NEAR EAST UNIVERSITY

GRADUATE SCHOOL OF APPLIED AND SOCIAL SCIENCE

Water Quality Analysis for Gemikonagi Reservoir in Northern Cyprus

Osama Ahmed Basyouni

Master Thesis

Department Of Civil Engineering

Nicosia-2003

Osama Basyouni: Water Quality Analysis for Gemikonagi Reservoir in Northern Cyprus.

Approval of the Graduate School of Applied and Social Sciences.

Prof. Dr. Fahreddin M. Sadıkoğlu
Director

We certify that this thesis is satisfactory for the award of the degree of Master of Science in civil engineering

Examining Committee in Charge:

Prof. Dr. Huseyin GÖKCEKUŞ	Chairman of committee. Charmin of Civil Engineering Department, NEU
Assist. Prof. Dr. Mehmet OKAYGÜN	Committee member, Civil Engineering Department, NEU
Assist. Prof. Dr. Umut TÜRKER	Committee Member, Supervisor, Civil Engineering Department, NEU

To My Family

ACKNOWLEDGMENTS

I would like to thank my family deserve many thanks for their support and encouragement. Without their Constant faith in me, I never would have finished this thesis.

I would like to express my profound gratitude and appreciation to my advisor Ass. Prof. Dr Umut Turker, Department of Civil Engineering, Near East University, for his valuable supervision and helpful suggestion knowledge, advice and Patience throughout this study.

I would also like to thank Water Department special Mr. Mustafa Sidal for providing me extremely helpful in assembling the data set I used in this thesis.

I would like to express my gratitude to near East University for scholarship that made the work possible.

Finally, I would like also to thank all my friends for their advice and support special Mr. Raed Alshaer and Mr. Raed Zourob and Mr. Ammar Mosleh.

ABSTRACT

Water Quality Analysis for Gemikonagi Reservoir in Northern Cyprus

Osama Ahmad Basyouni
M. Sc. Department of civil engineering
Supervisor: Assist. Prof. Dr. Umut Türker
October 2003

As can be said of many Mediterranean countries, due to its arid climate, the island of Cyprus suffers from considerable problems due to water shortage. In a country where agriculture and tourism represent one of the major forms of income, ensuring adequate water becomes especially important. This concern was addressed historically by the construction of dams throughout the island. However, the status of these dams, specifically the water quality, has not been monitored on a regular basis.

The purpose of this study was to evaluate the water quality and quantity of Gemikonagi dam. Optimize the use of it and further address the ongoing problem with water shortage. This study had two primary aims.

(1) To assess water quality of Gemikonagi sites of Northern Cyprus by using European standard for both drinking water and irrigation during the years 1994 through 2002

(2) To draw the Synthetic unit hydrograph with a view to fluctuation in the rain fall by using three methods.

The analyzed data is matched with European Standards of water quality. In term judged whether the reservoir is suitable for the drinking and irrigation or not. Also, the sodium absorbtin ration, which is helpfull for the agricultural quality of soil is mapped for last ten yers. Overall result showthat the quality of surrounding area is achiving good result, but unfortunately it is still not sutable for environmental and health standards.

NOMENCLATURE

T=time
R1, R2=effective rainfall.
UH= Unit Hydrograph.
P_s =shape and scale parameter.
γ' =shape and scale parameter.
Γ_G= Gamma function.
e = the base of natural logarithms
P_R = period of rise.
a= catchments parameter.
b= catchments parameters.
NI = integer number.
ZI =decimal number.
S_{av} =average slope.
A_W=Watershed area.
E_p =empirical value of the basin.
L_M = length of the main channel of the watershed in miles measured from the outlet to the uppermost part of the watershed
L_{mC} =length of the main channel (km).
L_{CC} = length of channel from centered watershed to the outlet (km).
S_{harm} = harmonic slope of the main channel (m/m).
q_p =unit discharge (l/s/km^2/mm).
t_p =time of rise (hr) and Q_P is the peak discharge (m^3/s).
Δh =elevation difference for the segment (m).
n_S = number of segments.
S_i = slope of each segment (m/m).
Q_p=peak discharge (m^3/s).
V=unit volume.
V_D =the volume of the dimensionless graph
h_a= unit depth for 1 mm.
t_b= Base time
L_C = length of the main channel.
tr = rainfall duration (hr).
t_S = time of recession (hr).
Y=basin coefficient.
T_c=time of concentration
Q_P=Peak discharge.
USPHS =United States Public Health Service.
MAC=maximum admissible concentration.
SAR= sodium hazard.

TABLE OF CONTENTS

LIST OF TABLE

LIST OF FIGURE

1. INTRODUCTION

The human race has been trying to control water for thousands of years. Archeologists believe that the Egyptians built a dam across the Nile River in 4000 B.C. There is also evidence that there were extensive irrigation canals in Egypt around 3200 B.C. For appropriate design and management of hydraulic structures, engineers must be concerned with the peak discharge and the time to peak for large storm events. This type of information is needed for a wide variety of design applications, including dams, spillways, and culverts. Unfortunately, many streams are ungauged and do not have flow records. Even when stream gauges are in place, the record is often too short to accurately predict extreme events [1].

The availability of water supply adequate in terms of both quantity and quality is essential for human existence. Early people recognized the importance of water from a quantity view point. Throughout the history, civilization developed around water bodies always support agriculture and transportation as well as drinking water. Recognition of the importance of water quality developed more slowly. Early humans could judge water quality only through the physical senses of sight, taste, and smell.

Not until the biological, chemical, and medical sciences developed were methods available to measure water quality and determine its effects on human health and well being [2].

1.1 Aim and Objectives of the Study

The improvements in water quality standards proportionally increased the lack of qualified water availability. Especially in small islands, where the surface water storage is limited the problem is inevitably increasing.

Cyprus, a small island in Mediterranean perennial structure on its river system, thus no dependable supplier is available for the storage. Due to salt water intrusion around the coasts, the groundwater resources are rapidly contaminating. In many cases, runoff characteristics may be estimated using rainfall-runoff models. Precipitation data is generally more available than stream flow data because there are a larger number of gauging stations and usually longer periods of record than are available for stream flow

The basin has two reservoirs, Kafizes at the upstream and Gemikonagi at downstream since Kafizes is constructed out of Turkish republic of northern Cyprus boundaries, only Gemikonagi reservoir is to be identified in this study. Gemikonagi has constructed for irrigation purposes. Somehow, since then, the deposit of mining activities has contaminated the reservoir. Therefore, the necessity for the analysis of the dam has been unavoidable.

1.2 Literatures Survey

Many researchers have developed rainfall-runoff models that attempt to accurately predict runoff hydrographs, peak flow rates, and times to peak. Early models were based on empirical equations.

In 1932, Sherman proposed the well-known theory of unit hydrographs. The unit hydrograph (originally named uni-graph) of a drainage basin is defined as a hydrograph of direct runoff resulting from 1 in. of effective rainfall generated uniformly over the basin area at a uniform rate during a specified period of time or duration. Sherman originally used the word "unit" to denote the specified period of time or a "unit of time" of the effective rainfall. Later, however, the word "unit" was often misinterpreted to denote 1 in or "unit depth" of the effective rainfall. Sherman classified the runoff only into surface runoff and groundwater runoff since subsurface runoff was not recognized during his time. Consequently, he defined the unit hydrograph only for the use of surface runoff [3].

In 1961, Gray has developed a method of synthesis of unit hydrographs that has approximates the upper limit of a watershed size where the geographic area of Central Lowa, Missouri, Llinois, and Wisconsin were studied. The method is a basically based on dimensionalizing the incomplete Gamma distribution [4].

DSI synthetic unit hydrograph method used in turkey, in fact is the modification of the SCS method of the dimensionless curvilinear hydrograph type. This method is used for the watershed area up to 1000 km^2. For large basins, the superimposing approach is valid so the area should be divided into sub basins and separate unit hydrograph should be determined for each sub basin [5].

The SCS method that is based on triangular hydrograph shape is generally known as mockus method in turkey. In this method, the calculations are more practical and the drawing of the triangular hydrograph is even easier than DSI method [6].

European standards about water quality divided the parameters affecting the quality into six groups. Namely, Organoleptic parameters, Physicochemical Parameters, parameters concerning substances undesirable in excessive amount, Parameters concerning toxic substances, Microbiological parameters, Minimum required for softened water. Each group involves the maximum admissible concentration (MAC) for the parameter defined. All the data since 1994 taken by the Gemikonagi for the region are collected together and analyzed [7].

1.3 Guides to Thesis

Thesis is divided into five chapters.

Chapter one discusses the aim and objectives of the study. And informs the reader about the literature survey followed, throughout the study.

In chapter two, the unit hydrograph is studied and illustrated in terms of its definition and the factors responsible for its forming shape and features. The unit hydrograph figured out by three methods, they are, Mokus method, DSI method and Gray method. These methods have been chosen because they fit the nature of Xeros Basin. The steps for constructing the unit hydrograph are elaborately discussed to show the change in the rainfall quantity with respect to the time.

The third chapter concentrates on the water quality of drinking and irrigation water according to the European standards. Moreover, a great attention will be given to the advancement of the European water Standards from 1920 up to now. These standards have been divided into six groups; they are, organoleptic parameters, physicochemical parameters, parameters concerning substances undesirable in excessive amount, parameters concerning toxic substances, microbiological parameters and minimum required for softened water. Each group discussed separately.

Great deal of this chapter focuses on the elements in the reservoir and their impacts on both the human health and the environment.

Due to the increasing demand of water especially for agriculture, this chapter sheds the light on the European standards for irrigation. Besides that, Sodium hazards (SAR) equation is discussed carefully which depends mainly on three basic elements; Na, Ca, Mg.

The forth chapter is concerned with the characteristics and basic objects in Xeros Basin, The synthetic unit hydrograph is analyzed in detail and the Gemikonagi reservoir is surveyed for the water quality Standard. Three methods are used to draw the unit hydrograph, which have been mentioned previously in chapter two.

In chapter five, the European water Standards matched with surveyed water quality with respect to available chemical elements and determined whether it is suitable for the drinking and irrigation or not. Each chemical element is represented on a separate graph to show the fluctuation of that element through time.

2. HYDROGRAPH ANALYSIS

2.1. Hydrograph Theory

A graphical representation of the discharge of a stream at single gaging station is called a *hydrograph.* During the period between storms the base flow is a result of ex filtration of ground water from the banks of the stream. Discharge from precipitation excess, which remains after abstractions, causes a hump in the hydrograph. This hump is called the direct runoff hydrograph (DRH). [8]

Obviously, any precipitation excess that occurs at the extremities of a watershed will not be recorded at the basin outlet until some time lapse has occurred. As precipitation continues, enough time elapses for the more distant areas to add to the outlet discharge. The lag time of the peak and the shape of the DRH depend on the precipitation pattern and the characteristics of the basin (size, slope, shape, and channel storage capacity).

The unit hydrograph is a linear response function of the watershed. It assumes that the time base of the hydrograph remains constant regardless of the amount of runoff resulting from different storms with the same duration. When using the unit hydrograph theory, it is assumed that the runoff response from a storm with a runoff depth other than one unit may be obtained by multiplying the runoff depth by the ordinates of the unit hydrograph that was developed for that duration.

Because the unit hydrograph is a linear function, the applicability of superposition is assumed. In order to calculate the runoff response from complex storm events, a series of unit hydrographs is constructed for a number of lagged volumes of rainfall excess. The set of unit hydrographs are lagged and summed to develop the composite runoff hydrograph. The composite hydrograph is a linear combination of the unit hydrograph ordinates. [8]

2.2. Hydrograph Analysis

Before trying to analyze a hydrograph, which describes the whole time history of the changing rate of flow from catchments due to a rainfall event rather than just the peak flow, it is essential first to appreciate some of its simple components. In Figure (2.1), rainfall intensity (i.e., in mm h) is shown in discrete block intervals of time (t). The lower continuous curve of discharge (Q in m^3/s) the hydrograph resulting from the event. The discharge hydrograph is obtained from continuously recorded river stage-discharge and the relationship appropriate to the river gauging The hydrograph of discharge against time has two main components, (i) the area under the hump, labelled surface runoff (which is produced by a volume of water derived from the storm event), and, (ii) the broad band near the time axis, representing base flow contributed from groundwater. At the beginning of the rainfall, the river level (and hence the discharge) is low and a period of time elapses before the river begins to rise. During this period the rainfall being intercepted by vegetation or is soaking into the ground and making up soil-moisture deficits. The length of the delay before the river rises depends on the wetness of the catchments before the storm and on the intensity of the rainfall itself.

When the rainfall has made up catchment's deficits and when surfaces and soil are saturated, the rain begins to contribute to the stream flow. The proportion of rainfall that finds its way into a river is known as the effective rainfall, the rest being lost (to quick runoff) in evaporation, detention on the surface or retention in the soil. As the storm proceeds, the proportion of effective rainfall increases and that of lost rainfall decreases as shown by the loss curve (Fig. 2.1). The volume of surface runoff, represented by the area under the hydrograph minus the base flow, can be considered in two main subdivisions to simplify the complex water movements over the surface and in the ground. The effective rainfall makes the immediate contribution to the rising limb from A to the peak of the hydrograph and, even when the rainfall ceases, continues to contribute until the inflection point (Fig. 2.1). Beyond this point, it is generally considered that the flow comes from the water temporarily stored in the soil. This so-called interflow continues to provide the flow of the recession curve until the water from the whole of the effective rainfall is completely depleted at B. One final term, lag or lag time requires explanation. There are many definitions of lag, which is a measure of the catchments response time, but here it is taken from the center of gravity of the effective rainfall to the center of gravity of the direct surface runoff.

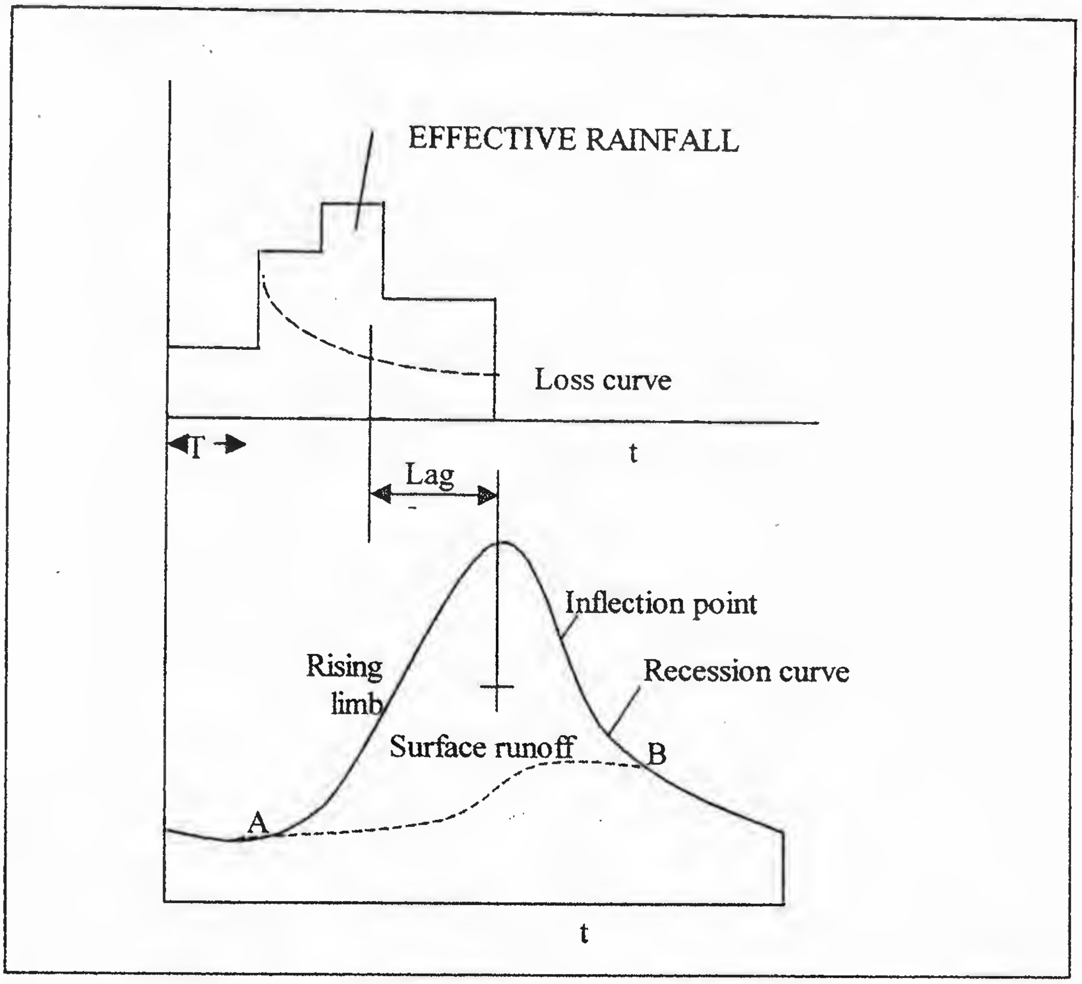

Figure 2.1 Rainfall and a river hydrograph.

The boundary between surface runoff and base flow is difficult to define and depends very much on the geological structure and composition of the catchment. Permeable aquifers, such as limestone and sandstone strata, sustain high base flow contributions, but impervious clays and built-up areas provide little or no base flow to a river. The base flow levels are also affected by the general climatic state of the area: they tend to be high after periods of wet weather and can be very low after prolonged drought. During the course of an individual rainfall event, the base flow component of the hydrograph continues to fall even after river levels have begun to rise, and only when the storm rainfall has had time to percolate down to the water table does the base flow division curve (shown schematically in Fig. 2.1) begin to rise. The base flow component usually finishes at a higher level at the end of the storm surface runoff than at the rise of the hydrograph and thus there is enhanced river flow from groundwater storage after a significant rainfall event. Groundwater provides the total flow of the general recession curve until the next period of wet weather. The main aims of the engineering hydrologist are to quantify the various components of the hydrograph, by analyzing past events, in order to relate effective rainfall to surface runoff, and thereby to be able to estimate and design for future events. As a result of the complexity of the processes that create stream flow from rainfall, some simplifications and assumptions have to be made [9].

2.3. The Unit Hydrograph

A major step for such simplifications in hydrological analysis was the concept of the unit hydrograph introduced by the American engineer Sherman in 1932. He defined the unit hydrograph as the hydrograph of surface runoff resulting from effective rainfall falling in a unit of time such as 1 hour or 1 day and produced uniformly in space and time over the total catchment area (Sherman, 1942). In practice, a T hour unit hydrograph is defined as resulting from a unit depth of effective rainfall falling in t in hour over the catchment. The magnitude chosen for t depends on the size of the catchment and the response time to major rainfall events. The standard depth of effective rainfall was taken by Sherman to be one inch, but with metrication, 1 mm or sometimes 1 cm is used. The definition of this rainfall-runoff relationship is shown in Fig. 2.2(a), with 1 mm of uniform effective rainfall occurring over a time t producing the hydrograph labelled TUH. The units of the ordinates of the T-hour unit hydrograph are m^3/s per mm of rain. The volume of water in the surface runoff is given by the area under the hydrograph and is equivalent to the 1 mm depth of effective rainfall over the catchment area [10].

The unit hydrograph method makes several assumptions that give it simple properties assisting in its application.

a) There is a direct proportional relationship between the effective rainfall and the surface runoff. Thus in Fig. (2.2 (b)) two units effective rainfall falling in time T produce a surface runoff hydrograph that has its ordinates twice the TUH ordinates, and similarly for any proportional value.

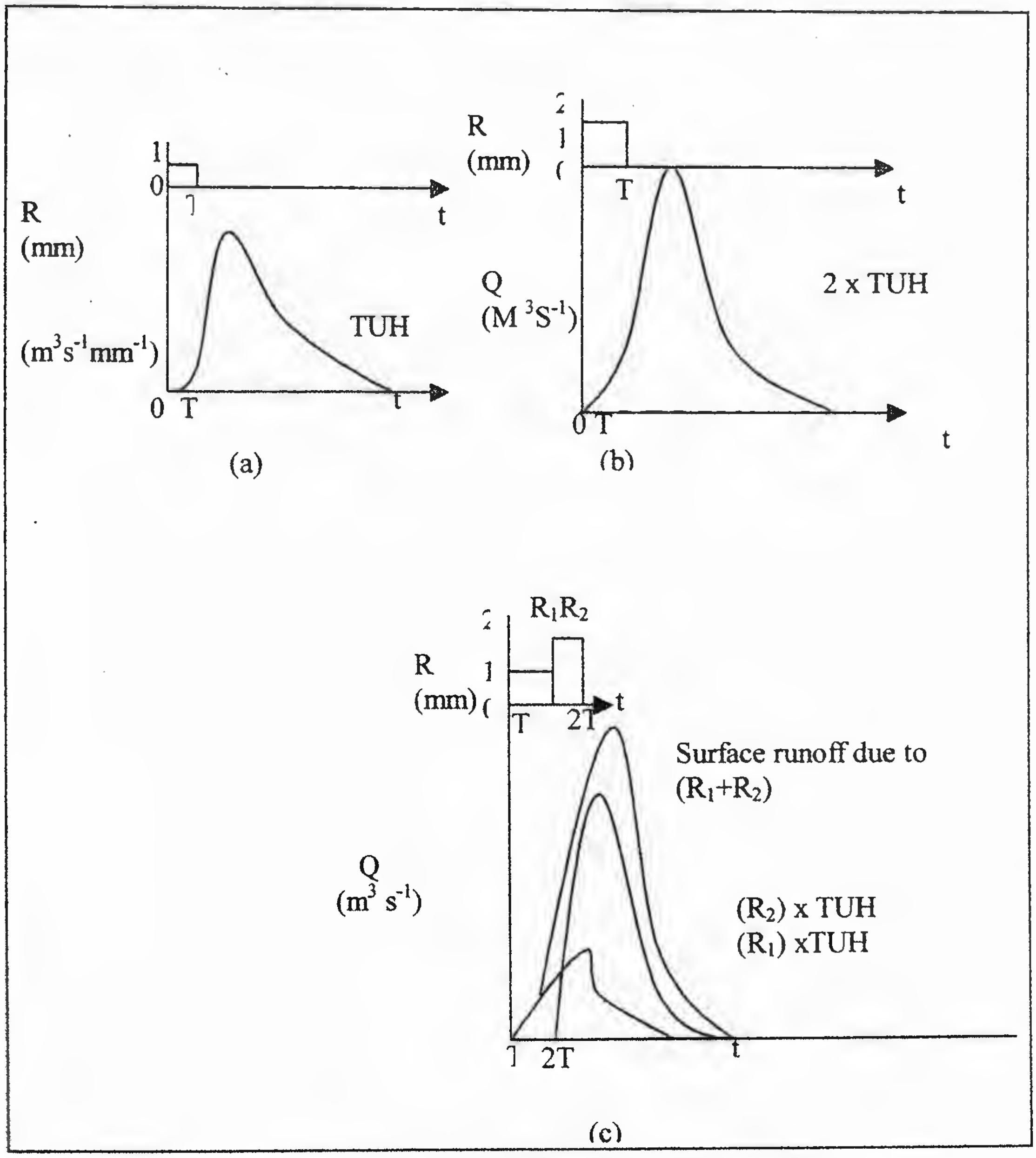

Figure 2.2 the Unit Hydrograph

b) A second simple property, that of superposition, is demonstrated Fig. (2.2(c)). If two successive amounts of effective rainfall, R1 and R2 each fall in T hours, then the surface runoff hydrograph produced is the sum of the component hydrographs due to R_1 and R_2 separately (the latter being lagged by T hours on the former). This property extends to any number of effective rainfall blocks in succession. Once a TUH is available, it can be used to estimate design flood hydrographs from design storms.

c) A third property of the TUH assumes that the effective rainfall-surface runoff relationship does not change with time, i.e. that same TUH always occurs whenever the unit of effective rainfall in is applied. Using this assumption of invariance, once a TUH has been derived for a catchment area, it could be used to represent response of the catchment whenever required. The assumptions of the unit hydrograph method must be borne in mind the when applying it to natural catchments. In relating effective rainfall to surface runoff, the amount of effective rainfall depends on the state of the catchment before the storm event. If the ground is saturated or the catchment is impervious, then a high proportion of the rain becomes effective. In absorbing the rainfall, unsaturated ground will have a certain capacity before releasing effective rainfall to contribute to the surface runoff. Only when the ground deficiencies have been made up and the rainfall become fully effective will extra rainfall in the same time period produce proportionally more runoff. The first assumption of proportionally of response to effective rainfall conflicts with the observed non-proportional behavior of river flow. In a second period of effective rain, the response of a catchment will be dependent on the effects of the first input, although the second assumption. Figure (2.2(c)) makes the two component contributions independent. The third assumption of time invariance implies that whatever the state of the catchment, a unit of effective rainfall in T hours will always produce the same TUH. However, the response hydrograph of a catchment must vary according to the season: the same amount of effective rainfall will be longer in appearing as surface runoff in the summer season when vegetation is at its maximum development and the hydraulic behavior of the catchment will be 'rougher'. In those countries with no marked seasonal rainfall or temperature differences and constant catchment conditions throughout the year, then the unit hydrograph would be a much more consistent tool to use in deriving surface runoff from effective rainfall. Another weakness of the unit hydrograph method is the assumption that the effective rainfall is produced uniformly both in the time t and over the area of the catchment. The real distribution of rainfall within a storm is very rarely uniform. For small or medium sized catchments (say up to 500 Km^2), a significant rainfall event may extend over the whole area, and if the catchment is homogeneous in composition, a fairly even distribution of effective rainfall may be produced. More usually, storms causing large river discharges vary in intensity in space as well as in time, and storm movement often affects the consequent response over the catchment area. However, rainfall variations are damped by the integrating reactions of the catchment, so the assumption of uniformity of effective rainfall over a selected period t is less serious than might be supposed at first. Making t smaller can reduce the effect of variable rainfall intensities, and where a catchment is affected by major storms of different origins, separate TUHs can be derived for each storm type.

At all, the unit hydrograph method has the advantage of great simplicity. Once a unit hydrograph of specified duration t has been derived for a catchment area (and/or specific storm type) then for any sequence of effective rainfalls in periods of T, an estimate of the surface runoff can be obtained by adopting the assumptions and applying the simple properties outlined above. The technique has been adopted and used world-wide over many years [8].

2.4. Unit Hydrograph Limitations

One of the most significant in the unity of the above mentioning, Unit hydrograph theory contains a number of assumptions that can limit its use. They are (Chow et al., 1988):

1. The excess rainfall has a constant intensity within the effective duration. When the unit hydrograph is developed using gauged data, the storms selected for analysis should have a short duration because they are the most likely to have a uniform intensity and produce a single-peaked hydrograph.
2. The excess rainfall is uniformly distributed throughout the entire drainage area. This assumption may pose difficulties for larger watersheds. For watersheds above a certain size, the assumption of uniform rainfall is no longer valid.
3. The base time of the direct runoff hydrograph is constant based on a given duration of rainfall. This assumption implies that the unit hydrograph model cannot account for differences in the watershed response to different rainfall intensities.

4. The ordinates of all direct runoff hydrographs with the same base time are proportional to the total amount of direct runoff represented by each hydrograph.
5. The hydrograph resulting from excess rainfall reflects the unique characteristics of the watershed. The unit hydrograph model cannot reflect variations in the watershed response due to changes in the season, land use or channel characteristics. The unit hydrograph is assumed to be a constant response function of the watershed as long as there are no major changes in the land use.

While many authors agree that the unit hydrograph is only applicable for a limited range of watershed sizes, they disagree about what the extent actually is. Sherman (1932) used the unit hydrograph theory on watersheds ranging from 1300 km^2 to 8000 km^2. Recommended that the unit hydrograph only can be used on watersheds less than 5000 km^2, while Ponce (1989) suggested that it should only be applied on midsize catchments between 2.5 km^2 and 250 km^2. Since the unit hydrograph model assumes that rainfall is uniform over an entire area, it is not applicable to large watersheds. Small catchments tend to reflect variations in the rainfall excess more than larger watersheds, because they have less channel storage than larger watersheds, thus the small catchments are less appropriate for unit hydrograph analysis [15].

One of the most significant limitations of the unit hydrograph theory is the assumption of linearity. In fact, the watershed is a highly nonlinear system (Huggins and Burney, 1982). Due to the assumption of linearity, the unit hydrograph method is not applicable for watersheds that have appreciable storage effects (Gray, 1973). In addition, the unit hydrograph theory may not be applicable to small watersheds because they tend to exhibit a nonlinear response more than larger areas (Huggins and Burney, 1982). In practice, the linearity assumption is useful because the equations are relatively simple and the results are acceptable for most engineering purposes [11].

2.5. Synthetic Unit Hydrographs

Synthetic unit hydrographs attempt to extend the application of unit hydrograph theory to ungauged catchments. It tries to relate the unit hydrograph shape to watershed characteristics such as basin length and area (Yen and Lee, 1997). Since Sherman's unit hydrograph is based on observed rainfall and runoff data, it is only applicable for gauged basins. Unfortunately; the majority of watersheds are ungauged. Primarily, based on empirical equations synthetic methods do not rely on observed runoff data, they may be applied to ungauged watersheds [11].

2.6. Method for Synthetic Unit Hydrographs

There are three major types of synthetic unit hydrographs. They can be:

1. Based on hydrograph characteristics such as peak discharge and time to peak [12].
2. Based on a dimensionless unit hydrograph [13]
3. Based on watershed storage, among those three methods the first two are most favorable [12]. Proposed the first unit hydrograph technique that was applicable to ungauged areas, based on a study of watersheds located in the Appalachian Mountains.

In his approach, the time to peak is estimated from watershed length, which is the distance from the outlet to the watershed centroid, and a regional coefficient. The predicted peak flow rate is calculated using the watershed area, the time to peak, and a storage coefficient.

The SCS unit hydrograph is based on a dimensionless hydrograph. The time to peak is estimated based on the duration of effective rainfall and the lag time between the centroid of the excess rainfall and the time to peak. The lag time is calculated using the watershed length, the average slope, and a factor based on watershed storage. The peak flow rate is based on the watershed area and the time to peak. A triangle is commonly used to estimate the unit hydrograph shape [11].

In the basis of the above methods, depending on watershed characteristic new methods are also developed. Gray (1961) DSI and Mockus methods are some of those methods which are usually preferred to be used in Turkey.

2.6.1. Gray Method

In 1961, Gray managed to develop a method that has an approximate upper limit of watershed size where the geographic areas of Central Iowa, Missouri, Illinois, and Wisconsin were studied, [9]. The method is based on dimensionalizing the incomplete Gamma Distribution and results in a dimensionless of the form.

$$Q_{t/p_R} = \frac{25.0(\gamma')^{P_s}}{\Gamma_G(p_S)}(e^{-\gamma' t/p_R})(\frac{t}{p_R})^{P_s-1} \qquad (2.1)$$

In the above equation P_s and γ' are the shape and scale parameters, respectively (Dimensionless), Γ_G is the Gamma function of p_s, equal to $(p_s - 1)!$, e is the base of natural logarithms , P_R is the period of rise (min) and t is the time (min). t/p_R, γ' and p are greater than zero; with Q_{t/p_R} being percent flow in o.25 P_R at any given t/P_R value.

If p_s is not an integer:

$$\Gamma(P_S) = \Gamma_G(NI + ZI) = (NI - 1 + ZI)(NI - 2 + ZI)\ldots(1 + ZI)/\Gamma_G(1 + ZI). \qquad (2.2)$$

where NI is integer and ZI is the decimal part. Hence for any p_S the function can be approximated as;

$$\Gamma(p_s) = p^{P_s} e^{-P_s}\sqrt{\frac{2\pi}{P_s}}\left[1 + \frac{1}{12_P} + \frac{1}{288_{P_s^2}} - \frac{139}{15{,}480_{P_s^3}} - \frac{571}{2{,}488{,}320_{P_s^4}} + \ldots\right] \qquad (2.3)$$

The relation for γ ' is defined as $\gamma' = \gamma . p_R$ and $q = 1 + \gamma$

P_R and γ' can be evaluated by correlating them with physiographic characteristics of the watershed. As an example, the storage factor p_r/γ', has been linked with watershed parameters $L_M/\sqrt{S_{av,}}$ where L_M is the length of the main channel of the watershed in miles measured from the outlet to the uppermost part of the watershed (Fig. 2.3); S_{av} is the average slope in percent obtained by plotting the main channel profile and drawing a straight line through the outlet elevation such that the positive and negative areas between the stream profile and the straight line are equated. The storage factor p_R/γ can also be correlated with the period of rise P_R as shown in Fig. (2.4.) these two correlations allow solution of Eq. (2.1) and produce a synthetic unit hydrograph of duration $P_R/4$ for an ungaged area.

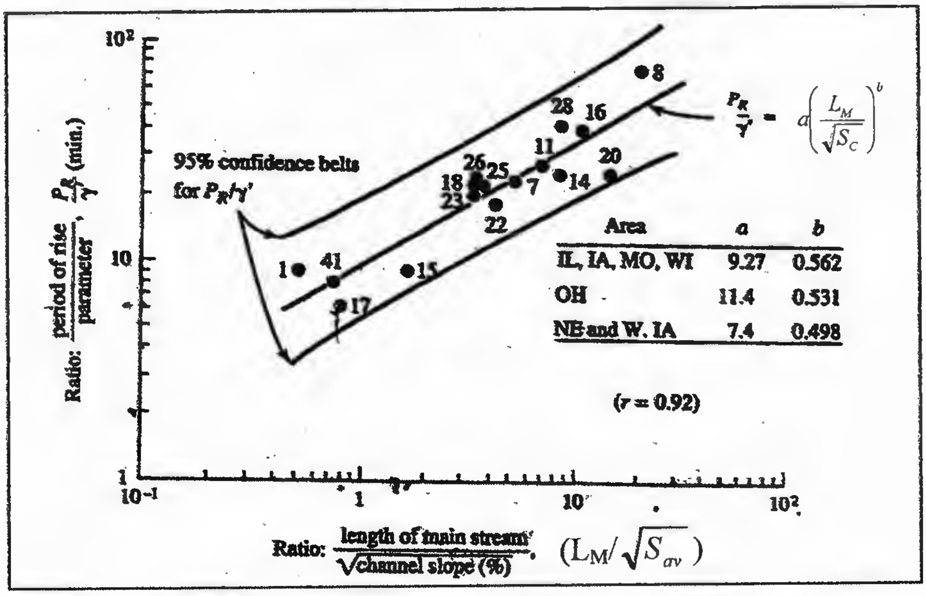

Figure 2.3 Relation of storage factor ($P_{R/\gamma'}$) and water shed parameter ($L_M/\sqrt{S_{av}}$) for watershed in Nebraska, lowa, Missouri, Illinois, and Wisconsin [4].

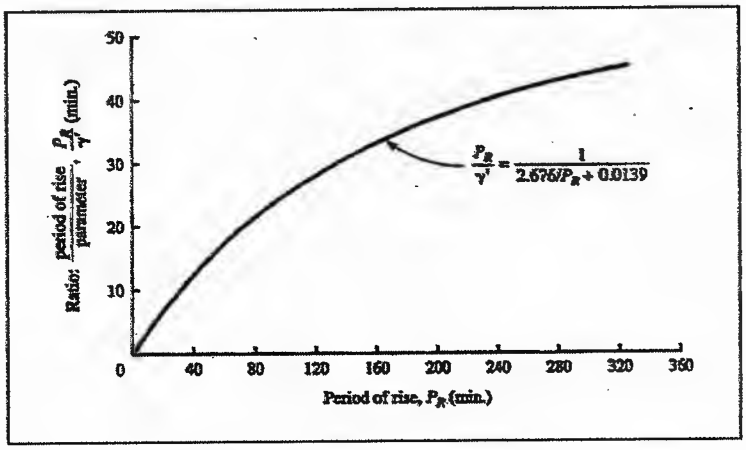

Figure 2.4 Relation of storage factor P_R/γ' and period of rise P_R [4].

The procedure to be used for solution of Gray method is illustrated as bellow:

1. Determine LM, Sav and A for the ungauged watershed.
2. Compute the ordinates for the dimensionless graph using Eq. (2.1) and

determine the percent flow in 0.25 for values of 0.125, 0.375, and 0.625... for every succeeding increment of until the sum of the percent flows approximates 100 percent. Also compute the peak percentage by substituting $t/P_R=1$.

3. Determine parameters P_R, γ' and P_S.
   a. With parameters $(L_M/\sqrt{S_{av}})$, use Fig 2.3 to select (P_R/γ')
   b. With (P_R/γ'), use Fig 2.4 obtain P_R to compute rainfall duration (t_r) as $P_R/4$ and compute γ' as the ratio $P_R/(P_R/\gamma')$.
   c. Substitute γ' obtained in Step 3b into the equation $p = 1 + \gamma'$.
4. In order to compute the unit hydrograph, the following procedure is applied
   a. Determine the necessary factor to convert the volume of the direct runoff under the dimensionless graph to 1 mm. of excess precipitation over the entire watershed.
      1. The volume of the unit hydrograph, V in m^3

$$V=1 \text{ mm.} \times A_W \text{ km}^2 \times 10^3 \tag{2.4}$$

      2. The volume of the dimensionless graph = V_D where

$$V_D = \Sigma qi \times 0.25 \times P_R \times 60\frac{\text{sec}}{\text{min}} \tag{2.5}$$

      3. Solve for Σqi by equating V and V_D, since they should be equal.
   b. Convert the dimensionless graph ordinates to the unit-hydrograph ordinates through

$$Q = \frac{percentflowin0.25p_R}{100}\Sigma qi \tag{2.6}$$

   c. Translate time base of dimensionless graph to absolute time units by multiplying $(t/p_R)\times p_R$ for each computed point. Because, that runoff does not commence until the centered of rainfall, or at a time $P_R/8$.

2.6.2. State Water Works (DS I) Method.

DSI synthetic unit hydrograph is the modification of the SCS method of the dimensionless curvilinear unit hydrograph type. This method is actually used for the watershed area up to 1000 km^2 [12].

An important point to be considered is the time of rise (t_p) that should be at least equal to the rainfall duration (t_r) or more than that. The unit hydrograph is obtained according to the 2 hr rainfall duration, so the time of rise should not be smaller than 2 hrs. If the time of rise of unit hydrograph is smaller than 2 hrs, it seems that while the rainfall continues, the hydrograph is declining instead of rising and this is not possible, so DSI method is not applicable when the time of rise is smaller than 2 hr. Hence from this method only 2 hr unit hydrographs are derived (UH_2). The hydrological characteristics should be determined from ungaged watershed. The equations for unit discharge (q_p), time of rise (t_p) and the peak discharge (Q_p) are given empirically as:

$$E_p = \frac{(L_{mC} \times L_{CC})}{\sqrt{S_{harm}}} \tag{2.7}$$

$$q_p = \frac{414}{A_W^{\;0.225} \times E_p^{\;0.16}} \tag{2.8}$$

$$t_p = \frac{202.78}{q_p} \tag{2.9}$$

$$Q_P = A_W \times q_p \times 10^{-3} \tag{2.10}$$

Where A_W is the Watershed size (km^2), E_p is the empirical value of the basin, L_{mC} is the length of the main channel (km), L_{CC} is the length of channel from centered watershed to the outlet (km), S_{harm} is the harmonic slope of the main channel (m/m), q_p is the unit discharge (l/s/km^2/mm), t_p is the time of rise (hr) and Q_P is the peak discharge (m^3/s).

The harmonic slope S_{harm} can be computed by dividing the main channel into smaller equal segments and determining the elevation differences (Δh) for these segments .The equations for determining the harmonic slope are given as:

$$S_i = \frac{\Delta h}{l_S} \tag{2.11}$$

$$S_{harm} = \left(\frac{n_S}{\Sigma \frac{1}{S_i}} \right)^2 \tag{2.12}$$

Where Δh is elevation difference of each segment (m) , l is the segment's length (m), n_S is the number of segments, S_i is the slope of each segment (m/m) and S_{harm} is the harmonic slope of the basin (m/m).

The other method suggested by DSI is through the available nomogram (Fig.2.5), which is constructed through Equation (2.7). The peak discharge (Q_P) is calculated from Equation (2.10) [10]. The equations of the unit volume (V_b) for 1 mm unit depth (h_a), base time (t_b) and time of rise (t_p) are given empirically as:

$$V_b = A_W \times h_a \times 10^{-3} \tag{2.13}$$

$$t_b = 3.65 \frac{V_b}{Q_P} \tag{2.14}$$

$$t_p = \frac{t_b}{5} \tag{2.15}$$

Where V_b is the unit volume (m^3), A_W is the area of the watershed (km^2), h_a is the unit depth over a watershed area (mm), t_b is the base time (hr) and t_p is the time of rise (hr).

The dimensionless unit hydrograph is drawn when the ordinates of hydrograph are divided by the maximum peak discharge (Q_p) and the abscissas are divided by the time of rise (t_p) of maximum peak discharge where the values of Q/Q_P and t/t_p are marked on ordinate and abscissa respectively. The dimensionless unit hydrograph for different rainfall duration are similar to each other. With the help of these hydrographs, the unit hydrograph is formed easily with the known peak values of the watersheds. DSI uses the same dimensionless unit hydrograph (Table 2.1) of SCS method, which is used in America, to form the unit hydrograph of the watersheds in Turkey.

Table 2.1 coordinates of DSI dimensionless curvilinear unit hydrograph, [5].

t/t_p	Q/Q_P	t/t_p	Q/Q_P
0	0	1.5	0.66
0.1	0.015	1.6	0.56
0.2	0.075	1.8	0.42
0.3	0.16	2	0.32
0.4	0.28	2.2	0.24
0.5	0.43	2.4	0.18
0.6	0.6	2.6	0.13
0.7	0.77	2.8	0.098
0.8	0.89	3	0.075
0.9	0.97	3.5	0.036
1	1	4	0.018
1.1	0.98	4.5	0.009
1.2	0.92	5	0.004
1.3	0.84	5.5	0
1.4	0.75		

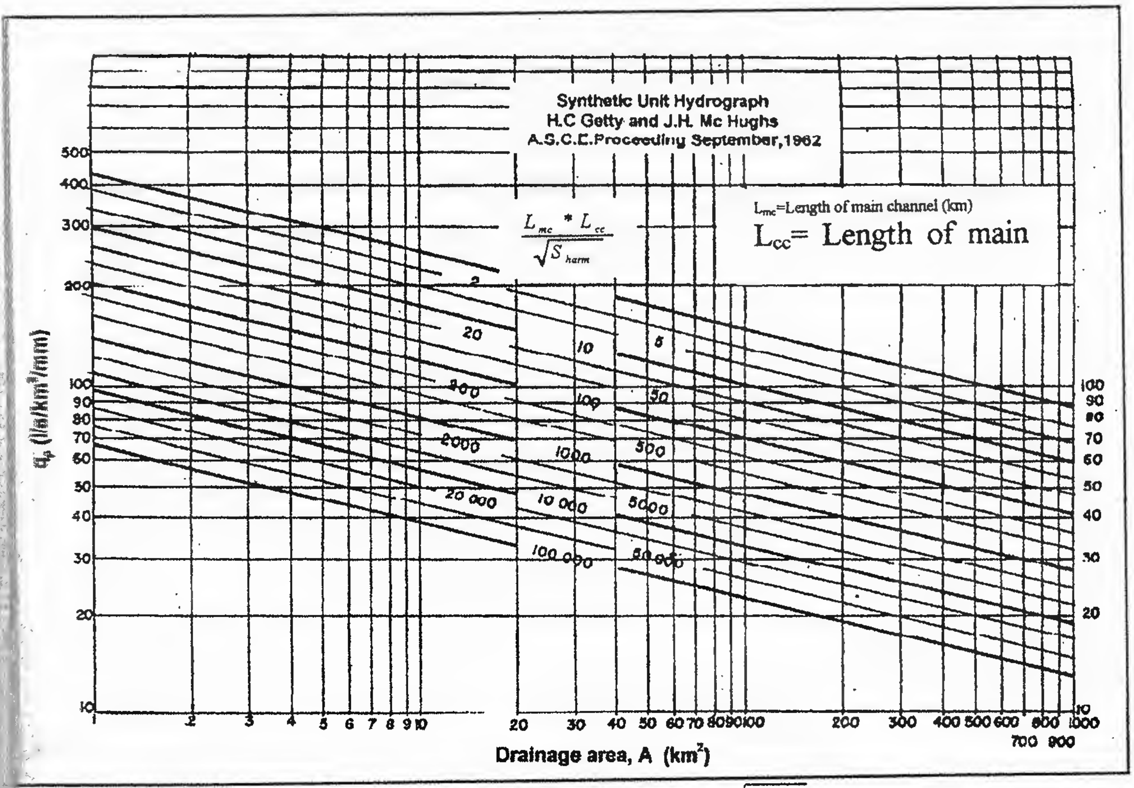

Figure 2.5 Nomogram of drainage area, A, (L_{mc}, $L_{cc}/\sqrt{S_{harm}}$) and q_p used in DSI Method [6].

2.6.3 Mockus Method.

Mockus method is modified SCS method that is based on triangular hydrograph shape. The calculation of mockus method is more practical and the drawing of the triangular hydrograph is easier than DSI method. [6-15]

Mockus method is applicable if the time of rise (t_p) is smaller than 2 hr (t_p<2hr). Thus, if $t_p \leq 2hr$, this method is not valid. The time of rise (t_p) is found empirically as given in DSI method. Mockus method is valid when the time of concentration (T_c) is smaller or equal to 30 hr ($T_c \leq 30hr$) where the time of concentration is defined as, the time required for a particle of water to flow hydraulically from the furthest location in the watershed to the outlet or the design point.

The selection of the unit rainfall duration (t_r) is also important. The criterion for the selection of the unit rainfall duration is given by $t_r \leq \frac{T_C}{5}$. It is recommended that, if the time of concentration (T_c) of the rainfall is within 6 hr (T_c =6hr) than the design rainfall duration t_r is practically taken as 1 hr. When the time of concentration is smaller than 3 hr, is practically taken as 0.5 hr. For T_C between 10 hr to 15 hr, t_r is taken as 2 hr. where T_c is between 15 hr to 30 hr, it is recommended to take t_r as 3 hr.

For this method, the time of rise (t_p) and the peak discharge (Q_P) are obtained by the following empirical equations:

$$T_c=0.00032\frac{{L_C}^{0.77}}{{S_{harm}}^{0.385}} \qquad (2.16)$$

$$t_r=2\sqrt{T_C} \qquad (2.17)$$

$$t_p=(0.5\times t_r)+(0.6\times T_C) \qquad (2.18)$$

$$t_S=1.67t_p \qquad (2.19)$$

$$t_S=t_p+t_S \qquad (2.20)$$

$$Q_P=\frac{Y\times A_W\times h_a}{t_p} \qquad (2.21)$$

Where A_W is the area of watershed (km^2), L_C is the length of the main channel (m/m), S_{harm} is the harmonic slope of the main channel (m/m), tr is the rainfall duration (hr), t_p is the time of rise (hr), t_S is the time of recession (hr), t_b is the base time (hr), Q_P is the peak discharge (m^3 /s)m, Y is 0.208, basin coefficient (dimensionless) and h_a is the unit depth over the basin area (mm).

3. FUNDAMENTALS OF WATER QUALITY

Water is the most important molecule that exists on the Earth. Without water living beings would not be able to live. Water is used for an immeasurable number of things. There are many properties of water, which makes this molecule so unique.

3.1. Standards and goal

In order to be used as healthful fluid for human consumption, water must be free from organisms that are capable of causing disease and from minerals and organic substances that could produce adverse physiological and chemical effects.

In recent years, increasing population pressures, the evolving industrial-chemical society, and great advances in science have resulted in many questions being raised about the potability or safety of drinking and irrigation water just as they have been raised about safety in all other aspects of life. The terms "safe" or "unsafe" have given way to the consideration of the concept of risk, the concept of risk is always present but not always articulated or quantifiable.

3.2 Drinking water standards.

3.2.1 Development

Historically, civilizations began and centered within regions of abundant water supplies. Water quality was not very well documented, and people knew relatively little about disease as it related to water quality. Early historical treatment was performed only for the improvement of the appearance or taste of the water. No definite standards of quality other than general clarity or palatability were recorded by ancient civilizations.

The first formal and comprehensive review of drinking water concerns was launched in 1913. In development of the standards, reviewers quickly realized that would be of no value if the water placed in them were unsafe. Thus, in 1914, a maximum level of bacterial contamination, 2 coliforms per 100 milliliters (mL), was recommended. And the concept of a maximum permissible, safe limit was introduced. In 1915 a federal commitment was made to review the drinking water regulations on a regular basis. By

1925, large cities applying filtration, chlorination, or both encountered little difficulty in complying with the 2 coliforms per 100 mL limit. Thus, the standards were revised to reflect the experience of systems with excellent records of safety against waterborne diseases. The limit was changed to 1 coliform per 100 mL, and the principle of attainability was established. In addition to bacteriological standards, standards were established for physical and chemical (lead, copper, zinc, excessive soluble mineral substances) constituents.

In February 1941, an advisory committee for revision of the 1925 drinking water regulations was appointed by the USPHS (United States Public Health Service). The committee has world for one year and finally in 1942 their published significant which includes;

1) Samples for bacteriological examination were to be obtained from points in the distribution system, a minimum number of bacteriological samples for examination each month was established, and the laboratories and procedures used in making these examinations became subject to state or federal inspection at any time.
2) Maximum permissible concentrations were established for lead, fluoride, arsenic, and selenium. Salts of barium, hexavalent chromium, heavy metals, or other substances having deleterious physiological effects were not allowed in the water system.
3) Maximum concentrations, not to be exceeded, where more suitable, i.e., where alternative water sources were available, were set for copper, iron plus manganese, magnesium, zinc, chloride, sulfate, phenolic compounds, total solids, and alkalinity.[16]

1942 standards were improved in 1946 where that a maximum permissible concentration was added for hexavalent chromium and wording that excluded the presence of salts of barium, hexavalent chromium, heavy metal glucosides, and other substances was changed to prohibit the use of these compounds in water treatment processes.

As of the early 1960s, water pollution control efforts had called attention to chemical and industrial wastes polluting many surface waterways. In addition, a concern for radioactive pollutants needed to be acknowledged. A new advisory committee was appointed including members from the USPHS; Food and Drug Administration; U.S. Geological Survey; and 12 national transportation, technical, professional, and trade associations.

The 1962 standards provided·

1) The addition of recommended maximum limiting concentrations for alkali benzene sulfonates (synthetic detergents), barium, cadmium, carbon-chloroform extract (a measure of organic residues), cyanide, nitrate, and silver
2) The addition of a new section on radioactivity.

Interim standards were set in 1975 and amended in 1976, 1979, and 1980. The standards specify maximum contaminant levels (MCLs) for a variety of substances.

Initial secondary drinking water standards Specifying secondary MCLs (SMCLs) were set in 1979. The SMCL for was revised in 1986, and additional SMCLs were proposed in 1989.

The European standards of water quality have been developed to the standards, which are used nowadays [16].

3.2.2 European Union Water Quality Standards.

European standards about water quality divided the parameters affecting the quality into six groups. Namely, Organoleptic parameters, Physicochemical Parameters, parameters concerning substances undesirable in excessive amount, Parameters concerning toxic substances, Microbiological parameters, Minimum required for softened water. Each group involves the maximum admissible concentration (MAC) for the parameter defined.

Table 3.1 EU drinking water directive parameters [17].

Group	Group description	Parameter	Maximum admissible concentration (MAC)
A	Organoleptic Parameter	Colour	20mg/l
		Turbidity Sio_2	10mg/l
		Odour	Dilution of 2 at 12 ^{0}C
		Taste	Dilution of 2 at 12^{0}C
B	Physicochemical Parameters	Temperature	12^{0}C
		PH	$6.5<PH<8.5$
		Conductivity	400µs/cm
		Chlorides, Cl	250mg/L
		Sulphates, SO_4	250mg/L
		Calcium, Ca	100mg/L
		Magnesium, Mg	50mg/L
		Sodium, Na	150mg/L
		Potassium, K	12mg/L
		Aluminum, Al	0.2mg/L
		Total dry residues	1500mg/L
C	Parameters Concerning Substances In excessive Amount	Nitrates NO_3	50mg/L
		Nitrites NO_2	0.1mg/L
		Ammonium NH_4	0.5mg/L
		Oxidizability, O2	5mg/L
		Hydrogen sulphide	Undetectable µg/L
		Substances extractable chloroform	No increase in above background
		Hydrocarbons	10 µg/L
		Phenols, C_6H_5OH	0.5 µg/L
		Boron, B	1000µg/L
		Surfactance	200µg/L

Table3.1 Continue

Group	Group description	Parameter	Maximum admissible concentration (MAC)
		Iron Fe	200µg/L
		Manganese, Mn	50µg/L
		Copper, Cu	100µg/L
		Zink, Zn	100µg/L
		Phosphorus, P_2O_5	500µg/L
		Fluride, F	1000µg/L
		Suspended solids	0
		Barium, Ba	100µg/L
D	Parameters concerning toxic substances	Arsenic, As	50µg/L
		Cadmium, Cd	5µg/L
		Cyanides, Cn	50µg/L
		Chromium, Cr	50µg/L
		Mercury, Hg	1µg/L
		Nickel, Ni	50µg/L
		Lead, Pb	50µg/L
		Antimory, Sb	10µg/L
		Selenium, Se	10µg/L
		Pesticides	0.1µg/L
		PAHs	0.2µg/L
E	Microbiological parameters	Total coliforms	1/100 m
		Faecal coliforms	1/100 ml
		Faecal streptococci	1/100 ml
		Sulphite reducing clostridia	1/100ml

Table 3.1 Continue

Group	Group description	Parameter	Maximum admissible concentration (MAC)
F	Minimum required for softened water	Total hardness $CaCO_3$	>60 mg/L
		Alkalinity HCO_3	30mg/L

3.2.3. Organoleptic Parameter (Group A).

For human being water quality is a matter of taste, clarity and odour, and in terms of other properties that determine whether water is fit for drinking. Therefore, Oraganoleptic parameters are those, which can be sensed by ordinary humans. For other uses different properties may be important. Most of these properties depend on the kinds of substances that are dissolved or suspended in the water. Water for most industrial uses, for instance, must not be corrosive and must not contain dissolved solids that might precipitate on the surfaces of machinery and equipment.

3.2.4. Physicochemical Parameters (Group B)

This group is actually divided into two as physical property and chemical property .The physical property is one that can be observed without changing the chemical make-up of substance. For example, it is well known that when sugar is stirred in water the solid sugar disappears as it dissolves. This ability of sugar to dissolve in water is a physical property because the act of dissolving the sugar doesn't alter its chemical composition. By evaporation processes the sugar can be recovered. Such changes are called physical changes.

A chemical property describes a chemical change (chemical reaction) that a substance undergoes. If sugar is melt in a pan and then heated to high temperature, the color of the sugar darkens as begins to decompose into carbon and water the decomposition of sugar at high temperature is a chemical property, and the act of observing this chemical leads to a chemical reaction a permanent change in chemical composition that is not reversed by cooling the sugar to room temperature [18].

In the following, light will be shed on some elements than would be considered in the case study cared in this thesis, which are aluminum, sodium, magnesium, chlorine, calcium, potassium, sulphate and pH.

- **pH** The concentration of H^+ and OH^- ions are frequently very small numbers and therefore inconvenient to work with, soren Sorensen in 1909 proposed a more practical measure called pH. The **pH** of a solution is defined as

  $$pH = -\log [H^+]$$

  Thus it is clear that the **pH** of a solution id given by the negative logarithm of the hydrogen ion concentration (in mol/L) [18].

- **Sulphates** High concentrations of sulphates are common in groundwater on the Prairies, but can also be found in surface sources (drained from saline soils) and groundwater-fed dugouts. At 500 mg/L, sulphates can affect calves, but over time they adapt with few health problems. 7,000 mg/L can result in death. Guidelines usually recommend a maximum sulphate concentration of 1,000 mg/L, but the effects for concentrations between 1,000 and 2,500 mg/L are not well documented. Waters containing high concentrations of sulfate, caused by the leaching of natural deposits of magnesium sulfate (Epsom salts) or sodium sulfate (Glauber's salt), may be undesirable because of their laxative effects [8].

- **Aluminum** Occurs naturally in nearly all foods, the average dietary intake being about 20 mg/day. Aluminum is common in treated drinking water, coagulation to 2.57 mg/L in surface water with coagulation. Aluminum shows low acute toxicity. At lower doses, aluminum ad-ministered to laboratory animals is a neurotoxin. Chronic exposure data are limited, but indicate that aluminum likely affects phosphorus absorption that can create weakness, bone pain, and anorexia.[16-20]

- **Sodium** Is a major constituent in drinking water. Intake from food is generally the major source of sodium. The typical intake for normal adults is 1100 to 3300 mg/day. For persons requiring restrictions on salt intakes, sodium levels are usually limited somewhere between 500 and 2000 mg/day. When it is necessary to know the precise amount of sodium present in a water supply, a laboratory analysis should be made. Home water softeners that use the ion exchange method increase the amount of sodium. When a strict sodium-free diet is recommended, any water should be regarded with suspicion. In light of the preceding facts and because individual intake of sodium varies, no recommended limit for sodium has been established [16-20].

- **Chlorine** At room temperature, chlorine is a greenish-yellow poisonous gas. When added to water, however, chlorine combines with water to form hypochlorous acid that then ionizes to form hypochlorite ion. Under typical drinking water conditions, negligible chlorine gas (CL_2) remains in solution. The relative amounts of hypochlorous acid and hypochlorite ion formed are dependent on pH and temperature. The most significant inorganic compounds that can be formed during chlorine disinfection (if ammonia is present) are chloramines. Hypochlorous acid reacts with ammonia to form monochloramine (NH_2Cl), dichloramine ($NHCl_2$), trichloramine or nitrogen trichioride (Cl_3), and other minor by-products. Monochloramine is the principal chloramines formed under usual drinking water treatment conditions and is, with increasing frequency, used as a disinfectant itself. Chlorine has been the primary drinking water disinfectant. Other less common disinfectants used in drinking water treatment include chlorinates, chlorine dioxide, ozone, and potassium permanganate [16-20].

3.2.5. Parameters concerning substances undesirable in excessive amount (Group C)

In this group there are five combined and seventeen elements as shown in the table (3.1). In the following, light will be shed on that will be searched in this thesis such as Iron, Copper, Manganese and Zinc.

- **Manganese** imparts a brownish color to water and to cloth that is washed in it and it flavors coffee and tea with a medicinal taste [16-20].

- **Zinc** is found in some natural waters, particularly in areas where these ore deposits have been mined. Zinc is not considered detrimental to health, but it will impart an undesirable taste to drinking water. Commonly occurs in source water and may be added to finished water through corrosion of metal pipes. The adult requirement for zinc is 15 mg/day. Drinking water contributes about 3 percent of this requirement [16-20].

3.2.6. Parameters concerning toxic substance (Group D)

In this group there are nine elements concerning toxic substances, they are Arsenic, Cadmium, Cyanides, Chromium, Mercury, Nickel, Lead, Antimony and Selenium, which in turn have a great effect on the human's health. In the following, light will be shed on the elements in Gemikongi's reservoir.

- **Arsenic** erosion of arsenic-containing surface rocks probably accounts for a significant amount of the arsenic in water supplies. The other major source of environmental arsenic is the smelting of nonferrous metal ores, especially copper. It is often present in organic arsenical forms, which are less toxic than inorganic arsenic [5-16].

- **Lead** occurs in drinking water primarily from corrosion of lead pipes and solders, especially in areas of soft water. Health effects of lead are generally correlated with blood test levels. Infants and young children absorb ingested lead more readily than do older children and young adults [16-20].

- **Mercury** Occurs primarily as an inorganic salt in water, the primary target of inorganic mercury is the kidney, and methyl mercury targets the nervous system causing death [16-20].

- **Chromium** occurs in drinking water in its +3 and +6 valence state with + 3 being more common. The valence is affected by the level disinfection and presence of reducible organics. Primary sources in water are due to old mining operations, wastes from plating operations and fossil fuel combustion [16].

3.2.7. Microbiological Parameters (Group E)

The existence of plant and animal life in rivers and water bodies is a prime indicator of water quality and it has different significance for the river engineer and the water supply engineer. Its well knows that the growths of algae and populations of small aquatic animals can cause serious problems in pipes, reservoirs and other control works.

3.2.8. Minimum required for softened water (Group F)

In this group there are two combined chemical parameters, which have a great influence on the water quality, namely, hardness ($CaCO_3$) and Alkalinity (HCO_3). Hardness is going to be considered in this study, which is.

- **Hardness** Is generally defined as the sum of the polyvalent cations present in water and expressed as an equivalent quantity of calcium carbonate ($CaCO_3$). The most common such cations are calcium and magnesium. Although no distinctly defined levels exist for what constitutes a hard or soft water supply, water with less than 75 mg/L $CaCO_3$ is considered to be soft and above 150 mg/L $CaCO_3$ to be hard. Also hardness is defined as the concentration of multivalent metallic cations in solution at supersaturated condition; the hardness cation will react with anions in the water to form a solid precipitate [1-16].

$$Ca(HCO_3)_2 \xrightarrow{\Delta} CaCO_3+CO_2+H_2O \tag{3.1}$$

$$Mg(HCO_3)_2 \xrightarrow{\Delta} Mg(OH)_2+2CO_2 \tag{3.2}$$

3.3. Irrigation Water Quality Criteria

There are four basic criteria for evaluating water quality for irrigation purposes:

1. Total soluble salty content (salinity hazard)
2. Relative proportion of sodium cations (Na^+) to other cations (sodium hazard). (An ion is an electrical atom or groups of atoms. Cations carry positive charge where anions carry negative charge.)
3. Excessive concentration of elements that causes ionic imbalance in plants or toxicity.
4. Bicarbonate anion (HCO_3-) concentration as related to calcium (Ca^{++}) plus magnesium (Mg^{++}) cations.

There are many other factors to be considered in deciding the usefulness of water for a specific situation. This includes soil texture and structure, drainage condition, gypsum and lime content of the soil, salt and sodium tolerance of the crop, and irrigation method and management [21].

3.3.1 Water-Quality Constituents and Their Significance

Water-quality constituents commonly found in ground and surface water and their significance for irrigation purposes are given in Table (3.2). The information presented has been gathered from different sources and is intended to provide general descriptions of the impacts of various water-quality constituents.

Table 3.2 Water Quality constituents for irrigation purpose [22].

Constituent or physical Property	Source or cause	Significance
Calcium(Ca) and Magnesium (Mg)	Dissolved from most soils and rocks, especially limestone dolomite and gypsum. Ca and Mg are found in some brine.	Cause hardness and most of the scale-forming properties of water; soap consuming. Usually have no effect on suitability of water for irrigation or stock water.
Sodium (Na) And potassium (K)	Dissolved from most rocks and soils. Also found in brines and sewage	High concentration gives a salty taste when combined with chloride for most purposes moderate levels have little effect on the use of water. Sodium salts may cause forming in boilers and high sodium adsorption ratio may limit use of water for irrigation.
Iron (Fe)	Dissolved from most rocks and soils. May also be derived from iron pipes, pumps, and other equipment.	On exposure to air, iron in ground water oxidizes to reddish brown sediment. More than about 0.3 mg/L stains laundry and utensils reddish brown. Iron and manganese together should not exceed 0.3mg/L. Great concentration cause unpleasant taste and favor growth of iron bacteria but do not endanger health. Excessive iron may also interfere with the efficient operation of exchange-silicate water softeners.
Manganese (Mn)	Dissolved from rocks and soils. High concentrations often associated with high iron content and with acid waters.	Same objections as iron. Causes dark brown or black stain for taste and aesthetic reasons iron and manganese together should not exceed 0.3mg/L.

Table 3.2 Continue

Constituent or physical Property	Source or cause	Significance
Chloride (Cl)	Dissolved from rocks and soils. Present in sewage and found in natural and industrial brines.	Chloride salts in excess of 100mg/L give a salty state to water. When combined with calcium, magnesium, and chloride may increase the corrosive activity of water.
Sulfat (SO4)	Dissolved from rocks and soils containing gypsum, iron sulfides, and other sulfur compounds. Often present in industrial wastes.	Sulfate in water containing calcium forms hard scale in boilers. In high concentrations, sulfate in combination with other ions gives a bitter taste to water. Concentration above 250mg/L may have a laxative effect. Domestic water supplies containing more than 1000 mg/L sulfate can be used for drinking if a less mineralized water supply is not available.
PH (hydrogen-Ion activity)	Acid, acid generating salts and free carbon dioxide lower pH. Carbonate, Bicarbonate, Hydroxide, phosphate, silicate, and borate raise the pH.	The pH is a measure of acidity. A pH Of7.0 indicates neutrality of a solution. Values higher than 7.0 indicate increasing alkalinity; values lower than 7.0 indicate increasing acidity. Corrosiveness of water generally increases with decreasing pH, but excessively alkaline waters may also attack metals. A ph range between 6.0 and 8.5 is acceptable and normal for most waters in Montana.
Hardness $CaCO_3$	In most water nearly all the hardness is because of calcium and magnesium.	Water of hardness 0 to 60 mg/L are termed soft; 61to120 mg/L moderately hard; 121 to 180 mg/L hard; more

Table 3.2 Continue

		Than180mg/L very hard.
Constituent Or physical Property	**Source or cause**	**Significance**
Sodium Adsorption Ratio (SAR)	Indicates the relative abundance of sodium as compared to calcium and magnesium. Greater SAR values indicate a greater relative abundance of sodium.	A high sodium concentration in irrigation water combined with low calcium and magnesium concentrate-ions usually reduces soil tilth and impairs plant growth.

3.3.2 Sodium Hazard

The sodium hazard of irrigation water is usually expressed as the sodium adsorption ratio (**SAR**). It is the proportion of Na^+ to Ca^{++} plus Mg^{++} in the water. The following formula is used to calculate **SAR**

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

Ions in the equation are expressed in mall's equivalents per liter. Although sodium contributes directly to the total salinity and may be toxic to sensitive crop, such as fruit trees, the main problem with a high sodium concentration is its effect on the physical properties of soil. Water supply with SAR value greater than 10 should not be used if it will be the only source of irrigation water for long periods. This is true even if the total content is relatively low. Since the soil contains an appreciable amount of gypsum, a **SAR** value of 10 may be exceeded somewhat. Continued use of water with a high **SAR** value leads to a break down in the physical structure of the soil caused by excessive amounts of colloid ally absorbed sodium. This break down results in the dispersion of soil dispersion results in hard and compact soil when dry, and increasingly impervious for water penetration when wet. Fine textured soils especially clay is usually subjected this action [22].

4. XEROS WATERSHED SURFACE WATER ANALYSIS

Cyprus being third biggest Island in Mediterranean suffers from arid-semi arid climatic environment of Eastern Mediterranean. Through its history, Cyprus has suffered from long droughts with a continuously growing water scarcity. Especially the problem is continuously growing due to the increasing demand for water and the declining rainfall. The problem can be best achieved by managing the surface water of the island. Therefore, especially the reservoirs should be reconsidered and analyzed.

Gemikonagi (Xeros) watershed is situated at the east corner of Cyprus where the copper mining of Cyprus was mainly carried out. The basin has two reservoirs, Kafizes at the upstream and Gemikonagi at downstream since Kafizes is constructed out of Turkish republic of northern Cyprus boundaries; only Gemikonagi reservoir is to be identified in this study. Gemikonagi has constructed for irrigation purposes. Somehow, since then, the deposit of mining activities has contaminated the reservoir. Therefore, the necessity for the analysis of the dam has been unavoidable.

4.1 Basin Characteristics

Important natural characteristics of the basin affecting stream flow are the basin's topographic and geologic features. Topography determines the slopes and location of drainage channels and the storage capacity of the basin. Channel slope and configuration are directly related to the rate of flow in a basin and the magnitude of the peak flows. Steep watersheds generally indicate a rapid rate of runoff with little storage, whereas relatively flat areas are subject to considerable storage and lower rates of flow. Off course the flow characteristics are best defined by unit hydrograph theories. Especially when there is no available data for watershed the synthetic methods are used the pre defined method, Gray, DSI, and Mockus are to be applied to xeros basin to search for the peak flow characteristics.

4.2 Synthetic Unit Hydrograph Analysis

The necessary map to calculate the unknown will be used in the calculation to draw the unit hydrograph to show the change in the rainfall during the time. The method can be applied if the topographic boundaries and characteristics of the basin could be searched out. The map of basin is given in Figure (4.2). The topographic elevations are also given in the figure. These elevations are used to calculate the slope of the basin. The cross-section of the basin are given in Figure (4.3)and (4.4) where the maximum elevation of the main channel and secondary and other channel are given in Figure (4.5) By using Figure (4.1), it can be possible to calculate the cross-section area of basin, A_w, the slope and the other characteristic.

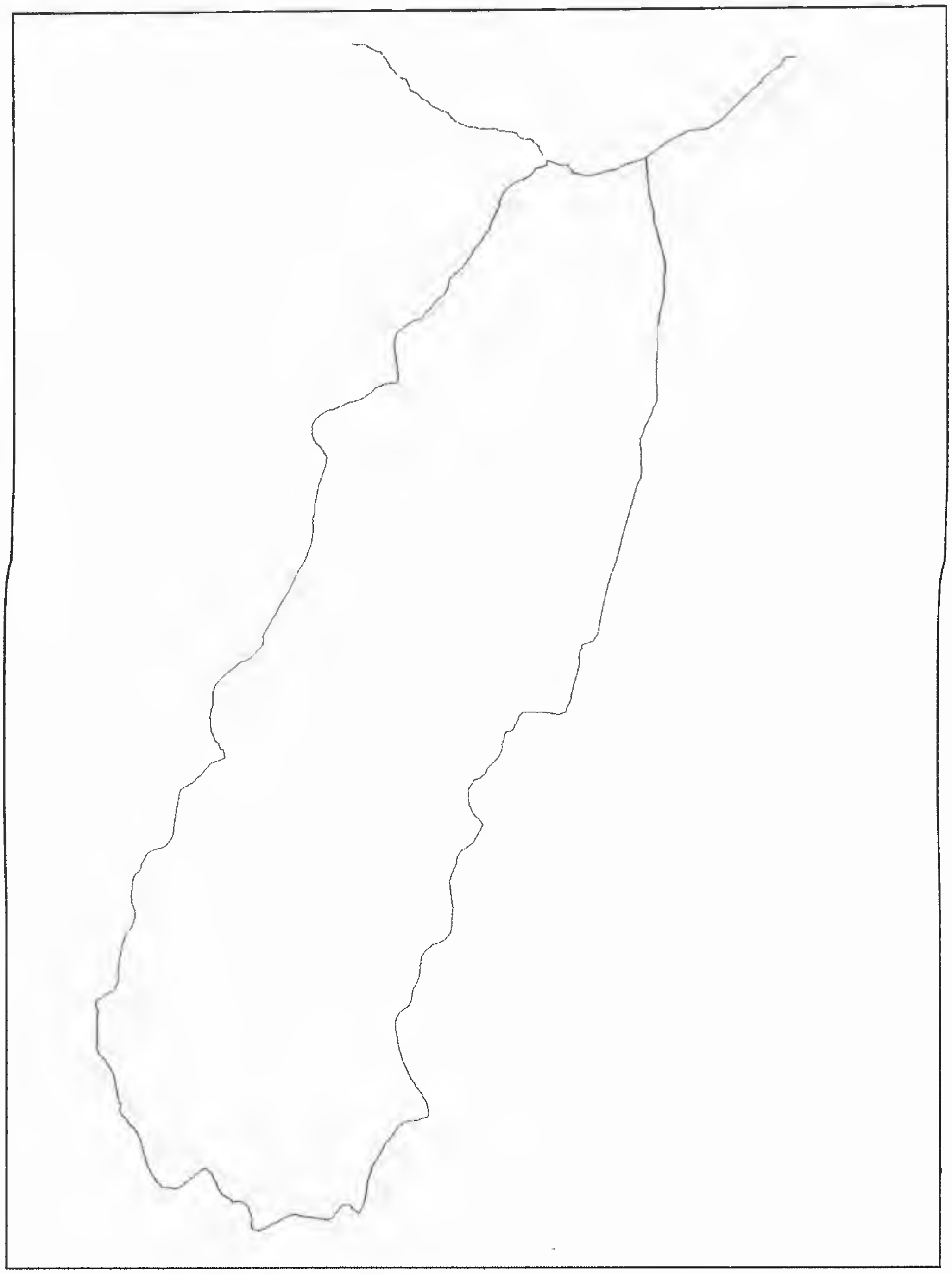

Figure 4.1 Xeros basin area scale (1:1000).

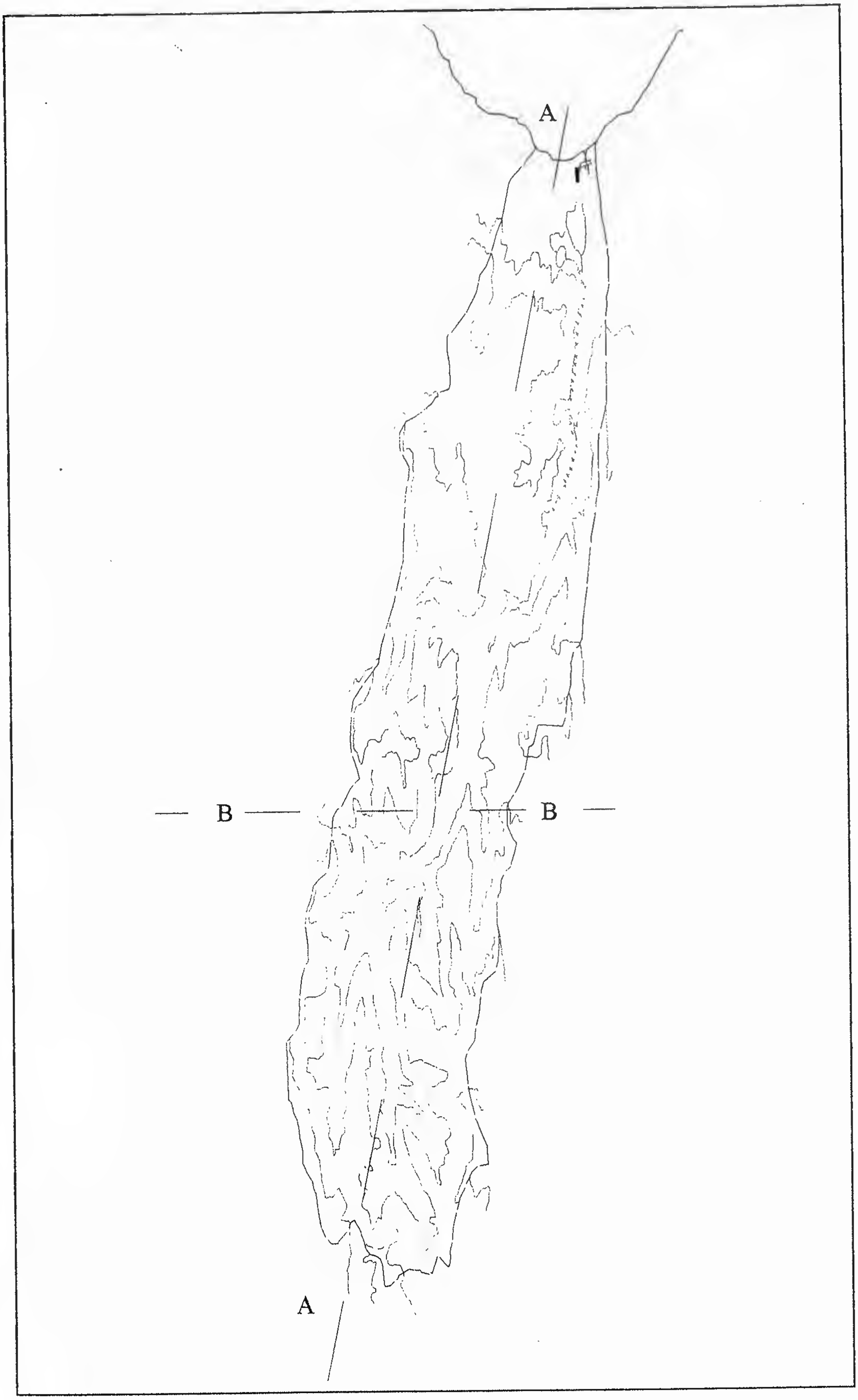

Figure 4.2 contour maps scale (1:1000) [23].

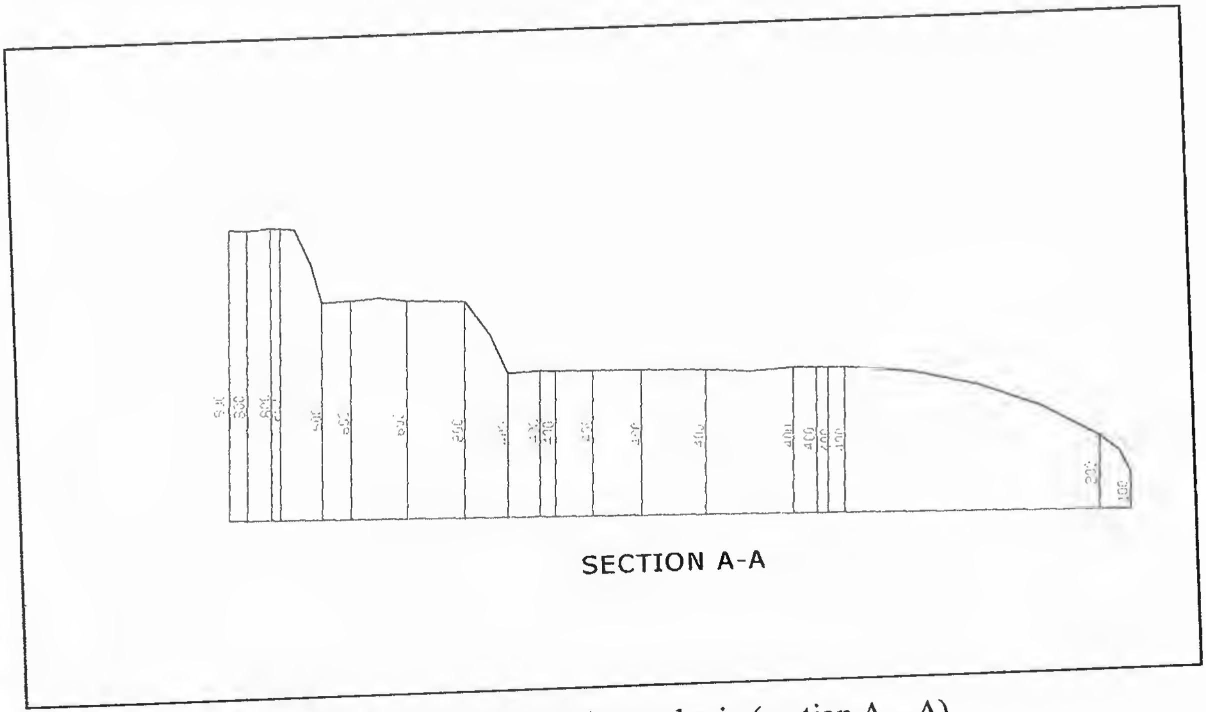

Figure 4.3 Cross section of xeros basin (section A – A)

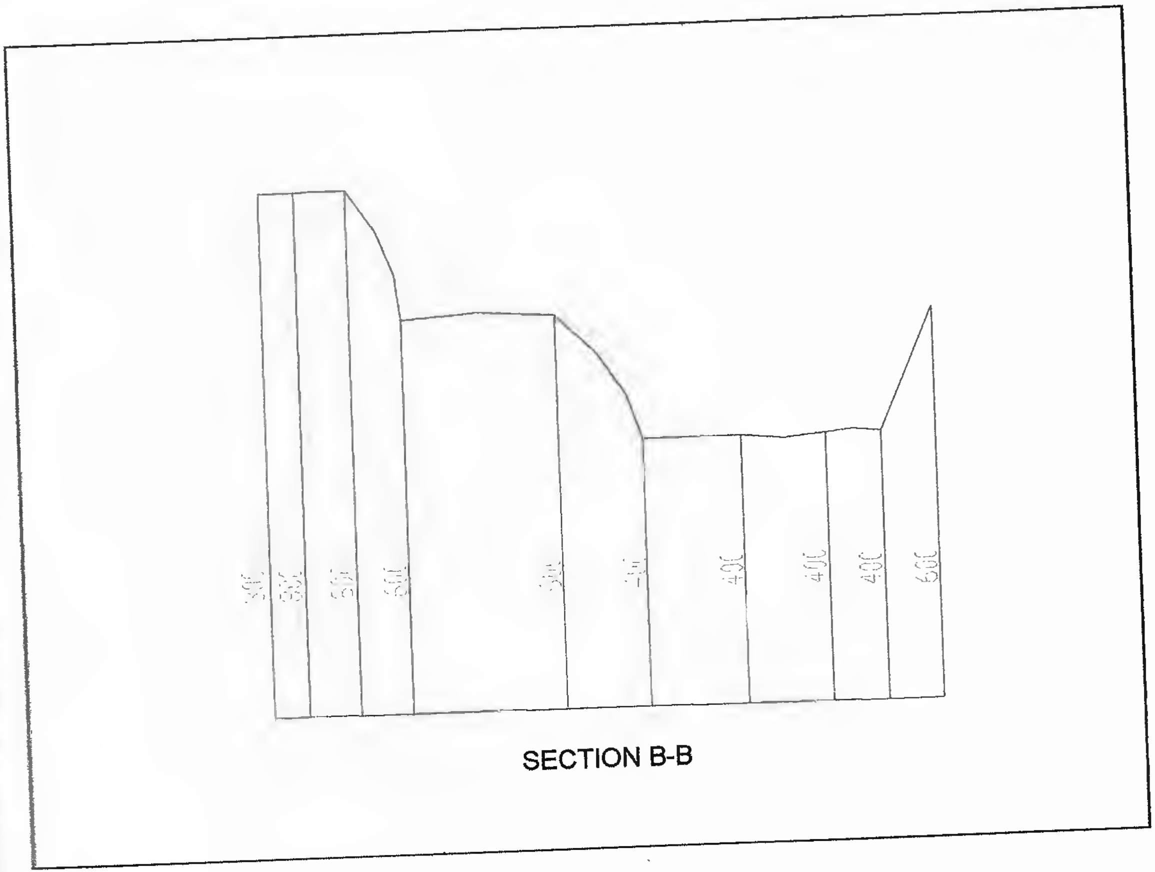

Figure 4.4 Cross section of xeros basin (B-B).

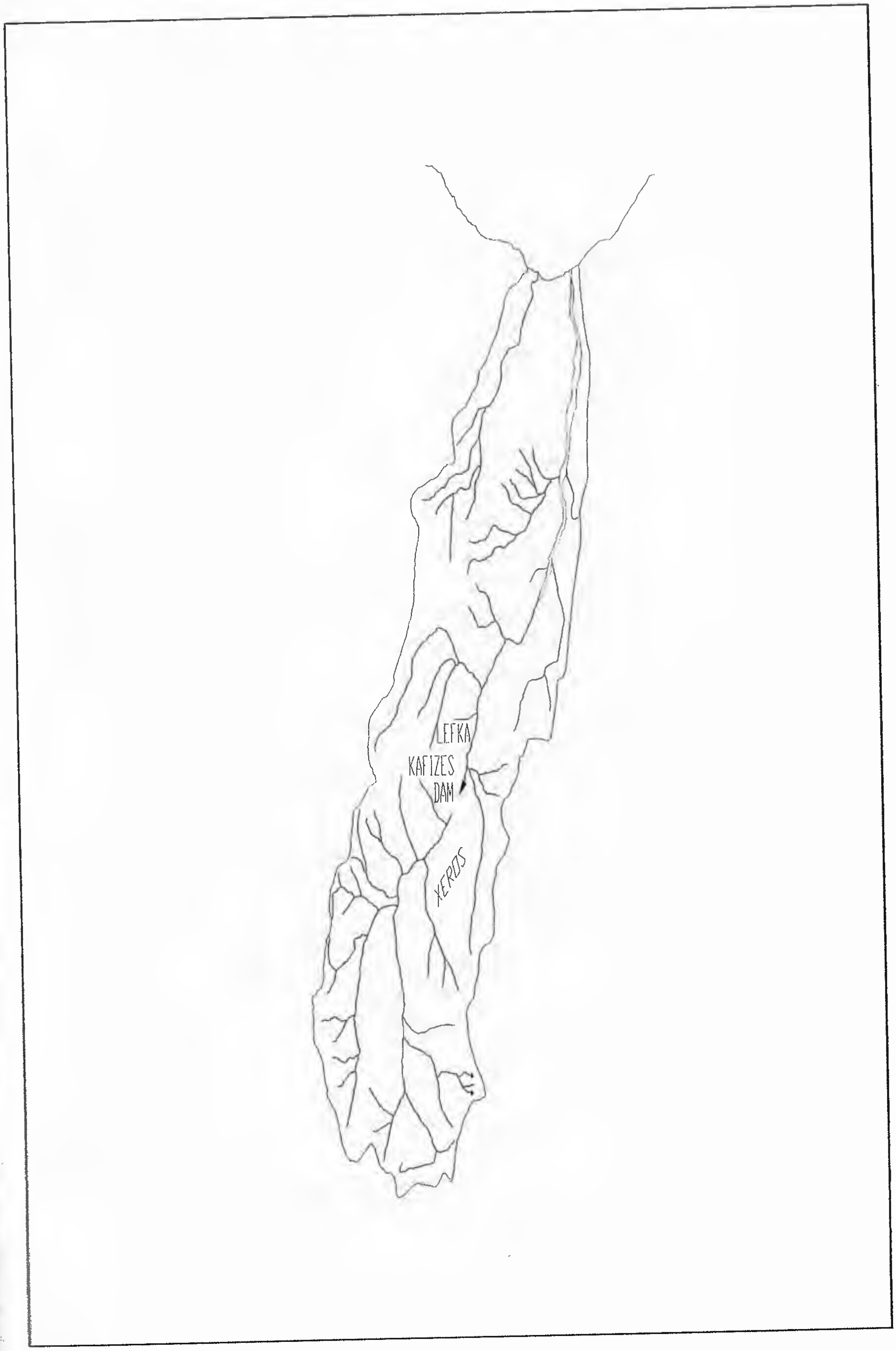

Figure 4.5 Channel map of Xeros basin.

4.2.1. Application of Gray Method

The necessary topographic parameters can be estimated from the available basin, so that the synthetic unit hydrograph of Xeros basin can be achieved. The area of basin, A_w is estimated to be 81.1 km^2. The length of the main channel, L_{mc} , was approximately 27 kilometers. L_m which is the length of the main channel of the Xeros watershed in miles measured from the outlet to the upper most part of the watershed. It is equal to 27 km =16.875 miles. Note that L_m is converted to miles, since the available equation (step 3.a of the solution procedure of gray method) is only applicable for the value given in miles. The Gray method uses the above information to obtain the synthetic unit hydrograph of the basin. The method prefers to calculate the average slope of basin S_{av}, as:

$$S_{av}=\frac{h}{l_{mc}}\times 100=\frac{728.87}{27\times 10^{3}}\times 100=2.7\% \tag{4.1}$$

Where h is the height of the triangle of the triangle in Figure (4.6).

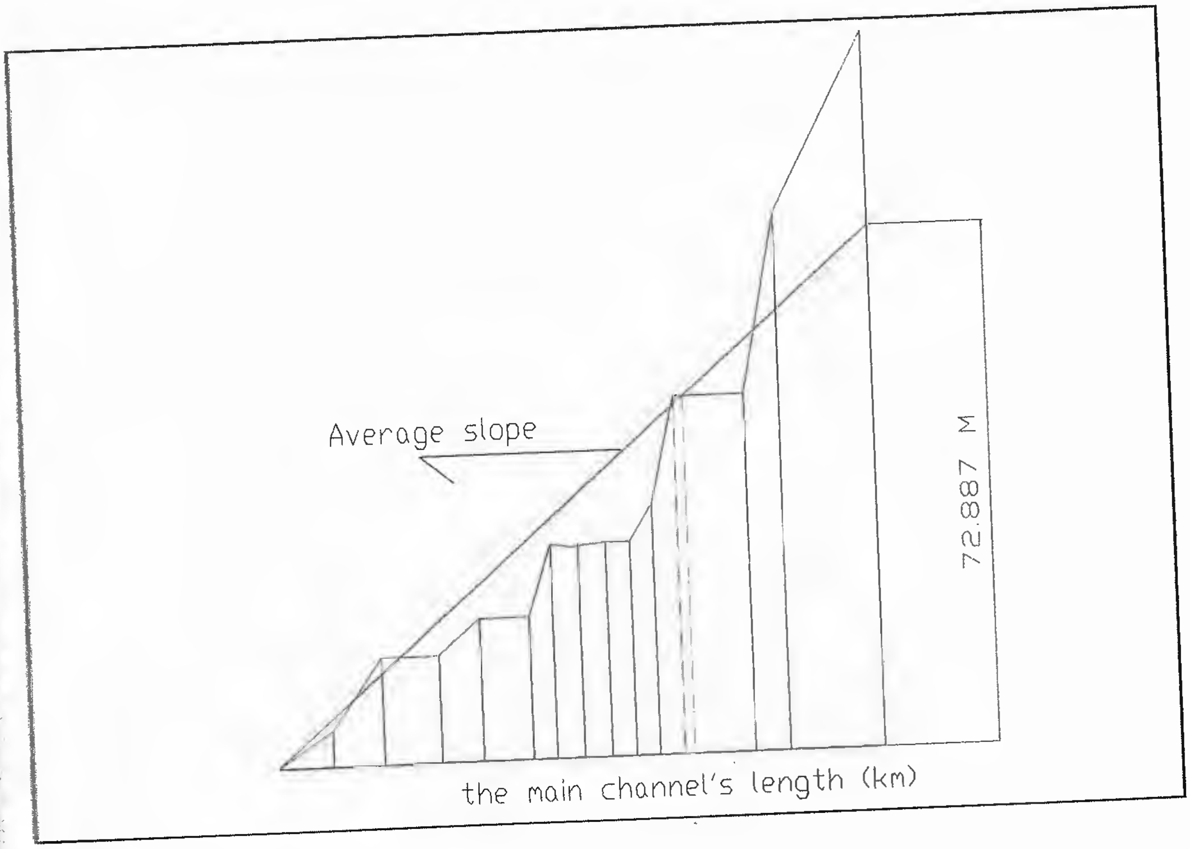

Figure 4.6 The Profile Of Xeros Basin. The Vertical Scale Is 1:10.

The ratio between the length of main channel and the average slope is necessary because the storage factor depends on this ratio. There fore,

$$\frac{l_m}{\sqrt{s_{av}}} = \frac{16.875}{\sqrt{2.7}} = 10.27 \text{ miles} \tag{4.2}$$

Hence, storage factor can be found by using

$$\frac{P_R}{\gamma'} = a\left[\frac{l_m}{\sqrt{s_{av}}}\right]^b = 7.4[10.27]^{.498} = 23.6mi \tag{4.3}$$

Where P$_R$ is the period of rise and γ' is the scale parameter. The catchments parameters a and b are taken to be 4.7 and 0.498 as they are given in Figure (2.3).

The ratio between the period of rise and scale parameters is calculated to be 23.6 mi but, still their value are not known. These values can be measured by;

$$\frac{P_R}{\gamma'} = \frac{1}{\dfrac{2.676}{P_R} + 0.0139} \tag{4.4}$$

Tow equation (4.3) and (4.4) unknowns are leading, therefore the parameter can be calculated by solving the equation .The final value of P$_R$ and γ' , P$_R$=93.98≈94 and γ' = 4 respectively.

The rainfall duration t$_r$ equal one fourth of period of rise;

$$t_r = \frac{P_R}{4} = \frac{94}{4} = 24 \text{ min} \tag{4.5}$$

The shape parameter p$_s$, is the next parameters for the solution technique of Gray method, it is necessary for the gamma function and can be estimated as;

$$p_s = \gamma' + 1 \quad p_s = 1+4=5 \tag{4.6}$$

Hence, gamma function $\Gamma(p)$ can be calculated by using Eq. (2.3) as;

$$\Gamma_{p_s} = p_s^{\,p_s} \times e^{p_s} \times \sqrt{\frac{2\pi}{p_s}}\left[1 + \frac{1}{12p_s} + \frac{1}{288p^2_s} + \frac{139}{51480p_s^3} + \frac{571}{2488320p_s^4}\right] \tag{4.7}$$

$$\Gamma_{p_s} = 5^5 \times e^5 \times \sqrt{\frac{2\pi}{5}}\left[1 + \frac{1}{12\times 5} + \frac{1}{288\times 5^2} + \frac{139}{51480\times 5^3} + \frac{571}{2488320\times 5^4}\right] = 24 \tag{4.8}$$

The gamma function conveys the calculation of flow discharge of the Xeros River. Off course the flow discharge is important parameters of predicted synthetic unit hydrograph. The equation of discharge is given in equation (2.1), which results in.

$$Q_{\frac{t}{P_R}} = \frac{25\times 4^5}{24}(e^{-4\times 0.125})(0.125^{(5-1)})=0.16 \tag{4.9}$$

The time necessary for the flow can be measured as:

$$t_{0.125}=0.125\times 94=11.75\ \text{hr} \tag{4.10}$$

And the volume of the unit hydrograph can be calculated by using Eq. (2.4)

$$V=1\times 81.1\times 10^3=81100\text{m}^3. \tag{4.11}$$

Finally the volume of the dimensionless graph V_D can be measured by using Eq (2.5).

$$V_D=\Sigma q_i\times .25\times 94\times 60 = 1410\sum q_i \tag{4.12}$$

Since the volume of unit hydrograph and the volume of the dimensionless graph V_D are equal to each other;

$$V=V_D \tag{4.13}$$

The total unit discharge can be estimated as

$81100=1410\Sigma q_i$

$\Sigma q_i=57.5\text{m}^3/\text{s}/\text{km}^2$

Table 4.1 Necessary Table to draw the synthetic unit hydrograph by Gay Method.

(1) t/P_R	(2) Time (min)	(3) Actual time (min)	(4) Actual time (hour)	(5) Percent Flow in 0.25 P_R	(6) Cumulated flow	(7) UH (m^3/s)
0	0	0	0	0	0	0
0.125	11.75	23.5	0.391667	0.158	0.158	0.9085
0.375	35.25	47	0.783333	4.7	4.858	27.025
0.625	58.75	70.5	1.175	13.36	18.218	76.82
0.875	82.25	94	1.566667	18.88	37.098	108.56
1	94	105.75	1.7625	19.54	56.638	112.355
1.25	117.5	129.25	2.154167	17.546	74.184	100.8895
1.375	129.25	141	2.35	15.58	89.764	89.585
1.625	152.75	164.5	2.741667	11.18	100.944	64.285
1.875	176.25	188	3.133333	7.29	108.234	41.9175

Table 4.1 Continue

(1) t/P_R	(2) Time (min)	(3) Actual time (min)	(4) Actual time (hour)	(5) Percent Flow in 0.25 P_R	(6) Cumulated flow	(7) UH (m^3/s)
2.125	199.75	211.5	3.525	4.43	112.664	25.4725
2.375	223.25	235	3.916667	2.54	115.204	14.605
2.625	246.75	258.5	4.308333	1.394	116.598	8.0155
2.875	270.25	282	4.7	0.74	117.338	4.255
3.125	293.75	305.5	5.091667	0.38	117.718	2.185
3.375	317.25	329	5.483333	0.19	117.908	1.0925
3.625	340.75	352.5	5.875	0.092	118	0.529
3.875	364.25	376	6.266667	0.0446	118.0446	0.25645
4.125	387.75	399.5	6.658333	0.021	118.0656	0.12075
4.375	411.25	423	7.05	0.00981	118.0754	0.056408

The change in discharge with respect to the change in time is the necessary data for the plot of unit hydrograph. The Table (4.1) is representing the changes of these parameters for the plot of synthetic unit hydrograph. The data of the above table is achieved by using Eq. (2.1). In this equation the time (min) can be calculated by multiplying column (1) by P_R which is equal to 94.the actual time is calculated by adding $P_R/8=11.75$ with the time given in minutes. Column number 4 is the representation of column number 3 in hour. The percent flow in 0.25 P_R is obtained by Eq (2.2). The values in column number 7 are determined by multiplying $\sum q_i = 57.5$ with the values in column number 5 divided by 100. By definition, while the summation of the values at column 6 and 7, the peak values are not considered. The peak value, 112.355 m^3/s, is subtracted from the summation of the values 678.933607m^3/s, and the result is equal the total discharge, 566.5786. These calculations the synthetic unit hydrograph of the watershed is constructed using column number 4 and 7.

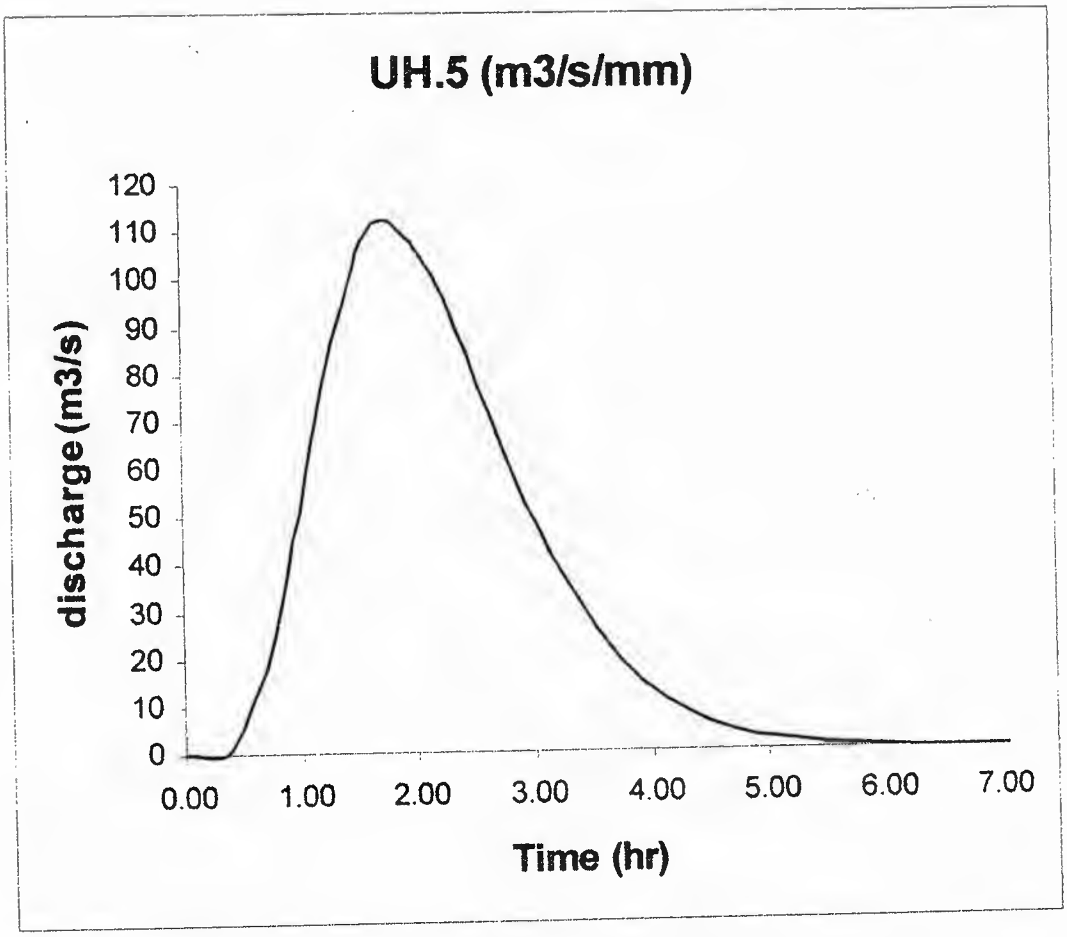

Figure 4.7 Synthetic Unit Hydrograph ($UH_{0.5}$) By Gray Method.

4.2.2 Application of DSI Method

The characteristic of xeros basin is also suitable for the application of DSI method. The necessary hydrograph characteristics are already determined in previous section. Extra information is needed in this method, which is the length of channel from the centroid of the watershed to the outlet, L_{CC} it is estimated to be 13.64 km. The harmonic slope, S_{harm}, is calculated by the help of Table (4.2), the first column represent number of segment in which the basin is divided. For the Xeros basin number of segment is sixteen. The elevations of each segment from mean sea level are given in column two. The elevation difference between two relative segments are calculated, Δh, and given in third column. The fourth column is the length of the main channel. The slope between each segment, S_i, is calculated in fifth column by taking the ratio between elevation difference and length of the main channel. The remaining two columns are the square root and the inverse of the slope of segments respectively.

Table (4.2) Calculation Procedure of Harmonic Slope for Xeros Watershed.

Number of segment	**H(m)**	**Δh(m)**	**L (m)**	**S_i=h/L**	$\sqrt{S_I}$	**$1/\sqrt{S_I}$**
1	50	50	27000	0.001852	0.043033	23.2379
2	170	120	27000	0.004444	0.210817	4.74344
3	180	10	27000	0.00037	0.192458	5.195945
4	190	10	27000	0.00037	0.06086	16.43102
5	200	10	27000	0.00037	0.06086	16.43102
6	300	100	27000	0.003704	0.19245	5.196155
7	370	70	27000	0.002593	0.161016	6.210581
8	380	10	27000	0.00037	0.375155	2.665567
9	390	10	27000	0.00037	0.06086	16.43102
10	340	50	27000	0.001852	0.136085	7.348374
11	350	10	27000	0.00037	0.06086	16.43102
12	570	220	27000	0.008148	0.285449	3.503256
13	590	20	27000	0.000741	0.086064	11.61927
14	500	90	27000	0.003333	0.182573	5.477253
15	700	200	27000	0.007407	0.272165	3.674236
16	1000	300	27000	0.011111	0.333333	3.000002
					Total	**147.6**

The information given in Table (4.2) can be used to calculate the harmonic slope as;

$$S_{harm}=\left[\frac{ns}{\sum\frac{1s}{Si}}\right]^2=\left(\frac{16}{147.6}\right)^2=0.012 \qquad (4.14)$$

The empirical value of the basin, E_P is thus can be measured by referring to Equation (2.7).

$$E_p=\frac{(L_{mC}\times L_{cc})}{\sqrt{S_{harm}}}=\frac{27\times 13.64}{\sqrt{.012}}=3362 \qquad (4.15)$$

And the unit flow discharge, q_p, thus can be measured as:

$$q_p = \frac{414}{81.1^{0.225} \times 3362^{0.16}} = 42 \text{ l/S/km}^2\text{/mm.}$$

Equation (2.9) can be applied to calculate the time of rise (t_p) of the basin, which is necessary for the estimation of peak discharge, Q_P.

$$t_p = \frac{202.78}{q_P} = \frac{202.78}{42} = 4.83 \text{hr} \qquad (4.16)$$

The aim of this calculation to fined the peak discharge Q_P to draw the unit hydrograph.

$Q_P = 81.1 \times 42 \times 10^{-3} = 3.4 \text{ m}^3\text{/s}$

(4.17)

The calculated t_p and Q_P multiplied by the dimensionless unit hydrograph values are used so as to construct the unit hydrograph coordinates. The third and fourth columns of Table (4.3) are the coordinates of the unit hydrograph of Xeros watershed.

Table 4.3 Unit Hydrograph data for Xeros watershed.

t/t_P	**Q/Q_P**	**T (hr)**	**Q (m^3/s)**	**t/t_P**	**Q/Q_P**	**T (hr)**	**Q (m^3/s)**
0	0	0	0	1.5	0.66	7.35	2.2176
0.1	0.015	0.49	0.0504	1.6	0.56	7.84	1.8816
0.2	0.075	0.98	0.252	1.8	0.42	8.82	1.4112
0.3	0.16	1.47	0.5376	2	0.32	9.8	1.0752
0.4	0.28	1.96	0.9408	2.2	0.24	10.78	0.8064
0.5	0.43	2.45	1.4448	2.4	0.18	11.76	0.6048
0.6	0.6	2.94	2.016	2.6	0.13	12.74	0.4368
0.7	0.77	3.43	2.5872	2.8	0.098	13.72	0.32928
0.8	0.89	3.92	2.9904	3	0.075	14.7	0.252
0.9	0.97	4.41	3.2592	3.5	0.036	17.15	0.12096
1	1	4.9	3.36	4	0.018	19.6	0.06048
1.1	0.98	5.39	3.2928	4.5	0.009	22.05	0.03024
1.2	0.92	5.88	3.0912	5	0.004	24.5	0.01344
1.3	0.84	6.37	2.8224	5.5	0	26.95	0
1.4	0.75	6.86	2.52				

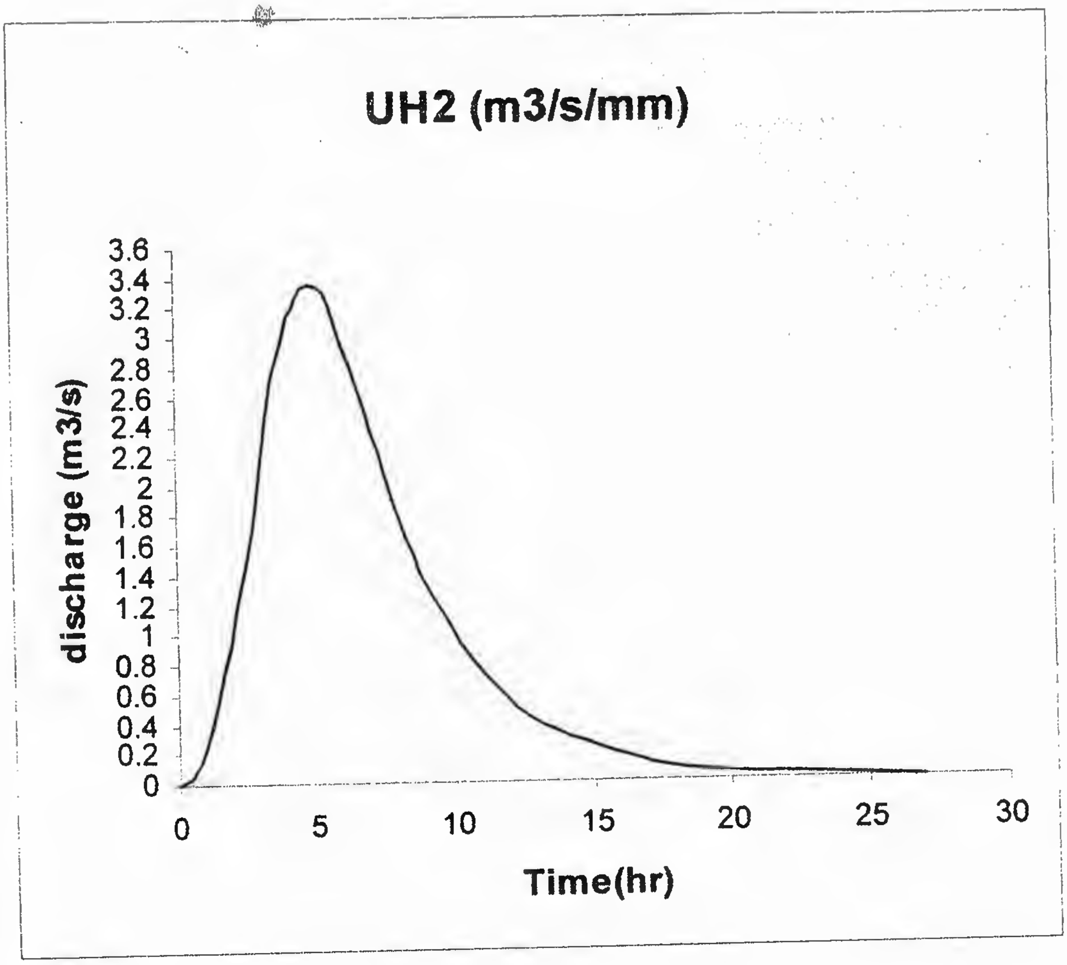

Figure 4.8 Unit hydrograph by (DSI method)

4.2.3 Application of Mockus Method

The time of concentration, T_C for mockus method is defined in Chapter (2). It can be estimated by Equation (2.16), where the length of main channel and harmonic slope directly involved in definition.

$$T_c=0,\ 00032\frac{(27000)^{0.77}}{.012^{0.385}}=4.54 \qquad (4.18)$$

In mockus method, it is recommended that, time of concentration (T_C) of the rainfall is less than or equal to 6 hr, than the design rainfall duration, t_r is practically taken as 1hr, which means that UH_1 should be constructed. Equation 2.17 helps to find time of rise, t_p by means of t_r and T_C as,

$$t_p=.5\times 1+0.6\times 4.54=3.2\text{hr}. \qquad (4.19)$$

The mockus method claims that the time of recession and time of rise is 1.67. Therefore, the time of recession can be estimated to be 4.38 hr.

The base time, t_b, as mentioned before is the total time necessary for time of recession and time of rise to occur.

t_b=3.2+4.384=7.584 hr (4.20)

The final requirement for the unit hydrograph is the peak discharge. This discharge can be estimated by Equation 2.20.This discharge can be estimated by the following equation.

$$Q_P = \frac{Y \times A_W \times h_a}{t_p} \tag{4.21}$$

Where Y is the basin coefficient which equal 0.208, A_W the watershed area h_a is the unit depth over the basin area and t_p is the time of rise therefore, the peak discharge is equal to:

$$Q_P = \frac{0.208 \times 81.1 \times 1}{3.2} = 5.27 \quad m^3/s. \tag{4.22}$$

Finally the mockus method can be computed such that the triangle. Unit hydrograph of the Xeros basin can be estimated.

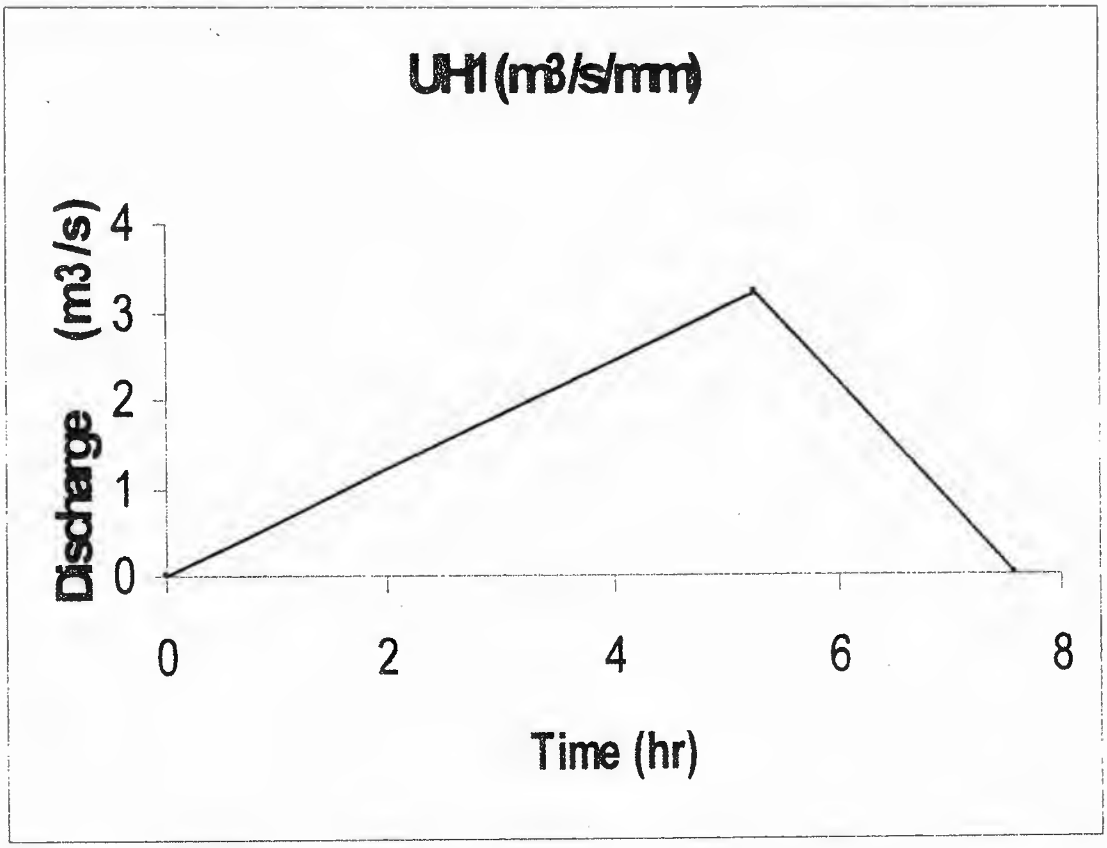

Figure 4.9 Unit Hydrograph of Xeros Watershed By Mockus Method

4.3 Dams

In an island like Cyprus where the water resources are limited the demand for water far exceeds the water available.

The problem of water scarcity should be achieved by the construction of water resource structures. In Xeros watershed area the dam is constructed to store the surplus water of the rivers to be used future. Two dams are already constructed Kafizes and Gemikonagi, to solve both the irrigation and potable water demand.

4.3.1 Kafizes Dam

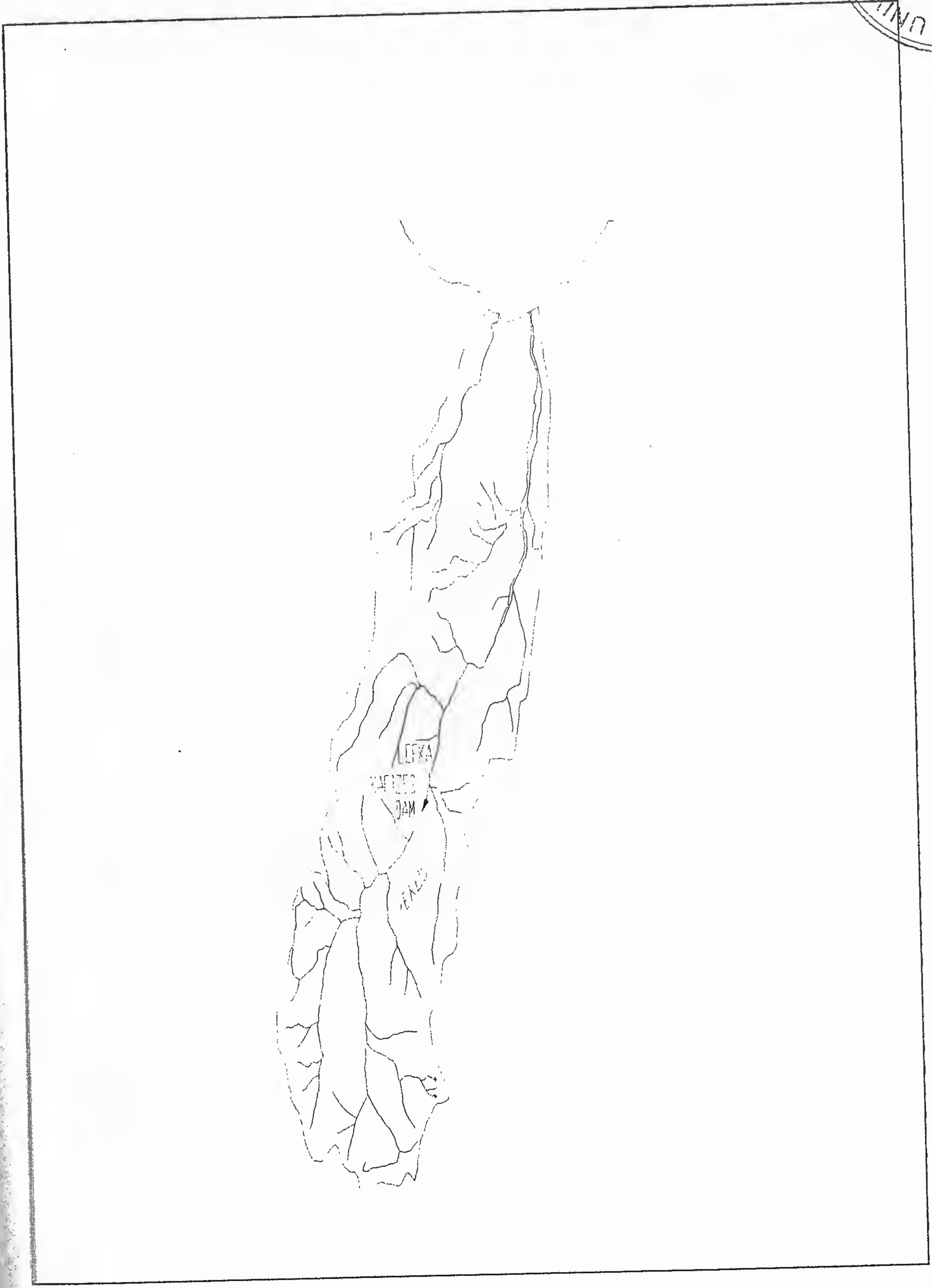

Figure 4.10 Kafizes Dam in Xeros Watershed Scale (1:1000)

The dam is constructed on the Xeros River in Gemikonagi region. It is situated at a distance of 11 km from the sea and at an elevation of about 260 m above sea level.

The project was constructed in order to supply additional water to orange of Lefka, which were previously relying on an intake and canalization system from the Marathasa River. The water supply to lefka from the Marathasa River were not enough to satisfy the 560 donums of orange groves which at the time, seventy years ago, represented the second largest orange plantations in Cyprus after Famagusta. As no more summer water could be allocated to lefka from the Marathasa River due to the heavy requirements of other villages upstream, it was considered necessary to bring water from Xeros River. The nearby river of Xeros on the west of Lefka was selected and a diversion scheme was designed in 1925 and constructed in 1935. This was then considered to be the most important irrigation work carried out on the island except for the Eastern Mesaoria irrigation works made up of the Kouklia, Akhyritou and Syngrasi reservoirs (Dams of Cyprus, 1974). Later on, as the summer flow diversion was not found to be reliable and adequate, the storage dam at Kafizes was built which supplies water through the pipeline laid in 1932. Now aday the dam is still supplying water to the region by pipe line system, but some how due to saltation problem it is not working efficiently [24].

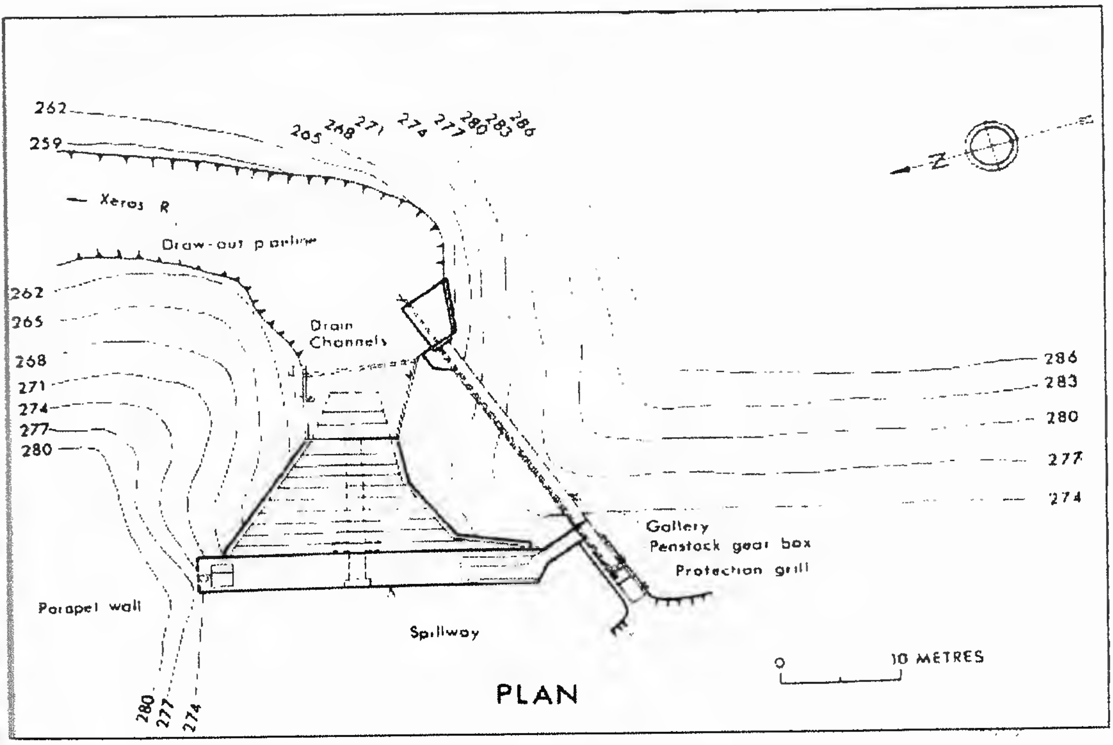

Figure 4.11 Plan View of Kafizes Dam [24].

4.3.2 Gemikonagi Dam

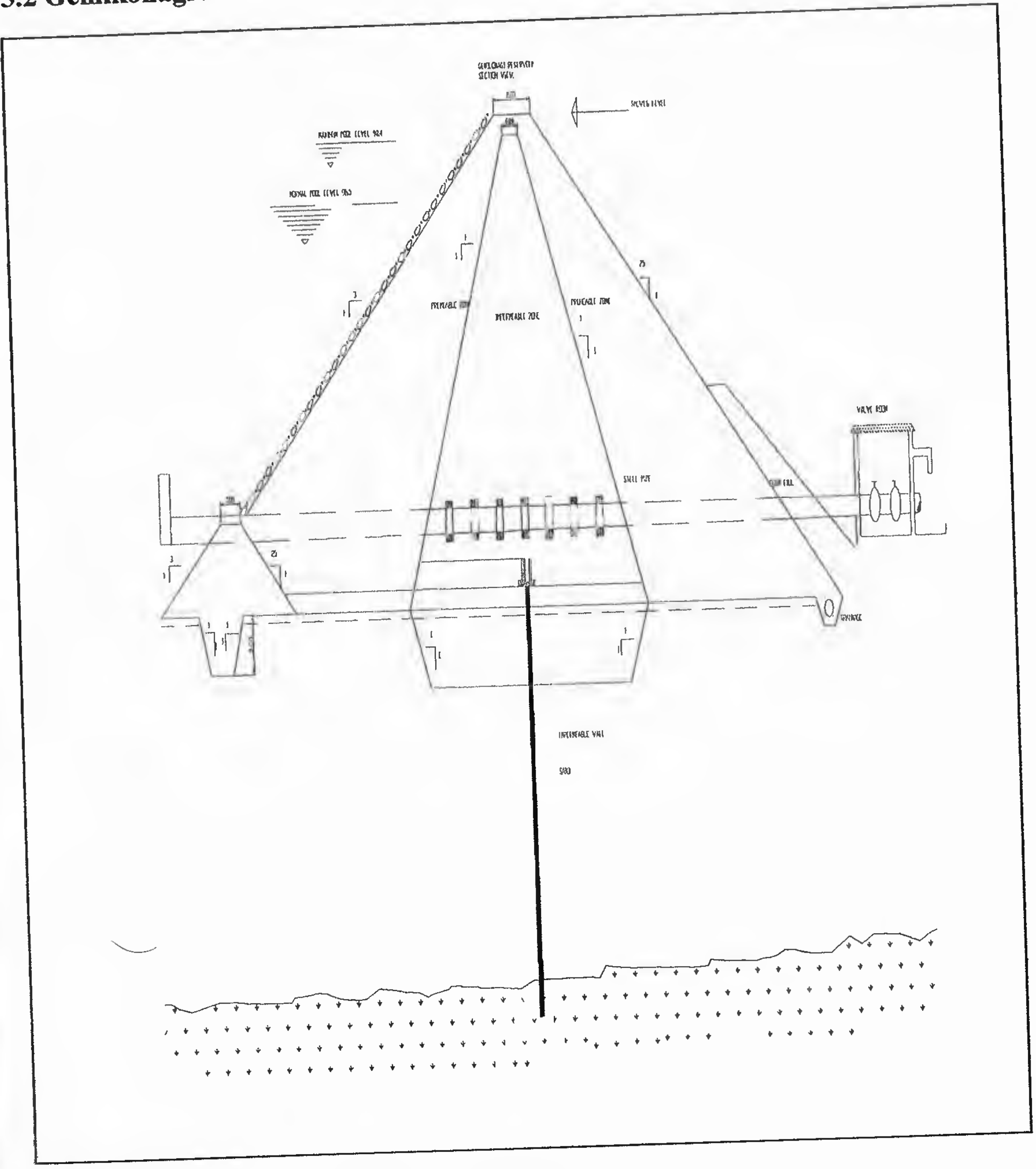

Figure 4.12 Gemikonagi Plan [23].

The aim of the construction was to supply water for irrigation to nearby cultivated lands. The total volume of concrete used for the construction of the Gemikonagi dam was 748549m^3. The maximum elevation of the dam was 99.7m. The seepage under the dam was controlled by a shear wall with a surface area of 8555.87m^2. The need for its construction arised due underlying formation [23].

4.3.2 Gemikonagi Dam

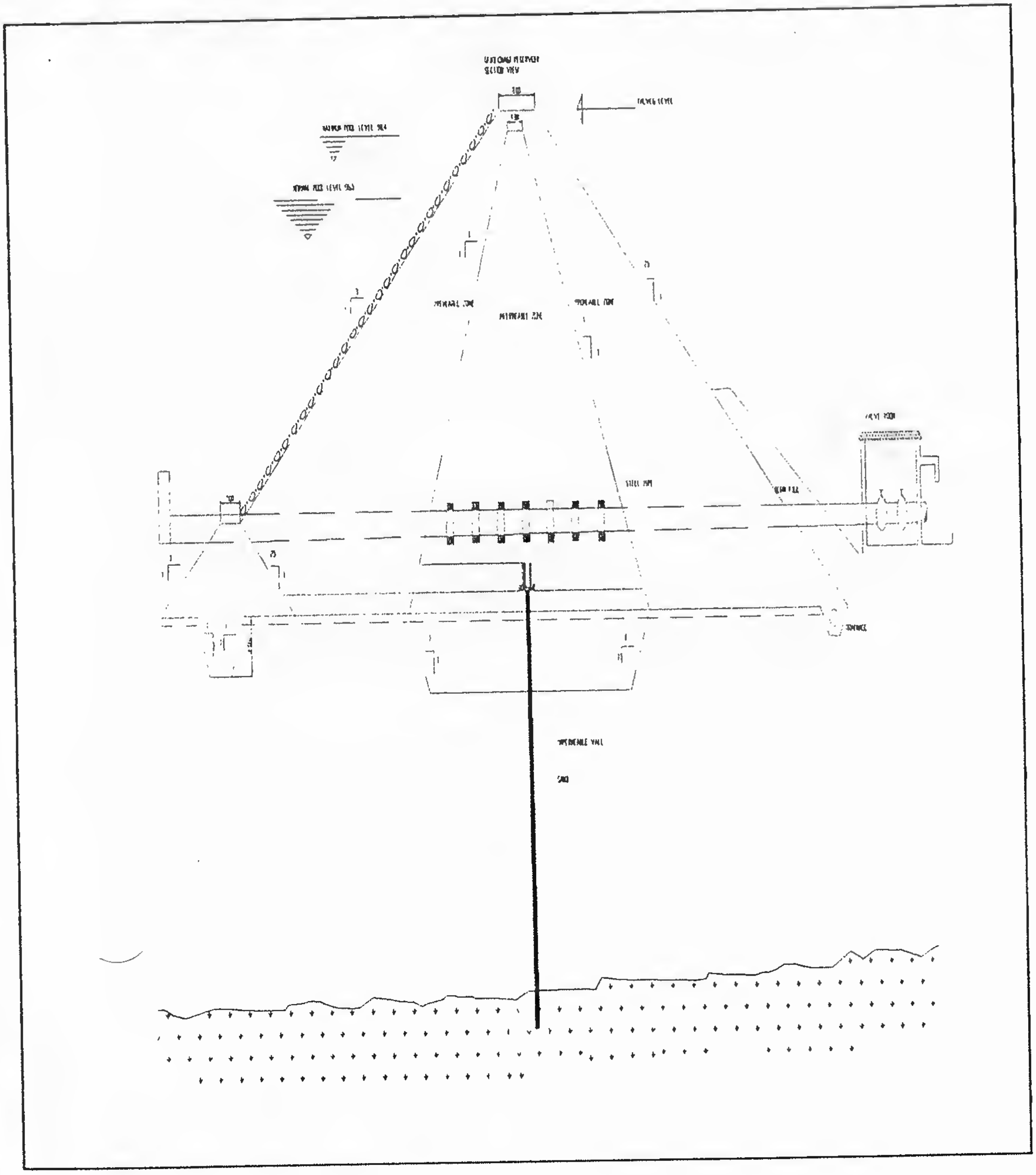

Figure 4.12 Gemikonagi Plan [23].

The aim of the construction was to supply water for irrigation to nearby cultivated lands. The total volume of concrete used for the construction of the Gemikonagi dam was 748549m^3. The maximum elevation of the dam was 99.7m. The seepage under the dam was controlled by a shear wall with a surface area of 8555.87m^2. The need for its construction arised due underlying formation [23].

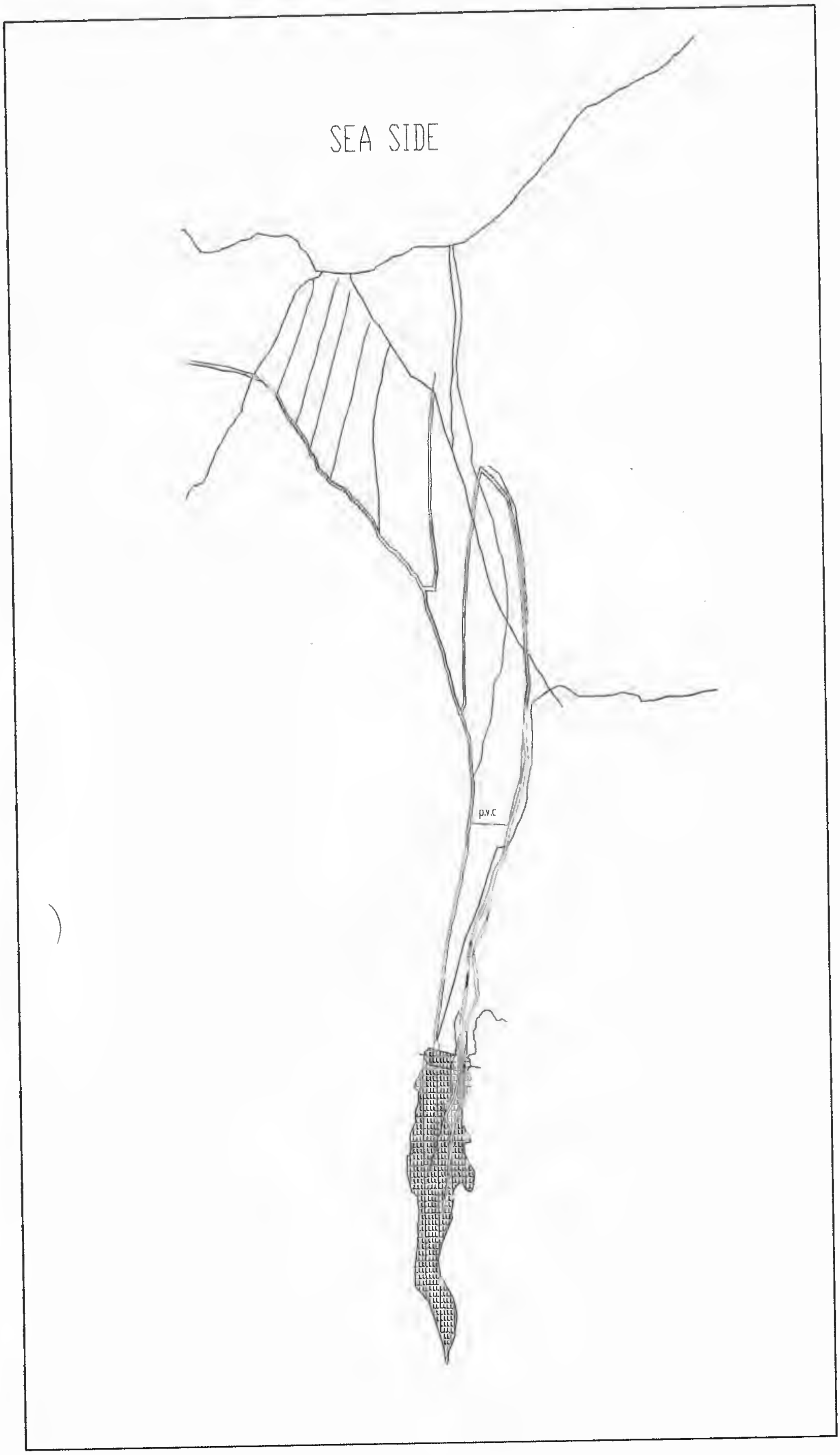

Figure 4.13 The plan view of the Gemikonagi dam and water distribution system [23].

During the design step of Gemikonagi Dam it was expected to irrigate an area of 640 hectares, such that the reservoir capacity is designed approximately as 8 million cubic meters [23].

5. WATER QUALITY AND DISCUSSION

5.1 Water Quality Analyses and Discussions

The Gemikonagi reservoir is already been under observation since 1994. All the data that has been sampled since then is analyzed and the water quality are mapped. There are four main points where these sample data are collected. These are reservoir, reservoir recharge, bottom discharge and reservoir feed point. The qualities of sample are compared with EU water directive parameters as shown in Table (3.1).

Table 5.1 The Quality Of Water In Gemikonagi Reservoir According To EU Water Directive Parameters.

Location	Parameter	Period	Average concentration mg/L	Maximum admissible concentration	Result
Reservoir	Al	1994	0.423	0.2 mg/L	Not safe
		1995-1999	2.88		Not safe
		2000-2001	0.38		Not safe
		2001	0.366		Not safe
	Cl	1994	61.24	250mg/L	Safe
		1995	68.8		Safe
		1996-1998	117		Safe
		1999-2002	65.11		Safe
	Cu	1994	0.6	0.11 mg/L	Not safe
		1995-1999	1.44		Not safe
		2000-20001	0.084		Safe
	SO_4	1994-1995	247.83	250mg/L	Safe
		1996-1998	389.5		Not safe
		1999-2002	69.2		Safe
	Na	1994-1995	37.6	150mg/L	Safe
		1996-1998	59.25		Safe
		1999-2000	44.89		Safe

Table 5.1 Continue

Location	**Parameter**	**Period**	**Average concentration mg/L**	**Maximum admissible concentration**	**Result**
	Mg	1994-1996	49		safe
		1997-1998	63.5		Not Safe
		1999-2002	28.1		Safe
	K	1994	1.37	12mg/L	Safe
		1995-1998	1.01		Safe
		1999-2002	1.38		Safe
	$CaCO_3$	1994	329.5	60mg/L	Not safe
		1995-1999	408.33		Not safe
		2000	343.33		Not safe
		2001	260		Not safe
		2002	205		Not safe
	Fe	1994-1999	0.334	200 µg/L	Not safe
		2000	0.3		Not safe
		2001	0.283		Not safe
	Ca	1994	62.3	100mg/L	Safe
		1995-1999	87.6		Safe
		2000-2002	72.9		Safe
	Zn	1994	0.5	100 µg/L	Not safe
	pH	1999-2001	7.4	$6.5<pH<8.5$	Safe
	Mn	1994	0.264	50 µg/L	Not safe
		1995-1999	0.91		Not safe
		2000	0.538		Not safe
		2001	0.11		Not safe

Table 5.1 Continue

Location	Parameter	Period	Average concentration mg/L	Maximum admissible concentration	Result
Reservoir recharge	pH	1995	7.58	6.5<pH<8.5	Safe
		1996	7.15		Safe
	Mn	1995	1.37	0.05 mg /L	Not safe
		1996	2.1		Not safe
	Mg	1995	43	50mg/L	safe
		1996	45.5		safe
	Fe	1995	0.45	0.2mg/L	Not safe
		1996	0.5		Not safe
	Al	1995	3.09	0.2 mg/L	Not safe
		1996	0.8		safe
	Cu	1995	2.3	0.1mg/L	Not safe
	Cl	1995-1996	51.5	250mg/L	Safe
	SO_4	1995-1996	261.4	250mg/L	Not Safe
	K	1995-1996	0.9	12mg/L	Safe
	Na	1995-1996	29.7	150mg/L	Safe
	Ca	1995-1996	68.4	100mg/L	Safe
Bottom discharge	pH	1994-1995	4.6	6.5<pH<8.5	Not safe
		1996	7.5		Safe
		1997	7.85		Safe
	Mg	1994-1995	102.93	50mg/L	Not safe
		1996	52		Not safe
		1997	63		Not safe
	SO_4	1994-1995	523.75	250mg/L	Not safe
		1996	336.5		Not safe
		1997	224.5		Safe
	Na	1994-1997	33.9	150mg/L	Safe

Table 5.1 Continue

Location	**Parameter**	**Period**	**Average concentration mg/L**	**Maximum admissible concentration**	**Result**
		1999	1.27		Not safe
	K	1994-1997	0.9	12mg/L	Safe
	Fe	1997-1999	1.3353		Not safe
		1997-1999	1.3353		Not safe
	Cu	1994-1995	3.9	100µg/L	Not safe
		1996-1997	0.33		Not safe
		1999	2.66		Not safe
	Cl	1994-1996	56	250mg/L	Safe
	Ca	1994-1997	63	100mg/L	Safe
	Al	1995-1999	5.18	0.2 mg/L	Not safe
Reservoir feed point					
	Mn	1997	1.94	0.05g/L	Not safe
		1998-1999	1.614		Not safe
		2000-2002	0.17		Not safe
	Fe	1997-1998	0.8	200 µg/L	Not safe
		1999-2000	0.15		Safe
		2001-2002	0.152		Safe
	Al	1997	0.71124	0.2 mg/L	Not safe
		1998-1999	0.642		Not safe
		2000-2002	0.165		Safe
	Mg	1997	158.7	50mg/L	Not safe
	Cu	1997	0.2	100µg/L	Not safe
		1998-1999	0.087		Not safe
		2000-2002	0.1		Safe

From Table (5.1) it can be clearly observed that at reservoir the concentration of Aluminum, Iron, Zinc, Manganese and hardness of water are greater than the maximum admissible concentration comparing to Table (3.1).

At reservoir recharge region there are also some parameters having their concentrations greater than the maximum admissible concentration. These elements are Aluminum, Iron, Manganese and Copper. Thus, the water is not suitable for drinking according to Table (3.1).

At feed point Manganese, Aluminum and Magnesium have their concentrations greater than the maximum admissible concentration.

At the bottom discharge it is observed that Magnesium, Sulphate, Manganese, Iron, Copper and Aluminum are overloaded.

5.2. Discussion of Water Quality Data

To show clearly the quantity of each element in the water and the fluctuation in the water throughout time, charts will be drawn for each element separately for each location.

The graphical representation of each element throughout the years can easily define the changes in concentrations. Therefore, for the four different locations, the changes of concentrations of elements within the water with respect to time are drawn.

5.2.1 Aluminum Concentration for Gemikonagi Dam.

According to the European standards the maximum admissible concentration for drinking water quality permits 0.2 mg/l Aluminum concentration in water. There is no data available at reservoir recharge before June 1995. Therefore, the sudden increase for aluminum concentration in reservoir area in August 1995 can not be discussed. However, second peak point which is approximately 5 mg/L which is represented in both reservoir and bottom discharge could be due to the reservoir recharge in August 1995. The reservoir feed point is under observation since February 1997, feed point and bottom discharge faced with aluminum concentration during winter months of 1997-1999. However those concentrations (2mg/L) are also above the maximum admissible concentration. As shown in the Figure 5.1, the quantity of Aluminum follows fluctuating path except during 1994 period. If the average values are compared, from 1994 the average amount of Aluminum was 0.423 mg/L, however, from 1995-1999 the average amount was 2.88 mg/L. The average amount of Aluminum in 2001 was 0.366 mg/L. Despite the fact that the Aluminum's rate was going down, it is still greater than the maximum admissible concentration, which is equal to 0.2 mg/L according to the European Standards. The maximum and the minimum concentration values for aluminum was occurred in August 1995 are 5.08 and in November 2001 are 0.0384. The amount of Aluminum has decreased during the years 1994-1999 as shown in Figure 5.2 in these years. If the average values are compared, from 1995-1999 the average amount of Aluminum was 5.18 mg/L, however, from 1995-1999 the average amount was more thane 0.2 mg/L it mean the water was not safe in relation to Aluminum's rate. The maximum and the minimum concentration values for Aluminum was occurred in August 1995 are 4.24 and in June 1997 are 0.05557. The amount of Aluminum has decreased during the years 1997-2002 as shown in Figure 5.3. If the average values are compared, from 1997 the average amount of Aluminum was0.71124 mg/L, however, from 1998-1999 the average amount was 0.642 mg/L. The average amount of Aluminum in 2000-2002 was 0.165 mg/L in these years the water was safe in relation to Aluminum's rate. The maximum and the minimum concentration values for Aluminum was occurred in April 1998 are 2.373 and in March 1999 are 0.011. The amount of Aluminum has decreased during the years 1995-1996 as shown in Figure 5.4. If the average values are compared, in 1995 the average amount of Aluminum was 3.09 mg/L, however, in 1996 the average amount was 0.8 mg/L. in these years the water was not safe in relation to Aluminum's rate. The maximum and the minimum concentration values for Aluminum was occurred in august 1995 are 6.4 and in June 1995 are 0.22. The reason for high concentration of aluminum is silicate and clays in the basin.

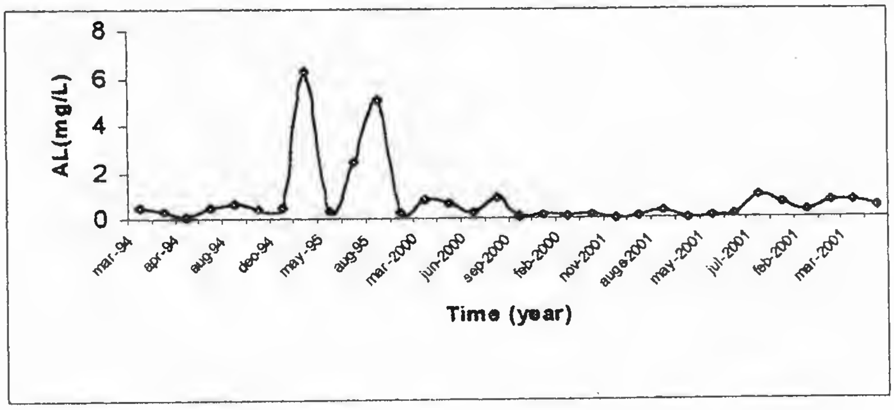

Figure 5.1 Fluctuation of Aluminum with time in the reservoir.

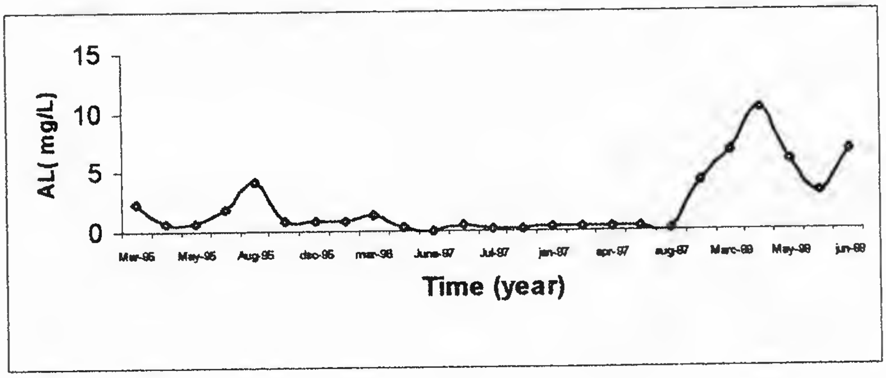

Figure 5.2 Fluctuation of Aluminum in the bottom discharge.

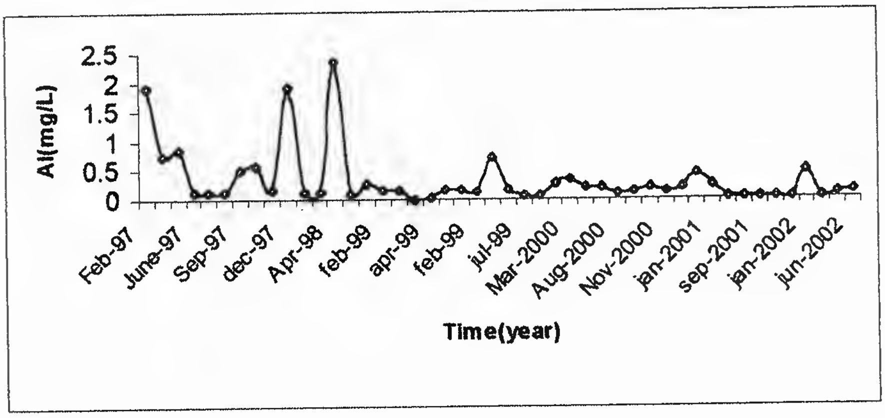

Figure 5.3 Fluctuation of Aluminum in the reservoir feed point.

2001-2002 Copper's rate was safe in relation to standards. The maximum and the minimum concentration values for Copper was occurred in April 1997 are 0.7781 and in august 1999 are 0.01. In Figure 5.8 that the amount of copper has increased during the years 1995 and decreased from 1995, mentioning that the water was not safe during the period 1997-1998 and during 1999-2001, but in 2001-2002 Copper's rate was safe in relation to standards. The maximum and the minimum concentration values for Copper was occurred in December 1995 are 1.58 and in June 1995 are 0.22. The reason for high concentration of Copper is due to main ore of the miner.

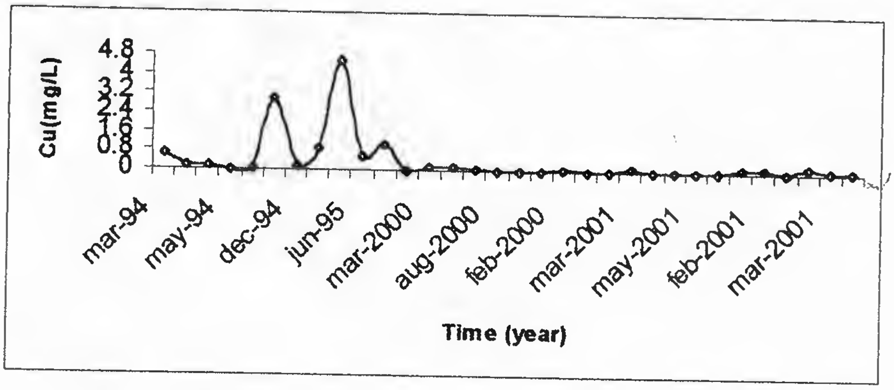

Figure 5.5 Fluctuation of Copper in the Reservoir.

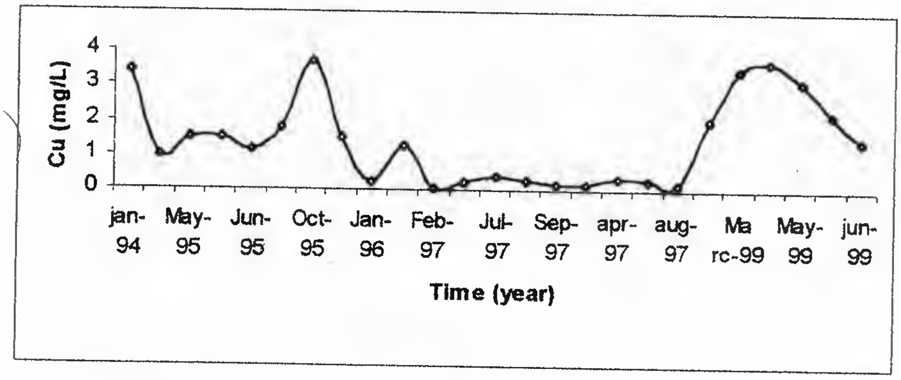

Figure 5.6 Fluctuation of Copper in the Bottom discharge.

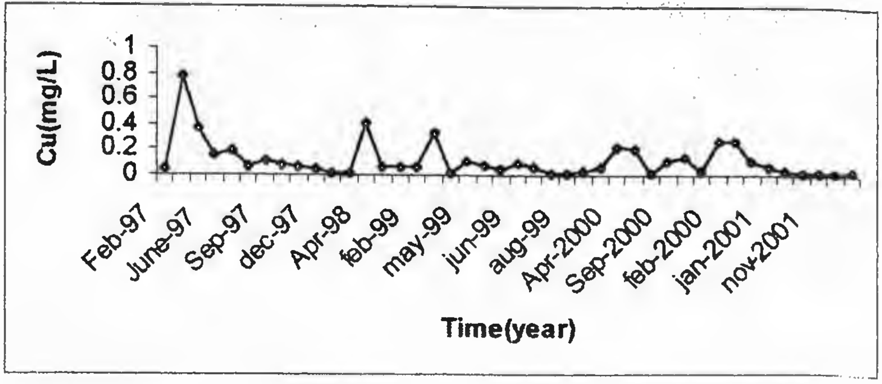

Figure 5.7 Fluctuation of Copper in the Reservoir feed point.

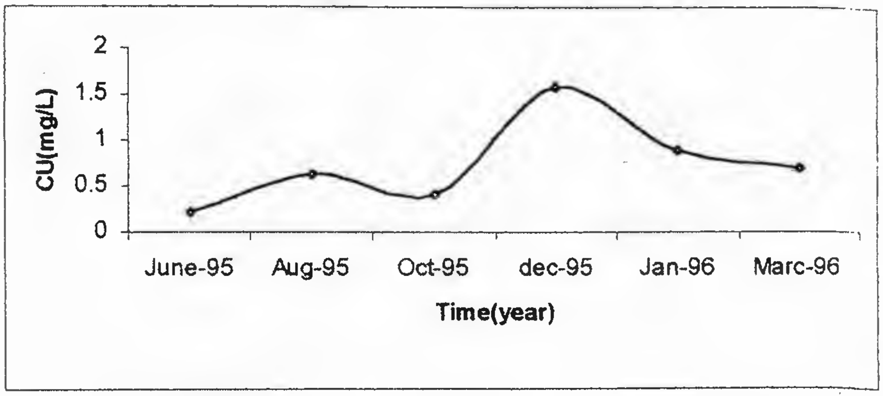

Figure 5.8 Fluctuation of Copper in the Reservoir recharge.

5.2.3 Chlorine Concentration for Gemikonagi Dam.

The chlorine observation is carried at reservoir, bottom discharge and recharge location. Discharge and recharge points are only analyzed during 1995 and 1996. The analyzes for these periods deduce that the chlorine concentration decreases during the summer months and increases as soon as the winter approaches. This may be due to surface runoff effect at winter months. As an overall estimation of reservoir the chlorine concentration is always bellow the admissible concentration. Where in 1998 180mg/L is observed in the reservoir. As shown in Figure 5.9, the average quantity of Chlorine has decreased throughout the years 1994-2002 till it reached the average quantity of 65.11 mg/L, which is considered safe according to the European Standards. It is obvious that the average of chlorine in the year 1994 was equal to 61.24 mg/L, where in 1995 the average quantity was 68.8 mg/L, in the years 1996-1998 was 117 mg/L and in the years 1999-2002 was 65.11 mg/L. The maximum and the minimum concentration values for Chlorine was occurred in April 1998 are 170 and in December 1994 are 39.1. The amount of chlorine's has decreased during the years 1994-1996 the average of chlorine in these years was 56 mg/L as shown in Figure 5.15. In these years the water was safe in relation to chlorine's rate. The maximum and the minimum concentration values for Chlorine was occurred in January 1996 are 64 and in January 1994 are 45. The amount of chlorine has decreased during the years 1995-1996 as shown in Figure 5.11. In these years the water was safe in relation to chlorine's rate. The maximum and the minimum concentration values for Chlorine was occurred in august 1995 are 53.3 and in December 1995 are 46.

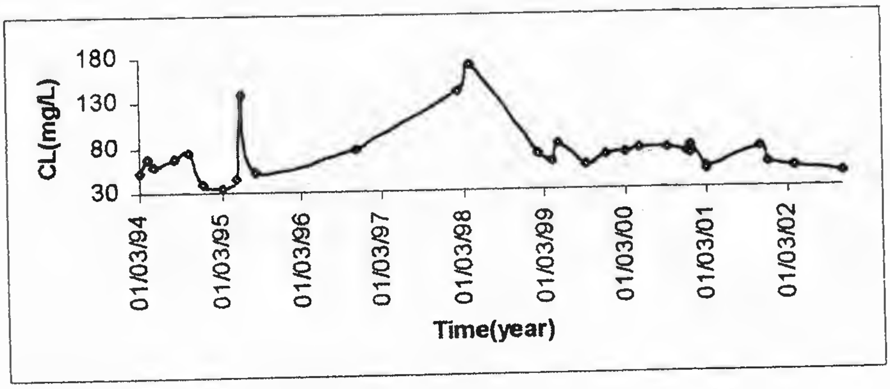

Figure 5.9 Fluctuation of Chlorine in the Reservoir.

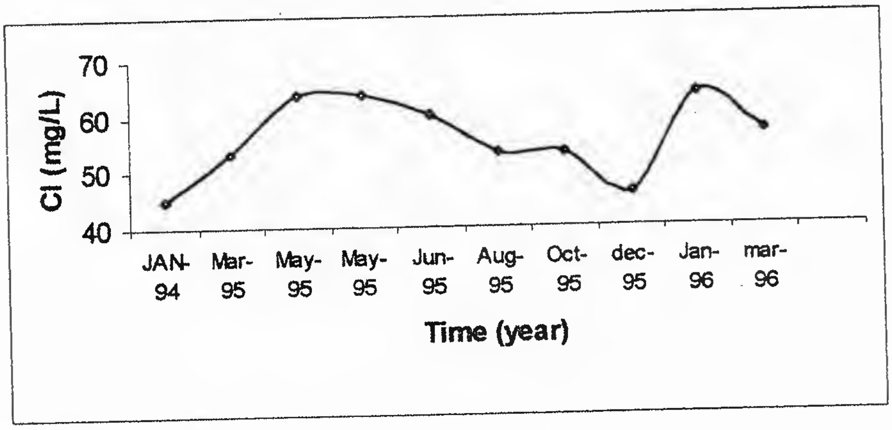

Figure 5.10 Fluctuation of Chlorine in the Bottom discharge.

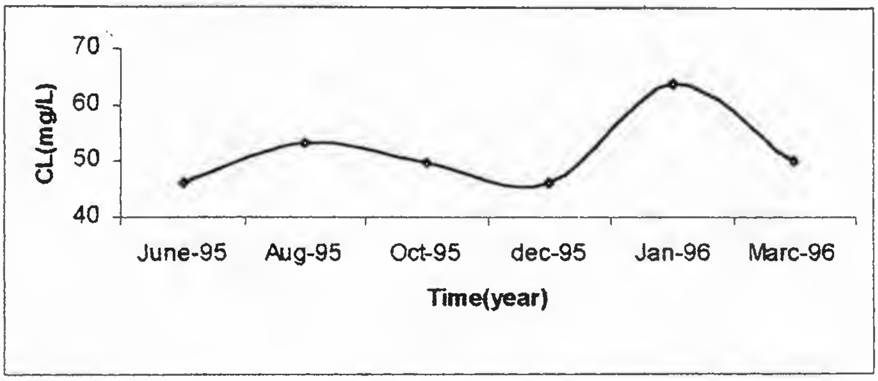

Figure 5.11 Fluctuation of Chlorine in the Reservoir recharge

5.2.4 Sulphate Concentration for Gemikonagi Dam.

The sulphate concentration is declining as the year's passes from 1994 to 2002.Especial in 1998 a sleep decrease can easily observe. The sulphate concentration in August 1995 show that while the discharging water involves 500 mg/L sulphate concentration, approximately 180 mg/L IS recharging to the reservoir. From that period while the recharge concentration increases the discharge continues to decline. The result depicts that while in summer period the recharge concentration is low, by the coming autumn and winter the concentration increases. The amount of SO_4 has increased during the years 1994and 1995 but in the years 2000- 2001 has decreased as shown in Figure 5.12. If the average values are compared, from 1994-1995 the average amount of sulphate was 247.83 mg/L, however, from 1996-1998 the average amount was 389.5 mg/L. The average amount of sulphate in 1999-2002 was 69.2 mg/L. During the period 1994-1998 the water was not safe, however, in the period 1999-2001 SO4 rate was safe. The maximum and the minimum concentration values for SO_4 was occurred in June 1995 are 716.6 and in December 1994 are 38.6. The amount of SO_4 has decreased during the years 1994-1997 as show in Figure 5.13. If the average values are compared, from 1994-1995 the average amount of sulphate was 523.75mg/L, however, from 1996 the average amount was 336.5 mg/L. The average amount of sulphate in 1997 was 224.5 mg/L in these years the water was not safe relation to SO_4 rate. The maximum and the minimum concentration values for SO_4 were occurred in May 1995 are 883.2 and in February 1997 are 438. The amount of SO_4 has decreased during the years 1995-1996 as shown in Figure 5.14. In these years the water was safe in relation to SO_4 rate. The maximum and the minimum concentration values for SO_4 was occurred in December 1995 are 332 and in August 1995 are 187.8. The reason for high concentration of sulphate is silica in the basin and can be fined in drained from saline soils.

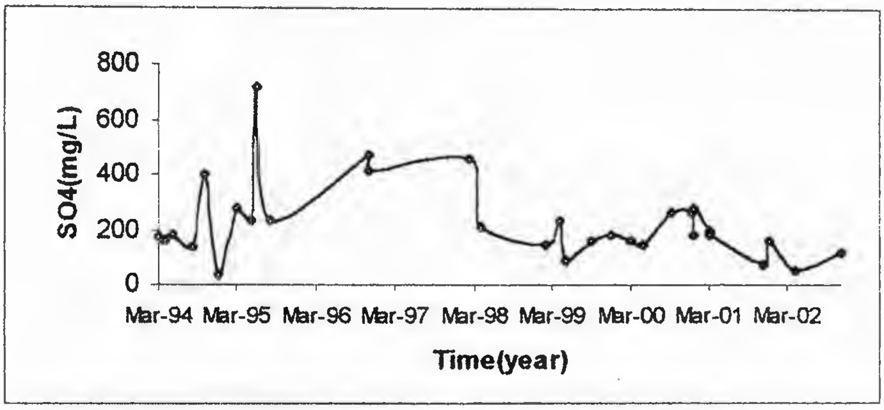

Figure 5.12 Fluctuation of SO_4 in the Reservoir.

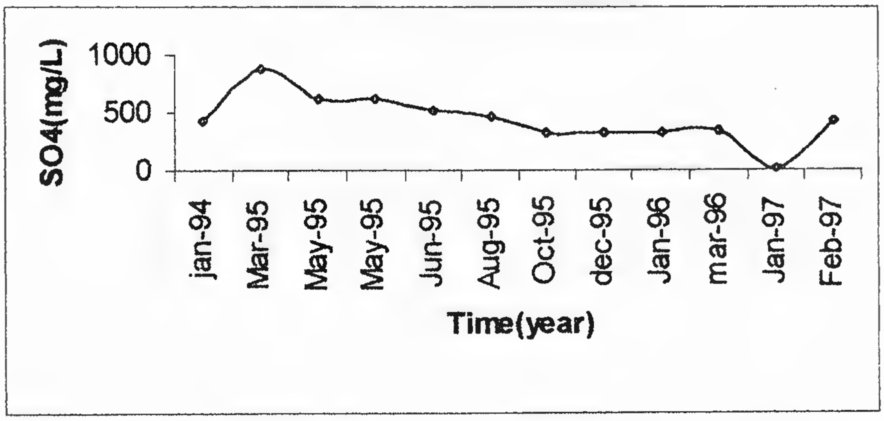

Figure 5.13 Fluctuation of SO_4 in the Bottom discharge.

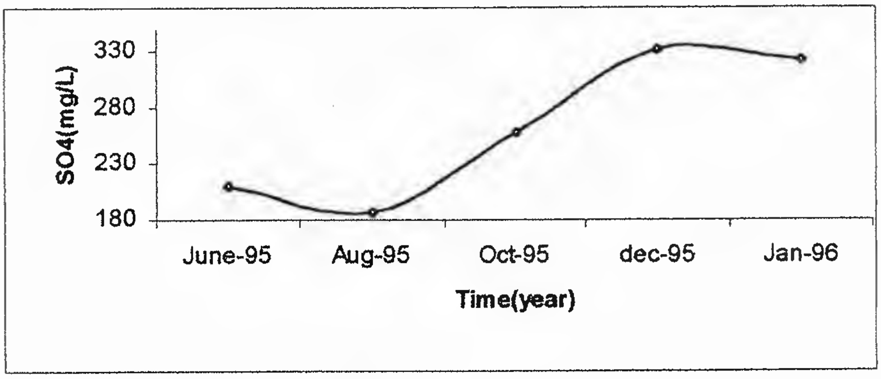

Figure 5.14 Fluctuation of SO_4 in the Reservoir recharge.

5.2.5 Sodium Concentration for Gemikonagi Dam.

Sodium concentrations are generally for below the maximum admissible concentrations. In 1995 as it happen to all the other elements the concentration of sodium reaches to its maximum concentrations so far the concentrations are between 40-50 mg/L per year with small fluctuation and no declining effect. From the graph plotted below, in 1994 the average quantity of Sodium was 36.6 mg/L, which are considered safe. The amount of Sodium has increased during the years 1994-1995, but in the years2000-2002 it has decreased as shown in Figure (5.15). The water was safe during the period 1999-2002 in relation to the Sodium's rate. The maximum and the minimum concentration values for Sodium was occurred in June 1995 are 106 and in May 1999 are 20. The amount of manganese has increased during the years 1994-2001 as shown in Figure 5.16. In these years the water was not safe in relation to manganese's rate. The maximum and the minimum concentration values for Sodium was occurred in January 1997 are 60 and in May 1995 are 26. The amount of Sodium has decreased during the years 1995-1996 as shown in Figure 5.17. In these years the water was safe in relation to Sodium's rate. The maximum and the minimum concentration values for Sodium was occurred in December 1995 are 35 and in March 1996 are 26. The reason for high concentration of Sodium is silicate and clays in the basin.

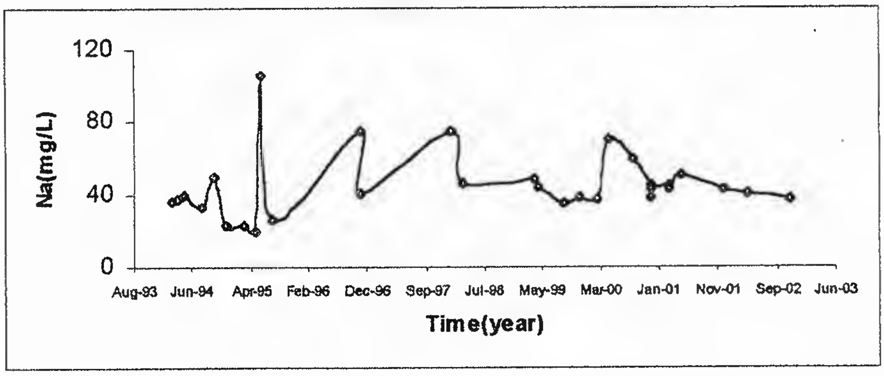

Figure 5.15 Fluctuation of Sodium in the reservoir.

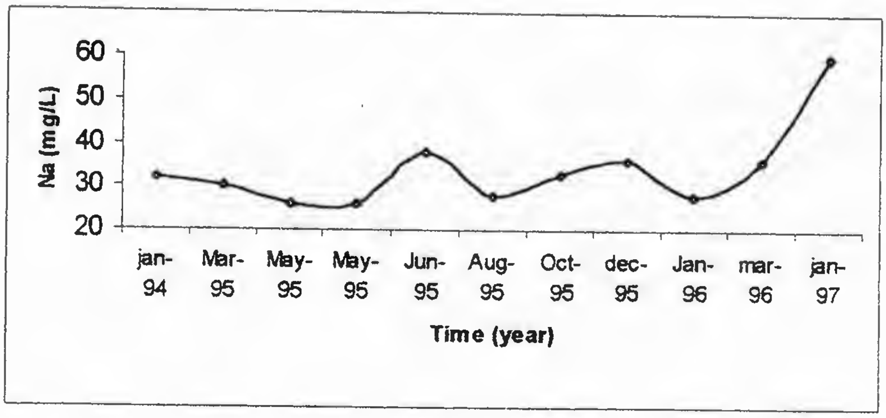

Figure 5.16 Fluctuation of Sodium in the Bottom discharge

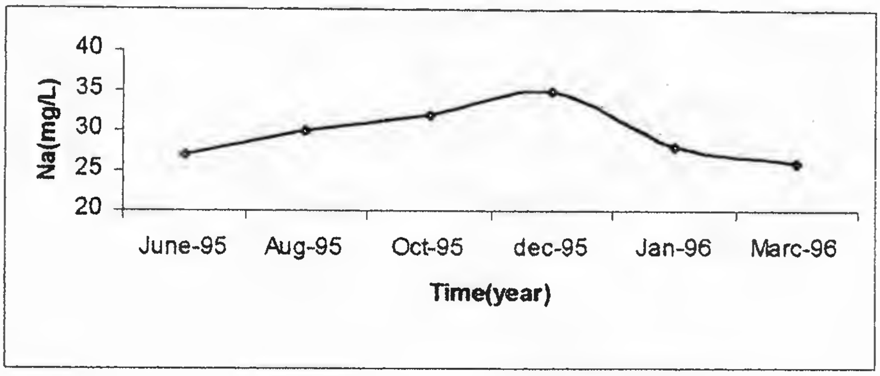

Figure 5.17 Fluctuation of Sodium in the Reservoir recharge

5.2.6 Magnesium concentration for Gemikonagi Dam

According to the European standards the maximum admissible concentration for drinking quality permits 50mg/L magnesium concentration at reservoir feed point it can be observed that within one month the magnesium concentration has increased from 50 to 250 mg/L which can not be explained unless there were a high dense precipitation at the region such that magnesium involved in the surrounding rocks has eroded to the region. Unfortunately, no data is available for the reservoir recharge area for 1997 period. For the year 1995 the data surveyed has given a constant input into the reservoir, approximately 40-45 mg/L. the reservoir data has shown that this data has already declined since 1999 such that the available concentrations 20-30 mg/L. From the graph 5.18 it's clear that the amount of Magnesium has increased during the years 1994-1998 and has decreased from the years 1998-2002. During the period 1994-1998 the water was not safe, but in the period 1998-2002 it was safe in relation to magnesium's rate.

The maximum and the minimum concentration values for Magnesium was occurred in February 1998 are 104 and in November 2001 are 4.9. The amount of magnesium's has decreased during the years 1994-1997 as shown in Figure 5.19. In these years the water was safe in relation to Magnesium rate. The maximum and the minimum concentration values for Magnesium was occurred in March 1995 are 257.6 and in October 1995 are 44.6. The amount of Manganese has increased during the year 1997 as shown in Figure 5.20 in this year the water was not safe in relation to Manganese's rate. The maximum and the minimum concentration values for Manganese were occurred in May 1997 are 268.6 and in April 1997 are 48.8. The amount of Magnesium has decreased during the years 1995-1996 as shown in Figure (5.21) in these years the water was safe in relation to Magnesium's rate. The maximum and the minimum concentration values for Magnesium was occurred in June 1996 are 51 and in August 95 are 40.7. The reason for high concentration of Magnesium is silicate and oxide clays in the basin.

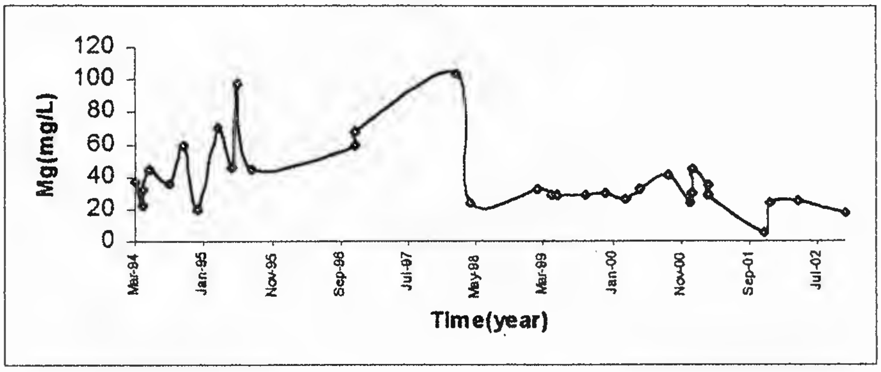

Figure 5.18 Fluctuation of Magnesium in the reservoir.

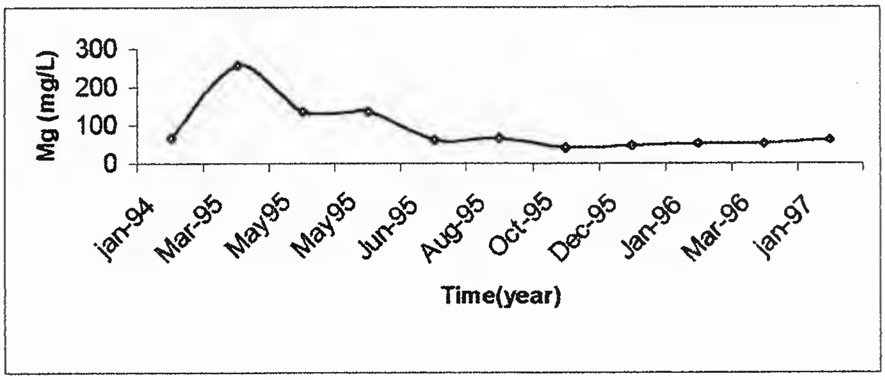

Figure 5.19 Fluctuation of Magnesium in the Bottom discharge

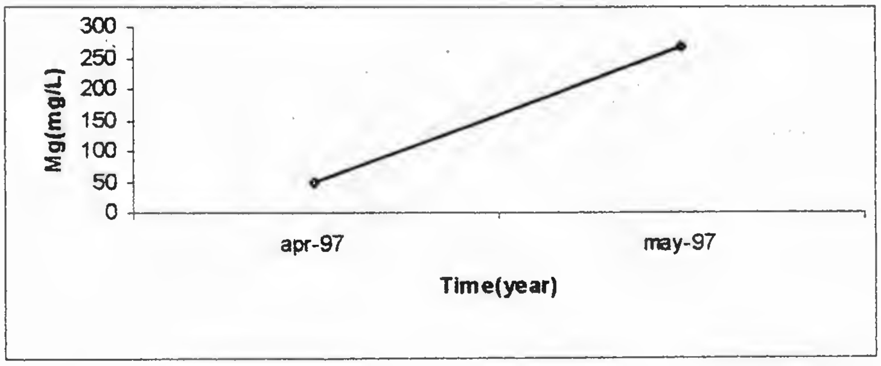

Figure 5.20 Fluctuation of Magnesium in the Reservoir feed point

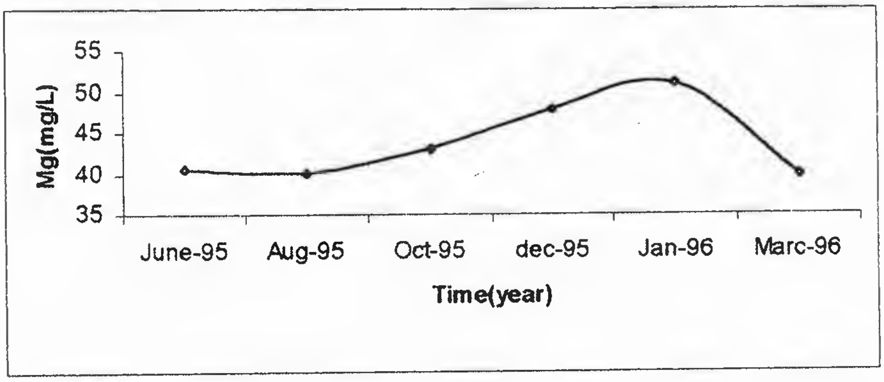

Figure 5.21 Fluctuation of Magnesium in the Reservoir recharge

5.2.7 Potassium Concentration for Gemikonagi Dam

Since Potassium has nothing to do with the environmental surrounding. The water itself is carrying the normal concentrations that should be. Although in 1994 the Potassium reaches to its optimum concentration, it is still not above the admissible values. Therefore, for the potassium point of view, reservoir, bottom discharge and recharge are all safe. It's clear as shown in Figure 5.22 the amount of Potassium has increased during the years 1994-1995 and has decreased from the years 1998-2002. In the period 1994-2002 the water was safe in relation to Potassium's rate. The maximum and the minimum concentration values for aluminum was occurred in November 2001 are 2 and in April 1994 are 0.1. The amount of Potassium has decreased during the years 1994-1997 as shown in Figure 5.23. In these years the water was safe in relation to Potassium's rate. The maximum and the minimum concentration values for Potassium were occurred in Jane 1997 are 2 and in May 1995 are 0.5. The amount of Potassium has decreased during the years 1995-1996 as shown in Figure 5.24 in these years the water was safe in relation to Potassium's rate. The maximum and the minimum concentration values for Potassium was occurred in June 1996 are 0.6 and in March 1996 is 1.2. The reason for high concentration of potassium is silicate clays in the basin.

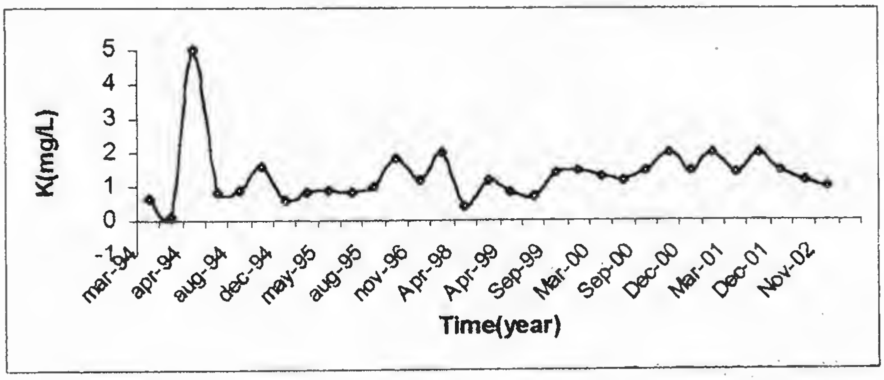

Figure 5.22 Fluctuation of Potassium in the reservoir.

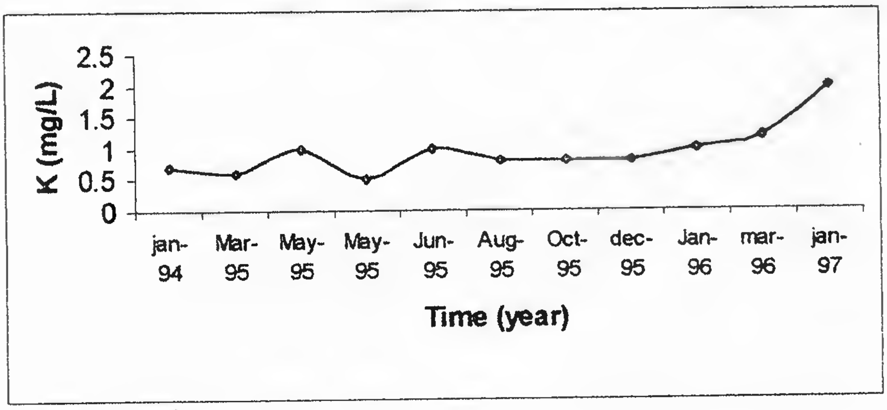

Figure 5.23 Fluctuation of Potassium in the Bottom discharge.

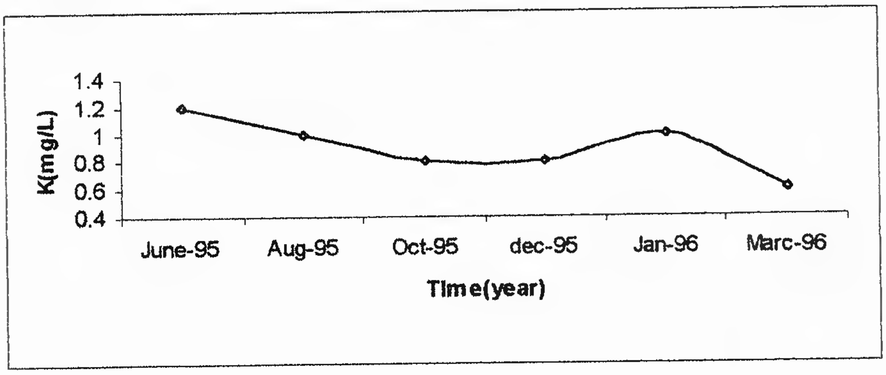

Figure 5.24 Fluctuation of Potassium in the Reservoir recharge.

5.2.8 Hardness Concentration for Gemikonagi Dam

CaCO3 concentrations are varying as the years passes. The available data is only belongs to reservoir point. Although the concentrations are six times greater than the admissible concentration values in 1998, it declining rapidly by the end of 1999. Later on, the fluctuations between 250-350 mg/L can be observed. In 2002 the concentration decreases up to 160mg/L which it still approximately three times bigger than the admissible concentration values. Somehow the decline of concentration is surprising since no precautions are taken such as preventing the erosion of clayey soil into water. The Hardness has increased during the years 1994-1998 but in the years 1999- 2002 it has decreased as shown in Figure 5.25. In the period 1994-1998 the water was not safe in relation to hardness's rate. The maximum and the minimum concentration values for Hardness was occurred in February 1998 are 600 and in November 2002) are 170. The reason for high concentration of hardness is limestone in the basin.

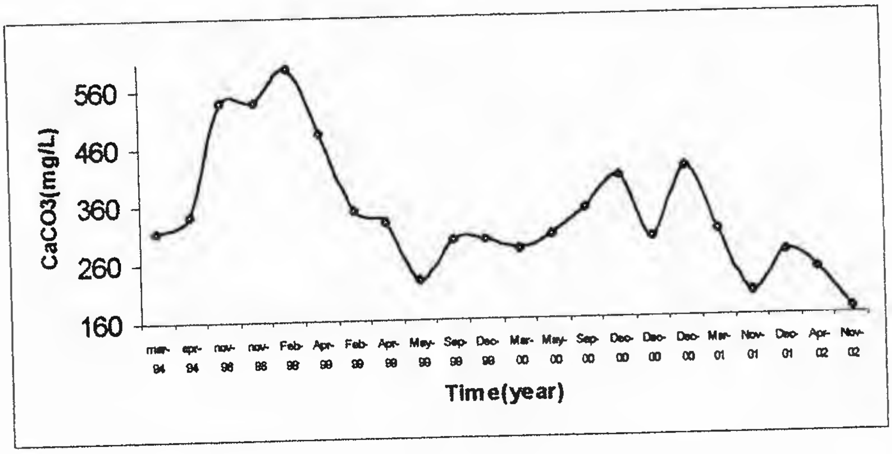

Figure 5.25 Fluctuation of Hardness in the reservoir.

5.2.9 Iron Concentration for Gemikonagi Dam.

In 1995 the recharge and discharge values of iron are nearly balancing each other. Later on, the data available are not represented well. The reason is that during 1997 and 2000 the concentration at reservoir feed point is around 0.3 mg/L where it is 2 mg/L at bottom discharge. There fore the data available seems to not reflect the accurate data at the field. However, it is also clear that all the data observed at above the admissible values. From the chart plotted above it is obvious that the amount of iron has increased during the years 1994-1999 but in the years 2000- 2001 it has decreased as shown in

Figure 5.26. In the period 1994-2001 the water was not safe in relation to iron's rate. The maximum and the minimum concentration values for Iron was occurred in August 1994 are 0.9 and in March 1994 are 0.0432. The amount of irons has decreases during the years 1994-1999 as shown in Figure 5.27. In these years the water was not safe in relation to iron's rate. The maximum and the minimum concentration values for Iron was occurred in March 1999 are 3.479 and in June 1999 are 0.0871. It's clear as shown in Figure 5.28 that the amount of Iron has increased during the years 1997-1999 and decreased from 2000 -2002,mentioning that the water was not safe during the period 1997-1998 and during 1999-2001, but in 2001-2002 Iron's rate was safe in relation to copper's rate. The maximum and the minimum concentration values for Iron was occurred in February 1997 are 2.402 and in March 1999 are 0.0115. The amount of Iron has decreased during the years 1995-1996 as shown in Figure 5.2. In these years the water was not safe in relation to iron's rate. The maximum and the minimum concentration values for Iron was occurred in Jane 1996 are 0.9 and in March 1996 are 0.1. The reason for high concentration of iron is silicate and oxide clays in the basin.

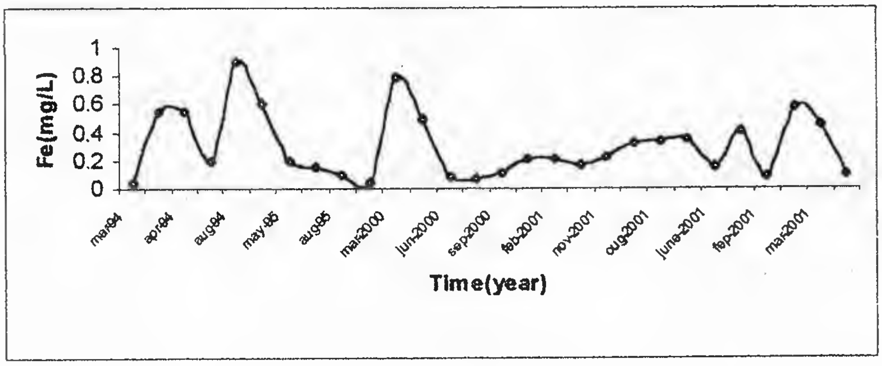

Figure 5.26 Fluctuation of Iron in the Reservoir

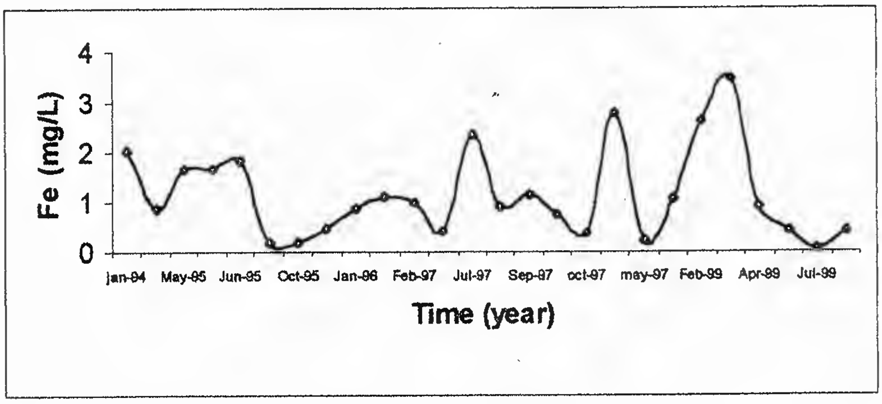

Figure 5.27 Fluctuation of Iron in the Bottom discharge

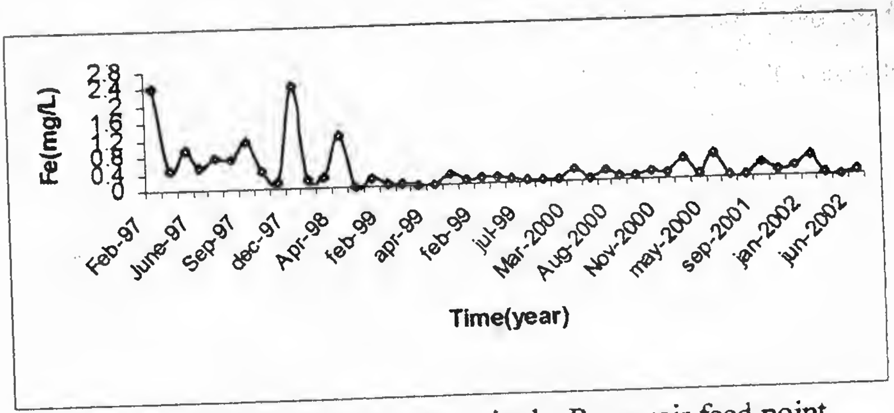

Figure 5.28 Fluctuation of Iron in the Reservoir feed point

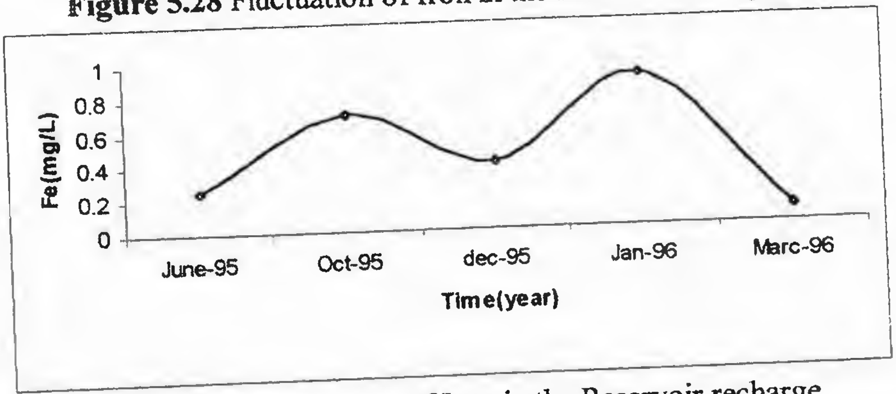

Figure 5.29 Fluctuation of Iron in the Reservoir recharge

5.2.10 Calcium concentration for Gemikonagi Dam

Except in 1995 actually the calcium concentration is around the limits of the European standards. It is interesting to note that while in 1995 the concentration of the calcium reach's to 185 mg/L; at the same period it reaches to it are minimum values at the bottom discharge. Also at the same period the recharge into reservoir fluctuates around 70-90 mg/L. Therefore, in the vicinity of these results it can be said that a professional survey should be cared to the region for better analyzes. The amount of calcium is increased during the years 1994-1998 but in the years 1999- 2002 has decreased as shown in Figure 5.30. In the period 1994-2002 the water was safe in relation to Calcium's rate. The maximum and the minimum concentration values for Calcium was occurred in April1998 are 152 and in May 1995 are 33.6. The amount of calcium's has decreased during the years 1994-1997 as shown in Figure 5.31. In these years the water was safe in relation to calcium's rate. The maximum and the minimum concentration values for Calcium was occurred in March 1995 are 116.8 and in May 1995 are 56. The amount of Calcium has decreased during the years 1995-1996 as shown in Figure 5.32. In these years the water was safe in relation to calcium's rate. The maximum and the minimum concentration values for Calcium was occurred in January 1996 are 94 and in June 1995 are 37.6. The reason for high concentration of calcium is limestone in the basin.

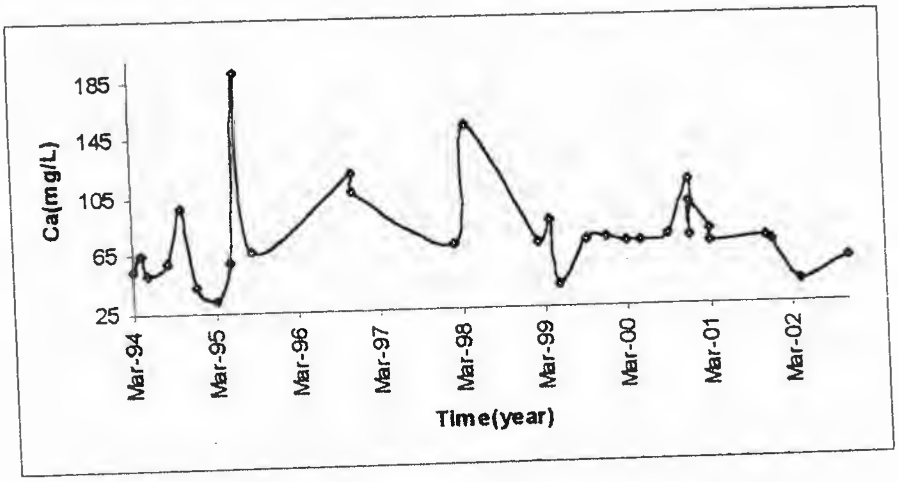

Figure 5.30 Fluctuation of Calcium in the reservoir.

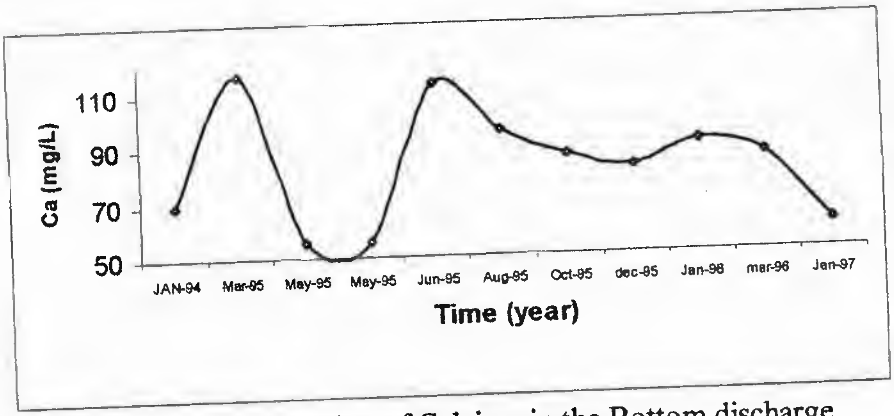

Figure 5.31 Fluctuation of Calcium in the Bottom discharge.

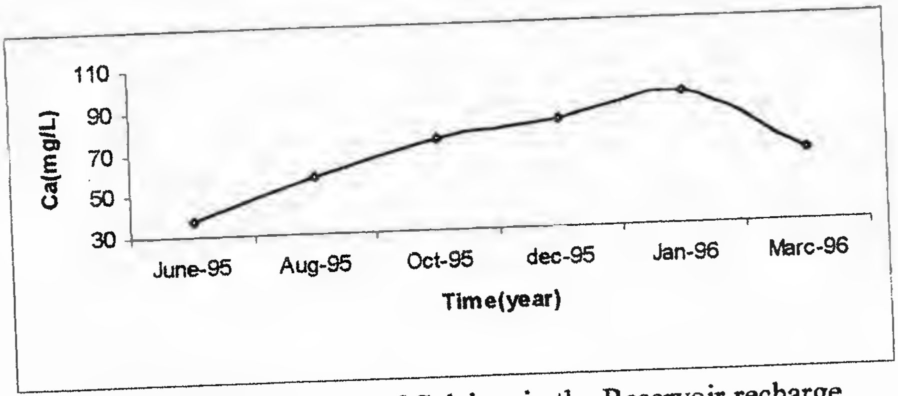

Figure 5.32 Fluctuation of Calcium in the Reservoir recharge.

5.2.11 Zinc Concentration for Gemikonagi Dam

Only a small survey is carried out zinc concentration. However, this is not enough to survey the rest concentrations. According to available the zinc concentration is above the admissible limits. The amount of zinc has decreased during the year 1994 as shown in Figure 5.11. In this year the water was not safe, relation to zinc's rate. The maximum and the minimum concentration values for Zinc was occurred in March 1994 are 0.68 and in April 1994 are 0.4. Zinc is found in some natural waters, particularly in areas where these ore deposits have been mined, so the reason of high concentration of zinc because there are too much mined in Xeros basin.

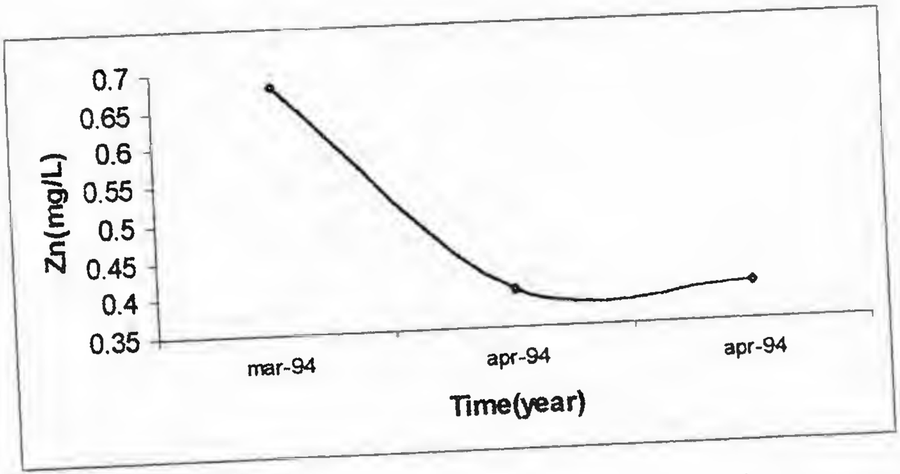

Figure 5.33 Fluctuation of Zinc in the reservoir.

5.2.12 pH Concentration for Gemikonagi Dam

The acidity of the alkalinity of the region is directly related with ph values. Within the years 1994 and 2001 the pH value at the reservoir seems to be around 7. This means neutral conditions. However, the measurements that were carried in Jan 1994 to August 1995 has shown acidic solutions in water at the bottom discharge, which is than recovered to neutral position. The recharge point at the same period declines from 8.1 to 6.7 but not less than that. Overall, since the variations are between 6.5 and 8.5, the water is safe. The amount of pH has decreased during the years 1994-2001 as shown in Figure 5.34 during these years the water was safe, in relation to pH rate. The maximum and the minimum concentration values for pH was occurred in August 1994 are 8.3 and in April 1998 are 6.8. It's clear as shown in Figure 5.35 that the amount of pH was less than 5.5 mg/L during the years 1994-1995 and more than 5.5 mg/L during the period

2000-2002. In the period 1994-1995 the water was not safe, but in the period 1999-2002 pH rate was safe in relation to pH rate. The maximum and the minimum concentration values for pH was occurred in Jane 1997 are 8 and in March 94 are 4.3. The amount of pH has decreased during the years 1995-1996 as shown in figure 5.36. In these years the water was safe in relation to pH rate. The maximum and the minimum concentration values for pH was occurred in June 1995 are 8.1 and in March 1996 are 6.7. The reason of high concentration of pH because the high concentration of H^+.

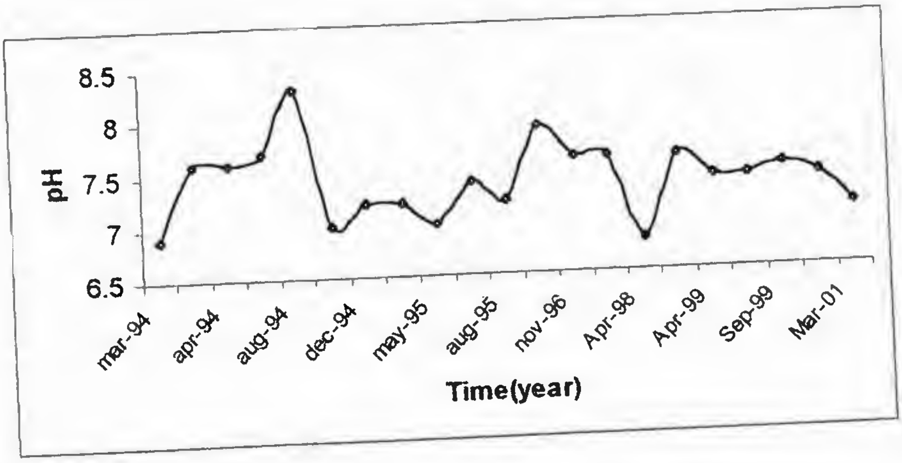

Figure 5.34 Fluctuation of pH in the Reservoir

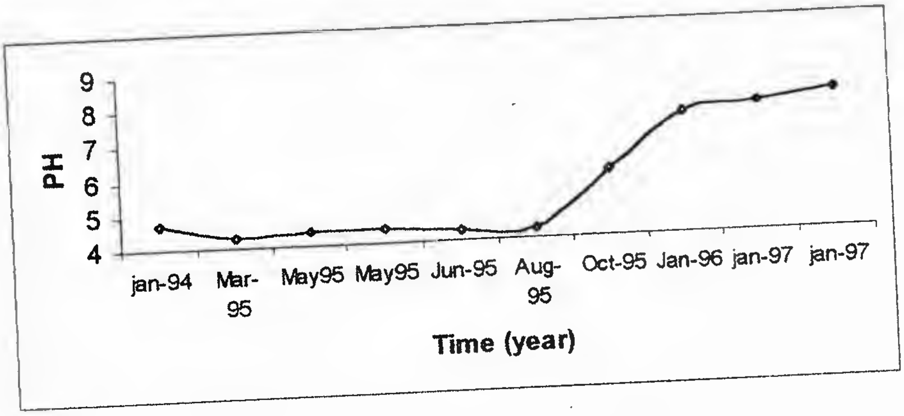

Figure 5.35 Fluctuation of pH in the Bottom discharge

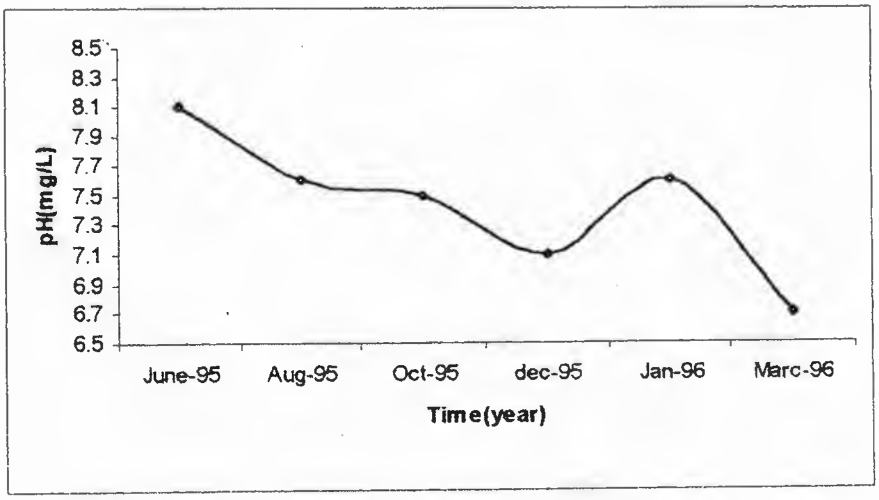

Figure 5.36 Fluctuation of pH in the Reservoir recharge

5.2.13 Manganese Concentration for Gemikonagi Dam

The concentration of manganese is always greater than the admissible values. In 1995 while it is around 2.5-3 mg/L at reservoir and reservoir recharge point, the concentration at the bottom discharge is around 6.5-7 mg/L. This data does not obey to input-output theory or continuity theory of the physical. However since manganese is metal, along period of settlement might innovate the concentration at the bottom. For the incoming years the concentration is around 0.5-1 mg/L, which is still not safe enough. The amount of manganese has decreased during the years 1994-2001 as shown in Figure 5.37. In these years the water was not safe in relation to manganese's rate. The maximum and the minimum concentration values for Manganese was occurred in May 1995 are 2.5 and in September 2001 are 0.038. The amount of manganese has decreased during the years 1994-1999 as shown in Figure 5.38. In these years the water was not safe in relation to manganese's rate. The maximum and the minimum concentration values for manganese was occurred in May 1998 are 6.1 and in June 1995 are 0.011. The amount of Magnesium has decreased during the years 1997-2002 as shown in Figure 5.39. In these years the water was not safe in relation to magnesium's rate. The maximum and the minimum concentration values for Magnesium was occurred in February 1997 are 3.529 and in June 2002 are 0.0122. The amount of Manganese has decreased during the years 1995-1996 as shown in Figure 5.40. In these years the water was not safe in relation to Manganese's rate. The maximum and the minimum concentration values for Manganese was occurred in Jane 1996 are 3.45 and in August

1995 are 0.035. The reason for high concentration of Manganese is the clays in the basin.

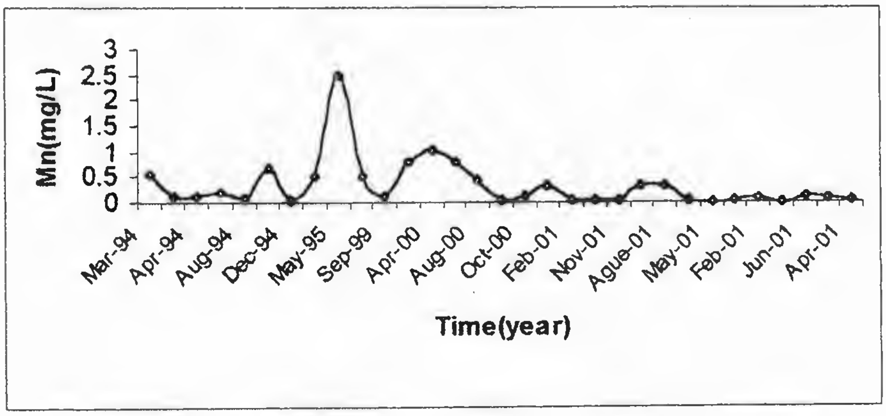

Figure 5.37 Fluctuation of Manganese in the Reservoir

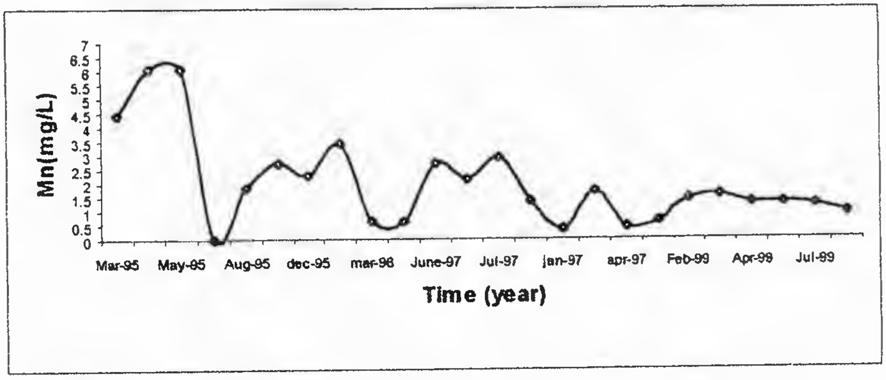

Figure 5.38 Fluctuation of Manganese in the Bottom discharge

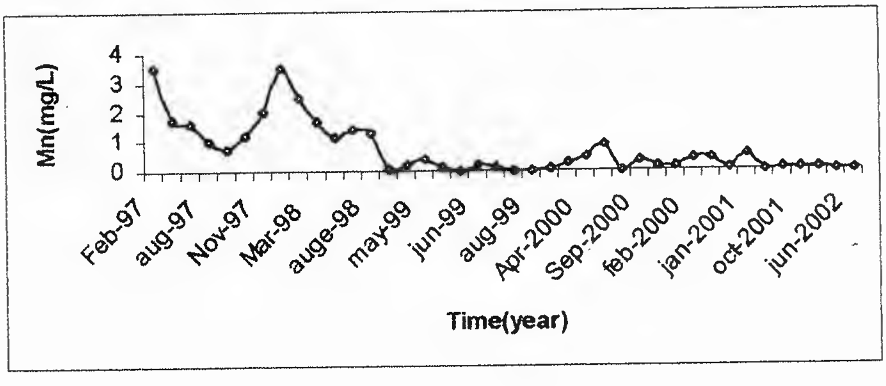

Figure 5.39 Fluctuation of Manganese in the Reservoir feed point

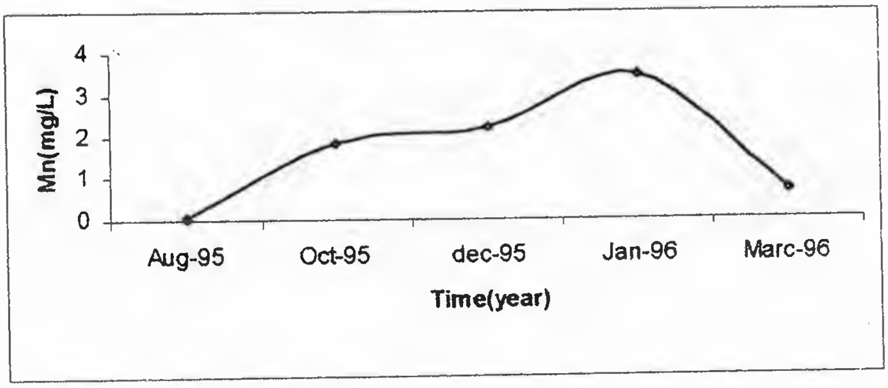

Figure 5.40 Fluctuation of Manganese in the Reservoir recharge

As obviously seen from the charts, it was concluded that there was an improvement in the quality of water but some elements are less than the required amount, in other words, their concentrations are greater than the maximum admissible concentration.

5.3 The Water Quality for Irrigation

The Gemikonagi reservoir is already been under observation since 1994. All the data that has been sampled since then is analyzed and the water quality for irrigation are mapped. There are four main points where these samples data are collected. They are reservoir, reservoir recharge, bottom discharge and reservoir feed point .The quality of sample is compared with water quality for irrigation as shown in Table (3.2).

Table 5.2 The Quality of Water in Gemikonagi Reservoir According to Table (3.2).

Location	Parameter	Date	Concentration mg/L	Maximum admissible concentration	Result
Reservoir	Cl	1994-1995	64	100mg/L	Safe
		1996-1998	117		Not safe
		1999-2002	65.11		Safe
	SO_4	1994-1995	246.5	250mg/L	Safe
		1996-1998	389.5		Not Safe
		1999-2002	69.2		Safe
	$CaCO_3$	1994-1996	434.75	121-180	Not Safe
		1998-1999	370.7		Not Safe
		2000-2001	351.56		Not Safe
		2001	260		Not Safe
		2002	205		Not Safe
	Fe	1994-1995	0.37	0.3	Not Safe
		1999-2000	0.26		Safe
		2001	0.283		Safe
	pH	1999-2001	7.4	$6<pH<8.5$	Safe
	Mn	1994-1995	0.533	0.3 µg/L	Not Safe
		1999	0.1285		Safe
		2000	0.54		Not Safe

Table (5.2) Continue

Location	**Parameters**	**Date**	**Concentration mg/L**	**Maximum admissible concentration**	**Result**
Reservoir recharge	pH	1995-1996	7.43	6<pH<8.5	Safe
	Fe	1995-1996	0.47	0.3mg/L	Not Safe
	Mn	1995-1996	1.65	0.3mg/L	Safe
	Cl	1995-1996	51.5	100mg/L	Safe
	SO_4	1995-1996	261.4	250mg/L	Not Safe
Bottom discharge	pH	1994-1995	4.614	6<pH<8.5	Not Safe
		1996	7.5		Safe
		1997	7.85		Safe
	SO_4	1994-1995	523.75	250mg/L	Not Safe
		1996	336.5		Not safe
		1997	224.5		Safe
	Mn	1995	3.36	0.3mg/L	Not Safe
		1996-1997	1.54		Not Safe
		1999	1.27		Not Safe
	Cl	1994-1996	56	100mg/L	Safe
	Fe	1994-1995	1.4	0.3mg/L	Not Safe
		1996-1997	1.1		Not Safe
		1999	1.34		Not Safe
Reservoir feed point	Mn	1997	1.94	0.3mg/L	Not Safe
		1998-1999	0.62		Not Safe
		2000-2002	0.138		Safe
	Fe	1997	0.993	0.3mg/L	Not Safe
		1998-2000	0.189		Safe
		2001-2002	0.171		Safe

Throughout the years between 1994 and 2002, it figured out that the water quality improved as shown in the Table (5.2). Although this improvement encourages future irrigation demands it is still not suitable for irrigation. This result is based on the concentration of CaCO3 and SO4, which are still more than the maximum admissible concentration.

5.4 SAR Estimation

One of the techniques used to examine the quality of water for irrigation is by using SAR equation. This equation depends mainly on the concentrations of three parameters; they are respectively, Sodium, Magnesium and Calcium this equation is applied to two locations, which are reservoir, bottom discharge.

5.4.1 SAR in the Reservoir

To chick if the water is suitable in the bottom discharge by using SAR equation during the period 1994-2002.

SAR from1994-2002 by:

$$\text{SAR}=\frac{Na^{+}}{\sqrt{\frac{Ca^{++}+Mg^{++}}{2}}} \tag{5.1}$$

Table 5.3 The SAR Value For The Reservoir 1994.

Date	Na	Mg	Ca
1994	36.1	37.2	53.9
	37.8	21.7	65.9
	37.8	31.7	52.2
	40	45	60
	32.5	36	98.4
	49	59.3	43.2
	23	20.1	
Total	256.2	251	373.6

$$\text{SAR}=\frac{256.2}{\sqrt{\frac{251+373.6}{2}}}=14.4975 \tag{5.2}$$

As in the equation (5.2) SAR value is greater than 10 so it will break down the physical structure of the soil caused by excessive amount of colloidally absorbed sodium. As a result the soil becomes hard and compact when dry. So it would not be suitable for irrigation.

Table 5.4 The SAR Value For The Reservoir 1995.

Date	Na	Mg	Ca
1995	23	70.1	33.6
	20	46.1	60
	106	89	192
	26	45.1	66.4
Total	175	259.3	352

$$SAR=\frac{175}{\sqrt{\frac{259.3+352}{2}}}=10 \qquad (5.3)$$

According to equation (5.3) SAR value in 1995 is equal 10 so it will break down the physical structure of the soil.

Table 5.5 The SAR Value For The Reservoir 1996.

Date	Na	Mg	Ca
1996	75	95	120
	41	68	107
Total	116	127	227

$$SAR=\frac{116}{\sqrt{\frac{127+227}{2}}}=8.72 \qquad (5.4)$$

As in the equation 5.4 during 1996 SAR is suitable for the irrigation.

Table 5.6 The SAR Value For The Reservoir 1998.

Date	Na	Mg	Ca
1998	75	104	70
	46	23	152
Total	121	127	222

$$SAR=\frac{121}{\sqrt{\frac{127+222}{2}}}=9.16 \qquad (5.5)$$

According to equation 5.4 during 1998 SAR is suitable for the irrigation because SAR equal 9.16, which it is less than 10.

Table 5.7 The SAR Value for the Reservoir 1999

Date	Na	Mg	Ca
1999	28	23.3	70
	48	28.9	85
	44	29	40
	35	29	71
	38	29.4	72
Total	314	148.6	338

$$SAR=\frac{314}{\sqrt{\frac{48.6+338}{2}}}=22.6 \qquad (5.6)$$

As it clear in equation (5.6) SAR is greater than 10 it mean the water not suitable for irrigation during the year 1999.

Table 5.8 The SAR Value For The Reservoir 2000.

Date	Na	Mg	Ca
2000	37	26	70
	70	32	70
	60	41.16	74.4
	45	23.4	112
	38	30	72
	43	44	96
Total	293	196.56	494.4

$$SAR=\frac{293}{\sqrt{\frac{196.56+494.4}{2}}}=15.76 \qquad (5.7)$$

In the year 2000 according to equation (5.7) SAR value is greater than 10 so it means the water in that time is not suitable for irrigation.

Table 5.9 The SAR Value For The Reservoir 2001.

Date	Na	Mg	Ca
2001	45	34.3	76.2
	43	28	68
	51	4.9	71.2
	43	24	68
Total	182	91.2	283.4

$$SAR=\frac{182}{\sqrt{\frac{91.2+283.4}{2}}}=13.3 \qquad (5.8)$$

It is obvious that the water is not suitable for irrigation in 2001 because SAR is greater than 10.

Table 5.10 The SAR Value For The Reservoir 2002.

Date	Na	Mg	Ca
2002	41	24.5	40.8
	37.2	17.5	56.2
Total	87.2	42	97

$$SAR=\frac{87.2}{\sqrt{\frac{42+97}{2}}}=10.46 \qquad (5.9)$$

It is obviously according to the result of Equation (5.9) during the year 2002 the water not suitable for irrigation.

Finally, it is obvious that in the reservoir the water is not suitable for irrigation according to SAR equation because the value is greater than 10. It will break down the physical structure of the soil caused by excessive amount of colloidally absorbed sodium. As a result the soil becomes hard and compact when dry. So it would not be suitable for irrigation.

5.4.2 SAR in the Bottom Discharge

To chick if the water is suitable in the bottom discharge by using SAR equation during the period 1994-1997.

Table 5.11 The SAR Value for the Bottom Discharge 1994.

Date	Na	Mg	Ca
1994	32	66	70
Total	32	66	70

$$SAR=\frac{32}{\sqrt{\frac{66+70}{2}}}=3.8 \qquad (5.10)$$

According to this calculation in 1994 the water is suitable is suitable for irrigation.

Table 5.12 The SAR Value for Bottom Discharge1995.

Date	Na	Mg	Ca
1995	30	257.6	116.8
	26	137.2	56
	26	137.2	56
	38	65.7	113.6
	28	67.1	96
	33	44.6	86.4
	36	48	82
Total	217	757.4	606.8

$$SAR=\frac{217}{\sqrt{\frac{757.4+606.8}{2}}}=8.3 \qquad (5.11)$$

Table 5.13 the SAR Value for the Bottom Discharge1996.

Date	Na	Mg	Ca
1996	28	51	91
	36	53	86
Total	64	104	177

$$SAR=\frac{64}{\sqrt{\frac{104+177}{2}}}=4.6 \qquad (5.12)$$

It is obvious that the water also in 1996 is suitable for irrigation according to SAR equation.

Table 5.14 The SAR Value For The Bottom Discharge 1997.

Date	Na	Mg	Ca
1997	60	63	60
Total	60	63	60

$$SAR=\frac{60}{\sqrt{\frac{63+60}{2}}}=7.65 \qquad (5.13)$$

In 1997 the water is suitable to use it for irrigation according to SAR equation.

It is clear in the bottom discharge the water is suitable for drinking according to these calculations. In the reservoir throughout the years between 1994 and 2002, we figured out that the water quality improved as shown before. This fact implies that the water can not be used for irrigation in the current time as we proved it by using SAR equation.

All those estimations related with sodium absorption ratio have shown that the available water is not suitable for irrigation. However, the quality is increasing as the years passes; this may be because of eroding effect of water during surface run-off. Thus, removing the remnants of mining activities.

CONCLUSIONS

In the Lefka area of northern Cyprus, where copper mining and smelting activities have occurred, some heavy metals, such as copper, constitute an important environmental concern [24]. For this reason, the Gemikonagi reservoir was selected to investigate the impacts of mining-related activities in the district. The Gemikonagi reservoir is already been under observation since 1994. All the data that has been sampled since then is analyzed and the water quality are mapped. There are four main points where these sample data are collected. These are reservoir, reservoir recharge, bottom discharge and reservoir feed point. The qualities of sample are compared with EU water directive parameters as shown in Table (3.1).

From Table (5.1) it can be clearly observed that the concentration of Aluminum, Hardness, Iron, Zinc, Manganese and hardness of water are greater than the maximum admissible concentration comparing to Table (3.1). The overall results for the four permeation locations are:

1-At reservoir the concentration of Aluminum, Iron, Zinc, Manganese and Hardness of water are greater than the maximum admissible concentration comparing to Table (3.1).

2-At reservoir recharge region there are also some parameters having their concentrations greater than the maximum admissible concentration. These elements are Aluminum, Iron, Manganese and Copper. Thus, the water is not suitable for drinking according to Table (3.1).

3-At feed point Manganese, Aluminum and Magnesium have their concentrations greater than the maximum admissible concentration.

4-At the bottom discharge it is observed that Magnesium, Sulphates, Manganese, Iron, Copper and Aluminum are overloaded.

To show clearly the quantity of each element in the water and the fluctuation in the water throughout time, charts will be drawn for each element separately for each location.

The graphical representation of each element throughout the years easily defines the changes in concentrations. Therefore, for the four different locations, the changes of concentrations of elements within the water with respect to time are drawn.

As obviously seen from the charts, it was concluded that there was an improvement in the quality of water but some elements are less than the required amount, in other words, their concentrations are greater than the maximum admissible concentration.

Throughout the years between 1994 and 2002, it figured out that the water quality improved. Although this improvement encourages future irrigation demands it is still not suitable for irrigation. This result is based on the concentration of $CaCO_3$ and SO_4, which are still more than the maximum admissible concentration.

One of the techniques used to examine the quality of water for irrigation is by using sodium absorption ratio. This ratio depends mainly on the concentrations of three parameters; they are respectively, Sodium, Magnesium and Calcium.

In the reservoir through the years between 1994and2002, it figured out that the water quality improved as shown before. This fact implies that the water cannot be used for irrigation in the current time as proved it by SAR equation.

The ration is applied to bottom discharge and reservoir. The result show that the sodium absorption ratio is suitable for bottom discharge but unfortunately, it is not suitable for reservoir.

REFERENCE

[1] Ajward, M.H.A. (1996) "Spatially Distributed Unit Hydrograph Model Using A Geographical Information System". Ph .D. diss. Civil Engineering Dept., University of Calgary, Calgary.

[2] Mc Graw. "Hill Series in Water Resource and Environmental Engineering".

[3] Chow, Ven T., (1964) "Runoff", Handbook of Applied Hydrograph, McGraw-Hill book Company, New York.

[4] Vissman, W, and Lewis, GL, (1996)" Introduction to hydrology", Harper Collins college publisher, Fourth Edition.

[5] Gunerman, H., (19975) "Bati Anadolu Akarsularina Mockus Birim Hidrograf metodunun Uygulanmasi". DSI Teknik Bulteni.

[6] Koc,S, (1995) "Sanat Yapilarinin Boyutlandirilmasinda Kullanilan Taskin Yontemleri Ve Uygulamalari". Lecture Note.

[7] M.A. Yukselen,(2002) "Characterization Of Heavy Metal Contaminated Soil In Northern Cyprus"

[8] Macknzie L. Davis David A. Cornwell. "Introduction to Environmental Engineering".

[9] Elizabeth M. Shaw (1994) "Hydrology in Practice". Third Edition.

[10] John W. Clark, Warren Viessman Jr. Mark J. Hammer. "Water supply and pollution Control". Third Edition

[11] Jennifer Leigh Kilgore Virginia Polytechnic Institute and State University. "Development and Evaluation of A Gis-Based Spatially Distributed Unit Hydrograph Model".

[12] Snyder, F.F. 1938. "Synthetic Unit-Graphs. Transactions, American Geophysics Union447-454".

[13] Soil Conservation Service.1972."Hydrology: National Engineering" handbook, Section 4.Washington, D.C. USDA.

[14] R.H. Follett and P.N Soltanpour (1995-2003) "Irrigation water quality criteria" Colorado stat university cooperative Extension.

[15] Hjelmfelt, A.T., and Cassidy, JR.J.J. (1975) "Hydrology for Engineers and Planners low State University Press", First Edition,

[16] Frederick W. Pontius (1990) "Water Quality and Treatment. A Handbook of Community Water Supplies". Fourth Edition.

[17] Davis .Cornwell (1995) "Environmental Engineering".

[18] Brady and Holum(1996) "Chemistry the Study of matter and Its Changes" Second Edition .

[19] Near East University: The Graduate Studies: A complete Reference. First Published 2001.

[20] New EU Chemicals Policy Key Elements of the New Legislation the view of Environmental NGOs Brussels This position paper is available on the Internet at http://www.eeb.org -July 2002.

[21] R.H. Follett and P.N Soltanpour (1995-2003) "Irrigation Water Quality Criteria". Colorado Stat University Cooperative Extension.

[22] Gwicweb data (1998-2003) "Water Quality constituents/ significance".

[23] Turkish Republic of northern Cyprus Water Department, Personal Communication.

[24] C. A. C. Konteatis. (1974) "Dams of Cyprus". Nicosia-Cyprus.