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RESEARCH ARTICLE

NEOTECTONICS & WATER CHEMISTRY OF GROUND WATER REGIME OF LOWER NARMADA VALLEY PARTS OF MP & GUJARAT STATE INDIA.

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Abstract

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The area is situated extreme west at the mouth of Gulf of Cambey at terminus point of basin which forms a oval depression which is elongated and starched in E-W direction and truncated by crossed structural lineaments trending NW –SE, NE-SW direction. The quaternary blanket exposed to post deposition activity which subsequently chiseled by cumulative geostatic and climatic changes resulting into various terraces, pre-quaternary and quaternary surfaces and landform elements of various domains. In the area Narmada channel course is both obstructed & guided and controlled by the cross lineament trending transverse to strongly dominated ENE-WSW to E-W SONATA LINEAMENT resulting in the channel dynamics which suddenly open out which at short range and became sluggish as evident by the disposition of quaternary landscape, river terraces, associated landform elements and channel morphology. The area possesses high ground water potential both at shallow and deep level. The ground water regieme is strongly influence by deep seated linaments and composite fabrics of Sonat system. The various diversified manifestation are recorded in tearms of landscape, morphogenetic, Neotectonic, geothermal and geochemical signatures.

In the area chmical aspects of ground water domain has been attempted to across the Narmada north fault (NNF) Narmada south fault (NSF) and their sympathetic farcture system. In the area about 206 water samples from deep bore holes were collected in vertical coloumn to evaluate water chemistry of shallow and deeper aquifers, to understand geochemical processes and integrated water flow, to identify groundwater sources its chemical status its path across the different rock types, different compotent of lineament fractures, subsurface mixing of water , linear and circuitous movement of ground water system in tectonic zone. A total of 118 groundwater samples in between Barwani and Bharouch section were also collected and analyzed for major redicales results are incorporated in this paper.

The study points and collection of samples are precisely selected in critical and crucial section with the assistence of satellite imagery and remote sensing techniques. The present study has revealed the relationship between groundwater flow systems and the distribution ofchemical facies with the aid of Geographical Information System (GIS). The study also

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Identifies the different geochemical processes responsible for the chemical evolution of groundwater chemistry. Analytical results of 43 groundwater samples from pizometers and deep bore holes indicate mean values of cations as Na+ (84.2 mg/l), K+ (4.2 mg/l), Ca2+ (27 mg/l), Mg2+ (11.5 mg/l) and Fe2+ (0.6 mg/l). The anion mean values are (4.5 mg/l), SO3? NO (3.7 mg/l), Cl– (22.5 mg/l) and (2.2 mg/l). Based on mean values, the cations are in order of abundance as Na+ > Ca2+ > Mg2+ > K+ > Fe2+ while the anions reveal order of abundance as Cl– > HCO > SO >. The geographical information system (GIS) using inverse Distance Weighted (IDW) delineate two groundwater zones into: Ca-Mg-SO4-Cl and Na-SO4-Cl water types. The Cl, SO4 display consistency where asCO3,HCO3,Mg, Na K mark fluctuation in their occurrence.Na, Ca Mg and HCO3.In Tilakwarda –Barouche section except SO4 Ca Na Mg Cl in shallow aquifer exhibit diverse concentration and diffrential frquency of distribution in depth 620m where as beyond their concentration is isotropic persistent and stable.The former phenomenon appears to be realted with mixing of water due to constant flushing of water under stress across the fault and lineament where later facies is sealed water domain in tectonic ecology with restricted outet along the fault and lineament.The water samples 1 to 23 Na Ca Mg display anisotropic concentration, execpt sample 11,12,13, Mg display highest vales where K is uniform and in consistency and in harmony, Cl and Na display synchronised frequency with little variation in system. These redicales in sample no 23 to 28 show higher peaks whereas other Ca, Na Mg and HCO3 exibit anisotropic mechnisam in rhytems of neoseismic micro events. Whereas the rest is under isotropic concentration.The sampes 50 to 70 the concentration of Na, Mg, Ca and HCO3 suddenly increses with little variation where as whereas SO4 and Cl exhibit harmony in their frequency. The sample no 1 to 10 (10+ 30=40) are in consistency & harmony in frequency distribution and revealed tectonic dislocation in aqufer strata and represnet disciplined inatct water domin with restricted inlet and outlet appers to be along fault and lineament.In the water domain of about 600m the Ca-Mg-SO4-Cl constitutes about 73 % of the chemical facies and its evolutionary trend is due to simple hydrochemical mixing between Ca-Mg-HCO3 and Na-SO4-Cl facies and reverse cation exchange where as 27% represent shallow fresh intact water intact domain which is secured within fault bounded block with in the cross lineament.The chemical facies beyond 600m domain Ca-Na-SO4-Cl and ca CO3, HCO3, HCO3 facies constitutes about 82 and 18 % chemical facies and represents fossil groundwater from deep source across the Narmada north fault (NNF). The Ca-Mg-SO4-Cl facies is persistent in outlet zone under tectonically conealled strata under stress where the other facies Na-SO4-Cl prevails in discharge areas.

Introduction:-

The Narmada River originates at Amarkantak at an elevation of about 1057 m above m.s.l.,it descends across the rugged and mountainous tract through deep and steep gorges in straight sinuous to meandering pattern over a distance of 1320 km across the middle of the Indian sub-continent to join the Gulf of Cambay in Arabian sea in Gujarat state. It negotiates in sinuous to meandering pattern, at places it has conspicuous straight segment controlled by E-W lineament. It is bound by Vindhyachal in the north and Satpura range to the south; the area in between these two upland is found to be ideal area for a study of Quaternary sedimentation as witnessed by the presence of multicyclic sequence of Quaternary terraces in Jabalpur Barouche section. These terraces represent the former levels of valley floors formed by cumulative erosional and depositional activities of the river system.

The area in western sector of Narmada between Grudeshwar and Barouche is occupied by thick Quaternary deposits of about 800 m which represent various domain of sedimentation. Based on sedimentlogical characters, depositional environments, and erosional processes and their correlation with depositional activity revealed that it comprised of four domains of sediments viz glacial, fluvio-glacial fluvial and tidal flats. The lower most units (Boulder bed) is, of glacial origin, the boulder conglomerate of glacio-fluvial, fluvial of paleo- domain of Narmada and tidal flats. The top four formations Ankleshwar, Tilakwarda&Bharouch and Aliabat are designated as (NTo-NT3). Boulder conglomerate is assigned an independent formational status based on distinct lithology and fossil assemblage. The sequence of Quaternary events and the history of sedimentation of Narmada indicate that the upper 180 of the Narmada alluvium was deposited in two distinct aggradations episode with a distinct, well defined break in sedimentation in rift system. The dissection of the quaternary blanket resulted in to two terraces (NT3-NT2), after break in sedimentation. The sediments of this aggradations episode constitute three lithostratigraphy units Ankhleshwar, Tilakwarda and Bhaoruch formation. The sediments of the alluvial phase are underlain by a boulder bed of glacio-fluvial origin. Thus, the fossiliferous boulder conglomerate, the basal unit of alluvium marks a disconformity between the lower glacial-boulder layer and upper fluvial sediments. The fossiliferous basal boulder conglomerate is being of middle Pleistocene age.

The Quaternary blanket of Narmada in western sector provides evidence for significant changes in channel kinetics of Paleo domain and present day domain of Narmada related with ecstatic & sea-level fluctuation. The Quaternary deposits contained in the western asymmetric trench consist of sediments of various domains viz glacial, fluvio-glacial, fluvial, lacustrine and tidal flats influenced by incursion of marine transgression and regression on tectonically active platform. It is evidenced by bore hole data and subsurface statistical analysis of sediments, quartz grain morphology of sediments, paleo sole geometry and configuration of quaternary deposits in western segments of Narmada rift valley and SONATA TECTONIC ZONE.

The Quaternary deposits and river terraces (NT1to NT3) entrapped in tectonic zone with rock cut equivalence and scare is significant signature of euestatic change / climatic changes in the western coast and Gulf sedimentation. The alluvial fan in between Tilakwarda and Rajpipla within the loop of Narmada Chamyal (2002) is mono illustration of morphogenetic process associated with geotectonic event. The disposition of Quaternary blanket, fan deposit and other quaternary land forms are controlled and restricted by SONATA LINEAMENT towards north. The convergence of fan deposits and its apex is not persistence and in conformity of piedmont sedimentation and devoid of torrential stream net work which firmly rule out to be endogenetic fan deposits and appears to be older quaternary deposits which have been moved from basement and have been pasted along SONATA LINEAMENT.

The area is situated extreme west at the mouth of Gulf of Cambey at terminus point of basin which forms a oval depression which elongated and starched E-W direction ad truncated by crossed structural lineaments trending NW –SE, NE-SW direction. The quaternary blanket exposed to post deposition activity which subsequently chiseled by cumulative geostatic ad climatic changes resulting into various terraces, pre-quaternary and quaternary surfaces and landform elements of various domain and plantation surface. In the area Narmada channel course is both obstructed & guided and controlled by the cross lineament trending transverse to strongly dominated ENE-WSW to E-W SONATA LINEAMENT resulting in the channel dynamics to suddenly open out which at short range became sluggish as evident by the disposition of quaternary terraces and various landform elements. Based on morphologenetic expression, elevation, slope characteristics, drainage density, erosional pattern, pedagogical characters and diagnostic land form elements, the area in lower Narmada valley is broadly three Quaternary terraces (NT1 to NT3) which are time equivalent to three terraces of central sector of Narmada Khan et.al (1982) Khan 1984, Khan 1992 & Khan 2014 Plate No 1 to 3

Tectonics:-

The area of study constitutes parts of SONATA LINEAMENT ZONE, it tectonically encompasses two crustal provinces of Central India Shield namely, the Northern Crustal Province (NCP) and the Southern Crustal Province (SCP (Acharyya and Roy, 1998; Roy, 1988). The two provinces are separated by a crustal level shear zone, referred as Central Indian Suture (CIS Jain et al. 1991,1995). The southern par of the NCP, containing the Satpura and Son Narmada (SONA) valley geographic domain, is known as Central Indian Tectonic Zone (CITZ; Radhakrishna and the CITZ are marked by Narmada North Fault (NNF) in the north and CIS in the south (Acharyya, 1999). The Jabalpur earthquake affected area lies in SONA lineament zone which forms the northern units of CITZ. The SONA zone is about 1600 km long and 150 km-200km wide, extending from the southern margin of Kathiawar peninsula in the west to the margin of Vindhyan basin in the east (Crewford, 1978: Ahmad, 1964). The zone has been a major locus of episodic tectonism with evidences of reactivation. The E-W to ENE-WSW trending Narmada and Tapti lineament from a prominent tectonic belt (SONATA) in midplate continental India.The Narmada tectonic line and its presumed eastward extension, Son, have been considered as a major Precambrian deep crustal features (Auden, 1949; West 1962) and possibly a palaeo-rift (Nayak 1990) extending hundreds of kilometer in E-W direction (Mishra 1987, 1992). Pascoe (1959) recognized the Narmada lineament as a rift at its western ends however, its eastward extension and the relative timing of the Narmada rifting and Daccan Trap eruption remained unknown. Khan et.al (1914) studied the Deccan Trap in western extremity of Narmada Rift valley of Quadrangle 46I, 46 J,46 M, 46 N covering an area about 45000 sq. km bounded by latitude 22 00 00 to 24 00 00 N and longitude74 00 00 to 76 00 00 which indicate repeated cyclic and intermittent eruption of basltic lava along ENE-WSW to E-W trending lineament in synchronization of mechanics of SONATA LINEAMENT ZONE which directly rest over the Proterozoic rocks south of Jhabua (46J). The complet sequence of lava flows is noticed in (46N) in Narmada valley.

The Narmada Rift valley is conspicuous ENE-WSW to E-W trending prominent composite structural system across Indian sub-continent. It consists of various blocks which are dislocated and faulted along various faults and lineaments in space and time. The Narmada Rift System consistsof various sub-basinslike Hiran , SherShakkar, Dudhi,Tawa,in central Narmada valley and KarjanMadhumati,OrsangUnchHeran,Aswan,Men rivers in lower Narmada valley are minor basins are tectonically segmented ecologically integrated and in built part of main rift System.which are minor basins are integrated and in built part of main rift System. The Narmada Rift valley in the western segment is sinuous to meandering in nature though it is strongly influenced by conspicuous ENE-WSW to E-W trending prominent composite structural system across which persistently extends in western part across the Indian sub-continent. It consists of various blocks which are dislocated and faulted along various faults and lineaments in space and time Rift System.

In lower Narmada valley (NSF) is mega component of SONATA LINEAMENT ZONE, it is expressed as a single deep-seated fault confirmed by the deep seismic sounding studies (Kaila et al., 1981). Seismic reflection studies have firmly established that the NSF is a normal fault in the subsurface and becomes markedly reverse near the surface (Roy, 1990). Reactivation of the fault in Late Cretaceous led to the formation of a depositional basin in which marine Bagh beds were deposited (Biswas, 1987). The NSF remained tectonically active since then with continuous subsidence of the northern block, designated as the Broach block, which accommodated 6–7-km thick Cenozoic sediments (Biswas, 1987). The total displacement along the NSF exceeds 1 kmwithin the Cenozoic section (Roy, 1990). However, the movements along this fault have not been unidirectional throughout. The general tendency of the basin to subside has been punctuated by phases of structural and tectonic inversion (Roy, 1990). The N–S-directed compressive stresses during the Early Quaternary, folded the Tertiary sediments into a broad syncline, the Bharouch syncline, in the rapidly subsiding northern block (Roy, 1990). The Bharouch syncline extends from the NSF to the Mahiriver in the north. The E–W trending axis of this syncline lies to the north of the Narmada river. Corresponding anticline structures are found in the Tertiary rocks exposed in the southern up thrown block. Historical and instrumental records indicate that the compressive stresses still continue to accumulate along the NSF due to continued northward movement of the Indian plate. This is evidenced by the fault solution studies of the earthquakes at Bharouch (23 March 1970) and Jabalpur (22 May 1997), which suggest a thrusting movement (Gupta et al., 1972, 1997; Chandra, 1977; Acharyya et al., 1998). However, the underlying cause of the seismicity in the NSF zone is not yet understood (Quittmeyer and Jacob, 1979) extending Gujarat alluvial plains. A significant feature of the lower Narmada valley is the deposition of a huge thickness of Tertiary and Quaternary sediments in a fault controlled basin. To the south of the ENE–WSW-trending Narmada–Son Fault (NSF), the Tertiary rocks and basaltic flows of Deccan Trap Formation occur on the surface while to the north they lie in the subsurface and are overlain by Quaternary sediments. However, the overlying Quaternary sediments having a maximum thickness of

800 m (Maurya et al., 1995) .The correlation of subsurface data of CGWB and other agencies on Quaternary Platform Khan (2012) and Khan (2014) Khan et.al (1984) Khan et.al (2013) Khan et.al.(2014) Khan et.al.(1991), Khan et.al.(1992), indicate presence of glacial fluvio-glacial deposits at the base of rock basin. Drill data from some of the deepest wells in the basin have revealed occurrence of Deccan Trap at depths of 6000 m followed by an Archaean basement (Roy, 1990). The Tertiary sediments, outcropping to the south of the NSF, represent the full sequence from Eocene to Pliocene overlying the Deccan Trap and show extensive deformation in the form of several ENE–WSW-trending anticline highs and ENE–WSW and E–W-trending reverse faults. Profuse occurrences of E–W-trending dykes suggest that the zone formed the main centre of eruptive activity (Bhattacharji et al., 1996). The entire zone is presently characterized by high gravity anomalies, high-temperature gradient and heat flow and anomalous geothermal regime (Ravishankar, 1991) suggesting that the zone is thermo mechanically and seismically vulnerable in the framework of contemporary tectonism (Bhattacharji et al., 1996). The westward extension of this zone into the lower Narmada valley exhibits a less complex structural setting.In the lower Narmada basin, it is expressed as a single deep-seated fault (NSF) confirmed by the Deep Seismic Sounding studies (Kaila et al., 1981). Seismic reflection studies have firmly established that the NSF is a normal fault in the subsurface and becomes markedly reverse near the surface (Roy, 1990). Reactivation of the fault in Late Cretaceous led to the formation of a depositional basin in which marine Bagh beds were deposited (Biswas, 1987). The NSF remained tectonically active since then with continuous subsidence of the northern block, designated as the Bharouch block, which accommodated 6–7-km thick Cenozoic sediments (Biswas, 1987). The total displacement along the NSF exceeds 1 km within the Cenozoic section (Roy, 1990). However, the movements along this fault have not been unidirectional throughout. The general tendency of the basin to subside has been punctuated by phases of structural and tectonic inversion (Roy, 1990). The N–S-directed compressive stresses during the Early Quaternary, folded the Tertiary sediments into a broad syncline, the Bharouch syncline, in the rapidly subsiding northern block (Roy, 1990). The Broach syncline extends from the NSF to the Mahiriver in the north. The E–W trending axis of this syncline lies to the north of the Narmada river. Corresponding anticline structures are found in the Tertiary rocks exposed in the southern up thrown block. (Historical and instrumental records indicate that the compressive stresses still continue to accumulate along the NSF due to continued northward movement of the Indian plate. This is evidenced by the fault solution studies of the earthquakes at Bharouch roach (23 March 1970) and Jabalpur (22 May 1997), which suggest a thrusting movement (Gupta et al., 1972, 1997; Chandra, 1977; Acharyya et al., 1998). However, the underlying cause of the seismicity in the NSF zone is not yet understood (Quittmeyer and Jacob, 1979).In lower Narmada valley to evaluate water chemistry of shallow and deeper aquifer across the NSP and its sympathetic fabrics and its impact on chemical domain of subsurface water sampling is carried out and analyised in addtion data from published litrature of CGWB, GSI ETO and other state agencies for comprehansive interpretation and scientific under standing behaviour of water domain in tectonic zone. The results of chemical analysis and their graphic representation are given in Table No 1 to 5 and Plate No _1 to _3.

The area has been selected on the merits of tectonic frame work geological set up, quaternary landscpe, neotectonoics, and quaternary sedimentation, seismo tectonic activity, sea level fluctuation and sea incurssions, Indian plate movement, NSF zone which cut across the coast line in Arbian sea. The collective manifestation of these various dominal activity is found to be unique area to under water chemistry and chemical facices in SONATA LINEAMENT ZONE which is attempted.

Geology:-

The Quaternary tract of Narmada basin covers an area of about 10830 sq. km starting from Gurudeshwar to Barouche for a distance of about 130 km. It is found to be ideal locus of Quaternary sedimentation in western India as witness by multi-cyclic sequence of Quaternary terraces in the valley. The general elevation of Narmada alluvial plain varies between 65.00 m to 95.00 m above the sea level. The general gradient of this plain in this stretch is about 1m /km towards West (Plate No 1)

The study area consists of geologic formations viz Precambrian, Tertiary, Cretaceous, Deccan trap and Quaternary deposits. The Precambrian rock gneiss granite, schist Tertiary consist of rocks are mostly carbonate, including dolomite, interbedded limestone, as well as thin layers of shale and quartzite. The Deccan trap thick pile of basaltic flows where as Quaternary deposits consist of sediments of four domainViz Glacial Fluvio-glacial, Fluvial and Tidal flats.

The Paleozoic rocks are mostly carbonate, including dolomite, interbedded limestone, as well as thin layers of shale and quartzite, which outcrop in various locations within the study region. The Tertiary rocks mainly consist of felsic volcanic rocks and are exposed widely within the area. Quaternary alluvial deposits are the weathering products of tuffaceous rocks derived from a Pleistocene unit consisting of gravels that represent earlier, dissected alluvial fans and a Holocene unit consisting of recent alluvial fans. The lower Paleozoic rock aquifer and valley-fill aquifer are considered major aquifers in the region, although the fractured Tertiary rock aquifer also transmits significant amounts of groundwater .The major hydrologic units were slightly revised from the earlier work to include (1) the basement confining unit, (2) carbonate rock aquifer, (3) Eleana confining unit, (4) the volcanic aquifers and confining unit, and (5) the valley-fill aquifer. The basement confining unit consists primarily of Precambrian metamorphic rock to Paleozoic marine sediments. The carbonate rock aquifer consists of Paleozoic carbonate rocks from the Middle to Late Cambrian up to the Lower to Middle Devonian. The upper carbonate aquifer, made up of the Limestone, is considered to be a localized aquifer located in the western part of valley. The lower carbonate aquifer, however, is of a regional extent and is very important in regard to ground-water flow. It consists of Paleozoic siliceous siltstone, sandstone, and minor limestone conglomerate and is considered to be a clasticaquitard or confining unit .This unit separates the lower and upper carbonate aquifers. The Deccan volcanic aquifers and confining unit together make up the complex regional unit which overlie most of the Paleozoic rocks and consist of some Mesozoic through Tertiary volcanic rocks. The Quaternary deposit & valley-fill aquifer in the lower Narmada valley is a regional and open system which constitutes both deep and shallow aquifers and possesses good potential of ground water. Groundwater flow through the valley-fill and pre- Quaternary aquifers appears to be controlled predominantly by ENE-WSW faults and fractures. Plate No_3

Geohydrology:-

The study area consists of geologic formations viz Precambrian, Tertiary, Cretaceous, Deccan trap and Quaternary deposits. The Precambrian rock gneiss granite, schist Tertiary consist of rocks are mostly carbonate, including dolomite, interbedded limestone, as well as thin layers of shale and quartzite. The Deccan trap thick pile of basaltic flows where as Quaternary deposits consist of sediments of four domains Viz Glacial Fluvio-glacial, Fluvial and Tidal flats.

The Quaternary deposits aquifers generally possess potential groundwater resources, where as Crystalline has limited potential, basaltic rocks moderate, moderate to high, however, some highly productive aquifers may be encountered, typically near tectonic discontinuities. In this study, we used a multidisciplinary experimental field approach to investigate the hydrogeological behavior Narmada Rift system of a sub-vertical permeable fault zone identified by lineament mapping. We particularly focused our investigations on the hydrogeological interactions specifically in Barwani_Bharouch section consists of geologic formations viz Precambrian, Tertiary, Cretaceous, Deccan trap and Quaternary deposits). The Precambrian rock gneiss granite, schist Tertiary consist of rocks are mostly carbonate, including dolomite, interbedded limestone, as well as thin layers of shale and quartzite. The Deccan trap thick pile of basaltic flows where as Quaternary deposits consist of sediments of four domains Viz Glacial Fluvio-glacial, Fluvial and Tidal flats. The geometry of the permeable domains was identified from geological information and hydraulic test interpretations. The system was characterized under natural conditions. The data base of pump testing of State Ground Water agency used for correlation and interpretation. The combination of piezometric analysis, flow logs, groundwater dating and tracer tests to describe the interactions between permeable domains and the general hydrodynamic behaviors. A clear vertical compartmentalization and a strong spatial heterogeneity of permeability are highlighted.Under ambient conditions; the vertical permeable fault zone allows discharge of deep groundwater flows within the superficial permeable domain. The estimated flow across the total length of the fault zone ranged from 170 to 200m3/day. Under pumping conditions, hydrological data and groundwater dating clearly indicated a flow inversion. The fault zone appears to be highly dependent on the different surrounding aquifer reservoirs which mainly ensure its recharge. Ground water fluxes were estimated from tracer tests interpretation. This study demonstrates the hydrogeological capacities in lineament zone of aquifers in composite geological domain. By describing the hydrological behavior of a fault zone, this study provides important formations about the behavior and ecology of ground domain in the Rift system.

The pre-quaternary and quaternary rocks occur in the Narmada rift valley possess size able potential of ground water. The porosity and permeability of these rocks are low to moderate, but their hydraulic properties is greatly modified as a result of tectonic activities physical and geochemical processes such as weathering and fluid circulation . Various conceptual models of hydrogeological compartmentalization in these rocks have been proposed (Chilton and Foster, 1995; Dewandel et al.). The rocks of Narmada Rift valley usually consist of quaternary blanket of as a specific reservoir with a relatively high porosity and storage, highly sensitive to rainfall recharge; the pr-quaternary composite rocks which has a superficial fractured zone, of various thickness and which may be characterized by relatively dense sub-horizontal and sub-vertical fracturing. This fractured reservoir has in general a higher permeability although well yields are typically limited to less than 10m3/h. However, highly reductive zones the idle sector of valley, considered to ensure the viability of the resource such as rock lithology affected by tectonic activity, stress fields and intensity of deformation. Such factors and fluid flow processes determine fault zone permeability. The hydrogeological studies conducted display relationships between lineaments structures, hydrogeological flow organization and productivity wells. The SONATA lineament zone may act as conduits, barriers, or as combined conduit-barrier systems that enhance or impede fluid flow and has significantly influence groundwater flow and raised water-table elevations in Narmada Rift System.

The rocks of Narmada Rift system cover large areas and constitute a crucial water resource for vast population. The porosity and permeability of primary crystalline rocks are extremely low, but their hydraulic properties can be greatly modified as a result of secondary physical processes (unloading, tectonic activities, etc.) and/or geochemical processes such as weathering and fluid circulation Various conceptual models of hydrogeological compartmentalization in crystalline rock aquifers, other rock aquifers and quaternary aquifers have been studied. They usually consist of two main reservoirs: (1) a layer of Quaternary deposits (<15 m bgs), identified as a specific reservoir with a relatively high porosity and storage, highly sensitive to rainfall recharge; (2) pre- quaternary rocks a superficial fractured zone, of various thickness and which may be characterized by relatively dense sub-horizontal and sub-vertical fracturing. This fractured reservoir has in general a higher permeability although well yields are typically limited to less tha 10 m3/h. However, highly productive zones have been locally highlighted in regions exposed to the Quaternary tectonic activity. Many factors must be considered to ensure the viability of the resource such as rock lithology affected by tectonic activity, stress fields and intensity of deformation. Such factors and fluid flow processes determine fault zone permeability. It is examined the relationships between lineaments structures, hydrogeological flow organization by suing chemical parameters as tool. The in SONATA LINEAMENT ZONE the fault net act as conduits, barriers, or as combined conduit-barrier systems that enhance or impede fluid flow but can also significantly influence groundwater flow, spring discharge, and water-table elevations. In some cases, aquifers near highly conductive fault zones and with relatively high production rates for Quaternary deposits specifically, but in case of deep seated fracture zone and dislocated and displaced showed the important effects of the geometry and anisotropy of a fault zone on its hydraulic properties.

The numerical studies, such as those by Anderson and Bakker (2008), also highlighted the influence of a vertical fault on groundwater flow. In the crystalline context, some studies have described the permeability architecture and hydrogeological functioning of fault zones for groundwater resources However, very few studies have analyzed the hydrological functioning of faults in a water abstraction context. In this context, aquifer yields will mainly depend on the ability of interactions between the fault and the surrounding reservoirs to allow recharge and water availability. On the other hand groundwater abstraction from a deep resource will undoubtedly modify the hydrodynamic gradients and lead to mixing between the different reservoirs and chemical gradients.The hydrogeological influence of deep fault zones on overlaying reservoirs is poorly known and is apparently difficult to characterize by field studies The first aim of this study is to characterize the hydrodynamic functioning of a sub-vertical permeable fault zone in crystalline basement from a large-scale field experiment. The main objectives are to (i) describe the architecture of the aquifer system, (ii) define the flow organization between the permeable zones and recharge processes towards the deep fault zone under natural and pumping conditions and (iii) characterize the origin of groundwater admixing processes due to groundwater abstraction and chemical parameters are used to develop a hydrogeological conceptual model of a sub-vertical fault zone in crystalline context.

In the area of study 161 water samples were collected across the length and breadth of valley which for complete water analysis from different NSF zone, and other structural component, from shallow and deeper aquifers. The results are incorporated in TableNo 1 to 5

The Ground water of the area has PH value ranging from 7.3 to 8.9, suggesting thereby slightly alkaline tendency. The Hardness of groundwater (as represented by $CaCO_3$) is generally highfor the area and it varies between 82 to 530 ppm.

The Degree of mineralization of ground-water of the area as reflected by specific conductance at 25°C is moderately high to vary high as it varies between 550 t 2373.

In view of comprehensive and comparative study and interpretation the results of water analysis, which were given as parts per million (ppm) have been divided by the equivalent weights of the cations and anions to obtain the values of equivalents per million (epm) as listed and from them the percentage reacting values (prv) have been calculated. On the basis of these values water samples have been plotted on the i) the Wilcox diagram for irrigation water classification, ii) Diagram after the U.S. Salinity laboratory and iii) Piper Trillinear diagram and also different parameters like pipers binomial symbol, Eaton's index (Residual alkalinity), per cent sodium, Kelly's ratio, Collin's index and sodium absorption ratio have been determined for understanding the geochemistry of ground water.

Piper has formulated a procedure for classifying the nature of hardness of water and for determination of the relative percentage of two type of hardness and it is called 'Binomial symbol'. It is written in the form of a decimal fraction, whose two terms are i) the percentage of hardness causing constituents (Ca + Mg) amongst the cations and ii) the percentage of bicarbonate (and carbonate, if present) amongst the anions. Thus the most common natural water containing chelly cadmium, magnesium and bicarbonates quality of water of the alkali-carbonate type, the symbol indicates relative hardness as percentages of total equivalents. If the second term exceeds the first term, the entire hardness is temporary is of carbonate type. But if the first term exceeds the second term, some of the hardness is permanent or of non-carbonate type. In case of non-carbonate hardness the relative amount of it is indicated by numerical difference between the two terms. The first term if this binomial symbol is also used for residing the effect of such water on soil since the first term is the complement of the percent sodium and thus if the first term is less than 40 the physical properties of the soil is likely to be impaired seriously by constant use of such irrigation water. Binomial symbol for 20 samples have been determind and it shows that for most of the samples the entire hardness is of termporary 1,4,10,12 and 14 for which some of the hardness is permanent type i.e. non-carbonate type. However, it also shows that amount of permanent hardness present is low. Further the value of the first term is less than 40 (for 6 samples numbering 7, 3,11,15,16 & 18). However, for two samples numbering 11 and 16 it is very low and almost care must be taken while using water from such wells for irrigation purposes since they are likely to damage the physical properties of soil heavily. Residual alkalinity or Eaton's Index is calculated by subtracting the values of Ca and Mg from these of CO_3 and HCO_3. According to the U.S. Salinity Laboratory staff, waters containing 1.25 to 2.50 epm. Are marginal and those containing less than 1.25 epm are probably safe. Eaton's Index for water samples reference number7,9,11,16,18 and 21 is 5.792, 4.485, 6.301, 7.807, 8.966 and 4.122 respectively and thus ground water is these area is not suitable for irrigation and for rest of the samples it is less than 2.5 epm and thus as per norm they are suitable for irrigation purposes.

Percent Sodium represents the percent of sodium and potassium epm values amongst the cations. When a soil containing exchangeable Ca and Mg ions when irrigation with water in which Ngreatly outnumbers other cations, the calcium and magnesium of the soil will tend to be replaced with sodium. Under these conditions, if irrigation is continued for long, the thereby get impaired in tilth and permeability. When the value of percent sodium is less than 20 the water is excellent, that in which it is between 20 and 40 it is still considered good, between 40 and 60 it is permissible but between 60 it is practically unsuitable. The values of percent sodium for water sample reference numbers 9, 14 and 16 and 87, 89 and 84 and thus they are highly unsuitable and for sample numbers 6, 7 and 13 they are 70, 63 and 61 they also come under doubtful category and the values of percent sodium for rest of samples are less than 60 and thus they range between excellent quality to permissible limits.. Kelly's ratio is the ratio of monovalent Na to that of bivalent Ca and Mg which is an indication of alkali hazard in water. Generally, for good water it is unity or less than unity. When it exceeds unity it indicates relatively inferior quality of water, which is harmful sensitive or low salt tolerant crop. Between one and two it is suitable for moderately salt tolerant crops. Beyond two it indicates relatively bad quality of water, which can be used only for highly salt tolerant crops.

Kelly's ratio for water sample number 7.11, 16 & 18 are more than 2 and thus in these are high salt tolerant crops should be cultivated and for rest of the samples it is less than 2. W.D. Collin's index is determined by taking the ratio of epm value of Cl to emp value of (CO_3 + HCO_3). In case of sea water this ratio is as high as 200, while in case of normal groundwater it is less than unity. With a value over unity, it indicates slightly contaminated groundwater, cound 3 it represent'smoderately contaminated ground water, with a value of 6 the groundwater is injuriously contaminated and in case of 15 this contamination is said to be high as observed typically near the sea shore. Collion's index is more than unity for only two samples numbers 12 and 15 and they are also just above unity, values being 1.205 and 1.463 respectively. Thus Collion's Index clearly indicates that groundwater from shallow aquifers of the area is not all contaminated. Samples may be collected form deeper aquifers and analysed to determine whether there is any evidence of contamination at deeper depth 'Sodium Adsorption Ratio' (S.A.R.) is determined by the following relation where ionic concentrations are expressed in epm.

The SAR value is thus related to the adsorption of sodium by soil to which the water is added. The SAR values of less than 10 are considered as excellent, those between 10 and 18 as good, between 18 and 26 as fair and more than 26 as poor.

$$SAR = \frac{Na}{-\sqrt{Ca + Mg/2}}$$

All the samples have value less than 18 and thus as per SAR norms they are suitable for agriculture purposes, but only at SAR values these groundwater cannot be termed suitable since the SAR value is more or less empirical and of significance only in considering the exchange reactions in soil and in the evaluation of irrigation water. Thus along with SAR values other parameters also have to be considered.

SAR values of 22 water samples have been plotted against their percent sodium values after a Wilcox diagram and 9 samples fall in area of diagram indicating excellent to good quality, 6 samples under goodto permissible area, 3 samples under permissible to doubtful area and one sample in doubtful to unsuitable area.

Further SAR values have been plotted against their specific conductance values in microhms at 25° C on a diagram for classification of irrigation water adopted from U.S. Salinity Laboratory (After U.S. Dept. of Agriculture Hand book Co., 1954). This diagram gives a picture of salinity hazard vis-à-vis alkali hazard.

Sample Nos 11 and 16 have both high salinity hazard and alkali hazard. 3 samples no. 7,19 and 18 have high salinity hazard and medium alkali hazard, 9 samples nos. 2,3,4,5,10,12,14,21 & 22 have high salinity hazard but low alkali hazard and 6 samples nos. 1,13,15,17,19 & 20 have medium salinity hazard and low alkali hazard.

The Percentage reacting values of three dominant cations namely Ca, Mg and Na + K and three dominant anions namely Cl, CO_3 + HCO_3 and SO4 have been plotted on a piper trilinear diagram adopted after A.M. Piper (1963). Here there are three distinct fields of plotting comprising two triangular fields at the lower left and lower right for cations and anions respectively and an intervening central diamond stepped field to show the overall chemical character of rater by a third single plot plotting which at the intersection of rays projected from the plotting of cations and anions, using the percentage reaching values. The Diamond-shaped field is further sub-divided into nine distinct sub-areas based on the chemical characters of waters namely 1. Alkaline earths exceed alkalis, 2. Alkalis exceed alkaline earths, 3. Weak acids exceed strong acids, 4. Strong acids exceed weak acids, 5. Carbonate hardness (Secondary alkalinity) exceeds 50 percent that is chemical properties of the groundwater are dominated by alkaline earths and weak acids, 6. Non-Carbonate alkali (Primary salinity) exceeds 50 percent, 7. Non-carbonate chemical properties are dominated by alkalis and strong acids, ocean water and many brines plot in this area, nearitsright hand vertex, 8. Carbonate alkali (Primary alkalinity) exceeds 50 percent the groundwater which are inordinately soft in proportion to their exceeds 50 percent 20 samples have been plotted on this diagram and out of which 10 samples numbering 1,3,4,10,12,15,16,17,18 & 22 fall in sub area 2 denoting that in case of these samples alkalis exceed alkaline earths. Further 15 samples numbering1,2,3,5,7,9,11,13,16,17,18,19,20,21 &22 fall in sub area 3 indicating that weak acids exceed strong acids and the rest 5 samples numbering 4,10,12,14 & 15 fall in sub area 4 indicating that strong acids exceed weak acids. 6 samples numbering as 1,3,13,19,20 & 21 fall in sub area 5 suggesting that in these samples carbonate hardness i.e. secondary alkalinity exceeds 50 percentage that is chemical properties of the groundwater are dominated by alkaline earths and weak acids, 11 samples numbering 2,4,5,7,9,11,12,14,16,17 & 22 fall in sub area-9 indicating that no one cation-anion pair exceeds 50 percent, 2 samples numbering 16 & 18 fall in sub area 8 suggesting that carbonate alkali-primary alkalinity exceeds 50 percent andone sample numbering 15 fall in sub area 7 suggesting that non-carbonate alkali i.e. primary salinity exceeds 50 percent By further extending the interpretation based on the position of samples in the sub area of the diamond shaped central field of the Piper Diagram and their correlation with placing of samples on the Wilcox diagram and Diagram adopted after U.S. Salinity Laboratory and also making comparison of these correlation with the various other parameters like Eaton's index. Collin's index etc. determined for these samples the following conclusion may be made about the chemistry of groundwater of the area.

i. The study and analysis of data of piper diagram that water domain no primary alkininty is present in except some area primary salinity exceeds 50 percent and this is probably due to some pollution and contaminations of Narmada river. These contaminations of Narmada water is further confirmed by Collin's Index which is 1.463 indicative of slightly contaminated ground water. The Collin's index excepting for one more sample is less than unityfor all samples indicating normal ground water and this is confirmed by the position of water plot in sub area 7 near its right hand vertex. Thus it may not be concluded beyond doubt that ground water of the area has had any connection with oceanic water nor had any contamination.

ii. The data plotting and data cluster of chemical gradients revealed that diagram adopted after U.S. Salinity Laboratory it is seen that abot 22% samples show very high salinity hazard and rest 78% and high to low salanity hazard. But after comparing the position of these samples on piper diagram it is seen that although salinity hazard is high but it is not of primary nature and also secondary hazard is reflected of high concentration of TDS in which are non-carbonated salts they do not predominate. Thus it can be calculated that salinity hazard of groundwater of the area is neither due to presence of any saline bed underneath the surface nor due to contamination of groundwater aquifer with any foreign source. The Salinity high for ground water is also not invariably present in the entire area but it becomes high at places and mostly it is due to checked and strangulated drainage through the silt beds, not permitting the quick ionic exchange.The water domain is contionously regulated from deep source fault and fracture zone.

iii. The study further revealed majority of water samples have high hardness as represented by total hardness on $CaCo_3$ (ranging between 82 to 530 ppm) by analysis and correlation of water samples on the piper diagram and Piper's binomial symbol suggest that hardness of water is mostly of carbonate type i.e. temporary hardness and in no case non-carbonate since no water sample falls in sub area 6 of the Piper diagram. Hence with suitable treatment hardness of water of this area can be removed if there is need for use of such water for some particular purpose in which carbonate hardness is in hazard.The study further revealed that water domain has deep circulation crabonate and limeston rocks cuttin across the fault zone.

iv. The critical analysis of data plots and their relative concentration in sub area 9 of the Piper diagram revealed that ground water domain of area has a mixed source of shallow aquifer and deeper aquifer across the lineament as such it posses neither neither primary alkalinity nor secondary alkalinity and neither primary salinity nor secondary salinity exceed 50 percent. Plate No_4

PLATE NO _1 LOCATION MAP OF AREA OF STUDY LOWER NARMADAD VALLEY, PARTS OF M.P. & GUJARAT STATE INDIA

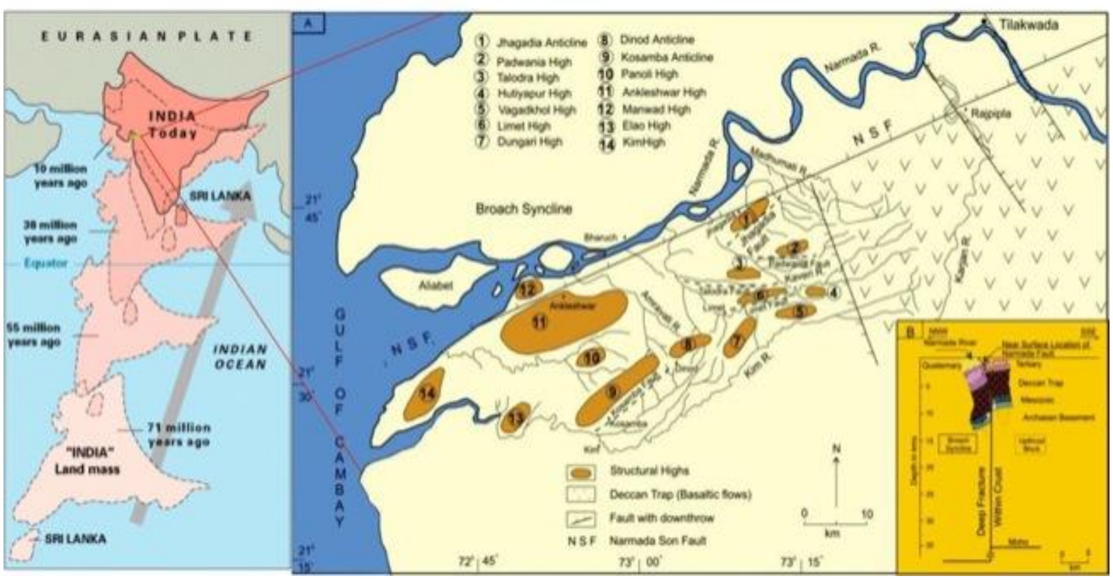


PLATE NO_2 GEOLOGICAL MAP OF AREA OF STUDY LOWER NARMADAD VALLEY, PARTS OF M.P. & GUJARAT STATE INDIA

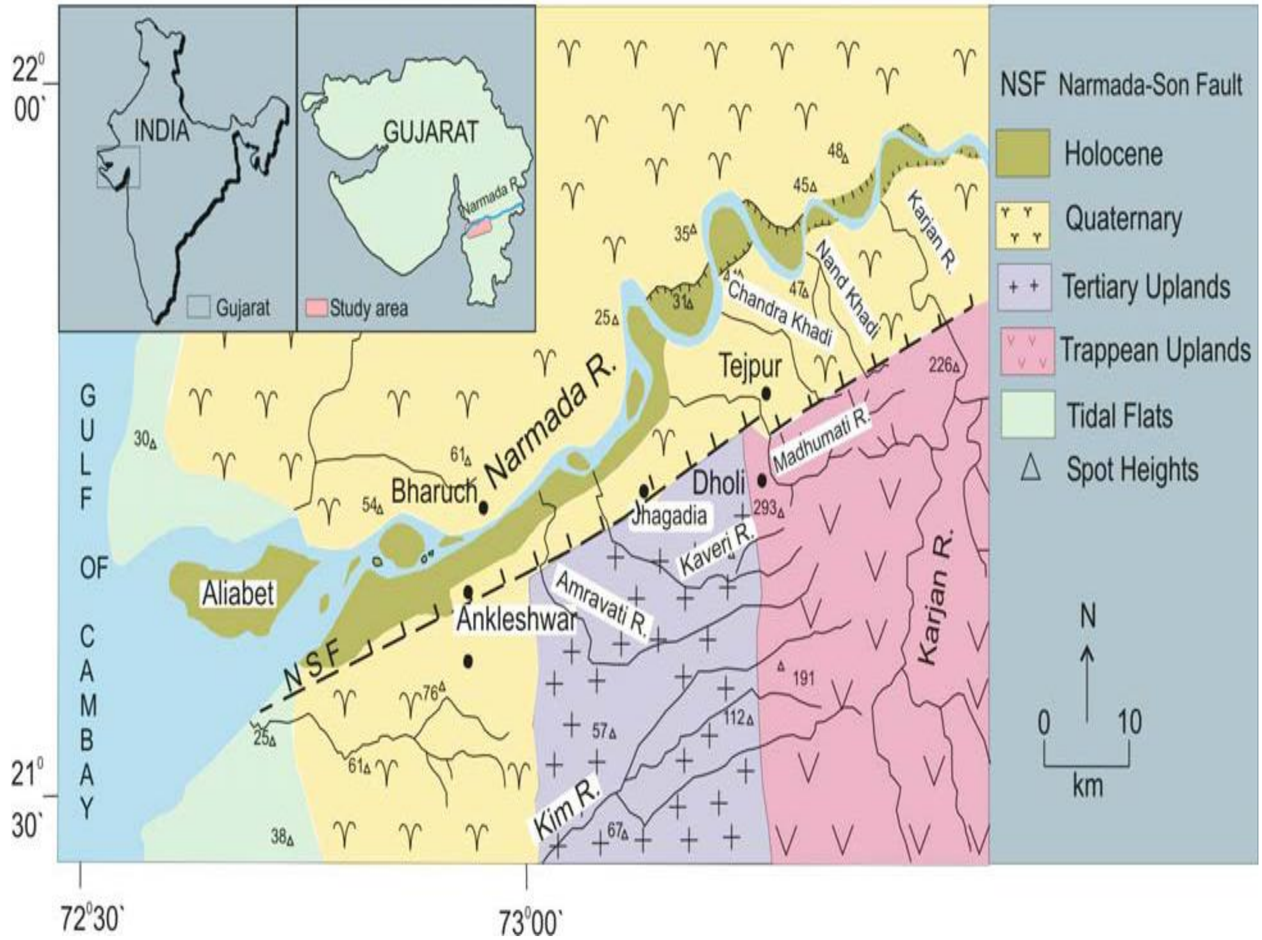


Plate No -3

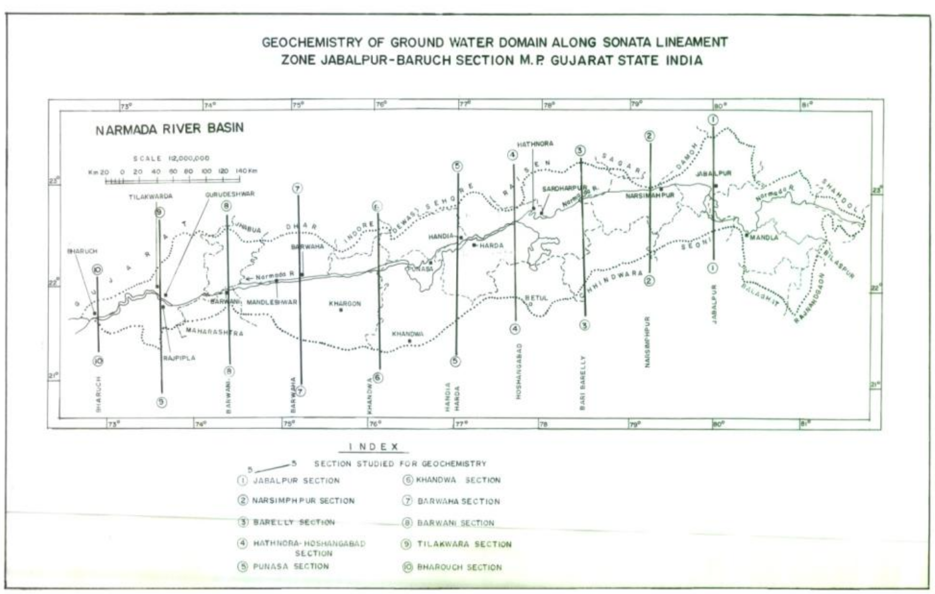


Table No -1

RESULTS OF CHEMICAL ANALYSIS OF GROUND WATER OF REPRESENTATIVE SAMPLES DEEPER AQUIFER IN SONATA LINEAMENT ZONE IN BARWANI _BHAROUCH SECTION, LOWER NARMADA VALLEY PARTS OF M.P. & GUJARAT STATE

S.No.	Water Sample No.	Location of water sample	Cations and Anions in ppm.								pH	Cond.	Total Hardness TH	TDS	Details of the Aquifer
			CO3	HCO3	Cl	SO4	Na	K	Mg	Ca					
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	NW2B-6	Tube well Bharouch town	ND	716	67	26	200	NA	70	22	7.45	115	290	734	Pebble gravel bed, Quaternary sediments
2	NW2B-7	Bharouch west of town	"	666	67	22	170	"	70	28	7.70	1102	300	643	Sandy silt, Quaternary sediments
3	NW3C-3	5 km upstream of Bharouch on the right bank of Narmada 10 kms up stream of Barouch on the left bank of Narmada	"	354	45	17	42	"	50	56	7.60	661	280	427	Weathered Deccan Traps
4	NW2C-5	Narmadai river water collected at Ankleshwar	"	415	96	31	140	"	45	25	7.50	891	205	541	Narmada river water
5	NW2C-6	Jagadia	"	388	91	22	140	"	45	25	7.60	848	205	517	Weathered granite -
6	NW3C-4	Public well of jagadia	ND	326	71	30	37	ND	42	87	7.40	729	305	491	Weathered basalt

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
7	NW2C-7	Rajpipla	"	388	56	23	95	"	45	56	7.40	805	260	530	Weathered Deccan Traps
8	NW2B-8	South of Rajpipla	ND	428	116	38	105	"	73	59	7.30	1150	365	774	Weathered basalt & quaternary sediments
9	NW2B-9	Right bank of Narmada around Tilakwarda	ND	367	67	20	75	"	46	62	7.25	767	275	498	Pebble gravel bed, Quaternary sediments
10	NW2C-16	5 kms south of Tilakwarda	14	558	253	51	235	"	77	48	7.40	1630	400	1005	Sandy silt, Quaternary sediments
11	NW3C-5	10 kms east of Tilakwrda	ND	333	131	55	46	"	71	106	7.40	1054	445	714	Weathered Deccan Traps
12	NW2B-10	Gurudeshwar town	"	272	56	20	33	"	39	78	7.50	657	280	474	-do-
13	NW2C-1	10 kms up stream of Gurudeshwar	ND	370	190	45	NA	NA	55	80	7.10	1320	420	NA	Weathered Deccan Traps
14	NW2B-3	Dhadgaon	20	53	100	20	200	2	50	25	8.4	1260	260	780	Yellow fine silt Quaternary sediment & weathered basalt
15	N12B-4	West of Dhadgaon	20	425	65	15	220	3	10	5	8.6	1070	55	650	-do-

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
16	NW2B-5	East of Dhadgaon	ND	270	55	25	55	1	30	70	8.0	7.40	302	500	Quaternary sediments &Weathered Deccan Traps
17	NW1B-1	South of Dhadgaon	71	639	524	86	400	15	112	28	8.5	2740	470	1571	sandy silt with calcareous nodules, Quaternary sediments
18	NW3B-1	Narmada River	14	256	44	17	45	<5	28	46	8.9	587	215	337	Quaternary sedfiment&Weath

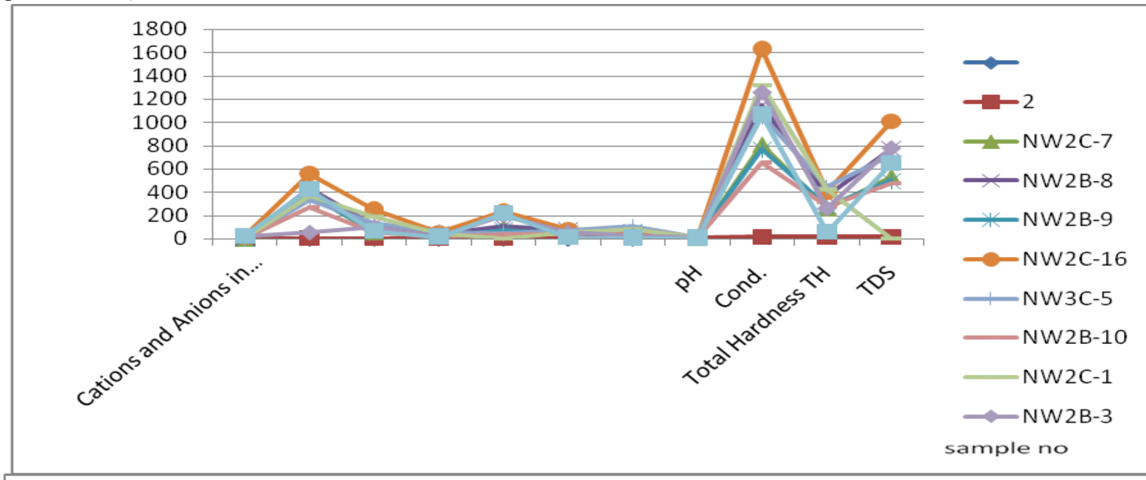
		water around Barwanifalut													ered Deccan Traps
19	NW1A-1	Right bank of Narmada about 500 from Narmada channel	57	312	25	27	90	6	35	18	8.7	705	170	489	Baslt&
20	NW2C-8	Left bank of Narmada along Shear zone of Barwani fault	57	724	127	41	260	11	49	28	8.3	1566	245	1000	Pebble gravel bed, Quaternary sediments
21	NW3B-2	2 kms East of Barwani Town	35	469	260	63	200	10	66	76	7.85	1810	425	982	&weatherd basalt , Quaternary sediments& weathered basalt

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
21	NW3B-2	North bank of Narmada around Dabhoi	35	469	260	63	200	10	66	76	7.85	1810	425	982	, Quaternary sediments
22	NW1A-2	Bore hole on the righ bank of Bhuki River	71	696	74	29	260	14	22	18	8.60	1419	125	935	Sandy silt, Quaternary sediments,Deccan Basaltic lava
23	NW1C-1	Bore hole water 20 kms north of Bharouch	71	795	49	23	325	13	21	10	8.40	1519	100	1008	Quaternary sediment ,sand silt caly and rock gravel Deccan Basaltic lava
24	NW3C-7	Bore hole water 15 kms north of Aliabat	14	284	78	34	36	< 5	32	98	7.70	636	360	491	Quaternary sediments sand silt caly Deccan Basaltic lava
25	NW2B-13	Bore hole water 10 kms west of Dabohi	43	568	88	37	220	14	22	20	8.30	1272	130	842	Quaternary sediments sandy silt with calcareous nodules, Deccan

															Basaltic lava
26	NWGR-1	Bore hole water Sankheda	7	163	20	ND	28	< 5	13	30	7.70	347	120	214	Quaternary sediments sand silt and caly Deccan Basaltic lava
27	NW1A-3	Orsang Channel water	49	646	34	17	180	9	41	26	8.40	1174	210	716	, Quaternary sediments Deccan Basaltic lava
28	NW2C-17	Channel water Aswan river	ND	114	10	ND	7	< 5	7	26	7.70	196	90	120	Channel water

1	2	3	4	5	6	7	8	9	10	11	1a2	13	14	15	16
29	NW3C-10	Bore well water 5 kms NW of Jhagadia	7	348	69	24	39	<6	39	80	7.90	817	340	417	Weathered Deccan Traps
30	NW2C-18	Bore hole 2 kms south of Rajpipla	71	497	127	30	160	8	48	42	8.40	1272	275	708	Sandy silt, Quaternary sediments and weathered basalt
31	NW3B-3	Bore hole water south east of Tilakwarda	ND	299	45	20	44	NA	41	70	7.40	652	270	NA	Quaternary sediments and Weathered Deccan Traps
32	NW3B-4	Bore hole water NW of Gurudeshwar on the left bank of Narmada	ND	381	136	40	75	NA	76	81	7.35	1054	415	NA	-do-
33	NW3B-5	Bore hole waterwest of Gurudehwar	ND	381	71	11	55	NA	52	70	7.30	767	310	NA	-do-

(Sample No 1 to 10)



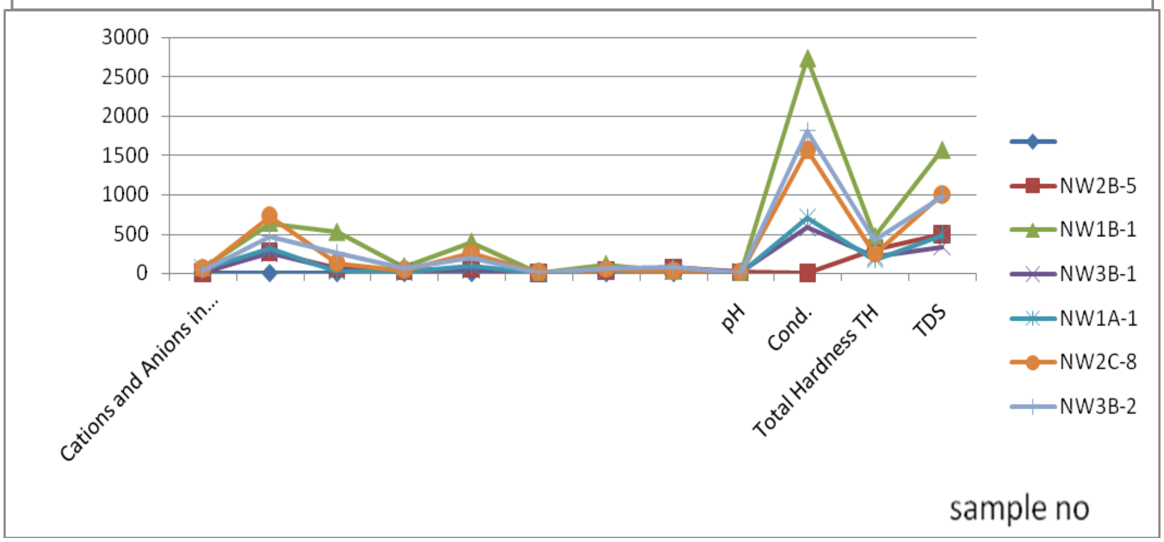


Table No-2

TABLE SHOWING THE EPM VALUES OF CATIONS AND ANIONS OF GROUND WATER OF REPRESENTATIVE SAMPLES OF SHALLOW & DEEPER AQUIFER IN SONATA LINEAMENT ZONE BARWANI _ BHAROUCH SECTION LOWER NARMADA VALLEY IN PARTS OF M.P. & GUJARAT STATE

S.No.	Water Sample No.	Reference No. of Sample	CO3	HCO3	CL	SO4	Mg	Na	K	Ca
1	2	3	4	5	6	7	8	9	10	11
1	NW2C-1	W1	Nil	6.064	5.358	0.937	4.523	-	-	3.993
2	NW2C-2	W2	Nil	3.278	8.319	1.145	4.112	-	-	4.492
3	NW2C-3	W3	Nil	4.917	7.332	0.625	4.112	-	-	0.998
4	NW2C-4	W4	Nil	2.786	6.768	0.520	2.878	-	-	3.494
5	NW3C-1	W5	Nil	4.425	1.128	0.312	2.467	-	-	2.994
6	NW2C-2	W6	Nil	5.163	1.410	0.416	2.056	-	-	2.494
7	NW2B-1	W7	Nil	4.096	1.128	0.312	1.645	-	-	3.494
8	NW2B-2	W8	Nil	5.327	4.935	1.249	3.290	-	-	6.488
9	NW2B-3	W9	0.667	8.687	2.820	0.416	4.112	8.696	-	1.248
10	NW2B-4	W10	0.667	6.966	1.833	0.312	0.822	9.566	-	0.249
11	NW2B-5	W11	Nil	4.425	1.551	0.520	2.391	2.391	0.026	3.494
12	NW1B-1	W12	2.366	10.473	14.777	1.791	9.211	17.392	0.384	1.397
13	NW3B-1	W13	0.467	4.196	1.241	0.354	2.303	1.956	0.128	2.296

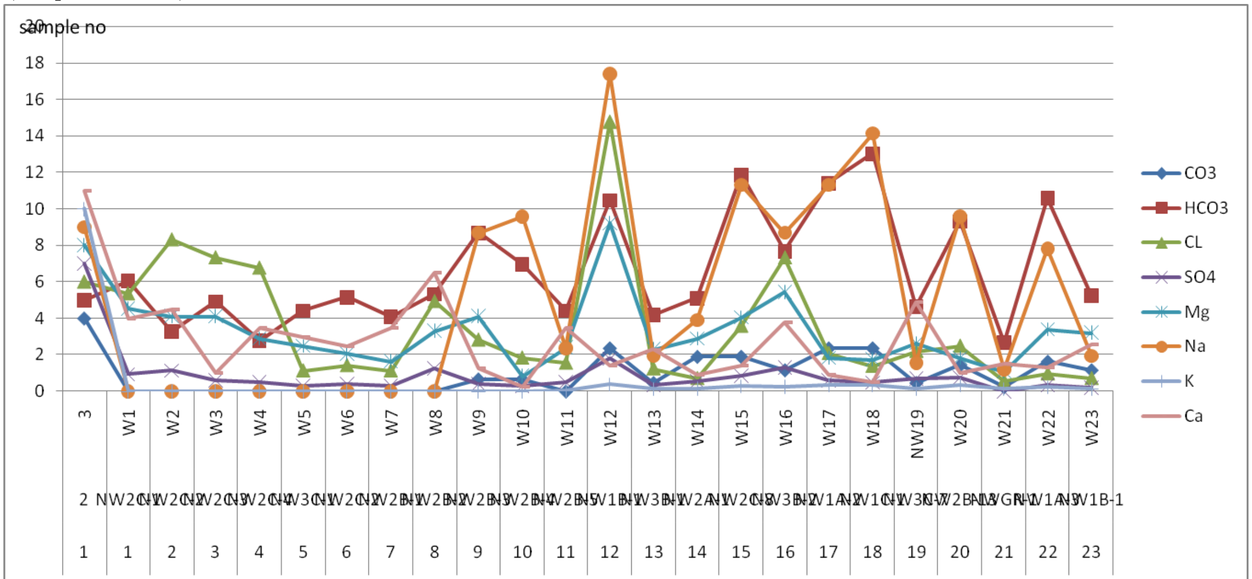
14	NW2A-1	W14	1.900	5.114	0.705	0.562	2.878	3.913	0.153	0.898
15	NW2C-8	W15	1.900	11.866	3.581	0.854	4.029	11.305	0.281	1.397
16	NW3B-2	W16	1.166	7.687	7.332	1.312	5.428	8.696	0.255	3.793
17	NW1A-2	W17	2.366	11.407	2.087	0.604	1.809	11.305	0.358	0.898
18	NW1C-1	W18	2.366	13.030	1.382	0.479	1.727	14.131	0.332	0.499
19	NW3C-7	NW19	0.467	4.654	2.200	0.708	2.632	1.565	0.128	4.891
20	NW2B-13	W20	1.433	9.310	2.482	0.770	1.809	9.566	0.358	0.998
21	NWGR-1	W21	0.233	2.672	0.564	ND	1.069	1.217	0.128	1.497
22	NW1A-3	W22	1.633	10.587	0.959	0.354	3.371	7.826	0.230	1.297
23	NW1B-1	W23	1.167	5.245	0.705	0.208	3.207	1.957	0.128	2.595

1	2	3	4	5	6	7	8	9	10	11
24	NW1C-1	W24	1.167	4.655	0.564	0.104	3.700	1.522	0.128	1.597
25	NW1C-2	W25	0.933	4.999	0.423	ND	3.454	1.304	0.128	2.196
26	NW2C-17	W26	ND	1.868	0.282	ND	0.576	0.304	0.128	1.298
27	NW3C-10	W27	0.233	5.704	1.946	0.4997	3.207	1.695	0.128	3.993
28	NW2C-18	W28	2.366	8.145	3.581	0.625	3.947	6.957	0.205	2.096
29	NW2B-6	W29	ND	11.702	1.889	0.541	5.757	8.696	-	1.098
30	NW2B-7	W30	ND	10.915	1.889	0.458	5.757	7.391	-	1.397
31	NW3C-3	W31	ND	5.802	1.269	0.354	4.112	1.826	-	2.795
32	NW2C-5	W32	ND	6.802	2.707	0.645	3.700	6.087	-	1.248
33	NW2C-6	W33	ND	6.359	2.566	0.458	3.700	6.087	-	1.248
34	NW3C-4	W34	ND	5.343	2.002	0.416	3.454	1.608	-	4.342
35	NW2C-7	W35	ND	6.359	1.579	0.479	3.700	4.130	-	2.795
36	NW2B-8	W36	ND	7.015	3.271	0.791	6.003	4.565	-	2.945
37	NW2B-9	W37	ND	6.015	1.889	0.416	3.783	3.261	-	3.095
38	NW2C-6	W38	0.467	9.146	7.134	1.062	7.237	10.217	-	2.396
39	NW3C-5	W39	ND	5.458	3.694	1.145	5.839	2.000	-	5.290
40	NW2B-10	W40	"	4.458	1.579	0.416	3.207	1.435	-	3.893
41	NW3B-7	W41	"	6.015	2.002	Trace	3.948	2.696	-	3.094
42	NW3B-8	W42	0.467	5.900	2.143	0.437	5.181	3.478	-	2.396
43	NW3B-3	W43	ND	4.900	1.269	0.416	3.372	1.913	-	3.494
44	NW3B-4	W44	"	6.245	3.835	0.832	6.250	3.261	-	4.043
45	NW3B-5	W45	"	6.245	2.002	0.229	4.276	2.391	-	3.494
46	NW3B-6	W46	"	5.343	1.438	0.250	3.125	1.522	-	3.793
47	NW3C-6	W47	"	5.802	2.284	0.354	3.454	2.609	-	3.643
48	NW2B-12	W48	"	11.588	2.002	0.229	1.974	10.87	-	0.998
49	NW2C-9	W49	"	5.802	11.252	2.228	12.089	3.696	-	8.684

1	2	3	4	5	6	7	8	9	10	11
50	NW2C-10	W50	ND	6.130	5.414	1.561	7.154	3.261	-	5.191
51	NW3C-8	W51	"	5.015	1.720	0.458	3.948	1.783	-	3.643
52	NW3B-5	W52	"	6.244	2.002	0.229	4.276	2.391	-	3.494
53	NW3B-6	W53	"	5.343	1.438	0.250	3.125	1.522	-	3.793
54	NW3C-6	W54	"	5.802	2.284	0.354	3.454	2.609	-	3.643
55	NW2B-12	W55	"	11.588	2.002	0.229	1.973	10.87	-	0.998
56	NW2C-9	W56	"	5.802	11.252	2.228	12.089	3.696	-	8.684
57	NW2C-10	W57	"	6.130	5.414	1.562	7.155	3.261	-	5.191
58	NW3C-8	W58	"	5.015	1.720	0.458	1.809	1.783	-	3.643
59	NW2C-11	W59	"	6.916	4.117	0.687	2.714	8.696	-	1.248
60	NW2C-12	W60	"	4.688	1.128	0.375	1.480	1.696	-	3.194
61	NW3B-9	W61	"	8.687	1.128	1.999	7.895	12.827	-	3.892
62	NW2C-13	W62	"	10.916	2.002	0.895	2.960	11.305	-	0.848

63	NW2C-13	W63	ND	10.916	2.002	0.895	2.960	11.305	-	0.848
64	NW2C-15	W64	"	6.130	5.132	0.645	5.098	9.826	-	3.094
65	NW3B-10	W65	"	5.458	1.438	0.416	3.125	3.348	-	1.547
66	NW3B-11	W66	"	7.802	1.438	0.666	3.207	5.739	-	3.344
67	NW2C-12	W67	"	12.932	2.566	0.666	3.783	11.305	-	1.098
68	NW2B-11	W68	"	4.458	0.564	0.125	3.207	1.217	-	3.344
69	NW1B-2	W69	"	7.802	1.128	0.312	3.125	5.305	-	1.697
70	NW2C-19	W70	"	10.916	9.250	1.145	4.605	13.044	-	2.246

(Sample No 1 to 23)



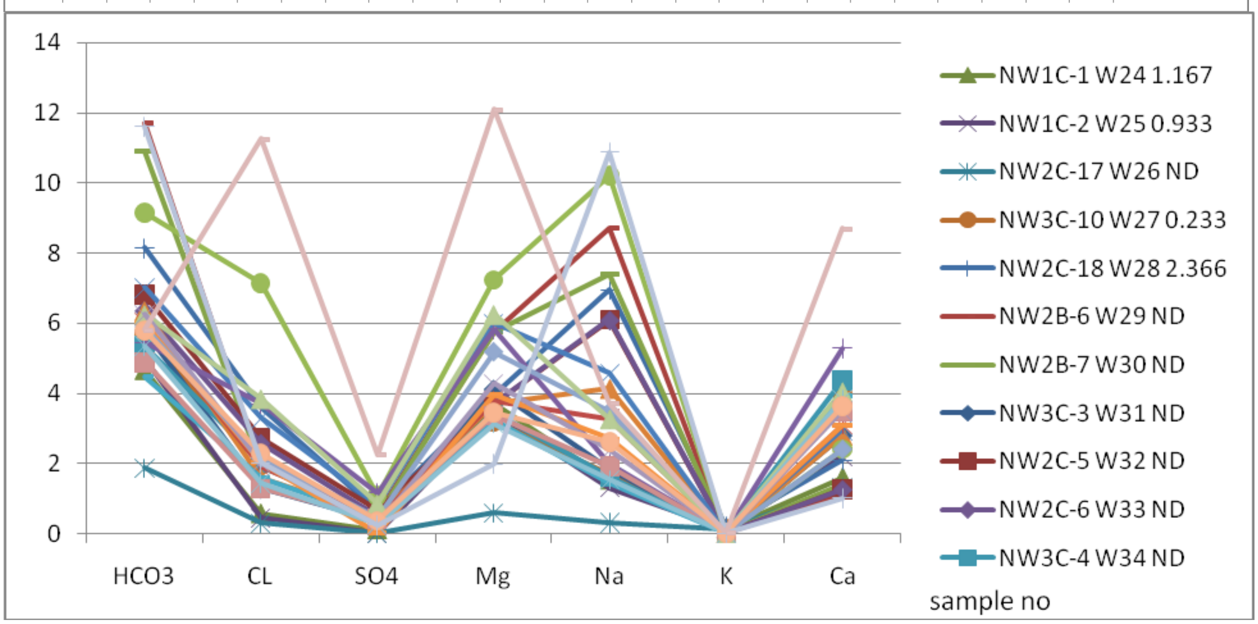
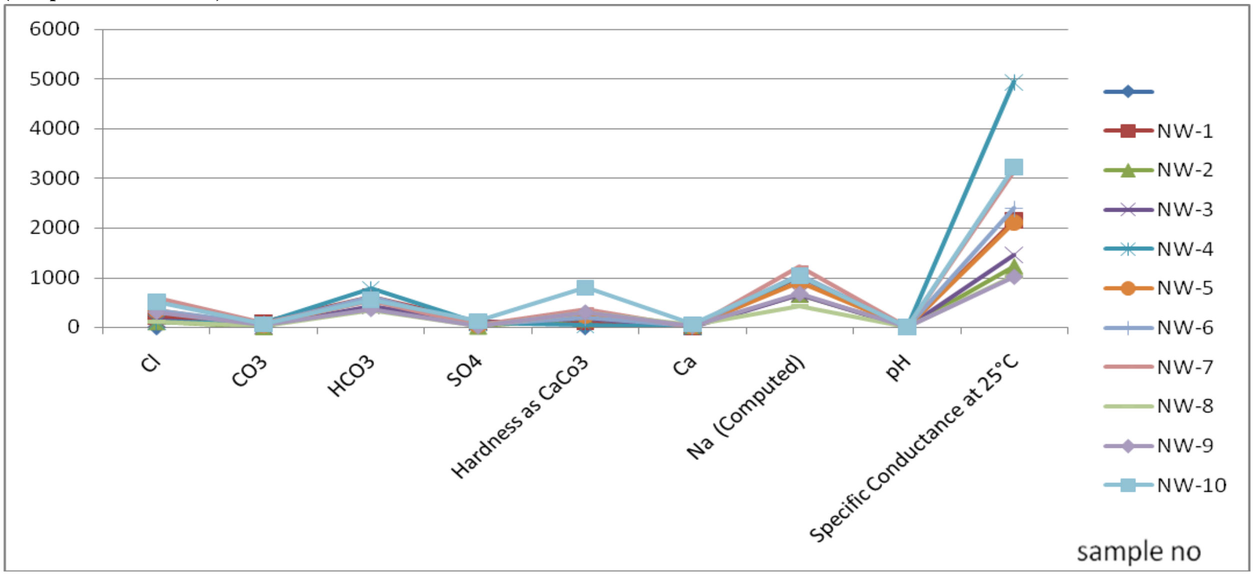


Table No-3

TABLE SHOWING RESULTS OF CHEMICAL ANALYSIS OF GROUND WATER OF DEEPER AQUIFER IN SONATA LINEAMENT ZONE IN BARWANI _ BHAROUCH SECTION LOWER NARMADA VALLEY IN PARTS OF M.P. & GUJARAT STATE

S.No.	Water Sample No.	Locality of water sample	Cl	CO3	HCO3	SO4	Hardness as CaCo3	Ca	Mg	Na (Computed)	pH	Specific Conductance at 25°C
							Results in ppm					
1	NW-1	Bharouch	225	105	625	107	115	16	18	1028	8.30	2153
2	NW-2	Ankleshwar	100	ND	584	15	160	22	25	652	7.60	1223
3	NW-3	Dabohi	165	28	438	90	175	18	31	672	8.00	1468
4	NW-4	Chandod	110	84	778	92	60	16	5	1043	8.50	4941
5	NW-5	Sjhagadia	340	42	556	42	230	30	37	913	7.90	2104
6	NW-6	Right bank of Aswan River	350	77	625	41	190	30	28	1055	8.30	2397
7	NW-7	Gurudeshwar	585	98	528	50	365	8	83	1215	8.80	3131
8	NW-8	Right bank of Karjan river	120	28	348	28	290	50	40	434	8.00	1027
9	NW-9	Rajpiplal	310	56	368	23	300	28	55	674	8.40	1010
10	NW-10	Tilakwardai	520	63	556	125	800	68	151	1045	8.00	3229

(Sample No NW 1 to 10)



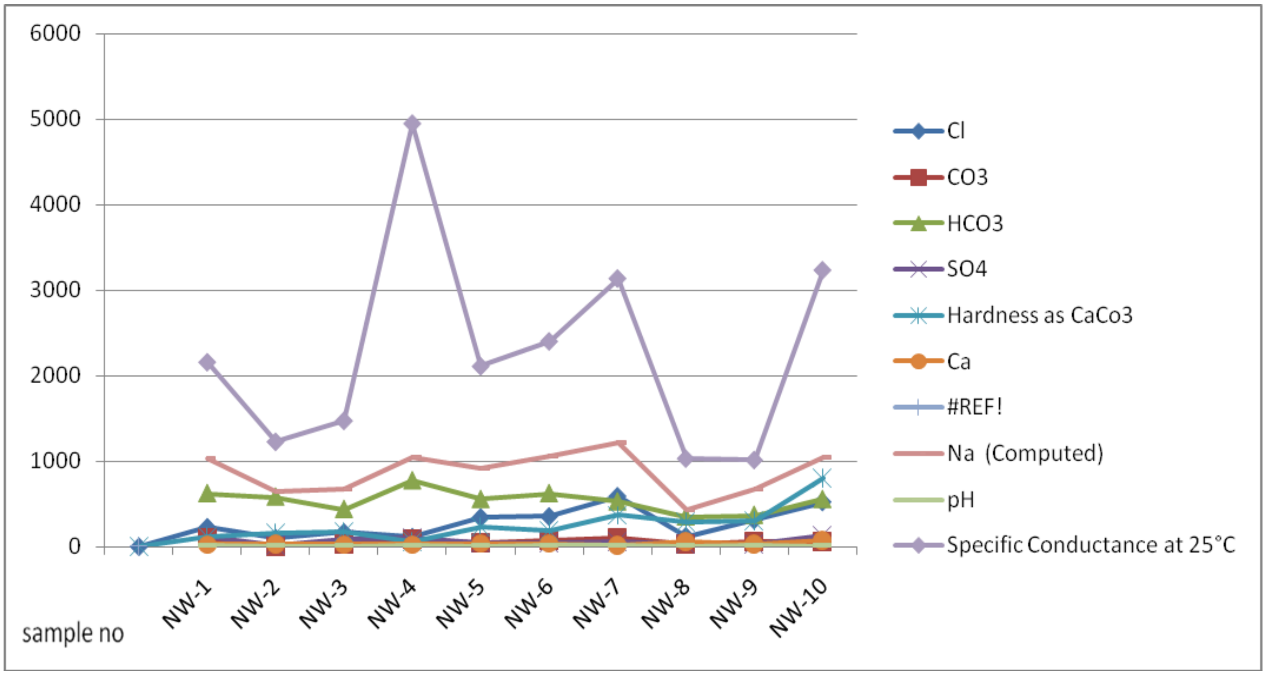
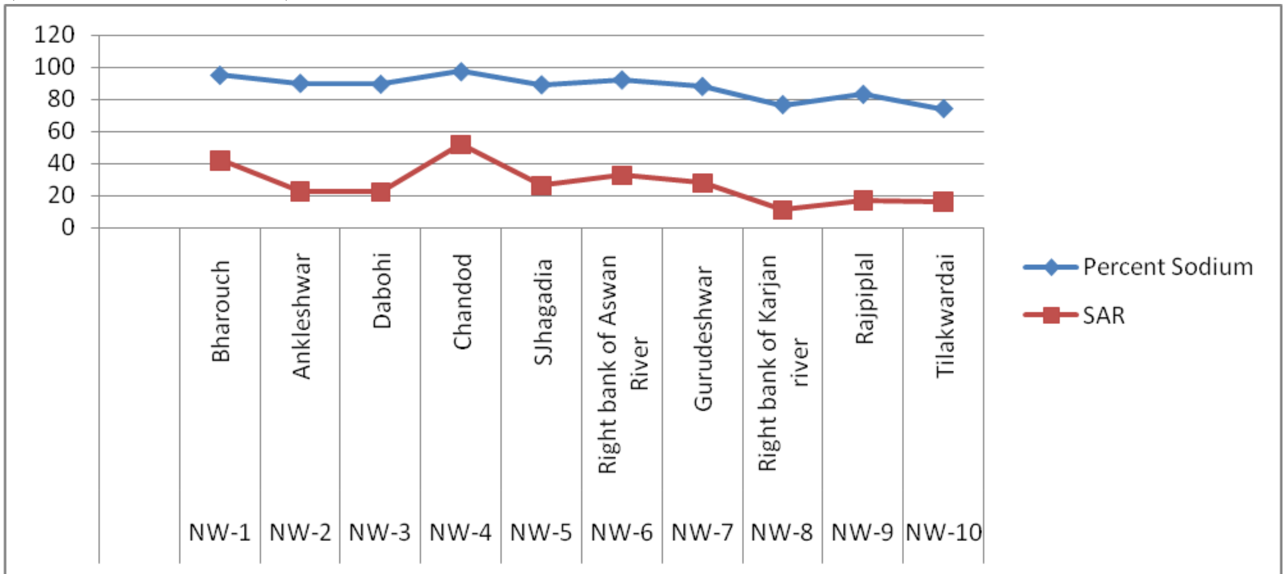


Table No-4

INTERPRETATION OF CHEMICAL ANAYSIS OF GROUND WATER OF DEEPER AQUIFER IN BARWANI _ BHAROUCH SECTION IN PARTS OF M.P. & GUJRAT STATE

S.No.	Water Sample No.	Discription with Locality	Percent Sodium	SAR	Water class as per sodium percent value	Water class as per SAR value
1	NW-1	Bharouch	95.148	41.873	Unsuitable	Poor
2	NW-2	Ankleshwar	89.988	22.575	Unsuitable	Fair
3	NW-3	Dabohi	89.445	22.253	Unsuitable	Fair
4	NW-4	Chandod	97.401	51.830	Unsuitable	Poor
5	NW-5	Sjhagadia	89.130	26.347	Unsuitable	Poor
6	NW-6	Right bank of Aswan River	92.209	32.657	Unsuitable	Poor
7	NW-7	Gurudeshwar	88.038	27.794	Unsuitable	Good
8	NW-8	Right bank of Karjan river	76.500	11.095	Doubtful	Good
9	NW-9	Rajpiplal	83.000	17.032	Unsuitable	Good
10	NW-10	Tilakwardai	74.00	16.159	Doubtful	Good

(SAMPLE NO NW 1 to NW10)



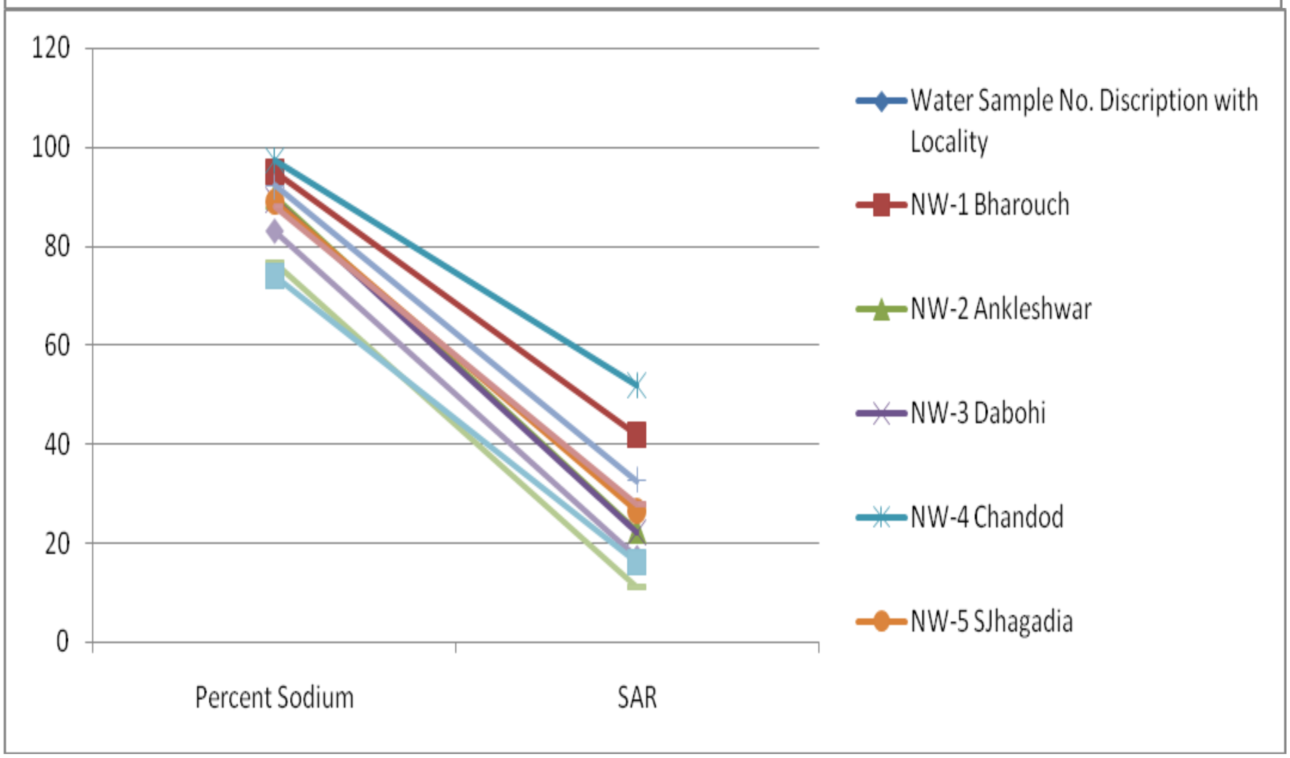
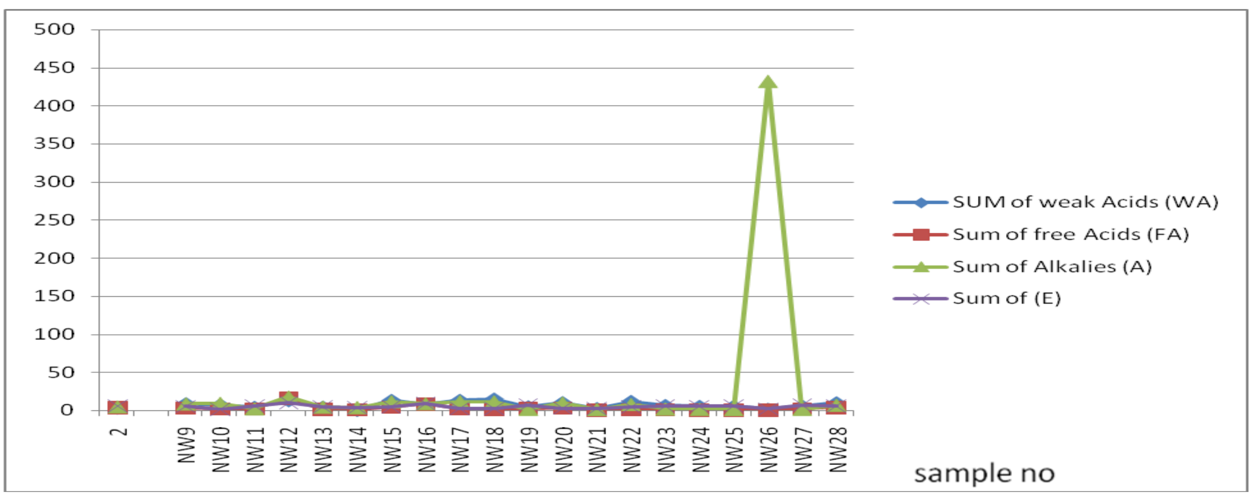
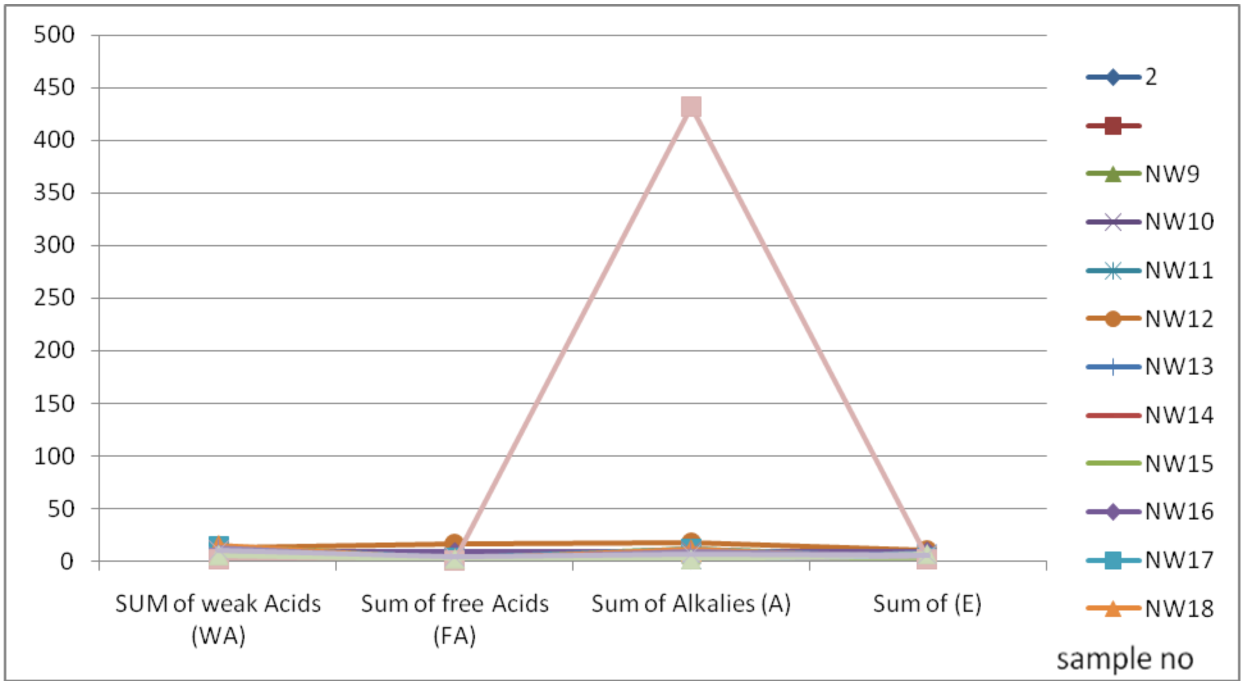


Table No-5

TABLE SHOWING THE RESULTS OF PADMER COMPUTATION IN RESPECT OF GRUND WATER AND RIVER WATER IN SONATA LINEAMENT IN LOWER NARMADA VALLEY ,PARTS OF M.P. & GUJARAT STATE

S.No.	Ref. No. of Water Sample	SUM of weak Acids (WA)	Sum of free Acids (FA)	Sum of Alkalies (A)	Sum of (E)	Class of Water Sample	Values of Primary salinity (S1); Seconday Salinity (S2); Primary Alkalinity (A1); Secondary Alkalinity (A2)
1	2	3	4	5	6	7	8
1	NW9	9.354	3.236	8.747	5.36	I	S1 = 6.472; A1 = 11.022; A2 = 10.72
2	NW10	7.633	2.145	9.642	1.071	I	S1 = 4.299; A1 = 14.994; A2 = 2.142
3	NW11	4.425	2.071	2.417	5.961	I	S1 = 4.142; A1 = 0.692; A2 = 11.922
4	NW12	12.839	16.568	17.776	10.608	I	S1 = 33.136; A1 = 2.416; A2 = 21.216
5	NW13	4.663	1.595	4.599	4.599	I	S1 = 3.190; A1 = 6.008; A2 = 9.198
6	NW14	0.011	1.267	4.066	3.776	I	S1 = 2.634; A1 = 5.598; A2 = 7.552
7	NW15	13.766	4.485	11.586	4.927	I	S1 = 8.870; A1 = 14.302; A2 = 9.854
8	NW16	8.853	8.644	8.951	9.221	I	S1 = 17.288; A1 = 0.614; A2 = 18.442
9	NW17	13.773	2.691	11.663	2.707	I	S1 = 5.382; A1 = 17.944; A2 = 5.419
10	NW18	15.396	1.861	11.463	2.226	I	S1 = 3.722; A1 = 25.204; A2 = 4.492
11	NW19	5.121	2.908	1.693	7.523	III	S1 = 3.386; A1 = 2.430; A2 = 12.616
12	NW20	10.743	3.292	9.924	2.807	I	S1 = 6.504; A1 = 13.341; A2 = 5.614
13	NW21	2.905	0.564	1.345	2.566	I	S1 = 1.128; A1 = 0.781; A2 = 5.132
14	NW22	12.22	1.313	8.056	4.668	I	S1 = 2.626; A1 = 13.486; A2 = 9.336
15	NW23	6.912	0.913	2.085	5.802	I	S1 = 1.826; A1 = 2.344; A2 = 11.604
16	NW24	5.822	0.668	1.65	5.297	I	S1 = 1.336; A1 = 1.964; A2 = 10.594
17	NW25	5.922	0.423	1.432	5.65	I	S1 = 0.846; A1 = 2.018; A2 = 11.300
18	NW26	1.868	0.282	432	1.874	I	S1 = 0.564; A1 = 0.300; A2 = 3.748
19	NW27	5.937	2.445	1.823	7.2	III	S1 = 3.646; A1 = 1.244; A2 = 17.998
20	NW28	10.511	4.206	7.162	6.043	I	S1 = 8.412; A1 = 5.912; A2 = 12.086





Conclusions:-

The area is situated extreme west at the mouth of Gulf of Cambey at terminus point of basin which forms a oval depression which elongated and starched E-W direction ad truncated by crossed structural lineaments trending NW –SE, NE-SW direction. The quaternary blanket exposed to post deposition activity which subsequently chiseled by cumulative geostatic ad climatic changes resulting into various terraces, pre-quaternary and quaternary surfaces and landform elements of various domain and plantation surface. In the area Narmada channel course is both obstructed & guided and controlled by the cross lineament trending transverse to strongly dominated ENE-WSW to E-W SONATA LINEAMENT resulting in the channel dynamics to suddenly open out which at short range became sluggish as evident by the disposition of quaternary landscape, river terraces, associated landform elements and channel morphology. The area possesses high ground water potential both at shallow and deep level. The ground water regieme is strongly influence by tectonic of the area and diversified manifestation are recorded in tearms of landscape, morphogenetic, Neotectonic, geothermal and geochemical signatures.

In this study, we used a multidisciplinary approach to investigate the hydrogeologic behavior of a sub-vertical permeable fault and quantify its interactions with surrounding reservoirs, under ambient and pumping conditions. This study provides a good example of the functioning of a sub-vertical fault determined from lineament mapping.
The critical analysis of ground water data base, data of National Hydrograph and piezometer suggest that sub-vertical fault and sub-surface reservoirs are highly dependent on each other. Under ambient conditions, the fault allows the discharge of regional old water into superficial aquifer domains. The natural discharge rate of the fault zone is estimated to be around 170–200 m3/day. Although relatively low, this value should be taken into account when estimating water fluxes, hydrologic budget and solute transport at the watershed scale. The hydrological system is dependent on storage from the deep source of reserviour and shallow sub-surface reservoir. Once the upper weathered reservoir has become mainly unsaturated, the system acts as a classic dual porosity medium with a highly transmissive structure embedded in lower permeable compartments. Thus, this high permeability fault zone appears to be an efficient thin permeable domain that permits rapid diffusion of pressure but is strongly dependent on sub-surface and adjacent domains of higher storativityaccorss the fault of faults system. The chemical signatures of water domain their aeria extension and dimention their their tracing and field measurements suggest that the most of the flow comes from superficial domains and from the vicinity of the fault zone, with a recharge area located at the surface mainly along the fault zone. Moreover, such steep fault zones, although of relatively high transmissivity, remain relatively limited in terms of groundwater yield. In this study, the data base of pumping test was also analysed taking in to account the piezometric analysis which indicates that this rate was certainly too high to be sustainable. A better estimate of sustainable flowrate would be around 20–30 m3/h. This is a much lower value than

some other fault zone aquifers, such as gently dipping fault zones which may provide higher groundwater resources (Le Borgne et al., 2006a; Ruelleu et al., 2010). This difference confirms the role of the dip of the fault-zone that may greatly increase borehole yield in some circumstances (Leray et al., 2013).

The comprehansive and multithem studies of Narmada rift system is critical to our understanding of fault systems, because the geometry of the fault zone in area is ill defined and their hidden mechanics and conductivity with deep seated source across the crust are attempted to understand through geochemical signatures, geothermal manifestation and facies variation across the depth of quaternary blanket and rock basin.

The Narmada north fault (NNF) and Narmada south fault (NSF) is complex, with multiple and composite fractures in the valley in addition to the exposed range/valley bounding fault.

Individual fault strands dip 70-80° or greater to a depth of at least 3 km. The dip of layering in the exposed reflects deep-seated shear deformation. The surface manifestation and signatures of deep seated composite fracture system documents the digonestic of megedefomity in the region.

The extensional strain in the Narmada Rift Valley area is not only accommodated by the range bounding surface trace, but also by the multitude of other range and valleystructures. Synclines in the valley fill, clearly imaged in the reflection sections, delineate areas where buried extensional accommodations are focused and antithetic faults are prominent.

Vertical and low angle structures can explain the complex surface shapes of the mapped scarps, but low angle faults cannot explain the thermal structure.

The study points and collection of samples are precisely selected in critical and crucial section with the assistence of satellite imagery and remote sensing techniques. The present study has revealed the relationship between groundwater flow systems and the distribution of chemical facies with the aid of Geographical Information System (GIS). The study also identifies the different geochemical processes responsible for the chemical evolution of groundwater chemistry. Analytical results of 43 groundwater samples from pizometers and deep bore holes indicate mean values of cations as Na+ (84.2 mg/l), K+ (4.2 mg/l), Ca2+ (27 mg/l), Mg2+ (11.5 mg/l) and Fe2+ (0.6 mg/l). The anion mean values are (4.5 mg/l), SO3□ NO (3.7 mg/l), Cl– (22.5 mg/l) and (2.2 mg/l). Based on mean values, the cations are in order of abundance as Na+ > Ca2+ > Mg2+ > K+ > Fe2+ while the anions reveal order of abundance as Cl– > HCO > SO >. The geographical information system (GIS) using inverse Distance Weighted (IDW) delineate two groundwater zones into: Ca-Mg-SO4-Cl and Na-SO4-Cl water types. The Cl, SO4 display consistency where as CO3,HCO3,Mg, Na K mark fluctuation in their occurrence.Na, Ca Mg and HCO3.In Tilakwarda –Barouche section except SO4 Ca Na Mg Cl in shallow aquifer exhibit diverse concentration and diffrentialfrquency of distribution in depth 620m where as beyond their concentration is isotropic persistent and stable.The former phenomenon appears to be realted with mixing of water due to constant flushing of water under stress across the fault and lineament where later facies is sealed water domain in tectonic ecology with restricted outet along the fault and lineament.The water samples 1 to23 Na Ca Mg display anisotropic concentration, execpt sample 11,12,13, Mg display highest vales where K is uniform and in consistency and in harmony, Cl and Na display synchronised frequency with little variation in system. These redicales in sample no 23 to28 show higher peaks whereas other Ca, Na Mg and HCO3 exibit anisotropic mechnisam in rhytems of neoseismic micro events.Where as the rest is under isotropic concentration. The sampes 50 to 70 the concentration of Na, Mg, Ca and HCO3 suddenly increses with little variation where as whereas SO4 and Cl exhibit harmony in their frequency. The sample no 1 to 10 (10+ 30=40) are in consistency & harmony in frequency distribution and revealed tectonic dislocation in aqufer strata and represnet disciplined inatct water domin with restricted inlet and outlet appers to along fault and lineament.In the water domain of about 600m the Ca-Mg-SO4-Cl constitutes about 73 % of the chemical facies and its evolutionary trend is due to simple hydrochemical mixing between Ca-Mg-HCO3 and Na-SO4-Cl facies and reverse cation exchange where as 27% represent shallow fresh intact water intact domain which is secured within fault bounded block with in the cross lineament.The chemical facies beyond 600m domain Ca-Na-SO4-Cl and ca CO3, HCO3, HCO3 facies constitutes about 82 and 18 % chemical facies and represents fossil groundwater from deep source across the Narmada north fault (NNF). The Ca-Mg-SO4-Cl facies is persistent in outlet zone under tectonically conealled strata under stress where the other facies Na-SO4-Cl prevails in discharge areas.

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