ST/ESA/112

Department of Technical Co-operation for Development

Natural Resources / Water Series No. 9

GROUND WATER IN THE EASTERN MEDITERRANEAN AND WESTERN ASIA

UNITED NATIONS
New York, 1982

OMAN

Area: 213,000 km^2

Population: 743,000 (United Nations estimate, 1975

General

The northern part of Oman is dominated topographically by the Oman mountain range, an arcuate belt of deeply dissected terrain with a maximum elevation of 2,980 m above mean sea level at Jebel Sham, one of the peaks of the Akhdar range. The mountains are flanked to the east by a fertile coastal plain (the Batimah plain) and to the west by gravel plains and the desert. The province of Dhofar is separated from the mountainous north by 200 km of mainly desert land, the western continuation of which merges into the Rub Al Khali (the Empty Quarter), the major sand mass of the Arabian Peninsula. The geographical areas are identified in map 15 and are described below in some detail.

Capital area

The capital area, the most densely populated in the country, is composed of four regions: Muscat, Mutrah, Bawshar and Sib.

Musandam

The isolated northern region of Musandam consists of rugged mountains rising to 1,800 m in height from a deeply indented fjord coastline. The principal villages are Khasab, Bayah and Bukha.

Batinah plain

The Batinah plain runs from the border with the United Arab Emirates for a distance of some 270 km south-east almost to Muscat. It is situated between the coast and the western Hajar, varying from 10 to 30 km in width. Cultivation is limited to a narrow strip, seldom wider than 3 km, adjacent to the sea. The Batinah is one of the most populous areas of Oman, the main towns being Barka, Masnaa, Suwaiq, Khaburah, Saham, Sohar, Liwa and Shinas.

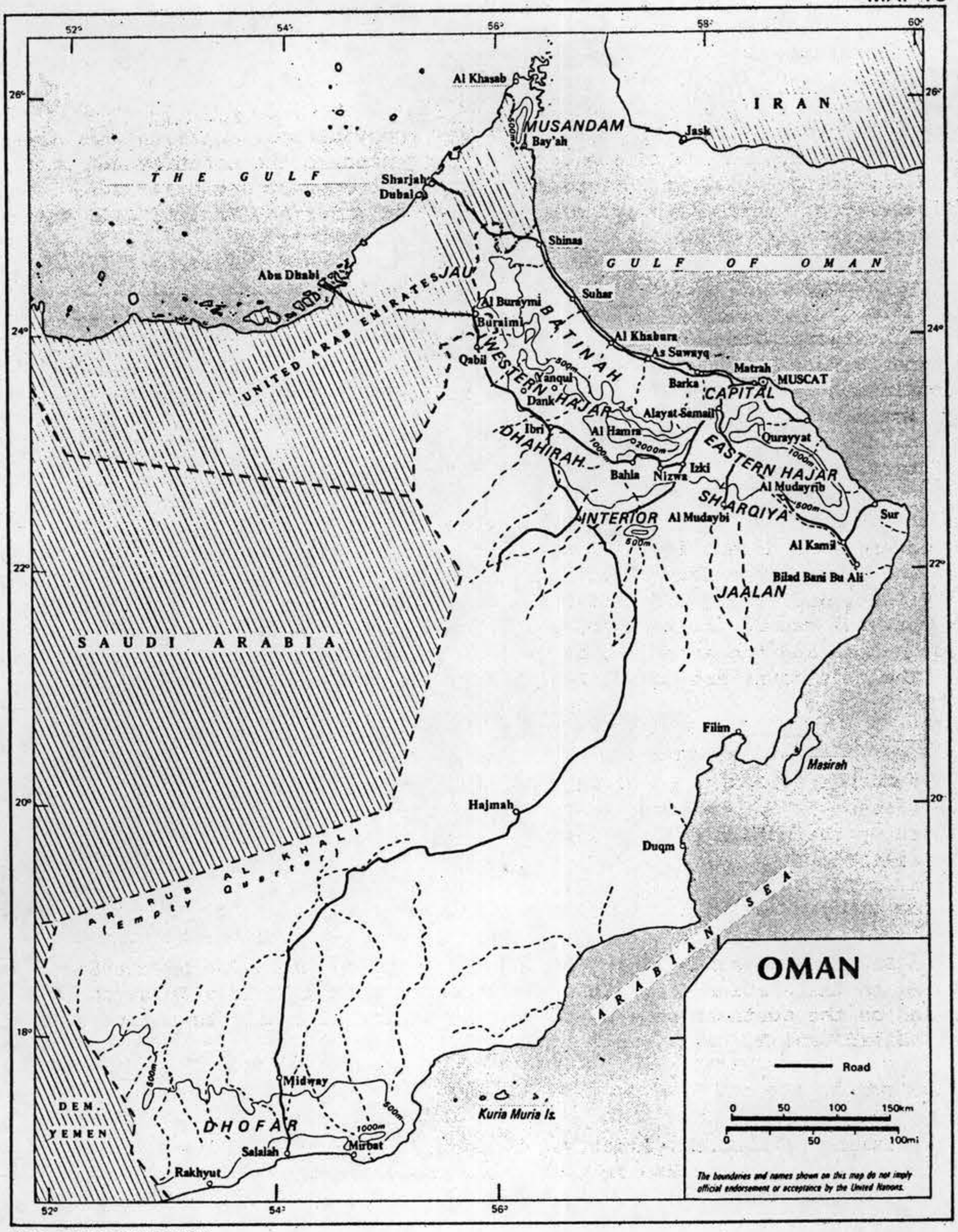
Western Hajar

The mountain range of western Hajar, parallel to the . . stretches from the border with the United Arab Emirates in the north to the gap in the south. The highest points are in the south-east, the Jebel al Akh... ...ving peaks approaching 3,000 m in height. There are groups of major se... ...ements on each side of the western Hajar. Those to the south make up the area known as Oman proper, while the main towns on the seaward side of the mountains are Rostaq, Awabi and Nakhl.

Map 15

Oman

MAP 15



MAP NO. 2993 REV. 1 UNITED NATIONS
SEPTEMBER 1981

Eastern Hajar

The eastern Hajar is the continuation of the main mountains of Oman from the Sumail gap to Jebel Khamis in the east, a distance of just over 200 km. To the north the mountains reach the sea and to the south they are bordered by the Sharqiya and the Jaalan. The highest elevation is 2,100 m. The principal towns on the seaward edge of the mountains are Sur, Tiwi and Qurayyat.

Dhahirah

Dhahirah is a semi-desert plain, sloping from the southern flanks of the western Hajar into the Rub al Khali. It is bordered to the north by Jau and Buraimi and to the south it is divided from Oman proper by Jebel al Kawr. The major settlements are on two principal wadis, wadi Dank and wadi al Ain, the towns being Dank, Ibri and Yanqal.

Jau

The northern extension of the plain of Dhahirah is known as Jau. In this small area between the border with the United Arab Emirates and the western Hajar, the population is concentrated around the Buraimi oasis where dates are grown under irrigation.

Oman interior

Oman interior is a central plateau sloping from the Jebel al Akhdar in the north towards the desert in the south. It is bounded in the west by the Dhahirah and in the east by the Sharqiya. There are four principal valleys: wadi Kabir, wadi Halfain, wadi Bahla and wadi Sumail. Wadi Halfain and wadi Sumail together form a natural gap in the main mountain range. This gap is a traditional route between Muscat and the interior, as well as being one of the most populous areas of Oman. The main towns are Nizwa, Bahla, Izki, Manah, Adam and Sumail.

Sharqiya

The Sharqiya is an area of sandy plains and valleys, lying on the inland side of the eastern Hajar, bordered to the south-east by the district of Jaalan and to the south by the Wahiba sands. The main towns are Inra, Mudaibi, Samad, Biddiyah and Mudairib.

Jaalan

The Jaalan is a sandy plain forming the southern extension of the Sharqiya and extending to the Arabian Sea. It is bordered on the northern side by the eastern Hajar and on the southern side by the Wahiba sands. The main towns are Bilad Bani Bu Ali, Bilad Bani Bu Hasan, Wafi and Kamil.

Masirah

The island of Masirah, almost 60 km long, is situated in the Arabian Sea. The other important islands, also in the Arabian Sea, are the Kuria Muria group, the largest of which is Hallaniya.

Dhofar

The southern region of Dhofar occupies almost one third of the area of the country. It is composed of two different climatic zones. The coastal plain, extending from Raysut in the west past Salalah, is nowhere wider than about 8 km but the fertile alluvial soil is well watered between June and September by the south-west monsoon. The monsoon also reaches the wooded hills which rise up to 1,500 m in elevation behind the coastal plain. North of the mountains and extending to the border with Saudi Arabia in the Rub al Khali there is very little rainfall and the area has desert vegetation. The main towns and villages are Salalah, Marbat, Taqa, Thamarit, Rakhyut and Mukhshin.

Monthly rainfall data and temperature averages are available for only a few stations in Oman. Rainfall figures for Muscat show an annual aggregate of 107 mm, of which 78 mm fall between December and April. Regional variations are indicated by rainfall figures for Sohar which receives a total of 38 mm a year, while in Dhofar about 115 mm fall mainly between May and November. Temperatures in Muscat range from an average maximum of 41° C in June to 27° C in January. Salalah, the regional capital of Dhofar, enjoys the more equable temperatures of 32° C maximum in June and 27° C in January. In spite of the arid climate, water is plentiful in many of the deeply incised wadis of the mountains and is present beneath the surrounding plains. Rain falls in short violent storms, which cause flash-flooding in the mountains, but cloud conditions without appreciable rain may persist for several days. Winds are light in clear weather, but may rise to gale force at night in the mountains. During stormy conditions high winds raise considerable amounts of dust.

A comprehensive network of meteorological stations is now being installed, which will generally improve the knowledge of climatic variations and phenomena, and also provide more complete data for navigation by sea and air.

Geology

In northern Oman mountains, Pre-Cambrian basement rocks are well exposed in Jebel al Akhdar, Sayh Hatat, and Jebel Jaalan. They include phyllite, green schist, granite and quartizite and are intersected by quartzoze veins. In the Dhofar region the basement is exposed in the area east of Salalah between Taqah-Mirbat and Al-Hasik. Here it includes gneisses, schists and pegmatic dykes. The basement rocks are unconformably overlain by thick beds of crystalline limestone with chert stringers and basal conglomerates. The limestones show solution textures and are cavernous. The age of these autochtonous rocks, which are well exposed on the flanks of Jebel al Akhdar and Sayh Hatat, ranges from Permian to Upper Cretaceous.

These series are unconformably overlain by an autochtonous unit called the Hawasina nappe. The contact is a thrust contact. The Hawasina nappe is composed of limestone, conglomerate, radiolarian chert and shale. The age of the Hawasina rocks ranges from the Permian to the Cretaceous. On top of the Hawasina rocks the Semail ophiolite nappe is in thrust contact with the lower rocks. The thrust contact is exemplified by metamorphic rocks and Oman melange which is a mechanical mixture of cherts, limestones, lavas and serpentinites, usually sheared. From the top to the bottom, the ophiolites are composed of basic extrusives, pillow lavas, dyke swarms, gabbros, banded gabbros, peridotites which are serpentinized in many places, and dunites and harzbergites. The ophiolites are unconformably overlain by the maestrichtian to Tertiary limestones, which are composed of reefal limestones that are crystalline at some places.

At the top of the geological column are the recent fluviatile sediments and fan deposits. These are formed of indurated well cemented conglomerates, wadi gravel and fanglomerate.

In general, the rocks of Oman reflect the effect of large-scale tectonism and thrusting and superposition of originally laterally equivalent units. This condition is well expressed in the Oman mountains. The nappes formation took place at the end of the Upper Cretaceous age. The Oman rocks were also subjected to the updoming and compression that took place in the early part of Tertiary. This resulted in the formation of the Sayh Hatat dome and the Jebel al Akhdar anticlines. All these events affected the rocks in Oman, so that they are all highly faulted and folded.

Surface water

Owing to the steep slopes, the low permeability of the rocks along the wadis and the intermittent rainfall of fairly high intensity, run-off in the mountains is high. Part of it comes down in the form of surface flows of short duration, while the remainder penetrates the gravel and sands of the wadis and is released as a perennial base flow. The Wadis Al Jizi, Al-Hawasina, Sumail and Bani Ummar in the northern Oman mountains provide a good example of this conditions.

Some streams tap the cavernous limestones, especially along the trust contact of the ophiolite rocks and the old shelf limestones. These are wadi Daiqua and wadi Bani Khlid. There are many other streams and springs especially at the base of Jebel al Akhdar, at Rustaq and at Tunhuf.

Ground water

Several large-scale resources surveys directed towards investigating the extent and availability of ground water to support further irrigation and urban development have been carried out. The main reports covering these investigations are identified in the list of references below.

In general, ground water in Oman is derived either from deep fossil aquifers extending over large portions of the Arabian Peninsula or from recent wadi deposits, alluvial fans and coastal plains along the mountain ranges. In view of the high cost of production from the deep aquifers and the scarcity of arable lands in the interior, the exploitation of this resource has to be limited to uses related to the development of petroleum and mineral resources. Most extraction takes place from the shallow acquifers, as described below for the three major regions.

Northern coastal plain

The aquifer system of the Batinah plain is contained in a wedge-shaped body of alluvial deposits which thicken from a feather edge adjacent to the mountain front towards the sea. The upper part of the system consists predominantly of gravel. Saturated thicknesses are as much as 100 m locally, but generally do not exceed 30 to 40 m and then narrow to a feather edge within 5 to 15 km of the coast. The lower part of the system is formed by clay gravels with maximum thicknesses in excess of 100 m adjacent to the coast.

The lower, essentially impermeable, boundary of that system is formed either by a thick unit of conglomerates and clays or by bedrock. However, with respect to ground-water development, there is a hydraulic boundary defined by the interface between fresh water and sea water, the position of which varies according to the head difference between the fresh water and sea level. Under transit conditions, the position of the interface is also dependent on the total porosity of that part of system in which the interface is moving.

The mean section permeability of the upper gravels is high, averaging about 50 m/day, though there is marked lateral and horizontal variation. The mean section permeability of the clay gravels is low, though lenses of clean gravel occur which will supply relatively high-yielding wells.

The hydraulic gradient is towards the coast. It averages about 1 in 100 where flow is predominantly in the clay gravels but slackens rapidly to less than 1 in 2,500 as the thickness of saturated upper gravels increases adjacent to the coast. Present extraction for irrigation is essentially concentrated in the coastal strip where water-level elevations are less than 2 m above sea level.

The studies show that, with local exceptions, the ground-water system is essentially in equilibrium. The outputs of the ground-water balance are consumptive use by irrigated agriculture; transpiration by natural vegetation; evaporation from the shallow water table (mainly in the sabkhah zone); and flow to the sea. A continuous cover of natural vegetation and palm trees, interspersed with irrigated gardens, extends to the coastal dunes. The presence of green vegetation at the heads of inlets to the sea indicates fresh water flow. However, the sabkhah zone is extensive. The economic and social values of the natural vegetation are not known but it must be accepted that the water it transpires forms an important part of the balance of the coastal aquifer system. It is likely that the flow to the sea is limited and that most of the underflow passing north of the cultivated zone is consumed by evaporation at the sabkhah.

Oman mountains and interior plains

The ground-water resources of the Oman mountains are developed in the narrow bottoms of deeply incised valleys which form line sinks for the ground-water discharge from the hills. The ground-water either discharges naturally as springs or base flows, or is developed by means of drainage galleries, known as *falajs*. Land limitations prevent any important extension of the irrigated areas and available water is often in excess of requirements. However, this excess should not be regarded as a loss as the valleys form closed systems and the water moves down-gradient to the benefit of users of lower aquifers on the plains. A major problem would appear to be maintenance of the *falaj* system, which can be the most efficient method of extracting the water under certain circumstances, but would be extremely expensive to replace.

The ground-water of the interior plains is contained in a relatively thin cover of coarse clastic materials overlying clay deposits which in turn overlie bedrock of low permeability. The coarse material consisting of gravel, sand and silt, forms aquifers when consolidated. Its thickness, however, is generally less than 10 m, though it may be up to 50 m in local depressions and along wadi channels. The exploitable ground water is therefore erratically distributed. Moreover, the irrigable land is also distributed, with few exceptions, in small areas which do not necessarily accord with the availability of water. An exception is the wadi Qurayyat plain where 2,900 hectares of new lands have been mapped, though the water resource to supply this land has not been identified.

Dhofar

The Salalah plain is about 50 km wide and a maximum of 15 km long. It is bounded to the south by the sea and to the north by mountains. Ground-water occurence is related to carbonate rocks and conglomerates. Recharge is by underflow from the mountain range and by springs which discharge at the foot of the mountains. Flood occurrences on the plain are extremely rare. The recharge appears to be very slight, although there is a fair amount of rainfall on the mountain catchment; much of this, however, occurs in the form of heavy mist. The ground-water quality is generally poor except in the central part of the plain behind Salalah.

In carbonate acquifers, low water levels, high cost of well construction and low yields combine to preclude the use of ground water for irrigation. In addition, the soils are patchy and thin, but development for domestic use and cattle watering appears feasible.

Little is known about ground-water conditions on the interior plateau (Nejd). The plateau is believed to be underlain by a carbonate aquifer system of regional extent. Artesian flows are obtained in some areas. Water quality is generally poor. The soils are structureless, highly permeable and of poor fertility.

The falaj system

In view of its historical importance the following discussion is devoted to a more detailed examination of the falaj and its role in water resources development in Oman. Viewed as an engineering system, it taps ground water in the coarse sediments of mountain-foot zones where the water is relatively close to the surface and has a low content of dissolved salts. Geological and geomorphological factors produce factors produce localized concentrations and channelling of ground-water flow. In most cases, a falaj is sited so as to tap such concentrations by means of "mother-wells". It then conveys ground water down-slope to areas of finer sediments more suitable for cultivation. The channel/tunnel gradient must be approximately uniform throughout and therefore differs from the varying surface gradients. Underground sections of a falaj have to be tunnelled through a variety of loose sediments (coarse and fine) and also through bedrock and cemented sediments. Underground sections may thus tap subsidiary ground-water flows also.

The main channel of the falaj is most vulnerable to mechanical damage when (a) underground sections are shallow or constructed in loose sediments; (b) it lies within wadis or crosses tributary wadis subject to severe floods; and (c) surface sections are embanked.

The rate of flow in a <u>falaj</u> is determined by a relatively large rainfall catchment area feeding a relatively small channel concentration of ground-water. Fluctuations in flow are therefore fairly limited except during prolonged dry or wet periods. <u>Falaj</u> construction is designed for equable flow conditions; if for some reason these conditions are not maintained major reconstruction becomes necessary.

Ground-water management

The fact that water has traditionally been relatively plentiful and was therefore developed in many scattered localities, has resulted in an absence of centralized control and regulation. Accelerated development, however, and the water problems that have arisen in the process, are beginning to create the need for government involvement and assistance. Problem areas include technical matters (salt-water intrusion, need for artificial recharge, interference of extraction patterns) and legal aspects (existing water rights, assignment of priorities).

In order to provide co-ordination in these matters the Water Resources Council was established as the supreme government body entrusted with the organization of co-ordinated water administration. Several measures are being implemented in that direction:

(a) A water resources law is being considered which will identify the co-ordinating functions, and will facilitate the procedures involved in the granting of permits and licences;

(b) The Government is studying alternative approaches to organizing a central administration;

(c) Several investigations are now being undertaken for the purpose of continuing or supplementing previous efforts. These include digital computer modelling studies of the coastal aquifers, and artificial recharge schemes for the more productive wadis;

(d) Long-term planning has been initiated for all major municipalities to cover needs and supplies.

The responsibility for these activities is at present shared by several government organizations, especially the Water Resources Council (co-ordination, legislation); the Ministry of Communications (urban water supply, meteorological data collection, desalination plants); and the Ministry of Agriculture, Fisheries, Petroleum and Minerals (hydrological data collection, irrigation, flood control).

Water drilling is carried out by a number of specialized firms, usually with broad experience in the region. At times, in response to specific emergency requests, the Government may assign its own equipment to assist villages or farmers in securing urgently needed supplies.

Problems

The main problems affecting ground-water resources are as follows:

(a) Saline (sea) water intrusion

This phenomenon is being monitored in several places, and is being countered by moving the extraction zone back from the coast;

(b) Net surface flow losses to the sea or the desert

Recharge schemes are being prepared which will not only minimize losses and recharge the alluvial fans, but will also help in the control of salt-water intrusion;

(c) Inefficient water use

To overcome this, educational efforts are being directed towards the introduction of water-saving techniques and practices. Results are expected from the publication of information on the subject and an efficient extension programme.

Conclusion

Ground water is one of the main natural resources in Oman and its availability is a limiting factor in many sectors of the economy of the country. It has received considerable development emphasis in recent years which is leading to an improved government role in co-ordination and the establishment of a proper infrastructure. On the basis of data and reports submitted as of 1977, it appears that cautious optimism is justified with regard to the adequacy of Oman's water resources to support planned economic development.

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