

# Evaluation of Groundwater Resources in Wadi Yalamlam Basin, Makkah Area

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## Introduction

Wadi Yalamlam is one of the undeveloped major wadis in the Makkah area. It is bounded by Latitudes  $20^{\circ} 30'$  and  $21^{\circ} 10' N$  and Longitudes  $39^{\circ} 45'$  and  $40^{\circ} 30' E$ . It lies about 125 km south east of Jeddah, and 70 km south of Makkah city (Figure 1). The wadi drains a wide catchment area of about 1600 km<sup>2</sup>. The catchment area starts from the Red Sea escarpment mountains (Ashafa area) which are characterized by high amount of annual rainfall of more than 200 mm. In addition, it has surface running water for most of the year.

## Previous Studies

Wadi Yalamlam runs through the middle of the Arabian Shield to the Red Sea. A systematic geological mapping survey of the Shield began in late 1950's. Maps with scale of 1:500,000 were completed by the Directed General Mineral Resources of the Ministry of Petroleum and Mineral of Saudi Arabia. In the study area, the only specific detailed geological study was made by Wier and Hadley (1975) as a reconnaissance geology of Wadi Sa'diyah (Yalamlam) quadrangle at 1:100,000 scale.

Since 1970's, a network of climatological and surface runoff stations

has been established for the preliminary assessment of water resources data around the study area. A number of studies had been conducted by various consulting firms working on behalf of the Ministry of Agriculture and Water (MAW) on various aspects of water resources, such as hydrology and agriculture. All of the consulting and academic hydrological and agricultural studies in western Saudi Arabia did not include any initial or preliminary study of Wadi Yalamlam, except the general geologic study.

### Objectives

Wadi Yalamlam has been selected as a potential new fresh water source for the Makkah area. The present study is aimed at evaluating the groundwater resources in this wadi. The major objectives of this research project are summarized in the following points:

1-To assemble and analyze available geological, hydrological, hydrogeological, morphological, climatological and geophysical data concerning the basin of Wadi Yalamlam.

2-To define and map the drainage network of the basin from the morphometrical characteristics.

3-To determine the annual actual groundwater recharge of the basin using the hydrological and Chloride Mass-Balance methods.

4-To determine the geometrical size and physical properties of the groundwater aquifer of the lower third of the basin.

5-To evaluate the water reserve of the basin using the hydrogeological and geophysical information.

6-To offers a complete chemical and biological analysis of surface and groundwater and compare these analyses with national primary drinking water standards.

7-To suggest a network of the water wells to be drilled in specific areas to supply water to Makkah area.

### **Results and Discussions**

The results of this research are summarized as follows:

1-The morphometric study shows that the basin is very elongated, has high relief, and of a moderate drainage density (i.e. 434 meter per square kilometer). It has low stream flow discharge due to surface roughness, and low rainfall intensity in the middle and lower parts of the basin.

2-Yalamlam basin can be divided into three main climate types: 1) the hot desert climate that prevails in the Red Sea coast at Tihamah, 2) the low latitude semi-arid climate that prevails on the Plateau, and 3) the warm temperate rainy climate with dry winters prevails on the Scarp Mountains.

3-Over the study area, rainfall occurs in every season of the year in the mountain area, but varies from year to year. It often occurs as thunderstorms of high intensity during a local storm followed by dry periods. The average annual rainfall exceeds 200 mm. in the mountains and decreases to 80 mm. in the Red Sea coast. In addition, wadi Yalamlam has surface running water in the upstream most of the year.

4-Subsurface investigations in wadi Yalamlam indicated that water bearing formations consist of alluvial deposits and top weathered zone of the

basement rocks as an unconfined aquifer. There are about thirty one wells in the basin of Wadi Yalamlam. The total daily abstraction of water from these wells is about 876m<sup>3</sup>.

5-The grain-size analysis of loose alluvial deposits samples was utilized to determine the permeability of the aquifer material. Average values were obtained for 44.5, 2.7, and 0.5 m/day for Sa'diyah, wadi outlet, and Almigat area, respectively. On the other hand, pumping and recovery tests carried out on several pumping wells were applied to calculate the transmissivity and storativity of the aquifer. Results indicate that the average transmissivity in Sa'diyah area is about 120 m<sup>2</sup>/day, and the average storativity is 0.09, which give rise to a moderate potential aquifer.

In Almigat area (downstream), the transmissivity values increase sharply, possibly as a result of the increase in the aquifer thickness. The average transmissivity is about 500m<sup>2</sup>/day, and the average storativity is 0.03, which indicates that the aquifer is of high potential herein.

6-The recharge rate into the aquifer investigated was calculated as 5.3 mm/year , which represents 3% only of the total annual rainfall. This means that more than 97% of rainwater is lost either as surface runoff or by evapo-transpiration.

7-The groundwater in Wadi Yalamlam is discharged into the sea. The amount of this discharge has been estimated at about 4 million m<sup>3</sup> annually.

8-Artificial abstraction by pumping all wells in the Wadi Yalamlam basin is relatively low compared to natural discharge. It amounts to 319740m<sup>3</sup> annually. This is because the agriculture activity in the area is very limited.

9-Geophysical survey in the study area indicated that the thickness of the saturated alluvial deposits in Sa'diyah area ranges between 6 and 12 m. On the other hand, the thickness of the water bearing formation in Almigat area ranges between 15 and 38 m.

10-Groundwater quality of Yalamlam basin has been investigated for major cations and anions, trace elements, and biological analysis. Two types of groundwater exist in the study area; calcium sulfate in the upstream and sodium chloride in the downstream area. The total Dissolved Solids (TDS) of groundwater varies from 1450-1835 mg/l. Analysis of toxic elements shows that the concentration is less than the national and international standards limits.

Analysis of coliform organisms indicated that they change from place to place. This is possibly due to random activity of farming, animal breeding, wastewater of scattered villages, and well design in the area.

### **Conclusion and Recommendation**

Morphometric study shows that the basin is elongated, has high relief, and a moderate drainage.

Although the basin receives an annual rainfall exceeding 200mm, only 5.3 mm/yr is calculated to recharge the aquifer which forms 3% of the total annual rainfall . This means 97% of the total rainfall is lost through evaporation and/or by surface and near-surface run-off, flowing into the Red Sea. The amount of discharge from the Wadi Yalamlam is calculated to be about 4million m<sup>3</sup> annually.

Chemical analysis of water shows that it has low toxic elements. The

total solids vary from 1450-1835 mg/l. Calcium sulfate occurs in upstream areas, and sodium chloride occurs in downstream area. Analysis of Coliform organisms varies from place to place depending the random activity of farming, animal breeding, improper waste water dumping in the scattered villages and the poor isolation of the aquifer due to improper casing design.

Due to high average annual rainfall (200mm/yr.), low recharge (5.3mm/yr), and high loss (97% of total rainfall) either due to evaporation and/or surface and near-surface run-off, it is suggested to make further detail feasible study to build subsurface dam across downstream channel which will retard and collect water upstream of the dam and thus increasing the volume of water in the aquifer.

An area of about 5 km<sup>2</sup> was chosen for future groundwater development. Twelve wells aim at producing 6000 m<sup>3</sup>/day of water are suggested to be drilled in the chosen area.

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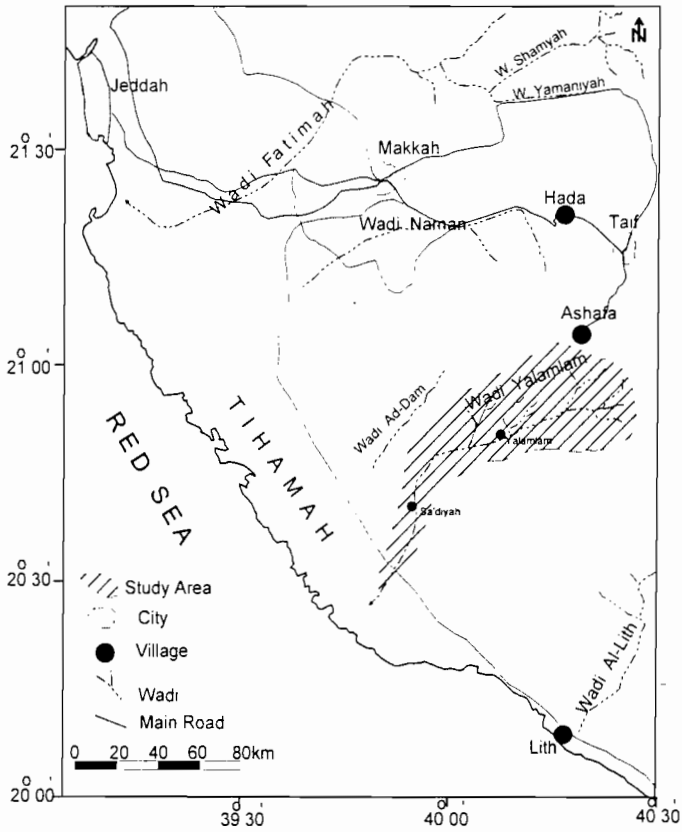


Figure 1. Location Map of the study area.

## تقييم الثروة المائية في وادي يَلَمَم في منطقة مكة المكرمة

علي الصباني و طارق بيومي

قسم الهيدرولوجيا - كلية علوم الأرض - جامعة الملك عبد العزيز

جدة ، المملكة العربية السعودية

بحث رقم : ٤٢٠ / ٢٠٣

**المستخلص :** تحتاج منطقة مكة المكرمة والمشاعر المقدسة بكثافتها السكانية وما يفد إليها من حجاج ومعتمرين إلى مصادر للمياه بصفة مستمرة ومتزايدة، وان تأمين مياه للشرب أو للإستعمالات المتعددة من أهم الأولويات التي توليها حكومة المملكة العربية السعودية جل اهتمامها . وهناك عدة مصادر حالياً تؤمن المياه بشكل جيد لمنطقة المشاعر المقدسة من خلال محطات تحلية المياه المالحة ومصادر المياه الجوفية من الوديان المجاورة.

ولما كانت نسبة الزيادة في السكان عالية نسبياً وكذلك عدد حجاج بيت الله الحرام والمعتمرين فإن البحث والتنقيب عن مصادر مساندة للمياه في هذه المنطقة يعتبر من المسلمات ، ومن هذا المنطلق فإن هذا البحث يهدف إلى دراسة مصادر المياه الجوفية في وادي يلملم والذي يقع على بعد ٧٠ كلم جنوب غرب مكة المكرمة ويتميز بأنه يصرف حوضاً كبيراً تبلغ مساحته حوالي ١٦٠٠ كلم مربع حيث يحده شرقاً حد توزيع المياه على أعلى قمم جبال السروات ( منطقة الشفا ) . ويتواجد في الوادي مياه جاريه محلية طوال أيام السنة في أعلى الوادي . وكذلك فإن معدل الأمطار السنوي يبلغ ٢٠٠ ملم وهي من ضمن القيم الأعلى في المملكة . ويجب أن نذكر أن مصادر المياه في الحوض المذكور لم تدرس حتى الآن وكذلك فإن الكثافة السكانية قليلة والنشاط الزراعي قليل أيضاً .

واشتملت هذه الدراسة علي دراسات للهيدرولوجيا السطحية للحوض المائي وخصائصه المورفومترية. ومن ثم تحديد الصفات الهندسية والهيدروليكية للوادي باستخدام الطرق الهيدرولوجية والجيوفيزيائية مع تحديد نوعية المياه في الحوض من الناحية الكيميائية والبيولوجية . وكذلك تحديد التغذية المطرية الحقيقية والمخزون العام .

وأخيراً تم اقتراح مواقع لإنشاء شبكة من الآبار ( ١٢ بئراً ) في منطقة الميقات لضخ حوالي ٦٠٠٠ متر مكعب يومياً بشكل آمن ومتجدد بالإضافة الي أربعة ونصف مليون متر مكعب متوفره في المنطقه المقترحه وذلك للاستفاده منها كمخزون مهم لمنطقة مكة المكرمة.