IJMRSETM

e-ISSN: 2395 - 7639

INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH

IN SCIENCE, ENGINEERING, TECHNOLOGY AND MANAGEMENT

Volume 10, Issue 5, May 2023

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

Impact Factor: 7.580

+91 99405 72462 +9163819 07438 ijmrsetm@gmail.com www.ijmrsetm.com

International Journal of Multidisciplinary Research in Science, Engineering, Technology & Management (IJMRSETM)

| ISSN: 2395-7639 | www.ijmrsetm.com | Impact Factor: 7.580| A Monthly Double-Blind Peer Reviewed Journal |

| Volume 10, Issue 5, May 2023 |

Underground Water Resources (A Geographical Appraisal of Luni Basin)

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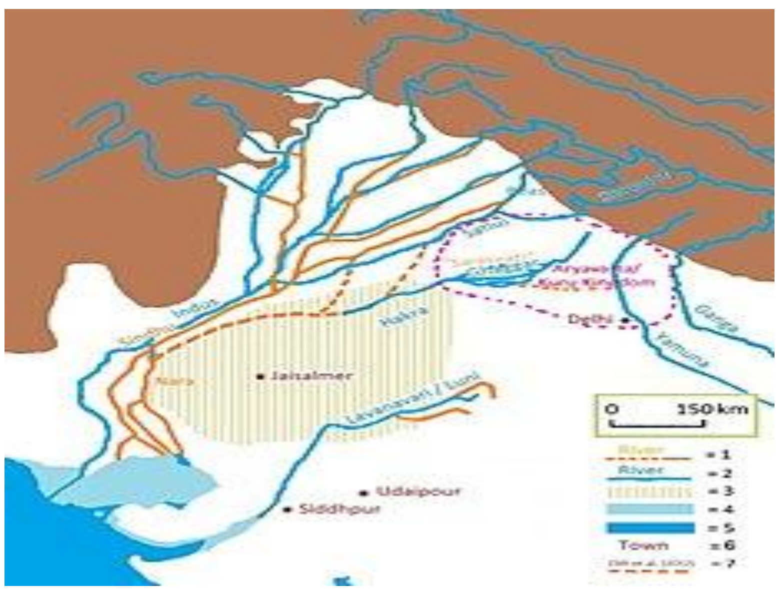
ABSTRACT: The Luni is the largest river in the Thar Desert of northwest India.[1] It originates in the Pushkar valley of the Aravalli Range, near Ajmer, passes through the southeastern portion of the Thar Desert, [27]and ends in the marshy lands of Rann of Kutch in Gujarat, after travelling a distance of 495 km (308 mi). It is first known as Sagarmati, then after passing Govindgarh, it meets its tributary Sarasvati, which originates from Pushkar Lake and from then on it is called Luni.[2]

In 1892, Maharaja Jaswant Singh II of Jodhpur constructed Jaswant Sagar in Pichiyak village between Bilara and Bhawi of Jodhpur district. It is one of the largest artificial lakes in India and irrigates more than 12,000 acres (49 km^2).[2] It is one of the internal drainage rivers in India; it does not meet with Arabian Sea. It is drained before it reaches the Arabian Sea.

KEYWORDS: Luni, water resources, Thar desert, Rajasthan, marshy lands, Pichiyak village, geographical

I.INTRODUCTION



Course of River Luni or Lavanaravi river, south of the estimated route of the ancient Sarasvati river

The Luni is also known as the Lavanavari or Lavanavati, which means "salt river" in Sanskrit, due to the high salinity of its water.[2] The Luni River basin is 37,363 km², which includes all or part of the Ajmer, Barmer, Jalore, Jodhpur, Nagaur, Pali and Sirohi districts of Rajasthan and the Banaskantha and Patan districts of northern Gujarat. Its major tributaries are the Sukri, Mithri, Bandi, Khari, Jawai, Guhiya and Sagi from the left and the Jojari from the right.[1]The Luni River begins near Ajmer in the Pushkar valley[28] of the western Aravalli Range at an elevation of about 550m. At this point, the river is also known as the Sagarmati. The river then flows in the southwest direction through the hills and plains of the Marwar region in Rajasthan. The river flows south-west and enters the Thar Desert before dissipating into the Rann of Kutch, traversing a total of 495 km.[29] In spite of the high salinity, it is a major river in the region and serves as a primary source of irrigation. The Luni is not saline until it reaches Balotra, where high salt content in the soil

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impacts the river.[1]The Luni may have been the southern portion of the historic Ghaggar-Hakra river channel.[1]The Jawai, Sukri, Guhiya, Bandi and Jojari rivers are the main tributaries of Luni river. The Jojari is the only tributary that merges to the right-bank of the river while other 10 tributaries reach its left bank.[30] All the tributaries except Jojari originates from the Aravalli hill.[3][4][5]

The dams in Luni river are:[3]

- Sipu dam
- Jaswant Sagar Dam - built in 1892 by Maharaja Jaswant Singh.It is one of the largest artificial lakes in India.

The two major irrigation projects on Luni river are Sardar Samand and Jawai dam.[3]

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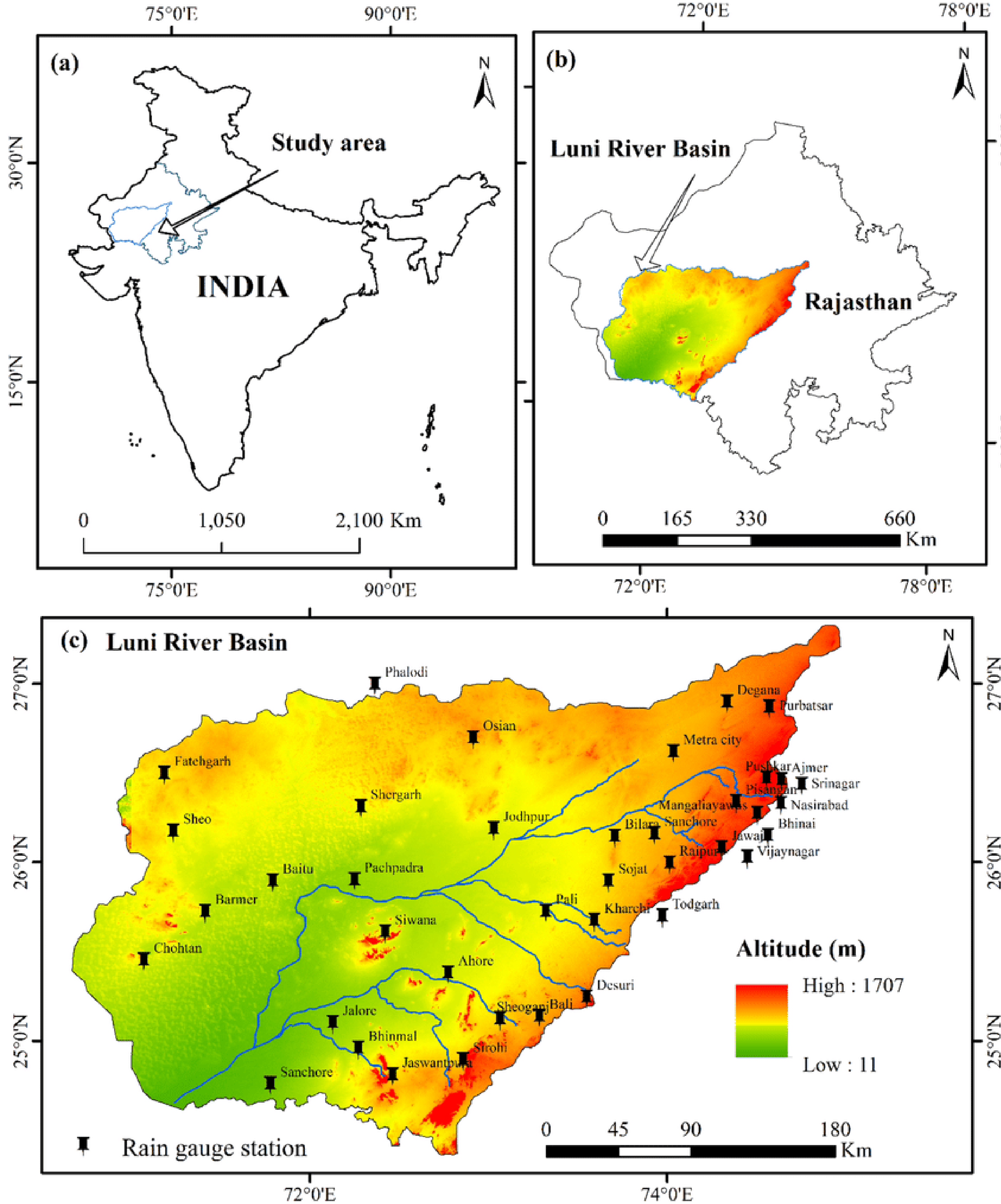

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Sardar Samand dam was constructed in 1905.Flash floods have occurred in the Luni river as the river flows on a shallow bed and the riverbank soil is easily flattened by the rain water.[3]The worst flood happened in 2006, when the desert region received heavy rain. The water levels rose to 15–25 feet submerging the surrounding region. [31]The 2006 flash floods caused water levels to rise to as high as 15–25 feet submerging many parts along the river in the Barmer district. A large number of people and animals died in the flood.[3]In 2010, another flood occurred but there were less casualties.[3]The fish diversity assessment of Luni river led by ICAR-National Bureau of Fish Genetic Resources, Lucknow from October, 2018 - November, 2019 reported the occurrence of 27 species belonging to 22 genera, dominated by Cyprinids.[32] The highest fish diversity of 12 species was reported in Samdhari and Gandhav. In this study, the wide distribution of Invasive Fish Species such as African Catfish (*Clarias gariepinus*) and *Mozambique tilapia* (*Oreochromis mossambicus*) were also reported from the river Luni.[6]

The Luni river basin has been evolved as a result of typical hydrogeomorphic processes of arid zone, operating under the influence of active tectonic lineaments. [33]A detailed analysis of stream morphology in relation to geology and lineaments carried out on selected windows indicated the morphological control of the streams while flowing over the lineaments from the eastern to the western part of the basin. Typical valley fills indicated by dark green tone on digitally processed images and the pediments showing greenish white tone appear in sharp contrast and indicate respectively the graben and horst structures. [34]A detailed identification of lineaments for the georesources and geological evaluation has been carried out. Earlier analysis carried out on Bouguer anomalies correlate with graben and horst structures in the subsurface. Quaternary sequences have been dated from 80 ka to 3 ka indicating a range of fluvial to aeolian deposits reflecting prevailing climatic conditions. However, the changes in sediment type from coarse and mixed of all size grades to fine in a vertical litho-column warrant further studies on fine resolution stratigraphy and high resolution[4] stratigraphy for understanding climatic variations[35] in the region. Luni basin being the major fluvial basin of the Thar desert in western India is an active tectonic basin where more than 300 m sediment accumulation has been reported (Bajpai et al 2001a). This is possibly due to subsidence in response to E-W faulting along the Sukri river (Henry et al 1983). [5]Deposition has taken place over an uneven basement as indicated by negative gravity anomalies across the basin (Bajpai et al 2001a). The basin is traversed by major lineaments: JaisalmerBarwani lineament trending NW-SE, Luni-Sukri lineament trending NE-SW (Ramasamy et al 1991; Dhir et al 1992), which intersect in the southwestern part of the basin at Jhab (Pal 1991) and partly Tonk-Raisinghnagar lineament NW-SE (Roy and Jakhar 2001) and also by several parallel major and minor lineaments.[6] Lineaments have controlled the channel processes and the spatial distribution of flood damages (Kar 1994). Delineation of lineaments is significant in terms of locating groundwater resources,[36] and oil reserves particularly in the Barmer region. Climate in the basin is semi-arid. Torrential and episodic rainfall (Bell 1979; Sharma and Chatterji 1982; Sharma et al 1984; Wheater 2002), intense physical weathering (Goudie and Wilkinson 1977), sparse vegetation cover (Pilgrim et al 1988) and aeolian surface deposits[7] (Jones 1981) give rise to an overall abundance of transportable material of all size grades (Reid and Frostick 1987). Flash flood regime further favours the availability of a higher volume of sediments and consequent influx and accumulation gives rise to thick sediment deposits (Abdullatif 1989). Besides nearly 400 times of the bedload sediment transport is possible by the ephemeral rivers in contrast to its perennial counterpart in the humid zones [37](Laronne and Reid 1993). Inspite of the work carried out on the different aspects of the Luni basin,[8] work is still required on the following:

• A detailed classification of major and minor lineaments and their influence on hydrogeomorphic processes.

• A co-relative evaluation of the lineaments for georesources.

• Type of geological material filled in the basin at least to a shallow depth of about 50 m. [9]

• Relation of aquifer geometry with major and minor lineaments. In view of the above, a detailed map showing major and minor lineaments has been prepared and the relation of lineaments with geological and geomorphic situation has been worked out. [38]

Field survey of hydrogeological sections along E-W reported in the earlier work (Bajpai et al 2001a) based on tube well lithologs have been utilized to find out the relation of aquifer geometry with lineaments. A co-relative evaluation of lineaments has also been provided in terms of georesources.[39]

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II.DISCUSSION

Field survey and investigations were carried out of geological material excavated out of various dug wells and tube wells, right from east to west. Mostly mixed material of all size grades, rounded to angular, and alternating with fluvial clay, kankar and sand and aeolian fine sand dominate. The geological material in the wells from east to west and above the basement consists of pebblycobbly conglomerate, gravel, coarse sand, fine sand, calcrete and clay. Calcrete and fine sand increase towards Jodhpur. Towards the west and central part of the basin, depth to basement is limited to the order of 18 to 20 m. Further west towards Jalor and Sindari, the thickness of alluvium increases.[40] At Sindari, the rhyolite basement occurs at a depth of 42 m. To the SW of Jalor the thickness increases towards Sanchor to an extent of about 300 m along the LuniSukri lineament extending in NE-SW direction[10]. The thickness of Quaternary sediments reduces considerably to the NE of Jalor to the west of Pali following the Luni-Sukri lineament zone. It is possible that the Luni-Sukri lineament in this region behaves like a hinge fault with increased throw towards SW, thus accommodating greater thickness of alluvium towards SW. Besides, the block developed in this region (around Sanchor) by intersection of Jaisalmer-Barwani and LuniSukri lineament at Jhab,[41] must have subsided more as compared to other blocks, thus giving rise to increased thickness of sediments. Luni-Sukri lineament appears to recharge groundwater from NE, as the artesian conditions have been found at Bijrol Ka Golia (N of Sanchor) situated towards SW of the basin,[11] where the thickness of sediments is more than 300 m. On the basis of the availability of the geological material in the basin, general comments on the hydrogeological evolution can be made: The basin had uneven basement topography with the occupation mostly of Erinpura granite and Malani granite and rhyolite, followed by Bilara limestone, Girbhakar and Sonia sandstones of Marwar Supergroup towards NE. In the west, to the outside of the basin the Malani rhyolites and granites occur in faulted contact with CretaceousCarboniferous sequences.[12] On such a basement, the Quaternary deposits have evolved though the deposition of material of all size grades and changing roundness. However, the presence of Tertiary formations, below the Quaternary sediments cannot be ruled out, particularly in the southwestern part of the basin. In the lower part of the Luni basin which receives a precipitation between 200 mm and 300 mm,[42] 6 distinct depositional environments have been identified (Jain and Tandon 2003) in the late Quaternary type II successions. These depositional environments are (a) Gravel bedload braided streams, [13](b) ephemeral sand bed streams, (c) sediment gravity flows (sheet flows), (d) sheet flows, (e) mixed load meandering streams and (f) aeolian dunes. Out of the sections described by Jain et al (2003), gravel-sand bedload braided streams during Oxygen Isotope Stage (OIS) 5, generally occurs at the base of these sections. The relatively older deposits near Khudala (> 90 ka) perhaps deposited at the beginning of late Pleistocene succession (OIS 5e) are without flood plain development. Lesser wet phases such as OIS 3 are represented by sediment gravity flows and ephemeral sand bed streams. The aeolian phase was followed with a gap by fluvial activity around 14 ka with incision and later deposition by gravel bedload braided streams (OIS 1). OIS 1 (11–14 ka) was a period characterized by high frequency climatic fluctuations and shows a spectrum of gravel-sand braided, meandering, sand bed ephemeral streams and aeolian. A second phase of incision occurred during the early Holocene,[43] this was followed by sheet flow aggradation between 5 and 9 ka corresponding to rapidly fluctuating lake levels during the early and middle Holocene (Enzel et al 1999). During the arid phase around 3 ka the streams became defunct as evident by the presence of aeolian dunes in the stratigraphic records. The subsequent wet phase after 3 ka caused the third incision that resulted in the present day sand bed Luni river channel.[14]

Hydrogeomorphic map of the basin, prepared in detail by using Landsat 1 and 2 images and IRS1B LISS-I images (Bajpai et al 2001b), has been presented in figure 5. The major morphologic units classified are rocky tracts, buried pediments, valley fills, flood plains, palaeochannels and dune fields. [15]The hydrogeomorphic variations are influenced by major and minor lineaments (Kar 1992, 1994; Bajpai et al 2001a). The palaeodrainage system analysis of the Luni river system observed on the radar images indicated that former Luni system joined directly the Sukri (Kar 1999) and the same is also indicated in the subsurface by continuous sand bodies between upper Luni and present NE-SW trending Sukri [44](Mandawla-Surana region, following the Luni-Sukri lineament (Bajpai et al 2001b). The aquifers formed in coarse sand and gravel of laterally pinching type formed in interridge areas or grabens are indicated in Jodhpur region in the vicinity of Golasani river, Digrana-Bhawal graben, Bhadrajan-Dewan region, Bhimgoda-Juna Motisara graben, Sindari-Khudala depression and in Ratanpura-Khanpur graben (Bajpai et al 2001a). Aquifers and their geometry reflect control by paleo-fluvial geomorphic processes over the entire basin. [17]A general pinch and swell character is common with the aquifers in alluvium. In order to understand the hydrogeomorphic processes in relation to lineaments and subsurface geologic structure an analysis of lineaments together with drainage network flowing across the lineaments has been carried out. [16]

III.RESULTS

Lineaments identified and mapped on multidate Landsat (1, 2 and TM) and IRS-1C, LISS III images are presented in figure 6. The present lineament map has an addition of several lineaments identified earlier by Bajpai et al (2001a). Lineaments have been classified into various categories. Out of 91 main lineaments selected for classification in the present work, 5 belong to straight to curvilinear structural ridges, 17 to buried pediment-valley fill contacts, 1 to straight interdunal depression, 32 to straight river segments (active channels), 13 to straight dry channels (active only during the monsoon period), 1 to a regional fault (deep dislocation), 6 to straight moisture zones with water bodies and vegetation,[18] 4 to straight topographic contrasts, 1 to straight natural vegetation border, 1 to straight fracture zone within rocky tract, 4 to escarpments and 6 to straight and sharp lithologic contacts. Lineaments, that are closely distributed and parallel have been numbered as a group of lineaments. As there is no minimum length of lineaments, in the present work, the lineaments more than 10 km in length are classified as major lineaments. Most of the lineaments do not belong to one category (simple lineaments), rather a combination of different categories: composite lineaments (Sabins 1987; Bajpai and Fallah Pour 1998).

For more detailed observations and understanding of hydrogeomorphic processes, the selected IRS-1C LISS III digital images (windows) have been produced in the central and western parts of the basin. [18]These are as follows:

Balwara – Birana – Sena window The image of this window belongs to IRS-1C (P92- R54, 29 Dec 1996) and is FCC (BGR-234 : Linear Enhancement). The window encompasses the area around Siwana granites in the NW and further towards south the Sukri river and its tributaries (figure 7). Balwara lineament (N-S) intersects with Luni-Sukri lineament to the south of Balwara near the Sukri river. The Sukri river takes a southwesterly turn after this intersection. The dark tone to the NE of Balwara along Luni-Sukri lineament[19] indicates moisture, while to the SW of Balwara along the Sukri river the pink tone indicates vegetation. The E-W trending parts of Sukri and Khari rivers indicate thick vegetation zones[45] which are possibly the E-W trending deep fracture zones controlling these rivers. For detailed observations 3 windows of 1000 by 1000 pixels (1 pixel = 23.5 m) and 1 window of 681 by 681 pixels have been selected out of this sector. The first three windows are Root Enhancement Images, where the contrast is maximum. The fourth window shows contrast in Adaptive Equalization Enhancement. [20]

The windows are described as follows:-

Balwara – Bharwani window This window encompasses Luni-Sukri lineament zone passing through Bharwani on one side and Bhavrani on the other and Sanwarla-Raithal lineament (north of Raithal with N-S trend). These lineaments have been described earlier by Kar (1994). On this window the geomorphic pattern in terms of buried pediment (appearing with rectangular blocks of light greenish white tone with NE-SW trend, location BP) alternate with wide graben structures with dark greenish tone (valley fills, Location VF).[21] The river adjustment is by incising the pediments and getting braided within grabens. This is illustrated by Mithri river to the east of Bharwani. The rivers also get disorganized and disappear as it appears to the west of Bhavrani. The entrenched meanders indicate the response to the areas of uplift (Burnett and Schumm 1983; and Ouchi 1985), which are here buried pediments. The heavy bedload falling into areas of subsidence (grabens) indicate braiding as a river adjustment. Shallow groundwater exploitation together with agricultural practices is common along these braided and disorganized streams and on buried pediments, as the deep groundwater (beyond 40–50 m) in grabens (deep valley fills) is saline. Sand dunes are mostly clustered on buried pediment regions (SW of Balwara and W of Raithal) where they provide recharge of fresh quality of groundwater to buried pediment areas. Jalor – Mera window .[22]

IV.CONCLUSIONS

The Luni basin is an active tectonic sedimentary basin where deposition has taken place on an uneven basement in the form of alternating horst and graben structures from east to west. Earlier analysis of Bouguer anomaly profiles (Bajpai et al 2001a) also indicates that the basement has been activated along horst and graben structures and as a result, most of the present river systems align and lie within the gravity lows (grabens). The depth to basement varies from few meters towards western and central parts of the basin and to more than 300 m to the SW of Jalor in the Sanchor-Haryali region. In the NE near Merta city[23] it is about 45 m, however to the south of Merta thickness increases to about 150 m. In the western part near Sindari this ranges from about 40 m to 70 m. Initially the basin has uneven basement consisting of Erinpura granite and Malani rhyolite with Bilara limestone, Girbhakar and Sonia sandstone (Marwar Supergroup). In the west, out of the basin in Barmer district the rhyolite occurs in faulted contact with Lathi sandstone (Cretaceous-Carboniferous). In such a basin the records of

Quaternary deposition showing a sequence of pebbly-cobbly conglomerate, gravel, coarse sand, fine sand, calcrete, clay and fine sand are present. In the western part of the basin the optical ages indicate older deposits near Khudala (dated to > 90 ka) at the beginning of Late Pleistocene (Jain and Tandon 2003). Around 14 ka there is a resumption of fluvial activity that showed incision and deposition by gravel bedload braided streams (OIS 1). OIS 1 between 11 and 14 ka showed a spectrum of gravel sand braided, meandering, sandy ephemeral streams and aeolian. The second phase of incision occurred during the early Holocene followed by sheet flow aggradations between 5 and 9 ka. Finally during the arid phase around 3 ka streams become defunct and only aeolian dunes remain on stratigraphic record. After 3 ka the wet phase gave rise to incision resulting into the present day sandy Luni river channel (Jain and Tandon 2003). The processes of incision and braiding are well exhibited by Mithri (Sankwali - Panchhota region) and Sukri (Balwara - Jalor region), which require further study regarding age determination together with climate analysis. General observations show that depth to the basement along the Luni-Sukri lineament, increases towards SW and slowly decreases towards NE. On an imagery, this is indicated by pink tone along Sukri river (S of Jalor) and dark greenish tone to the NE of Jalor. Geomorphologically, the rocky tract, buried pediments and valley fills are indicated with a sharp contrast on IRS - LISS III images. It is easy to see the dark green areas as valley fills in contrast to greenish-white pediments on digitally processed images. [24]Rivers while flowing from east to west have hydrodynamically adjusted to the buried pediment and valley fill structures as these incise the areas of buried pediments and braid, disorganize and defunct in valley fill regions. The braiding is typical for a river adjusting on slopes in arid region, due to quick filling, however the same in humid region corresponding to slow uplift gives rise to sinuosity. The changes in depositional material from coarse and mixed of all size grades to fine requires more study on climatic changes in the region. Lineaments trending NE-SW, NW-SE and E-W indicate the adjustment of various streams flowing across them. This is conspicuously visible along Sukri and Mithri river systems. The lineaments show tectonic control and depositional behaviour of streams. Regarding geological and georesource point of view[25] the Luni-Sukri, Jaisalmer-Barwani, and the lineament to the east of Rabasar-Sarli extending to Baorli are important for groundwater reservoir and petroleum occurrence. Thus an overall analysis of lineaments and hydrogeomorphic processes together with gravity profiles indicate a hydrogeological evolution of the Luni basin. Initially it was an uneven basement in the hard rock with several faults trending mostly NE-SW, NW-SE and E-W. Sudden downpouring of sediments in the grabens have filled them maintaining the geomorphic adjustments of the rivers during subsidence. The deposition has started with clay and ended with multistoried sand and gravel sequences fining upwards. The activation along faults is still visible on satellite images (straight drainages) and occurrence of earthquakes in the region[26]

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