Exploration for Deeper Unconventional Aquifers – A Feasibility Study in Western Rajasthan Based on Information from Drilled Wells of ONGC

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Summary

This paper evaluates the possibility of application of data, knowledge and skills developed in the course of hydrocarbon exploration to the new area of exploration for unconventional deeper ground water aquifers. Feasibility of evaluating ground water occurrences in a small block in Western Rajasthan based on information from seismic data and drilled wells of ONGC is examined. The targets are deeper ground water aquifers, generally not explored by ground water organizations. Drilled well data available in Jaisalmer basin of Rajasthan comprising 24 well completion reports, 7 Formation Evaluation Reports and wire line logs from 13 wells were studied to identify water bearing horizons and their nature. The study identified low salinity zones in Kharatar, Ghotaru, Bankia, Manhera Tibba and further east. Regional disposition of these water-bearing horizons was attempted on few seismic lines shot in the area by ONGC. Intensive studies through geophysical surveys, drilling and testing of wells are recommended for eventual exploitation of deeper aquifers (below 200m) in view of acute water shortage faced in these areas. The study is considered important in view of the impending menace of water shortage and the urgent necessity of pooling available resources towards its mitigation. This approach was based on successful efforts in tapping unconventional (deep) ground water resources elsewhere in the world, particularly the Great Man-made River (GMR) Project of Libya.

Introduction

Water, like energy in the late 1970s, is likely to become the most critical natural resource issue facing most parts of the world by the start of the next century. This analogy is also reflected in the oft-repeated observation that water is likely to replace oil as a future cause of war between nations. Mankind's most serious challenge in the 21st century might not be war or hunger or disease or even the collapse of civic order, a UN report says; it may be the lack of fresh water. Unlike energy whose scarcity may affect civilized life, scarcity of water threatens life itself.

Although water is the commonest stuff on earth, only 2.53 per cent of it is fresh water, while the rest is salty. And of the freshwater, two thirds is locked up in glaciers and permanent snow cover. What is available in lakes, rivers, aquifers (ground water) and rainfall run-off is now increasingly coming under pressure from several directions at once.

The picture is a distinctly gloomy one – of a vital but limited human resource subject to increasingly unsatisfiable demands. In India, home to 1.002 billion people, key aquifers are being over pumped and in states like Gujarat, Rajasthan, Punjab and Haryana, due to overexploitation, ground water level has gone down fast. Water has been a contentious issue in recent river water sharing negotiations involving several states in India. The need of the hour is to initiate urgent measures to tackle this impending menace by all possible means not only by Govt. organizations entrusted with the task of water resource management but also by all private, semi-government and local bodies directly or indirectly connected to natural resource management. The present study in Western Rajasthan is a beginning in that direction.

Western Rajasthan is drought prone having scanty rainfall and is known to have arid/semi arid climate with acute shortage of drinking water. Aridity increases westward as reflected by desert landforms, salt lakes and high evapo-transpiration rates. Average annual rainfall in western Rajasthan varies from 198 mm at Jaisalmer to 634 mm at Sirohi compared to India's annual average rainfall of around 1100 mm. Ephemeral rivers like Luni, Kantli and Ghaggar are the only drainage systems developed in the desert terrain. Groundwater is the only dependable source in most parts of the desert. Due to increasing dependency on ground water, ground water level is fast depleting. The study covers part of the area in Jaisalmer Basin in Western Rajasthan where wells have been drilled by ONGC for hydrocarbon exploration. The objective is to evaluate the feasibility of groundwater exploration (including depths below 200m) in a small block in Western Rajasthan based on information from seismic data and drilled wells of ONGC.

The study area with the wells considered for present study is shown in Fig.-1.

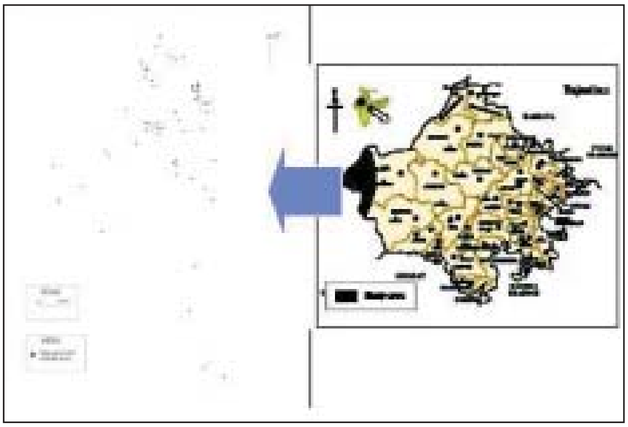

Fig.1: Study area showing wells drilled

Geologic/ Palaeo climatic Evolution

The Jaisalmer Basin records oscillatory depositional condition marked by transgressive / regressive cycles punctuated by hiatus. Jurassic Lathi formation has been deposited in Fluvio – Deltaic environment. Bhuana, Jaisalmer, Baishakhi-Bhadasar, Pariwar, Habur, Goru and Parh Formations were deposited in marine environments during Triassic to Cretaceous. This was followed by a regression and Sanu formation was deposited in marine environment with continental influence on the sediments during Upper Paleocene.

The Khuiala and Bandah formations were deposited in marine environment during the Eocene time. Deposition of these sediments was followed by regression of the sea and the Shumar formation was deposited in a complex continental setup varying from lacustrine, fluvial to aeolian during the Holocene.

Geologic studies indicate destabilizing tectonic events had occurred around the beginning of Pleistocene, about 1.8 my ago in the entire Siwalik domain, extending from Potwar in Pakistan to Assam in India, resulting in massive landslides and avalanches. These disturbances, which continued intermittently, were all linked to uplift of the Himalayas which was at its peak during 0.8–0.9 my span. The meteorological research about palaeoclimates, oxygen isotopic studies, thermo luminescent (TL) dating of wind-borne and river-borne sands in the Thar desert region, radiocarbon dating of lake-bed deposits etc. have all indicated that during early to middle Pleistocene period this region had enjoyed wetter climate, heavy rainfall and even recurring floods.

The first major study on the paleo environmental changes in the Thar Desert was carried out by Singh et al. (1974). An attempt was made to reconstruct Holocene vegetation and salinity conditions, based on pollen analysis of deep cores from saline lakes viz. Sambhar, Lunkaransar, and Didwana. Based on radio carbon dating a comprehensive salinity and climatic condition was deduced and shown on a chronological scale. Bryson and Swain (1981) used this data in conjunction with modern pollen evidences to reconstruct the Holocene rainfall variation in the region. This study provided an interesting result of a three fold higher rainfall during the period 10,000-5,000 yr BP.

The age analysis of the water samples (on the basis of Pearson Model) from the wells existing in Jaisalmer Area carried out by Bhava Atomic Research Centre (BARC), Mumbai for Ground Water Department, Govt. of Rajasthan indicates the ages of water for locations Sadewala 18800 BP, Longewala 12400 BP, Ghotaru 8910 BP (Rao and Kulkarni, 1997; Nair et al., 1999).

In 1953, the search for new oilfields in the deserts of southern Libya led to the discovery not only of the significant oil reserves, but also vast quantities of fresh water trapped in the underlying strata. This has given birth to the Great Manmade River Project (GMR) - an enormous, long-term undertaking to supply the country's needs by drawing water from aquifers beneath the Sahara and conveying it along a network of huge underground pipes.

According to Prof. Mike Edmunds, Director of the Oxford University Center for Water Research, much of the water in the sub-Saharan aquifers fell as rain 25,000 to 75,000 years ago. The rest fell 4,500 to 10,000 years ago, when Libya was a broad and lush savanna, where elephants, giraffes, leopards and great herds roamed while early humans harvested crops on plains washed by heavy rains. The excess rainfall infiltrated into the ground and was trapped in the porous rocks between impermeable layers, forming huge reservoirs of underground fresh water, particularly in the thick sandstone sequences. Radio-carbon dating shows that the majority of this fresh water is between 38,000 and 14,000 years old although there are some lenses of water dating from 7,000 years ago.

Though tectonic history and geological set ups in Thar and Sahara are wide apart, the possibility of infiltration of excess rain water during the rainy periods of geologic past can not be ruled out in Thar.

Methodology

Well completion reports (WCR), Formation Evaluation Reports (FER) and other available geological information were studied to understand surface and subsurface geology. Lithologs of representative wells were prepared from the composite logs available in the well completion reports, showing lithologies encountered in various wells (Fig.-2). Panel diagram to show vertical and lateral distribution of various Formations has been prepared (Fig.-3). Based on lithological and log characters (SP and resistivity log), water-bearing layers have been identified. The salinity of the Formation water has been computed from SP log after applying necessary correction. The same has also been computed from resistivity and porosity log and compared with salinity obtained from SP. Log derived salinity was used as a prime factor to identify suitable aquifer zones. Based on the log-derived salinity, panel diagram showing Class – I and Class – II salinity zones has been prepared (Fig.-4). Cluster diagram showing the variation of the log-derived salinity with depth has been prepared (Fig.-5). Delineation of the geometry of the identified aquifers has been attempted by means of constructed panel diagrams and prospective areas have been identified (Fig.-6).

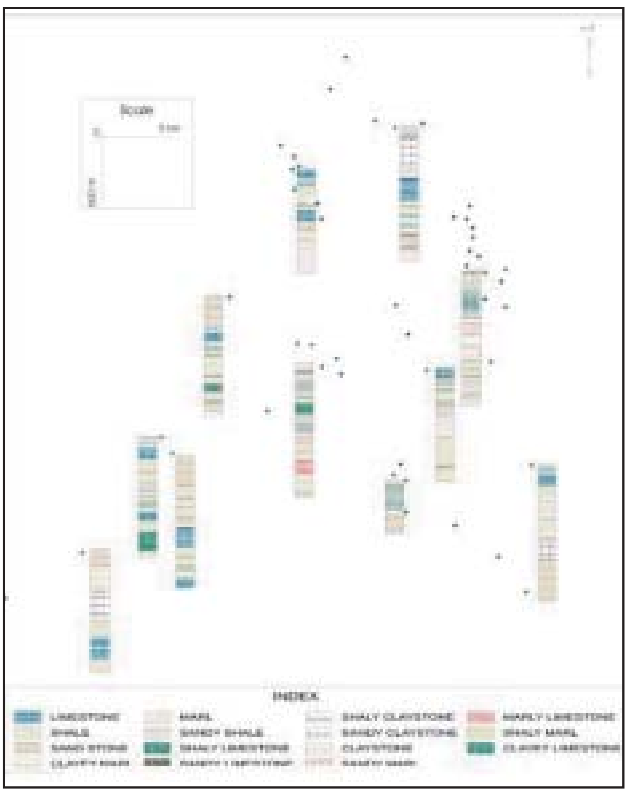

Fig.2: Column Diagram showing Lithology encountered in various wells

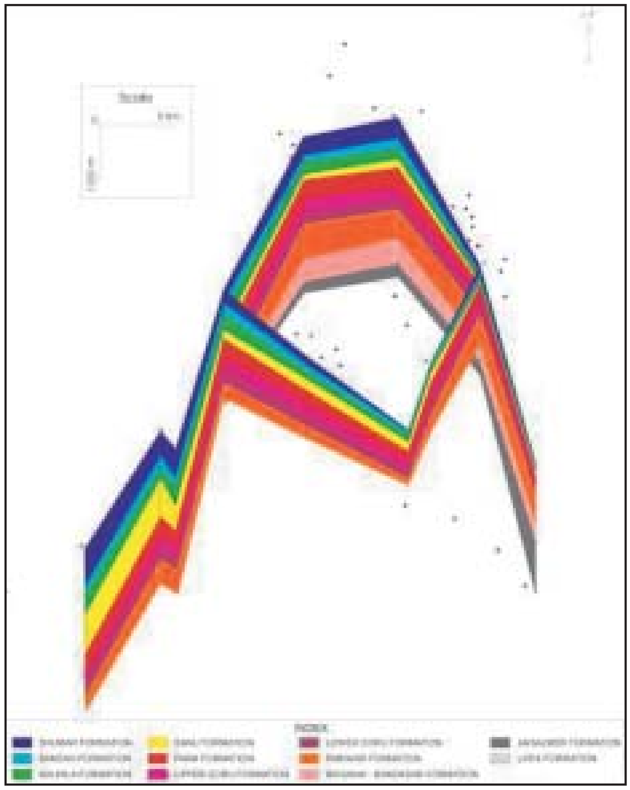

Fig 3 : Panel diagram showing formations encountered in select wells.

Water Quality:

Department of Agriculture, Western Australia, uses water salinity classes for plants as non saline, slightly saline, moderately saline, very saline and extremely saline with salinity ranges for water, < 2.75, 2.75-5.5, 5.5-11, 11-16.5 and > 16.5 g/l respectively as guides for re-vegetation. Water salinity levels for various usage and salinity levels that can be tolerated by livestock, as given by the department, considers safe upper limit for hot water systems as 0.9g/l of total salts, 2 g/l for Laundry and up to 3.5 g/l of total salts for showers and baths. As per World Health Organization (WHO) specification, the maximum permissible level of

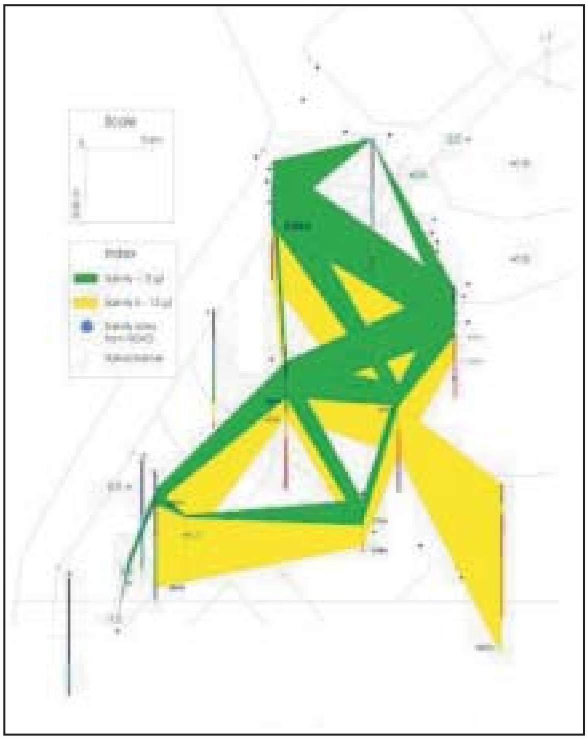

Fig.4 : Panel diagram showing formations encountered in select wells

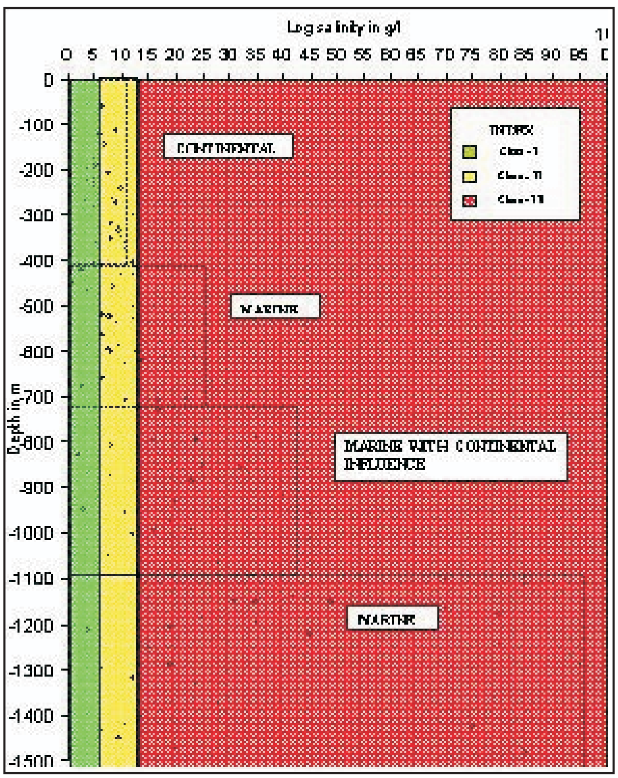

Fig.5: Cluster diagram showing change in Formation water salinity with depth

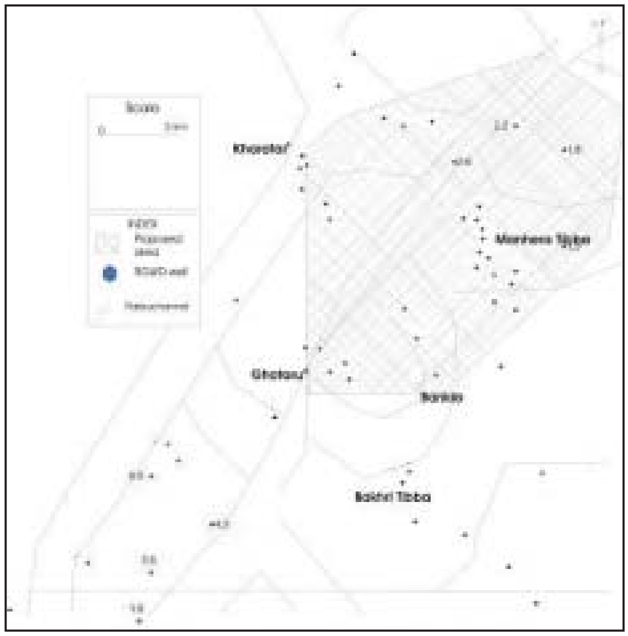

Fig.6 : Map showing low salinity area proposed as Pilot Area

soluble salt for human consumption is 1.5 g/l. Taking a cue from above, the salinity values of formation water were grouped into 3 broad classes, depending upon usage:

1. Class – I: Water up to the salinity 5 g/l, covering non saline and slightly saline water salinity classes for plants and also covering salinity levels defined for various domestic uses such as laundry, water heating, showers and baths etc. as defined by Department of Agriculture, Western Australia (the Class includes drinking water as defined by Bureau of Indian Standards (BIS) with maximum permissible limit for Total Dissolved Solid content of 2.0 g/l). However, for drinking water purpose, BIS specifies the level of various other common solvents in water and their permitted levels.
2. Class – II: Water with salinity from 5 – 12 g/l (covering moderately saline water salinity class for plants and close to the maximum upper limit range of salinity level, below which animal production is likely to fall (4-13 g/l), as defined by Department of Agriculture, Western Australia).
3. Class – III: Water with salinity beyond 12 g/l (covering very saline and extremely saline classes of water for plants by Department of Agriculture, Western Australia) and practically of no use to humans and animals.

Observations

The study on the basis of well logs shows that water-bearing zones occur in almost all the formations, however, their thickness varies from well to well as could be observed from the plotted salinity values against the litho logs of 14 selected wells in the area.

The study on the basis of well logs also reveals that the formation water has less salinity (up to 5 g/l) in the shallow intervals (surface to 600 m average) and 10 g/l up to 1000 m. Beyond this interval the salinity of the formation water increases from 12 g/l to 140 g/l and even more.

The cluster diagram showing variation of salinity with respect to depth shows that the salinity value increases rapidly with depth beyond 1000m, whereas it is gradual up to 400m.The older marine formations show higher degree of randomness and high salinity values whereas the younger continental formation is more clustered with less salinity values (Fig.-5).

The following observations/inferences can be drawn from the Panel diagram showing Class – I and Class – II salinity zones (Fig.-6).

- The thickness of the Class – I zone varies from a few meter in the western part to a maximum thickness beyond 400m in the eastern and northern part. Class–I zone mostly contains salinity between 3-5 g/l, however isolated occurrences of fresh aquifers may not be ruled out especially along the palaeochannels of Saraswati at shallower depths.
- The main aquifer present in this zone (Class-I) is confined within the Sand in the top most part (Shumar formation) followed down below by aquifers within the limestone in the Bandah and Khuiala formation having porosity ranging up to 36%.
- The Class – I (low salinity zone), mostly occurs in the Kharatar, Ghotaru, Manhera Tibba and Bankia area.
- The Class – II zone, on the other hand, thickens towards west and southern part; however, it is relatively thinner, occurring at shallower depth in the eastern and central part of the basin.
- The aquifers present in this zone are mainly confined within limestone, sandstone and in a few places within shale of Khuiala, Sanu, Parh and Goru formation having porosity ranging between 24 - 36%

An attempt was made to decipher regional disposition of low salinity water bearing layers observed on well logs in the study area using 2D seismic data. To achieve this, 2D seismic data around the interesting well clusters were reviewed and initially efforts were directed to select lines connecting wells having low salinity water columns. However, it was observed that most of such lines are of old vintages with processing parameters (mute varying from 50 to 300 ms) suitable for hydrocarbon exploration, for which they were acquired and processed and are of little significance from point of view of groundwater applications. However, few lines with mute parameter maximum up to 200 ms were picked up having straight-line connection from well to well covering three clusters. The easily recognizable reflectors corresponding to Bandah top and Khuiala top were traced for verifying continuity of low salinity water bearing layers identified through log interpretation and it is observed that such layers are regionally disposed and are dipping towards west.

Limitations of the Study

It is pertinent to mention data constraints as part of an effort to better appreciate the overall limitations of the study. The study is constrained by the following:

1. Well logs were mostly old, Russian type.
2. Non-availability of salinity data in most of the studied wells.
3. In some wells the Logs are either not recorded or are not available in the interval of 0 – 400 m.
4. In most of the seismic lines available in the study area the information at shallow levels are muted, as the lines have been processed from an angle of hydrocarbon exploration. Therefore, study of seismic data has been essentially confined to assess the regional extent/ continuity of water bearing horizons identified through log interpretation.

Conclusions

1. It is concluded from the study that the Kharatar, Ghotaru, Manhera Tibba and Bankia area is the most prospective area having possibility of finding reasonably non-saline water aquifer in the depth zone up to 1000m.
2. It is, therefore, suggested that low salinity areas, viz., Kharatar, Ghotaru, Bankia, Manhari Tibba may be considered for further detailing (Fig.-6) to carry out the intensive study including geophysical survey, drilling and testing of wells and preparation of project plan for exploitation of deep aquifers (up to 1000m) based on the intensive study.
3. Prospectivity of Class – II type of water, defined as

moderately saline exists in this area and thickens towards west and southern part. However, it is relatively thinner occurring at shallower depth in the eastern and central part of the basin.

4. The study demonstrates the possibility of using existing knowledge base and vast repository of sub-surface data acquired for oil exploration, in spear-heading future studies and formulating broad strategy for deep seated aquifer investigations on a regional scale.

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Views expressed in this paper are those of the authors only and may not necessarily of ONGC.

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