Nature of Seawater Intrusion in Jodiya and Dhrol Taluka by using GALDIT Method

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Abstract— This study presents the application of GALDIT method to evaluate the ground water vulnerability due to seawater intrusion in the Jodiya and Dhrol region of the saurashtra coast line. In 2001, Chachadi and Lobo-ferreria, developed the GALDIT method. Later in 2005, they modified the method specifically for coastal aquifers. Here the GALDIT index is used for the ground water vulnerability to sea water intrusion. The GALDIT index is based on four intrinsic hydro geological parameters, one spatial parameter and one boundary parameter. The parameters of GALDIT index are: ground water Occurrence (aquifer type), Aquifer hydraulic conductivity, High ground water level above the sea level, distance from the shore, impact of existing status of sea water intrusion in the area, and thickness of the aquifer GALDIT index is calculated after deciding the weightage, range and rate of each factor. The maps obtained using GALDIT method indicates that the aquifer system of Jodiya and Dhrol tehsil was low to medium vulnerable to seawater intrusion. GALDIT index of Jodiya tehsil villages were higher than Dhrol tehsil villages. Jodiya region is more vulnerable to seawater intrusion as compared to Dhrol region.

Key words: GALDIT Index, Jodiya-Dhrol, Seawater Intrusion Vulnerability

I. INTRODUCTION

Water is Essential to Life. Water is the most important substance in our evolution and our daily lives. Mankind uses both surface water as well as ground water sources.

Ground water one of the most precious and abundant natural resource, controls the development of civilization on the globe [14]. The annual replenishment of groundwater is obtained from the meteoric precipitation. The total water resources of world are estimated: 1.37 x 10^8 million ha-m. Out of these global water resources around 97.2% is salt water mostly in oceans, and only 2.8% as other in which 2.2% is available as surface water and 0.6% as groundwater. In 2.2% of surface water, 2.15% is fresh water in glaciers and icecaps and only around 0.01% (1.36 x 10^4 M ha-m) is available in lakes and reservoirs, and 0.0001% in streams. The remaining in other forms such as 0.001% in water vapour form in atmosphere, and 0.002% as soil moisture in the top 0.6 m. In 0.6% of stored ground water, only around 0.3% (41.1 x 10^4 M ha-m) can be efficiently extracted with the present drilling technology and remaining is situated below a depth of 800 m and hence is unavailable.

Seawater intrusion is the movement of seawater into fresh water aquifers [1]. It is one of the main causes for ground water pollution. The definition of groundwater vulnerability to seawater intrusion is defined as "the sensitivity of groundwater quality to an imposed groundwater pumpage or sea level rise or both in the coastal belt, which is determined by the intrinsic characteristics of the aquifer" [1].

II. STUDY AREA

Jodiya is a Taluka in Jamnagar District of Gujarat State, India. It is located 39 Km towards North from District headquarters Jamnagar. It is located at 22.7000°N latitude 70.3000°E longitude [10]. There are about 41 villages under Jodiya tehsil [10]. Jodiya is located near the shore of Arabian Sea.

Dhrol is a Taluka and a municipality in Jamnagar district in the state of Gujarat, India. It is located at latitude 22.57°N longitude 70.42°E [11]. It has an average elevation of 26 meters (85 feet). There are about 51 villages under Dhrol tehsil [11].

The climate of Jodiya and Dhrol tehsil is humid because of Arabian Sea [10], [11]. The main river of Jodiya and Dhrol tehsil is Aaji river [10], [11]. The soil is salty and black [10], [11]. In the present study, 13 villages of Jodiya- Dhrol tehsil is adopted which is listed in Table 1.

Table 1: Latitude and longitude of villages of Jodiya-Dhrol Tehsil of study area

Sr.	TEHSIL	VILLAGE	LATITUDE	LONGITUDE
1	Jodiya	Beraja	22°33'00"	70°18'00"
2		Jodiya	22°42'00"	70°18'45"
3		Balambha	22°44'20"	70°25'00"
4		Amran	22°49'30"	70°33'45"
5		Fatsar	22°47'22"	70°38'15"
6		Pithad	22°41'25"	70°33'22"
7		Tarana	22°43'25"	70°28'35"
8	Dhrol	Hadatoda	22°38'50"	70°26'10"
9		Gokalpar(Latipur)	22°36'00"	70°30'30"
10		Nathuvadla	22°35'30"	70°22'05"
11		Dhrol	22°33'07"	70°26'50"
12		Laiyala	22°30'40"	70°29'30"
13		Dangra	22°23'48"	70°28'25"

III. METHODOLOGY

GALDIT factors are used to devise a numerical ranking system to assess seawater intrusion in hydrogeologic settings. The system contains three significant parts: weights, ranges and importance ratings [7]. GALDIT index is based on following parameters: Groundwater Occurrence (aquifer type; unconfined, confined and leaky confined), Aquifer Hydraulic Conductivity, Height of Groundwater Level above Sea Level, Distance from the Shore (distance inland perpendicular from shoreline), Impact of existing status of seawater intrusion in the area and Thickness of the aquifer. Each GALDIT factor has been evaluated with respect to the other by assigning a relative weight to determine the relative importance of each factor. The weightage and ratings of the parameters of GALDIT index for the study area- Jodiya and Dhrol region are given in Table. 2. The GALDIT Index is determined by computing the individual indicator scores as per the below equation:

$$\text{GALDIT-Index} = \sum_{i=1}^{6} \{(Wi)\ Ri\} / \sum_{i=1}^{6} Wi$$

W_i - Weight of ith parameter, R_i - Rating of ith parameter

Parameters	Weight	Rating			
		2.5	5	7.5	10
Groundwater Occurrence (G)	1		Leaky	Unconfined	Confined
Aquifer Hydraulic Conductivity A)	3	<5	5-10	10-40	>40
Height of Groundwater Level above Sea Level L)	4	>2	1.5-2	1-1.5	<1
Distance from the Shore (D)	4	> 30	20-30	15-20	<15
Impact of existing status of seawater intrusion in the area(I)	3	< 1	1.5	1.5-2	>2
Thickness of the aquifer(T)	2	<5	5-7.5	7.5-10	>10

Table 2: Weightage and Rating of parameters of GALDIT index [2]

Hence the minimum and maximum GALDIT-Index varies between 2.5 to 10. The vulnerability of the study area to seawater intrusion is determined on the magnitude of the GALDIT Index. In a general way, if the index is low it is less vulnerable to seawater intrusion [2].

Sr. no	GALDIT Index Range	Vulnerability class
1	≥ 7.5	High vulnerability
2	5 - 7.5	Moderate vulnerability
3	<5	Low vulnerability

Table 3: GALDIT index Vulnerability class [2]

IV. RESULT

A. Groundwater Occurance (G):

Groundwater is found in the geological layers (Aquifer) and these layers may be confined, unconfined, leaky. Confined aquifer has pressure higher than atmospheric pressure and unconfined aquifer is under atmospheric pressure. Here in the study area, the aquifer is unconfined. So, the rating of the parameter groundwater occurrence is 7.5. Fig.1 shows representation of parameter (G).

B. Aquifer hydraulic conductivity (A):

Aquifer hydraulic conductivity is used to measure the water flow rate in the aquifer. Aquifer hydraulic conductivity is the ability of aquifer to transmit water under the effect of hydraulic gradient. High conductivity value is more vulnerable for inland movements of the seawater intrusion. Here in the study area the hydraulic conductivity parameter has been recorded lowest at Jodiya (City) 2.97 m/day and highest at Gokalpar (Latipur) village 14.34 m/day. Thus the rating of the parameter hydraulic conductivity ranges between 2.5 to 7.5. Fig. 2 shows representation of parameter (A).

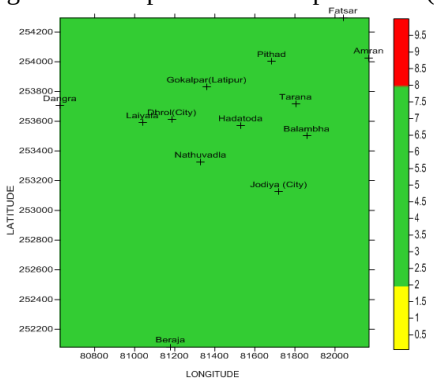

Fig.1: Representation of parameter G

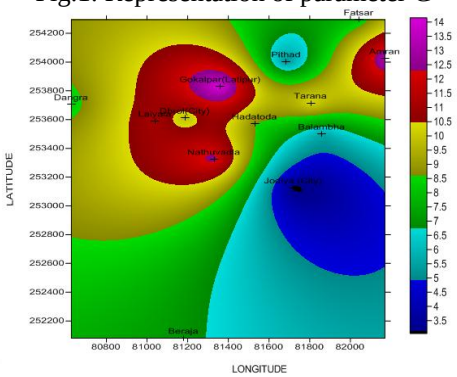

Fig. 2: Representation of parameter A

C. Height of Groundwater level above sea level (L):

Height of groundwater is used in determining the hydraulic pressure. Hydraulic pressure has ability to push back the sea water front. For the ratings of GALDIT parameter L, one should consider the sequential long-term variation of the groundwater level. The values with minimum groundwater levels above sea level may be considered, as this would give the highest possible rate of vulnerability risk. The height of groundwater above mean sea level is calculated for pre-monsoon and post-monsoon season of year 1993 to 2013. Minimum height of groundwater above mean sea level was recorded at Balambha village for pre-monsoon season (-2.1 m and year 2003) and post-monsoon season (-5.70 m and year 1998). Maximum Height of groundwater above mean sea level was recorded at Hadatoda village for pre-monsoon season (51.1 m and year 2008) and for post-monsoon season at Gokalpar(Latipur) village (57.83 m and year 2013). The rating of parameter height of ground water above the mean sea level ranges between 2.5 to 10. Fig. 3.1 shows representation of parameter (L) for pre-monsoon season for year 2013. Fig. 3.2 shows representation of parameter (L) for post-monsoon season for year 2013.

D. Distance from the shore (D):

The impact of seawater intrusion generally decreases if the area is inside towards right angles to the shore. The rating of the parameter distance from shore ranges between 2.5 to 7.5. Fig. 4 shows representation of parameter (D).

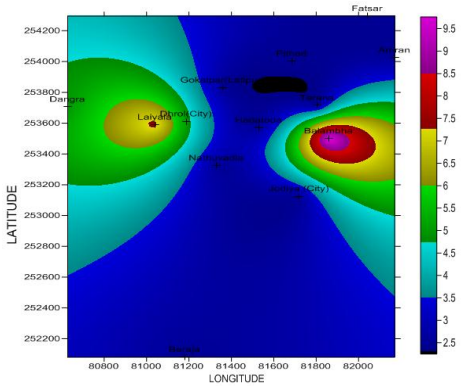

Fig. 3.1: Representation of parameter L for pre-monsoon season for year 2013

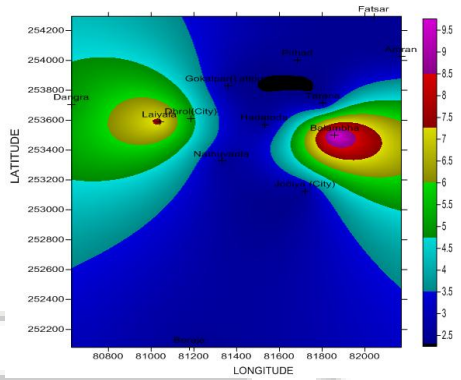

Fig. 3.2: Representation of parameter L for post-monsoon season for year 2013

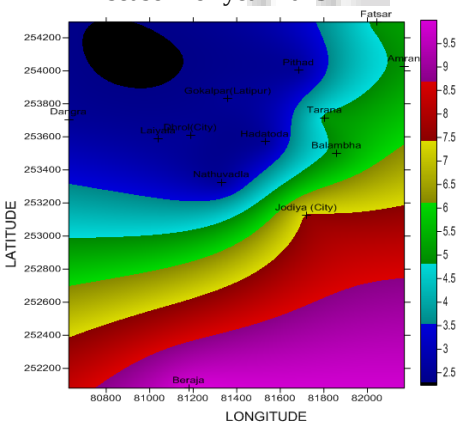

Fig. 4: Representation of parameter D

E. Impact of existing status of Seawater Intrusion (I):

The ratio Cl/HCO_3 is used to evaluate sea water intrusion into the coastal aquifer if the area under mapping is invariably under stress and this stress has already modified the natural hydraulic balance between fresh groundwater and seawater. If Cl/HCO_3 is greater than one (>1) it clearly indicates the presence of sea water intrusion. Chloride ion is the dominate ion in sea water and Bicarbonate ion is the dominate ion in ground water. Minimum Ratio of Cl/HCO_3^{-1} was recorded at Gokalpar (Latipur) village (0.13 and year 2003) for pre-monsoon season and Amran village (0.14 and year 1993) for post-monsoon season. Maximum ratio of Cl/HCO_3^{-1} is recorded at Jodiya (City) village (7.37 and year 1993) for pre-monsoon season and (9.4 and year 1993) for post-monsoon season. Rating of parameter, impact of existing status of seawater intrusion ranges between 2.5 to 10. Fig. 5.1 shows representation of parameter (I) for pre-monsoon season for year 2013. Fig. 5.2 shows representation of parameter (I) for post-monsoon season for year 2013.

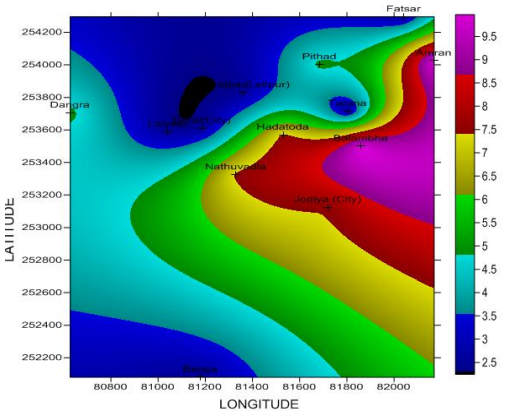

Fig. 5.1: Representation of parameter I for pre-monsoon season for year 2013

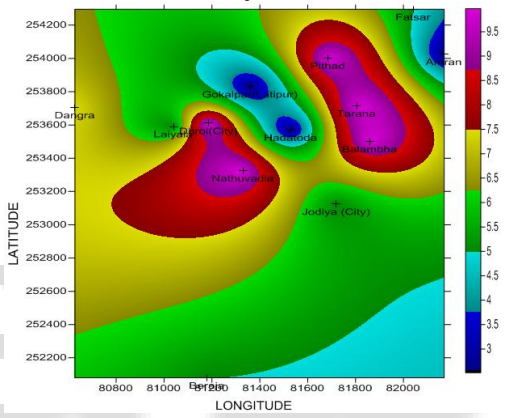

Fig. 5.2: Representation of parameter I for post-monsoon season for year 2013

F. Thickness of Aquifer (T):

Aquifer thickness or saturated thickness of an unconfined aquifer plays an important role in determining the extent of vulnerability of seawater intrusion in the coastal areas. Larger the extent of seawater intrusion is there if the thickness of Aquifer is large. Minimum thickness of aquifer is at Navagam (1.06 m) and maximum at (9.4 m) Khakhrala. Rating for thickness of aquifer varies between 2.5 to 7.5. Fig. 6 shows representation of parameter (T).

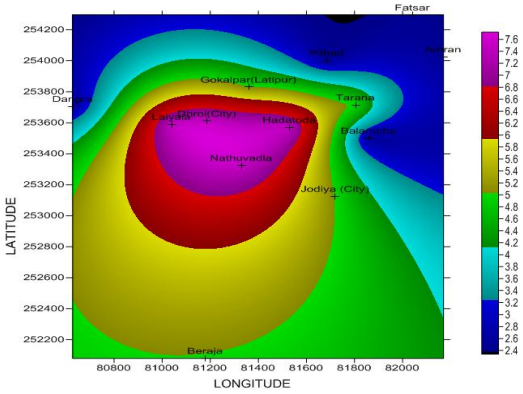

Fig. 6: Representation of parameter T

G. GALDIT index

Computation of GALDIT index for pre monsoon season of year 2013 is shown in Table 4. Computation of GALDIT index for post monsoon season of year 2013 is shown in Table 5.

Sr. No.	Tehsil		R_i						GALDIT index	Vulnerability Classification Based On GALDIT index
		$W_{i>}$	1	3	4	4	3	2		
		Village	**G**	**A**	**L**	**D**	**I**	**T**		
1	Jodiya	Beraja	7.5	5	2.5	10	2.5	5	5.29	Moderate
2		Jodiya	7.5	2.5	2.5	7.5	7.5	5	5.15	Moderate
3		Balambha	7.5	5	10	5	10	2.5	6.91	Moderate
4		Amran	7.5	7.5	2.5	5	10	2.5	5.59	Moderate
5		Fatsar	7.5	5	2.5	5	2.5	2.5	3.82	Less
6		Pithad	7.5	5	2.5	2.5	5	2.5	3.68	Less
7		Tarana	7.5	7.5	2.5	5	2.5	5	4.56	Moderate
8	Dhrol	Hadatoda	7.5	5	2.5	2.5	7.5	7.5	4.71	Less
9		Gokalpar(Latipur)	7.5	7.5	2.5	2.5	2.5	5	3.97	Less
10		Nathuvadla	7.5	7.5	2.5	2.5	7.5	7.5	5.15	Moderate
11		Dhrol	7.5	5	5	2.5	2.5	7.5	4.41	Less
12		Laiyala	7.5	7.5	7.5	2.5	2.5	7.5	5.44	Moderate
13		Dangra	7.5	5	5	2.5	5	2.5	4.26	Less

Table: 4 Computation of GALDIT index for pre monsoon season of year 2013

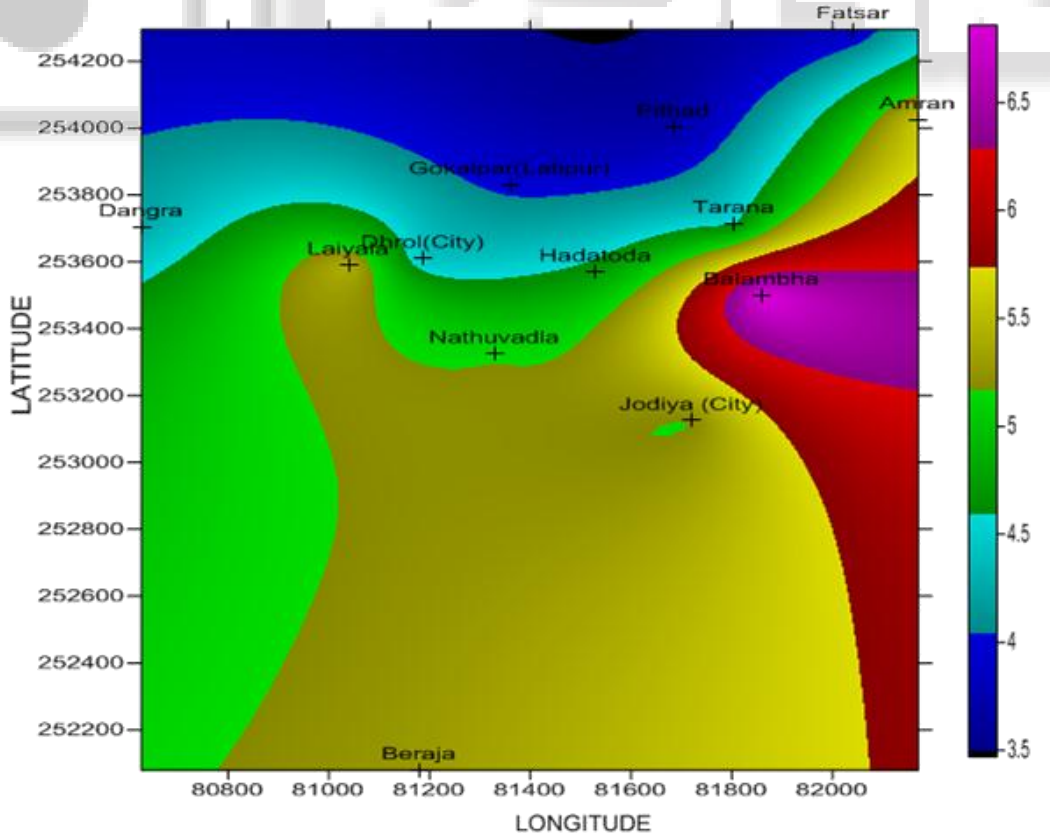

Fig. 7.1: Representation of GALDIT index for pre-monsoon season of year 2013

Sr. No.	Tehsil		R_i						GALDIT index	Vulnerability Classification Based On GALDIT index
		$W_{i>}$	1	3	4	4	3	2		
		Village	**G**	**A**	**L**	**D**	**I**	**T**		
1	Jodiya	Beraja	7.5	5	2.5	10	5	5	5.74	Moderate
2		Jodiya	7.5	2.5	2.5	7.5	5	5	4.71	Less
3		Balambha	7.5	5	10	5	10	2.5	6.91	Moderate
4		Amran	7.5	7.5	2.5	5	2.5	2.5	4.26	Less
5		Fatsar	7.5	5	2.5	5	5	2.5	4.26	Less
6		Pithad	7.5	5	2.5	2.5	10	2.5	4.56	Less
7		Tarana	7.5	7.5	2.5	5	10	5	5.88	Moderate
8	Dhrol	Hadatoda	7.5	5	2.5	2.5	2.5	7.5	3.82	Less
9		Gokalpar(Latipur)	7.5	7.5	2.5	2.5	2.5	5	3.97	Less
10		Nathuvadla	7.5	7.5	2.5	2.5	10	7.5	5.59	Moderate
11		Dhrol	7.5	5	5	2.5	10	7.5	5.74	Moderate
12		Laiyala	7.5	7.5	7.5	2.5	5	7.5	5.88	Moderate
13		Dangra	7.5	5	5	2.5	7.5	2.5	4.71	Less

Table: 5 Computation of GALDIT index for post monsoon season of year 2013

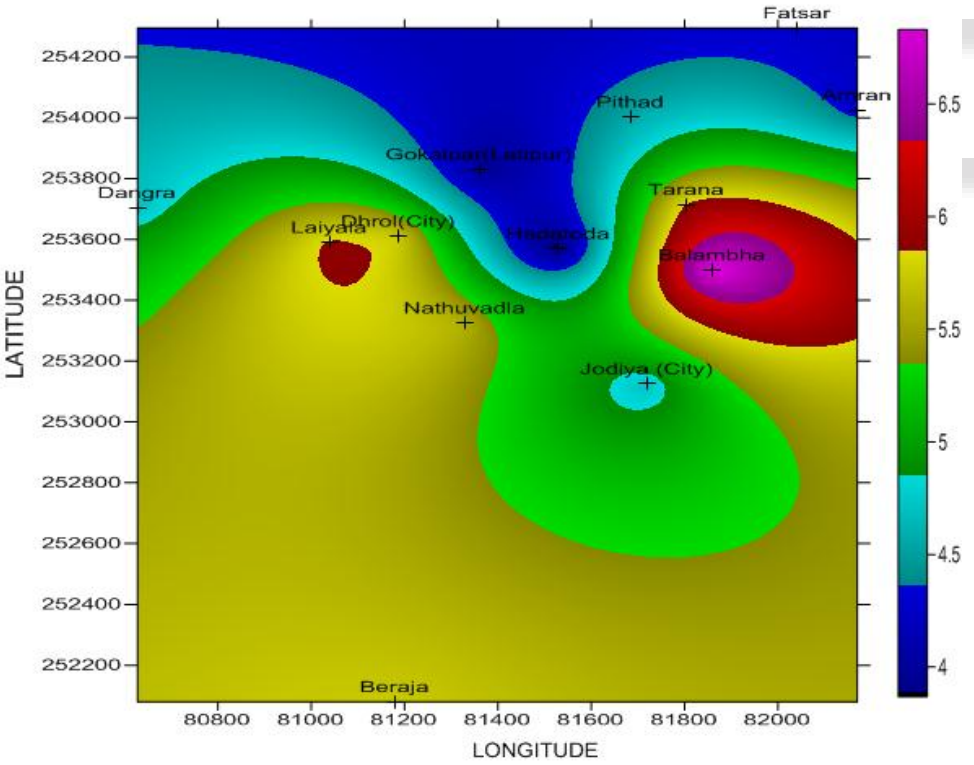

Fig. 7.2: Representation of GALDIT index for post-monsoon season of year 2013

V. CONCLUSION

Jodiya Dhrol taluka is low to moderately vulnerable to seawater intrusion. GALDIT index of villages of Jodiya were high as compared to villages of dhrol tehsil. The higher GALDIT index indicates the jodiya tehsil is more vulnerable to seawater intrusion as compared to dhrol tehsil. Fromyear 1993 to 2013 the water level was increased by 1.62 m which decreased the impact of seawater intrusion. laiyala village of Dhrol tehsil is more prone to seawater intrusion which is situated at 39 km from shore because of its heavy ground water extraction for industrial area. It was observed that the seawater intrusion is dynamic for the villages of Jodiya Dhrol Tehsil. The results obtained from the investigations may be useful for judicious planning of ground water development in coastal aquifer of Jodiya- Dhrol region.

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