Int. J. Econ. Environ. Geol. Vol. 9 (3)25-32, 2018
Journal home page: www.econ-environ-geol.org

Open Access
ISSN: 2223-957X

Appraisal of Ground Water Potential through Remote Sensing in River Basin, Pakistan

Rakhshanda Sadaf[1], Gohar Ali Mahar[2], Isma Younes[3]

[1]Department of Geology, Federal Urdu University of S &T, Karachi, Pakistan
[2]Department of Geography, Federal Urdu University of S &T, Karachi, Pakistan
[3]Departmentof Geography, Punjab University, Lahore, Pakistan

*****Email: r.sadaf@fuuast.edu.pk

Received: *9 August, 2018* ***Accepted:*** *22 September, 2018*

Abstract: Groundwater is an important source of water supply throughout the world and is one of the vital parts of the hydrological cycle. Its availability depends on the precipitation and recharge conditions. In arid regions, recharge amount is smaller than semiarid regions. Recharge is the basic phenomenon for the sustainability of ground water resources. Pakistan has inadequate water resources and inflow pattern due to arid climate. There are so many factors which make the conditions gradually worst such as increasing population, change in climate condition and misuse of water resources etc. These factors lead to the situation of water scarcity rather than any addition. watershed is positioned at the boundary of Sindh and Balochistan, Pakistan. It is the most important water supply source to Industrial area and the mega city of Karachi, which is getting only about 50 percent of water supply against its fast-increasing requirement. Hab watershed is therefore considered for this study. Remote Sensing and GIS are very effective tools for the assessment and exploration of potential sites of groundwater in any of the watershed. A case study was conducted for the assessment of groundwater potential sites in study area. For this purpose, different thematic layers were created like drainage map, structural and geological map and Overlay analysis was performed and to determine the potential zone of groundwater in the study area.

Keywords: Remote sensing, GIS, image enhancement, groundwater, watershed.

Introduction

One of Earth's most valuable and vulnerable assets is water which signifies the intense requirements of living things and people (WHO, 2012). Groundwater is an important source of water supply throughout the world and is one of the vital parts of the hydrological cycle. Groundwater and surface water are interconnected components of hydrological cycle. This interconnection affects their quality and quantity (Spanoudaki et al., 2010). Drainage water is a major source of water for land use practices throughout the world (Gungor and Arsalan, 2016).

Pakistan is facing high level water deficiency condition. In the words of Asian Development Bank, Pakistan is moving towards the condition of scarcity swiftly and its accessibility to per capita already has crossed its threshold of 1000 cubic meters per year (World Bank, 2006). Accessibility to water resources in Pakistan has also decreased. According to a study, in 1951, it was 5000 cm^3 per head which is reduced to 1000 cm^3 per head in 2010 and is likely to decrease to 600 cubic meters per capita by 2050 (WAPDA, 2010).

Hab river is the major supply of water contribution to Hab industrial area and partly to the mega city of Pakistan, Karachi (Aftab, 1997; Siddique, 2012). At present, Karachi is getting about 50 percent of water against its fastest expanding requirement. Hab watershed, which is a macro watershed regarded as one of the significant sources to be investigated and developed for the nearby and upcoming requirements of the state (Sadaf, 2014).

Groundwater can be an alternative source of water supply for multi-purpose usage and it can be better exploited if potential areas with abundant groundwater can be identified. There are a number of methods such as hydrogeological, geophysical, geological and remote sensing (RS) techniques, which are used to find out groundwater potential zone (Mukherjee, 1996). Conventional methods for the assessment of groundwater potential like geophysical methods, drilling etc. are not enough due to its costs, labor and time, therefore, emerging technologies RS and GIS are very effective for this purpose.

Recently, RS has been increasingly in use to replace conventional methods. RS techniques make it possible to get better assessment and characterization of the land surface, which is very important and effective in hydro-geological studies. Remote sensing is very effective to give a wide-variety of observations and also it is time and cost effective (Jha, 2007, Murthy,2000, Saraf, 2004; Solomon and Quiel, 2006; Tweed et al 2007; Rahman, 2008; Chowdary et al, 2009; Gupta and Srivastava, 2010; Preeja et al, 2011., Choi et al, 2012). Remote Sensing and Geographical Information System (GIS) are the best tools of water related studies (Yahaya et al., 2007; Mahar et al., 2014). These techniques have provided the best and effective means of groundwater exploration (Chowdhury et al., 2009, Meijerink et al., 2007). Many types of hydro-geological information can be extracted space from remote sensing data which can be effectively used in estimation of potential groundwater sites. Remote sensing technology has the ability to efficiently scan huge parts of land, recognize hydrological structures and gauge their physical characters like gradient and pattern etc. It is accepted as being easy to use, cost-effective and a resourceful device to examine earth system processes owing to most recent progress in digital multi-to-hyper spectral devices (Miller, 1993; Miller et al., 1994; Miller et al., 1995).

Study Area

The study area is located at the boundary of Sindh and Balochistan provinces of Pakistan. The catchment area of the river and the lower part of the river is located within the boundary of Balochistan (Fig.1). The study has been conducted for the assessment of potential sites of groundwater in Hab watershed, which is a branch of Porali river system in Balochistan. In this study, Lasbela and Karachi are very important as they are the major segments of Hab basin. Lasbela in size is about 4671361.676 acres out of which 47251.491 acres (approximately 1 percent), have great profitable prospective. Hab Dam reservoir irrigates a large portion of Lasbela. According to soil survey of Pakistan, the soil of Lasbela can be classified in five major physiographic elements.

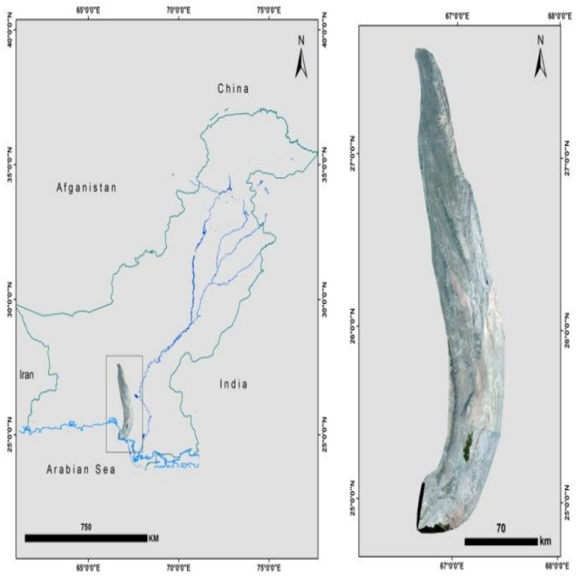

Fig. 1 Location map of study area.

i. Gravelly stony piedmont terraces, ii. Piedmont plains, iii. Piedmont basins, iv. River plains, v. Sandy plain. Very limited availability of hydrological data for this basin makes it tough to examine it hydro-geologically. New plane will also solve left space problem. In general, yearly rainfall rate is low but it takes place as high intensity storm with partial spatial scope. Potential evaporation is high and overflow amount is low and irregular.

Materials and Methods

Present study is mainly based on the Remote Sensing Analysis (RSA) and field visits. Four tiles of Landsat images covering the Hab watershed have been used. Multiple field visits have also been conducted for the accomplishment of RSA. Landsat 7 ETM+, dated 2010 have been downloaded from USGS site (USGS, 2013). Landsat 7 ETM+ images collected after 30 May 2003 have Scan Line Corrector (SLC) off data (http://landsat.usgs.gov/Landsat_7_ETM_SLC_off_data.php, 2013). SLC off data was also found in the studied images. Each band of the image was already ortho-rectified on the datum of WGS-1985 and projection of Universal Transferred Mercator (UTM), zone 42 and in true color composite. In this RSA study, following techniques have been applied (Fig. 2).

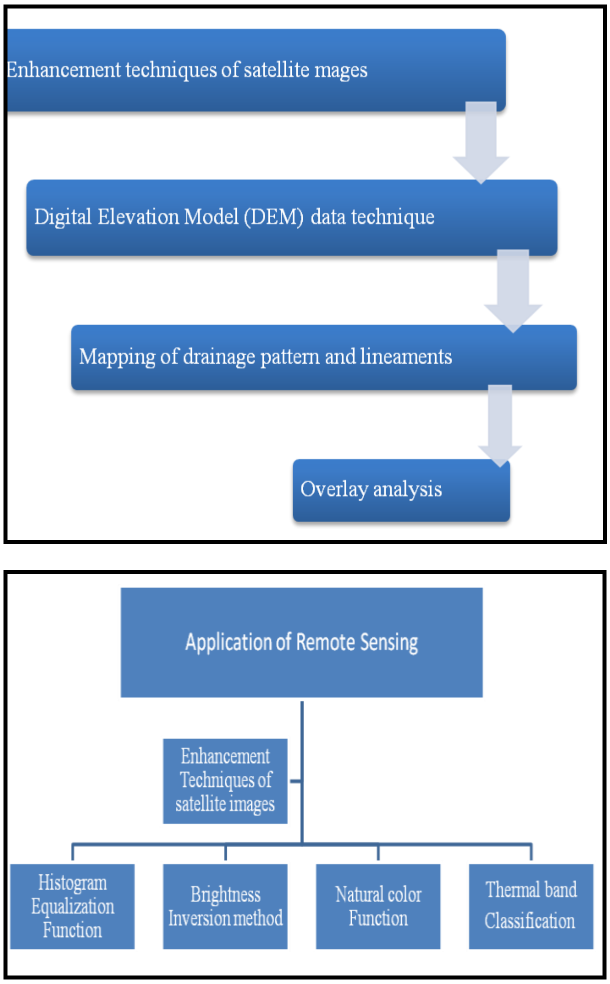

Fig. 2 Methodological framework adopted in this study.

Enhancement of Satellite Images

Image enhancement improves visual understanding of an image. In this function, dissimilar features in an image have been improved by applying special algorithms. Improved image has same information as original one; however, better tone and color of features make it easier to visually distinguish and become comprehensible. It improves an image to a point where it is more appropriate for a particular purpose (Maini and Aggarwal, 2010). Histogram Equalization, Brightness Inversion, Natural Color and Thermal Band Classification functions were considered more suitable for hydro-geological study (Fig 2).

Digital Elevation Model (DEM)

Digital Elevation Models (DEMs) are grid-based GIS coverage which show altitude, which are used to display topographic information. ASTER (Advanced Space borne Thermal Emission and Reflection Radiometer) is an imaging device which gives the excellent quality and high-resolution data with 30 m resolution. In recent study, ASTER data of 30 m resolution with SRTM data is used to demonstrate the flow direction.

Mapping of Drainage Pattern and Lineaments

In recent study, Arc Hydro/Arc GIS is used for the mapping and drainage analysis. Lineaments have been digitized by geologic maps collected from Geological Survey of Pakistan. The geological maps were scanned, mosaic and georeferenced using the projection Universal Transverse Mercator (UTM). Digitized shape files of lineaments were also geo-referenced on the same coordinates system.

Overlay Analysis

Overlay analysis was performed by overlay combination of drainage and lineament, drainage and DEM, lineaments and DEM. This technique is helpful to assess groundwater sources by overlaying of mapped surface structures.

Results and Discussion

Histogram Equalization Function (HEF)

In this study, the Histogram Equalization Function (HEF) was applied to image using the combination of 3, 5 and 7 bands to create pronounced contrast among different hydro-geological features (Fig 3). Histogram equalization is basically an adjustment of normalized pixel values. For doing this transformation, we perform a function that takes the pixel value from the original image and transform them to a pixel value of a different image so for a given image all the pixel values are transformed into exactly the same pixels' place with a new value. The decisions are made only on the basis of pixel values not on the neighborhood pixels i.e. the values of the pixels around the pixel.

For a histogram with a distribution S defining the probability of a pixel value, which is basically looking for a transform *T*, we have a map like;

$$S = T(r)$$

So, the relationship between these two distributions is

$$P_s(s) = P_r(r)\left|\frac{\partial r}{\partial s}\right|$$

So, for s transform S for every pixel value T and current probability distribution *P(w)* by integrating the number of pixels to achieve a given value from *0* to *r* over a probability function

$$S = T(r) = (L-1)\int_0^r P_r(w)\partial w$$

$$\frac{\partial S}{\partial r} = \frac{\partial T(r)}{\partial r} = \frac{\partial (L-1)\int_0^r P_r(w)\partial w}{\partial r} = (L-1).P_r(r)$$

The inversion of this expression would result in

$$\frac{\partial r}{\partial s} = \frac{1}{(L-1).P_r(r)}$$

Computing new distribution from the old distribution would achieve histogram equalization

$$P_s(s) = P_r(r)\left|\frac{1}{(L-1).P_r(r)}\right| = \frac{1}{(L-1)}$$

HEF has distinctly marked the geological as well as hydrological characteristics of the Hab drainage basin. Vegetation cover is more visible in band 3. Similarly, geology and land water contrast was observed in band 5 and band 3, 5, 7 combinations. Some small water patches have been identified in the catchment area and Hab dam is also visible in enhanced image. In catchment area near the Dhureji and surrounding of Meher mountain, vegetation patches also can be seen. During the field survey, this area was identified as cultivated land with randomly dispersed villages. Large area of vegetation cover was also observed to the south of Hab river.

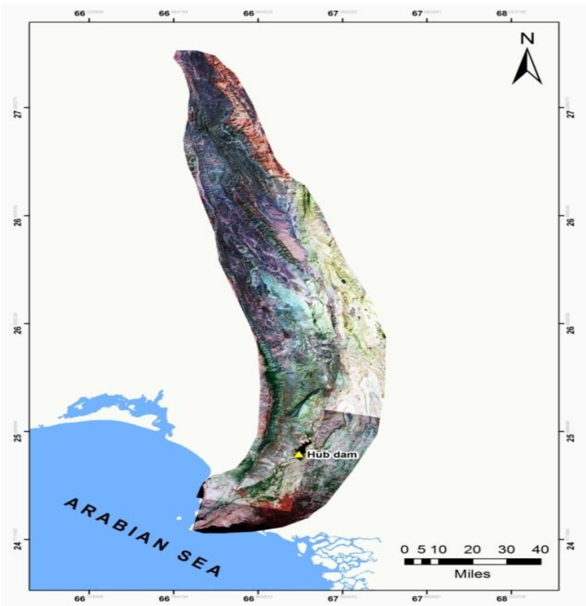

Fig. 3 Enhanced map of study area by histogram equalization function (HEF).

Bright Inversion Function / Inverse Compositing

Generally, it is observed that the details of the darker features are not very clear sometimes i.e. they are obscured. Likewise, sometimes lighter features are also not visible due to higher reflectance. The Brightness Inversion Function (BIF) was applied by using the combination of 4, 3, 2 bands to obtain details of darker, lighter or obscure features, sharp and clear image (Fig. 4). This function inversely displays the reflectance of features. BIF enhanced image differentiated the details of the objects, which were camouflaged because of very dark tones during the HEF filtering like vegetation covers and water found on the image are darker in HEF whereas they become brighter in BIF. Figure 4 displays geological and hydrological features more prominently like tributaries of the river. This figure displays many linear patches of Hab river with brighter tone. Alluvium patches with darker tone have been observed at some locations of the catchment area. Some brighter patches of vegetative cover can also be seen in brighter tone.

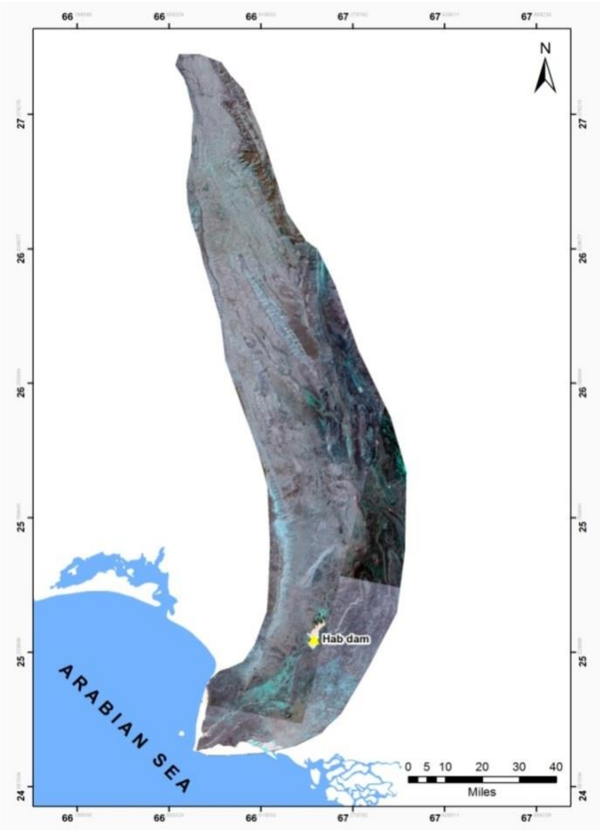

Fig. 4 Enhanced map of study area by BI F.

Natural Color Function /Natural Compositing

Natural Color Function (NCF) with the combination of 3, 5 and 7 bands were applied which enhanced the image with real colors. The NCF enhanced image shows the natural color and sharp contacts of the rocks, faults, fractures and river courses and vegetation covers also became very prominent after enhancement (Fig. 5).

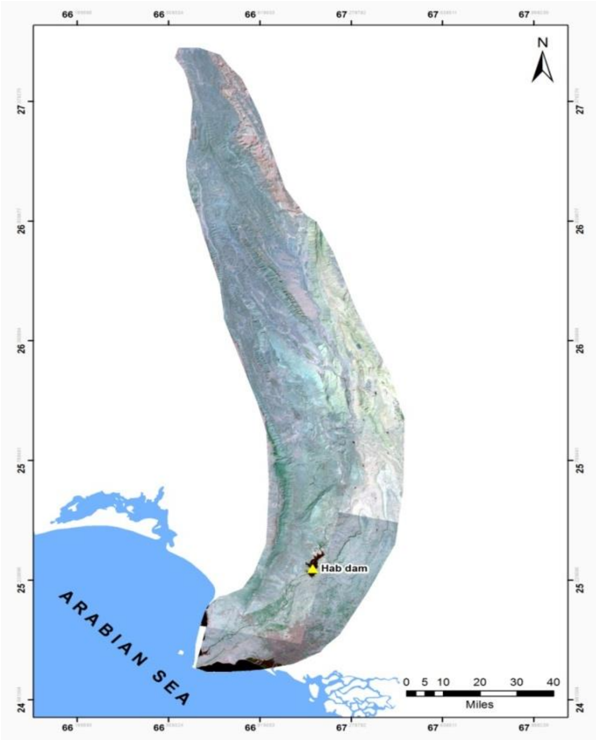

Fig. 5 Enhanced map of study area by N C F.

During the RSA study, it was observed that the natural color enhancement distinctly classified the presence of near surface varying moisture within the sand-silt-clay deposits of the valley's channels. South of Hab dam and southeastern part show large areas of vegetation cover with some agricultural features. Water storage of Hab river is also very prominent. NCF enhancement has delineated the geological and hydro-geological features of the basin very similar to the HEF enhancement, where same bands were used. In fact, the tonal differences between these two enhancements are more prominent in HEF as compared to NCF. Thus, more or less, the hydro-geological interpretations are the same except the fact that NCF has very prominent vegetative covers.

Thermal Band Classification

Thermal band was also used for analysis. Classification was applied by stretching the digital numbers (DN) values into colors on the image. Thermal band has a vital role to monitor the variations in temperature associated with different geological components. Thermal band clearly differentiated between the areas of low temperature and high temperature, moist and dry soils and vegetation. It has also differentiated the courses of the river beds with reference to water moisture and vegetation (Fig. 6). Different thermally classified outputs are found from thermal band analysis. Features on the either sides of the Hab river are also visible from thermal classification. In the downstream area after the Hab dam, synclinal features indicated by the low thermal values and anticlinal features are indicated by high thermal values. Some sharp light green shades found in the north of Hab dam on either side of the river indicate the low values. However, these are shadows of the western sides of anticlines. Low DN values on the eastern side of the Hab dam indicate a large basin with potential of groundwater. The sky-blue colors in the upper catchment area indicate the river tributaries with potential of groundwater.

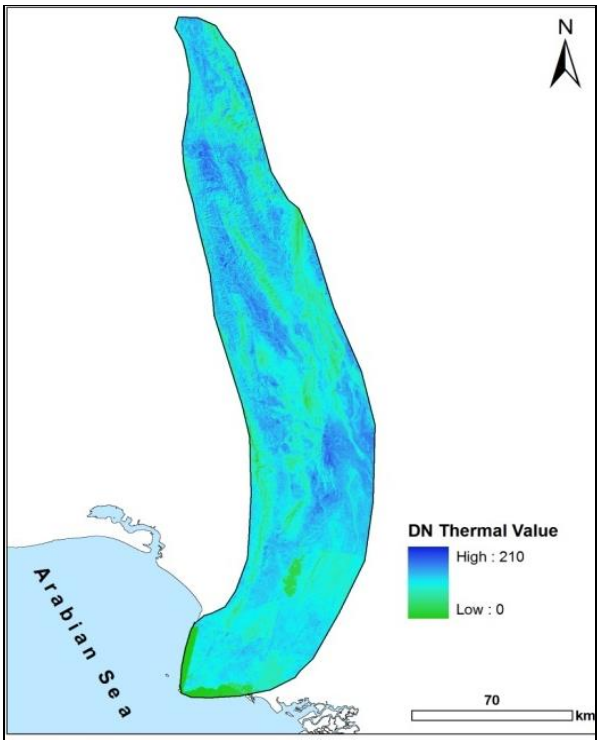

Fig. 6 Land surface temperature map.

Analysis of Digital Elevation Model (DEM)

Analytical process was performed on SRTM image of the study area (Fig.7) which provided many results including gradients near the tributaries and on main stream. Similarly, catchment area is found on high altitude which shows abrupt changes towards the lower (southern) side of the river. Color shaded map through DEM data also supports the complications of geology of the Hab river basin. Drainage and DEM maps have a correlation pattern. Map shows the linear features parallel with river. Sharp linear features also show the steepness of their characters. A shaded relief map has been developed on the DEM file to study the topography of the study area (Fig. 7).

Drainage System

The main stream of the river is flowing from the catchment of the Hab river to Hab dam area (Fig. 8). Drainage pattern shows that there is no meandering and sinuosity in the main stream of the river. River path is irregular, small tributaries are converging and drainage pattern seems to be geologically controlled. It has long catchment, therefore in rainy season; huge amount of water is contributed into the river which flows from upper catchment area to south. As the water is stored at Hab dam, surrounding groundwater area of dam is recharged to higher level. The Hab dam water storage is the main source which contributes in recharging the groundwater level of low-lying area of Hab river, has a perennial to subperennial flow mostly during the extensive arid period and waterway reduces in size to a series of pool. The irregular flow is a unique feature of dry weather. Hab river course follows North South trend. It runs with the length of the margin of Balochistan and Sindh province and deplete in to the Arabian sea. Drainage pattern of Hab river shows that flow of the river is not smooth and straight from origin to its destination into the Arabian sea. Several sharp turnings of the course and abrupt angular flow have been observed on many conjunctions of the river. In the uppermost catchment area, it has many sources which converge into the main stream towards south. In many places 90˚ turning was found. This pattern of angular turning of river tributaries has also been observed during field visits. Extracted lineament map of the Hab river supports the idea that the Hab river is geologically shaped and controlled by the faults and fractures found in and around the Hab river. Based on observations related to drainage flow trends and other hydro-geological conditions reported during the field work, it inferred that the fault/fracture zones have caused the rectangular flow patterns in whole Hab drainage basin. Such hydrogeological conditions can provide vertical as well as horizontal multiple intersectional inter-exchangeable aquifers, which need to be further investigated in detail.

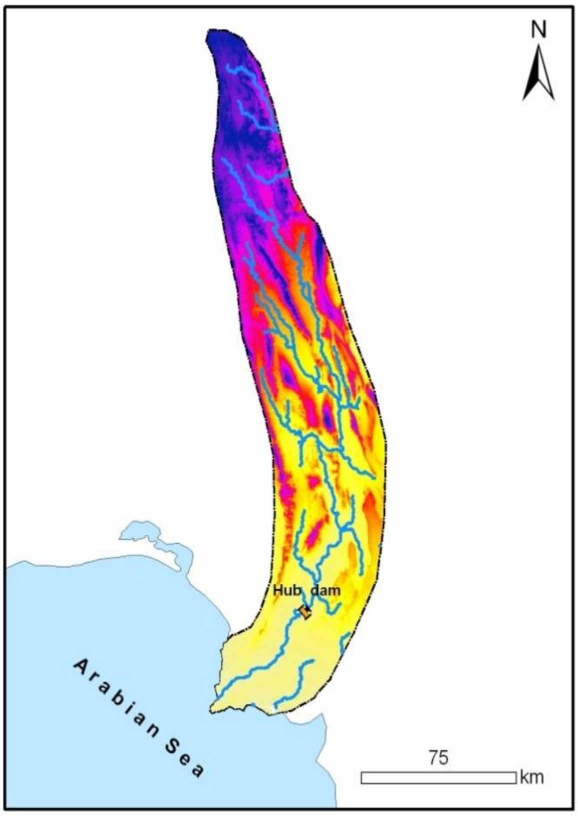

Fig. 7 Drainage pattern map of study area.

Fig. 8 Drainage map of study area.

Faults and Fractures

Hab river is surrounded by the high density of faults and fractures (Fig. 9). Uppermost catchment and middle part has highly dense structures of lineaments. Faults passing through the mountain and rivers support the idea that these tributaries and runoff from the catchment share the surface water with the subsurface and with the same flow direction towards the south. It has high gradient area with mountains in its long catchment area. In south, low gradient has been found which can store water coming from high gradient area of north. Therefore, it can be stated that groundwater and fault to the south have the capacity to store in the southern part.

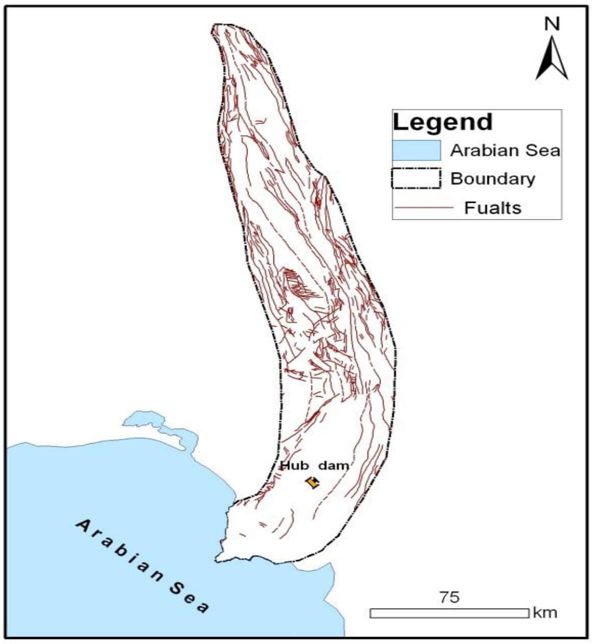

Fig. 9 Faults and fractures map of study area.

Overlay Analysis

Overlay analysis of drainage with structural features like faults and fractures shows tributaries, runoff, faults and fractures have relation to divert the water flow towards the main stream of the river (Fig.10). Mostly, the faults directions have been found parallel with the direction of river. Fractures with high density have also been found on many places near the river tributaries. Fractures, faults and river flow directions have developed a system in which rainfall water flows on the surface and percolates to groundwater through the fracture zone areas. Water percolated through the fractures and alluvium material in upper catchment area moves downward by groundwater. This water flows through faults towards south. Surface and subsurface water moves southward whereas high gradient in the catchment support this flow system.

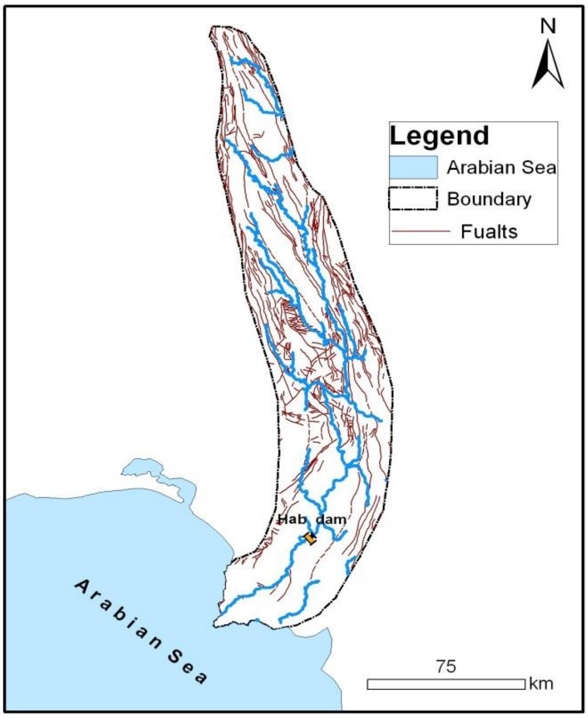

Fig. 10 Overlay map of study area.

Conclusion

Many specific studies have been carried out during the last few decades on Hab river either to explore or to manage the groundwater resources in the area. Hab dam is one of the achievements of those studies. It not only feeds Hab industrial area and Karachi city but also the agriculture of the surrounding areas of Hab and downstream. In spite of the fact, Hab river is perennial and seasonal in nature and has direct response to the erratic rainfall. This basin has surface and groundwater potential.

Hab watershed is systematically analyzed through Remote Sensing and GIS.

Many Remote Sensing and spectral enhancement techniques are applied and results are incorporated with other thematic layers generated through GIS. Assessment of existing hydro-geological condition of Hab river basin and its surrounding regions with satellite images has been carried out which provided the preliminary understanding about the status of potential groundwater sites, geology, geomorphology and hydro-geological characteristics. Hab river basin is significantly covered by sedimentary rocks, with alluvium deposited within their courses. Present study explains that most of the courses apparently show better groundwater conditions, which are mainly based on groundwater from the aquifers. Human settlements, agriculture and natural vegetation have also been observed around these courses. The interpretation of the enhanced satellite images shows that Hab river basin is a dense watershed with large catchment and a big water storage in north of the Hab city. Many small patches of potential groundwater have been identified during the remote sensing analysis, where potential of groundwater and potential of agriculture could occur. Overlay analysis of the drainage pattern, with DEM and fault maps supports the groundwater flow trend from catchment area. It is inferred that hydrogeological conditions associated with the drainage of the Hab river indicate substantial groundwater that discharges into the Arabian sea.

References

Aftab, M. (1997). Hydrogeology and groundwater resources of Balochistan, Pakistan, An overview. *ACTA Mineralogical Pakistanica*. **8**, 30-38.

Choi, W., Galasinski, U., Cho, S. J., Hwang, C.S. (2012). A spatiotemporal analysis of groundwater level changes in relation to urban growth and groundwater recharge potential for Waukesha County, *Wisconin Geographical analysis*, **44** (3), 219-234.

Chowdary, V. M., Ramakrishnan, D., Srivastava, Y. K., Chandran, V., Jeyaram, A. (2009). Integrated water resource development plan for sustainable management of Mayurakshi watershed, India using remote sensing and GIS. *Water Resources Management*, **23** (8), 15811602. DOI.org/10.1007/s11269-008-9342-9

Chowdhury, A., Ja, M. K., Chowdary, V. M., Mal, B. C. P. (2009). Integrated remote sensing and GIS-based approach for accessing ground water potential in west Medinipur district, west Bengal, India. *International Journal of Remote Sensing*, **30** (1), 231-250.

Gungor, A., Arslan, H. (2016). Assessment of water quality in drainage canals of Carşamba plain, Turkey, through Water Quality Indexes and Graphical Methods. *Global NEST Journal*, **18** (1), 67-78.

Gupta, M., Srivastava, P. K. (2010). Integrating GIS and remote sensing for identification of groundwater potential zones in the hilly terrain of Pavagarh, Gujarat, India. Water International, **35** (2), 233-245.

Jha, M. K, Chowdhury, A., Chowdary, V. M, Peiffer, S. (2007). Groundwater management and development by integrated remote sensing and geographic information systems: prospects and constraints. *Water Res. Management*, **21**, 427-467.

Mahar, G. A., Al Amri, N., Aburizaiz, O. S. (2014). Spatiotemporal change assessment using normalized difference vegetative index and spatial analysis techniques for vegetation cover on wadi auranah. *Global Nest Journa*l, **16** (5), 955-965.

Maini, R., Aggarwal, H. (2010). A Comprehensive review of image enhancement techniques. *Journal of Computing*. **2,** ISSN 2151-9617.

Meijerink, A., Bannert, D., Batelaan, O., Lubczynski, M., Pointet, T. (2007). Remote Sensing applications to groundwater, Paris, France, IHP-VI. pages. 304.

Miller, R. L., De Campo, J. D., Leming, T., Hughes, K. (1995). Affordable solution for analyzing coastal processes using remotely sensed data, proceedings of the third thematic conference, remote sensing for marine and coastal environments, 308-314 Seattle, WA.

Miller, R. L., De Campo, J. D. (1994). C COAST: A P C Based Programmed for the analysis of coastal processing using NOAA coast watch data. *Photogrammetric Engineering and Remote Sensing*, **60** (2), 155-160.

Miller, R. L. (1993). High resolution image processing on low cost microcomputers. *International Journal of Remote Sensing*, **14**, 655-667.

Mukherjee, S. b (1996). Targeting saline aquifer by remote sensing and geophysical methods in a part of Hamirpur- Kanpur, India. *Hydrogeology Journal*, 19,53-64.

Murthy, K. S. R. (2000). Ground water potential in a semi-arid region of Andhra Pradesh - a geographical information system approach. *International Journal of Remote Sensing*, **21** (9), 1867-1884.

Preeja, K. R, Joseph, S., Thomas, J., Vijith, H. (2011). Identification of groundwater potential zones of a tropical river basin (Kerala, India) using remote sensing and GIS techniques. *Journal of Indian Society Remote Sensing*, **39** (1):83-94.

Rahman, A. (2008). A GIS based drastic model for assessing groundwater vulnerability in shallow aquifer in Aligarh, India. *Applied Geography*, **28**, 32-53.

Sadaf, R. (2014). Watershed modeling of Hab river valley, Balochistan Pakistan through RS and GIS techniques. Published Ph.D. dissertation. Department of Geography, University of Karachi.

Saraf, A. K., Choudhury, P. R., Roy, B., Sarma, B., Vijay, S., Choudhury, S. (2004). GIS based surface hydrological modelling in identification of groundwater recharge zones. International Journal of Remote Sensing, **25** (24), 5759-5770.

siddique, a. (2012). Temporal variability of disinfection by-products concentration in urban public water system. Global NEST Journal**, 14** (4), 393-398.

Solomon S, Quiel, F. (2006). Groundwater study using remote sensing and geographic information systems (GIS) in the central highlands of Eritrea. *Hydrogeology Journal,* **14**(5), 729-741.

Spanoudaki, K., Nanou-Giannarou, A., Paschalinos, Y., stamou, A. I. (2010). Analytical solutions to the stream-aquifer interaction problem. A critical review. *Global Nest Journal,* **12** (2), 126-139.

Tweed, S. O., Leblanc, M., Webb, J. A., and Lubczynski, M. (2007). Remote sensing and GIS for mapping groundwater recharge and discharge areas in salinity prone catchments, Southeastern Australia. *Hydrogeology Journal*, **15 (**1), 75-96.

USGS, (2013). Using Landsat 7 Data, In: Landsat Mission. United States Geological Survey http:// landsat.usgs.gov.

World Health Organization**.** (2012). World Water Day report, water for Health- Taking Charging. Geneva Switzerland. http://www.worldwaterday.org

WAPDA, (2010). Hydro potential in Pakistan, Water and Power Development Authority, Pakistan. Web site: www.wapda.gov.pk.

World Bank, Pakistan. (2006). Strategic Country Environmental Assessment. Washington, DC: World Bank

Yahaya, A. N., Issa, A. K., Yusof, K.W., Arof, Z. A. (2007). Exploration of groundwater by integrated modeling using remote sensing and geographical information System in Kedah and Perlis. pilot study and data Analysis. *Map Asia* 2007, Kuala Lumpur.