

# Regional Study of the Hydraulic Behaviour and Flood Probability in Some Major Wadis in the Western Part of Saudi Arabia

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## Introduction

The research area lies within the Western Province of Saudi Arabia between latitudes 21° 00' and 23° 00'N and longitudes 39° 00' and 40° 30' E. Sixteen major basins and sub-basins were selected in the present study and they are as follows:

- An Numan, including Yarij, Rahjan and Uranah sub-basins.
- Khulais, including Murawani, Ghiran and Abu Hulayfah sub-basins.
- Qudaid, including Sitarah and Marrakh sub-basins.
- Thamarh
- Rabigh, including Nada, Nuwaibah and Al Akhal sub-basins.

The above mentioned wadis constitute the most important drainage systems in the Western Province of Saudi Arabia and they are considered to be the most important sources for groundwater to major cities, towns and villages. These drainage basins lie partially within the Arabian Shield while their lower parts are on the Red Sea coastal plain.

The area has arid climate with irregular rainfall which is torrential in nature whenever it occurs. Rainfall occurs during the winter season, while in Autumn and Spring the area is subjected to isolated events. Hot and dry climate prevails during the long summer months with occasional dry, dusty storms. The

average annual rainfall is about 60 mm in the lowland areas and it increases to more than 200mm/year towards east. Such variations in the rainfall amount are attributed to the orographic effects of the escarpments facing the Red Sea. The groundwater aquifers within these catchments may receive direct recharge from the rainfall which infiltrates through the ground, or through indirect recharge where portion of water from the runoff infiltrates through the wadi beds or flood plain.

In spite of the arid climate, flash floods from torrential rains often cause severe destruction to human lives and properties, including engineering structural features such as highways and bridges. The study was aimed to provide valuable information that can be used for hydraulic designing in the construction of dam highways, bridges, flood control storm channels and heavy industrial complex buildings.

### **Previous Works**

The area investigated had been studied previously from the point of view of hydrogeology, geomorphology and geology. Several hydrogeological research activities were made in the area since the early seventies. Most of the works were concerned with the groundwater condition, aquifer characteristics and the water quality in the wadi sediments (e.g. Jamman, 1978 ; Mansour, 1984; No attention had been given to surface water investigation in these reports. The only available works which concern with flood analysis, were carried out by El-Didy (1998) and Bayomi et al. (2000), which were in the form of local investigations, while several detailed studies regarding geological and geomorphological characteristics of parts of the studied area are available (e.g.)

Some of these researches were in the form of regional investigations, describing different rock units, groups, and formations settings in the region.

### **Methods of Study**

In the present study, landsat images and topographic maps were used to delineate drainage boundaries, while control sections of the wadi channels were measured in the field.

The set of available rainfall data, together with the drainage basin characteristics facilitate the use of empirical equations to estimate relevant flood discharges. Rational formula is used that takes into consideration the rainfall intensity and drainage area of the wadis. Dimensionless method introduced by Soil Conservation Services (SCS), was also used for constructing hydrographs (Viessman et al., 1989). Other data pertaining to these methods such as soil moisture condition and morphological characteristics were obtained either from field survey and/or from relevant existing maps. Infiltration tests were carried out within the wadis considered, using double rings infiltrometer.

The morphometric characteristics of the selected basins and sub-basins were determined using Strahler technique for ranking the order of different branches. These characteristics involved drainage area, average general slope of the catchment, drainage density, stream channel length, bifurcation ratio, mean channel length, main trunk length, basin shape and stream frequency.

Maximum daily rainfall records for eight rain gauges of different length of records were analyzed using Log Pearson Type-III method to establish rainfall frequency curves. Infiltration tests as well as sieve analysis were carried

out and the results were graphically illustrated.

The hydraulic response of the basins and sub-basins were determined using intensity of rainfall frequency and morphometric parameters. The results obtained have been given in the form of runoff hydrographs. The corresponding water volume for infiltration, interception, and surface runoff has been computed for storms of different return periods (2,5,10, 25, 50, and 100 years) and different duration (0.5, 1.0 and 1.5 hours). Sediment load transported by flood waters was also estimated in terms of rate and volume. All the results concerning the hydraulic behavior and sediment load have been tabulated.

### Discussion

Present study has led to the clarification of several aspects of the response of these basins based on hydrological and geomorphological points of view. The study reveals that for each basin and sub-basin, the results of the hydraulic response are in a numerical form concerning runoff, infiltration and interception due to rainy storms. Hydrographic characteristics in terms of peak charges, time to peak and lag time are presented in the form of runoff hydrographs and tables. Repeated studies for storms of return periods 2, 5, 10, 25, 50 and 100 years at different duration of 0.5, 1.0 and 1.5 hours indicate that the least frequent storms bring rain more than the most frequent ones. The infiltration tests give the range of steady infiltration rates of the surface sediments between 0.27cm/min at Wadi Murawani sub-basin and 1.3cm/min at Wadi Sitarah sub-basin. The mechanical analysis of the collected sediment samples shows that most of the sediment brought by the surface runoff are moderately to

poorly sorted while the mean diameter of the sediment particles is in the range of 0.3 to 0.44 mm, with an average of 0.37mm.

### Conclusion and Recommendation

Results of the study on hydraulic response for each basin and sub-basin show interception that they are in a numerical form concerning runoff, and infiltration due to rainy storms. Repeated study for storms of various periods reveals that the least frequent storms bring rain more than the most frequent ones. The infiltration tests show the range of steady infiltration rates through the surface sediment between 0.27 cm/min at Wadi Murawani sub-basin and 1.32 cm/min at Wadi Sitarah sub-basin. Most of the sediments transported by surface runoff are moderately to poorly sorted while the mean size particles range from 0.30 to 0.44 mm, with an average of 0.37.

Due to the absence of adequate systematic long-term climatological data in the study area, it is recommended to set up climatological observatory stations, including guage stations to measure water generated in the selected drainage basins and sub-basins. These stations will be able to forecast valuable information concerning the floods resulting from rain storms and help in computer modeling which can be used in future planning of the areas.

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## دراسة إقليمية للسلوك المائي واحتمالية فيضان الأودية الرئيسية في الجزء الغربي من المملكة العربية السعودية

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المستخلص : تضمنت الدراسة الحالية تحديد التصرف الهيدروليكي وإحتمالات السيول لبعض الأودية الرئيسية وافرعاها وهي : (١) حوض والدي النعمان (٢) حوض وادي خليص (٣) حوض وادي قديد (٤) حوض وادي ثمره (٥) حوض وادي رابغ والواقعة في الجزء الغربي من المملكة العربية السعودية . تم حساب الخصائص المورفومترية لهذه الأحواض التصريفية والمتضمنة الرتب المتعاقبة لفروع الأودية - مساحة حوض التصريف - كثافة حوض التصريف - متوسط الإنحدار العام - شكل الحوض - نسبة التشعب وتكرار الفروع . كما استخدمت الطريقة اللوعاريمية لبيرسون ( النوع الثالث ) في تحليل البيانات اليومية العظمى للأمطار لثمانى محطات ذات فترات تسجيل مختلفة لغرض إنشاء منحنى المطر الترددي لكل من هذه المحطات .

بناءً على البيانات المأخوذة من منحنى المطر الترددي وكذلك البيانات المورفومترية الخاصة للأودية تم حساب التصرف الهيدروليكي للأحواض لعواصف مطرية ذات مدد تكرار مختلفة ( ١٠٠،٥٠،٢٥،١٠،٥،٢ سنة ) مع تغير مدد استمرار العواصف ( ١،٥،١،٠،٠،٥ ساعة ) وتم تحديد كميات المياه المعترضة على شطح الأرض والمتسربة في التربة ومعدل السيل السطحي وتقدير حجم كم منها . وتم عرض النتائج في شكل هيدروجرافات وجداول تحوي القيم العددية للتصرف الهيدروليكي لكل حوض . وتضمنت الدراسة حساب حركة الرواسب المنقولة بواسطة مياه السيول في صورة معدلات وحجوم تم جدولتها .