Chapter Four

GEOMORPHOLOGY AND GEOLOGY

4. 1 Geomorphology

The Eastern Coast Region in the UAE is distinguished into four geomorphic units. These units include: mountains, alluvial plains, coastal plain and drainage basins (Figure 4.1).

4.1.1 Mountains

The Northern Oman Mountains cover about 90% of the surface area in the Eastern Coast Region in the UAE. The mountains extend for 155 km between Sha'am in the north and Al Ain in the south, with an average width of 10 km in the north, 38 km in the middle and 27 km in the south.

The elevations of the mountain peaks vary between 500 and 900 m above sea level. Some salient peaks, however, may reach an elevation of 2,000 m. With the exception of its northern portion, the mountain peaks are underlain by hard rocks belonging to the Semail Ophiolite group. In the northern portion, at Dibba and along the channel of Wadi Khasarah, the surface of the mountains is underlain by Hawasina hard rocks. (IWACO, 1986)

The Northern Oman Mountains are severely deformed by three major structural trends: Dibba zone, Hatta zone and Wadi Ham line. The Dibba zone represents the most important geologic structure in the Northern Oman Mountains. This province is topographically low and extends for 30 km from northeast to southwest, with an average width of 20 km. The Dibba zone is considered a tectonic window that separates between Musandum calcareous sequence in the northwest and the Ophiolite sequence in the southeast. The Dibba zone is occupied by stratified rocks of tectonic boundaries. The Hatta zone represents a tectonic window which is similar to a great extent to Dibba zone. The folding and rock stratification in this zone are parallel to the longitudinal direction of the tectonic opening in the west-northwest - east-southeast direction. Along Wadi Ham line, the mountains are highly deformed by a major fault zone oriented NW-SE.

The results of deformation are demonstrated by the depression areas dissected by the various wadi systems, which sculpture the surface of the mountains. Such depressions are usually filled with dark-colored fluviatile deposits, belonging to the Quaternary and possibly the late Tertiary times. The older generation of such deposits is hardened into a conglomerate-type formation (Al-Matari, A.S., 2010).

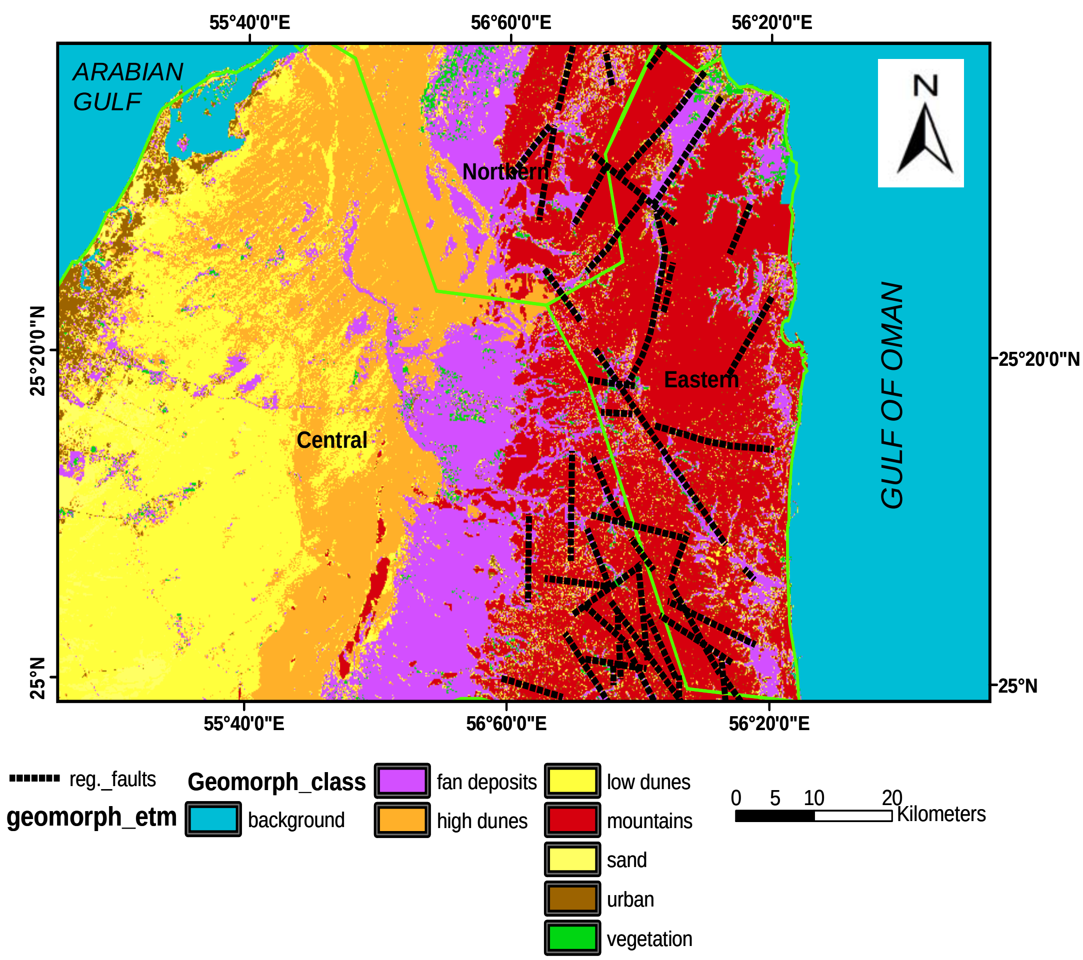

Figure 4.1 Geomorphic map of the Eastern Coast Region in the United Arab Emirates, showing major landforms and regional faults (modified from IWACO 1986).

The attitude of the slopes of the mountains is generally to the west, but the degree of slope varies considerably according to the local conditions. (IWACO, 1986) The surface of the mountains is generally barren, but in winter the rain-fed wild vegetations give the mountains green shades rainy seasons. The wadi beds and the morphotectonic depressions are generally occupied by dense palm grooves and by acacia trees.

The Northern Oman Mountains comprise the northern part of the Semail Ophiolite nappe that is composed of a repeated Ophiolite sequence caused by internal low-angle thrust faults. The Ophiolite complex is divided from base to top into: an ultramafic mantle sequence, layered peridotite, coarse-grained gabbros, fine-grained gabbros, sheeted dyke complex and extrusive lava.

4.1.2 Alluvial Plain

The alluvial plain forms the major portion of the low land area at the foot slopes of the mountain ridges. Local tongues of the alluvial plain extend inland for various kilometers, which may be in excess of 25 km, as in the case of Wadi Khasarah and Wadi Ham.

The alluvial plain shows many signs of irregularity. In the north, the plain is rather narrow and widens slowly southwards, in the direction of Fujairah and Khor Kalba. Further south, it merges into the wide Al Batina bajada in Oman. Drilling for groundwater in Fujairah indicates that the alluvial plain has been much wider in earlier Quaternary times and was subjected later to gradual subsidence under the Oman Gulf water. The surface of the alluvial plain is not even, but it generally slopes to the east. Old wadi terraces contribute locally to the complexity of the topography of the alluvial plain (IWACO, 1986).

4.1.3 Coastal Plain

The eastern coastal plain is a narrow strip, between the Gulf of Oman in the east and the Northern Oman Mountains in the UAE in the west. The width of the plain varies between 4 km wide in Fujairah and 10 km wide Kalba, and its length reaches 70 km between Dibba in the north and Kalba in the south. The plain is disconnected and dominated by salt marshes and wet land areas.

No sandy beaches are noticeable between Dadinah and Sha'am and also between Luluiyah and Khor Fakkan. In some locations, namely at Ras Dibba, Rag Dadinah, Sharm, Ras Luluiyah and at Khor Fakkan, rocky sea cliffs are predominant land features and rise in places several tens of meters above sea level.

At Khor Kalba, a dense cover of natural vegetation composed of mangrove trees contribute largely to the landscape, particularly along the creek (IWACO, 1986). The coastal plain is composed of sand and gravel brought by runoff water from the mountains. The size of coastal sediments varies from large gravel in the west to fine sand and slit in the east, close to the Gulf of Oman.

4.1.4 Drainage Basins

Within the UAE, the Northern Oman Mountains are dissected by the drainage nets of 58 basins, which reach to an area of 5 km^2 (Wadi Dadinah, Al Fujairah). The drainage pattern in all of the basins within the study area belongs to the elongated trellis type and structurally controlled (Figure 4.2).

The floor in most of the wadis is a flat-gravelly plain with triangular shape broadening towards the sea and draining the surrounding mountains. Along the coast, the inward land becomes a river terrace or alluvial plain. These relatively permeable surfaces coupled with low to moderate drainage density values reflect a low efficiency in discharging the rainwater by channel flow, thus increase in water loss via infiltration. Physiographic characteristics of the basins such as relief ratio, drainage density and bifurcation ratio reinforce the higher groundwater potentiality in most of wadis. The low relief ratio (1.04-1.08) for most of the wadis indicates low overall slope and hence low runoff velocity. (IWACO, 1986)

The relatively low drainage density suggests the low efficiency of the wadis in carrying their excess precipitation, as water moves slowly through the soil cover, as compared to its movement in an active stream channel. The higher the bifurcation ratio the lower capacity of wadis in moving their excess precipitation from the lower to the higher order streams. Therefore, the high bifurcation ratio of some of the basins indicates high groundwater potentiality and low flooding possibilities. It is locally dissected by stream channels filled with cobble and gravel. The number and the depth of channels decrease towards the coast (Figure 4.2).

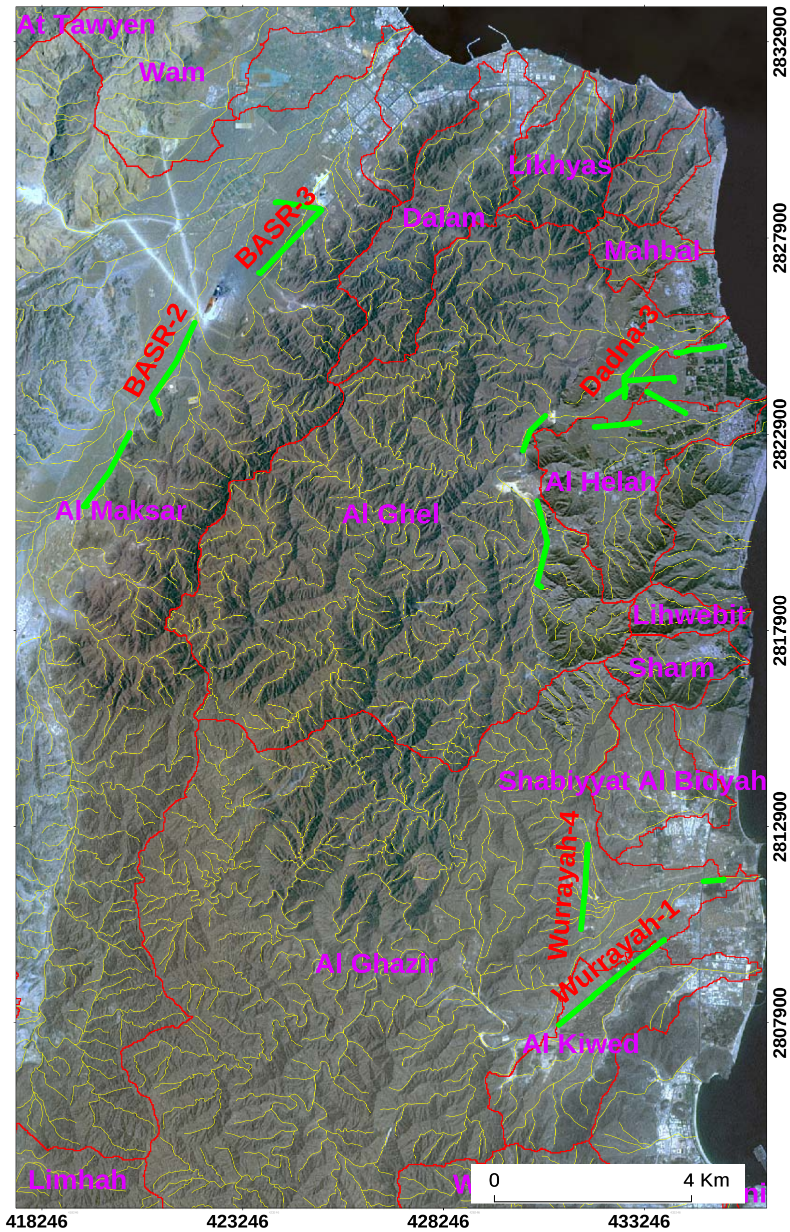

Figure 4.2 Drainage pattern (yellow lines) and catchment areas (red lines) in the northern part of the study area (modified after Almatari 2010).

4.2 Geology

4.2.1 Surface Geology

The geological map of the Eastern Coast Region in the UAE indicates that the upstream part of the area is dominated by the Masafi Mountains whereas the alluvial

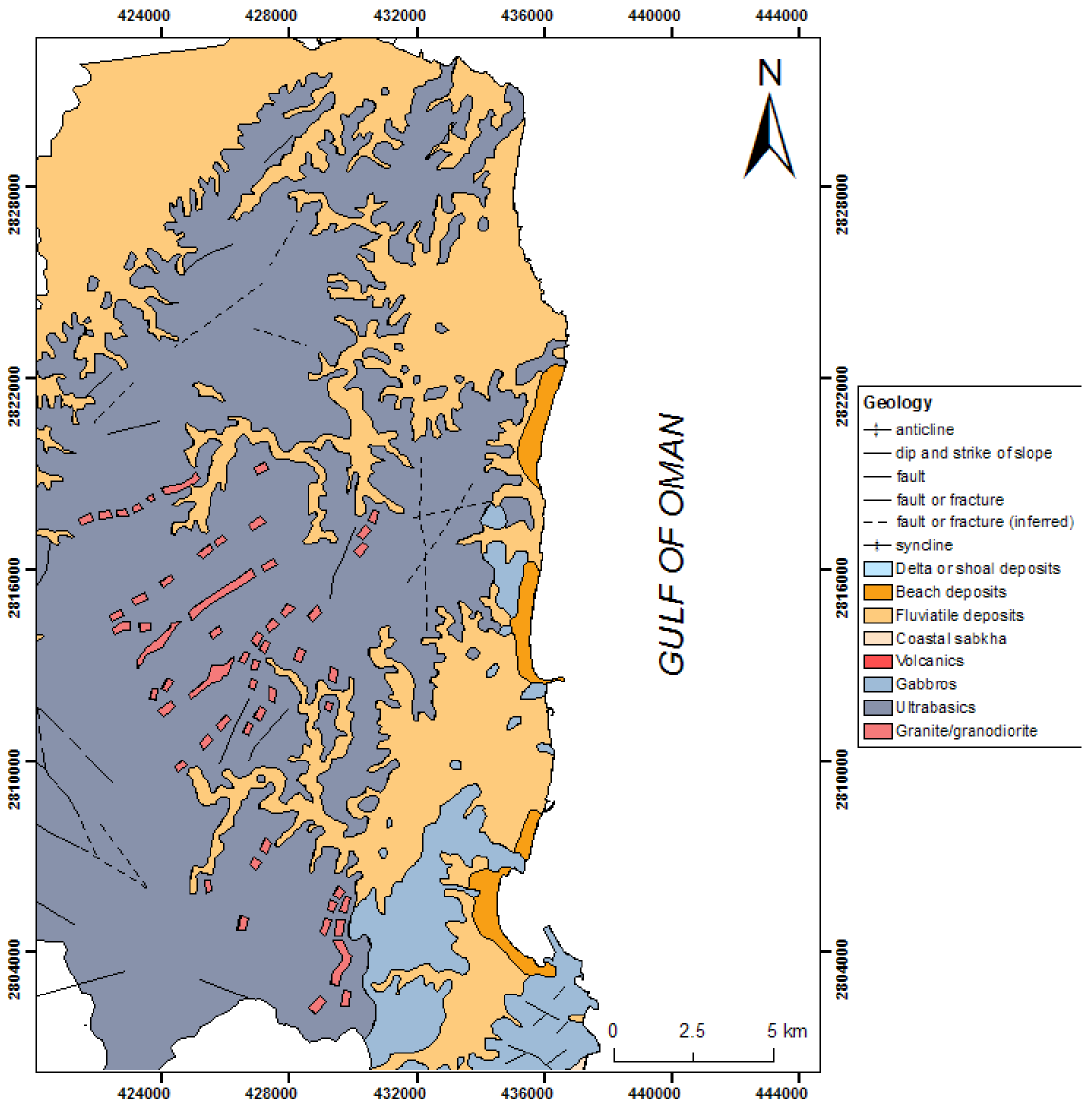

Figure 4.3 Geologic map of the Eastern Coast Region in the UAE, illustrating the Wadi Wurayah drainage basin and its hinterlands (modified after the UAE atlas, 1993).

As indicated earlier, the geological structure of the region is influenced by three main elements; Dibba zone, Hatta zone and Wadi Ham line (Figures 4.1 and 4.3). The Dibba fault system is striking NE-SW and the Wadi Ham line is striking NW-SE. The Dibba fault system controls the shape of the catchment area of Wadi Shimal and its downstream portion entitled Wadi Khasareh. On the other hand, the main trunk of Wadi Hera is superimposed on the NW-SE Wadi Ham structural trend (IWACO 1986). Sediments of the lower plains are composed of recent Pleistocene wadi gravels. The alluvium gravels layer overlay the consolidated rocks of the Semail Ophiolite sequence with a separating mantle of fractured zones at some locations.

Wadi Wurayah gravels and deposits are poorly sorted and sub-rounded to sub-angular. The degree of consolidation varies from recent un-cemented sandy gravel to the older well cemented and consolidated gravels. The clastic sediments range in size from silt to boulder, with a very high sand content. The thickness of the unconsolidated-material layer varies from 15 to 100 m (Figure 4.4).

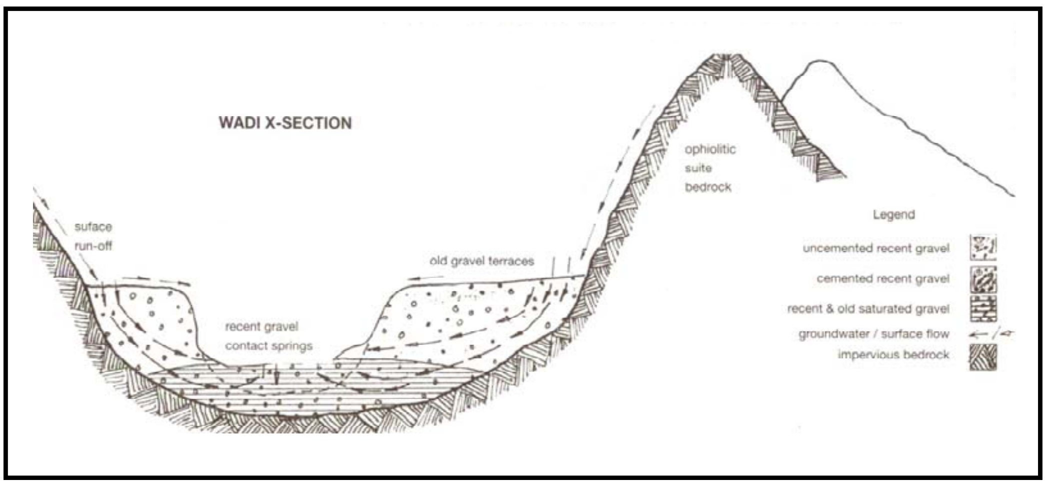

Figure 4.4 Geologic cross-section across Wadi Wurayah, illustrating old terraces, recent gravel and contact springs (Tourenq, et al. 2006).

The gabbros and serpentenite of the Semail Ophiolite lies beneath the unconsolidated material layer (Figure 4.8 and 4.9). Gabbros/diorite is likely to be confined in some places by the cemented units within the base of the overlying layer. The depth to the

Ophiolite layer varies from less than 5 m to more than 40 m. The basement Ophiolite layer is generally dipping towards the coast as well as towards the wadi course. The alluvium gravels layer overlay the consolidated rocks of the Semail sequence with a separating mantle of fractured zones at some locations as shown in Figure 4.9.

Structurally, the Shimayliyyah (northern) Mountains are part of a complex anticline system which has been subject to thrusting and over folding during emplacement of basic igneous crustal rocks. There major fault systems affect the study area; NW-SE, NE-SW and ENE-WSS), but the Dibba zone fault system striking NE-SW in the most pronounced structural element (Figure 4.5).

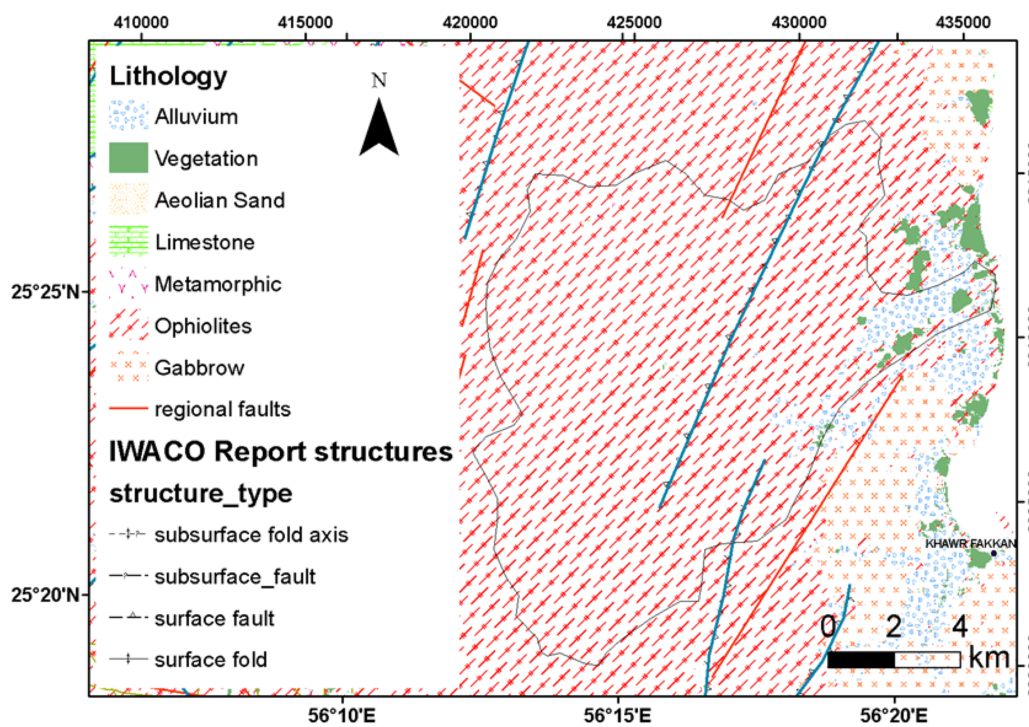

Figure 4.5 Geological map of the Wadi Wurayah drainage basin (modified after Ebraheem et al., 2008).

Rainfall provides low salinity and low temperature runoff water which infiltrates through the fractured Ophiolite and the recent and older wadi gravel terraces in the upper parts of the catchments. Runoff quickly finds its way downstream in flash floods which also provide significant recharge to the alluvial aquifer in the middle part of the wadi Wurayah catchment, culminating in storage for the Wurayah recharge dam (Figure 4.6).

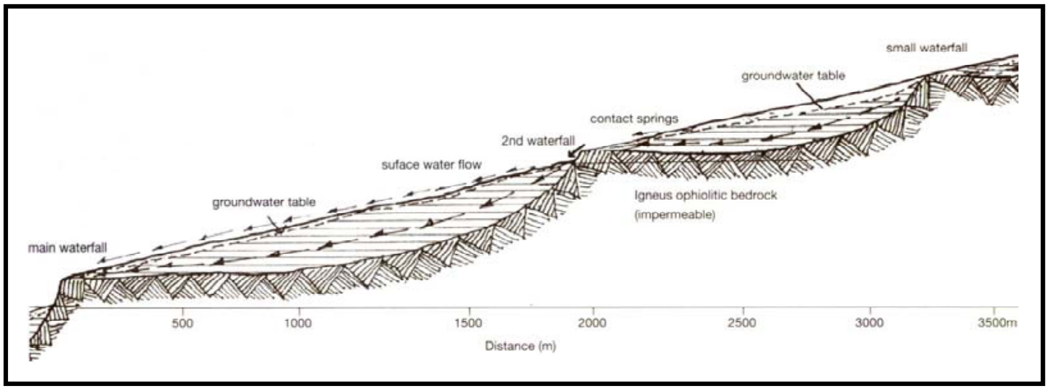

Figure 4.6 Schematic of surface and groundwater flow processes upstream of main waterfall (Joudah, 1994).

Undulations within the impermeable igneous bedrock are filled with shallow alluvium. Upstream of the contact spring waterfall, springs bring water to surface both at the contact between bedrock and alluvium and also at the contact between cemented and un-cemented gravels. The cemented gravel acts as an impermeable barrier forcing the water to move into the wadi channels. Fractures within the cemented gravels may also produce temporal springs during rainy seasons.

4.2.2 Subsurface Geology

The subsurface geology of the Eastern Coast Region in the UAE is, at present, little understood. However, the current activities may include the launching of intensive program of petroleum exploration, which will reveal valuable information subsurface strategraphy and geologic structures. Enthusiasm may from now be directed to the answer of two questions having a bearing on the future development of groundwater and agriculture. The first question is about the occurrences of the lower Cretaceous-Triassic fissured carbonates below the Semail Ophiolite and the Hawasina. It is already shown that such carbonates form an important aquifer in the Northern

Agricultural Region. The second question is about the continuity and the rate of subsidence of the alluvium and the coastal plain and its subsequent influence of seawater intrusion. This phenomenon now represents a serious problem in this region (IWACO 1986).

The available drilling information of several monitoring wells (Figure 4.7) was used to construct subsurface geologic cross sections shown in Figures 4.8 and 4.9. These cross sections show that the thickness of the unconsolidated materials is generally controlled by the topographic setting and structural pattern. The unconsolidated material layer is composed of an upper sub-layer of gravels and boulder underlay by another layer of Seprentinite.

The importance of the geology and the geomorphology to Wadi Wurayah and its hinterlands is that the geomorphic features have a major role in the movement and development of both surface water and groundwater, while the geology determines the characteristics and patterns of the storage layers, stratigraphic sequences and structural zones of hydrogeological systems. Such factors greatly affect surface water runoff from rainfall events, infiltration rates, storage capacity and groundwater table fluctuation in the system.

The infiltration rate and the vertical hydraulic conductivity of the upper layer of the unsaturated/saturated soil would determine, to a great extent, the ability of the system to be recharged from rainfall events.

In most arid regions, the amount of recharge would be in the order of 2% to 10% from the total volume of annual precipitation (Rizk, 1990). This percent depends on the rainfall pattern, distribution and surface characteristics of the catchment area. Alsharhan et al., 2001, indicated that the percentage of recharge form rainfall events is believed to be around 2% of the total precipitation in the UAE.

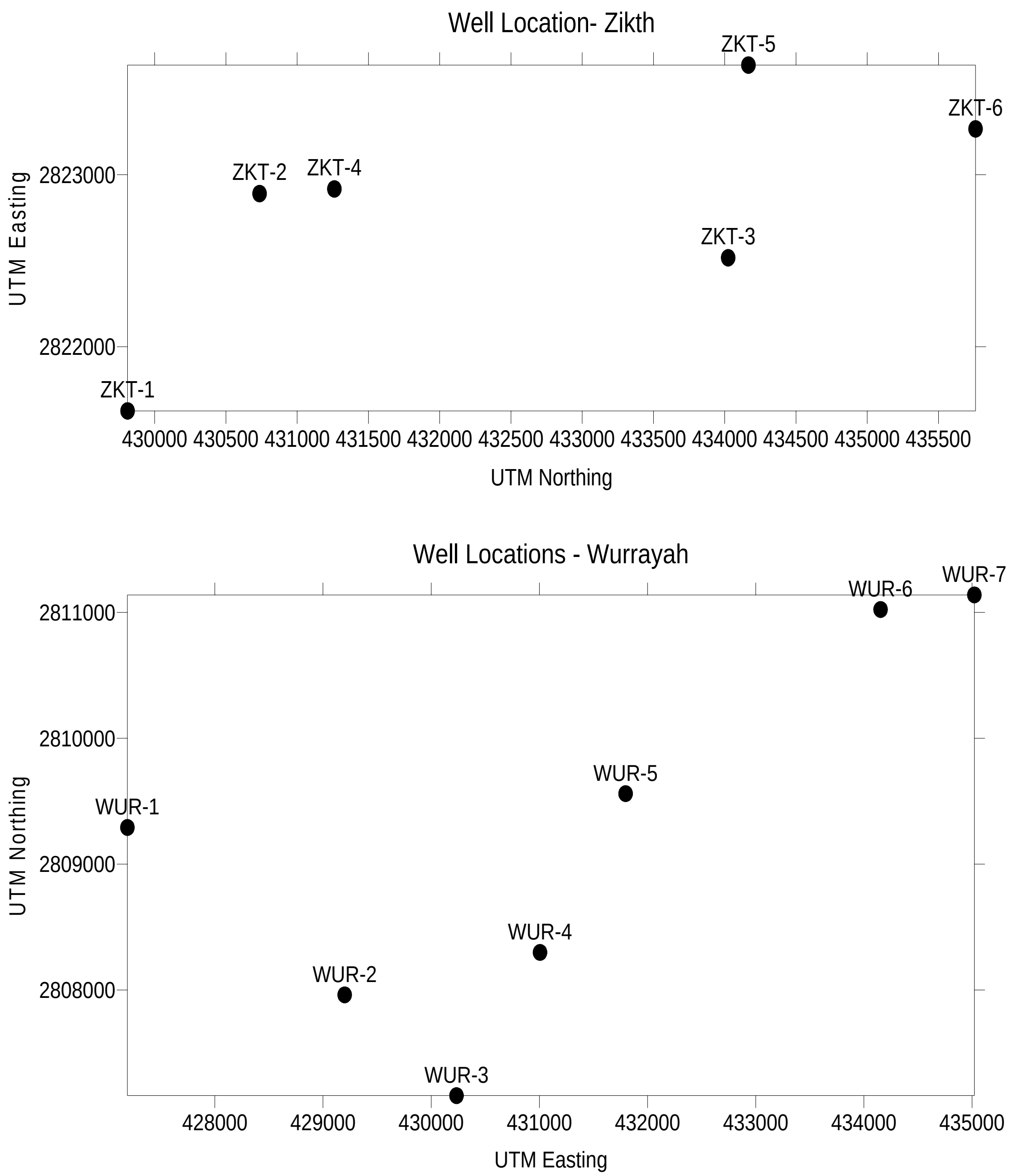

Figure 4.7 Location maps of observation wells in wadis Zikt (Al Ruheib) and Wurayah respectively (modified from Almatari 2010).

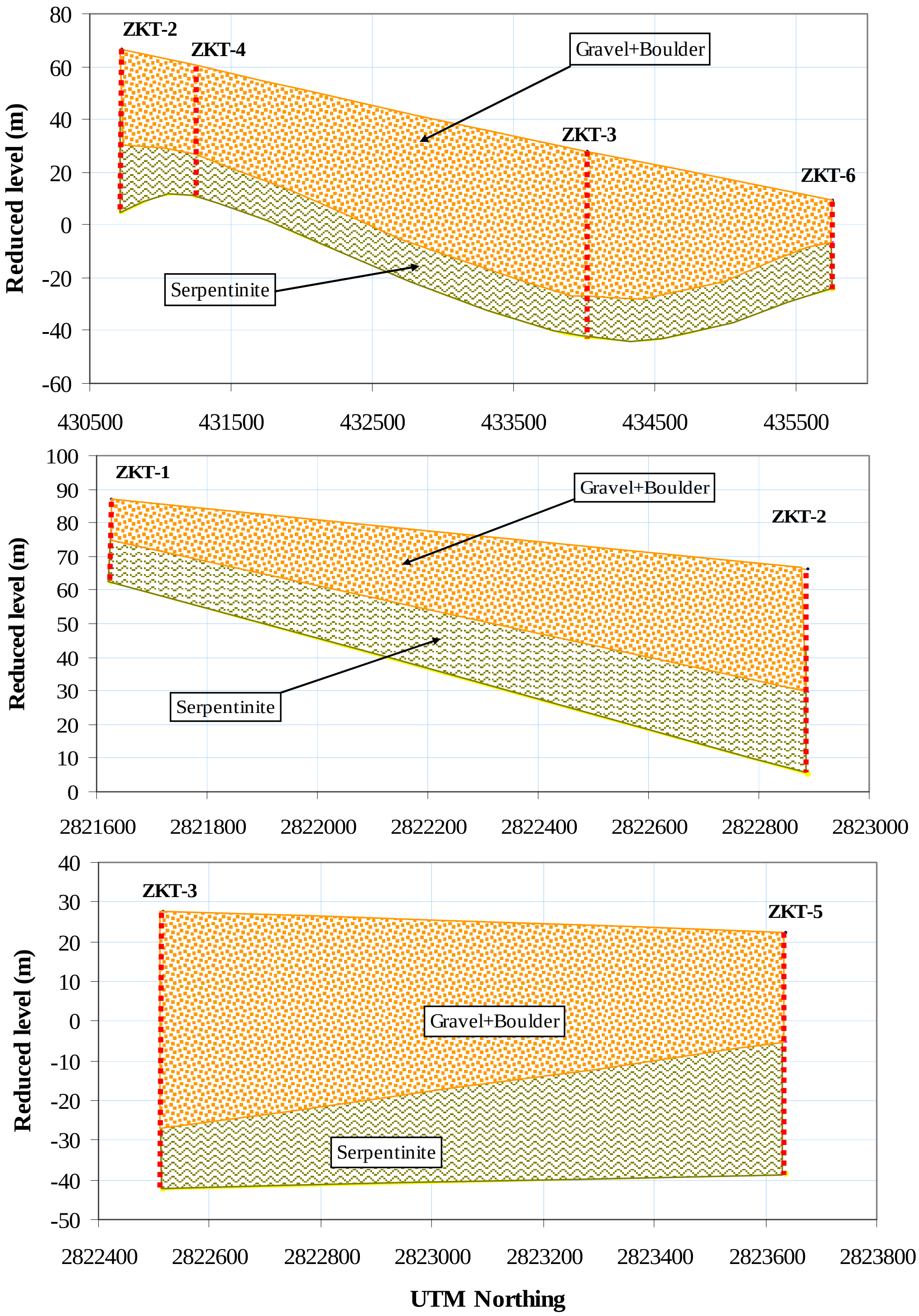

Figure 4.8 Subsurface geologic cross sections along different directions in Wadi Zikt (Al Ruheib). For wells locations see Figure 4.7 (above) (modified after Almatari 2010).

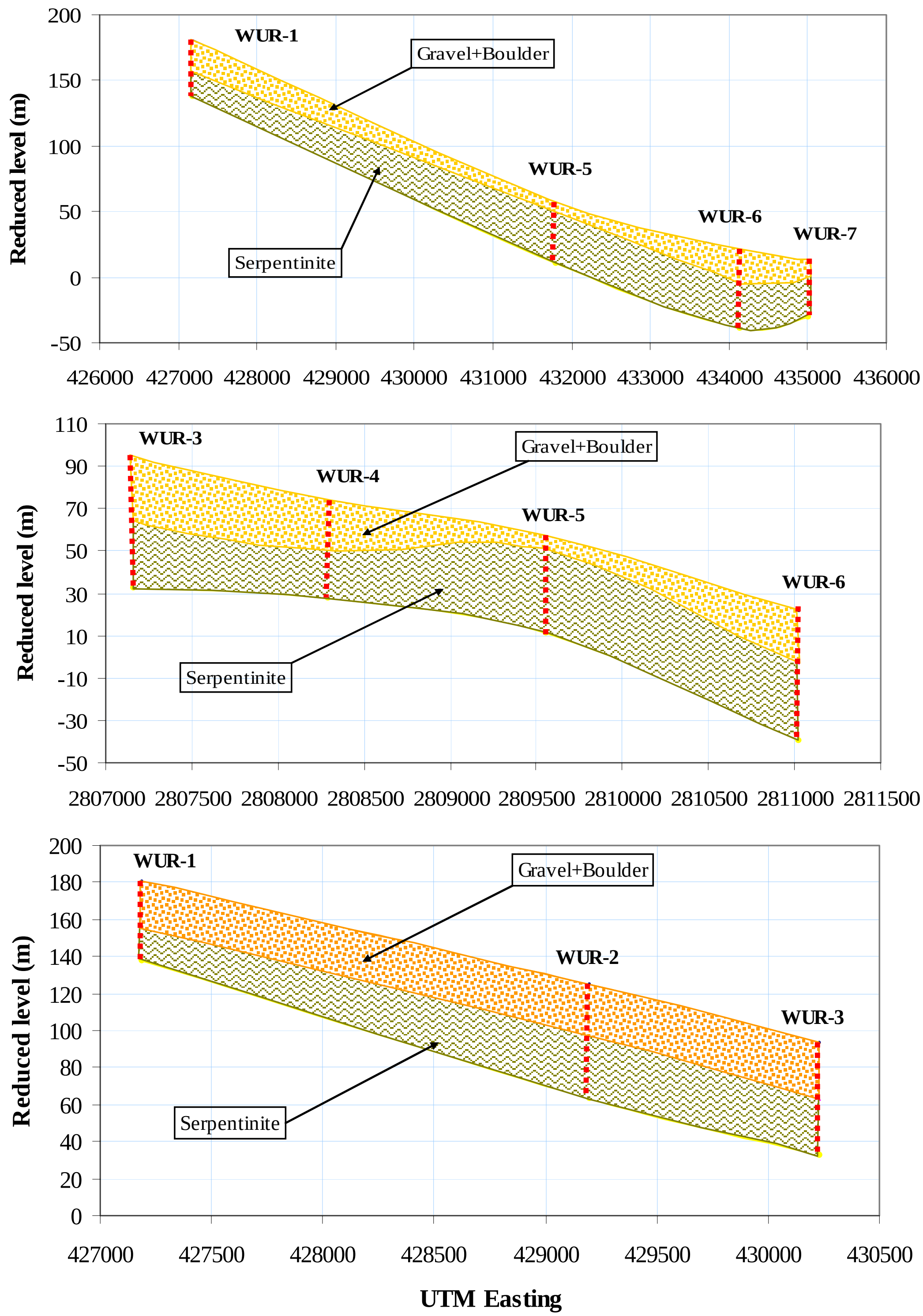

Figure 4.9 Subsurface geological cross sections along different directions in Wadi Wurayah. For wells locations see Figure 4.7 (below) (modified after Almatari 2010).

Picture 4.1 The broad outlet of Wadi Wurayah into the flat gravel plain. Steep ridges of ophiolite outcrops are clear in the back of the photographs.

Picture 4.2 Photograph showing a thick section of alluvial gravel that forms the main fresh water aquifer in the region. Deep in sizing of wadi channel coincided with drop in sea level.