GROUND WATER IN THE THAR DESERT OF SINDH[1]

By
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There are twenty major deserts of the world namely:-

1. Rajisthan Desert (including Thar of Sindh).
2. North American temperature deserts (Idaho Wyoming Montana etc.).
3. Death Valley (California).
4. Sonoran Desert (Arizona).
5. Mojave (Nevada).
6. Chihuohuan (Mexico).
7. Patagonian (Argentina).
8. Atacama (Chile and Peru).
9. Kalhari (South-Eastern Africa).
10. Naimb (South-West Africa).
11. Sahara.
12. Sinai Desert (Eastern Egypt).
13. Negev Desert (Isreal).
14. Syrian Desert.
15. Arabian Desert.
16. Persian Desert.
17. Baluchistan and Sindh Kohistan Desert.
18. Takla Makan. (Sinkiang, China).
19. Mongolian Desert (Gobi).
20. Australian Desert.

Their climate is mostly and (rainfall less than 10 inches), although along the margins, some of them have rain fall of 10-20 inches and are classified as semi-arid deserts. Now there are elaborate formulas graphs and mathematical equations to define aridity. Kopeen-Gieger and Thornthwaire systems are the most accepted ones.

All these deserts have many things in common. The most celebrated of them, fall between 15 and 40th parallels. The, precipitation falls short of evaporation, causing moisture deficit. Rainfall variability is great. Variation increases as average rainfall decreases. Variabilities of 500% occur a few times a century although 50-70% variability is common, year after year. Variability of 200-300% could occur once in every ten years.

[1] This article was written in 1993.

Humidity can be of low orders of 25-30%. Difference between hottest and coldest months, highest and lowest temperatures, can be 30-40°F (17-72°C). Summer temperatures even in temperature deserts at some places can exceed 104°F (40°C), unless they are at high altitudes. Years of no rainfall can occur once in a decade. Many similarities in soils, erosion patterns, bio-climatology, ecology, bio-chore, land-forms, deflation, abrasion, dust-storms, sand-storms, types of sand dunes (active, inactive, crescent, barkhan, traverse, longitudinal, parabolic), loesses, fluvial processes, poor vegetation cover, sun baked dry soils, powered soils, man-made desertification, alluvial fans of rainy streams, and land mass denudation are common.

Even many common flora occur in the deserts of old world. Others belong to same families. They are similar although not always identical to New World and Australian flora. The fauna too show similar characteristics in deserts of the old and new worlds.

There is also lack of ground water in all deserts. Since less recharge, water mining resulting into many problems, is a common phenomenon. All these deserts took their present shape at the beginning of Quaternary (1000,000 years ago). Since then climatic changes have been a few and of these most remarkable occurred between 20,000-18,000 years ago, which was a wet period but with fluctuations such as had never occurred in the geological history of earth. These deserts also have fossil ground water, which was charged by wet conditions occurring between 35,000- 28,000 years ago.

Some specific climatic changes took place in Sindh between 90,000 years ago to 4,000 years back. Sea level rose. Around 20,000 years ago it was near Multan, 10,000 years ago near Larkana, 9,000 years ago near Hyderabad and 5,000 years ago near Talhar. The Indus irrigated plains being under sea, sand blown from the shores of inland sea creek, spread over the desert. During the Upper and Middle Holocene (12,500 years to 4,000 years ago), Sindh had four rivers, namely, the Indus, the Sarswati (Hakra), the Dirshadvati and the Luni. Between 9,500 to 4,000 years the desert had much more rainfall (842 inches in Pat of Sukkur and Khairpur, 12-25 inches in Khipro to Mithi, and 25-50 inches in Diplo and Parkar areas). This made the Western Desert of Sindh a savana land, where Mesolithic man started domestication of sheep, goat, cattle and lastly camel.

Four thousand years ago the present dry climatic conditions started in Sindh. Compelled to make a living the man in the Thar Desert, resorted to over-stocking of animals over-grazing and power the soil under animal hooves, leading to wind erosion. Lack of ground cover resulted into sheet, nil and gully erosion of the desert.

Thirty present of worlds dry land is covered by deserts. Man having occupied fertile lands first, has turned to the deserts. Our position is the worse of, as we have highest density of population in Thar desert as compared to any other desert. It is greater than the Western Rajasthan desert, if area irrigated by Bhakhra Canal is excluded. We are

also densely populated in our irrigated area, where due shortage of water, intensity of agriculture cannot be increased further. 1.8 million acres between the Flood Protection Embankments of the Indus, have also become arid and is getting depopulated.

We have therefore no alternative but to turn to the desert for absorption of more people, who are bound to do more stocking of animals and add more to the desertification. We have therefore to plan against this catastrophe by:-

- Conserving rain water.
- Conserving soil.
- Recharging ground water.
- Using ground water mostly for human and cattle and for irrigation only, when simultaneous recharging is done to off-set any depletion of aquifer.

The paragraph below describe water in the Thar desert as ground water. They do not touch upon, the use of rain water for raising crops, trees, fruits and range management, which are discussed separately in other articles of the author.

THE DESERT ZONE

The desert zone may be divided into three distinct parts known as: (i) Rann, (ii) Thar, and (iii) Pat.

THE FORMATION OF RANN OF KUCH

The rann has played the most important part in the formation of the whole desert. According to some geographers and geologists, the Thar desert has formed by sand blown across the Rann from the sea. Had that really been so, the Rann of Kuch itself would have been covered with sand hills first. In the Rann, however, we find deposits which are of much finer material than the coarse sand found in the desert, and therefore the sand blown from the Rann's surface could not have formed the desert.

(i) The water in Thar desert is not so brackish as that on the west of the desert, at some places to a distance of even 20 to 30 miles, in alluvial plains.

(ii) In the desert *dhands* or lakes, some marine bacteria abide, which exist only in the sea, and therefore, these *dhands* must have been connected with the sea at some time even after their formation.

(iii) Salt lakes are common only on western border of the desert, which fact clearly shows their origin form the sea.

The silting of present Rann started in the recent times by both the Hakra Dirshadvati and Indus flowing into it. At the time of Alexander's conquest, according to Greek writers, the Rann was a shallow sea. When Mahmud Ghaznavi was returning from his march to Somanath, 1025 A.D., he was told that sea waves will wash away his boats. This clearly shows that the Rann of Kuch was not dry in the early eleventh century. The town of Pari Nagar, a sea port in Nagarparkar Taluka, was destroyed in 1226 A.D. by Khawarizm Shah. This was the year when Hakra dried up near Umerkot also, clearly showing that the Rann of Kuch was an arm of the sea, and was fed by Hakra. Feroze Shah Tughiak crossed the Rann in 1361 A.D., when it was dry. His army on retreat from Sindh to Gujarat nearly perished from heat and thirst. According to historians, "no tree was to be seen, no bird ever flapped in the howling desert, there was not a blade of grass, not even a miserable weed". Two centuries later, Abul Fazal in Ain-i-Akbari called it depression 90 Kuroch in length and 30 to 80 Kuroh in width, which represents nearly the same size as it has today, after another four centuries. Balmar was a sea port on Luni river near Nagarparkar in historic times, which shows that in those days Luni was also navigable. All this proves that the Rann of Kuchh, at one time a sea creek, was silted up slowly, possibly due to silt bought by Luni from Rajasthan, and Kakra and Indus from the north. Some geologists have said that the Rann is creation of earthquakes and slow elevation of the land, but the historical and scientific evidence is against this. Silt brought by the Luni, the Dirshadvati, the Indus and the Hakra, raised the level of its bottom.

It is not possible to lay down exact location of the Rann of Kuchh, but it seems likely that it extended over some of area now covered by Kotri Barrage and also some area commanded by Sukkur barrage in the Tharparkar District. A projection of it must have extended beyond Rohri and probably up to Multan. In all this area, we should not therefore, expect any sweet water for irrigation purposes. Small quantities of water for domestic and small scale irrigation purposes could however be located along the banks of old Hakra or Eastern and Western Purans, to shallow depths of 40' to 50' at isolated spots. Test bores along Nara from Alore to Jamrao Head have shown sweet water, in a width of half a mile.

Today the Rann of Kuchh is a dry barren country which turns into swamp after rains, when waters brought by Luni from the east, Puran from the north, and some stream of Kuchh from the south fill it up, to the depth of a few feet. The water does not dry till about November. There is no vegetation in the Rann. It is an abode of wild ass, occasional deer and constant mirage.

Some desert bushes and tamarisk etc. grow in odd patches near the Thar border. The Rann once full of sweet water was a bridge between Sindh and Cutch and the latter was part of Sindh until the Arab conquest of Sind in 711-614 A.D.

FORMATION OF THAR DESERT

Underneath the Thar desert at the depth of about 1000' rock has been located, out-crops of which appear at Aravalhi hills, and Nagarparkar. On the top of this rock, lies the 1000' mass of earth which has continuously blown from the Rann of Kuchh, which, as described above, extended to the west, south and south-east of the great Indian desert, and on Pakistan side beyond Rohri. Due to south-west winds, the silt, sand and tiny sea shells were blown from the Rann, which have formed this mass of earth. The sea shells, decomposed and formed calcareous grains, which are saline, and are responsible for brackish water in the desert.

In due course of time, calcareous shells and the sea salts were dissolved and redeposited in the form of kankar and saline concentration. In places, sand became cemented giving rise to soft-stone. The soft sand-stone and kankar are scattered in the whole desert, and are encountered at various depths, while drilling or digging. Being impervious, they hold water above them, known as "perched" or "trapped" water. This water will obviously be somewhat brackish, depending upon contact with kankar etc. The actual ground water lies much below this, possibly 500-1000' deep.

In this area, only a few wells have been sunk below 300' and therefore nothing could be said about the quality and quantity of its ground water. At Gadra Road Railway Station, across its Pakistan border on the Indian side, a well 350' deep was sunk by the J. B. Railway. The quality of water is said to be good, and the well is yielding substantial quantities of it. It is very much desirable, therefore, that a number of test bores to a depth of 350'-500' are sunk at different places in the desert area. These should penetrate the perched water zone, and the kankar and sand stone beds, to see the quantity and quality of water sown below. Recently UNECEF put in a well in Gadra village. It yields sweet water. UNECEF has also put in wells at Virawah, Mithi and Islamkot. These places were investigated by present author and report published in 1963.

NAGARPARKAR AREA OF THAR DESERT

The Parkar part of Nagarparkar area is altogether different from the rest of the Thar desert. From the pattern of ground water in this area, it seems certain that at. one time river Luni was flowing across the Peninsula between Virawah, and Dinsi. Parkar was an island then. Even now if there is more than 5 inches rainfall in a day in the Luni catchment, waters of Luni cut across its dried bed in Parkar making it an island for a few days.

PRINCIPLE OF FLOATION OF SWEET WATER ON BRACKISH WATER

In Nagarparkar, Southern Mithi and Southern Diplo near the Rann of Kuchh the water is located in many wells. The brackish water is heavier than sweet water by 8½% and more. The sweet water being lighter floats on brackish water and the height of sweet

water above the level of brackish water of Rann is governed by formula t = H (g - 1) where H is total depth of water, g the specific gravity of brackish water.

A special phenomenon is observed in some islands; even though surrounded by sea, they contain sweet ground water. Many Pirs and Saints have risen to the position as originators of this miracle. The phenomenon can scientifically be explained, and even the precise depth of the sweet water determined mathematically. Even if Parkar was not an Island, it was, and is, surrounded by the Rann of Kuchh (old sea creek) along almost 85% to 95% of its border. The Rann of Kuchh still contains brackish water. The fresh water which seeps in, floats on it. This theory is further supported by evidence in as much as in the centre of peninsula, water to greater depth is sweet whereas away from the central region, water turns brackish with depth.

The out-cope of the Karunjhar rocks is almost in the centre of this island or peninsula. The depth of sand clay over it is not so much as in the desert. The sand is porous and absorbs huge quantities of water. Even the rocks which are of pre-Cambrian group, (probably 3000,000,000 years old) are not soluble in water. They are impervious but hold water in fissures and cracks. This water slowly moves under the ground and is available in the wells. Near these rocks, artesian conditions can be expected. There are no changes of artesian conditions in the rest of the desert. The appended map shows the sweet and brackish water zones of Parkar area.

PAT AREA

The desert area lying in Khairpur Division is called Pat. Its main difference with the Thar is that vegetation and rain-fall is comparatively less and the Bhits or sand hills do not lie S.W. to N.E. but to SEE-NNe in the southern portion, and north-south in the northern portion, along the usual direction of wind. The sand hills are not only a function of wind direction but also wind velocity, and when velocity decreases, the sand hills tend to lie across the wind directions. The sand hills here are also smaller than those in Thar. The area is otherwise flatter and therefore called Pat (*i.e.* flat ground). The top sand lies on impervious clay layers and the rain water, after seeping through the sand, collects over clay and comes out in the low spots as 'sim' or spring water. Though the rainfall is only 4", luxuriant grasses grow, on which cattle thrives.

Like Thar, that Pat rests on rocks which lie about 1000' deep. Its continuity is Cholistan, where water has been found at depth of about 300 feet. In Khairpur district, on the west of the Pat, lie Kot-Diji hills, which are Eocene lime stone (Khirthar-hills group). An outcrop of these hills appears near Jaislmir. Down below in Hyderabad District near Badin, at the depth of 950', the Standard Vacuum Oil Co., while drilling for oil, located Khirthar lime stone. This clearly indicates that most of the Pat area and the western part of Thar is underlain by Khairthar hills, and the eastern Thar by Pre-Cambrian rocks of Aravalli group.

Up north in Sukkur district, the Pat is geologically of the same formation as the desert zone of Ambala and Bikanir. The depth of alluvial is 100' or more. The whole tract is traversed by beds of old Hakra and the spill channels to it from the Indus and the Sutlej. The soil lying below the sandy desert, is hard alluvial. The water in the shallow depths is brackish, but sods the case in similar formations up north in Bikanir area. Deep drilling up to 100' or more is necessary to determine if there is any water down below. It may be mentioned here that Geological Survey of India in 1926, while drilling located substantial quantities of sweet water on the Indus side of Pat area in Ambala at depth of about 1000'.

DESERT AREA OF SUKKUR DISTRICT OF PAT

This area had the eastern Nara or Hakra or Rainee to the east and Indus to the west. Eastern Nara was getting water from Jamuna in recent geological times. At times Sutlej also contributed its spill-water to it. Regular over-spills have also flowed from Indus into Hakra in Rohri sub-division as well as in Bahawalpur area over a distance of 120 miles. Some spill-channels are still traceable from Indus to Hakra, two of which are shown in ordinary maps of Sindh. Due to such a long and wide-spread spilling of water over the area and seepage from the Indus, the tract holds considerable quantities of sweet ground water.

Western part of Pat has been irrigated by the Guddu Barrage, but the water supply is only in seasonal. The barrage area, therefore, is most suitable for tube well irrigation to increase intensities and to grow Rabi crops.

No survey of desert area of this district called Pat has been done. In the desert, there are old beds of Hakra (or the Eastern Nara river), which dried up in 1226 A.D. But the chances of getting sweet water in the upper strata are limited.

Below the sands at depth of 1000' or so lie the rocks. Since the Hakra had flowed over the desert sands for centuries, there are, however, possibilities of water having seeped down and accumulated over the rocks. Deep drilling may give clue to this. There are shallow wells in the area, but water in these wells is mostly brackish. Geological survey of India carried out deep boring (1012') in 1925-26 in Ambala district, and found sweet water at great depth. Geological formation of this part of Pat is closely connected with Ambala formations. Test boring to the rock level may therefore be worthwhile in the area. In adjoining desert areas of Rahim Yar Khan district water is struck at 400 feet.

KHAIRPUR DESERT

Khairpur desert it forms 75% of Khairpur district. Here the water is mostly brackish at least in the upper strata. There is some chance of getting sweet water from wells close to

the Eastern Nara, but it will be more economical to pump water from Nara for irrigation rather than putting in the wells, at this stage. A time is however going to come when the barrage authorities will, no longer allow pumping from Nara. At that stage, wells will have to be put in. The desert zone is covered with a large number of lakes which are either saltish or alkaline. Since these lakes are by-products of ground water, they are briefly described in following paragraphs.

It has already been explained that the Thar in Hyderabad and Sukkur divisions is formed by sand, silt, salts, and fine sea shells, blowing from Rann of Kuchh, which extended as far as Rohri in the recent geological times. In Tharparkar district due to high wind velocities, the sand hills, which are sometime 300' high, lie southwest to north-east along the direction of wind. In southern Khairpur, where wind velocity decreases, the direction of sand hills changes slightly and becomes south-south-west to north-north-east. In northern Khairpur and Sukkur districts, the sand hills lie south-north.

The sand hills of Khairpur are not so high as those of Thar. Among the sand hills there are, at place, lakes or *dhands*, which are formed by rain water seeping down the sand mounds. In the neighborhood of Nara, there is also seepage from the canal into these lakes. The rain water percolates down the sand, where it is held by impervious clay which lines under the sand. The water so 'trapped' or 'perched' comes out in the form of springs or as locally called 'Sim'. All lakes in the desert area are formed by this process called 'sim'. The salt content in these lakes depends upon the salts dissolved by rain water and appearing as 'Sim'. Water in most of the *dhands* is brackish, as the salts keep on accumulating into them year after year, unless these salts are removed by human hand when water evaporates leaving cakes of salt behind. In some cases, water from wells in the neighborhood is available at higher water table than in the *dhands* and is potable. This is actually the 'Sim'., water, which instead of seeping into lakes seeps into the wells. The *dhands* are shallow, but some of them extend about a mile in length. Local belief, however, is that these lakes are unfathomable. Actually they are hardly 10' to 12' deep. At one time, these lakes yielded soda ash. This industry slowly disintegrated as old Hakra was converted into a canal and embankments were raised on its sides, so that water from it no more wandered into the desert lakes away from it. *Dhands* close to Nara are even now always full of water due to seepage from the canal. But this water, no longer so brackish, has instead become an abode of crocodiles and water loving reeds and canes like 'Sarr'. The lakes away from the canal are highly saline. In general, the Khairpur lakes are alkaline as compared to the Thar lakes which are saline. There is always a dispute about the causes of this phenomenon. It is believed that the salts of the lakes, whether in Khairpur or Sanghar district are basically of similar ingredients, but in the Khairpur lakes, due to presence of some bacteria or organic material, the sodium salts are converted into soda ash.

In the desert area of Khairpur district, normally similar ground water conditions should be expected, as in the desert area of Sukkur district. The deep drilling can give clear indication if there is water at the lower depths in the area.

The origin of lake a geological mystery was recently resolved by the present author. A river called the Dirshadvati once flowing from the Indian desert was joining the Hakra or Nara or Sarswati river. Its delta was in Khairpur and Sanghar desert Talukas. The Dirshadvati dired up in second millennium B.C. Lakes of the two districts are remainants of such deltas.

DESERT OF KHIPRO TALUKA

Small western a part of desert area is irrigated by Sukkur Barrage. Further to the east is the desert, the conditions of which are similar to the Thar desert, with the only exception that it is less grassy, and gets less rainfall. Northern part has lakes like Khairpur district.

GROUND WATER IN THE THARPARKAR DISTRICT

As explained in the preceding paragraphs, the Pat, Thar, and Parkar were formed by the action of south-west winds which blew sand, tiny sea shells and salts over the desert area. There is some contribution of denudating hills between Budhapur and Karachi including Ganjo-Takar also, but most of the sand came from the old sea (the Rann of Kuchh which extended beyond Rohri to Multan). The occasional sand-stone layers are met, but there seems to be the sand formed sand-stone. These two are responsible for the "perched water zones" in Pat and Thar.

In Nagarparkar, an 1100' Karunjhar rock out-crop lies in the centre of the peninsula, and the soil is not so deep. Occasional sand-stone layers are met, but there seems to be absence of calcareous formations, particularly in the sweet water zone.

In Thar, sand hills formed due to south-western winds lie parallel to each other. The rain water flowing down the sand hills does not move as runoff, for long distances but it is absorbed in the ground or evaporates. It is subsequently lost largely in the atmosphere, by evaporation and transpiration, and the rest percolates down in the ground in small quantities. There are no rain-fed streams in Pat and Thai. In Parkar area there are a few streams, which flow for a few hours after rains. Only in the southern parts of Mithi and Diplo, near the edge of the desert, water collects and flows to the Rann of Kuchh in nominal quantities. Since the absorbed water remains there for some time, wheat crop is raised in isolated patches, on the preserved moisture of the soil. Summer crops are grown where water seep underground quickly.

There are low valleys between the high sand hills, lying in high wind belt near the lower Indus delta, in which cultivation to a limit is done on rain water. These sand hills grow smaller further east. Bajra is the main crop in these valleys. Mostly the land is not prepared in advance. Only after the first shower, some ploughing is done. Even a small quantity of rain suffices to grow a surprisingly good crop, and profuse green vegetation crops up immediately all around. The crops grown on rain water are Bajra, Till, Sarseem, Jambho and Castor.

In the Thai area only those places, where ground water for human and cattle consumption is available, are populated. The economy of Thar depends in grazing. Complete failure of rains in one year or partial failure in two successive years often causes famine. The cattle which is the only capital and mainstay of the people when overtaken by such conditions, cannot cross 150 miles of the desert, and perish almost entirely. Goats and camel alone which live on the desert shrubs, survive such conditions. Many tracts are un-inhabitable mainly for want of drinking water, which lies buried as deep as 300 feet.

There are approximately 4,50,000 heads of cattle in Thai desert. Their life, as much as the life of their human masters, depends on rain water. In every 11 years there is a cycle of about 2 years of scanty rain-fall, when famine conditions exist, and the cattle perish for want of food and water. The water from wells is to be raised by human beings, who under such circumstances, migrate, leaving their cattle behind.

WELLS IN THAR AREA

A large number of small diameter wells exist in the Thai area. The largest number of them is in Chhachro Taluka, which gets less rain fall than Mithi, Nagarpakar and Diplo. The average rain fall in the desert Talukas is as under:-

1.	Nagarparkar	14"
2.	Mithi	11"
3.	Diplo	11"
4.	Chhachro	10"
5.	Umerkot	8"
6.	Khipro	6"
7.	Ubauro	4"
8.	Mathelo	4"
9.	Rohri	4"
10.	Kahirpur District	5"

Along the edge of Rann of Kuchh, water is found at the depth of only 26' to 30' whereas, away from the Rann, the water table becomes deeper. It is difficult to generalize but in the case of limited areas there seems to be a general co-relation between the depth of

water and level of ground. The level as a rule rises towards Aravalli hills, and therefore in the Thar area it rises as one goes east-wards from the Indus Plains or north-wards from Nagarparkar. The water depth also seems to increase on the similar lines. In the case of Pat area, reverse will be the case. Deepest wells are in Khipro Taluka, on the Indian Border. Near the western fringes of the desert along eastern Nara or old Kakra, water is available in plenty at shallow depths.

This water had its origin from the river Hakra, which remained dry for at least 6 centuries, and as such the original sweet water turned brackish. 30 miles east-waters from Nara bed, water is reached at the depth of 200'. Near the Indian border in Chhachro and Khipro Talukas one must go 300' or more to get some water. This water is being utilized for drinking purposes, but invariably salt contents are too high to make it fit for irrigation.

On both the sides of Hakra or old Nara, water up to a depth varying between 50' to '70' is sweet. The Department of Agriculture carried out some borings near Umerkot, where sweet water was located up to approximately 60' to 70'. This is the residual water due to seepage from the old Hakra river. In Diplo Taluka, along the bed of old Hakra or Eastern Puran, in a width of 2 miles or so, some open wells have been dug, which contain sweet water. Similar pockets of sweet water may be excepted along the whole length of Hakra, though water is brackish in the surrounding areas. This is a special phenomenon. The sweet water being lighter than brackish water, floats on it. So long the water supply in the Nara bed is maintained, water on both the banks, in narrow width, and shallow depths, shall remain fit for drinking, and even for irrigation, though for the latter purpose the quantities available would be too small.

EXISTING WELLS IN THAR AREA

Wells are usually of 3' to 4' diameter, and are dug 3' to 4' below the water-table. Their depth sometimes goes up to 300'. Because of small diameter, they do not collapse. Below this depth, due to small diameter, further excavation becomes impossible. The portion below the water table usually contains the coarse gravel and sand and apt to collapse by caving in, unless protected by some artificial means. This is usually done by lowering a circular frame, made from the branches of Laee or other bushes.

It looks like a 3' to 4' diameter circular ring. A number of rings each 6" in height are piled over one another and wooden pegs are driven through them. The space around the whole frame is filled with bushes, etc. This works as a filter and its life is approximately one to two years. Sometimes bricks are used in place of the above mentioned wooden ring. But in absence of proper curb and binding cement, the bricks usually give way. Being very shallow, below the water table, the wells usually dry up after a few dozen gallons are lifted from them, and people have to wait hours, till water again percolate into the same. If a small water bearing stratum is encountered, it is

chocked up by bricks and cement etc. If the wells were of bigger diameter, it would be possible to go 15' to 20' below the water level, and then alone it will be possible to fit large quantities of water, from them. Because of the scarcity of water, many areas in the desert have become uninhabitable for human beings and for their cattle, though in those areas lumurant grasses grow.

A survey of the existing wells in a limited area of Diplo Taluka was carried out be me in 1959. The results showed that in approximately 40% cases, water was sweet and fit for irrigation. The phenomenon could only be explained on the basis of the theory that sweet water floats on brackish water below it. It has already been mentioned that open wells in the bed of Puran, in Diplo Taluka, can yield smaller quantities of water, fit for irrigation. Even left bank out fall drain has water fit for re-use at present and could be utilized.

Perched water can definitely not be a perennial source of water. One has therefore to look for deep seated water, which may be available at a much lower depth. This water could only be tapped by tube wells. Sand in the desert is coarser than that existing in the alluvial plains, and therefore is more suited for tube wells, if large volumes of water are discovered. No artesian conditions exist in the desert area.

In order to protect, and further develop, cattle industry in Thar, the ground water investigation, and conservation of rain water, wherever it may collect, is necessary. The areas being inaccessible, wind mills probably will be the only practical power unit in the Thar area. Their application is described in author's book "Ground Water in Hyderabad and Khairpur Divisions, 1969".

SALT DEPOSITS

Salt industry in Thai is a by-product of ground water. The water at places collects by process called 'Sim'. Near Rann, the brackish water from the rain-fed river Luni fills the ground. This water evaporates, leaving salts behind. Over thousands of years, these deposits have become voluminous. All along the border with Rann, in Deplo and Mithi Talukas or elsewhere in Sanghar and Khipro Talukas, and Khairpur district, there are salt deposits formed by the above process. Some of these deposits probably will be economical to develop. The matter is worth investigating. These salts, being of sea origin, may not be inferior to any sea salt.

EXISTING WATER RESOURCES OF NAGARPARKAR

There is a number of wells in the whole area called Parkar, in each village there being at least one. According to rough estimate, their number reaches as thousad. A survey of these wells was carried out in 1959 to find out suitability of ground water for irrigation. The depth of the well, depth of water table, total soluble salts and pH. Value of 60

representative wells from the whole area was collected. On the basis of this data the ground water map of the area has been prepared. (Refer map of Nagar Parkar). The water table in the wells, varies between 10' to 60', the average being 30'. From these results it was found that 60% of the wells were fit for irrigation, 10% marginal and 30% unfit. The survey was carried out in the later part of May, when water table was at the lowest, and the brackish water from Rann of Kuchh had done maximum encroachment upon the sweet water of wells. It is known that after the rainy season, water in many wells towards the southern border changes for the better. This local report were verified by actual investigation of the conditions after rains. The sweet water zone in the area extends to approximately 1,50,000 acres, which could be put under well-irrigation. The population is almost 90% Hindus of Soda Rajput, Kucchi or Guajarati origin. The more advanced and educated Thakurs migrated to India after partition, leaving behind backward class of Hindus, Kolhies, Bhils and Menghwars etc. These people lack initiative and never construct lined wells. The unlined wells collapse after a year or two, due to caving in. It was with very great difficulty, that the department of agriculture installed some open wells there, in 1960-61. To this day, locals have not added a single lined well, and unless the initiative comes from some outside agency, there are rare chances of developing ground water in the Parkar area.

The Nagarparkar soil is also better than that of the desert. There is more silt and clay in it than in the desert, though sand still is dominant. In Parkar area they grow Mung, Gowar, Til, Methi, Urid, Tuna, but important cash crops are castor and onion. What is also grown on well-irrigation, on a limited scale. The Parkar area grows more than 50 thousand munds of castor seed and an equal quantity of Til, annually. If proper communication facilities are made available in that area, castor cultivation could be increased considerably. It may be worthwhile mentioning here that Parkar, unlike Thar desert, is a flat country, with no sand dunes. Its land is of a good quality and has enough ground water. It can easily be converted into greenery. The area is very suitable for growing jojoba which can fetch Rs. 250,000 per acre.

The wells as a rule being unlined, usually collapse as mentioned above, due to caving in from sides, after a few months or at the most a year's service. Water for the purpose of irrigation is lifted from these wells, by means of leather buckets (locally known Bokas), which can lift 40 gallons at a time. Boka is pulled by a Pair of bullocks or four donkeys. The camel is not used for this purpose. Persian wheels and diesel pumping sets were unknown in this area till they were introduced by the Department of Agriculture in 1960-61. The Boka seems to be originally a device adopted from Central India. It is similar to the one used in Daccan and Madhya Pradesh. Boka has an advantage to the Persian wheel in as-much-as it does not spill water back into the well. It has the form of a tea kettle with a spout. It is raised or lowered from its top, with, rope over a pulley. Another rope is attached to the spout which passes over a small pulley kept at a lower level. When the bag passes over the level of the smaller pulley, the spout is pulled horizontally and the water rushes out from the spout into the outlet already built.

THE DISADVANTAGES OF BOKA AREA

(1) The animals for each turn have to walk forward and get back in the reverse. This walking back in the reverse is a very hard and slow job for the animals.

(2) At least one person is needed all the time to guide the animals, and another to watch the lower pulley and guide the rope over it.

The capital outlay on the Boka devise is much less than that on the Persian wheel. But its hourly discharge does not match with that of the latter. After introduction of the Persian wheel in the area in 1960, local people therefore seem to have at once preferred Persian wheel to the Boka system, for it reduced all the drudgery both on the man and the animal. The chief advantage of a Persian wheel besides is that even a child could keep the animals working once they were yoked and got going. Diesel engines may be introduced with caution due to high price of oil.

While carrying out the survey for wells in the area, it was expected that the wells like those in the lower Indus valley will give discharge of 1/8 to 1/6 of cusec of water, but at the time of constructing open wells in this area, it was found that the permeability of the sand was very high, and at one place excavation of an open well further down was even abandoned as the dewatering pump of one cusec capacity could not dry it up even alter 24 hours pumping. The average wells in this area thus can give about 1/2 a cusec of water. Where it not for the difficulty of transporting diesel oil, the 6.7 h.p., pumping set would be most ideal, unit. The area happens to be outside the high wind zone, and data about the wind velocity in the area is not known. If wind velocities of 10 to 12 miles per hour were available, a 25' diameter wind mill could replace a Persian wheel, as water is available at shallow depths. The cost of wind mill of this size, including tower and installation, would be about Rs. 1,25,000.

There is no danger of wells drying up in the Parkar area., Average rainfall is 14", which is the highest in the southern zone. Though the rain-fall in some years is scanty, still the wells do not dry up in next year. The rain fall during 1958 was 12.99 inches, and at the time of survey in May 1959, none of the wells had dried up, though as locally reported, the water table had fallen down generally by 10' in 10 months. This figure shows a rather too exorbitant natural drainage. It could therefore be assumed that most of the wells got initially filled up due to rain water an seepage from surrounding area, rather than by the actual rise of water: table by 10'.

The sweet water perhaps extends up to the depth of 100' or so in the centre of the Parkar area, and this depth slowly decreases till near the Rann of Kuchh water turn saline.

Open well 40' deep, with 20-30 feet of filter in it can easily yield ½ a cusec of more water. A hundred feet deep tube well fitted with a turbine pump can give 1.5 cusec in suitable areas. However, for this area an open well instead of a tube well will be preferable, until such time the area is properly connected by metal rod with the plains. The results of investigation has shown ground water of five different qualities. Very poor should not be utilized even for cattle. Poor water cannot be used for irrigation, but is used for cattle.

Good: Vethakioo Ramji Metha, Tarachani-Veri, Careoramji Veri, Bhatiani Barwaro Khuh, Ramawah, Waghawah, L.B. Well, Gordharo (i), Gordharo (ii), Ramat Sam Khuh, Sudran, Maijijo Vandhio (Pamjijo Santar), Un, Un Sarupo Sautar, Swachand Suria Khuh, Bartala I, Bartala II, Bartala III, Chruio, Virawah, Dungri, Wadampa, Jamamadar-jo Goth, Bartalao VI, Kasbo Narumal, Masbo Chiman Sangh, Kashbo Chaman Sangh, Kasbo Dergi, Barkalao.

Fair: Krishan Lohami, Maijijo Vandhio (Nathuram Suntar), Maljijo Vandhio (Gangaram Lohano), Maijijo Vandhio (Channba Maleji), Rampur Saran, Padamsar Tala.;

Doubtful: Souraji-Veri, Lovehi Lohano (Nagarparkar), Ashram well,

Poor: Govt. L. B. Weel, Dameji Khuh (Nagarparkar), Govt. well, Dreh., Rampur, Hamirji-jo-Goth, Vadharui HI, Virwah Chachhro Road, Virawal Watasar I, Vail, Vadhral II Pucca.;

Very Poor: Khariro, Lakar Khadio, Sahensan, Baka Talao, Gadro Karku, Ghanido, Virawash Ditcher.

GROUND WATER IN NARA COMMAND

There is an impression that ground water in area below Jamrao head was definitely brackish. M/s. Huntings who carried out investigations in 1959-1965, do not seem to have put in any test bore above Jamrao head. They however suggested that strata up-streams of Jamrao head were not suitable for tapping ground water. To verify the truth of this statement, we put in 40 test each 100' deep at distance of every two miles from Rohri to Jamrao head in 1967. The statement of M/s. Huntings has to be reconsidered in light of these test bores which showed that ground water in the first 22 miles (definitely due to nearness of Eocene hills of Rohri and Kot Dijji) was brackish but beyond this point right up to Jamrao head was sweet.

The water bearing strata starts at depth of 50' and continues beyond 100'. It consists of coarse sand and lime stone gravel. The width of sweet water belt could not be checked but apparently it was more than couple of miles wide on either side of river. The source of this water was seepage from Nara canal which has been flowing as perennial stream

since Fife opened in 1859, more than 600 years after it had dried up. Any water pumped from the ground will be replenished by Nara canal, which then, must be supplied with extra water at suitable times to store it in the underground reservoir.

The results below Jamrao head were equally interesting. Water on both sides of Jamrao canal was sweet up to a point a few miles south of famous ruins of Mansura of Bahamanabad. The sweet water column is more than two hundred feet deep near Jamrao head and it tappers off slowly as one moves south wards to Sanghar where depth of sweet water column was only 100 feet.