Terrain Analysis and Hydrogeochemical Environment of Aquifers of the southern West Coast of Karnataka, India

2 authors:

s.s. Honnanagoudar
B.V. Bhoomaraddi College of Engineering and Technology (BVBCET)

Venkat Reddy
National Institute of Technology Karnataka

Indexed in
Scopus Compendex and Geobase Elsevier, Chemical
Abstract Services-USA, Geo-Ref Information Services-USA

International Journal of Earth Sciences and Engineering

www.cafetinnova.org

ISSN 0974-5904, Volume 05, No. 06

December2012,P.P.1619-1629

Terrain Analysis and Hydrogeochemical Environment of Aquifers of the southern West Coast of Karnataka, India

S. S. HONNANAGOUDAR[1], D. VENKAT REDDY[1] and MAHESHA. A[2]

[1]Dept of Civil Engineering, National Institute of Technology Karnataka, Surathkal, Mangalore - 575025, Karnataka

[2]Department of Applied Mechanics and Hydraulics, National Institute of Technology Karnataka, Surathkal, Mangalore - 575025, Karnataka

***Email:** sh6696@gmail.com, dvr1952@gmail.com, amaimahesha@gmail.com*

Abstract: Dakshina kannada district is situated in peninsular region. The peninsula is composed of geologically ancient rocks of diverse original and most of them have undergone metamorphism. The early Precambrian tonalitic gneisses invaded by granites, granulites and dolerite dykes. Granulites are mostly restricted to areas south of Mangalore. High grade alumina rich (corundum bearing) metamorphic schists have been encountered and younger alkaline intrusive rocks like Aegerine syenites have been reported. There are five rivers and estuaries. Number of lineaments cut across each other and some lineaments are parallel to each other. The Arabian sea class is the largest among other land cover features in the study area. The river/tidal creek land cover appear as long irregular and sinous in outline. Mulki river, Netravati river, Gurupur river at southern terrain. The qualities of groundwater at sandy aquifer are good, lateritic/weathered gneissic rocks it is sweet.

Keywords: *Groundwater, Rock Types, Lineaments, Water Quality*

Introduction:

The Dakshina Kannada district which is a coastal district of Karnataka spreads along the west coast of India covering coastal track of about 40 km. It has been found that two-third of the population of the world lives within a narrow belt, directly landward from the ocean edges. Also, the rivers of district are being seasonal and tidal in nature; seawater intrusion into adjoining aquifers during the non-monsoon period is greatly felt up to several kilometres inland along and on either side of the river courses. Hence, the present work is aimed at groundwater related investigation involving aquifer characterization and seawater intrusion of coastal Dakshina Kannada district, Karnataka between Talapady to Mulki towns. The focus of the present work is to create awareness on water quality degradation and its management in rural coastal areas between the rivers Talpady, Gurupur, Pavanje, Mulki, and Netravati. The fresh water partly met by surface water resources.

Geology:

Dakshina kannada district is situated in peninsular region. The process of erosion, transportation and deposition, the shape of the coastline changes, often slowly but sometimes rapidly. The intersection between rock, water, wind and vegetation are responsible for the dramatic landforms along the coast. The peninsula is composed of geologically ancient rocks of diverse original and most of them have undergone metamorphism. It represents a stable land of the earth's crust. The geological formations of the district are similar those of Karnataka state but for the coastal sedimentary deposits and laterites. The geological section across Netravati river of dakshina kannada district is shown in figure (Figure1)

The early Precambrian tonalitic gneisses invaded by granites, granulites and dolerite dykes. Granulites are mostly restricted to areas south of Mangalore; however tongues of granulites can be seen in gneissic granite quarries north of mangalore. High grade alumina rich (corundum bearing) metamorphic schists have been encountered and younger alkaline intrusive rocks like Aegerine syenites have been reported (Ravindra and Janardhan 1981). Marine expeditions conducted by Geological Survey of India (GSI) identified the existence of sandy paleobeach ridges some 25 km offshore of Mangalore coast. Earlier Murty (1977) reported occurrences of lignite in clays from the foundation wells of Netravati bridge, south of Mangalore. Black clays occur in some of the paleo fluvial courses such as Baikampadi, Kuloor and Kottar usually admixed with plant remains (peat or lignite).

The geology of the terrain comprises peninsular gneissic basements, laterites, coastal alluvium, granite-migmatite complexes and intrusions of acid, basic and ultramafic into the basement rocks. Sparsely developed quaternary formations are also seen along the coastal tract. The deposition of number of rocky and Sandy Island of the coast are also important landscapes of the terrain. The different drainage patterns found in the study area are dendratic, trellis, parallel, rectangular radial and complex patterns (Figure 2)

Stream density over the terrain and the distribution pattern clearly envisages 3 distinct categories as given in table 1.1.

Table 1.1: *Stream Density*

Sl No.	Category	Stream density (Km/unit area)
1	Low density	0.0 - 3.0
2	High density	3.0 - 5.0
3	Extremely high density	> 5.0

*(**Source**: Sreedharamurthy, et. al., 2002)*

Table 1.2: *Stream Frequencies*

Sl No.	Category	Stream frequency (No. of stream unit area)
1	Low frequency	0.0 - 5.0
2	High frequency	5.0 - 15.0
3	Extremely high frequency	15.0 – 25.0

*(**Source:** Sreedharamurthy, et. al., 2002)*

Northern Coastal Terrain: Most of the western part of the terrain is characterized by low density where the coastal study plain occurs. This plain is also characterized by lateritic plateaus and sand dunes.

Southern Coastal Terrain: Major part of the southern coastal terrain is characterized by low stream density. In general there is trend to increase in stream density from west to east (Figure 3)

Spatial distribution pattern of stream frequency over the terrain three distinct categories are identified by the stream frequency distribution patterns in table 1.2.

Southern Coastal Terrain: The entire area shows drastically low stream frequency occurrences. (fig 4)

Lineaments:

Lineaments have been detected in northern coastal terrain. Number of lineaments cut across each other and some lineaments are parallel to each other. These lineaments represent faults, fractures, escarpments, dykes, ridges etc. The length of the lineaments varies from 1.5 km to 18 km (B.R.Raghavan, 2002). The orientation of the lineaments is east to west and some lineaments show nearly north south orientation. (Figure 5).

Geomorphology:

The Arabian sea class is the largest among other land cover features in the study area. The river/tidal creek land cover appear as long irregular and sinous in outline. Mulki river, Netravati, Gurupur river at southern terrain. Along with the rivers a number of tidal creeks also mark the study area. However the extent of the tidal creeks is restricted only to the coastal plains. The occurrence of marsh land is restricted to the coastal plains. The marsh lands are observed Netravati and Gurupur rivers. The occurrence of the sand bodies has also been observed along either bank of Gurupur and Netravati rivers as intermittent patches. The built-up lands are increasing all along the sides of the National Highway (No. 66.) (Udayashankar, 1994). The coastal plain, valley fills and either side of the rivers; there are two types of cropping practices differ from each other in season and cropping pattern. Kharrif cropping season is from June to September while rabi cropping season is from October to March. The minor forests are mainly observed along the foothills of western ghats.

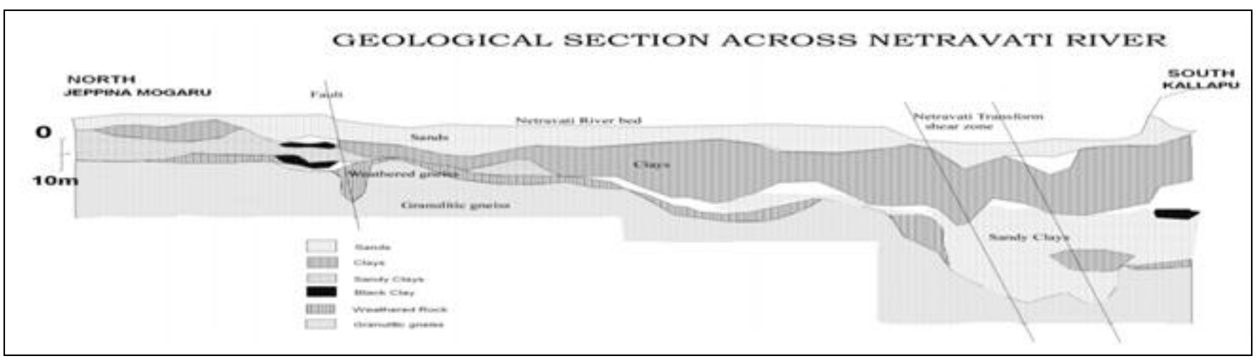

Figure 1: *Geological section map of Netravati River, Dakshina Kannada district (after Ravindra and Venkat Reddy, 2011)*

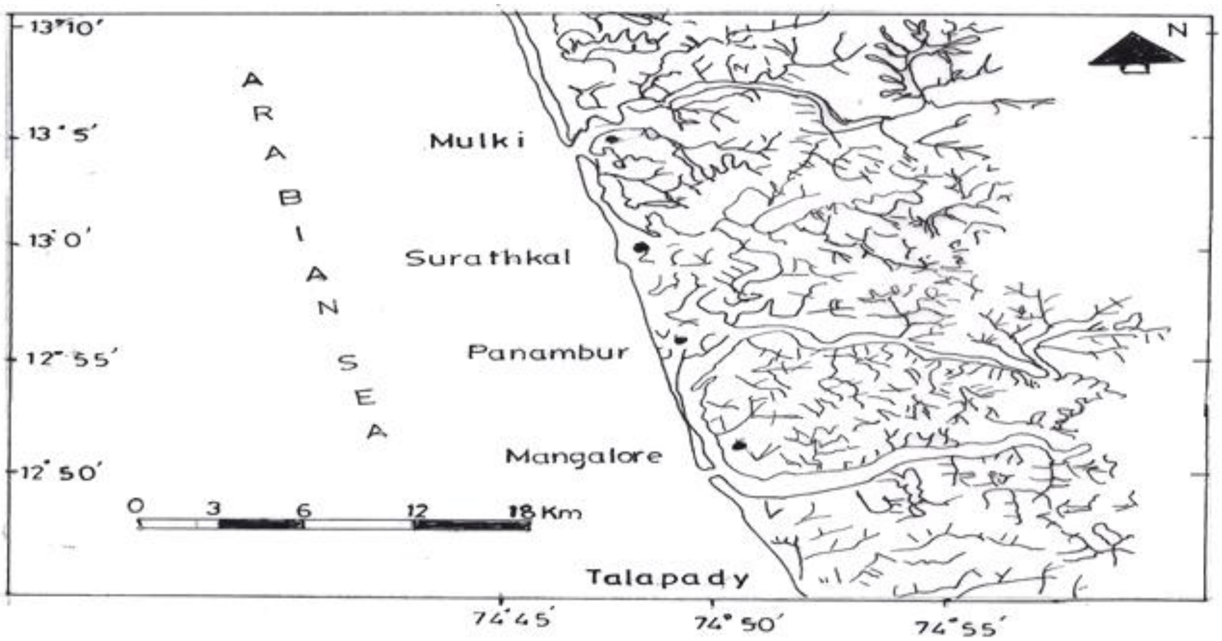

Figure 2: *Drainage Pattern: Southern Coastal Karnataka*

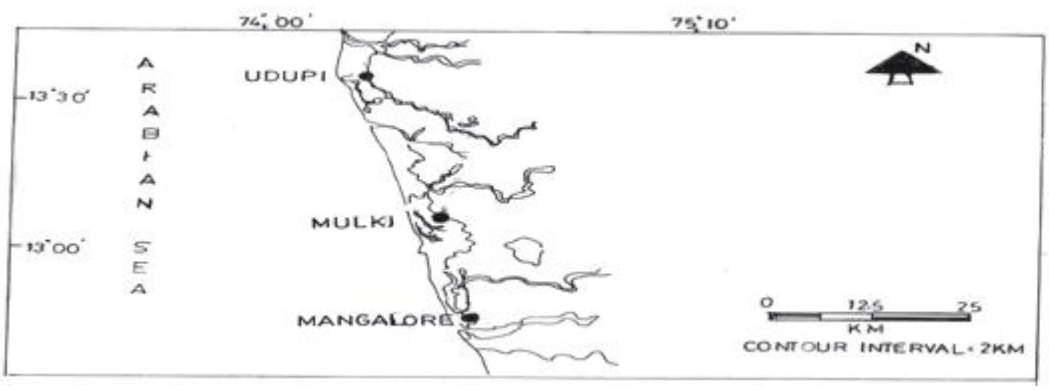

Figure 3: *Distribution of Stream Density*

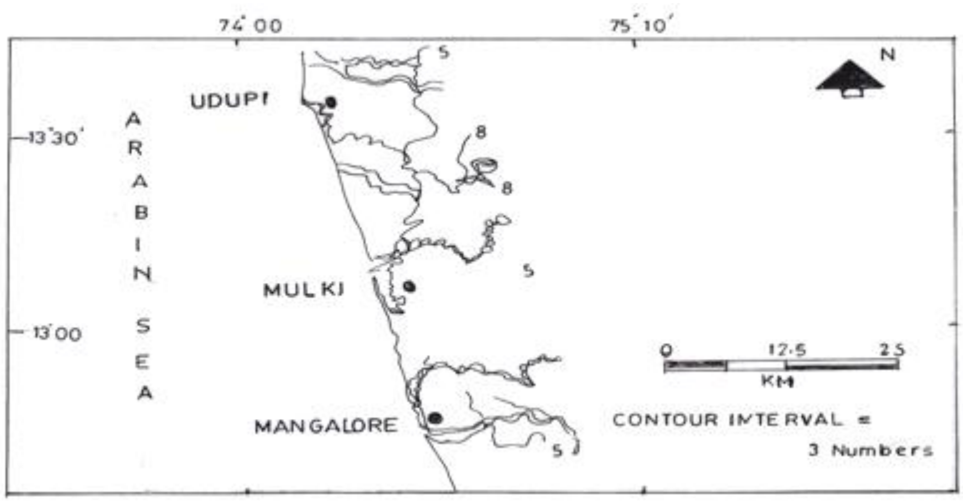

Figure 4: *Distribution of Stream Frequency*

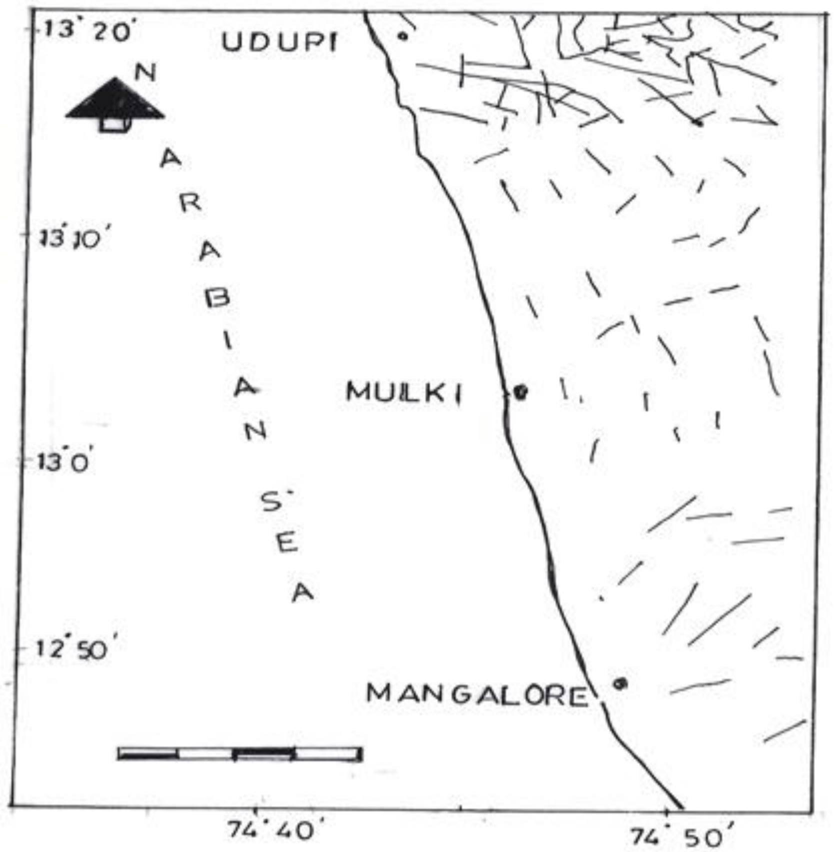

Figure 5: *Lineaments of Southern Coastal Karnataka*

Land use:

Land use refers to human activities for various use carried out on land and cover refers to natural vegetation, water bodies, rock, soil, artificial cover and others resulting due to land transformations. Change in land use pattern influences the hydrological regime of the basin (James et, al., 1987). Various hydrological processes such as infiltration, evapotranspiration, soil moisture status etc., are influenced by land use characteristics of water shed. The deforestation may cause peak flows in the river due to reduced infiltration leading to floods, due to increased soil erosion, removal of too fertile soil layer may result in drop in soil fertility.

The spatial information on land use and their pattern of changes are essential for planning, management and utilization of land for agriculture, forestry, urban industries, environmental studies etc.

Infiltration:

Infiltration rates are very widely depending on the condition of the land surface. Infiltration has an important place in the hydrological cycle. Detailed study of hydrological process helps planners, hydrologists, farmers and decision makers in number of ways. The infiltration rate of the area which helps in estimating peak rate and volume of runoff, estimation of surface runoff and overland flow, estimation of groundwater recharge, estimation of soil moisture deficits. Typical infiltration rates are at the end of one hour after the commencement of the storm are presented in table 1.3.

Table 1.3: *Infiltration Rate*

Sl. No.	Soil Type	Infiltration rate cm/hr
1	High (Sandy soil)	1.25 – 2.54
2	Intermediate (loam, silt, clay)	0.25 -1.25
3	Low (clay, clay-loam)	0.025 – 0.25

From east to west the majority of the sedimentary units consists of a wedge of permeable sand sediments deposited in shallow marine water, littoral sands formed in the fore shore and the adjacent beach and sand-dune systems (Antonelline et al. 2008). In the westernmost are fine continental alluvial deposits (silt and clay) overlay the littoral sands (Amorosi et al. 2002; Bondesan et al. 1995).

Groundwater Quality:

The qualities of groundwater at sandy aquifer are good, lateritic/weathered gneissic rocks it is sweet. The dug wells in the alluvial area are saline water during summer months and in the monsoon period fresh water they are getting. There are 30 open well samples are collected and test the well water samples to detect the presence of drinking water. The drinking water quality parameters for analysis are TDS, pH, Turbidity, Total hardness, Fe, Nitrate, Sulphate and Coliform. The well location is mentioned in Table no. 1.4. The results are calculated in the three seasons April, August and October 2012.

Table 1.4: *Well Inventories*

Well No.	Location	Well No.	Location
1	Hotel Nisarga, Talapady	16	NMPT, Panambur
2	Uchilla	17	Hotel Vishwasagar, Panambur
3	Kotekar	18	Jyothi service station, Hosabettu
4	Thokkuttu	19	KEB Quarters, Surathkal
5	S.S. Bricks, Thokkuttu	20	Veerabhadra Temple, Marigudi
6	Adam kadru school	21	NITK, Surathkal
7	Kalapu	22	Gerald Kuvelo Nivas, Mukka
8	Shaikh cottage	23	K.A. Abdulkadar, Mukka
9	Mogaru (Near Netravathi Bridge)	24	"Kiran" Haliyangadi
10	Ronsun service centre, Mogaru	25	Kikanda House, Near Pavanje Bridge
11	Karnataka Bank, Near pumpwell	26	Venkappa shetty, Padambadur
12	Kuntikana	27	Nani House, Kolnad
13	VRL, kuloor	28	Sri Guru, Kolnad
14	Vivekanand, Panjioruguru, Kuloor	29	Srinivas, Bappanadu temple, Mulki
15	Thokuru	30	Gopalkrishna Naik, Mulki

Table 1.5: *Water Quality Test Results for pH*

Well No.	pH April	pH August	pH October	Well No.	pH April	pH August	pH October
1	6.63	5.86	7.67	16	5.97	7.55	6.52
2	6.36	6.69	6.9	17	6.19	6.48	6.13
3	6.17	7.13	7.56	18	6.22	6.51	6.32
4	6.33	6.53	6.82	19	6.08	6.41	6.23
5	6.49	6.06	6.6	20	5.71	6.44	6.13
6	6.66	6.6	6.87	21	5.91	7.87	6.17
7	6.54	6.54	6.8	22	6.11	7	5.93
8	5.89	6.16	6.5	23	6.36	6.31	5.83
9	6.47	5.94	6.25	24	6	7.01	6.78
10	6.58	6.45	6.65	25	6.51	6.29	5.94
11	6.63	6.2	6.39	26	6.83	6.51	6.34
12	6.16	6.28	6.54	27	6.32	6.91	6.53
13	6.38	6.1	6.17	28	5.69	6.45	6.01
14	6.63	6.48	6.45	29	6.2	6.37	5.96
15	6.38	6.19	6.43	30	6.38	6.6	6.19

Table 1.6: *Water Quality Test Results for TDS mg/l*

Well No.	TDS April	TDS August	TDS October	Well No.	TDS April	TDS August	TDS October
1	6.63	5.86	7.67	16	5.97	7.55	6.52
2	6.36	6.69	6.9	17	6.19	6.48	6.13
3	6.17	7.13	7.56	18	6.22	6.51	6.32
4	6.33	6.53	6.82	19	6.08	6.41	6.23
5	6.49	6.06	6.6	20	5.71	6.44	6.13
6	6.66	6.6	6.87	21	5.91	7.87	6.17
7	6.54	6.54	6.8	22	6.11	7	5.93
8	5.89	6.16	6.5	23	6.36	6.31	5.83
9	6.47	5.94	6.25	24	6	7.01	6.78
10	6.58	6.45	6.65	25	6.51	6.29	5.94
11	6.63	6.2	6.39	26	6.83	6.51	6.34
12	6.16	6.28	6.54	27	6.32	6.91	6.53
13	6.38	6.1	6.17	28	5.69	6.45	6.01
14	6.63	6.48	6.45	29	6.2	6.37	5.96
15	6.38	6.19	6.43	30	6.38	6.6	6.19

Table 1.7: *Water Quality Test Results for Turbidity*

Well No.	Turbidity April	Turbidity August	Turbidity October	Well No.	Turbidity April	Turbidity August	Turbidity October
1	6.63	5.86	7.67	16	5.97	7.55	6.52
2	6.36	6.69	6.9	17	6.19	6.48	6.13
3	6.17	7.13	7.56	18	6.22	6.51	6.32
4	6.33	6.53	6.82	19	6.08	6.41	6.23
5	6.49	6.06	6.6	20	5.71	6.44	6.13
6	6.66	6.6	6.87	21	5.91	7.87	6.17
7	6.54	6.54	6.8	22	6.11	7	5.93
8	5.89	6.16	6.5	23	6.36	6.31	5.83
9	6.47	5.94	6.25	24	6	7.01	6.78
10	6.58	6.45	6.65	25	6.51	6.29	5.94
11	6.63	6.2	6.39	26	6.83	6.51	6.34
12	6.16	6.28	6.54	27	6.32	6.91	6.53
13	6.38	6.1	6.17	28	5.69	6.45	6.01
14	6.63	6.48	6.45	29	6.2	6.37	5.96
15	6.38	6.19	6.43	30	6.38	6.6	6.19

Table 1.8: *Water Quality Test Results for Chloride mg/l*

Well No.	Chloride April	Chloride August	Chloride October	Well No.	Chloride April	Chloride August	Chloride October
1	6.63	5.86	7.67	16	5.97	7.55	6.52
2	6.36	6.69	6.9	17	6.19	6.48	6.13
3	6.17	7.13	7.56	18	6.22	6.51	6.32
4	6.33	6.53	6.82	19	6.08	6.41	6.23
5	6.49	6.06	6.6	20	5.71	6.44	6.13
6	6.66	6.6	6.87	21	5.91	7.87	6.17
7	6.54	6.54	6.8	22	6.11	7	5.93
8	5.89	6.16	6.5	23	6.36	6.31	5.83
9	6.47	5.94	6.25	24	6	7.01	6.78
10	6.58	6.45	6.65	25	6.51	6.29	5.94
11	6.63	6.2	6.39	26	6.83	6.51	6.34
12	6.16	6.28	6.54	27	6.32	6.91	6.53
13	6.38	6.1	6.17	28	5.69	6.45	6.01
14	6.63	6.48	6.45	29	6.2	6.37	5.96
15	6.38	6.19	6.43	30	6.38	6.6	6.19

Table 1.9: *Water Quality Test Results for Hardness mg/l*

Well No.	Hardness April	Hardness August	Hardness October	Well No.	Hardness April	Hardness August	Hardness October
1	300	278	276	16	50	46	45
2	160	157	156	17	190	189	190
3	40	41	45	18	80	76	78
4	90	87	86	19	50	47	44
5	580	569	589	20	30	31	37
6	120	122	128	21	50	48	54
7	50	46	47	22	110	109	109
8	50	47	40	23	70	65	65
9	370	375	379	24	30	32	32
10	80	81	83	25	350	346	346
11	280	275	278	26	80	76	76
12	20	22	23	27	130	126	126
13	250	245	249	28	50	48	48
14	80	76	79	29	280	267	267
15	200	201	208	30	70	65	65

Table 1.10: *Water Quality Test Results for Nitrate mg/l*

Well No.	Nitrate April	Nitrate August	Nitrate October	Well No.	Nitrate April	Nitrate August	Nitrate October
1	4.76	4.7	4.98	16	15.17	15.89	14.8
2	13.21	12.41	12.95	17	29.25	29.84	28.45
3	39.64	36.61	35.61	18	18.52	17.58	18.89
4	9.58	9.89	9.09	19	14.26	13.2	14.27
5	11.26	10.23	11.29	20	19.31	20.39	19.56
6	1.09	1.02	1.98	21	8.66	8.9	9.12
7	0.81	0.4	1	22	19.76	18.78	19.23
8	23.16	22.12	22.94	23	6.78	6.7	6.12
9	2.41	2.19	2.86	24	5.26	5.98	5.23
10	10.25	9.26	10.01	25	9.53	9.53	8.92
11	1.09	1.67	1.41	26	7.62	6.89	6.21
12	20.44	21.32	21	27	4.53	5.56	5.12
13	10.85	11.85	11.01	28	12.82	12.86	11.86
14	17.9	16.76	15.23	29	5.64	5.9	6.24
15	5.57	6.5	5.59	30	4.51	4.98	4.89

Table 1.11: *Water Quality Test Results for Coliform Count CFU/ml*

Well No.	Coliform		Coliform		Coliform		Well No.	Coliform		Coliform		Coliform	
	A	B	A	B	A	B		A	B	A	B	A	B
1	1	-	1	-	2	-	16	-	-	-	-	-	-
2	-	-	-	-	-	-	17	2	-	2	-	1	-
3	-	-	-	-	-	-	18	-	-	-	-	-	-
4	1	-	1	-	1	-	19	-	-	-	-	-	-
5	-	-	-	-	1	-	20	1	-	-	-	-	-
6	-	-	-	-	-	-	21	-	-	-	-	-	-
7	-	-	-	-	-	-	22	5	-	4	-	5	-
8	1	-	2	-	1	-	23	1	-	1	-	1	-
9	-	-	-	-	-	-	24	-	-	-	-	-	-
10	-	-	-	-	-	-	25	3	1	2	1	1	1
11	1	-	1	-	1	-	26	-	-	-	-	-	-
12	-	-	-	-	-	-	27	1	-	-	-	-	-
13	1	-	1	-	-	-	28	-	-	-	-	-	-
14	-	-	-	-	-	-	29	3	-	1	-	1	-
15	4	-	5	-	3	-	30	1	-	2	-	1	-

Table 1.12: *Water Quality Test Results for Sulphate as SO_4 mg/l*

Well No.	Sulphate April	Sulphate August	Sulphate October	Well No.	Sulphate April	Sulphate August	Sulphate October
1	-	-	-	16	18.59	17.21	33.62
2	31.56	30.54	65.08	17	30.99	31.9	65.2
3	7.438	7.41	16.82	18	23.26	24.16	50.34
4	7.53	7.51	11.02	19	20.99	22.29	46.5
5	-	-	-	20	18.19	19.59	18.89
6	24.02	24	50	21	12.08	13	14.3
7	36.3	35.1	64.4	22	29.27	28.25	29.85
8	19.55	19.45	37.9	23	35.82	36.84	38.74
9	-	-	-	24	13.38	14.14	16.18
10	13.17	14.15	32.2	25	30.67	30.21	32.11
11	20.7	20.1	45	26	20.86	20.06	23
12	13.16	11.19	27.58	27	14.03	13.08	12.07
13	23.37	22.27	46.58	28	28.67	27.6	28.9
14	13.7	14.5	31.6	29	31.83	32.14	37.1
15	39.68	37.64	79.38	30	13.13	14.1	17.16

Table 1.13: *Water Quality Test Results for Dissolved Iron Fe mg/l*

Well No.	Iron (Fe) April	Iron (Fe) August	Iron (Fe) October	Well No.	Iron (Fe) April	Iron (Fe) August	Iron (Fe) October
1	0.837	0.887	0.91	16	0.489	0.47	0.49
2	0.878	0.8	0.9	17	0.535	0.55	0.54
3	0.809	0.84	0.89	18	0.967	0.99	0.89
4	0.86	0.9	0.96	19	0.942	0.98	0.79
5	0.926	0.91	0.87	20	0.995	0.95	0.85
6	0.829	0.88	0.83	21	0.542	0.59	0.58
7	0.803	0.89	0.8	22	0.541	0.56	0.49
8	0.887	0.89	0.78	23	0.478	0.49	0.48
9	0.829	0.88	0.8	24	0.3	0.52	0.57
10	0.808	0.84	0.9	25	0.546	0.65	0.58
11	0.818	0.89	0.68	26	0.451	0.55	0.52
12	0.828	0.85	0.86	27	0.517	0.57	0.55
13	1.025	1.02	1.1	28	0.474	0.64	0.87
14	0.977	0.91	0.93	29	0.584	0.5	0.9
15	0.64	0.69	0.68	30	1	1.09	1

Results:

The pH in the month of April 2012 well no. 2, 3, 4, 5, 8, 9, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24,and 27, 28, 29, 30 are 6.54 to 6.83 is the highest and remaining wells having the pH is 5.87 to 6.33. In the month of August 2012 the pH varies 6.51 to 7.87. The well numbers are 2, 3, 4, 5, 7, 16, 18, 21, 22, 24, 26, 27 and 30. The remaining wells of the water quality pH is 5.86 to 6.48 in the month of October 2012 the pH varies 5.93 to 6.45 the well numbers are 9, 11,13, 14, 15, 17, 18, 19, 20, 21, 22, 23, 25, 26, 28, 29 and 30. The pH varies from 5.93 to 6.45. The remaining wells pH is 6.50 to 7.67 which is acceptable. TDS in the month of April 2012 well number 1, 15 and 25 are more than acceptable limit and in the month of August and October 2012 all the wells are within the acceptable limit. Turbidity in the month of April 2012 the well nos. are 1,5, 15, 24 and 30 are more than 5 NTU, in the month of August well nos. 5 and 25 are more than 5 NTU and in the month of October 2012 well nos. are 5 only. Well nos. 5, 9 and 25 are more than acceptable limit for Hardness. Chloride in the month of August 2012 well nos. are 1, 5, 25 are more than 1000 mg/l. Nitrate and sulphate are within the limit. Coliform count is found in the well nos.1, 4, 5, 8, 11, 15, 17, 22, 25, 29 and 30 for all the season.

This contamination is more pronounced in wells along the stream courses up to the distance where tidal effect extends. Further, Ground water in proximity to stream course is contaminated with seepage of domestic waste. As a general rule, pumpage must be distributed in time and space and there should not be any concentration of wells to avoid saline water ingress.

Conclusions:

The intersection between rock, water, wind and vegetation are responsible for the dramatic landforms we see along the coast. Dakshina kannada district is situated in peninsular region.

The slope density and stream frequency of the study area are characteristically high along the eastern part of the terrain because the streams originate on the scarps of the Western Ghats.

The land use and land cover pattern of the terrain is suggestive of probable stress on the terrain in future in terms of expansion of built-up land and loss of agricultural land due to a probable increase in the number of industries and population.

From the field study some of the area is affected by saltwater intrusion during the summer period and some of the areas are affected almost throughout the year.

Ground water in proximity to stream course is contaminated with seepage of domestic waste. As a general rule, pumpage must be distributed in time and space and there should not be any concentration of wells to avoid saline water ingress.

References:

[1] Adyalkar, P. G., and Shrihari Rao, S. (1979). Hydrodynamic method of assessing groundwater recharge by precipitation in Deccan trap region-case study. *Jour. Geol. Soc. Ind., V. 20,* pp. 134-137.

[2] Adrian D. Werner, James D. Ward, Leanne K. Morgan, Craig T. Simmons, Niville I. Robinson, and Michael D, Teubner., (2012).“Vulnerability indicators of seawater intrusion.” *Ground Water* 50 (1), pp.48-58.

[3] Aghashe, R.M. (1994). Artificial recharge of groundwater in critical and semi-critical areas. *Proc. Natl. Workshop Development of groundwater in critical and semi-critical areas: Alternatives, Options and Strategies, NewDelhi,* pp. 75-88.

[4] Alley,William M. and C. J. Taylor.(2001).“Groundwater level monitoring and the importance of long term waterlevel data.” *U.S.Geol. Survey Circular:* pp.*1217*.

[5] Anbazhagan, S., and Ramasamy, S.M., (1993). Role of Remote Sensing in geomorphic analysis for water harvesting structures, In: S.M. Ramasamy, (Ed.) Trends in Geological Remote Sensing, *Rawat Publications, New Delhi,* pp. 208-212.

[6] Anning, D., (2008). “Dissolved solids in basin-fill aquifers of the southwest”. *Hydrogeol. J.*, pp.18-19.

[7] Bloom, A. L. (1978). Geomorphology - A systematic analysis of late Cenozoic Landforms. *Prentice Hall*, pp. 1-510.

[8] Boulton (1970). “Analysis of data from pumping tests in unconfined anisotropic aquifers.” *J. Hydrol*., 10, 369-381.

[9] Chitea. F. (2011). “Geophysical detection of marine intrusions in Black sea coastal areas (Rommania) using VES and ERT data”, Geo-*Eco-Marina*, pp.95-102.

[10] Coates, D. R. and Vitek, J. D. (1980). Threshold in Geomorphology, *George Allen, London,* pp. 223.

[11] Kelly W.E., (1977).“Geoelectric sounding for estimating aquifer hydraulic conductivity”, *Ground Water*, 15(6), pp.420-425.

[12] Mahesha A., (1996).“Control of seawater intrusion through injection – extraction well system”, *J. Irrig. Drain. Eng., ASCE*, pp.314-317.

[13] Manjunath B.R. and Harry N.A. (1994). “Geology of Western Coastal Karnataka, GeoKarnataka”, MGD Centenary Volume, pp. 109-116.

[14] Moench, A.F., (1994). “Specific yield as determined by type curve analysis of aquifer test data”, *Ground Water*, 32(6), pp.949-957.

[15] Moench, A.F., (1997). “Flow to a well of finite diameter in a homogeneous, anisotropic water table aquifer”, *Water Resour. Res.*, 33 (6), pp.1397-1407.

[16] Mohsen Sheriff., (1999). “Seawater intrusion in the Nile delta aquifer: An overview”, http://aguas.igme.es/igme/publica/tiac-02/EGIPTO-I.pdf. pp.296-308 (April 10, 2012).

[17] Polemio. M.V., Dragone and Limoni, P.P., (2009), “Monitoring and methods to analyse the groundwater quality degradation risk in coastal karstic aquifers (Apulia, Southern Italy)”, *Environ. Geol.*, 58, pp. 299-312.

[18] Ravindra, B. M., Venkata Reddy, D. (2011). “Neotectonic Evolution of Coastal Rivers of Mangalore Karavali Karnataka, India”. *Int. Jour. Of Earth Science and Engineering, V.04. No. 04,* pp. 561-574.

[19] Reddy, N. and Prakasam, P. (1982). “Evaluation of artificial recharge projects in Granitic Terrains of Andhra Pradesh”. *Workshop on Artificial Recharge of Groundwater in Granitic Terrain,* pp. 194-210.

[20] Singh, O. P. (1981), “Morphometric evalution of landforms in Palamau Upland.” In: H. S. Sharma (Ed) Perspectives in Geomorphology”, *Concept Publishing Co., New Delhi, V. 4,* pp. 109-131.

[21] Singh (2006). “Semi-analytical model for drawdown due to pumping a partially penetrating

large diameter well", *J.Irrig. Drain., ASCE*, 133(2), pp.155-161.

[22] Sridharan. K, D. Sathyanarayana, A. Siva Reddy., (1990), "Analysis of flow near a dug well in an unconfined aquifer, *J.Hydrol*., 119, pp.89-103.

[23] Sreedharamurthy, T. R., Raghavan, B. R. and Bhat, V.T., (2002). "Terrain Analysis of Coastal Karnataka", Sponsored project by Ministry of Environment and forests, Mangalore University, Mangalore.

[24] Sung-Ho Song, Jin Yong Lee and Namsik Park., (2006). "Use of vertical electrical sounding to delineate seawater intrusion in coastal area of Byunsan, Korea", *Environ. Geol.* (2007), Vol 52:1, pp.1207-1219.

[25] Todd, D. K. (1980). " Groundwater Hydrology." *John Willey and Sons, Newyork,* pp. 1-535.

[26] Ward, R. C. (1968), "Some hydrological characteristics of British Rivers", *Jour. Hydrol., V.* pp. 358-372.

[27] Way, D. A. (1973). "Terrain Analysis," Hutchinson *and Ross, Stroudsburg, Pasadina, Dowden,* pp. 72-124.