	85.7	Coarse silt	2.68	3.80
Nr. 40	0.43	116.7	67.2	Medium silt	0.00	
Nr. 100	0.15	12.4	7.1	Fine silt	1.13	
Nr. 200	0.07	9.3	5.4			
Pan	---	0.0	0.0	Clay	1.55	1.55

*Percentages relative to entire sample mass



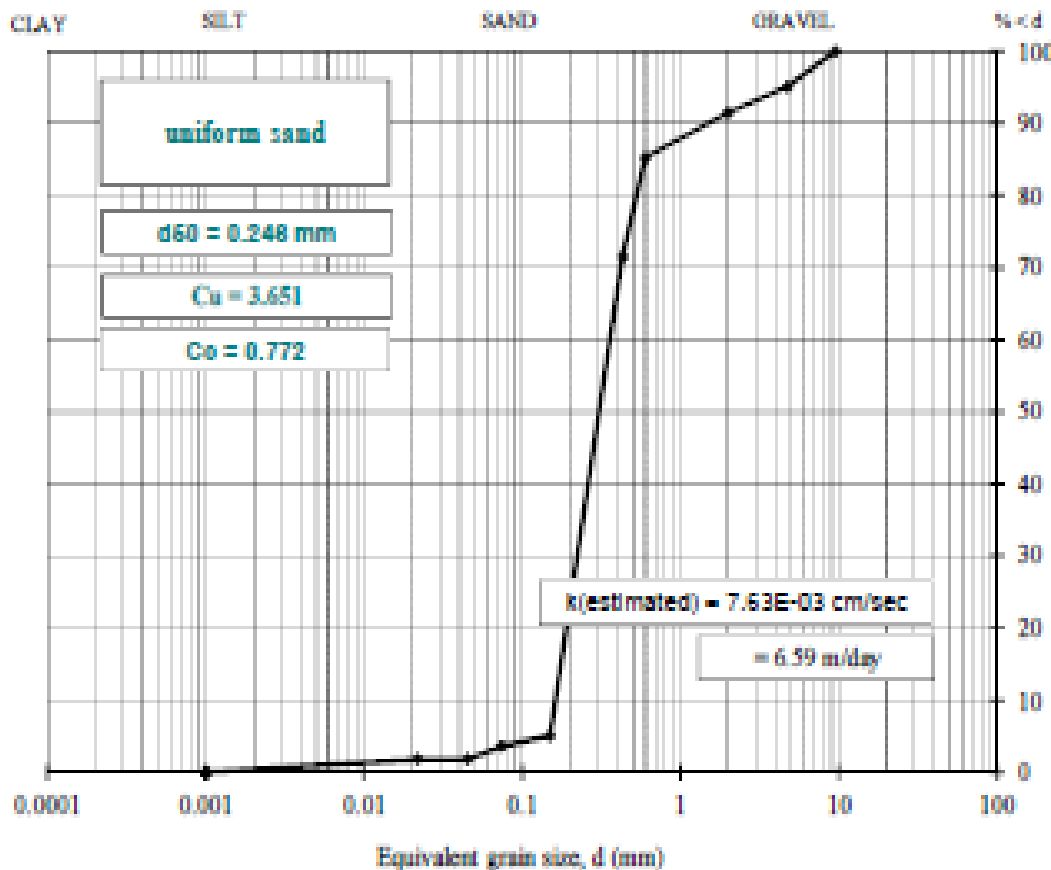
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH1
Depth	7.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	4.9
				Medium gravel	0.0	
				Fine gravel	4.9	
3/8"	9.50	144.1	100.0	Coarse sand	3.7	91.5
Nr. 4	4.75	137.1	95.1	Medium sand	19.9	
Nr. 10	2.00	131.8	91.5	Fine sand	67.9	
Nr. 30	0.60	122.9	85.3	Coarse silt	1.80	2.56
Nr. 40	0.43	103.1	71.5	Medium silt	0.00	
Nr. 100	0.15	7.3	5.1	Fine silt	0.76	
Nr. 200	0.07	5.2	3.6	Fine silt	0.76	
Pan	---	0.0	0.0	Clay	1.05	1.05

*Percentages relative to entire sample mass



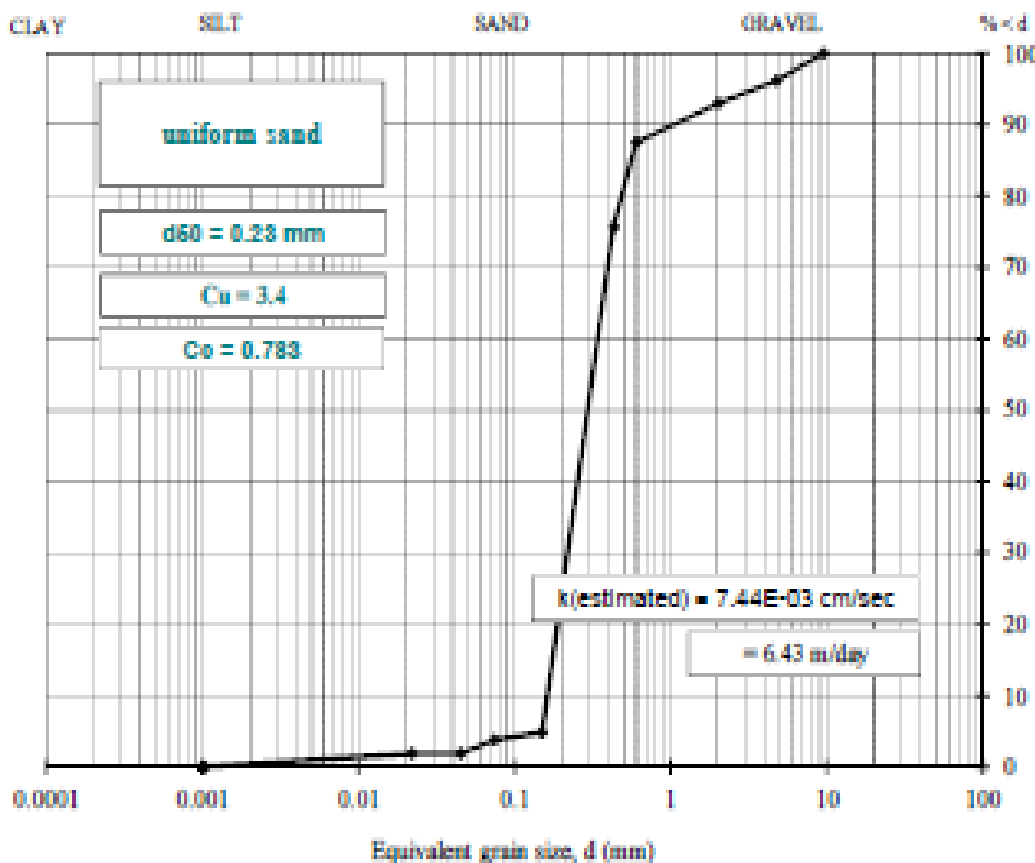
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH1
Depth	8.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Course gravel	0.0	3.8
				Medium gravel	0.0	
				Fine gravel	3.8	
3/8"	9.50	101.4	100.0	Course sand	3.2	92.4
Nr. 4	4.75	97.5	96.2	Medium sand	17.4	
Nr. 10	2.00	94.3	93.0	Fine sand	71.9	
Nr. 30	0.60	88.7	87.5	Course silt	1.87	2.66
Nr. 40	0.43	76.7	75.6	Medium silt	0.00	
Nr. 100	0.15	4.9	4.8	Fine silt	0.79	
Nr. 200	0.07	3.8	3.7	Clay	1.09	
Fin	--	0.0	0.0			1.09

*Percentages relative to entire sample mass



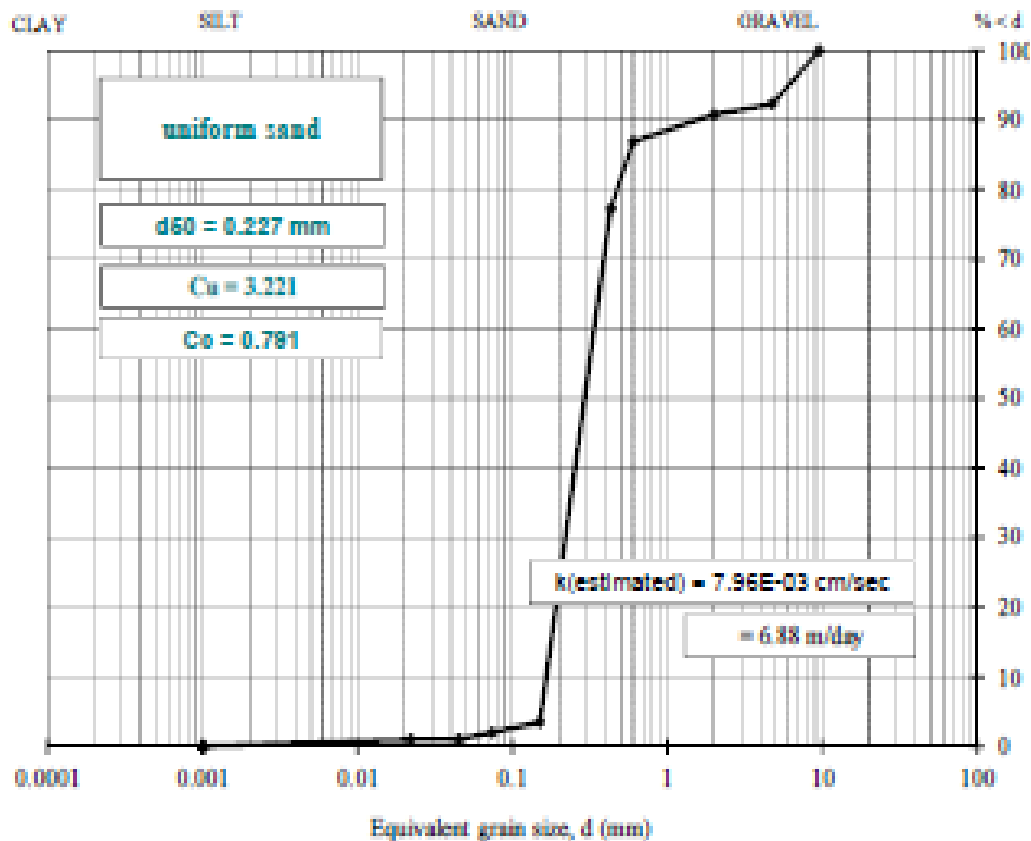
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH1
Depth	9.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	7.7
				Medium gravel	0.0	
				Fine gravel	7.7	
3/8"	9.50	104.5	100.0	Coarse sand	1.5	90.3
Nr. 4	4.75	96.5	92.3	Medium sand	13.6	
Nr. 10	2.00	94.9	90.8	Fine sand	75.2	
Nr. 30	0.60	90.8	86.9	Coarse silt	1.00	1.43
Nr. 40	0.43	80.7	77.2	Medium silt	0.00	
Nr. 100	0.15	3.6	3.4	Fine silt	0.42	
Nr. 200	0.07	2.1	2.0	Fine silt	0.42	
Fan	---	0.0	0.0	Clay	0.58	0.58

*Percentages relative to entire sample mass



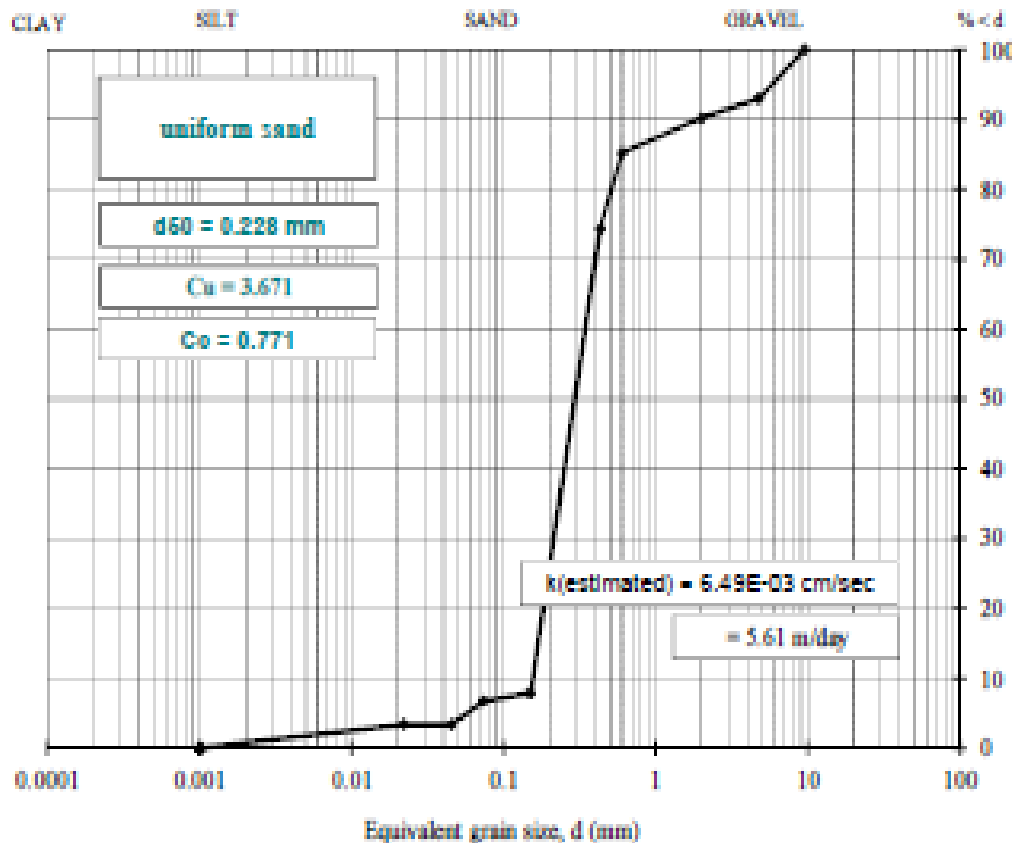
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH1
Depth	10.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	7.0
				Medium gravel	0.0	
				Fine gravel	7.0	
3/8"	9.50	120.3	100.0	Coarse sand	2.8	86.3
Nr. 4	4.75	111.9	93.0	Medium sand	15.8	
Nr. 10	2.00	108.5	90.2	Fine sand	67.7	
Nr. 30	0.60	102.5	85.2	Coarse silt	3.37	4.78
Nr. 40	0.43	89.5	74.4	Medium silt	0.00	
Nr. 100	0.15	9.5	7.9	Fine silt	1.42	
Nr. 200	0.07	8.1	6.7	Clay	1.95	
Pan	---	0.0	0.0			

*Percentages relative to entire sample mass



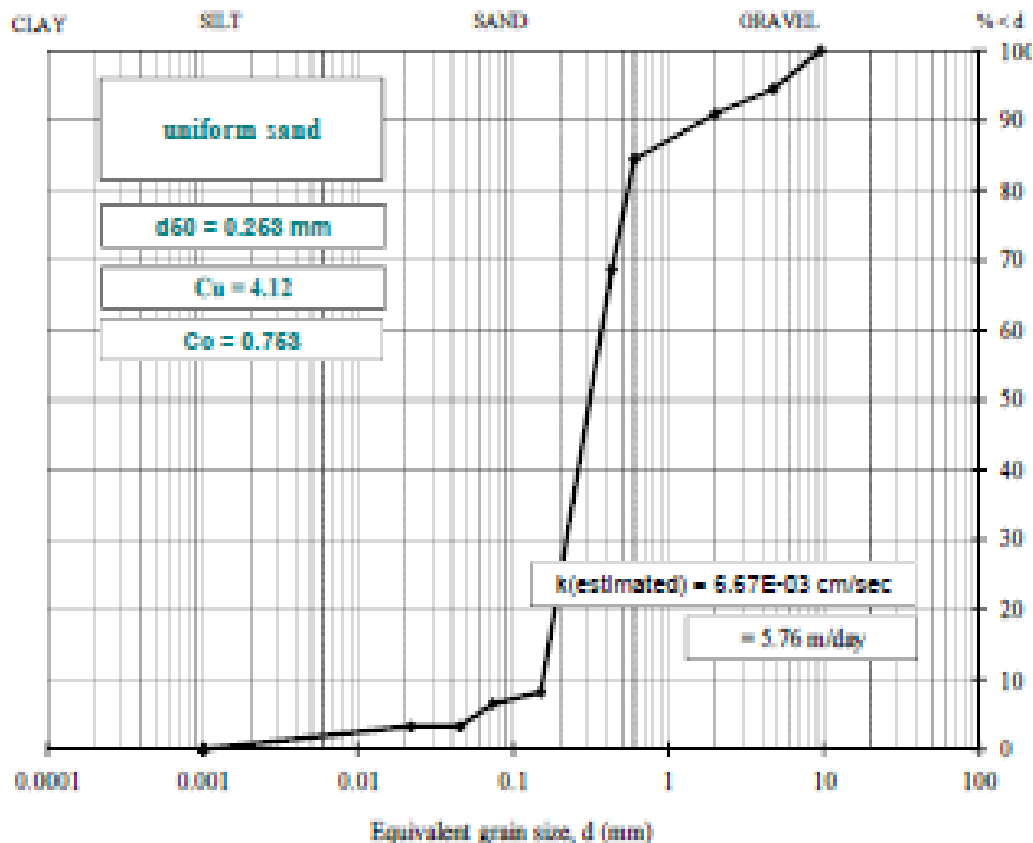
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH1
Depth	11.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	5.5
				Medium gravel	0.0	
				Fine gravel	5.5	
3/8"	9.50	114.9	100.0	Coarse sand	3.6	88.0
Nr. 4	4.75	108.6	94.5	Medium sand	22.3	
Nr. 10	2.00	104.5	90.9	Fine sand	62.1	
Nr. 30	0.60	97.0	84.4	Coarse silt	3.26	4.64
Nr. 40	0.43	78.9	68.7	Medium silt	0.00	
Nr. 100	0.15	9.4	8.2	Fine silt	1.37	
Nr. 200	0.07	7.5	6.5	Fine silt	1.37	
Fan	---	0.0	0.0	Clay	1.89	1.89

*Percentages relative to entire sample mass



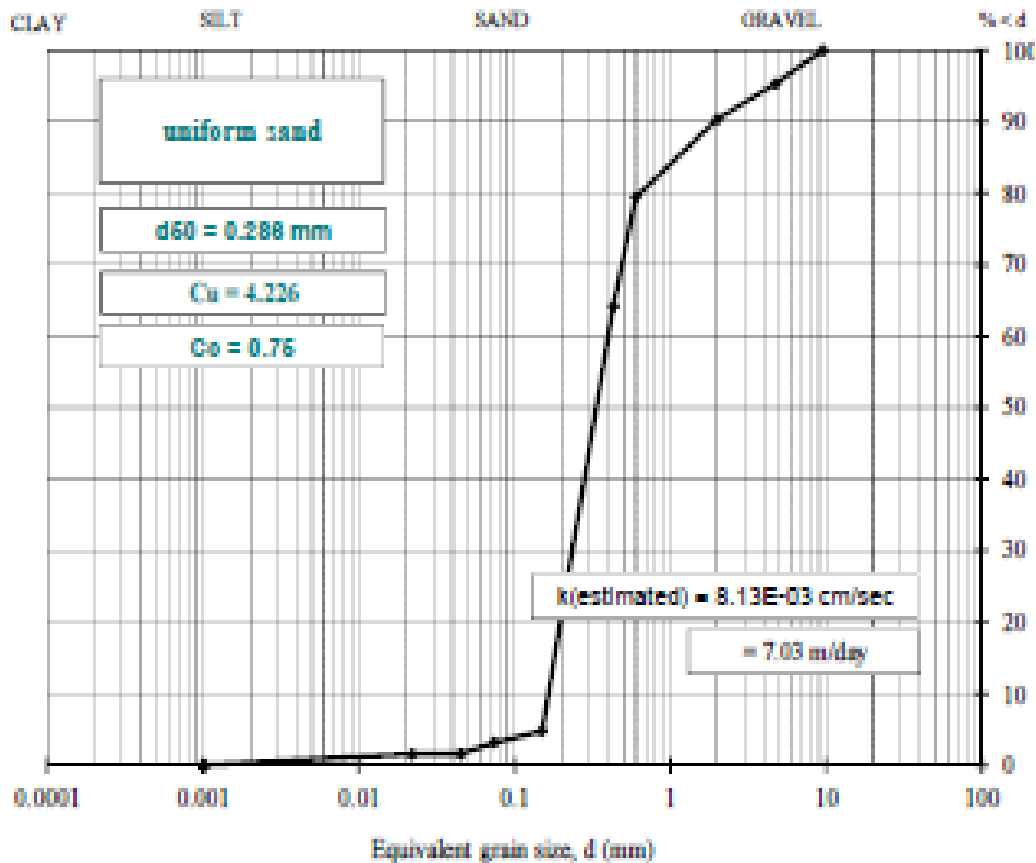
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH1
Depth	12.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	4.7
				Medium gravel	0.0	
				Fine gravel	4.7	
3/8"	9.50	86.0	100.0	Coarse sand	5.0	92.2
Nr. 4	4.75	82.0	95.3	Medium sand	26.2	
Nr. 10	2.00	77.7	90.3	Fine sand	61.0	
Nr. 30	0.60	68.3	79.4	Coarse silt	1.57	2.23
Nr. 40	0.43	55.2	64.2	Medium silt	0.00	
Nr. 100	0.15	4.1	4.8	Fine silt	0.66	
Nr. 200	0.07	2.7	3.1	Clay	0.91	
Pan	--	0.0	0.0	Clay	0.91	0.91

*Percentages relative to entire sample mass



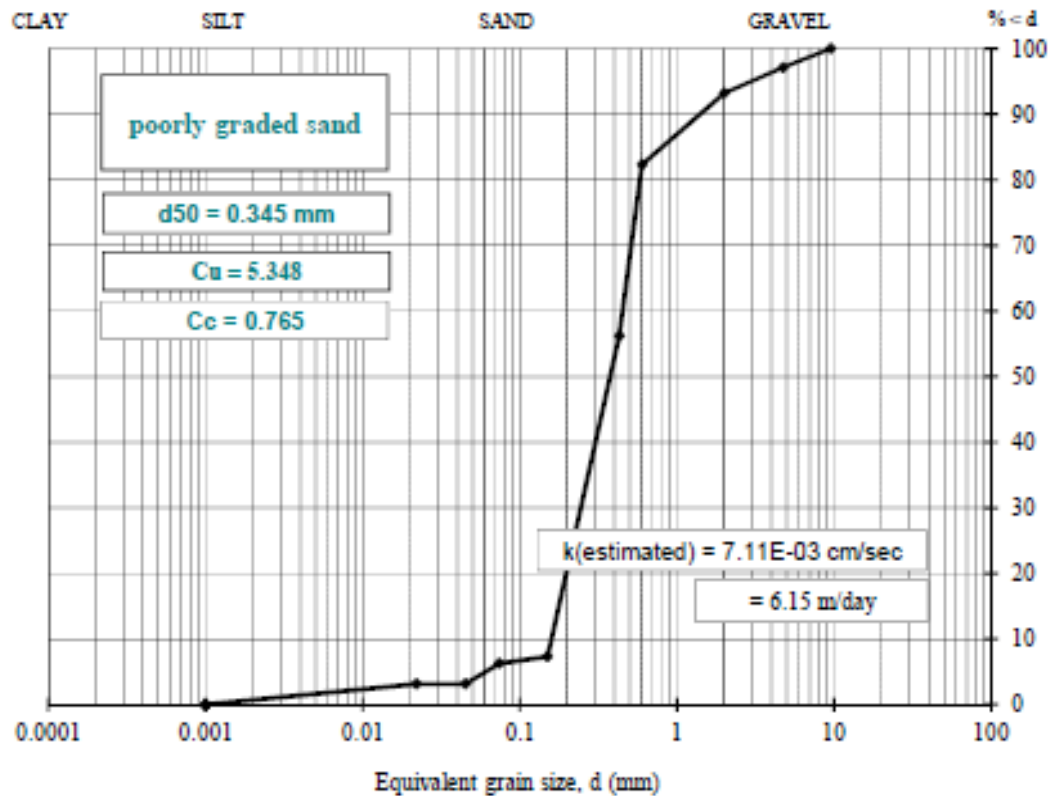
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH2
Depth	0.3 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	2.9
				Medium gravel	0.0	
				Fine gravel	2.9	
3/8"	9.50	125.7	100.0	Coarse sand	3.9	90.9
Nr. 4	4.75	122.1	97.1	Medium sand	37.0	
Nr. 10	2.00	117.2	93.2	Fine sand	50.0	
Nr. 30	0.60	103.5	82.3	Coarse silt	3.14	4.46
Nr. 40	0.43	70.7	56.2	Medium silt	0.00	
Nr. 100	0.15	9.2	7.3	Fine silt	1.32	
Nr. 200	0.07	7.9	6.3	Fine silt	1.32	1.82
Pan	---	0.0	0.0	Clay	1.82	

*Percentages relative to entire sample mass



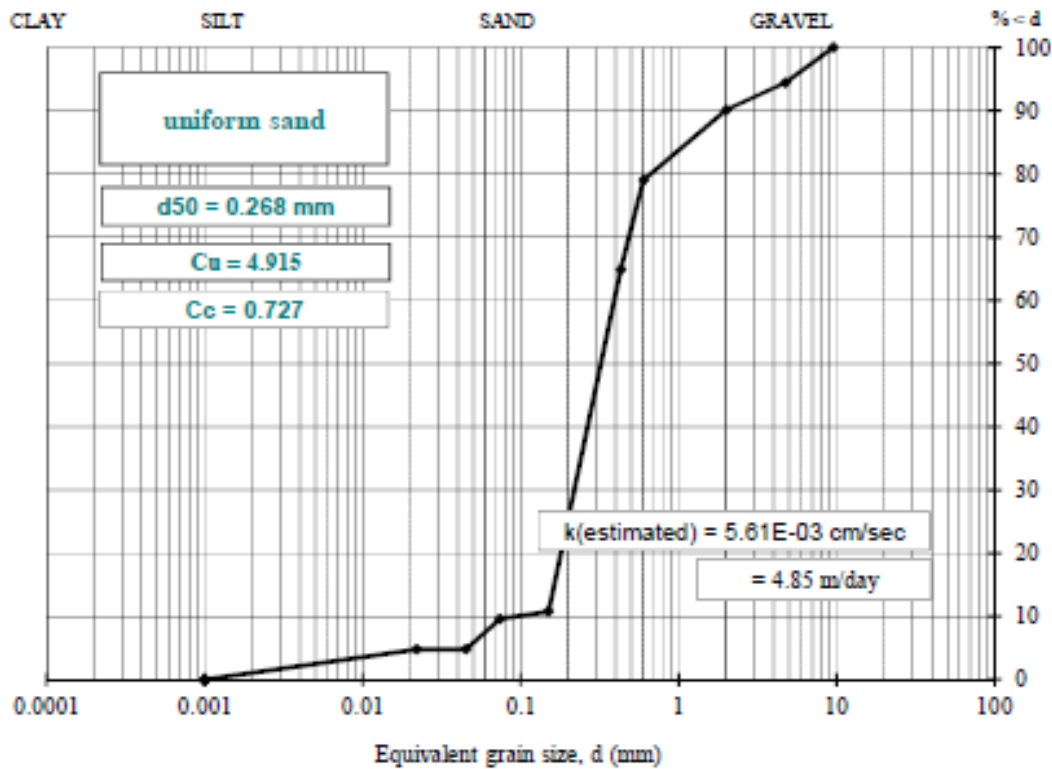
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Serdah)
Bore Hole No.	BH2
Depth	0.6 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	5.6
				Medium gravel	0.0	
				Fine gravel	5.6	
3/8"	9.50	120.7	100.0	Coarse sand	4.3	84.8
Nr. 4	4.75	114.0	94.4	Medium sand	25.3	
Nr. 10	2.00	108.8	90.1	Fine sand	55.3	
Nr. 30	0.60	95.4	79.0	Coarse silt	4.81	6.83
Nr. 40	0.43	78.3	64.9	Medium silt	0.00	
Nr. 100	0.15	13.0	10.8	Fine silt	2.02	
Nr. 200	0.07	11.6	9.6	Fine silt	2.02	2.79
Pan	---	0.0	0.0	Clay	2.79	

*Percentages relative to entire sample mass



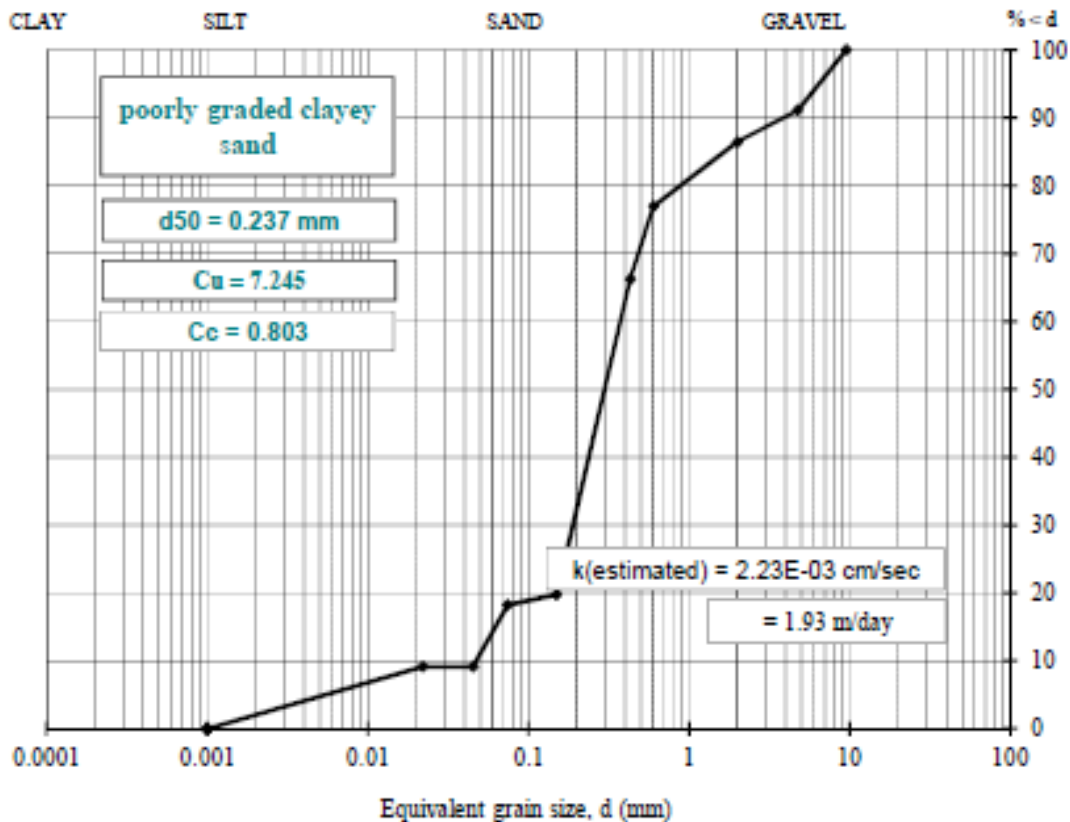
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH2
Depth	0.9 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	8.9
				Medium gravel	0.0	
				Fine gravel	8.9	
3/8"	9.50	125.0	100.0	Coarse sand	4.6	72.9
Nr. 4	4.75	113.9	91.1	Medium sand	20.2	
Nr. 10	2.00	108.1	86.5	Fine sand	48.0	
Nr. 30	0.60	96.2	77.0	Coarse silt	9.12	12.95
Nr. 40	0.43	82.8	66.2	Medium silt	0.00	
Nr. 100	0.15	24.7	19.8	Fine silt	3.83	
Nr. 200	0.07	22.8	18.2			
Pan	---	0.0	0.0	Clay	5.29	5.29

*Percentages relative to entire sample mass



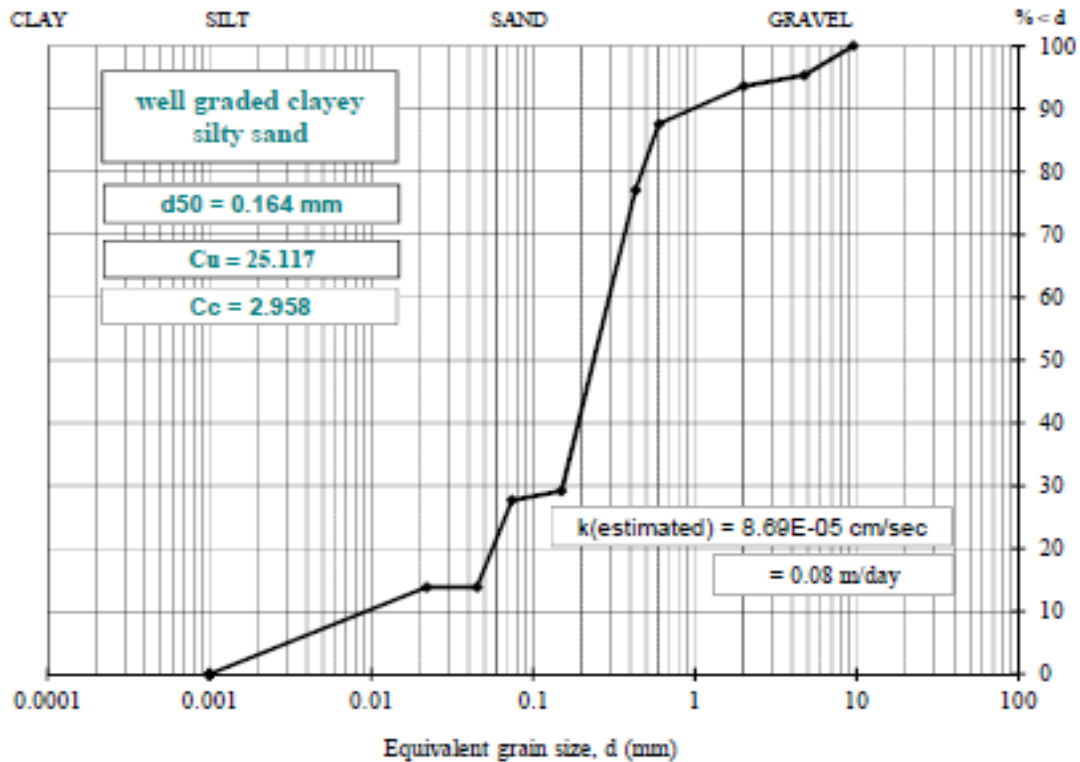
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Serdah)
Bore Hole No.	BH2
Depth	1.2 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	4.6
				Medium gravel	0.0	
				Fine gravel	4.6	
3/8"	9.50	195.7	100.0	Coarse sand	1.7	67.7
Nr. 4	4.75	186.6	95.4	Medium sand	16.6	
Nr. 10	2.00	183.2	93.6	Fine sand	49.4	
Nr. 30	0.60	171.4	87.6	Coarse silt	13.85	19.67
Nr. 40	0.43	150.8	77.1	Medium silt	0.00	
Nr. 100	0.15	57.1	29.2			
Nr. 200	0.07	54.2	27.7	Fine silt	5.82	
Pan	---	0.0	0.0	Clay	8.03	8.03

*Percentages relative to entire sample mass



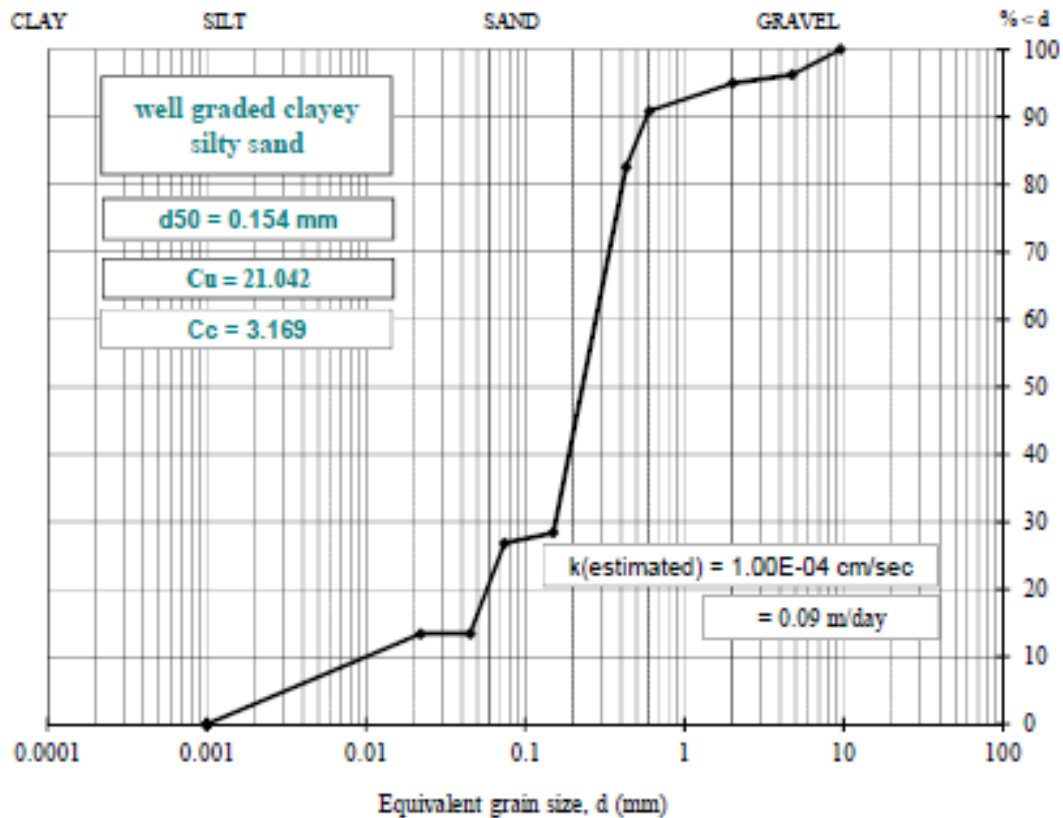
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH2
Depth	1.5 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	3.7
				Medium gravel	0.0	
				Fine gravel	3.7	
3/8"	9.50	161.0	100.0	Coarse sand	1.2	69.4
Nr. 4	4.75	155.0	96.3	Medium sand	12.4	
Nr. 10	2.00	153.0	95.0	Fine sand	55.8	
Nr. 30	0.60	146.3	90.9	Coarse silt	13.42	19.06
Nr. 40	0.43	133.0	82.6	Medium silt	0.00	
Nr. 100	0.15	45.7	28.4	Fine silt	5.64	
Nr. 200	0.07	43.2	26.8	Fine silt	5.64	
Pan	---	0.0	0.0	Clay	7.78	7.78

*Percentages relative to entire sample mass



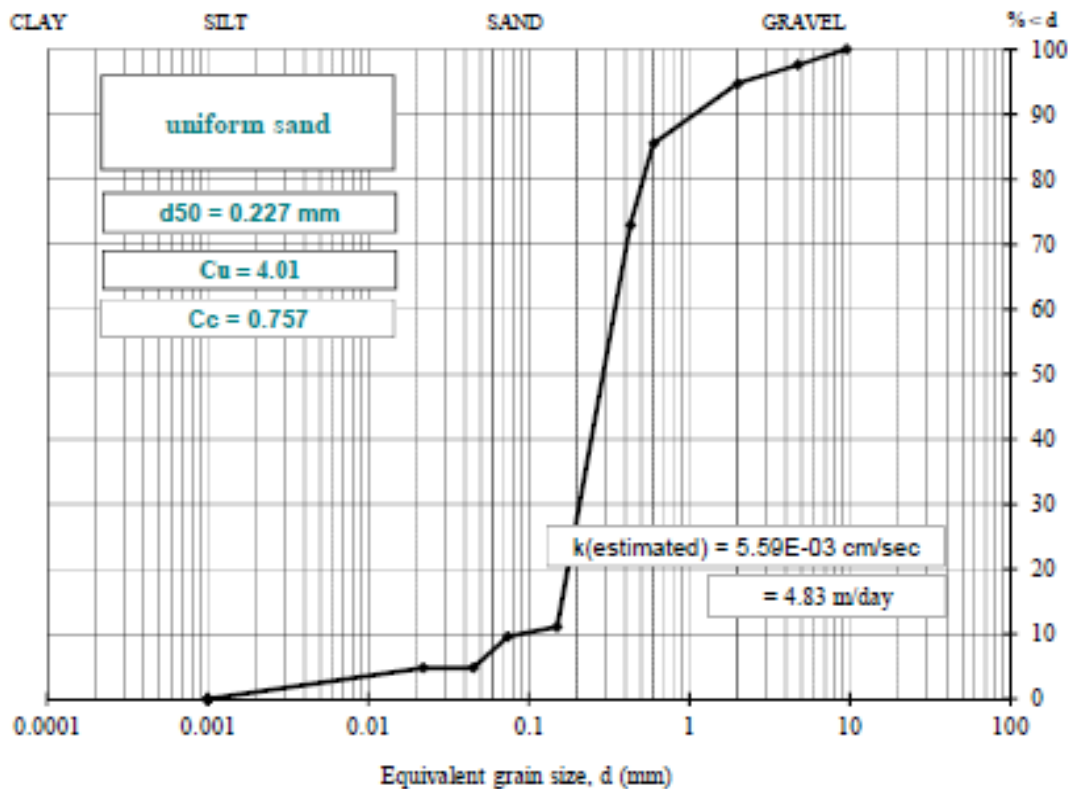
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH2
Depth	1.8 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	2.4
				Medium gravel	0.0	
				Fine gravel	2.4	
3/8"	9.50	121.7	100.0	Coarse sand	2.9	88.0
Nr. 4	4.75	118.8	97.6	Medium sand	21.8	
Nr. 10	2.00	115.3	94.7	Fine sand	63.4	
Nr. 30	0.60	104.1	85.5	Coarse silt	4.81	6.83
Nr. 40	0.43	88.8	73.0	Medium silt	0.00	
Nr. 100	0.15	13.5	11.1	Fine silt	2.02	
Nr. 200	0.07	11.7	9.6	Fine silt	2.02	
Pan	---	0.0	0.0	Clay	2.79	2.79

*Percentages relative to entire sample mass



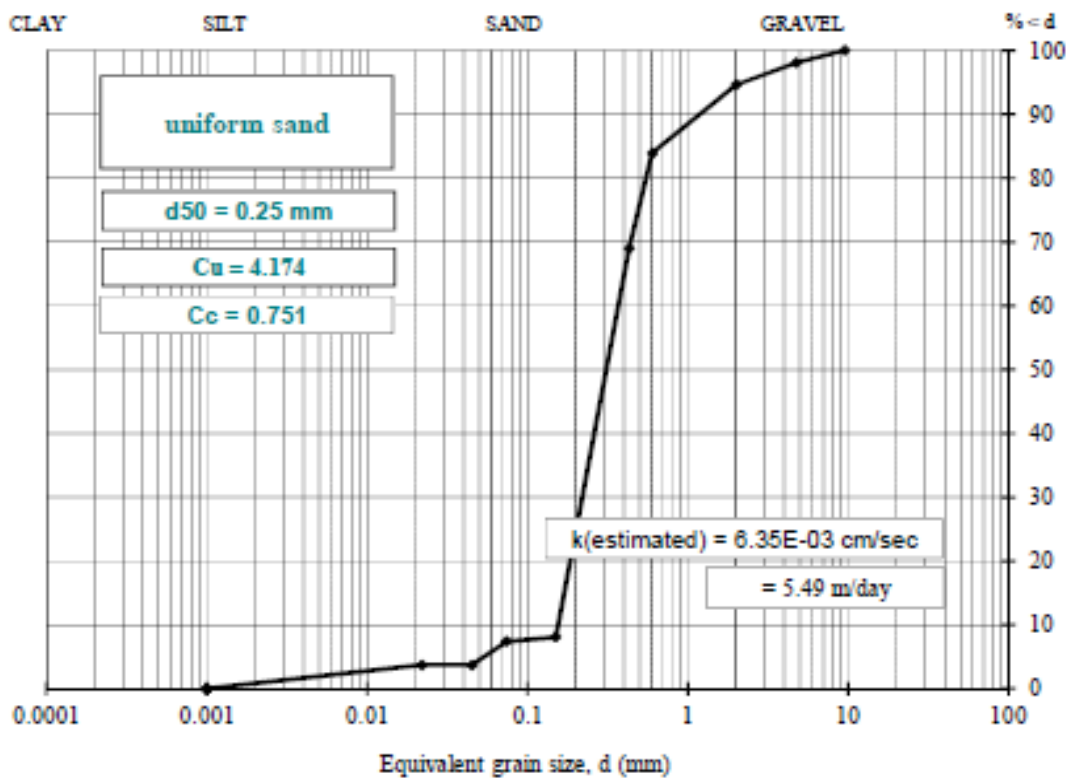
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH2
Depth	2.1 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	1.9
				Medium gravel	0.0	
				Fine gravel	1.9	
3/8"	9.50	87.7	100.0	Coarse sand	3.4	90.6
Nr. 4	4.75	86.0	98.1	Medium sand	25.7	
Nr. 10	2.00	83.0	94.6	Fine sand	61.6	
Nr. 30	0.60	73.6	83.9	Coarse silt	3.71	5.26
Nr. 40	0.43	60.5	69.0	Medium silt	0.00	
Nr. 100	0.15	7.1	8.1	Fine silt	1.56	
Nr. 200	0.07	6.5	7.4			
Pan	---	0.0	0.0	Clay	2.15	2.15

*Percentages relative to entire sample mass



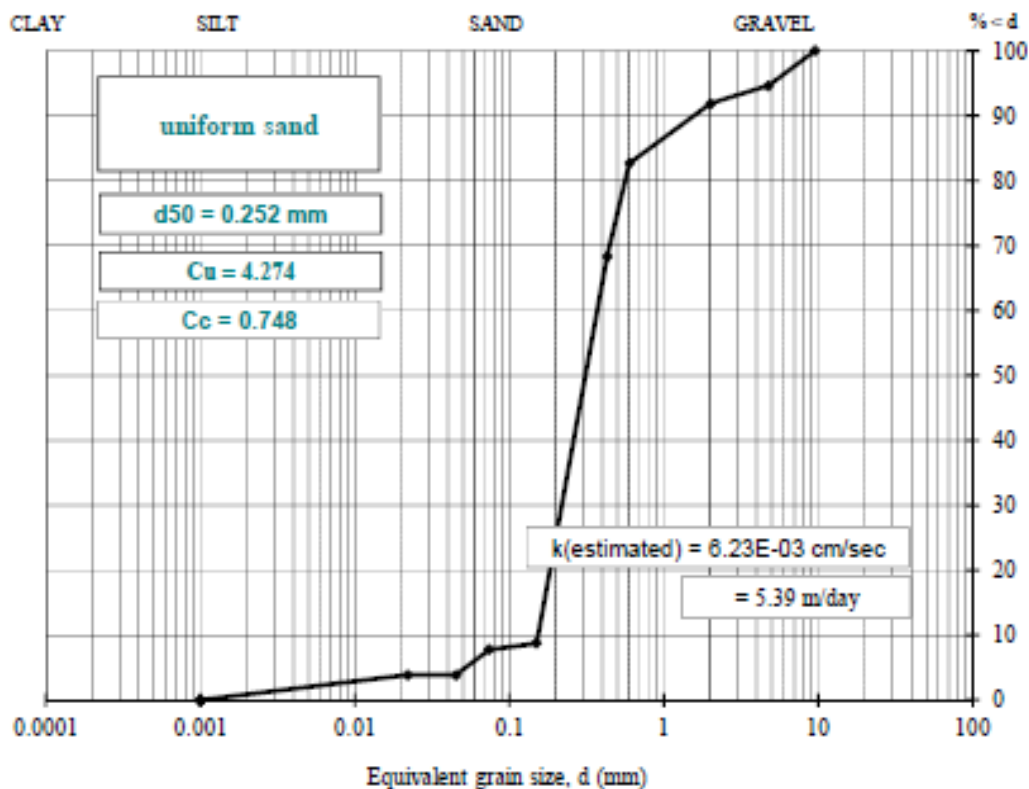
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH2
Depth	3.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	5.4
				Medium gravel	0.0	
				Fine gravel	5.4	
3/8"	9.50	101.7	100.0	Coarse sand	2.8	86.8
Nr. 4	4.75	96.2	94.6	Medium sand	23.5	
Nr. 10	2.00	93.4	91.8	Fine sand	60.6	
Nr. 30	0.60	84.1	82.7	Coarse silt	3.88	5.52
Nr. 40	0.43	69.5	68.3	Medium silt	0.00	
Nr. 100	0.15	8.9	8.8	Fine silt	1.63	
Nr. 200	0.07	7.9	7.8	Clay	2.25	2.25
Pan	---	0.0	0.0			

*Percentages relative to entire sample mass



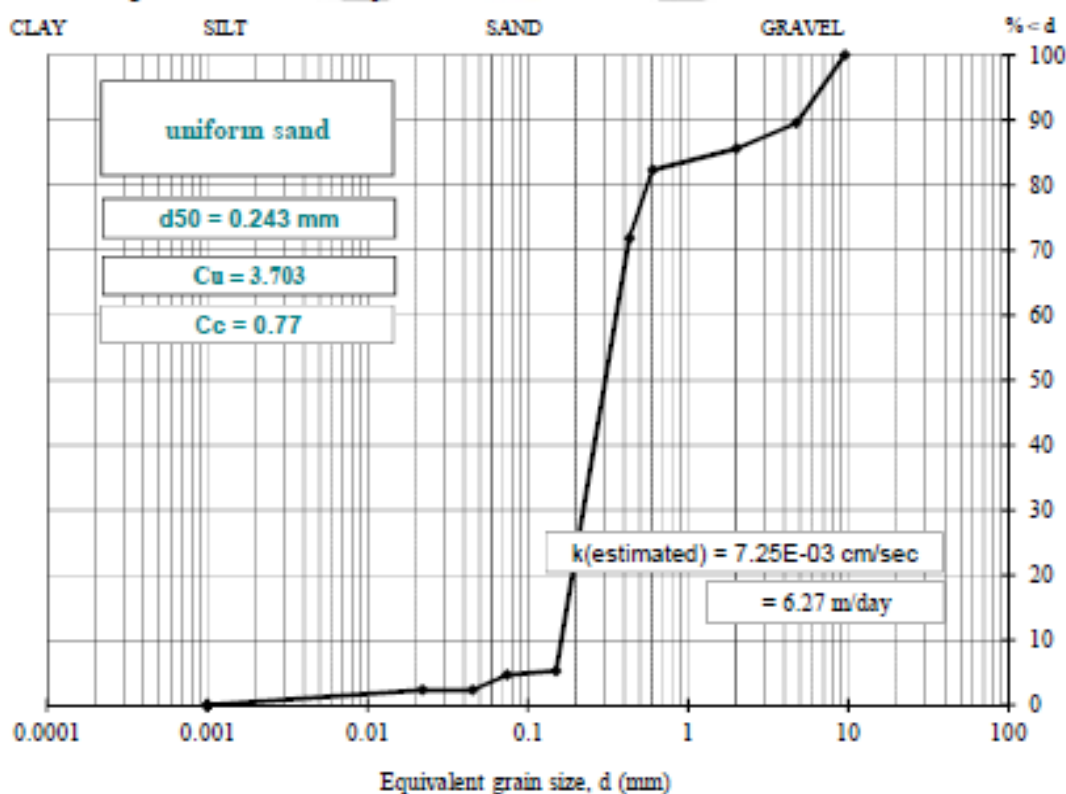
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH2
Depth	4.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	10.4
				Medium gravel	0.0	
				Fine gravel	10.4	
3/8"	9.50	122.9	100.0	Coarse sand	4.0	84.9
Nr. 4	4.75	110.1	89.6	Medium sand	13.8	
Nr. 10	2.00	105.2	85.6	Fine sand	67.2	
Nr. 30	0.60	101.2	82.3	Coarse silt	2.32	3.29
Nr. 40	0.43	88.3	71.8	Medium silt	0.00	
Nr. 100	0.15	6.5	5.3	Fine silt	0.97	
Nr. 200	0.07	5.7	4.6	Fine silt	0.97	
Pan	---	0.0	0.0	Clay	1.34	1.34

*Percentages relative to entire sample mass



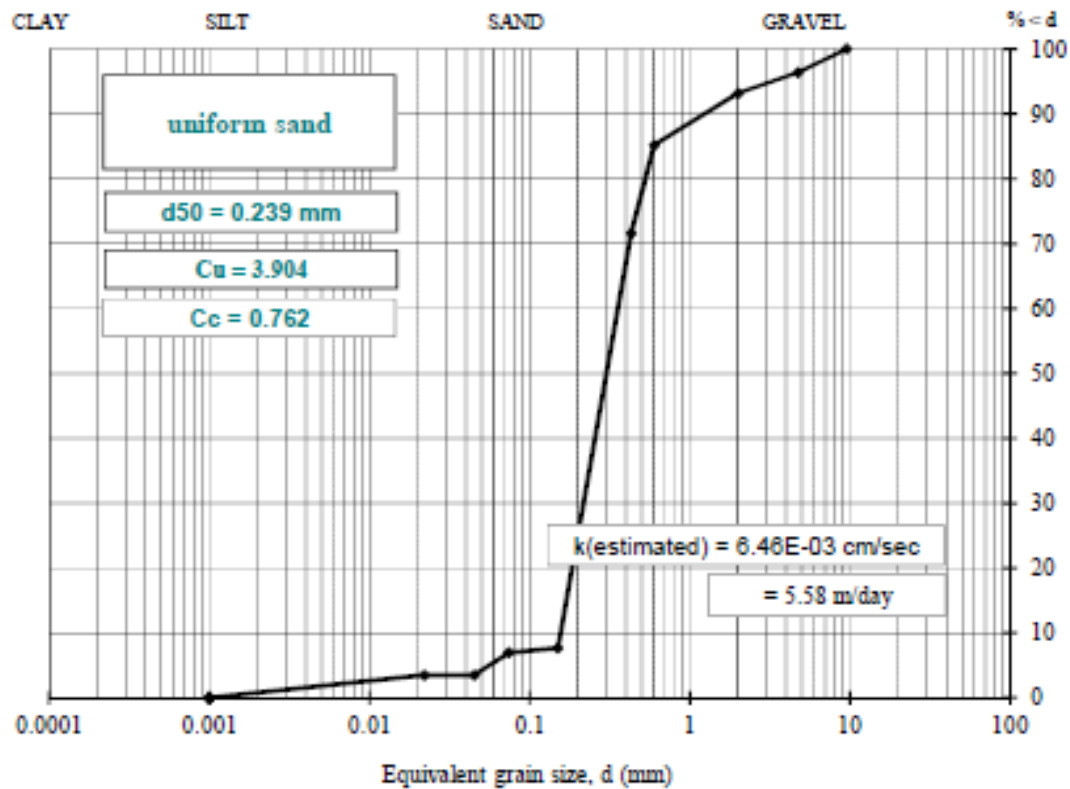
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Serdah)
Bore Hole No.	BH2
Depth	5.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	3.6
				Medium gravel	0.0	
				Fine gravel	3.6	
3/8"	9.50	127.7	100.0	Coarse sand	3.2	89.4
Nr. 4	4.75	123.1	96.4	Medium sand	21.6	
Nr. 10	2.00	119.0	93.2	Fine sand	64.6	
Nr. 30	0.60	108.8	85.2	Coarse silt	3.48	4.95
Nr. 40	0.43	91.4	71.6	Medium silt	0.00	
Nr. 100	0.15	9.8	7.7	Fine silt	1.46	
Nr. 200	0.07	8.9	7.0			
Pan	---	0.0	0.0	Clay	2.02	2.02

*Percentages relative to entire sample mass



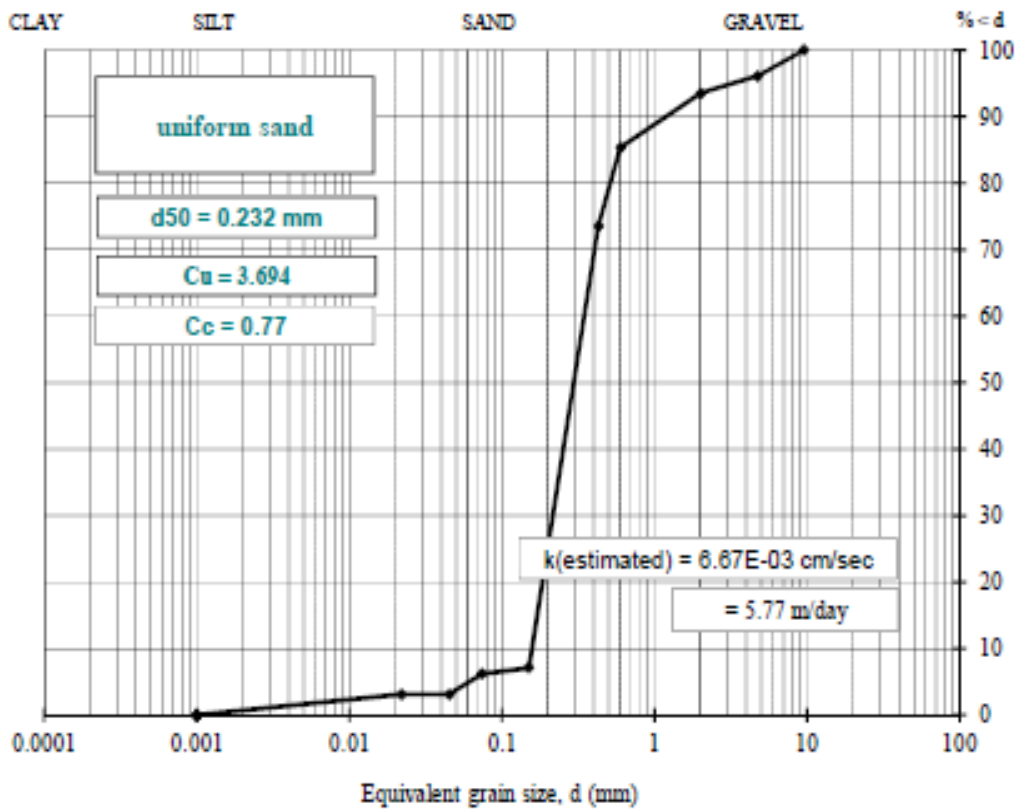
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH2
Depth	6.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	3.9
				Medium gravel	0.0	
				Fine gravel	3.9	
3/8"	9.50	99.8	100.0	Coarse sand	2.6	89.9
Nr. 4	4.75	95.9	96.1	Medium sand	19.9	
Nr. 10	2.00	93.3	93.5	Fine sand	67.3	
Nr. 30	0.60	85.2	85.4	Coarse silt	3.11	4.41
Nr. 40	0.43	73.4	73.5	Medium silt	0.00	
Nr. 100	0.15	7.1	7.1	Fine silt	1.31	
Nr. 200	0.07	6.2	6.2	Fine silt	1.31	1.80
Pan	---	0.0	0.0	Clay	1.80	

*Percentages relative to entire sample mass



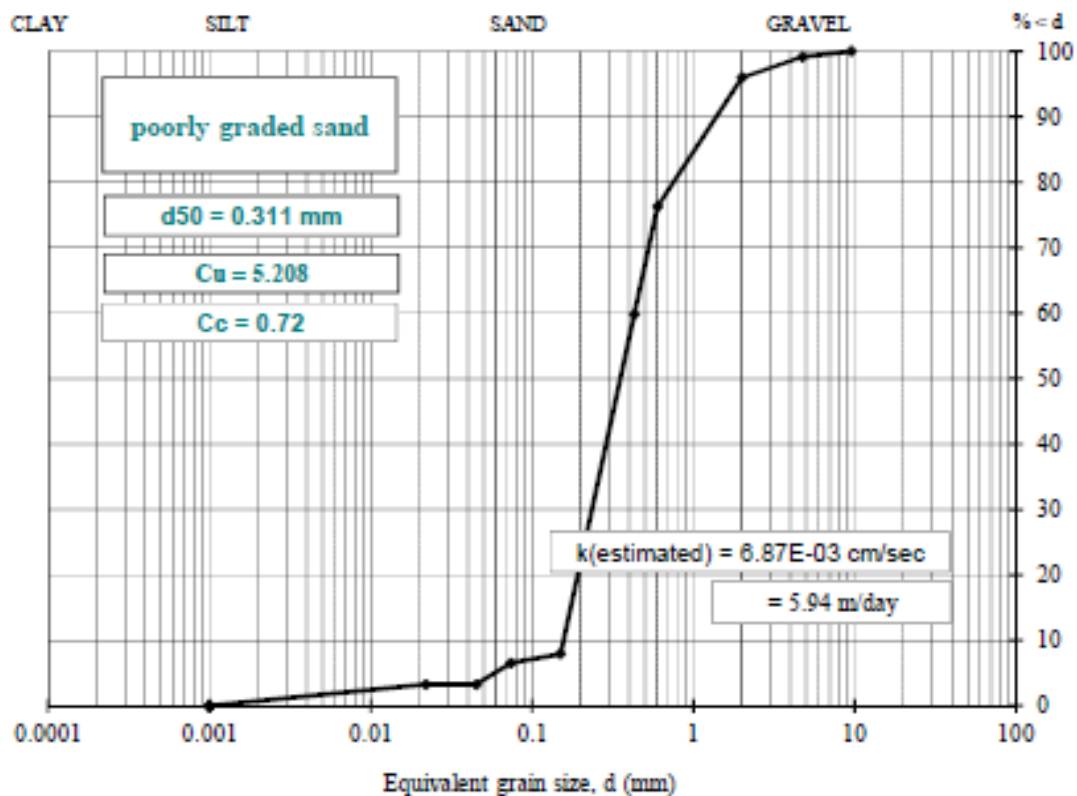
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH2
Depth	7.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	0.8
				Medium gravel	0.0	
				Fine gravel	0.8	
3/8"	9.50	94.5	100.0	Coarse sand	3.2	92.6
Nr. 4	4.75	93.7	99.2	Medium sand	36.2	
Nr. 10	2.00	90.7	96.0	Fine sand	53.2	
Nr. 30	0.60	72.1	76.3	Coarse silt	3.28	4.66
Nr. 40	0.43	56.5	59.8	Medium silt	0.00	
Nr. 100	0.15	7.5	7.9	Fine silt	1.38	
Nr. 200	0.07	6.2	6.6	Clay	1.90	
Pan	---	0.0	0.0			1.90

*Percentages relative to entire sample mass



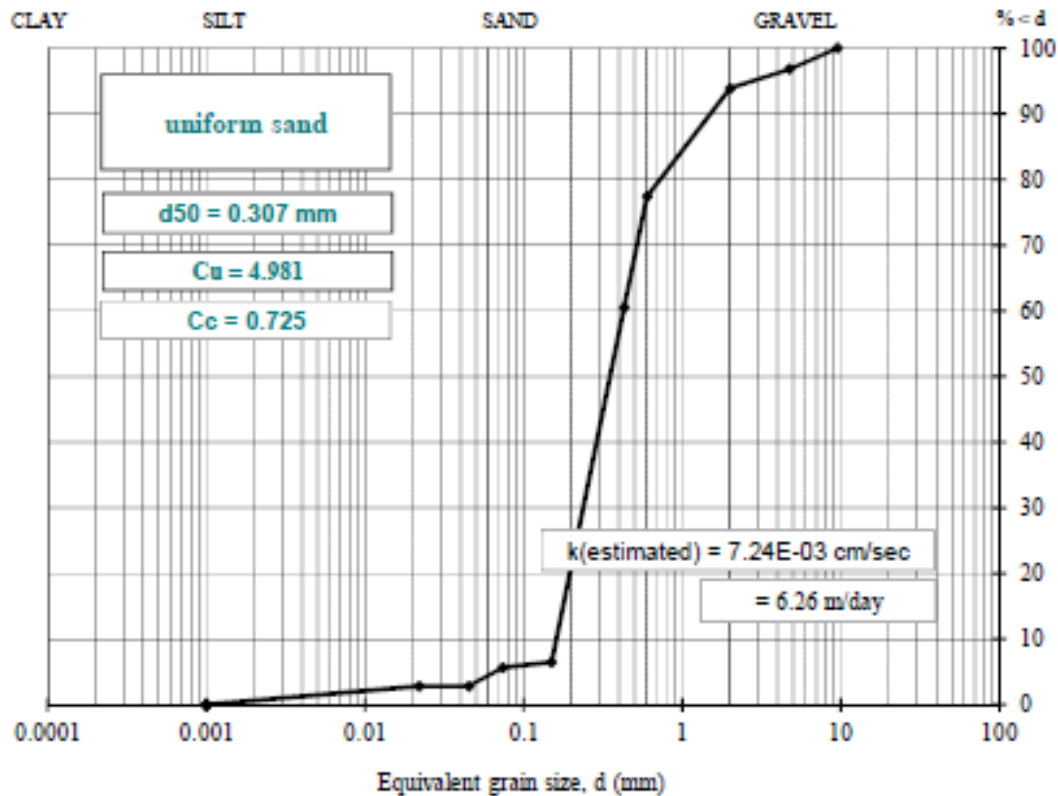
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Serdah)
Bore Hole No.	BH2
Depth	8.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	3.2
				Medium gravel	0.0	
				Fine gravel	3.2	
3/8"	9.50	146.9	100.0	Coarse sand	2.9	91.2
Nr. 4	4.75	142.2	96.8	Medium sand	33.4	
Nr. 10	2.00	137.9	93.9	Fine sand	54.8	
Nr. 30	0.60	113.7	77.4	Coarse silt	2.83	4.01
Nr. 40	0.43	88.8	60.4	Medium silt	0.00	
Nr. 100	0.15	9.5	6.5	Fine silt	1.19	
Nr. 200	0.07	8.3	5.7	Fine silt	1.19	
Pan	---	0.0	0.0	Clay	1.64	1.64

*Percentages relative to entire sample mass



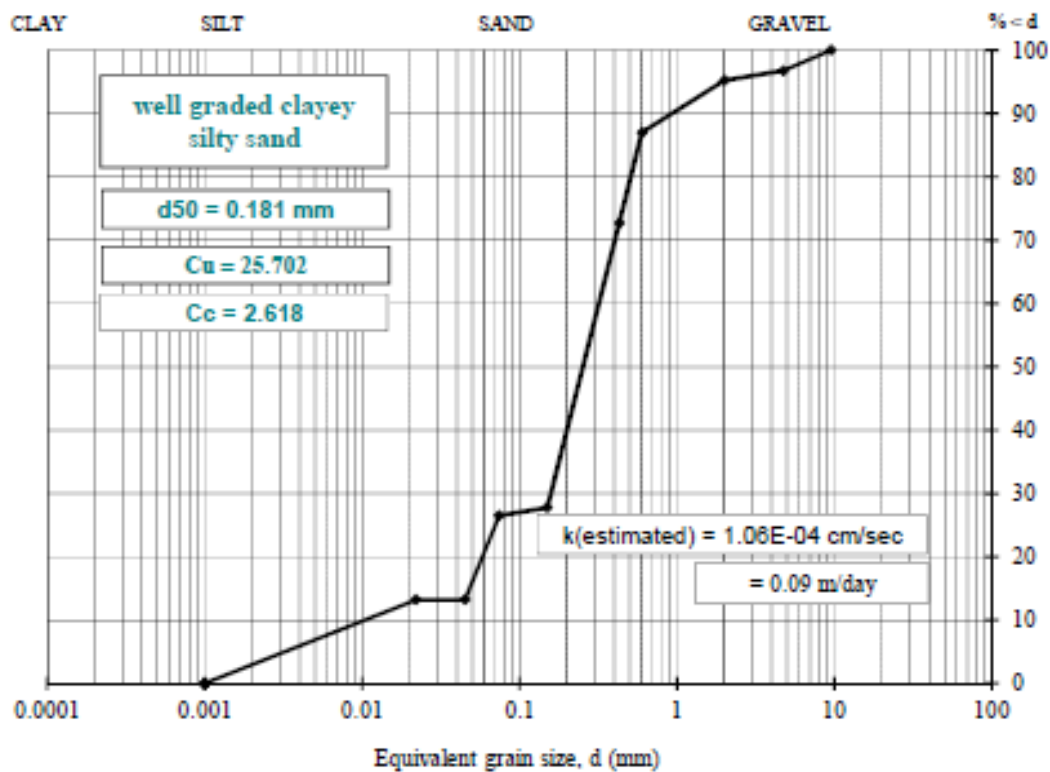
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH2
Depth	9.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	3.2
				Medium gravel	0.0	
				Fine gravel	3.2	
3/8"	9.50	180.0	100.0	Coarse sand	1.6	70.3
Nr. 4	4.75	174.2	96.8	Medium sand	22.5	
Nr. 10	2.00	171.4	95.2	Fine sand	46.2	
Nr. 30	0.60	156.6	87.0	Coarse silt	13.25	18.82
Nr. 40	0.43	130.9	72.7	Medium silt	0.00	
Nr. 100	0.15	50.0	27.8	Fine silt	5.57	
Nr. 200	0.07	47.7	26.5	Fine silt	5.57	7.68
Pan	---	0.0	0.0	Clay	7.68	

*Percentages relative to entire sample mass



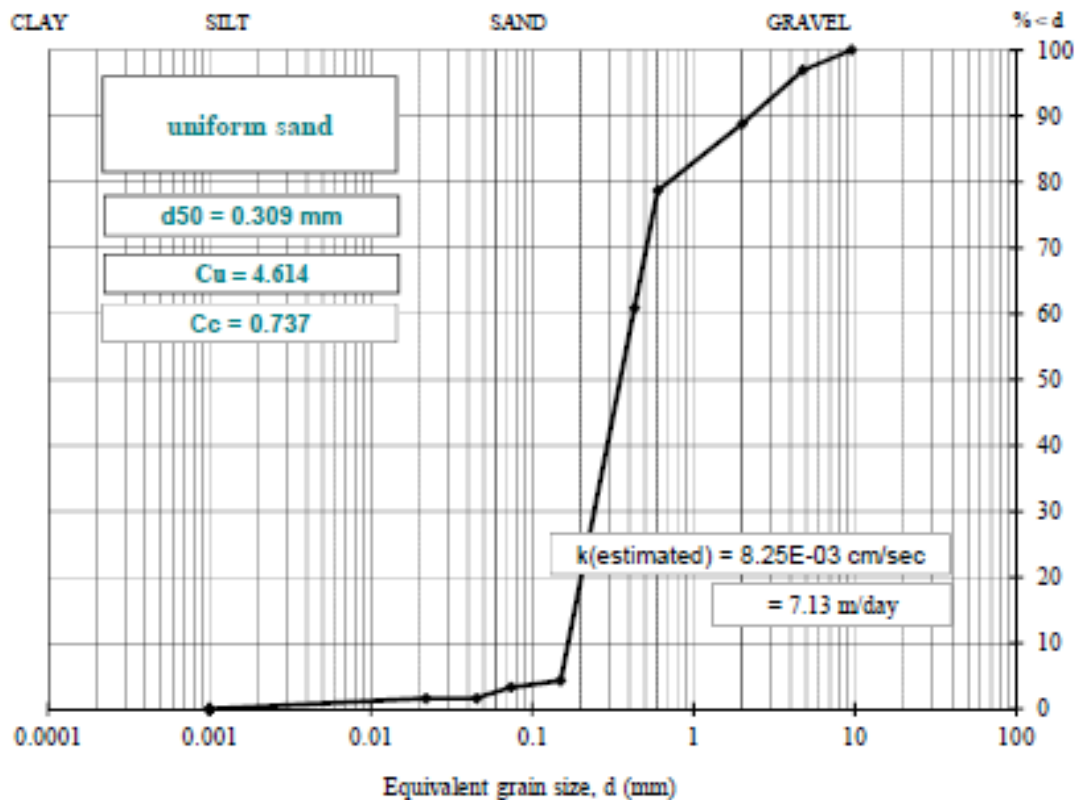
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH2
Depth	10.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	3.0
				Medium gravel	0.0	
				Fine gravel	3.0	
3/8"	9.50	115.4	100.0	Coarse sand	8.1	93.7
Nr. 4	4.75	111.9	97.0	Medium sand	28.0	
Nr. 10	2.00	102.5	88.8	Fine sand	57.5	
Nr. 30	0.60	90.8	78.7	Coarse silt	1.65	2.34
Nr. 40	0.43	70.2	60.8	Medium silt	0.00	
Nr. 100	0.15	5.0	4.3	Fine silt	0.69	
Nr. 200	0.07	3.8	3.3			
Pan	---	0.0	0.0	Clay	0.95	0.95

*Percentages relative to entire sample mass



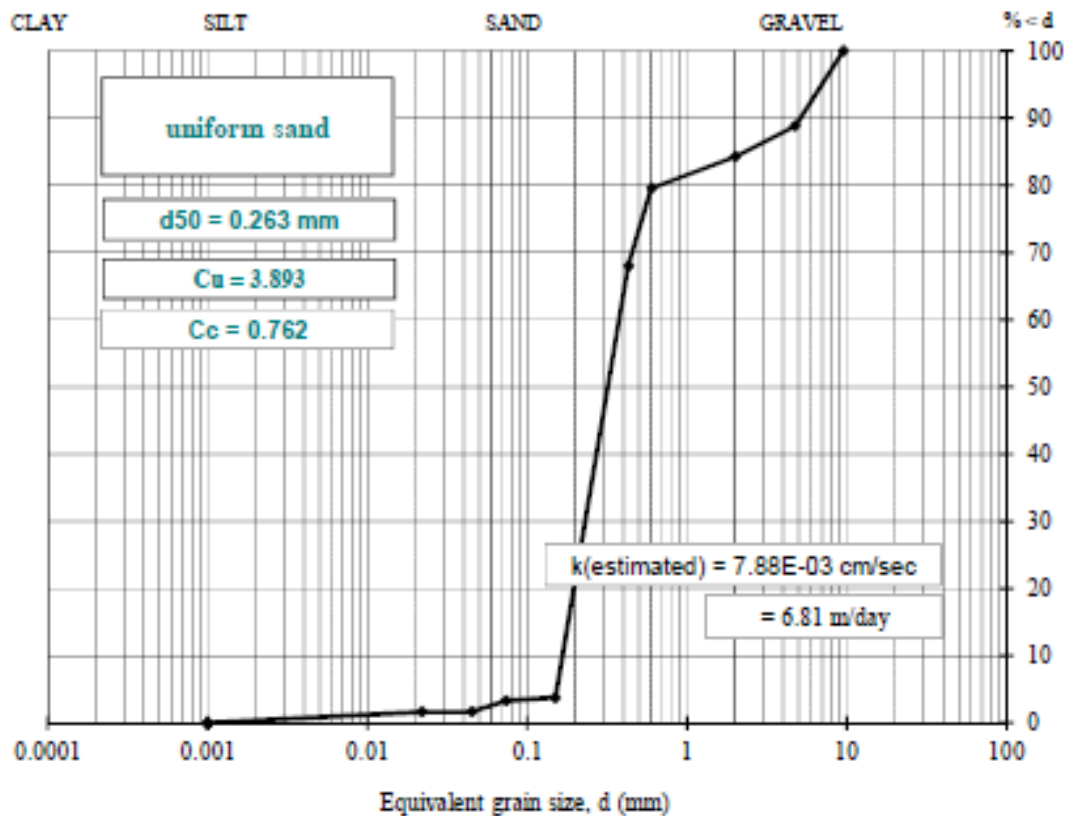
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH2
Depth	11.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	11.2
				Medium gravel	0.0	
				Fine gravel	11.2	
3/8"	9.50	120.8	100.0	Coarse sand	4.6	85.5
Nr. 4	4.75	107.3	88.8	Medium sand	16.2	
Nr. 10	2.00	101.8	84.3	Fine sand	64.7	
Nr. 30	0.60	96.1	79.6	Coarse silt	1.66	2.35
Nr. 40	0.43	82.2	68.0	Medium silt	0.00	
Nr. 100	0.15	4.6	3.8	Fine silt	0.70	
Nr. 200	0.07	4.0	3.3	Fine silt	0.70	
Pan	---	0.0	0.0	Clay	0.96	0.96

*Percentages relative to entire sample mass



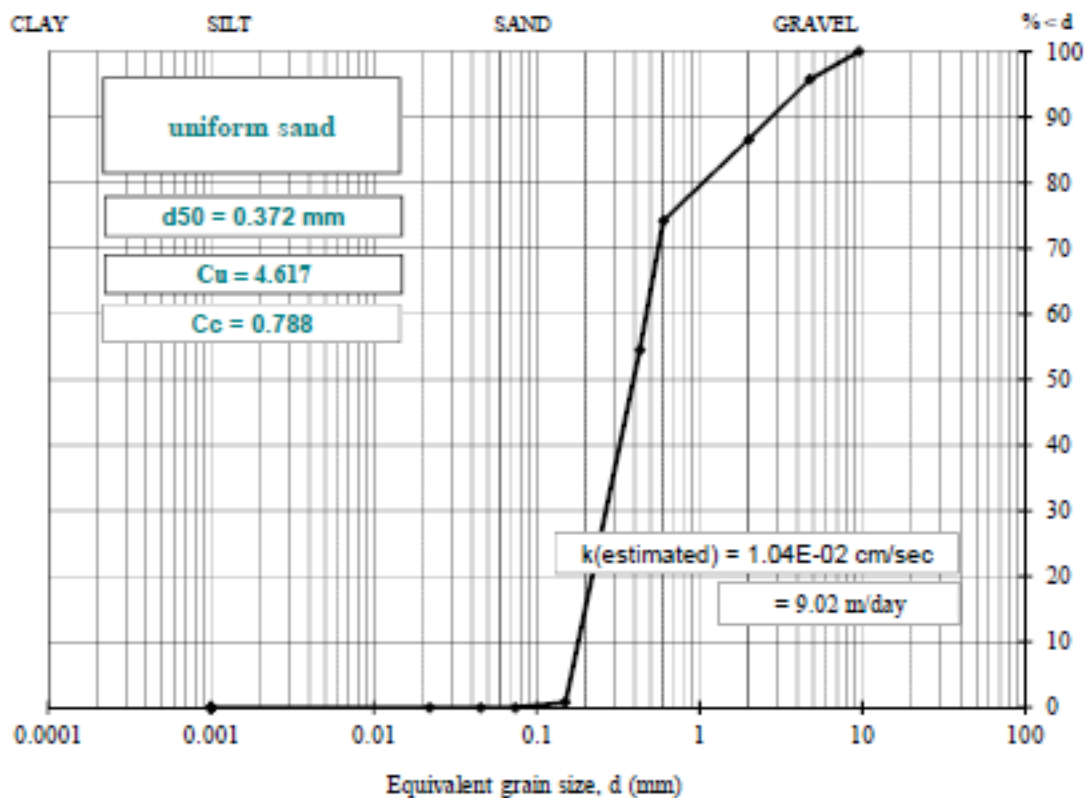
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH2
Depth	12.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	4.2
				Medium gravel	0.0	
				Fine gravel	4.2	
3/8"	9.50	103.8	100.0	Coarse sand	9.2	95.8
Nr. 4	4.75	99.4	95.8	Medium sand	32.1	
Nr. 10	2.00	89.9	86.6	Fine sand	54.5	
Nr. 30	0.60	77.0	74.2	Coarse silt	0.00	0.00
Nr. 40	0.43	56.6	54.5	Medium silt	0.00	
Nr. 100	0.15	0.8	0.8	Fine silt	0.00	
Nr. 200	0.07	0.0	0.0			
Pan	---	0.0	0.0	Clay	0.00	0.00

*Percentages relative to entire sample mass



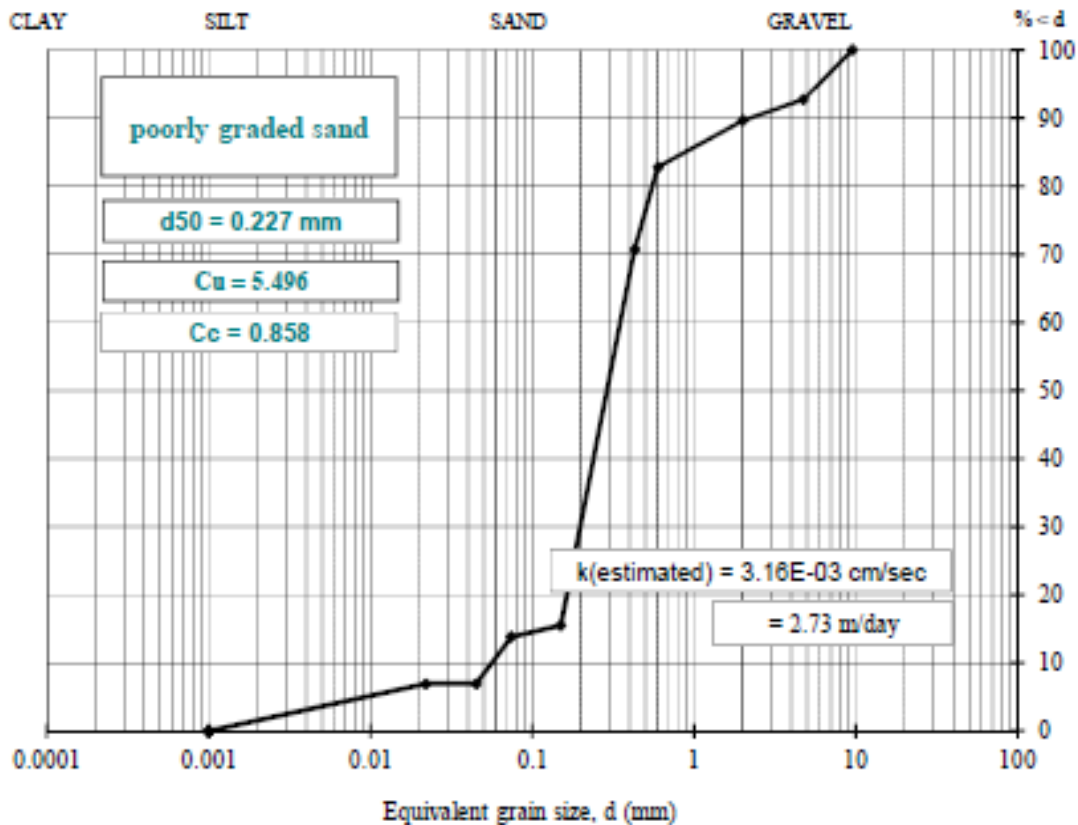
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH3
Depth	0.3 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	7.2
				Medium gravel	0.0	
				Fine gravel	7.2	
3/8"	9.50	118.7	100.0	Coarse sand	3.1	78.9
Nr. 4	4.75	110.1	92.8	Medium sand	19.0	
Nr. 10	2.00	106.4	89.6	Fine sand	56.9	
Nr. 30	0.60	98.3	82.8	Coarse silt	6.91	9.81
Nr. 40	0.43	83.9	70.7	Medium silt	0.00	
Nr. 100	0.15	18.4	15.5	Fine silt	2.90	
Nr. 200	0.07	16.4	13.8			
Pan	---	0.0	0.0	Clay	4.00	4.00

*Percentages relative to entire sample mass



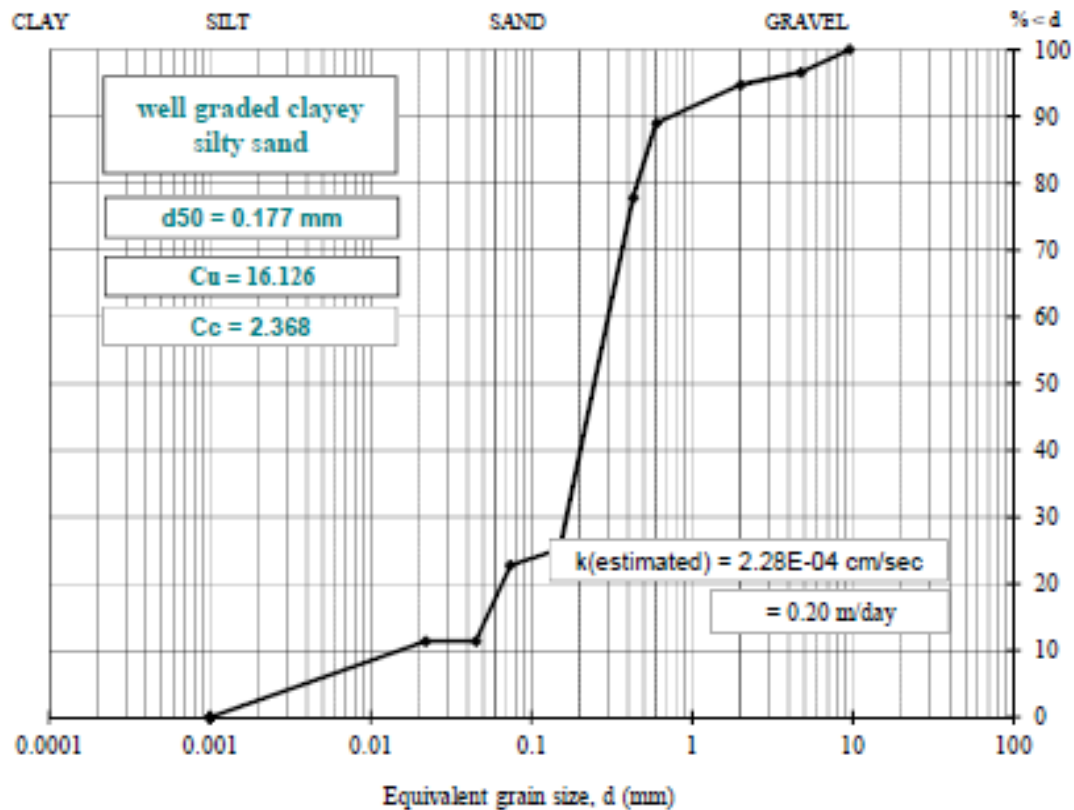
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH3
Depth	0.6 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	3.4
				Medium gravel	0.0	
				Fine gravel	3.4	
3/8"	9.50	133.0	100.0	Coarse sand	1.9	73.8
Nr. 4	4.75	128.5	96.6	Medium sand	16.9	
Nr. 10	2.00	126.0	94.7	Fine sand	55.0	
Nr. 30	0.60	118.4	89.0	Coarse silt	11.39	16.18
Nr. 40	0.43	103.5	77.8	Medium silt	0.00	
Nr. 100	0.15	33.6	25.3	Fine silt	4.79	
Nr. 200	0.07	30.3	22.8	Fine silt	4.79	6.60
Pan	---	0.0	0.0	Clay	6.60	

*Percentages relative to entire sample mass



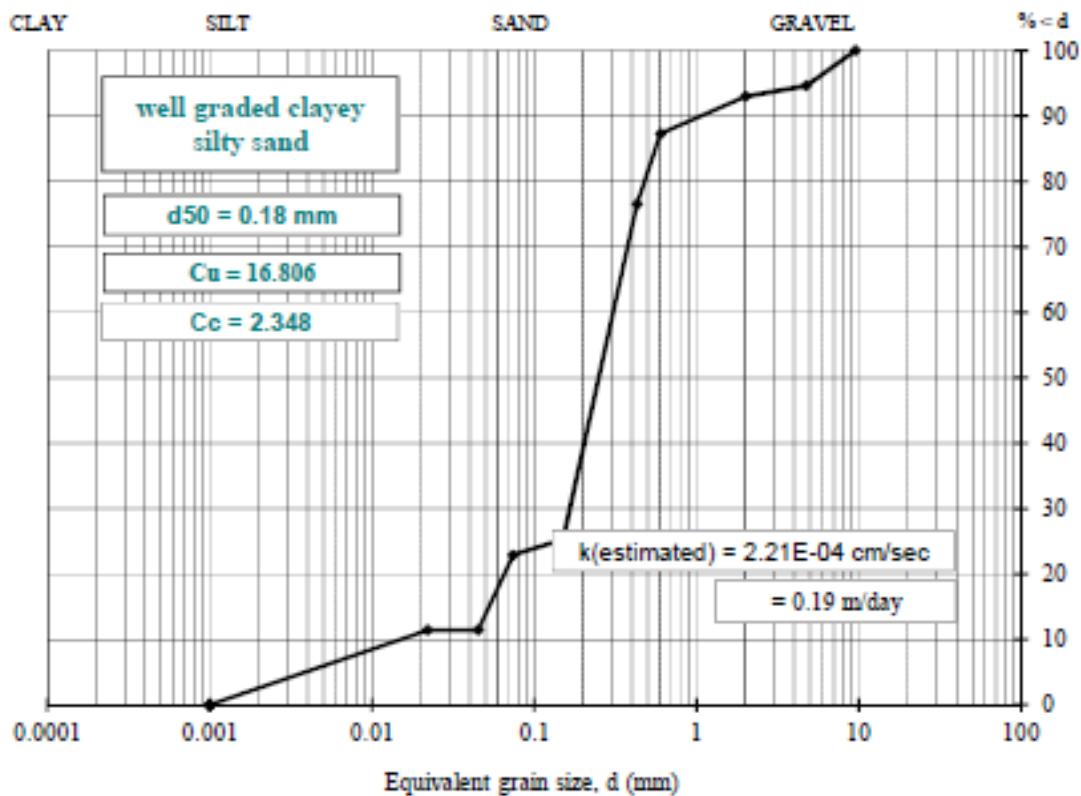
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH3
Depth	0.9 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	5.4
				Medium gravel	0.0	
				Fine gravel	5.4	
3/8"	9.50	181.2	100.0	Coarse sand	1.7	71.7
Nr. 4	4.75	171.5	94.6	Medium sand	16.4	
Nr. 10	2.00	168.5	93.0	Fine sand	53.6	
Nr. 30	0.60	158.2	87.3	Coarse silt	11.45	16.26
Nr. 40	0.43	138.7	76.5	Medium silt	0.00	
Nr. 100	0.15	45.7	25.2	Fine silt	4.81	
Nr. 200	0.07	41.5	22.9	Fine silt	4.81	
Pan	---	0.0	0.0	Clay	6.64	6.64

*Percentages relative to entire sample mass



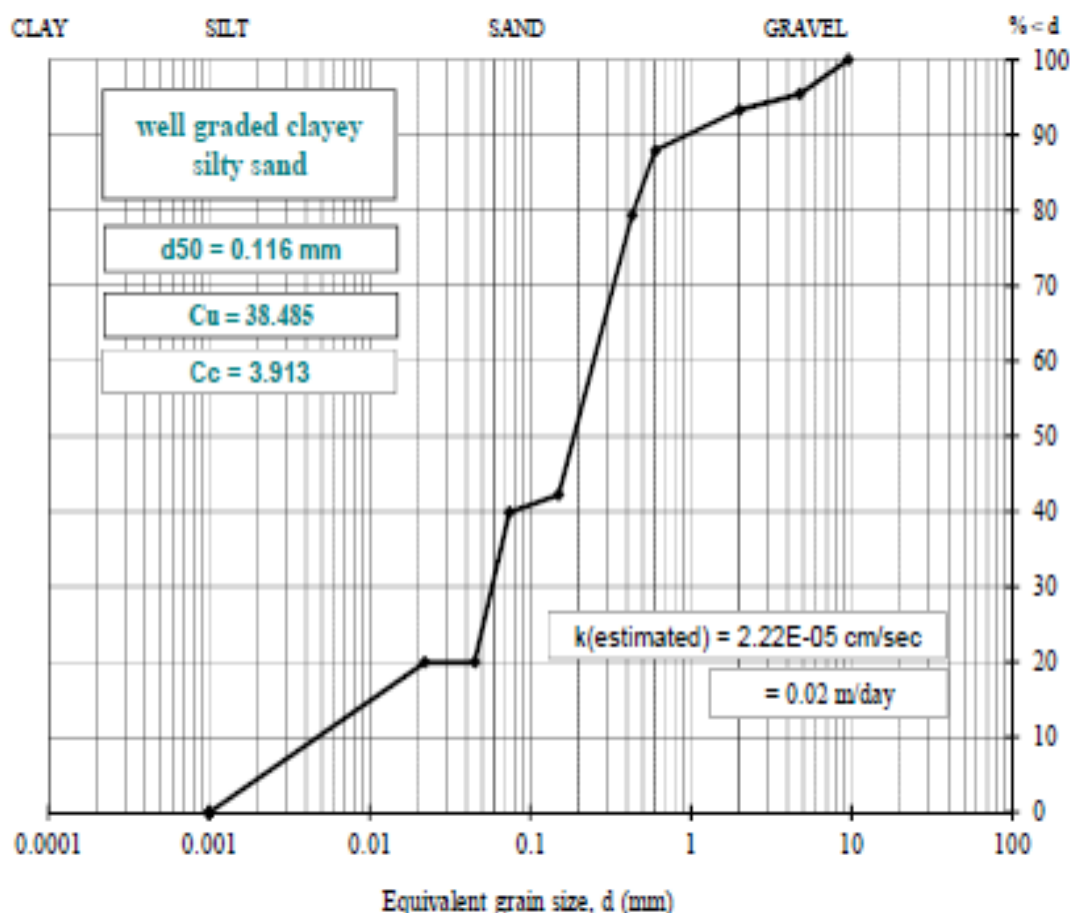
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH3
Depth	1.2 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	4.5
				Medium gravel	0.0	
				Fine gravel	4.5	
3/8"	9.50	108.1	100.0	Coarse sand	2.1	55.6
Nr. 4	4.75	103.2	95.5	Medium sand	14.0	
Nr. 10	2.00	100.9	93.3	Fine sand	39.5	
Nr. 30	0.60	95.1	88.0	Coarse silt	19.94	28.31
Nr. 40	0.43	85.8	79.4	Medium silt	0.00	
Nr. 100	0.15	45.6	42.2	Fine silt	8.38	
Nr. 200	0.07	43.1	39.9	Fine silt	8.38	
Pan	---	0.0	0.0	Clay	11.56	11.56

*Percentages relative to entire sample mass



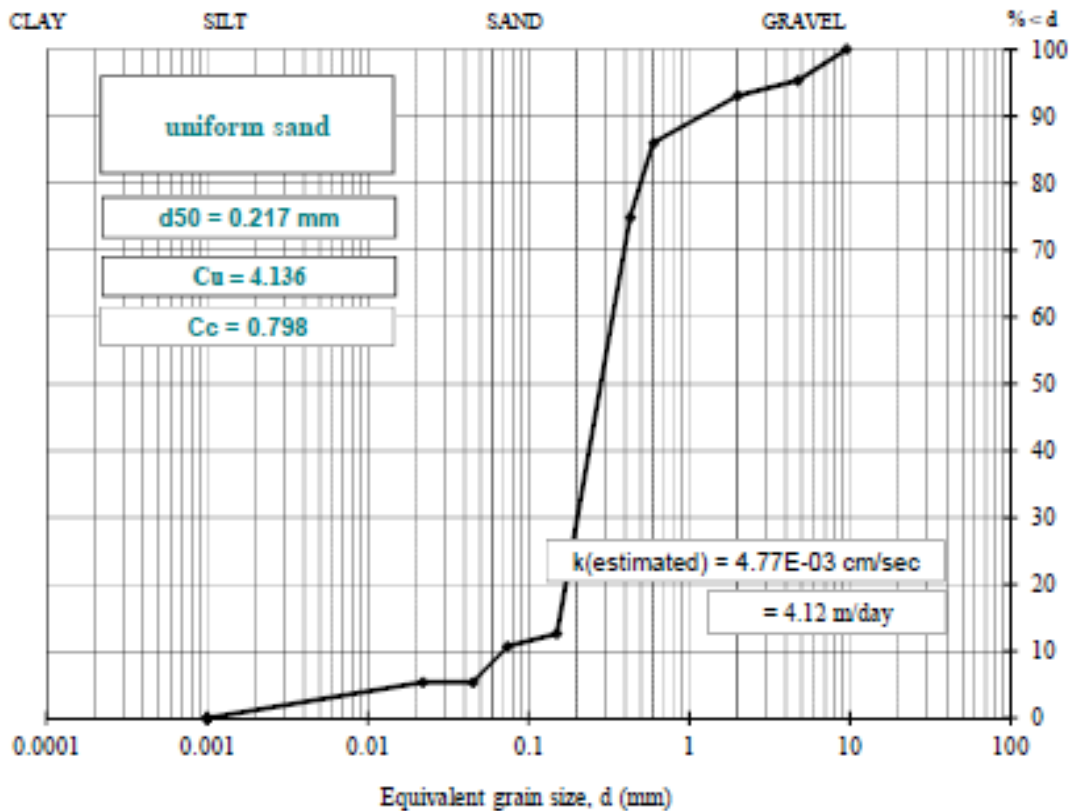
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH3
Depth	1.5 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	4.7
				Medium gravel	0.0	
				Fine gravel	4.7	
3/8"	9.50	105.2	100.0	Coarse sand	2.3	84.6
Nr. 4	4.75	100.3	95.3	Medium sand	18.2	
Nr. 10	2.00	97.9	93.1	Fine sand	64.2	
Nr. 30	0.60	90.5	86.0	Coarse silt	5.37	7.63
Nr. 40	0.43	78.8	74.9	Medium silt	0.00	
Nr. 100	0.15	13.3	12.6	Fine silt	2.26	
Nr. 200	0.07	11.3	10.7	Fine silt	2.26	
Pan	---	0.0	0.0	Clay	3.11	3.11

*Percentages relative to entire sample mass



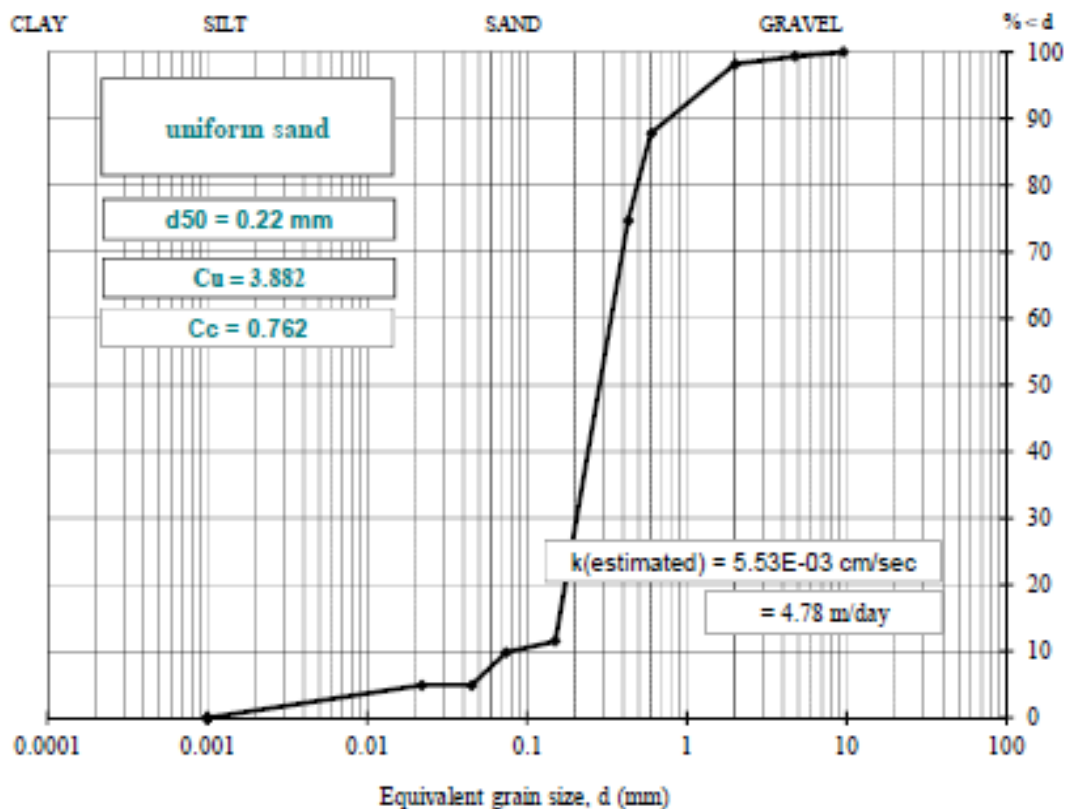
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH3
Depth	1.8 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	0.7
				Medium gravel	0.0	
				Fine gravel	0.7	
3/8"	9.50	105.9	100.0	Coarse sand	1.1	89.5
Nr. 4	4.75	105.2	99.3	Medium sand	23.5	
Nr. 10	2.00	104.0	98.2	Fine sand	64.9	
Nr. 30	0.60	93.0	87.8	Coarse silt	4.91	6.97
Nr. 40	0.43	79.1	74.7	Medium silt	0.00	
Nr. 100	0.15	12.2	11.5	Fine silt	2.06	
Nr. 200	0.07	10.4	9.8	Fine silt	2.06	
Pan	---	0.0	0.0	Clay	2.85	2.85

*Percentages relative to entire sample mass



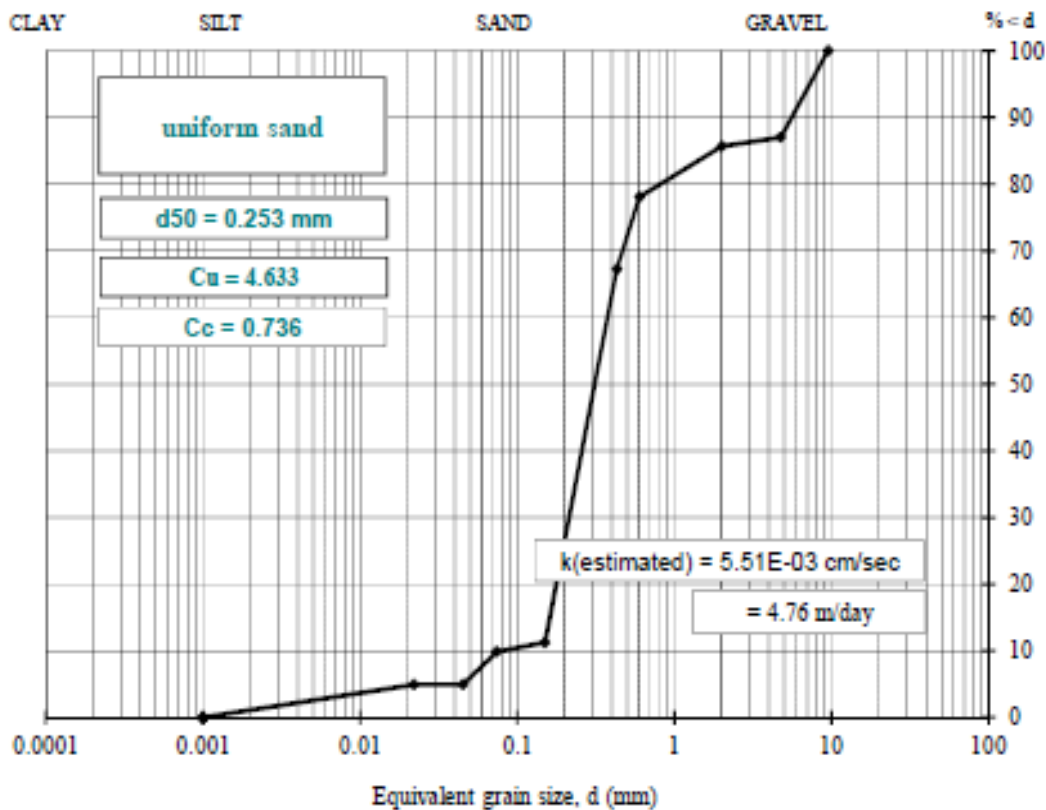
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Serdah)
Bore Hole No.	BH3
Depth	2.1 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	13.0
				Medium gravel	0.0	
				Fine gravel	13.0	
3/8"	9.50	88.0	100.0	Coarse sand	1.4	77.2
Nr. 4	4.75	76.6	87.0	Medium sand	18.4	
Nr. 10	2.00	75.4	85.7	Fine sand	57.4	
Nr. 30	0.60	68.7	78.1	Coarse silt	4.94	7.02
Nr. 40	0.43	59.2	67.3	Medium silt	0.00	
Nr. 100	0.15	9.9	11.3	Fine silt	2.08	
Nr. 200	0.07	8.7	9.9	Fine silt	2.08	2.87
Pan	---	0.0	0.0	Clay	2.87	

*Percentages relative to entire sample mass



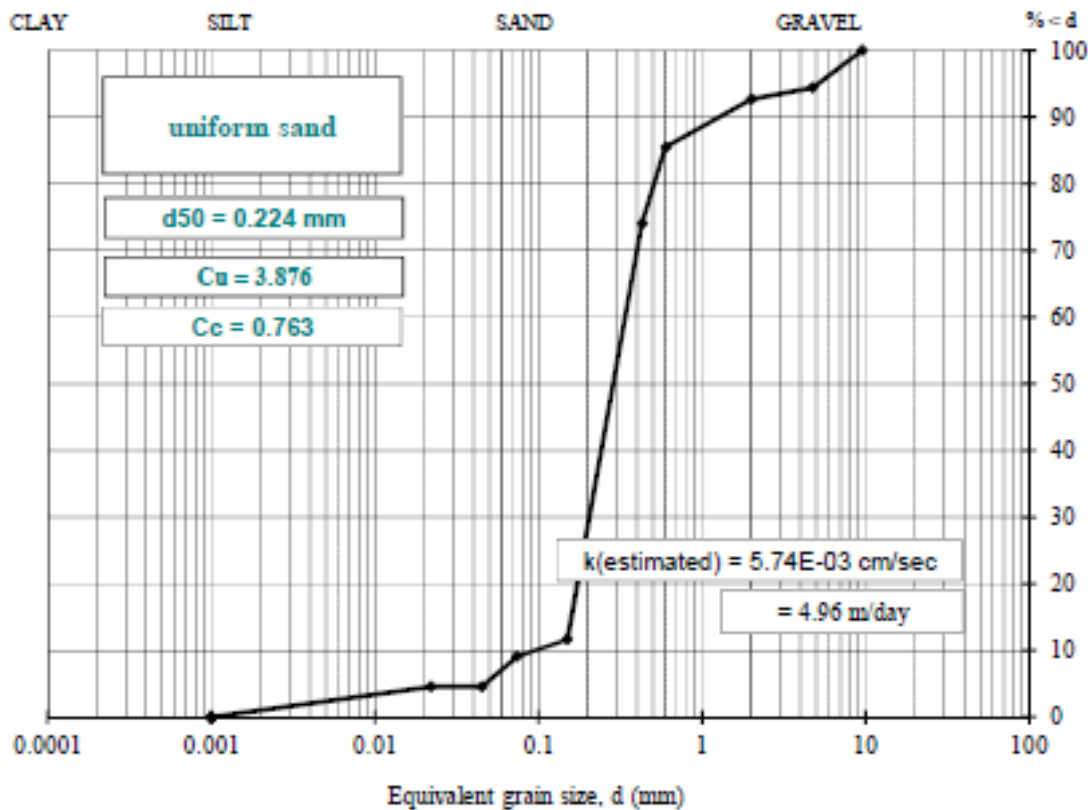
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Serdah)
Bore Hole No.	BH3
Depth	3.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	5.6
				Medium gravel	0.0	
				Fine gravel	5.6	
3/8"	9.50	98.7	100.0	Coarse sand	1.7	85.3
Nr. 4	4.75	93.2	94.4	Medium sand	18.6	
Nr. 10	2.00	91.5	92.7	Fine sand	64.9	
Nr. 30	0.60	84.4	85.5	Coarse silt	4.56	6.48
Nr. 40	0.43	73.1	74.1	Medium silt	0.00	
Nr. 100	0.15	11.5	11.7	Fine silt	1.92	
Nr. 200	0.07	9.0	9.1	Fine silt	1.92	
Pan	---	0.0	0.0	Clay	2.64	2.64

*Percentages relative to entire sample mass



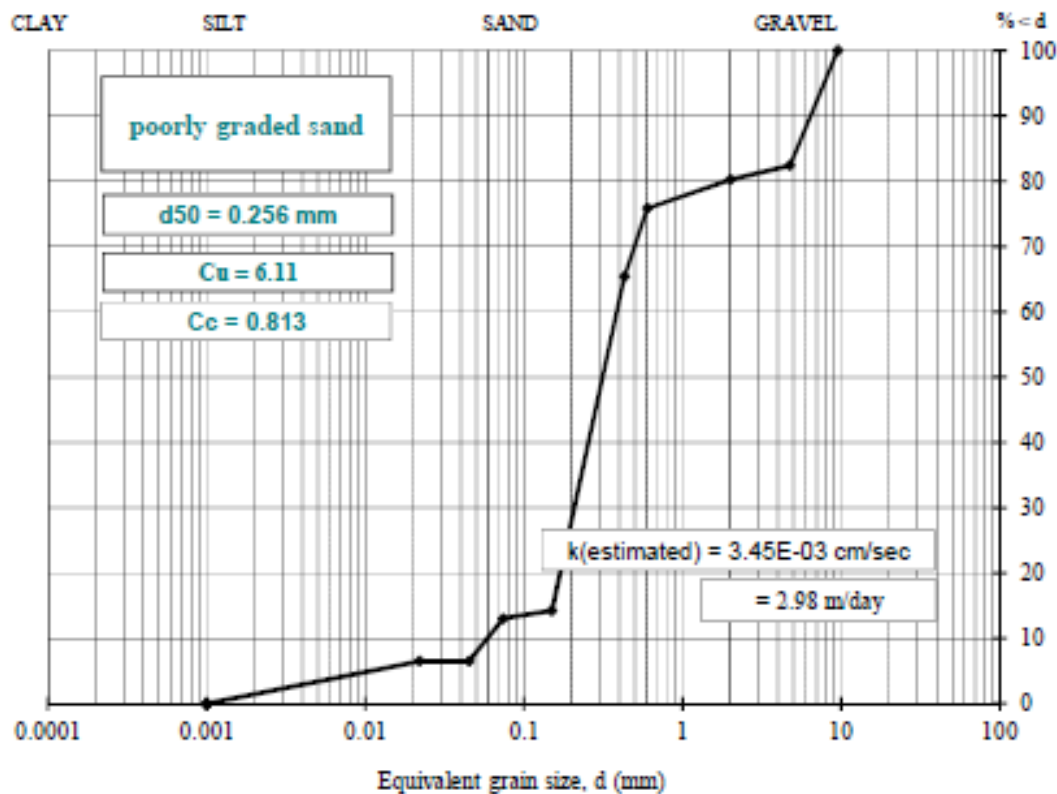
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Serdah)
Bore Hole No.	BH3
Depth	4.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	17.6
				Medium gravel	0.0	
				Fine gravel	17.6	
3/8"	9.50	131.2	100.0	Coarse sand	2.1	69.4
Nr. 4	4.75	108.1	82.4	Medium sand	14.9	
Nr. 10	2.00	105.3	80.3	Fine sand	52.4	
Nr. 30	0.60	99.5	75.8	Coarse silt	6.52	9.26
Nr. 40	0.43	85.8	65.4	Medium silt	0.00	
Nr. 100	0.15	18.7	14.3	Fine silt	2.74	
Nr. 200	0.07	17.1	13.0	Fine silt	2.74	
Pan	---	0.0	0.0	Clay	3.78	3.78

*Percentages relative to entire sample mass



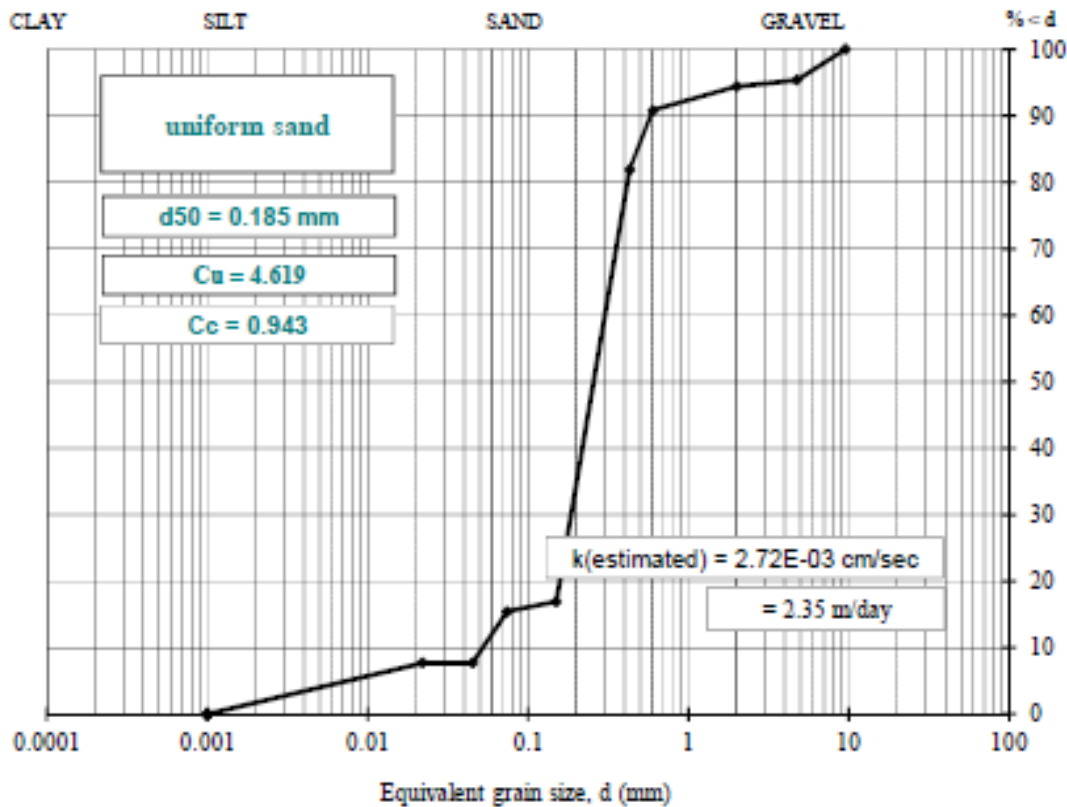
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Serdah)
Bore Hole No.	BH3
Depth	5.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	4.6
				Medium gravel	0.0	
				Fine gravel	4.6	
3/8"	9.50	102.3	100.0	Coarse sand	1.0	80.0
Nr. 4	4.75	97.6	95.4	Medium sand	12.5	
Nr. 10	2.00	96.6	94.4	Fine sand	66.5	
Nr. 30	0.60	92.9	90.8	Coarse silt	7.72	10.97
Nr. 40	0.43	83.8	81.9	Medium silt	0.00	
Nr. 100	0.15	17.3	16.9	Fine silt	3.25	
Nr. 200	0.07	15.8	15.4	Fine silt	3.25	
Pan	---	0.0	0.0	Clay	4.48	4.48

*Percentages relative to entire sample mass



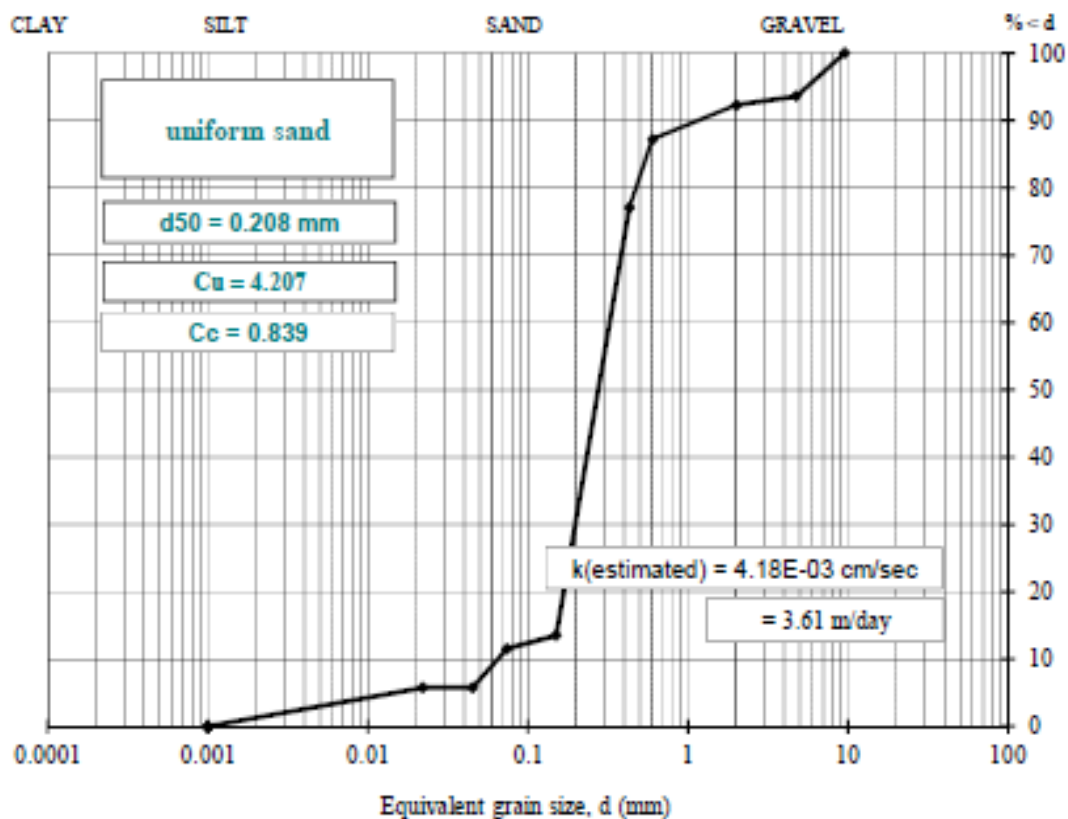
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Serdah)
Bore Hole No.	BH3
Depth	6.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	6.4
				Medium gravel	0.0	
				Fine gravel	6.4	
3/8"	9.50	106.3	100.0	Coarse sand	1.3	82.0
Nr. 4	4.75	99.5	93.6	Medium sand	15.2	
Nr. 10	2.00	98.1	92.3	Fine sand	65.5	
Nr. 30	0.60	92.7	87.2	Coarse silt	5.79	8.22
Nr. 40	0.43	81.9	77.0	Medium silt	0.00	
Nr. 100	0.15	14.4	13.5	Fine silt	2.43	
Nr. 200	0.07	12.3	11.6			
Pan	---	0.0	0.0	Clay	3.35	3.35

*Percentages relative to entire sample mass



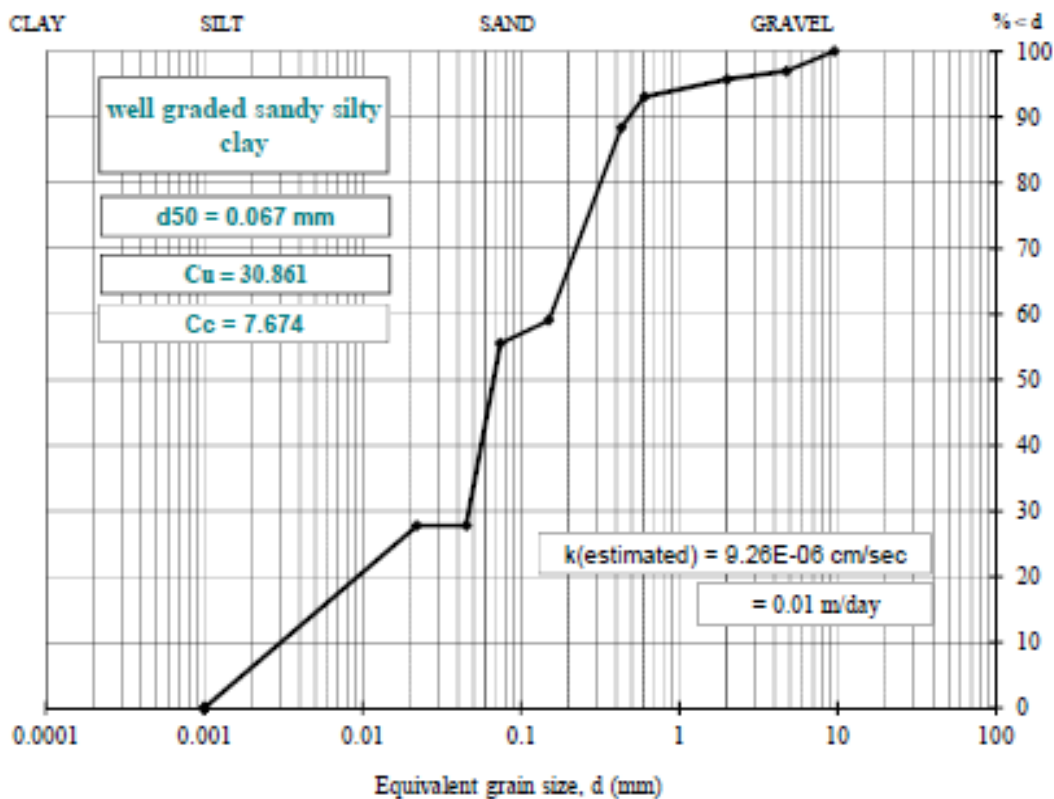
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH3
Depth	7.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	3.0
				Medium gravel	0.0	
				Fine gravel	3.0	
3/8"	9.50	140.4	100.0	Coarse sand	1.3	41.5
Nr. 4	4.75	136.2	97.0	Medium sand	7.3	
Nr. 10	2.00	134.4	95.7	Fine sand	32.8	
Nr. 30	0.60	130.7	93.1	Coarse silt	27.78	39.45
Nr. 40	0.43	124.1	88.4	Medium silt	0.00	
Nr. 100	0.15	82.9	59.0	Fine silt	11.68	
Nr. 200	0.07	78.0	55.6			
Pan	---	0.0	0.0	Clay	16.10	16.10

*Percentages relative to entire sample mass



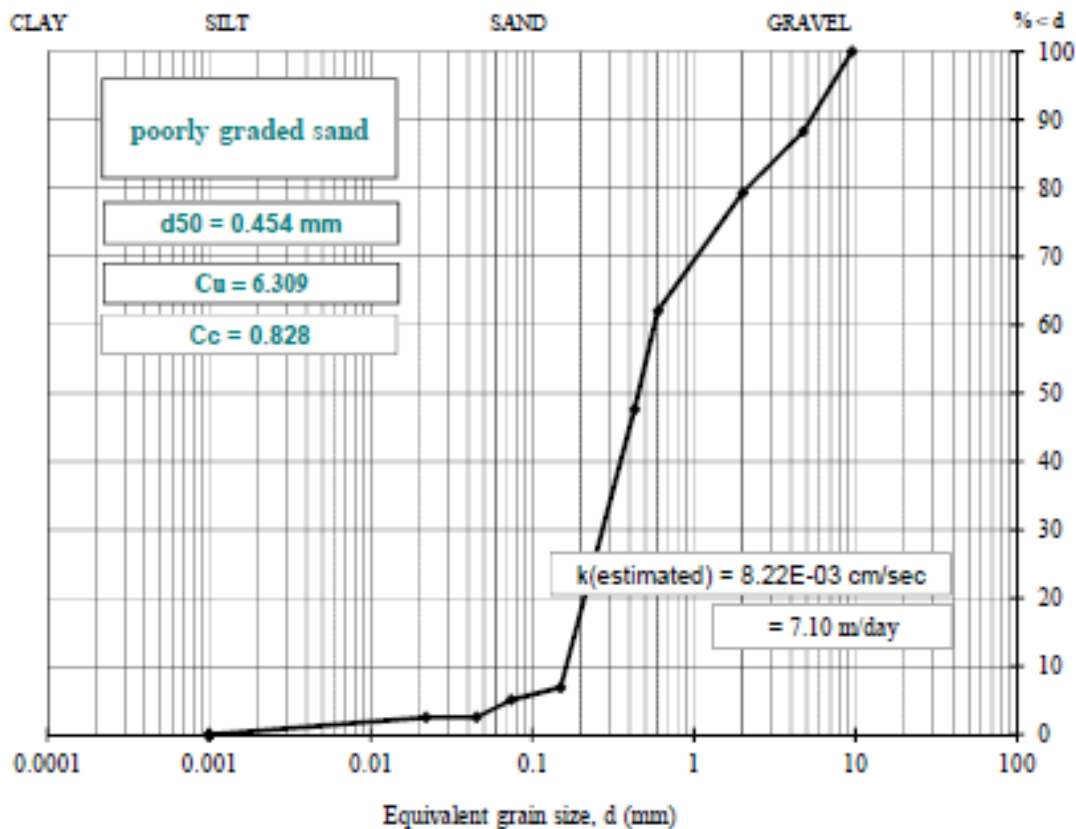
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH3
Depth	8.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	11.7
				Medium gravel	0.0	
				Fine gravel	11.7	
3/8"	9.50	92.3	100.0	Coarse sand	9.0	83.2
Nr. 4	4.75	81.5	88.3	Medium sand	31.6	
Nr. 10	2.00	73.2	79.3	Fine sand	42.6	
Nr. 30	0.60	57.3	62.1	Coarse silt	2.55	3.62
Nr. 40	0.43	44.0	47.7	Medium silt	0.00	
Nr. 100	0.15	6.4	6.9	Fine silt	1.07	
Nr. 200	0.07	4.7	5.1	Fine silt	1.07	
Pan	---	0.0	0.0	Clay	1.48	1.48

*Percentages relative to entire sample mass



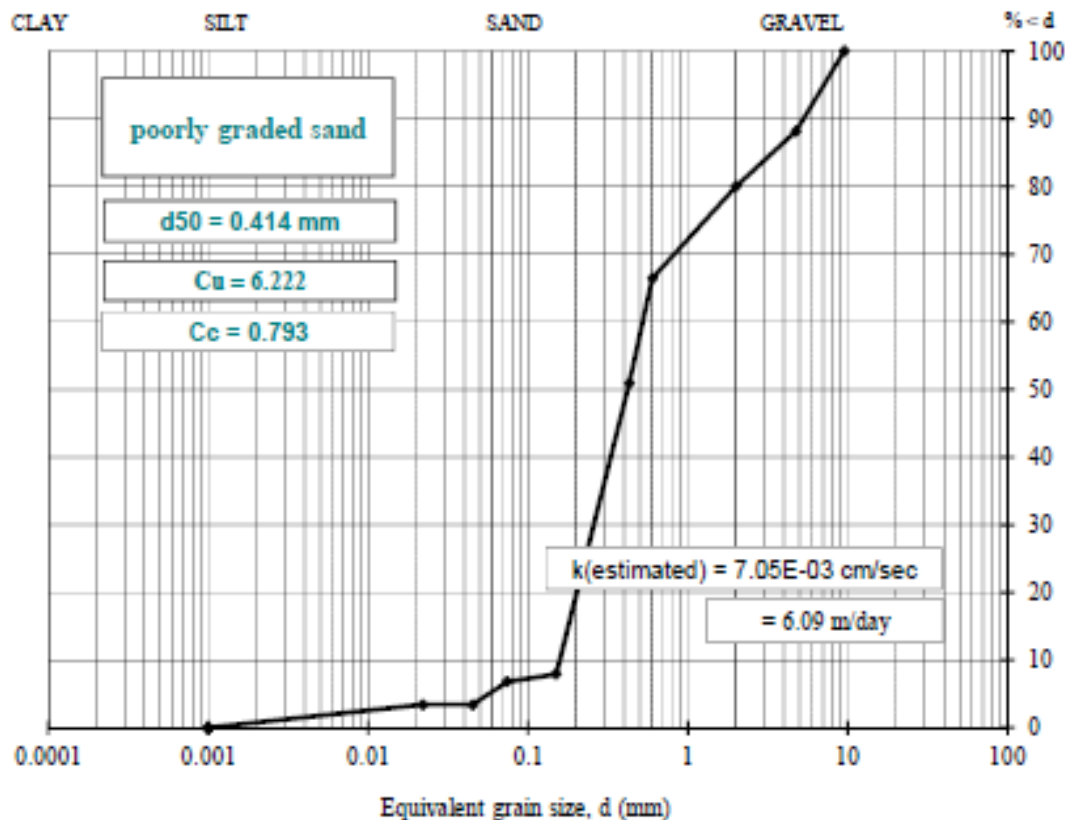
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH3
Depth	9.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	11.8
				Medium gravel	0.0	
				Fine gravel	11.8	
3/8"	9.50	118.6	100.0	Coarse sand	8.2	81.4
Nr. 4	4.75	104.6	88.2	Medium sand	29.1	
Nr. 10	2.00	94.9	80.0	Fine sand	44.1	
Nr. 30	0.60	78.8	66.4	Coarse silt	3.41	4.85
Nr. 40	0.43	60.4	50.9	Medium silt	0.00	
Nr. 100	0.15	9.4	7.9	Fine silt	1.44	
Nr. 200	0.07	8.1	6.8	Fine silt	1.44	
Pan	---	0.0	0.0	Clay	1.98	1.98

*Percentages relative to entire sample mass



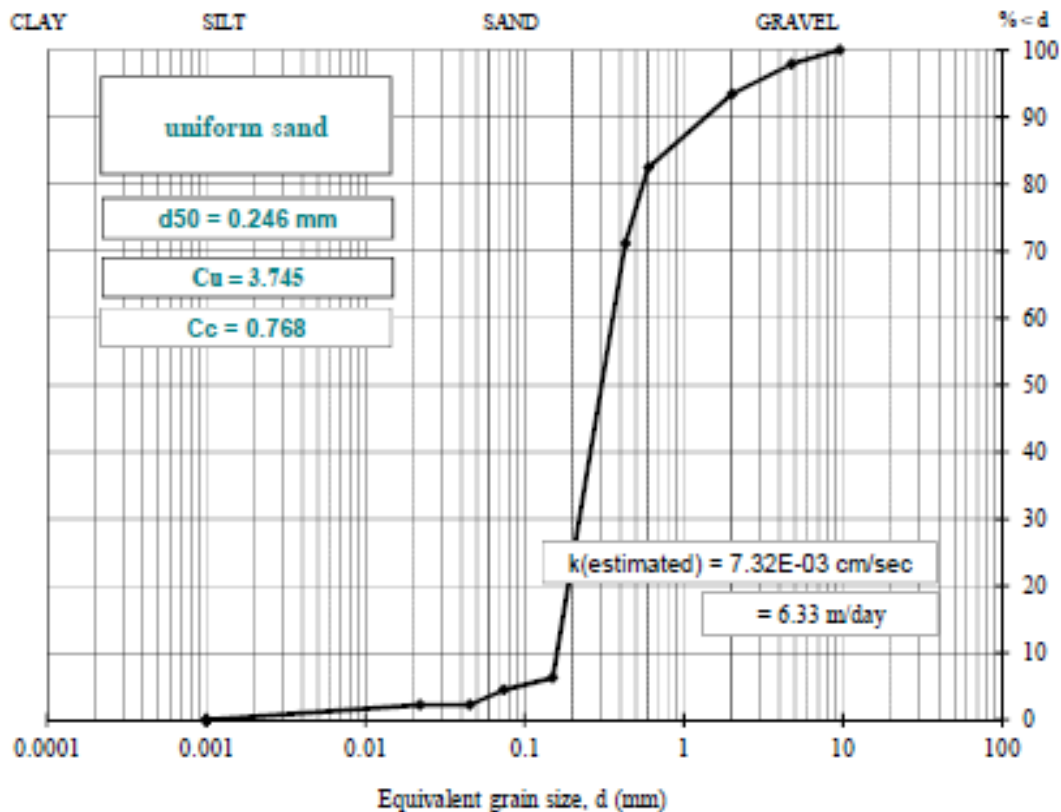
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH3
Depth	10.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	2.1
				Medium gravel	0.0	
				Fine gravel	2.1	
3/8"	9.50	106.7	100.0	Coarse sand	4.5	93.4
Nr. 4	4.75	104.5	97.9	Medium sand	22.3	
Nr. 10	2.00	99.7	93.4	Fine sand	66.6	
Nr. 30	0.60	88.0	82.5	Coarse silt	2.25	3.19
Nr. 40	0.43	75.9	71.1	Medium silt	0.00	
Nr. 100	0.15	6.7	6.3	Fine silt	0.95	
Nr. 200	0.07	4.8	4.5	Fine silt	0.95	
Pan	---	0.0	0.0	Clay	1.30	1.30

*Percentages relative to entire sample mass



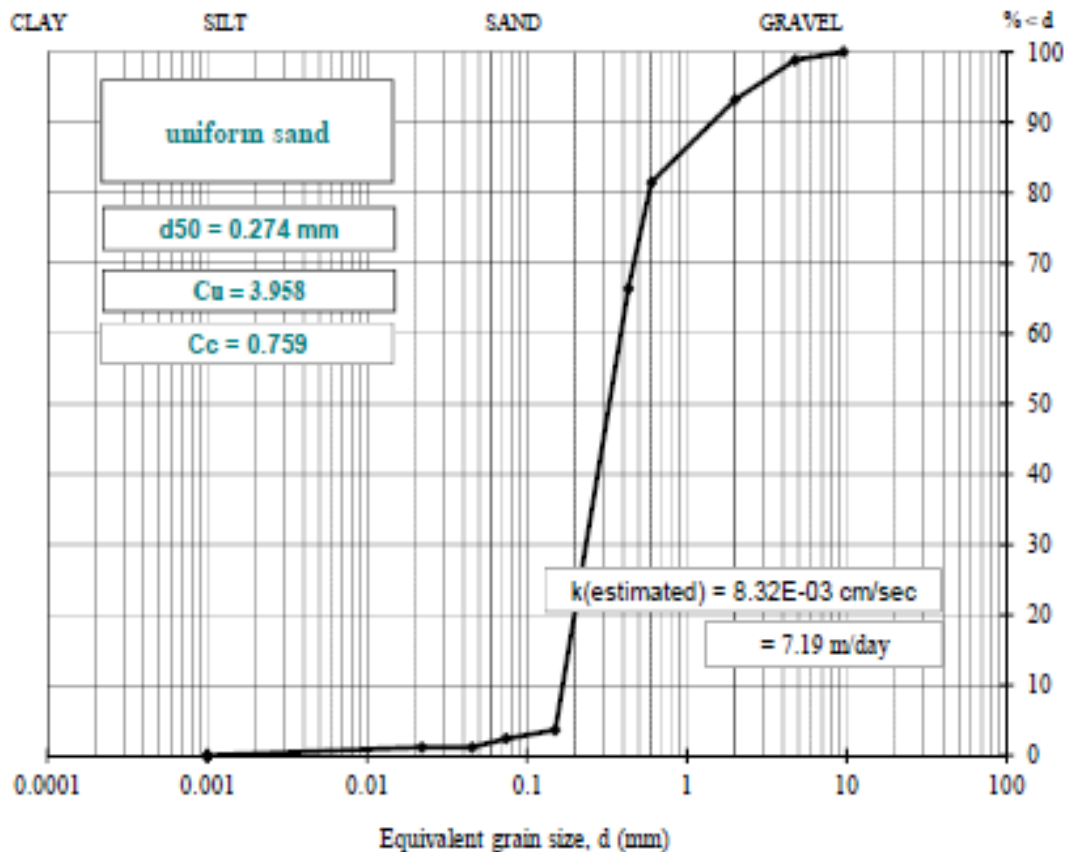
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Serdah)
Bore Hole No.	BH3
Depth	11.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	1.1
				Medium gravel	0.0	
				Fine gravel	1.1	
3/8"	9.50	96.0	100.0	Coarse sand	5.6	96.5
Nr. 4	4.75	94.9	98.9	Medium sand	26.9	
Nr. 10	2.00	89.5	93.2	Fine sand	64.0	
Nr. 30	0.60	78.2	81.5	Coarse silt	1.20	1.70
Nr. 40	0.43	63.7	66.4	Medium silt	0.00	
Nr. 100	0.15	3.5	3.6	Fine silt	0.50	
Nr. 200	0.07	2.3	2.4	Fine silt	0.50	
Pan	---	0.0	0.0	Clay	0.69	0.69

*Percentages relative to entire sample mass



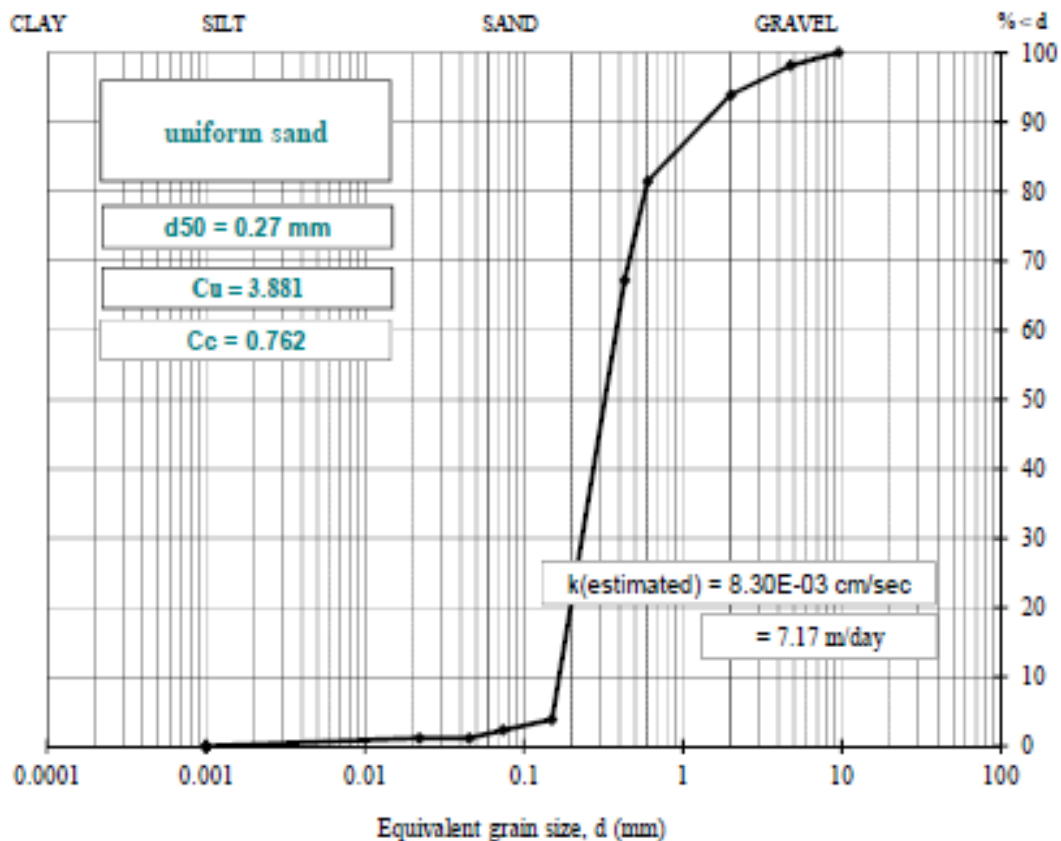
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH3
Depth	12.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	1.9
				Medium gravel	0.0	
				Fine gravel	1.9	
3/8"	9.50	85.7	100.0	Coarse sand	4.2	95.8
Nr. 4	4.75	84.1	98.1	Medium sand	26.7	
Nr. 10	2.00	80.5	93.9	Fine sand	64.9	
Nr. 30	0.60	69.8	81.4	Coarse silt	1.17	1.66
Nr. 40	0.43	57.6	67.2	Medium silt	0.00	
Nr. 100	0.15	3.3	3.9	Fine silt	0.49	
Nr. 200	0.07	2.0	2.3	Fine silt	0.49	
Pan	---	0.0	0.0	Clay	0.68	0.68

*Percentages relative to entire sample mass



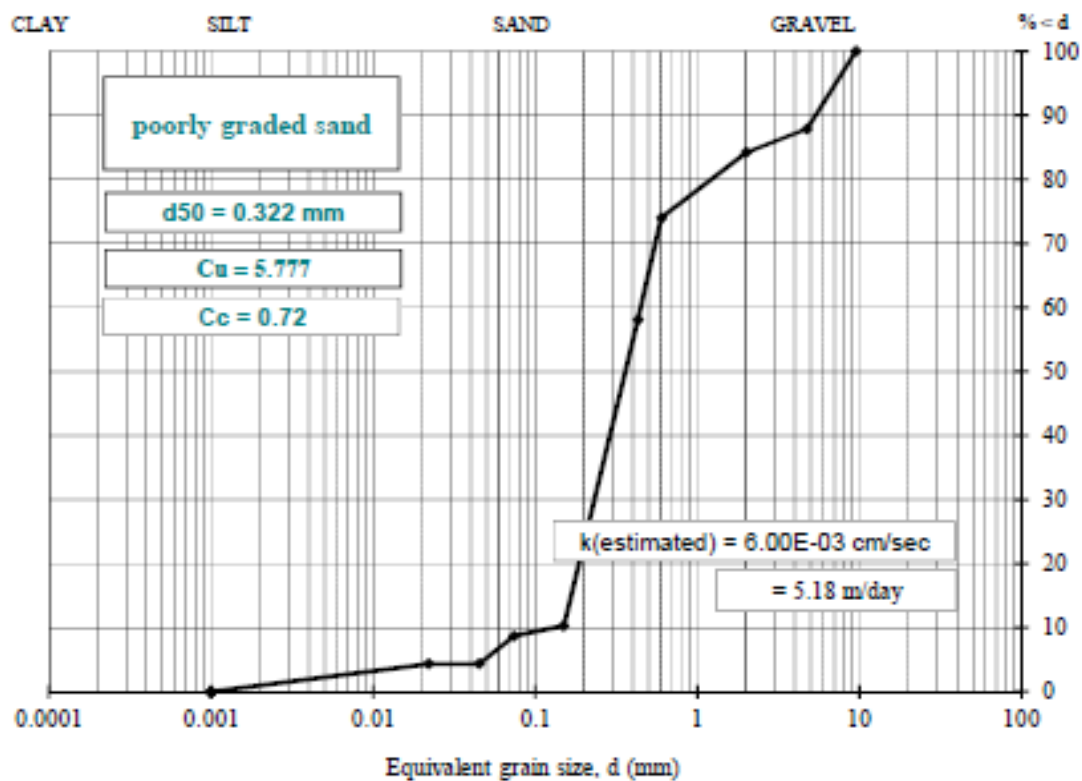
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH4
Depth	0.3 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	12.1
				Medium gravel	0.0	
				Fine gravel	12.1	
3/8"	9.50	97.4	100.0	Coarse sand	3.7	79.2
Nr. 4	4.75	85.6	87.9	Medium sand	26.1	
Nr. 10	2.00	82.0	84.2	Fine sand	49.4	
Nr. 30	0.60	72.1	74.0	Coarse silt	4.36	6.20
Nr. 40	0.43	56.6	58.1	Medium silt	0.00	
Nr. 100	0.15	10.0	10.3	Fine silt	1.83	
Nr. 200	0.07	8.5	8.7	Clay	2.53	
Pan	---	0.0	0.0	Clay	2.53	2.53

*Percentages relative to entire sample mass



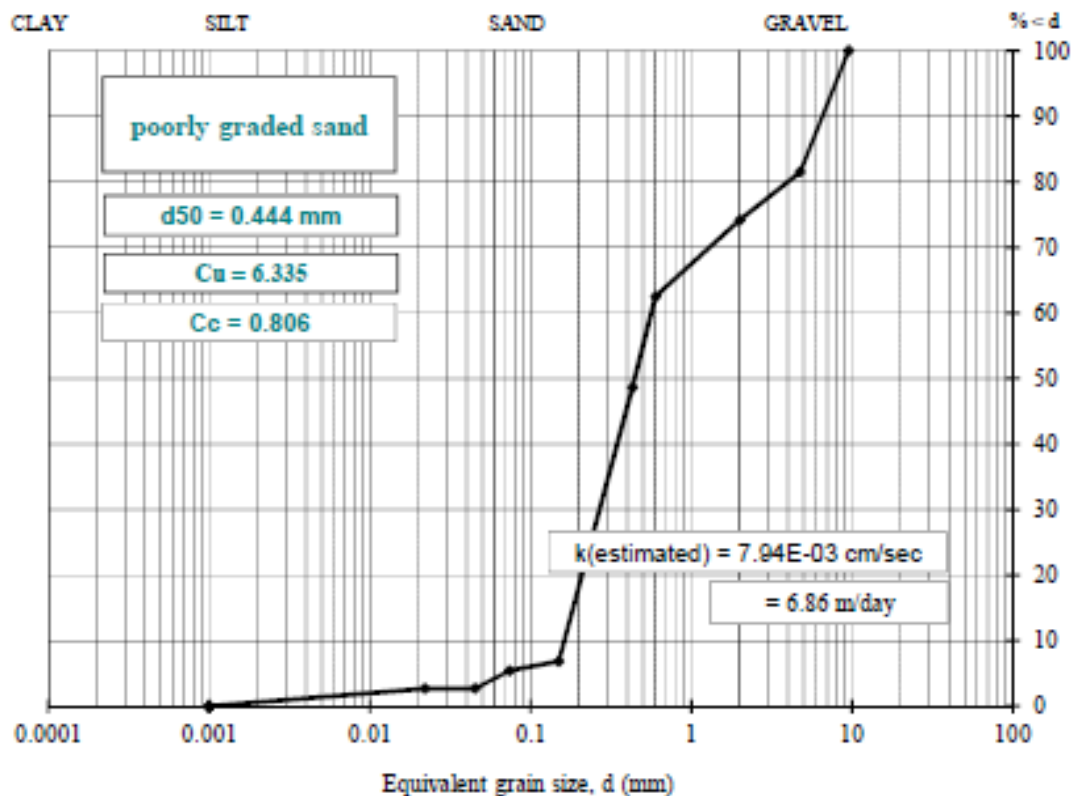
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH4
Depth	0.6 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	18.5
				Medium gravel	0.0	
				Fine gravel	18.5	
3/8"	9.50	104.9	100.0	Coarse sand	7.3	76.1
Nr. 4	4.75	85.5	81.5	Medium sand	25.5	
Nr. 10	2.00	77.8	74.2	Fine sand	43.2	
Nr. 30	0.60	65.6	62.5	Coarse silt	2.72	3.86
Nr. 40	0.43	51.0	48.6	Medium silt	0.00	
Nr. 100	0.15	7.2	6.9	Fine silt	1.14	
Nr. 200	0.07	5.7	5.4	Fine silt	1.14	
Pan	---	0.0	0.0	Clay	1.57	1.57

*Percentages relative to entire sample mass



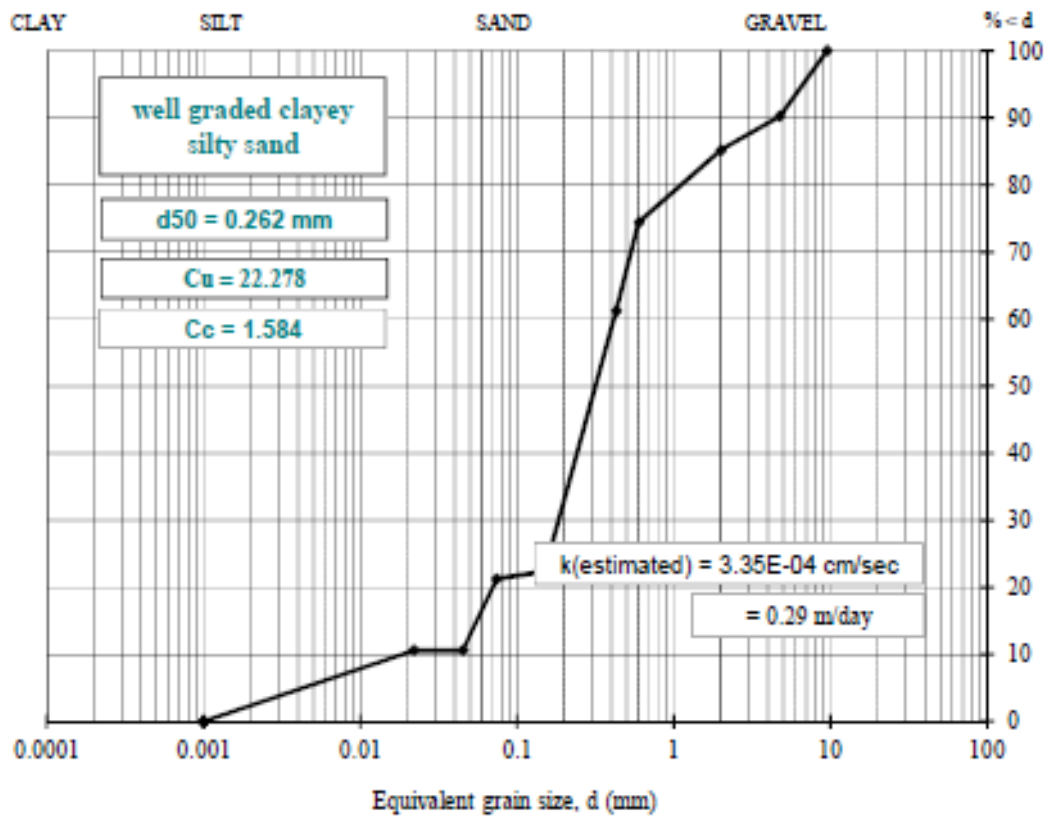
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH4
Depth	0.9 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	9.8
				Medium gravel	0.0	
				Fine gravel	9.8	
3/8"	9.50	131.2	100.0	Coarse sand	5.0	69.0
Nr. 4	4.75	118.4	90.2	Medium sand	24.0	
Nr. 10	2.00	111.8	85.2	Fine sand	39.9	
Nr. 30	0.60	97.7	74.5	Coarse silt	10.63	15.10
Nr. 40	0.43	80.3	61.2	Medium silt	0.00	
Nr. 100	0.15	29.4	22.4	Fine silt	4.47	
Nr. 200	0.07	27.9	21.3	Fine silt	4.47	
Pan	---	0.0	0.0	Clay	6.16	6.16

*Percentages relative to entire sample mass



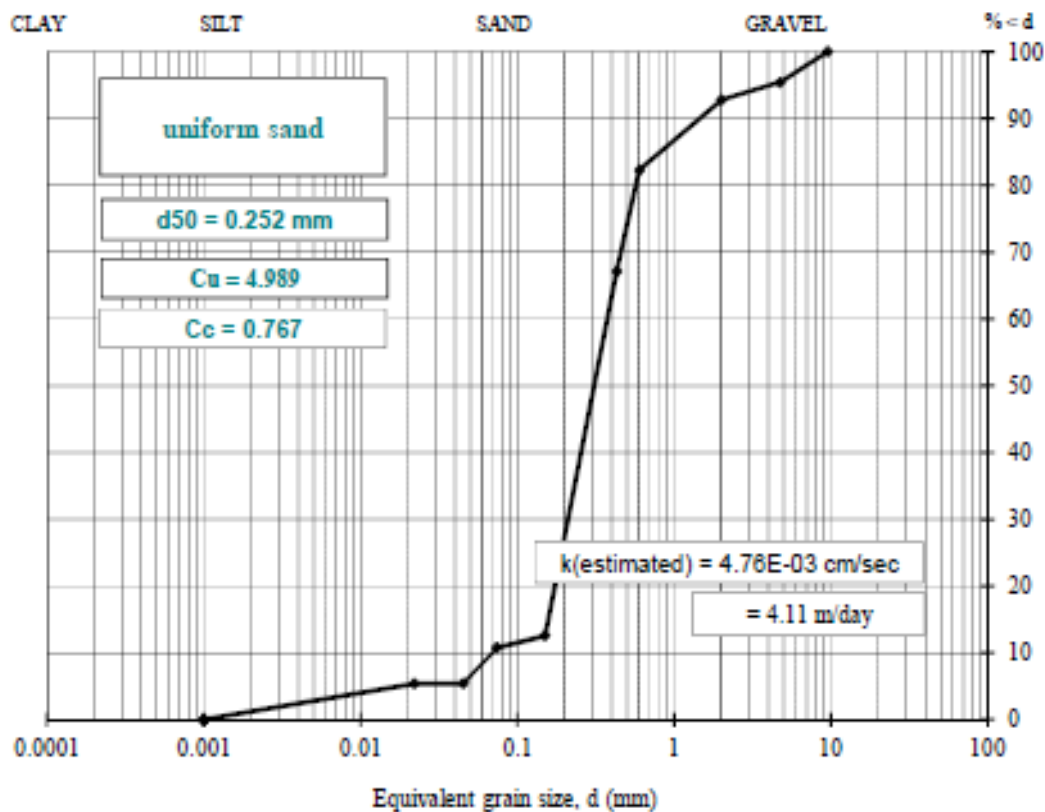
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Serdah)
Bore Hole No.	BH4
Depth	1.2 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	4.6
				Medium gravel	0.0	
				Fine gravel	4.6	
3/8"	9.50	105.0	100.0	Coarse sand	2.7	84.7
Nr. 4	4.75	100.2	95.4	Medium sand	25.6	
Nr. 10	2.00	97.4	92.8	Fine sand	56.4	
Nr. 30	0.60	86.4	82.3	Coarse silt	5.38	7.64
Nr. 40	0.43	70.5	67.1	Medium silt	0.00	
Nr. 100	0.15	13.2	12.6	Fine silt	2.26	
Nr. 200	0.07	11.3	10.8	Fine silt	2.26	
Pan	---	0.0	0.0	Clay	3.12	3.12

*Percentages relative to entire sample mass



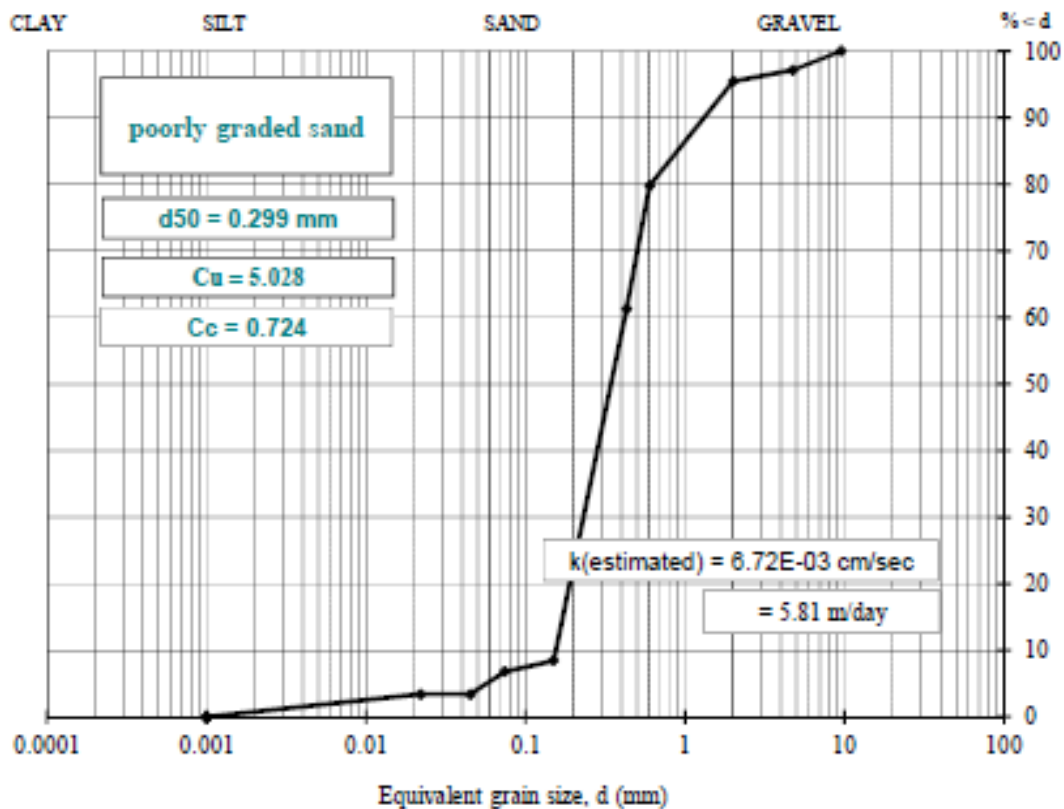
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH4
Depth	1.5 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	2.9
				Medium gravel	0.0	
				Fine gravel	2.9	
3/8"	9.50	121.7	100.0	Coarse sand	1.6	90.3
Nr. 4	4.75	118.2	97.1	Medium sand	34.2	
Nr. 10	2.00	116.2	95.5	Fine sand	54.5	
Nr. 30	0.60	97.1	79.8	Coarse silt	3.41	4.84
Nr. 40	0.43	74.6	61.3	Medium silt	0.00	
Nr. 100	0.15	10.3	8.5	Fine silt	1.43	
Nr. 200	0.07	8.3	6.8	Fine silt	1.43	
Pan	---	0.0	0.0	Clay	1.98	1.98

*Percentages relative to entire sample mass



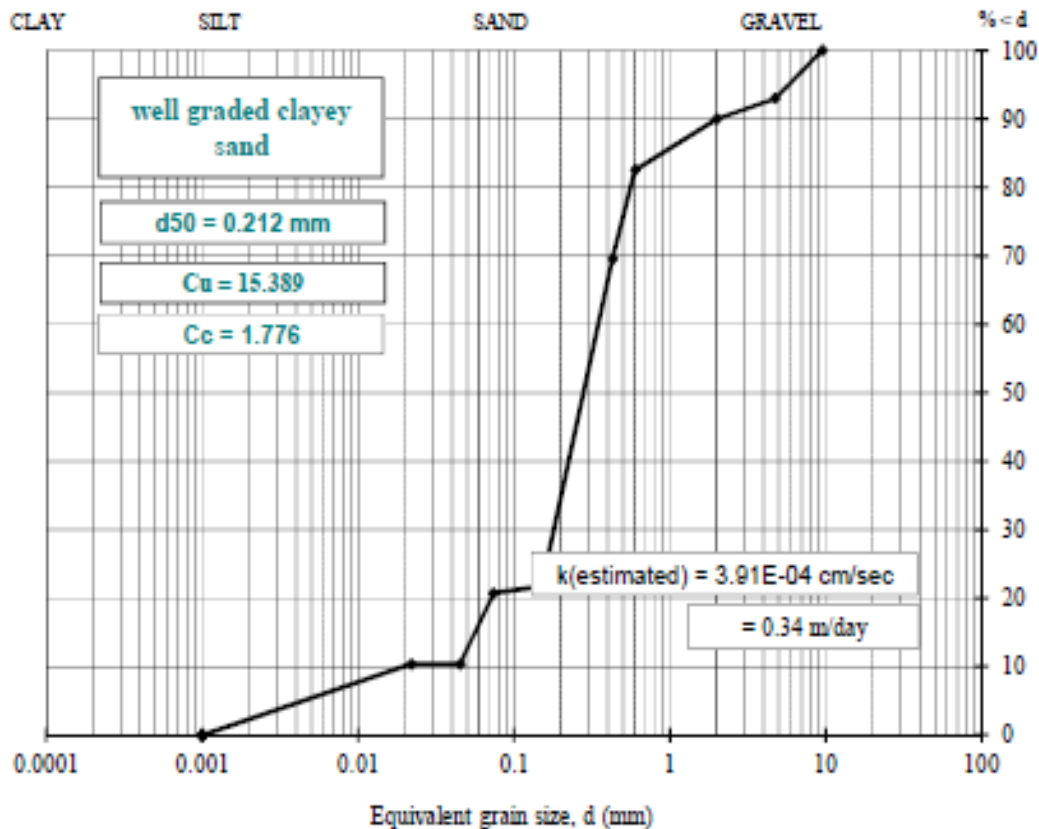
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH4
Depth	1.8 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	7.0
				Medium gravel	0.0	
				Fine gravel	7.0	
3/8"	9.50	131.3	100.0	Coarse sand	3.0	72.3
Nr. 4	4.75	122.1	93.0	Medium sand	20.4	
Nr. 10	2.00	118.2	90.0	Fine sand	48.9	
Nr. 30	0.60	108.4	82.6	Coarse silt	10.36	14.71
Nr. 40	0.43	91.4	69.6	Medium silt	0.00	
Nr. 100	0.15	28.5	21.7	Fine silt	4.35	
Nr. 200	0.07	27.2	20.7	Fine silt	4.35	
Pan	---	0.0	0.0	Clay	6.00	6.00

*Percentages relative to entire sample mass



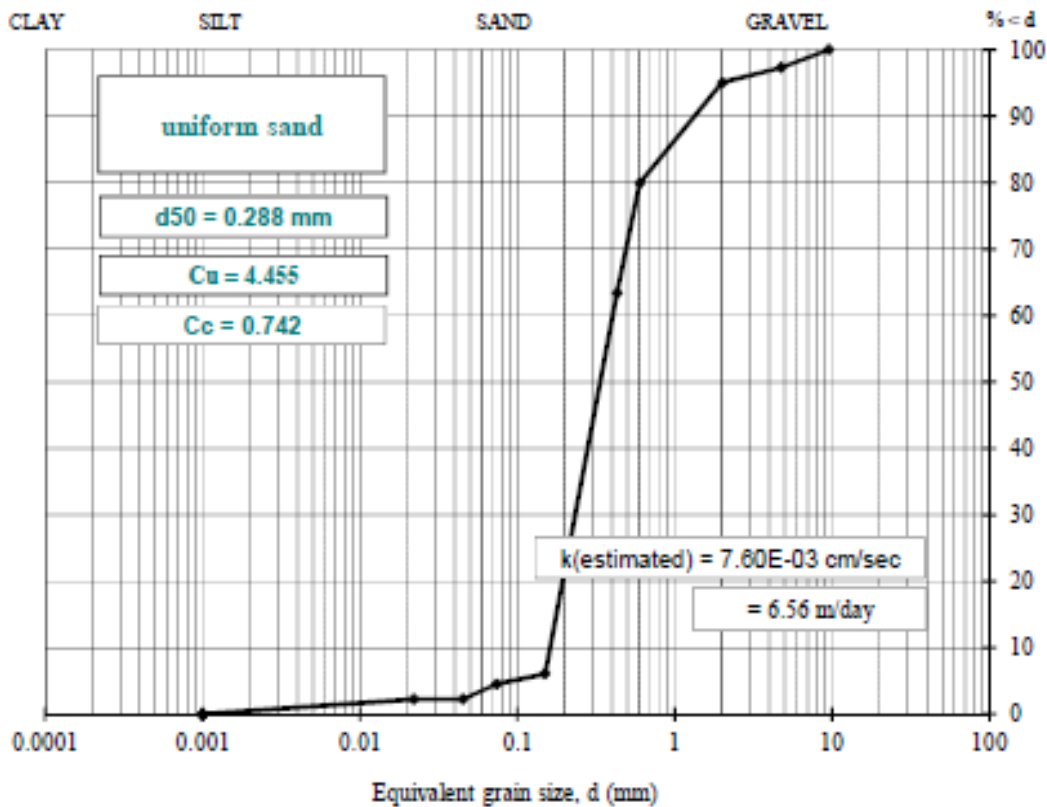
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Serdah)
Bore Hole No.	BH4
Depth	2.1 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	2.7
				Medium gravel	0.0	
				Fine gravel	2.7	
3/8"	9.50	97.3	100.0	Coarse sand	2.3	92.8
Nr. 4	4.75	94.7	97.3	Medium sand	31.7	
Nr. 10	2.00	92.5	95.1	Fine sand	58.9	
Nr. 30	0.60	77.8	80.0	Coarse silt	2.26	3.21
Nr. 40	0.43	61.7	63.4	Medium silt	0.00	
Nr. 100	0.15	5.9	6.1	Fine silt	0.95	
Nr. 200	0.07	4.4	4.5	Fine silt	0.95	
Pan	---	0.0	0.0	Clay	1.31	1.31

*Percentages relative to entire sample mass



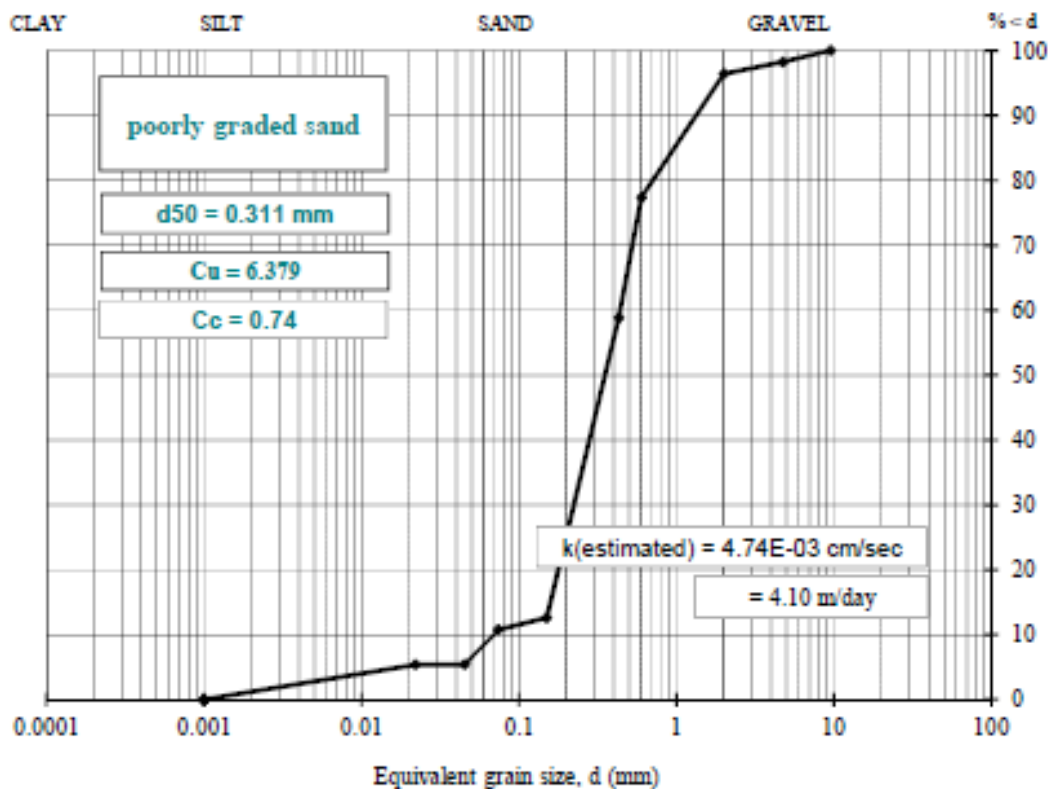
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH4
Depth	3.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	1.7
				Medium gravel	0.0	
				Fine gravel	1.7	
3/8"	9.50	103.9	100.0	Coarse sand	1.8	87.5
Nr. 4	4.75	102.1	98.3	Medium sand	37.6	
Nr. 10	2.00	100.2	96.4	Fine sand	48.0	
Nr. 30	0.60	80.4	77.4	Coarse silt	5.39	7.66
Nr. 40	0.43	61.1	58.8	Medium silt	0.00	
Nr. 100	0.15	13.1	12.6	Fine silt	2.27	
Nr. 200	0.07	11.2	10.8	Clay	3.12	
Pan	---	0.0	0.0	Clay	3.12	3.12

*Percentages relative to entire sample mass



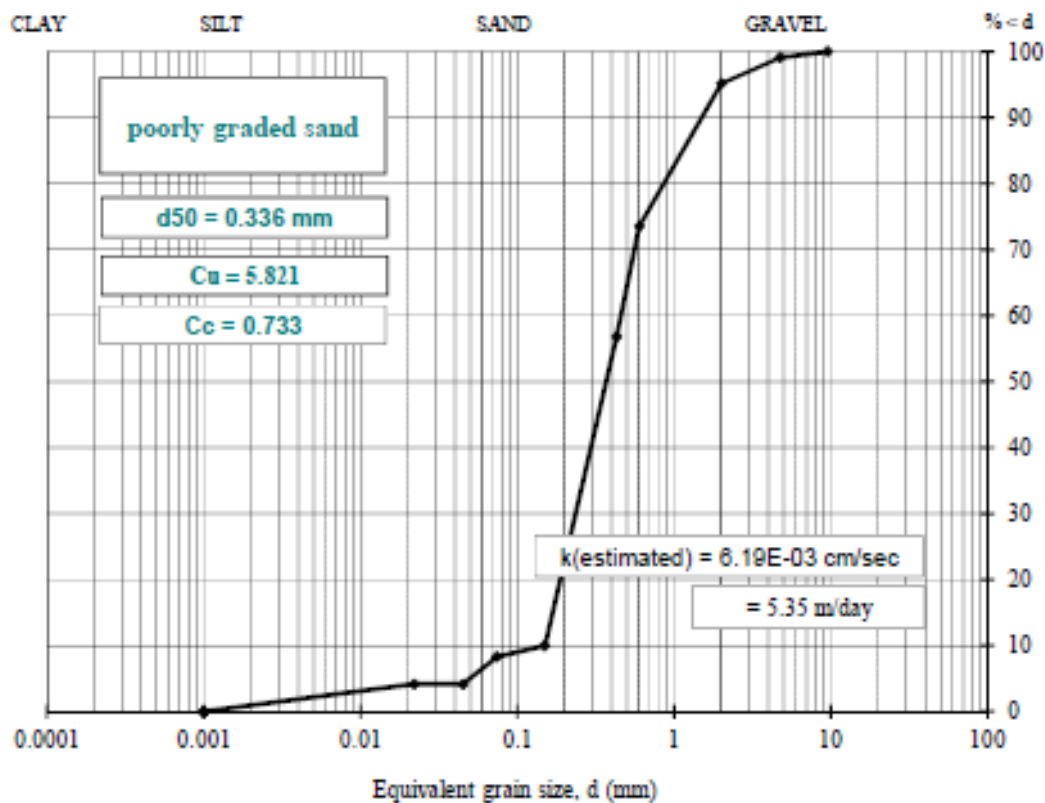
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Serdah)
Bore Hole No.	BH4
Depth	4.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	0.9
				Medium gravel	0.0	
				Fine gravel	0.9	
3/8"	9.50	101.2	100.0	Coarse sand	4.0	90.8
Nr. 4	4.75	100.3	99.1	Medium sand	38.3	
Nr. 10	2.00	96.3	95.2	Fine sand	48.5	
Nr. 30	0.60	74.4	73.5	Coarse silt	4.15	5.89
Nr. 40	0.43	57.5	56.8	Medium silt	0.00	
Nr. 100	0.15	10.1	10.0	Fine silt	1.74	
Nr. 200	0.07	8.4	8.3	Fine silt	1.74	
Pan	---	0.0	0.0	Clay	2.41	2.41

*Percentages relative to entire sample mass



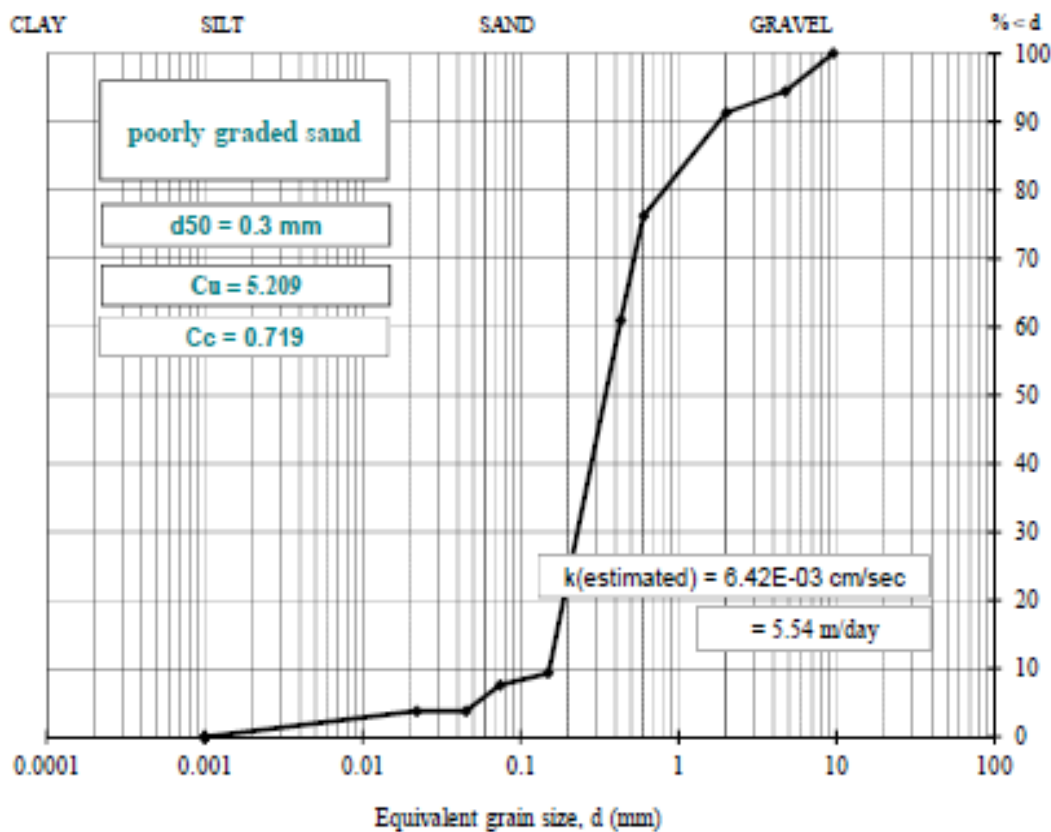
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH4
Depth	5.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	5.5
				Medium gravel	0.0	
				Fine gravel	5.5	
3/8"	9.50	92.1	100.0	Coarse sand	3.1	86.9
Nr. 4	4.75	87.0	94.5	Medium sand	30.4	
Nr. 10	2.00	84.1	91.3	Fine sand	53.3	
Nr. 30	0.60	70.2	76.2	Coarse silt	3.80	5.40
Nr. 40	0.43	56.1	60.9	Medium silt	0.00	
Nr. 100	0.15	8.6	9.3	Fine silt	1.60	
Nr. 200	0.07	7.0	7.6	Fine silt	1.60	
Pan	---	0.0	0.0	Clay	2.20	2.20

*Percentages relative to entire sample mass



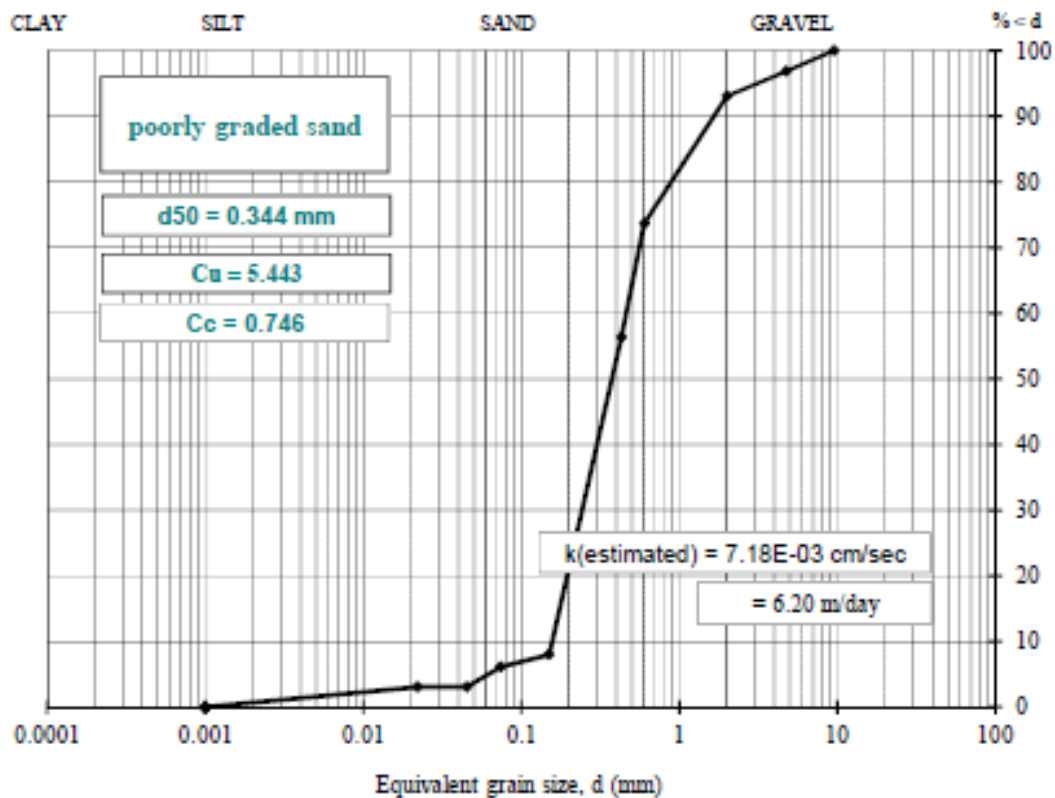
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH4
Depth	6.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	3.1
				Medium gravel	0.0	
				Fine gravel	3.1	
3/8"	9.50	112.5	100.0	Coarse sand	3.8	90.8
Nr. 4	4.75	109.0	96.9	Medium sand	36.7	
Nr. 10	2.00	104.7	93.1	Fine sand	50.2	
Nr. 30	0.60	82.9	73.7	Coarse silt	3.07	4.36
Nr. 40	0.43	63.4	56.4	Medium silt	0.00	
Nr. 100	0.15	9.0	8.0	Fine silt	1.29	
Nr. 200	0.07	6.9	6.1			
Pan	---	0.0	0.0	Clay	1.78	1.78

*Percentages relative to entire sample mass



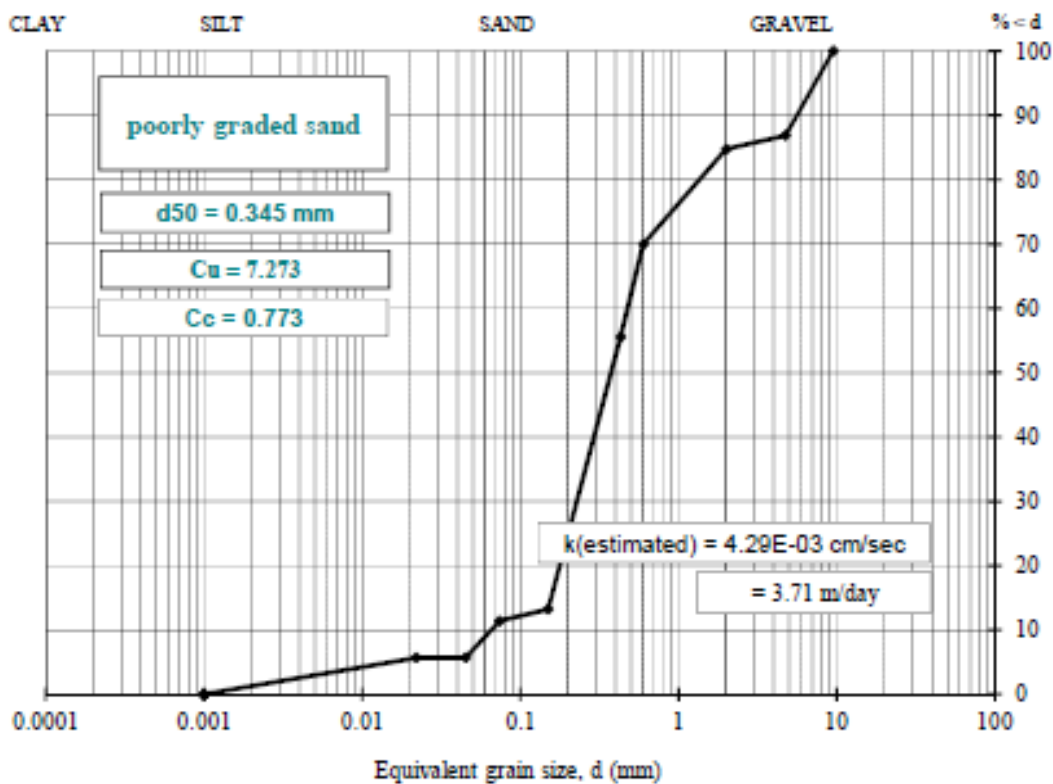
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH4
Depth	7.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	13.1
				Medium gravel	0.0	
				Fine gravel	13.1	
3/8"	9.50	98.3	100.0	Coarse sand	2.1	75.5
Nr. 4	4.75	85.4	86.9	Medium sand	29.2	
Nr. 10	2.00	83.3	84.7	Fine sand	44.2	
Nr. 30	0.60	68.8	70.0	Coarse silt	5.70	8.09
Nr. 40	0.43	54.6	55.5	Medium silt	0.00	
Nr. 100	0.15	13.0	13.2	Fine silt	2.39	
Nr. 200	0.07	11.2	11.4			
Pan	---	0.0	0.0	Clay	3.30	3.30

*Percentages relative to entire sample mass



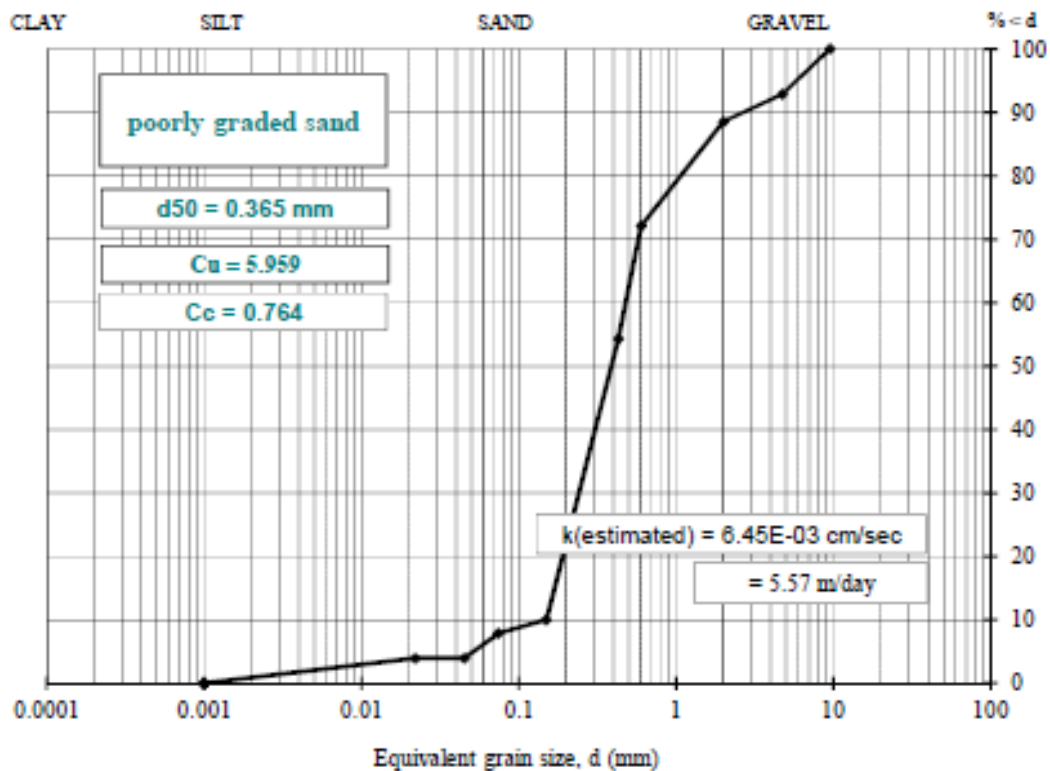
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH4
Depth	8.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	7.1
				Medium gravel	0.0	
				Fine gravel	7.1	
3/8"	9.50	94.3	100.0	Coarse sand	4.3	85.0
Nr. 4	4.75	87.6	92.9	Medium sand	34.3	
Nr. 10	2.00	83.5	88.5	Fine sand	46.4	
Nr. 30	0.60	68.0	72.1	Coarse silt	3.92	5.57
Nr. 40	0.43	51.2	54.3	Medium silt	0.00	
Nr. 100	0.15	9.4	10.0	Fine silt	1.65	
Nr. 200	0.07	7.4	7.8	Fine silt	1.65	2.27
Pan	---	0.0	0.0	Clay	2.27	

*Percentages relative to entire sample mass



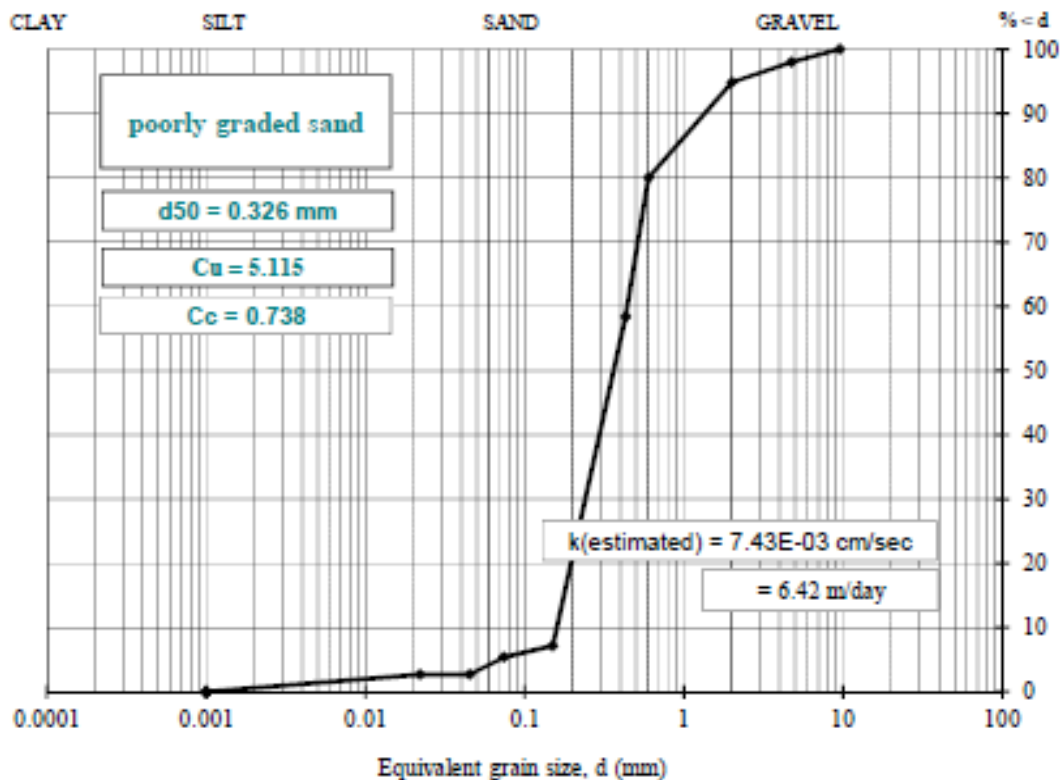
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH4
Depth	9.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	2.0
				Medium gravel	0.0	
				Fine gravel	2.0	
3/8"	9.50	114.6	100.0	Coarse sand	3.1	92.6
Nr. 4	4.75	112.3	98.0	Medium sand	36.5	
Nr. 10	2.00	108.7	94.9	Fine sand	53.0	
Nr. 30	0.60	91.7	80.0	Coarse silt	2.71	3.84
Nr. 40	0.43	66.9	58.4	Medium silt	0.00	
Nr. 100	0.15	8.2	7.2	Fine silt	1.14	
Nr. 200	0.07	6.2	5.4	Clay	1.57	
Pan	---	0.0	0.0	Clay	1.57	1.57

*Percentages relative to entire sample mass



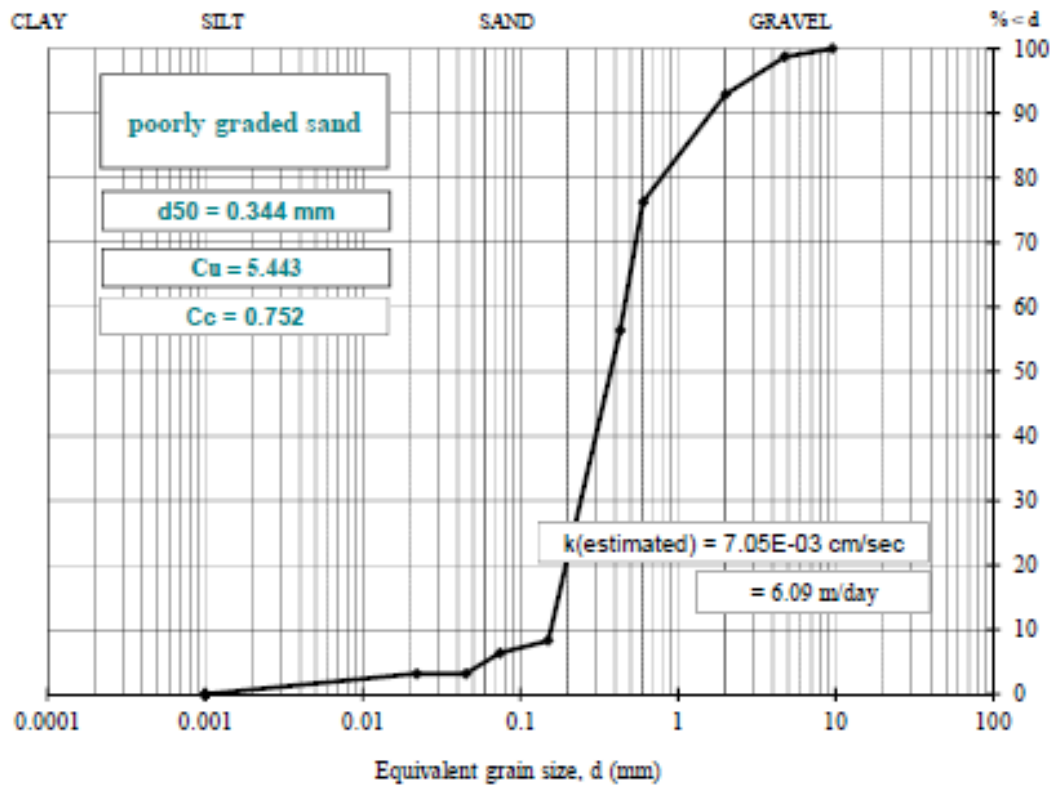
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Serdah)
Bore Hole No.	BH4
Depth	10.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	1.2
				Medium gravel	0.0	
				Fine gravel	1.2	
3/8"	9.50	88.9	100.0	Coarse sand	5.8	92.4
Nr. 4	4.75	87.8	98.8	Medium sand	36.6	
Nr. 10	2.00	82.6	92.9	Fine sand	49.9	
Nr. 30	0.60	67.8	76.3	Coarse silt	3.21	4.55
Nr. 40	0.43	50.1	56.4	Medium silt	0.00	
Nr. 100	0.15	7.4	8.3	Fine silt	1.35	
Nr. 200	0.07	5.7	6.4			
Pan	---	0.0	0.0	Clay	1.86	1.86

*Percentages relative to entire sample mass



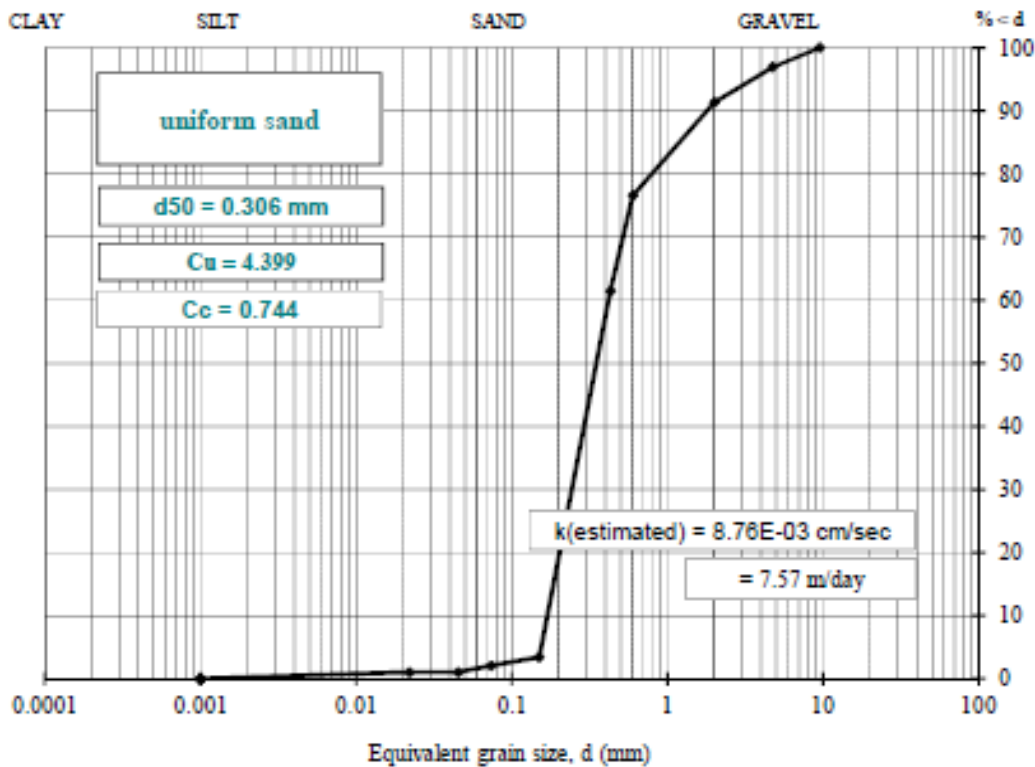
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Serdah)
Bore Hole No.	BH4
Depth	11.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	3.0
				Medium gravel	0.0	
				Fine gravel	3.0	
3/8"	9.50	82.0	100.0	Coarse sand	5.6	94.9
Nr. 4	4.75	79.5	97.0	Medium sand	29.9	
Nr. 10	2.00	74.9	91.3	Fine sand	59.4	
Nr. 30	0.60	62.8	76.6	Coarse silt	1.04	1.47
Nr. 40	0.43	50.4	61.5	Medium silt	0.00	
Nr. 100	0.15	2.8	3.4	Fine silt	0.44	
Nr. 200	0.07	1.7	2.1	Fine silt	0.44	
Pan	---	0.0	0.0	Clay	0.60	0.60

*Percentages relative to entire sample mass



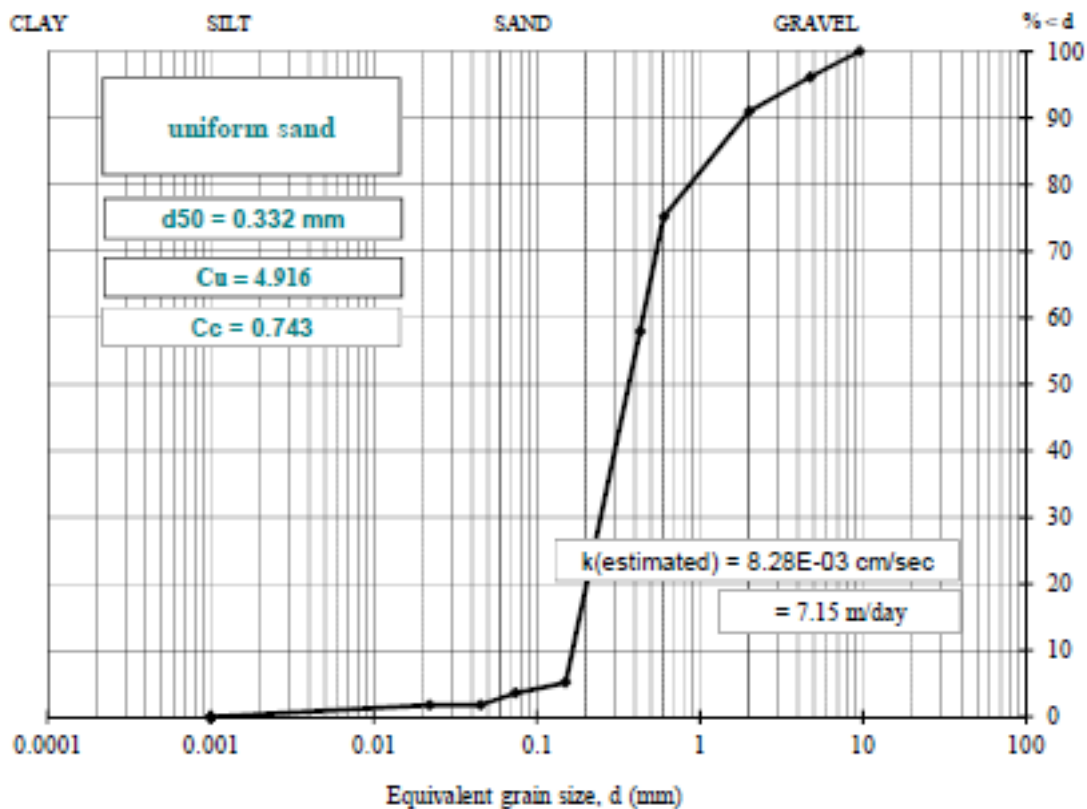
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Serdah)
Bore Hole No.	BH4
Depth	12.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	3.8
				Medium gravel	0.0	
				Fine gravel	3.8	
3/8"	9.50	96.6	100.0	Coarse sand	5.2	92.5
Nr. 4	4.75	92.9	96.2	Medium sand	33.0	
Nr. 10	2.00	87.9	91.0	Fine sand	54.3	
Nr. 30	0.60	72.6	75.2	Coarse silt	1.81	2.57
Nr. 40	0.43	56.0	58.0	Medium silt	0.00	
Nr. 100	0.15	5.0	5.2	Fine silt	0.76	
Nr. 200	0.07	3.5	3.6	Fine silt	0.76	
Pan	---	0.0	0.0	Clay	1.05	1.05

*Percentages relative to entire sample mass



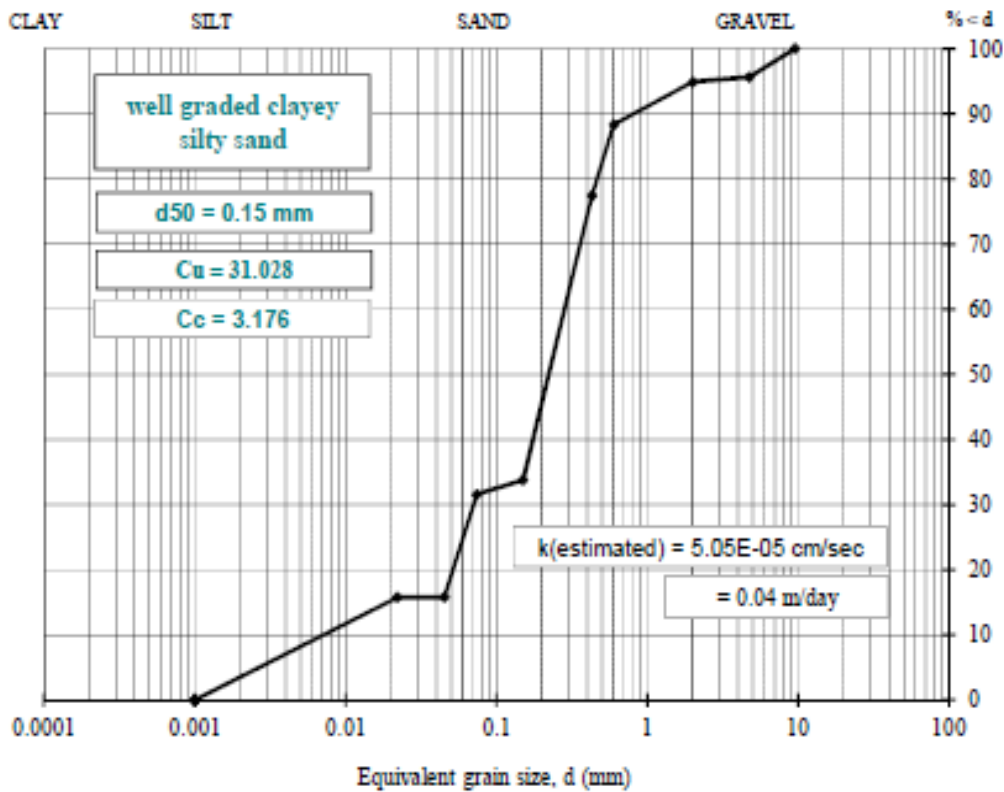
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Serdah)
Bore Hole No.	BH5
Depth	0.3 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	4.3
				Medium gravel	0.0	
				Fine gravel	4.3	
3/8"	9.50	103.7	100.0	Coarse sand	0.8	64.1
Nr. 4	4.75	99.2	95.7	Medium sand	17.5	
Nr. 10	2.00	98.4	94.9	Fine sand	45.9	
Nr. 30	0.60	91.6	88.3	Coarse silt	15.77	22.39
Nr. 40	0.43	80.3	77.4	Medium silt	0.00	
Nr. 100	0.15	35.0	33.8	Fine silt	6.63	
Nr. 200	0.07	32.7	31.5	Fine silt	6.63	
Pan	---	0.0	0.0	Clay	9.14	9.14

*Percentages relative to entire sample mass



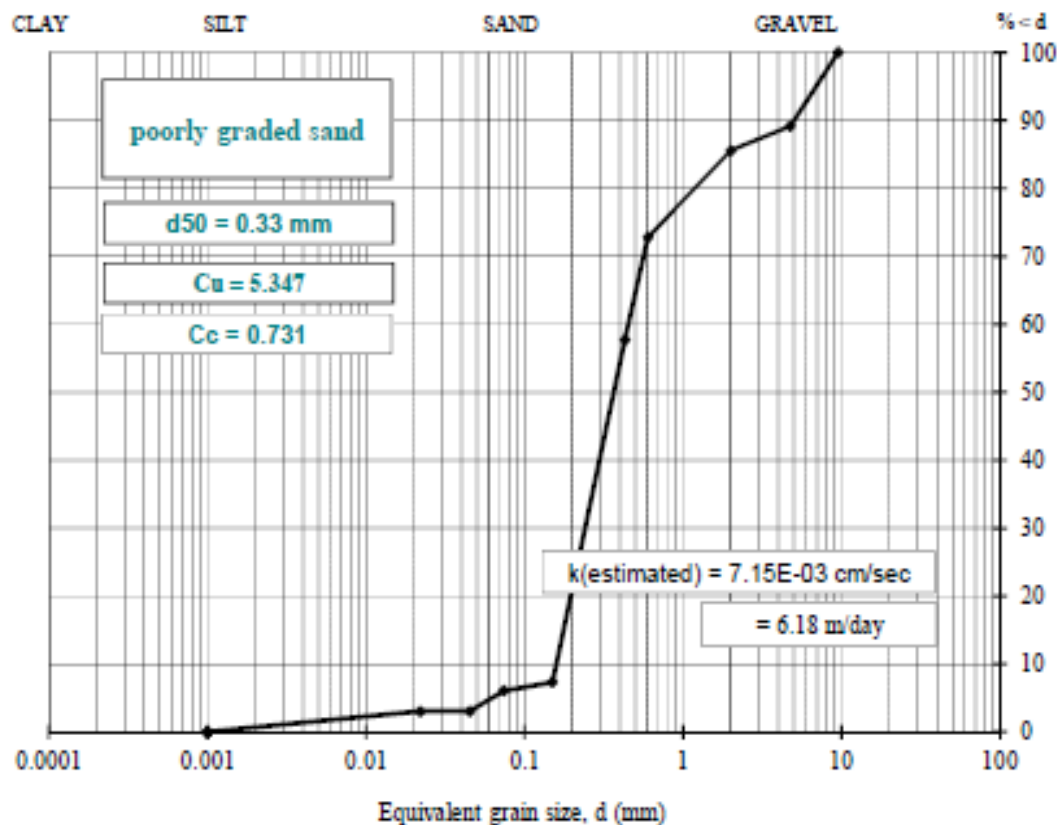
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH5
Depth	0.6 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	10.8
				Medium gravel	0.0	
				Fine gravel	10.8	
3/8"	9.50	97.0	100.0	Coarse sand	3.6	83.1
Nr. 4	4.75	86.5	89.2	Medium sand	27.8	
Nr. 10	2.00	83.0	85.6	Fine sand	51.6	
Nr. 30	0.60	70.6	72.8	Coarse silt	3.04	4.32
Nr. 40	0.43	56.0	57.7	Medium silt	0.00	
Nr. 100	0.15	7.1	7.3	Fine silt	1.28	
Nr. 200	0.07	5.9	6.1	Fine silt	1.28	
Pan	---	0.0	0.0	Clay	1.76	1.76

*Percentages relative to entire sample mass



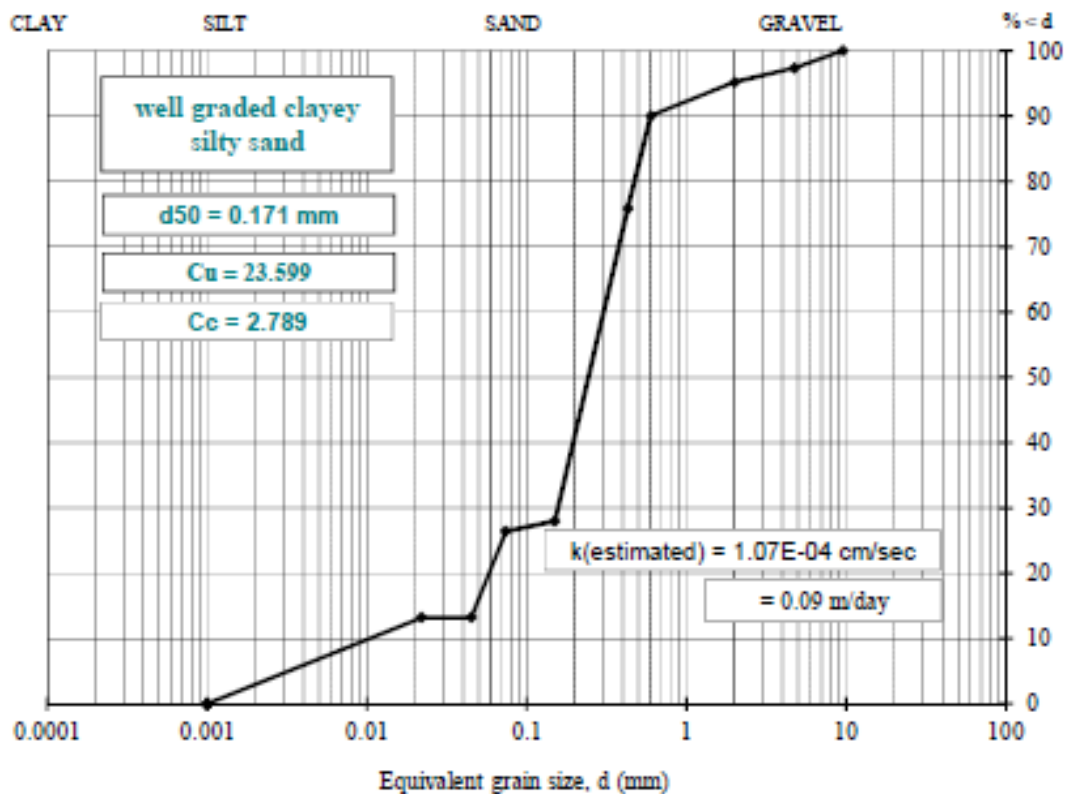
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH5
Depth	0.9 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	2.6
				Medium gravel	0.0	
				Fine gravel	2.6	
3/8"	9.50	106.6	100.0	Coarse sand	2.2	70.9
Nr. 4	4.75	103.8	97.4	Medium sand	19.3	
Nr. 10	2.00	101.5	95.2	Fine sand	49.4	
Nr. 30	0.60	96.0	90.1	Coarse silt	13.23	18.79
Nr. 40	0.43	80.9	75.9	Medium silt	0.00	
Nr. 100	0.15	29.8	28.0	Fine silt	5.56	
Nr. 200	0.07	28.2	26.5			
Pan	---	0.0	0.0	Clay	7.67	7.67

*Percentages relative to entire sample mass



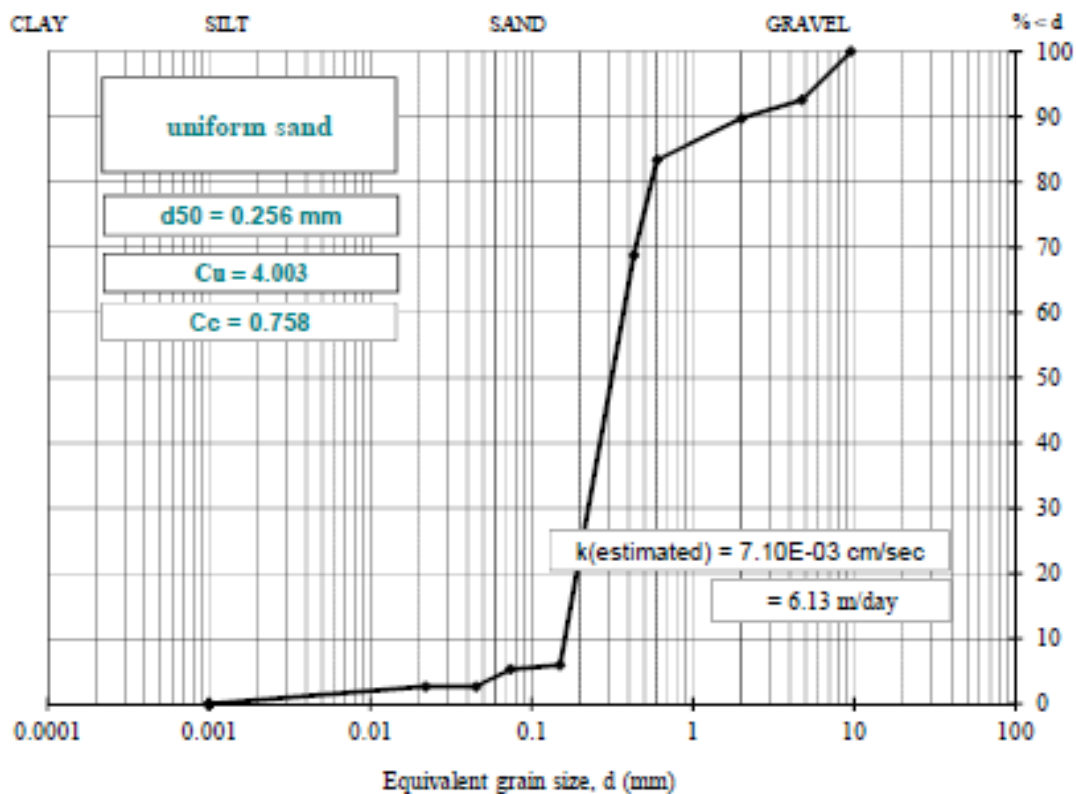
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH5
Depth	1.2 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	7.5
				Medium gravel	0.0	
				Fine gravel	7.5	
3/8"	9.50	93.8	100.0	Coarse sand	2.8	87.2
Nr. 4	4.75	86.8	92.5	Medium sand	21.0	
Nr. 10	2.00	84.2	89.8	Fine sand	63.4	
Nr. 30	0.60	78.2	83.4	Coarse silt	2.67	3.79
Nr. 40	0.43	64.5	68.8	Medium silt	0.00	
Nr. 100	0.15	5.6	6.0	Fine silt	1.12	
Nr. 200	0.07	5.0	5.3	Fine silt	1.12	
Pan	---	0.0	0.0	Clay	1.54	1.54

*Percentages relative to entire sample mass



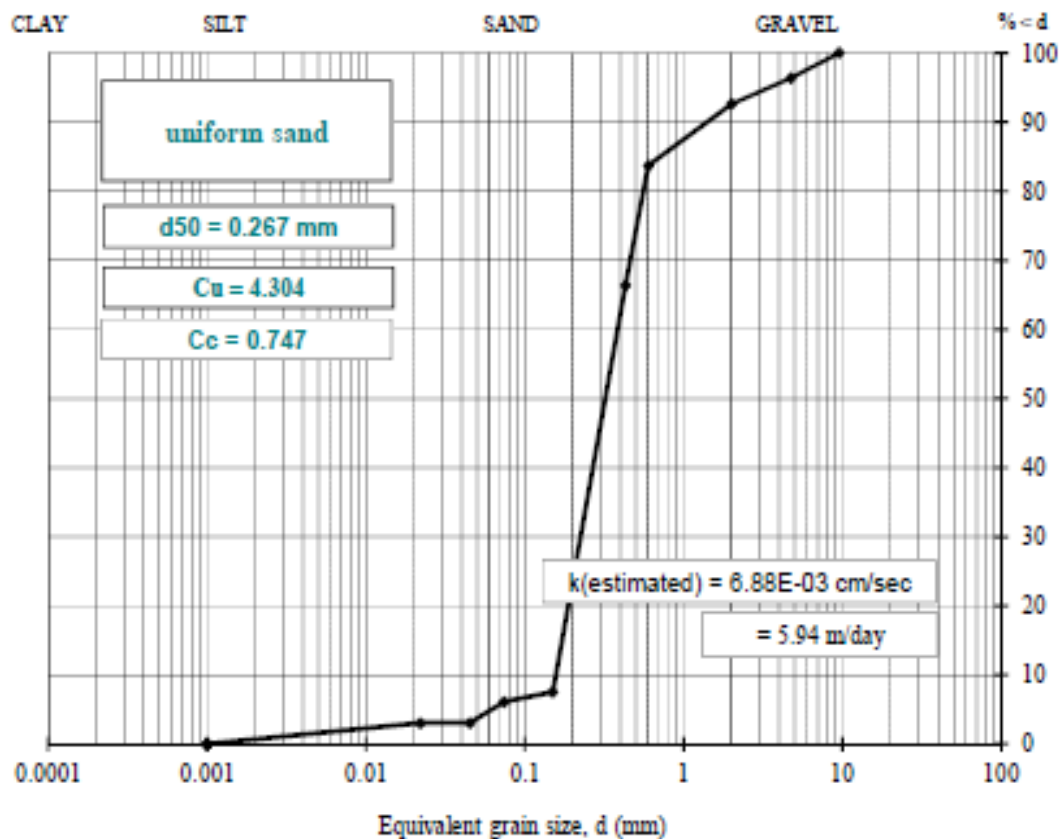
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH5
Depth	1.5 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	3.6
				Medium gravel	0.0	
				Fine gravel	3.6	
3/8"	9.50	147.8	100.0	Coarse sand	3.8	90.3
Nr. 4	4.75	142.5	96.4	Medium sand	26.3	
Nr. 10	2.00	136.9	92.6	Fine sand	60.3	
Nr. 30	0.60	123.7	83.7	Coarse silt	3.04	4.32
Nr. 40	0.43	98.1	66.4	Medium silt	0.00	
Nr. 100	0.15	11.1	7.5	Fine silt	1.28	
Nr. 200	0.07	9.0	6.1			
Pan	---	0.0	0.0	Clay	1.76	1.76

*Percentages relative to entire sample mass



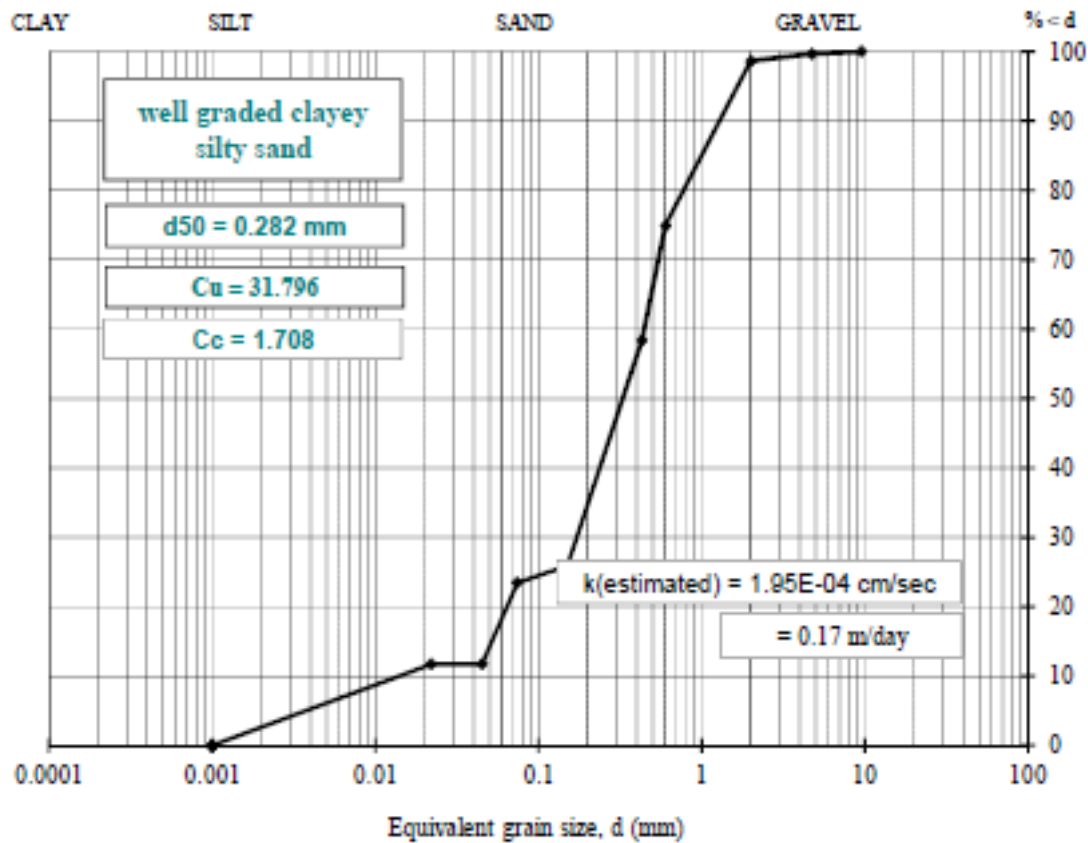
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH5
Depth	1.8 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	0.3
				Medium gravel	0.0	
				Fine gravel	0.3	
3/8"	9.50	155.7	100.0	Coarse sand	1.0	76.2
Nr. 4	4.75	155.2	99.7	Medium sand	40.3	
Nr. 10	2.00	153.6	98.7	Fine sand	34.9	
Nr. 30	0.60	116.6	74.9	Coarse silt	11.72	16.65
Nr. 40	0.43	90.9	58.4	Medium silt	0.00	
Nr. 100	0.15	40.3	25.9	Fine silt	4.93	
Nr. 200	0.07	36.5	23.4			
Pan	---	0.0	0.0	Clay	6.79	6.79

*Percentages relative to entire sample mass



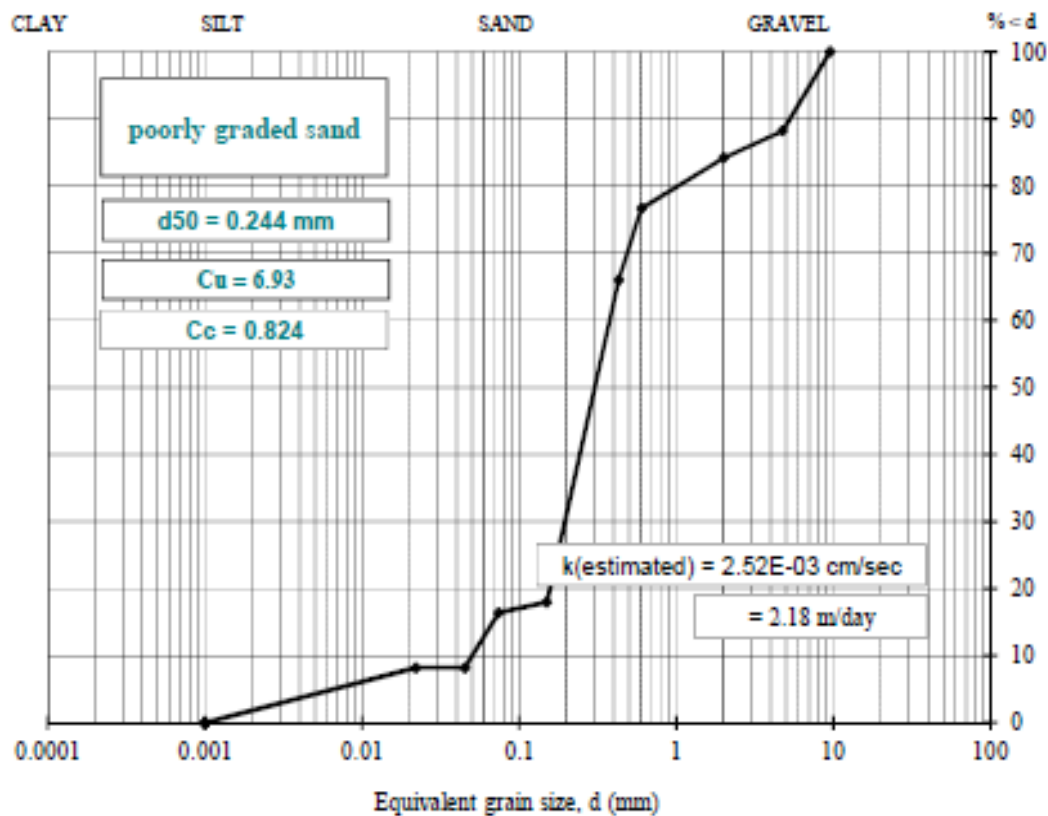
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Serdah)
Bore Hole No.	BH5
Depth	2.1 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	11.8
				Medium gravel	0.0	
				Fine gravel	11.8	
3/8"	9.50	82.3	100.0	Coarse sand	4.0	71.8
Nr. 4	4.75	72.6	88.2	Medium sand	18.2	
Nr. 10	2.00	69.3	84.2	Fine sand	49.6	
Nr. 30	0.60	63.1	76.7	Coarse silt	8.20	11.65
Nr. 40	0.43	54.3	66.0	Medium silt	0.00	
Nr. 100	0.15	14.8	18.0	Fine silt	3.45	
Nr. 200	0.07	13.5	16.4	Fine silt	3.45	
Pan	---	0.0	0.0	Clay	4.75	4.75

*Percentages relative to entire sample mass



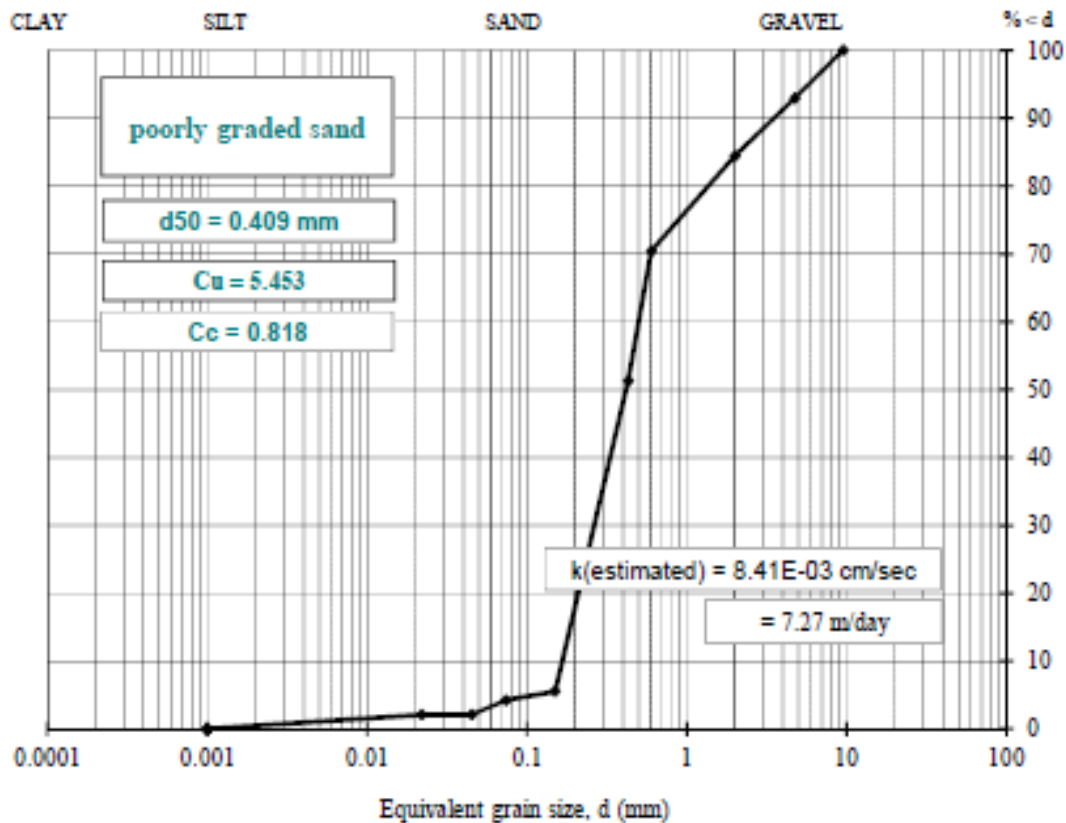
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Serdah)
Bore Hole No.	BH5
Depth	3.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	7.0
				Medium gravel	0.0	
				Fine gravel	7.0	
3/8"	9.50	101.1	100.0	Coarse sand	8.5	88.7
Nr. 4	4.75	94.0	93.0	Medium sand	33.1	
Nr. 10	2.00	85.4	84.5	Fine sand	47.1	
Nr. 30	0.60	71.2	70.4	Coarse silt	2.13	3.02
Nr. 40	0.43	51.9	51.3	Medium silt	0.00	
Nr. 100	0.15	5.6	5.5	Fine silt	0.89	
Nr. 200	0.07	4.3	4.3	Fine silt	0.89	1.23
Pan	---	0.0	0.0	Clay	1.23	

*Percentages relative to entire sample mass



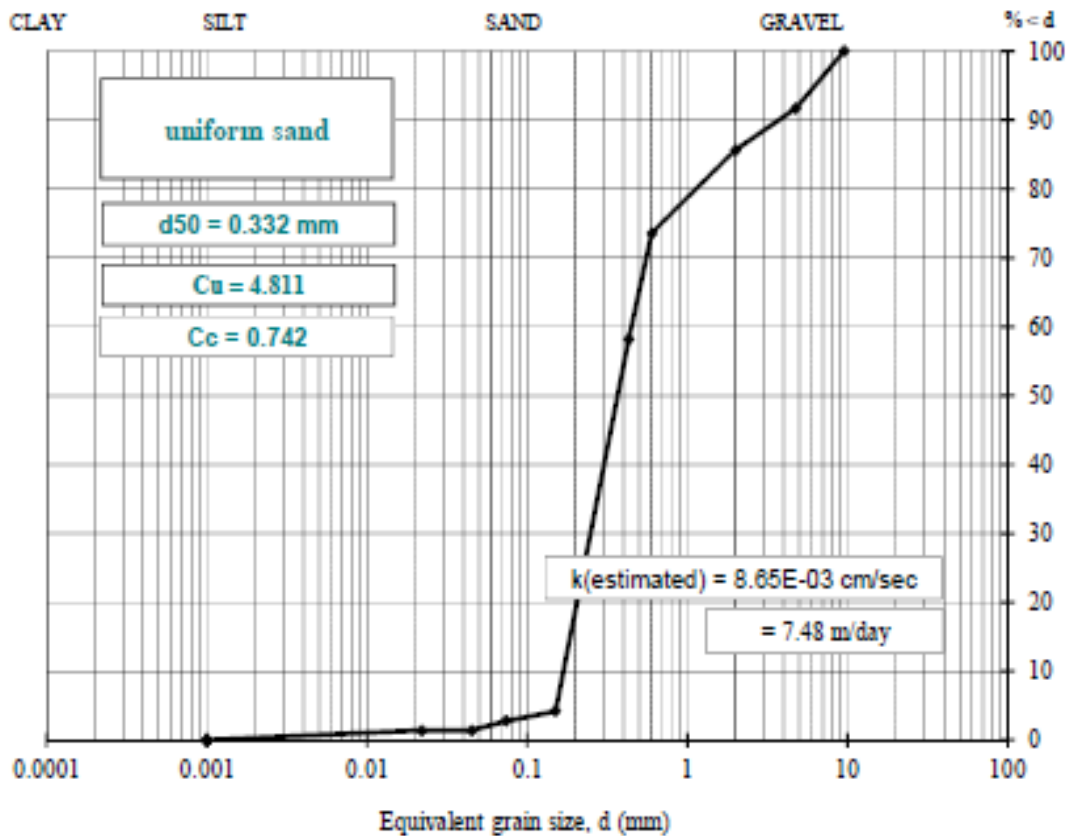
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH5
Depth	4.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	8.3
				Medium gravel	0.0	
				Fine gravel	8.3	
3/8"	9.50	114.2	100.0	Coarse sand	6.0	88.9
Nr. 4	4.75	104.7	91.7	Medium sand	27.5	
Nr. 10	2.00	97.8	85.6	Fine sand	55.3	
Nr. 30	0.60	84.0	73.6	Coarse silt	1.40	1.99
Nr. 40	0.43	66.4	58.1	Medium silt	0.00	
Nr. 100	0.15	4.8	4.2	Fine silt	0.59	
Nr. 200	0.07	3.2	2.8	Fine silt	0.59	
Pan	---	0.0	0.0	Clay	0.81	0.81

*Percentages relative to entire sample mass



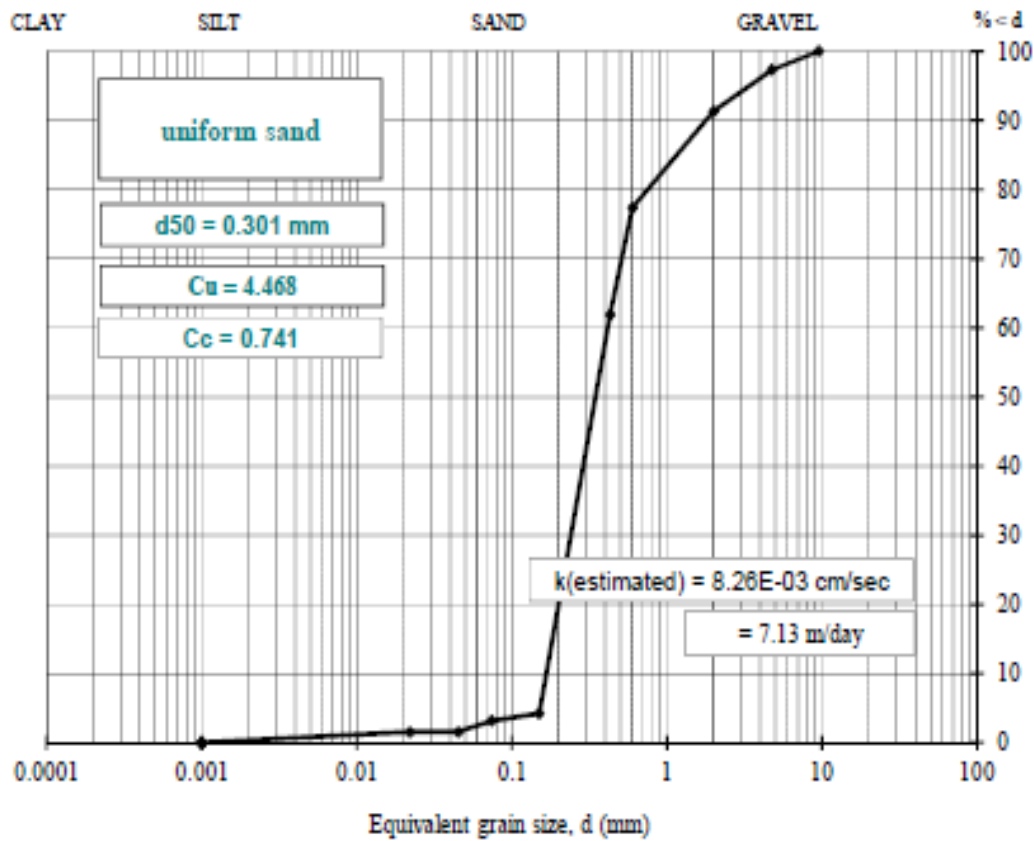
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Serdah)
Bore Hole No.	BH5
Depth	5.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	2.7
				Medium gravel	0.0	
				Fine gravel	2.7	
3/8"	9.50	108.2	100.0	Coarse sand	6.0	94.2
Nr. 4	4.75	105.3	97.3	Medium sand	29.4	
Nr. 10	2.00	98.8	91.3	Fine sand	58.8	
Nr. 30	0.60	83.7	77.4	Coarse silt	1.57	2.23
Nr. 40	0.43	67.0	61.9	Medium silt	0.00	
Nr. 100	0.15	4.6	4.3	Fine silt	0.66	
Nr. 200	0.07	3.4	3.1	Fine silt	0.66	
Pan	---	0.0	0.0	Clay	0.91	0.91

*Percentages relative to entire sample mass



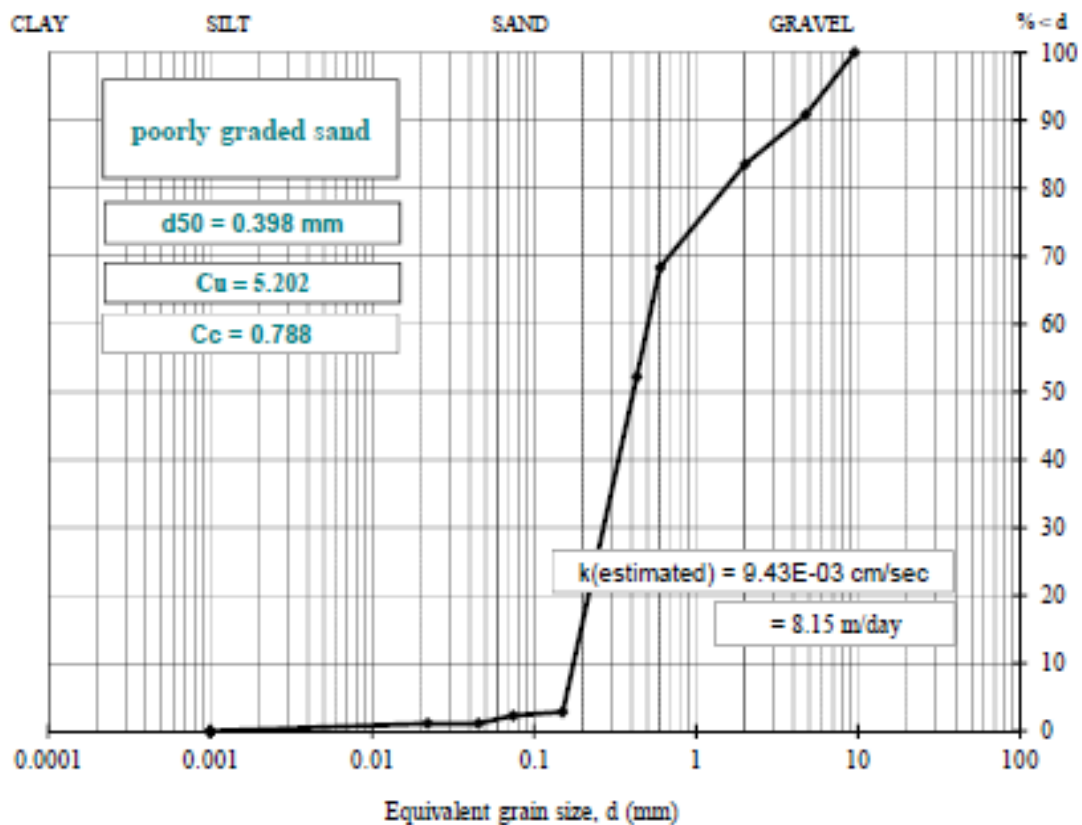
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH5
Depth	6.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	9.2
				Medium gravel	0.0	
				Fine gravel	9.2	
3/8"	9.50	91.6	100.0	Coarse sand	7.3	88.5
Nr. 4	4.75	83.2	90.8	Medium sand	31.3	
Nr. 10	2.00	76.5	83.5	Fine sand	49.9	
Nr. 30	0.60	62.6	68.3	Coarse silt	1.15	1.63
Nr. 40	0.43	47.8	52.2	Medium silt	0.00	
Nr. 100	0.15	2.6	2.8	Fine silt	0.48	
Nr. 200	0.07	2.1	2.3	Fine silt	0.48	0.66
Pan	---	0.0	0.0	Clay	0.66	

*Percentages relative to entire sample mass



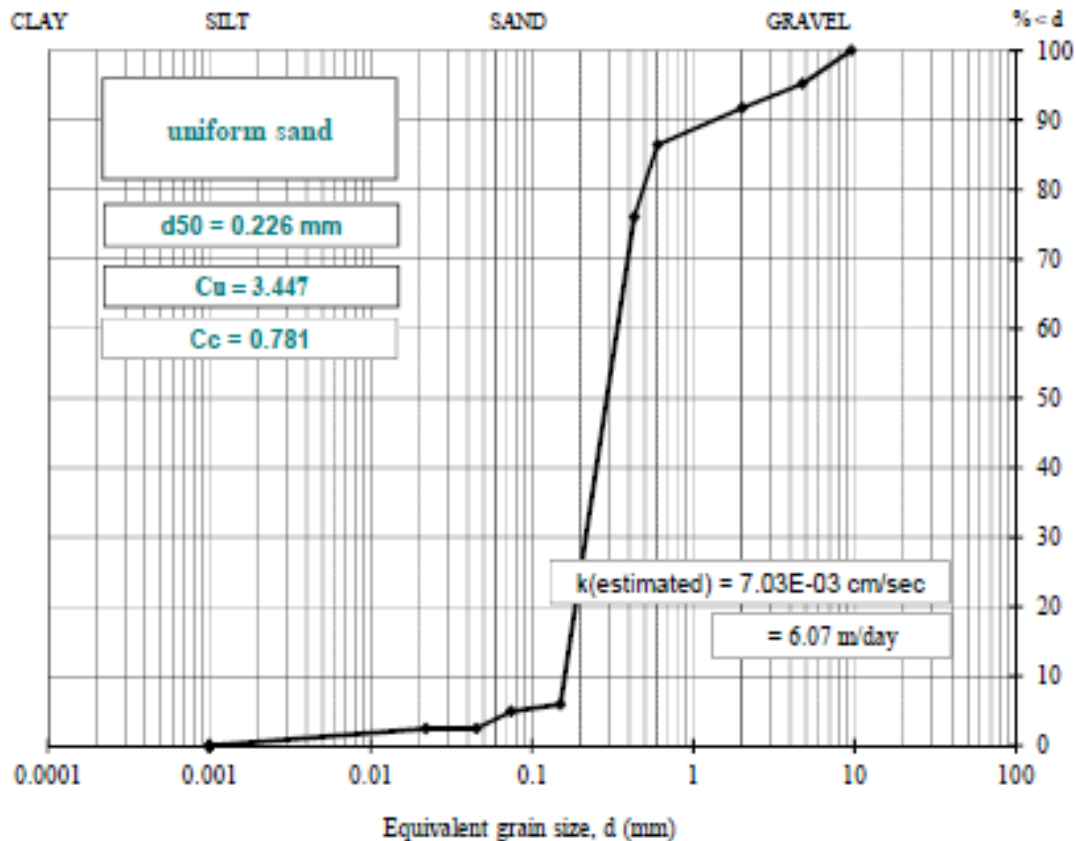
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH5
Depth	7.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	4.8
				Medium gravel	0.0	
				Fine gravel	4.8	
3/8"	9.50	109.0	100.0	Coarse sand	3.5	90.3
Nr. 4	4.75	103.8	95.2	Medium sand	15.7	
Nr. 10	2.00	100.0	91.7	Fine sand	71.1	
Nr. 30	0.60	94.2	86.4	Coarse silt	2.48	3.52
Nr. 40	0.43	82.9	76.1	Medium silt	0.00	
Nr. 100	0.15	6.5	6.0	Fine silt	1.04	
Nr. 200	0.07	5.4	5.0	Clay	1.44	
Pan	---	0.0	0.0	Clay	1.44	1.44

*Percentages relative to entire sample mass



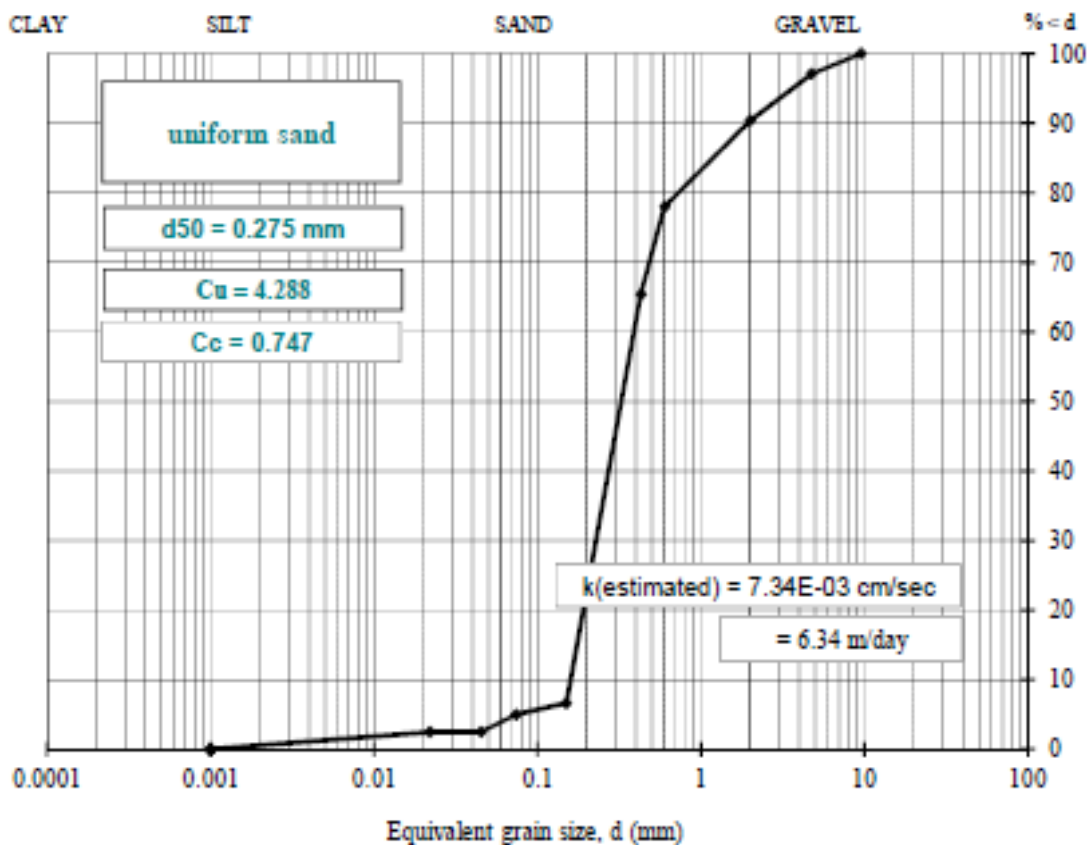
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH5
Depth	8.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	2.9
				Medium gravel	0.0	
				Fine gravel	2.9	
3/8"	9.50	114.5	100.0	Coarse sand	6.7	92.1
Nr. 4	4.75	111.2	97.1	Medium sand	25.0	
Nr. 10	2.00	103.5	90.4	Fine sand	60.4	
Nr. 30	0.60	89.3	78.0	Coarse silt	2.49	3.54
Nr. 40	0.43	74.9	65.4	Medium silt	0.00	
Nr. 100	0.15	7.6	6.6	Fine silt	1.05	
Nr. 200	0.07	5.7	5.0	Fine silt	1.05	
Pan	---	0.0	0.0	Clay	1.44	1.44

*Percentages relative to entire sample mass



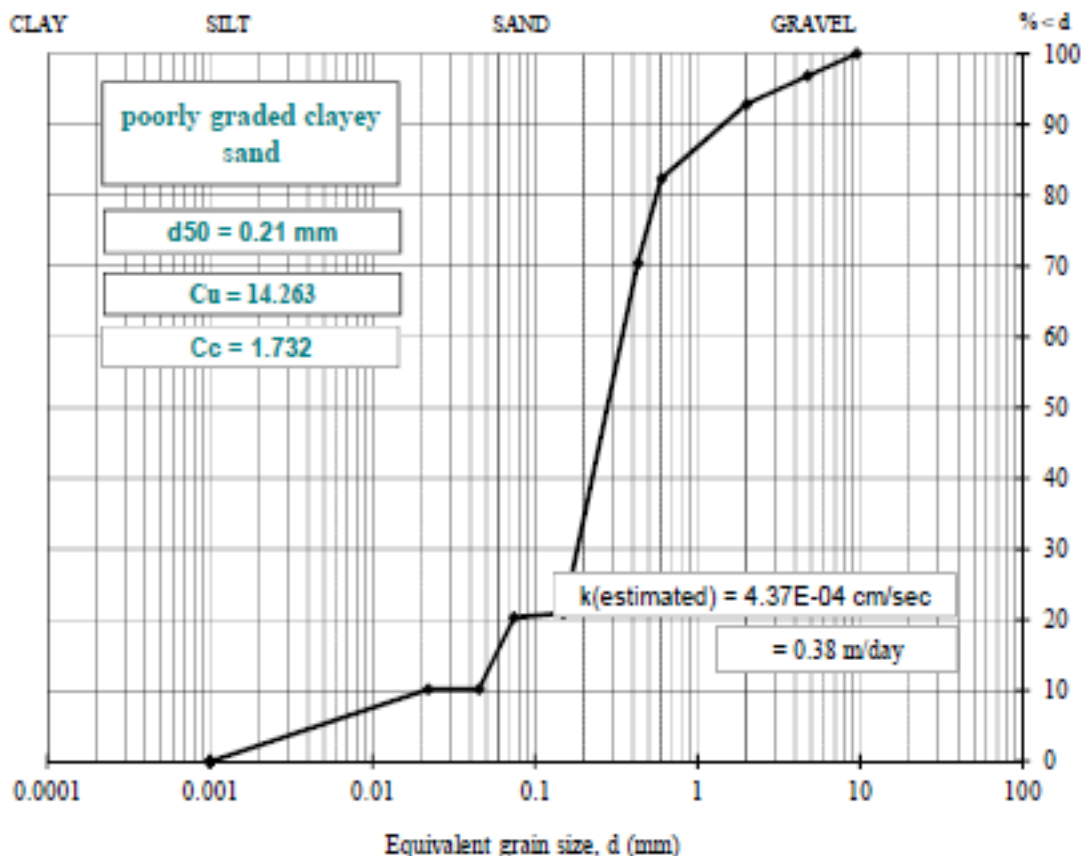
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH5
Depth	9.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	3.1
				Medium gravel	0.0	
				Fine gravel	3.1	
3/8"	9.50	125.4	100.0	Coarse sand	4.0	76.6
Nr. 4	4.75	121.5	96.9	Medium sand	22.5	
Nr. 10	2.00	116.5	92.9	Fine sand	50.1	
Nr. 30	0.60	103.3	82.4	Coarse silt	10.17	14.44
Nr. 40	0.43	88.3	70.4	Medium silt	0.00	
Nr. 100	0.15	26.3	21.0	Fine silt	4.27	
Nr. 200	0.07	25.5	20.3	Fine silt	4.27	
Pan	---	0.0	0.0	Clay	5.89	5.89

*Percentages relative to entire sample mass



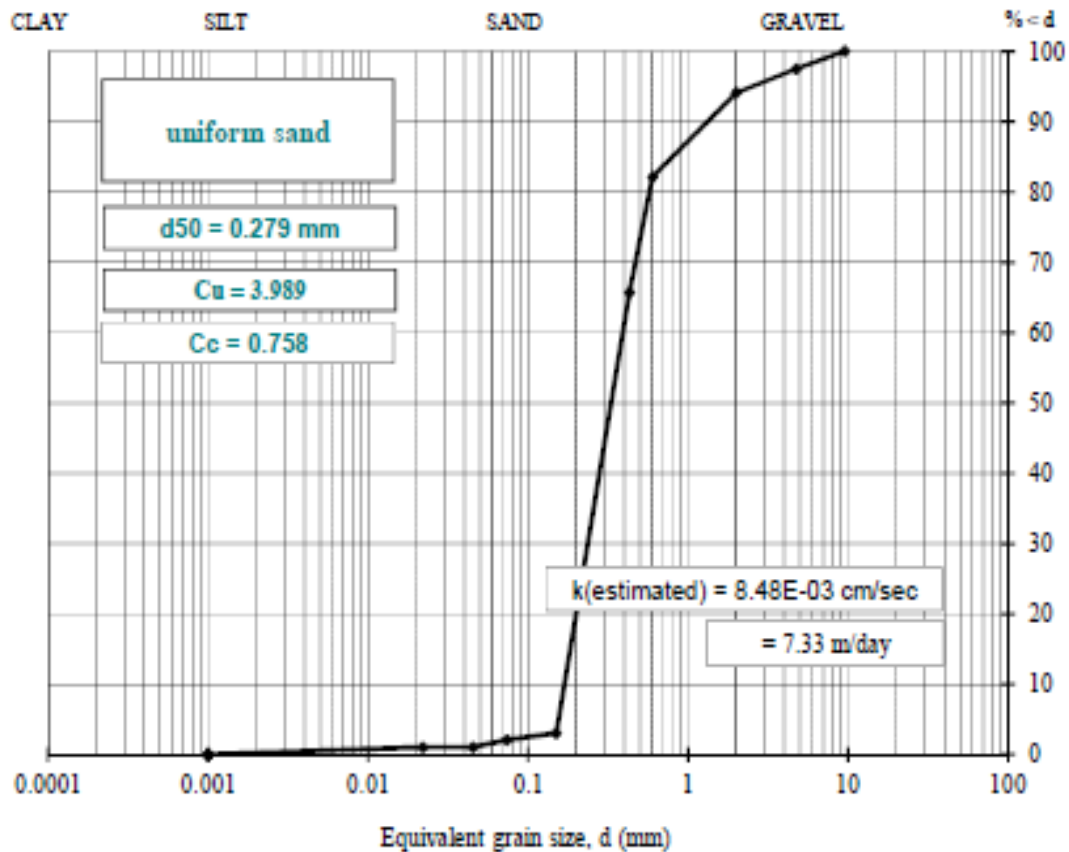
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH5
Depth	10.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	2.5
				Medium gravel	0.0	
				Fine gravel	2.5	
3/8"	9.50	105.2	100.0	Coarse sand	3.4	95.4
Nr. 4	4.75	102.6	97.5	Medium sand	28.4	
Nr. 10	2.00	99.0	94.1	Fine sand	63.6	
Nr. 30	0.60	86.4	82.1	Coarse silt	1.05	1.49
Nr. 40	0.43	69.1	65.7	Medium silt	0.00	
Nr. 100	0.15	3.2	3.0	Fine silt	0.44	
Nr. 200	0.07	2.2	2.1			
Pan	---	0.0	0.0	Clay	0.61	0.61

*Percentages relative to entire sample mass



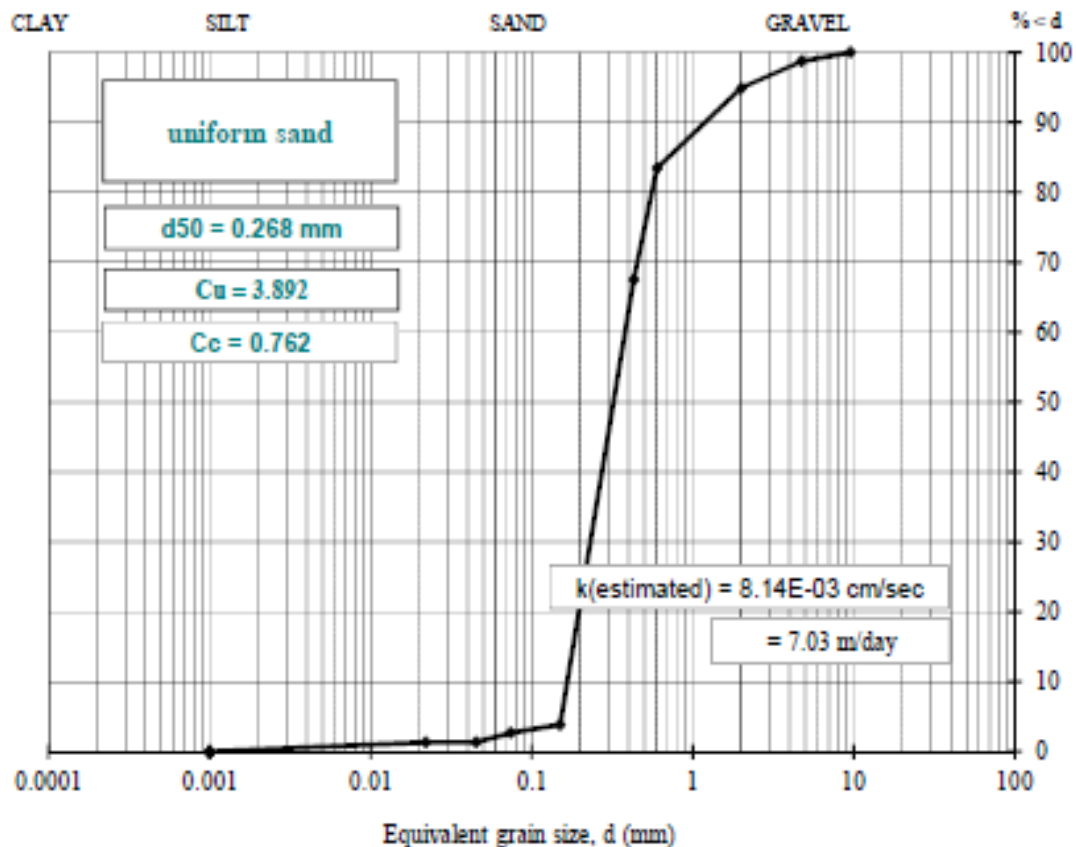
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH5
Depth	11.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	1.2
				Medium gravel	0.0	
				Fine gravel	1.2	
3/8"	9.50	121.4	100.0	Coarse sand	3.9	96.0
Nr. 4	4.75	119.9	98.8	Medium sand	27.4	
Nr. 10	2.00	115.2	94.9	Fine sand	64.7	
Nr. 30	0.60	101.3	83.4	Coarse silt	1.36	1.93
Nr. 40	0.43	81.9	67.5	Medium silt	0.00	
Nr. 100	0.15	4.7	3.9	Fine silt	0.57	
Nr. 200	0.07	3.3	2.7	Fine silt	0.57	
Pan	---	0.0	0.0	Clay	0.79	0.79

*Percentages relative to entire sample mass



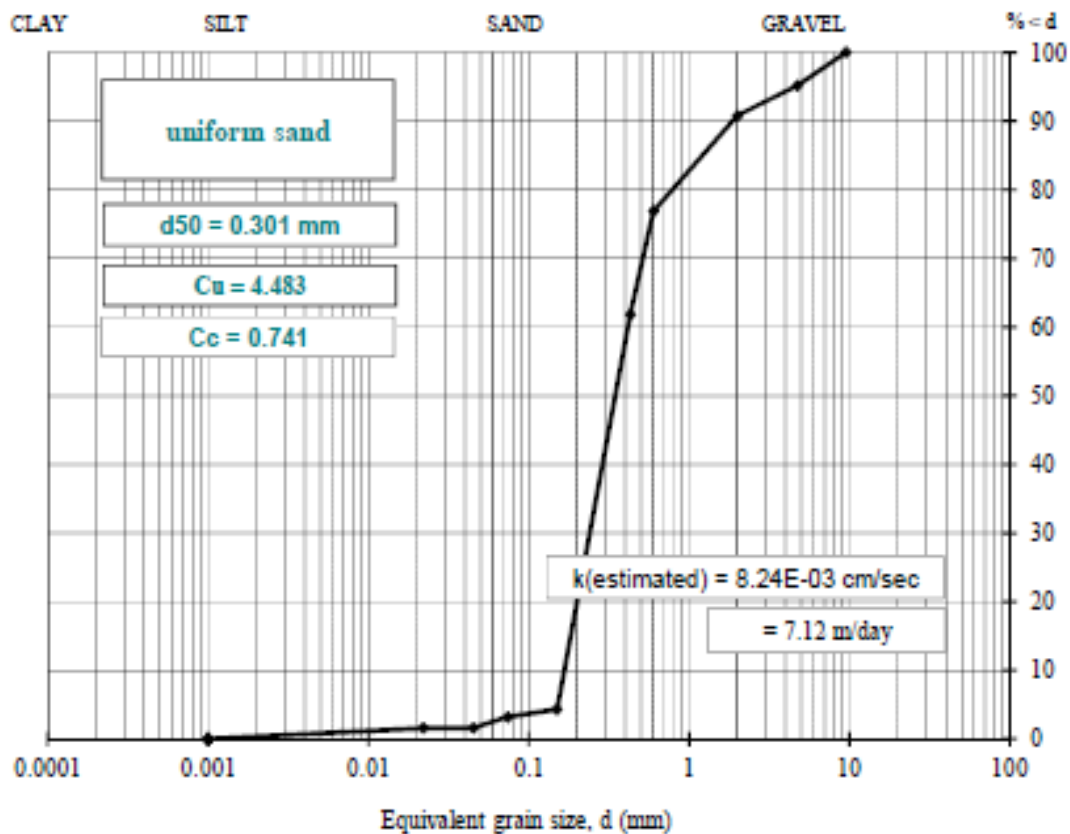
Grain Size Distribution of Soil

ASTM D 422-63 (1998)

Project:	Master Research-Study- (Eng. Basem Sirdah)
Bore Hole No.	BH5
Depth	12.0 m

Mechanical (sieve) analysis				Soil Type	%	Tot. %
Sieve Number	Sieve mesh opening, mm	Mass passing, g	Percent passing, %	Coarse gravel	0.0	4.8
				Medium gravel	0.0	
				Fine gravel	4.8	
3/8"	9.50	106.4	100.0	Coarse sand	4.4	92.0
Nr. 4	4.75	101.3	95.2	Medium sand	28.9	
Nr. 10	2.00	96.6	90.8	Fine sand	58.6	
Nr. 30	0.60	81.8	76.9	Coarse silt	1.60	2.27
Nr. 40	0.43	65.8	61.8	Medium silt	0.00	
Nr. 100	0.15	4.6	4.3	Fine silt	0.67	
Nr. 200	0.07	3.4	3.2	Fine silt	0.67	0.93
Pan	---	0.0	0.0	Clay	0.93	

*Percentages relative to entire sample mass



APPENDIX (3)

Modeling Calculations

Model (1), K =37.458cm/hr

<i>K (cm/hr)</i>	<i>ψ(cm)</i>	<i>t (hr)</i>	<i>η</i>	<i>θr</i>	<i>θe</i>	<i>Δθ</i>	<i>F (cm)</i>	<i>f (cm/hr)</i>	<i>f (m/d)</i>	<i>Kt</i>	<i>F (t)</i>	Equation	Ln
37.458	4.950	0.0	0.430	0.042	0.388	0.349	0			0	0	0.000	0.000
37.458	4.950	0.1	0.430	0.042	0.388	0.349	6.428	47.531	11.408	3.746	6.428	3.746	1.552
37.458	4.950	0.2	0.430	0.042	0.388	0.349	10.934	43.380	10.411	7.492	10.934	7.492	1.991
37.458	4.950	0.3	0.430	0.042	0.388	0.349	15.180	41.724	10.014	11.238	15.180	11.238	2.281
37.458	4.950	0.4	0.430	0.042	0.388	0.349	19.302	40.813	9.795	14.983	19.302	14.983	2.499
37.458	4.950	0.5	0.430	0.042	0.388	0.349	22.869	40.290	9.670	18.729	22.869	18.279	2.655
37.458	4.950	1	0.430	0.042	0.388	0.349	43.085	38.961	9.351	37.458	43.085	37.458	3.255
37.458	4.950	1.1	0.430	0.042	0.388	0.349	46.975	38.837	9.321	41.204	46.975	41.204	3.338
37.458	4.950	1.2	0.430	0.042	0.388	0.349	50.853	38.732	9.296	44.950	50.853	44.950	3.415
37.458	4.950	1.3	0.430	0.042	0.388	0.349	54.722	38.642	9.274	48.696	54.722	48.696	3.486
37.458	4.950	1.4	0.430	0.042	0.388	0.349	58.582	38.564	9.255	52.442	58.582	52.442	3.552
37.458	4.950	1.5	0.430	0.042	0.388	0.349	62.435	38.495	9.239	56.188	62.435	56.188	3.614
37.458	4.950	2	0.430	0.042	0.388	0.349	81.616	38.252	9.180	74.917	81.616	74.917	3.876
37.458	4.950	2.5	0.430	0.042	0.388	0.349	100.702	38.101	9.144	93.646	100.702	93.646	4.082
37.458	4.950	3	0.430	0.042	0.388	0.349	119.725	37.999	9.120	112.375	119.725	112.375	4.252
37.458	4.950	3.5	0.430	0.042	0.388	0.349	138.705	37.925	9.102	131.104	138.705	131.104	4.397
37.458	4.950	4	0.430	0.042	0.388	0.349	157.653	37.869	9.089	149.833	157.653	149.833	4.524

K (cm/hr)	ψ (cm)	t (hr)	η	θ_r	θ_e	$\Delta\theta$	F (cm)	f (cm/hr)	f (m/d)	Kt	F (t)	Equation	Ln
37.458	4.950	4.5	0.430	0.042	0.388	0.349	176.577	37.825	9.078	168.563	176.577	168.563	4.636
37.458	4.950	5	0.430	0.042	0.388	0.349	195.480	37.790	9.069	187.292	195.480	187.292	4.737
37.458	4.950	6	0.430	0.042	0.388	0.349	233.241	37.736	9.057	224.750	233.241	224.750	4.912
37.458	4.950	8	0.430	0.042	0.388	0.349	308.639	37.668	9.040	299.667	308.639	299.667	5.190
37.458	4.950	10	0.430	0.042	0.388	0.349	383.930	37.627	9.030	374.583	383.930	374.583	5.408
37.458	4.950	12	0.430	0.042	0.388	0.349	459.155	37.599	9.024	449.500	459.155	449.500	5.586
37.458	4.950	16	0.430	0.042	0.388	0.349	609.476	37.565	9.015	599.333	609.476	599.333	5.868
37.458	4.950	20	0.430	0.042	0.388	0.349	759.690	37.544	9.010	749.167	759.690	749.167	6.088
37.458	4.950	24	0.430	0.042	0.388	0.349	909.834	37.529	9.007	899.000	909.834	899.000	6.268

Model (2), K =11.780cm/hr

K (cm/hr)	ψ (cm)	t (hr)	η	θ_i	$\Delta\theta$	F (cm)	f (cm/hr)	f (m/d)	Kt	F (t)	Eq.	Ln
11.780	4.95	0.0	0.430	0.000	0.430	0			0	0	0.000	0.000
11.780	4.950	0.1	0.430	0.000	0.430	3.085	19.909	4.778	1.178	3.085	1.178	0.896
11.780	4.950	0.2	0.430	0.000	0.430	4.898	16.899	4.056	2.356	4.898	2.356	1.194
11.780	4.950	0.3	0.430	0.000	0.430	6.517	15.627	3.751	3.534	6.517	3.534	1.402
11.780	4.950	0.4	0.430	0.000	0.430	8.041	14.898	3.576	4.712	8.041	4.712	1.564
11.780	4.950	0.5	0.430	0.000	0.430	9.505	14.418	3.460	5.890	9.505	5.890	1.698
11.780	4.950	1	0.430	0.000	0.430	16.384	13.310	3.194	11.780	16.384	11.780	2.163
11.780	4.950	1.1	0.430	0.000	0.430	17.709	13.196	3.167	12.958	17.709	12.958	2.232
11.780	4.950	1.2	0.430	0.000	0.430	19.024	13.098	3.144	14.136	19.024	14.136	2.296
11.780	4.950	1.3	0.430	0.000	0.430	20.329	13.013	3.123	15.314	20.329	15.314	2.356
11.780	4.950	1.4	0.430	0.000	0.430	21.627	12.939	3.105	16.492	21.627	16.492	2.412
11.780	4.950	1.5	0.430	0.000	0.430	22.917	12.874	3.090	17.670	22.917	17.670	2.465
11.780	4.950	2	0.430	0.000	0.430	29.290	12.636	3.033	23.560	29.290	23.560	2.692
11.780	4.950	2.5	0.430	0.000	0.430	35.568	12.485	2.996	29.450	35.568	29.450	2.874
11.780	4.950	3	0.430	0.000	0.430	41.782	12.380	2.971	35.340	41.782	35.340	3.027
11.780	4.950	3.5	0.430	0.000	0.430	47.952	12.303	2.953	41.230	47.952	41.230	3.158
11.780	4.950	4	0.430	0.000	0.430	54.088	12.244	2.938	47.120	54.088	47.120	3.274

K (cm/hr)	ψ (cm)	t (hr)	η	θ_i	$\Delta\theta$	F (cm)	f (cm/hr)	f (m/d)	Kt	F (t)	Eq.	Ln
11.780	4.950	4.5	0.430	0.000	0.430	60.198	12.197	2.927	53.010	60.198	53.010	3.377
11.780	4.950	5	0.430	0.000	0.430	66.286	12.158	2.918	58.900	66.286	58.900	3.470
11.780	4.950	6	0.430	0.000	0.430	78.414	12.100	2.904	70.680	78.414	70.680	3.633
11.780	4.950	8	0.430	0.000	0.430	102.531	12.025	2.886	94.240	102.531	94.240	3.895
11.780	4.950	10	0.430	0.000	0.430	126.531	11.978	2.875	117.800	126.5306	117.800	4.102
11.780	4.950	12	0.430	0.000	0.430	150.454	11.947	2.867	141.360	150.4536	141.360	4.272
11.780	4.950	16	0.430	0.000	0.430	198.153	11.907	2.858	188.480	198.1526	188.480	4.544
11.780	4.950	20	0.430	0.000	0.430	245.726	11.882	2.852	235.600	245.7262	235.600	4.757
11.780	4.950	24	0.430	0.000	0.430	293.219	11.866	2.848	282.720	293.2193	282.720	4.933

Model (3), K = 8.042cm/hr

<i>K (cm/hr)</i>	<i>ψ(cm)</i>	<i>t (hr)</i>	<i>η</i>	<i>θr</i>	<i>θe</i>	<i>Δθ</i>	<i>F (cm)</i>	<i>f (cm/hr)</i>	<i>f (m/d)</i>	<i>Kt</i>	<i>F (t)</i>	Eq.	Ln
8.042	20.880	0.0	0.460	0.156	0.304	0.195	0			0	0	0.000	0.000
8.042	20.880	0.1	0.460	0.156	0.304	0.195	3.118	18.520	4.445	0.804	3.118	0.804	0.570
8.042	20.880	0.2	0.460	0.156	0.304	0.195	4.757	14.909	3.578	1.608	4.757	1.608	0.775
8.042	20.880	0.3	0.460	0.156	0.304	0.195	6.163	13.342	3.202	2.413	6.163	2.413	0.923
8.042	20.880	0.4	0.460	0.156	0.304	0.195	7.448	12.428	2.983	3.217	7.448	3.217	1.041
8.042	20.880	0.5	0.460	0.156	0.304	0.195	8.658	11.815	2.836	4.021	8.658	4.021	1.141
8.042	20.880	1	0.460	0.156	0.304	0.195	14.133	10.353	2.485	8.042	14.133	8.042	1.499
8.042	20.880	1.1	0.460	0.156	0.304	0.195	15.160	10.197	2.447	8.846	15.160	8.846	1.554
8.042	20.880	1.2	0.460	0.156	0.304	0.195	16.173	10.062	2.415	9.650	16.173	9.650	1.606
8.042	20.880	1.3	0.460	0.156	0.304	0.195	17.173	9.944	2.387	10.454	17.173	10.454	1.654
8.042	20.880	1.4	0.460	0.156	0.304	0.195	18.162	9.840	2.362	11.258	18.162	11.258	1.699
8.042	20.880	1.5	0.460	0.156	0.304	0.195	19.142	9.748	2.340	12.063	19.142	12.063	1.743
8.042	20.880	2	0.460	0.156	0.304	0.195	23.923	9.407	2.258	16.083	23.923	16.083	1.930
8.042	20.880	2.5	0.460	0.156	0.304	0.195	28.568	9.185	2.204	20.104	28.568	20.104	2.083
8.042	20.880	3	0.460	0.156	0.304	0.195	33.119	9.028	2.167	24.125	33.119	24.125	2.214
8.042	20.880	3.5	0.460	0.156	0.304	0.195	37.603	8.910	2.139	28.146	37.603	28.146	2.328
8.042	20.880	4	0.460	0.156	0.304	0.195	42.034	8.819	2.117	32.167	42.034	32.167	2.429

<i>K (cm/hr)</i>	$\psi(cm)$	<i>t (hr)</i>	η	θ_r	θ_e	$\Delta\theta$	F (cm)	<i>f (cm/hr)</i>	<i>f (m/d)</i>	Kt	F (t)	Eq.	Ln
8.042	20.880	4.5	0.460	0.156	0.304	0.195	46.425	8.745	2.099	36.188	46.425	36.188	2.520
8.042	20.880	5	0.460	0.156	0.304	0.195	50.781	8.685	2.084	40.208	50.781	40.208	2.603
8.042	20.880	6	0.460	0.156	0.304	0.195	59.417	8.591	2.062	48.250	59.417	48.250	2.749
8.042	20.880	8	0.460	0.156	0.304	0.195	76.467	8.469	2.033	64.333	76.467	64.333	2.987
8.042	20.880	10	0.460	0.156	0.304	0.195	93.323	8.392	2.014	80.417	93.323	80.417	3.177
8.042	20.880	12	0.460	0.156	0.304	0.195	110.050	8.339	2.001	96.500	110.050	96.500	3.335
8.042	20.880	16	0.460	0.156	0.304	0.195	143.254	8.270	1.985	128.667	143.254	128.667	3.591
8.042	20.880	20	0.460	0.156	0.304	0.195	176.241	8.227	1.974	160.833	176.241	160.833	3.793
8.042	20.880	24	0.460	0.156	0.304	0.195	209.088	8.198	1.967	193.000	209.088	193.000	3.960

Model (4), K = 1.083cm/hr

<i>K (cm/hr)</i>	<i>ψ(cm)</i>	<i>t (hr)</i>	<i>η</i>	<i>θr</i>	<i>θe</i>	<i>Δθ</i>	F (cm)	<i>f (cm/hr)</i>	<i>f (m/d)</i>	Kt	F (t)	Eq.	Ln
1.083	20.880	0.0	0.460	0.127	0.333	0.250	0			0	0	0.000	0.000
1.083	20.880	0.1	0.460	0.127	0.333	0.250	1.135	6.063	1.455	0.108	1.135	0.108	0.197
1.083	20.880	0.2	0.460	0.127	0.333	0.250	1.652	4.502	1.081	0.217	1.652	0.217	0.275
1.083	20.880	0.3	0.460	0.127	0.333	0.250	2.064	3.821	0.917	0.325	2.064	0.325	0.333
1.083	20.880	0.4	0.460	0.127	0.333	0.250	2.423	3.415	0.820	0.433	2.423	0.433	0.382
1.083	20.880	0.5	0.460	0.127	0.333	0.250	2.752	3.136	0.753	0.542	2.752	0.542	0.424
1.083	20.880	1	0.460	0.127	0.333	0.250	4.118	2.455	0.589	1.083	4.118	1.083	0.582
1.083	20.880	1.1	0.460	0.127	0.333	0.250	4.362	2.379	0.571	1.192	4.362	1.192	0.608
1.083	20.880	1.2	0.460	0.127	0.333	0.250	4.595	2.313	0.555	1.300	4.595	1.300	0.632
1.083	20.880	1.3	0.460	0.127	0.333	0.250	4.823	2.255	0.541	1.408	4.823	1.408	0.655
1.083	20.880	1.4	0.460	0.127	0.333	0.250	5.047	2.203	0.529	1.517	5.047	1.517	0.677
1.083	20.880	1.5	0.460	0.127	0.333	0.250	5.264	2.156	0.518	1.625	5.264	1.625	0.698
1.083	20.880	2	0.460	0.127	0.333	0.250	6.296	1.981	0.475	2.167	6.296	2.167	0.792
1.083	20.880	2.5	0.460	0.127	0.333	0.250	7.254	1.862	0.447	2.708	7.254	2.708	0.872
1.083	20.880	3	0.460	0.127	0.333	0.250	8.163	1.775	0.426	3.250	8.163	3.250	0.942
1.083	20.880	3.5	0.460	0.127	0.333	0.250	9.034	1.709	0.410	3.792	9.034	3.792	1.005
1.083	20.880	4	0.460	0.127	0.333	0.250	9.873	1.656	0.397	4.333	9.873	4.333	1.062

K (cm/hr)	ψ (cm)	t (hr)	η	θ_r	θ_e	$\Delta\theta$	F (cm)	f (cm/hr)	f (m/d)	Kt	F (t)	$Eq.$	Ln
1.083	20.880	4.5	0.460	0.127	0.333	0.250	10.690	1.612	0.387	4.875	10.690	4.875	1.115
1.083	20.880	5	0.460	0.127	0.333	0.250	11.487	1.575	0.378	5.417	11.487	5.417	1.164
1.083	20.880	6	0.460	0.127	0.333	0.250	13.031	1.517	0.364	6.500	13.031	6.500	1.252
1.083	20.880	8	0.460	0.127	0.333	0.250	15.979	1.437	0.345	8.667	15.979	8.667	1.402
1.083	20.880	10	0.460	0.127	0.333	0.250	18.796	1.384	0.332	10.833	18.796	10.833	1.527
1.083	20.880	12	0.460	0.127	0.333	0.250	21.524	1.346	0.323	13.000	21.524	13.000	1.635
1.083	20.880	16	0.460	0.127	0.333	0.250	26.796	1.294	0.311	17.333	26.796	17.333	1.815
1.083	20.880	20	0.460	0.127	0.333	0.250	31.901	1.260	0.303	21.667	31.901	21.667	1.963
1.083	20.880	24	0.460	0.127	0.333	0.250	36.892	1.236	0.297	26.000	36.892	26.000	2.089

Model (5), K = 0.833cm/hr

<i>K (cm/hr)</i>	<i>ψ(cm)</i>	<i>t (hr)</i>	<i>η</i>	<i>θ_r</i>	<i>θ_e</i>	<i>Δθ</i>	F (cm)	<i>f (cm/hr)</i>	<i>f (m/d)</i>	<i>Kt</i>	F (t)	Eq.	Ln
0.833	20.880	0.0	0.460	0.121	0.339	0.254	0			0	0	0.000	0.000
0.833	20.880	0.1	0.460	0.121	0.339	0.254	0.995	5.280	1.2672	0.083	0.995	0.083	0.172
0.833	20.880	0.2	0.460	0.121	0.339	0.254	1.445	3.895	0.9347	0.167	1.445	0.167	0.241
0.833	20.880	0.3	0.460	0.121	0.339	0.254	1.800	3.291	0.7899	0.250	1.800	0.250	0.292
0.833	20.880	0.4	0.460	0.121	0.339	0.254	2.109	2.931	0.7035	0.333	2.109	0.333	0.334
0.833	20.880	0.5	0.460	0.121	0.339	0.254	2.391	2.684	0.6441	0.417	2.391	0.417	0.372
0.833	20.880	1	0.460	0.121	0.339	0.254	3.553	2.078	0.4988	0.833	3.553	0.833	0.512
0.833	20.880	1.1	0.460	0.121	0.339	0.254	3.759	2.010	0.4824	0.917	3.759	0.917	0.535
0.833	20.880	1.2	0.460	0.121	0.339	0.254	3.957	1.951	0.4684	1.000	3.957	1.000	0.557
0.833	20.880	1.3	0.460	0.121	0.339	0.254	4.148	1.900	0.4559	1.083	4.148	1.083	0.577
0.833	20.880	1.4	0.460	0.121	0.339	0.254	4.337	1.853	0.4448	1.167	4.337	1.167	0.597
0.833	20.880	1.5	0.460	0.121	0.339	0.254	4.520	1.812	0.4349	1.250	4.520	1.250	0.616
0.833	20.880	2	0.460	0.121	0.339	0.254	5.384	1.655	0.3972	1.667	5.384	1.667	0.700
0.833	20.880	2.5	0.460	0.121	0.339	0.254	6.183	1.549	0.3717	2.083	6.183	2.083	0.772
0.833	20.880	3	0.460	0.121	0.339	0.254	6.937	1.471	0.3530	2.500	6.937	2.500	0.836
0.833	20.880	3.5	0.460	0.121	0.339	0.254	7.658	1.411	0.3386	2.917	7.658	2.917	0.893
0.833	20.880	4	0.460	0.121	0.339	0.254	8.350	1.363	0.3272	3.333	8.350	3.333	0.945

<i>K (cm/hr)</i>	<i>ψ(cm)</i>	<i>t (hr)</i>	<i>η</i>	<i>θ_r</i>	<i>θ_e</i>	<i>Δθ</i>	<i>F (cm)</i>	<i>f (cm/hr)</i>	<i>f (m/d)</i>	<i>Kt</i>	<i>F (t)</i>	<i>Eq.</i>	<i>Ln</i>
0.833	20.880	4.5	0.460	0.121	0.339	0.254	9.022	1.324	0.3177	3.750	9.022	3.750	0.993
0.833	20.880	5	0.460	0.121	0.339	0.254	9.676	1.291	0.3097	4.167	9.676	4.167	1.038
0.833	20.880	6	0.460	0.121	0.339	0.254	10.938	1.238	0.2971	5.000	10.938	5.000	1.119
0.833	20.880	8	0.460	0.121	0.339	0.254	13.336	1.165	0.2796	6.667	13.336	6.667	1.256
0.833	20.880	10	0.460	0.121	0.339	0.254	15.614	1.117	0.2680	8.333	15.614	8.333	1.371
0.833	20.880	12	0.460	0.121	0.339	0.254	17.811	1.082	0.2596	10.000	17.811	10.000	1.471
0.833	20.880	16	0.460	0.121	0.339	0.254	22.035	1.034	0.2482	13.333	22.035	13.333	1.639
0.833	20.880	20	0.460	0.121	0.339	0.254	26.105	1.003	0.2407	16.667	26.105	16.667	1.778
0.833	20.880	24	0.460	0.121	0.339	0.254	30.069	0.980	0.2353	20.000	30.069	20.000	1.897

Model (6), K = 0.042cm/hr

<i>K (cm/hr)</i>	<i>ψ(cm)</i>	<i>t (hr)</i>	<i>η</i>	<i>θ_r</i>	<i>θ_e</i>	<i>Δθ</i>	<i>F (cm)</i>	<i>f (cm/hr)</i>	<i>f (m/d)</i>	<i>Kt</i>	<i>F (t)</i>	<i>Eq.</i>	<i>Ln</i>
0.042	23.900	0.0	0.480	0.179	0.301	0.211	0			0	0	0.000	0.000
0.042	23.900	0.1	0.480	0.179	0.301	0.211	0.203	1.073	0.258	0.004	0.203	0.004	0.040
0.042	23.900	0.2	0.480	0.179	0.301	0.211	0.289	0.767	0.184	0.008	0.289	0.008	0.056
0.042	23.900	0.3	0.480	0.179	0.301	0.211	0.371	0.608	0.146	0.013	0.371	0.013	0.071
0.042	23.900	0.4	0.480	0.179	0.301	0.211	0.425	0.535	0.128	0.017	0.425	0.017	0.081
0.042	23.900	0.5	0.480	0.179	0.301	0.211	0.474	0.484	0.116	0.021	0.474	0.021	0.090
0.042	23.900	1	0.480	0.179	0.301	0.211	0.679	0.351	0.084	0.042	0.679	0.042	0.126
0.042	23.900	1.1	0.480	0.179	0.301	0.211	0.712	0.337	0.081	0.046	0.712	0.046	0.132
0.042	23.900	1.2	0.480	0.179	0.301	0.211	0.743	0.324	0.078	0.050	0.743	0.050	0.138
0.042	23.900	1.3	0.480	0.179	0.301	0.211	0.774	0.313	0.075	0.054	0.774	0.054	0.143
0.042	23.900	1.4	0.480	0.179	0.301	0.211	0.803	0.303	0.073	0.058	0.803	0.058	0.148
0.042	23.900	1.5	0.480	0.179	0.301	0.211	0.839	0.292	0.070	0.063	0.839	0.063	0.154
0.042	23.900	2	0.480	0.179	0.301	0.211	0.970	0.258	0.062	0.083	0.970	0.083	0.176
0.042	23.900	2.5	0.480	0.179	0.301	0.211	1.094	0.233	0.056	0.104	1.094	0.104	0.197
0.042	23.900	3	0.480	0.179	0.301	0.211	1.207	0.216	0.052	0.125	1.207	0.125	0.215
0.042	23.900	3.5	0.480	0.179	0.301	0.211	1.312	0.202	0.048	0.146	1.312	0.146	0.232
0.042	23.900	4	0.480	0.179	0.301	0.211	1.411	0.190	0.046	0.167	1.411	0.167	0.247

<i>K (cm/hr)</i>	<i>ψ(cm)</i>	<i>t (hr)</i>	<i>η</i>	<i>θr</i>	<i>θe</i>	<i>Δθ</i>	F (cm)	<i>f (cm/hr)</i>	<i>f (m/d)</i>	<i>Kt</i>	F (t)	Eq.	Ln
0.042	23.900	4.5	0.480	0.179	0.301	0.211	1.504	0.181	0.043	0.188	1.504	0.188	0.261
0.042	23.900	5	0.480	0.179	0.301	0.211	1.589	0.174	0.042	0.208	1.589	0.208	0.274
0.042	23.900	6	0.480	0.179	0.301	0.211	1.758	0.161	0.039	0.250	1.758	0.250	0.299
0.042	23.900	8	0.480	0.179	0.301	0.211	2.060	0.144	0.034	0.333	2.060	0.333	0.343
0.042	23.900	10	0.480	0.179	0.301	0.211	2.336	0.131	0.032	0.417	2.336	0.417	0.381
0.042	23.900	12	0.480	0.179	0.301	0.211	2.589	0.123	0.029	0.500	2.589	0.500	0.415
0.042	23.900	16	0.480	0.179	0.301	0.211	3.054	0.110	0.026	0.667	3.054	0.667	0.474
0.042	23.900	20	0.480	0.179	0.301	0.211	3.476	0.102	0.024	0.833	3.476	0.833	0.525
0.042	23.900	24	0.480	0.179	0.301	0.211	3.872	0.096	0.023	1.000	3.872	1.000	0.570

APPENDIX (4)

Palestinian Standards for Treated Wastewater

Description mg/l	Discharge to see (500)m	Recahrg to Ground Water by Infiltration
BOD ₅	60	40
COD	200	150
DO	> 1	> 1
TDS	-	1500
TSS	60	50
pH	6-9	6-9
Color (PCU)	-	-
Fat Oil & Grease	10	0
Phenol	1	0.002
DETERGENTS	25	5
No ₃ (N)	25	15
NH ₄ (N)	5	10
Organic N	10	10
PO ₄ (P)	5	15
CL	-	600
SO ₄	1000	1000
Na	-	230
Mg	-	150
Ca	-	400
Al	5	1
Ar	0.05	0.05
Cu	0.2	0.2
Fe	2	2
Mn	0.2	0.2
Ni	0.2	0.2
Pb	0.1	0.1

Description mg/l	Discharge to see (500)m	Recahrg to Ground Water by Infiltration
Se	0.02	0.02
Cd	0.01	0.01
Zn	5	5
CN	0.1	0.1
Cr	0.5	0.05
Hg	0.001	0.001
Co	1	0.05
B	2	1
FC /100ml	50000	1000
Pathoens	-	-
Amoebo & Gardia	-	-
Nematodes (Eggs/L)	< 1	< 1