Assessing Temporal and Spatial Changes of Salinity by Inverse Distance Weighted Modeling in ArcGIS

Nirav Shah[1] Yashodhar Pathak[2] Milan Chudasama[3]
[1]P.G Student [2,3]Assistant Professor
[1,2,3]Department Civil Engineering
[1,3]Shantilal Shah Engineering College, Bhavnagar, Gujarat, India [2]Government Engineering College, Bhavnagar, Gujarat, India

Abstract— Present Paper concentrates to study seawater intrusion phenomena in the aquifers of the coastal talukas of Junagadh district of Gujarat State in India using ArcGIS. Well location and corresponding quality data were collected from Gujarat Water Resources Development Corporation (GWRDC). The data were used to generate 2 dimensional maps of spatial distribution of Static Water Level (SWL), Chloride (CL) and Electrical Conductivity (EC) of the last fifteen years to study the temporal and spatial distribution of the salinity before and after monsoon using Inverse Distance Weightage (IDW) method after sorting out global and local outliers. These maps were used to identify the movement of the seawater-freshwater interface and consequent seawater intrusion over the last fifteen years if any.

Key words: ArcGIS, Inverse Distance Weightage (IDW), Salinity, Seawater Intrusion

I. INTRODUCTION

Salinity is the saltiness or dissolved salt content of a body of water or in soil. The State of Gujarat has the longest coastline of 1600 km, which is about one third of the total coastline of India. Of this, Saurashtra and Kachchh districts have an 1125 km coastal belt from Bhavnagar to Lakhpat. Due to heavy withdrawal of groundwater and very less recharge sources (only rainfall), ingress of sea water has converted the available groundwater resources into a saline belt, rendering cultivable land useless and the water in the wells saline and unsuitable for irrigation and drinking purposes.

Saltwater intrusion is the movement of saline water into freshwater aquifers, which can lead to contamination of drinking water sources and other consequences. Saltwater intrusion occurs naturally in some coastal aquifers, owing to the hydraulic connection between groundwater and seawater. As a result, saltwater can push inland beneath the freshwater. Certain human activities, especially groundwater pumping from coastal freshwater wells, have increased saltwater intrusion in many coastal areas. Water extraction drops the level of fresh groundwater, reducing its water pressure and allowing saltwater to flow further inland.

Seawater intrusion constitutes a prominent hydrological problem in many coastal areas of the world. Werner and Simmons define it as the encroachment of saline water into fresh groundwater domains in coastal aquifer settings. This phenomenon will occur when the natural equilibrium state established between fresh and sea water is disturbed as a result of natural or artificial effects, which in turn results in the deterioration of fresh water resources affecting human, animals and agriculture and industrial resources within the contaminated zones (Xu et al. 1999).

II. STUDY AREA AND DATA COLLECTION

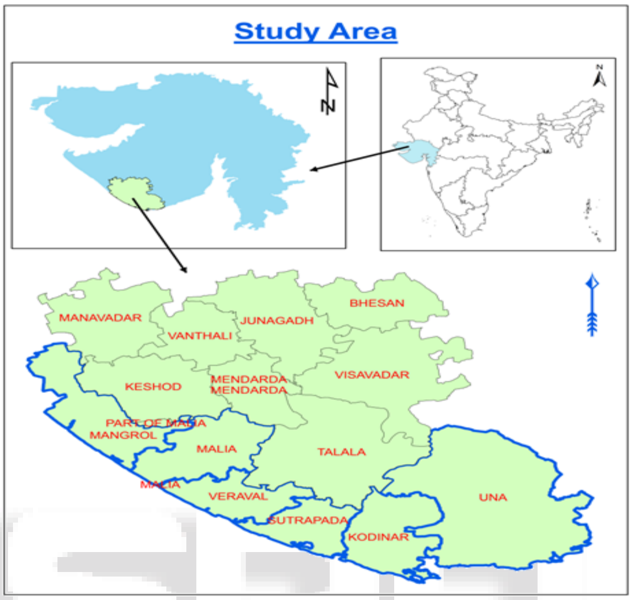


Fig. 1: Study Area

Study Area Covers Junagadh district which lies between 21º 10’ and 21º 40’N latitude and 70º 18’ and 71º 15’E longitude region, in the state of Gujarat India, known as Kathiawar or Saurashtra. It has an average elevation of 107 meters (351 ft.). This district is bounded by the Rajkot district in North, Amreli district in East, Arabian Sea in South and Porbandar district in the West. Starting from west to east there are five major intermittent rivers exist i.e Netravali, Devka, Hiran, Saraswati and Singwadi. Study Area comprises of six Talukas i.e Una, kodinar, Malia, Sutrapara, Mangrol and Veraval in Junagadh Coastal Reach which is shown in fig 1 below. This is also called Una to Madhavpur Coastal Reach as suggested in High Level Committee-1 (HLC-1) report. Data requirement for the analysis are mention below in table. Total study area is 98,763 Ha. The study area falls in the SOI toposheets nos. from (F_42_Q3), (F_42_Q8), (F_42_Q12), (F_42W1_W5), (F42_P15_P11),(F42_Q4_P16),(F42W9_W10).

Data requirement for the analysis are mention below in table

Sr.no	Name of Organization	Types of Data
1.	Survey of India (SOI), Gandhinagar	Topographical sheets of Study Area
2.	Central Ground Water Board(CGWB), Ahmedabad	Groundwater Data: SWL, CL, EC, TDS, Locations, village name, talukas name

Table 1: Data Collection

III. INVERSE DISTANCE WEIGHED (IDW) MODELING

Inverse distance weighted (IDW) interpolation determines cell values using a linearly weighted combination of a set of sample points. The weight is a function of inverse distance. The surface being interpolated should be that of a locational dependent variable.

$$\hat{Z}(s_0) = \sum_{i=1}^{N} \lambda_i Z(s_i) \qquad \lambda_i = d_{i0}^{-p} \Big/ \sum_{i=1}^{N} d_{i0}^{-p} \qquad \sum_{i=1}^{N} \lambda_i = 1$$

The general formula is
Where:

$\hat{Z}(s_0)$ Is the value we are trying to predict for location s0.

N is the number of measured sample points surrounding the prediction location that will be used in the prediction.

λi are the weights assigned to each measured point. These weights will decrease with distance.

Z (si) is the observed value at the location si.

The formula to determine the weights is the following:

As the distance becomes larger, the weight is reduced by a factor of p.

The quantity di0 is the distance between the prediction location, s0, and each of the measured locations, si.Mainly there are two parameter which is directly affect the IDW Modelling

A. Power:

The optimal power (p) value is determined by minimizing the root mean square prediction error (RMSPE). The RMSPE is the statistic that is calculated from cross-validation. In cross-validation, each measured point is removed and compared to the predicted value for that location.

B. The Search Neighborhood:

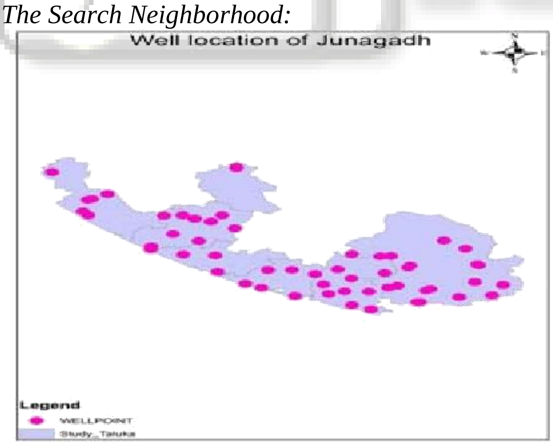


Fig. 2: well location of Junagadh

The shape of the neighborhood is influenced by the input data and the surface which are trying to create. If there are no directional influences on the weighting of the data, consider points equally in all directions. The adjustment for this directional influence is justified because that location from a prediction location is going to be more similar at remote distances than locations that are perpendicular to the location.

C. Generation of Well Shape File:

Generations of point shape file for locate wells using ArcGIS, it is necessary to availability of the precise data of the well latitude and longitude. The data is form of Excel file contain geographic data (coordinates) in the form of XY column (long, lat). From Attribute tables it is easy to generate year wise location and quality database for Pre and Post monsoon period of 2002 to 2014year.

D. Outlier Detection and Elimination from Datasets:

An outlier is an observation that lies outside the overall pattern of a distribution (Moore and McCabe 1999). Usually, the presence of an outlier indicates some sort of problem. This can be a case which does not fit the model under study or an error in measurement. In present study propose an approach using histograms for outlier detection. Outliers are often easy to spot in histograms.

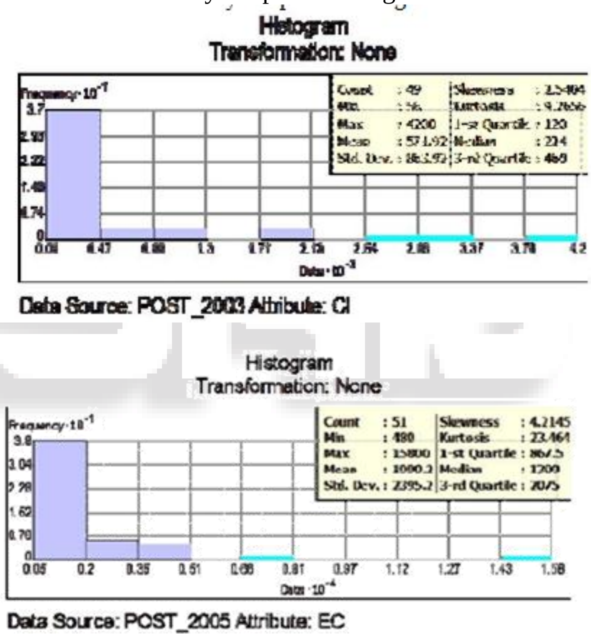


Fig. 3: Histograms for the Elimination Of Outliers

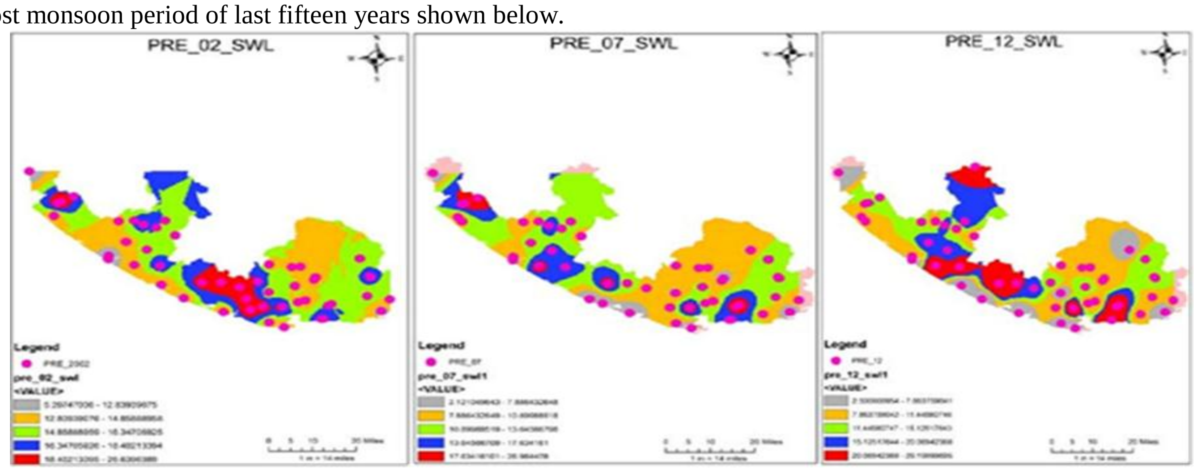
Changing in the Shape of sector for the neighborhood include gives different root mean square error (RMSE). With the same process changing in power also gives different RMSE. From the detail study select t the best suitable shape and power value for the least RMSE. Detail analysis shows in the form of attribute table below.

							RMSE			
INPUT_DATA	**TYPE**	**FID_NO**	**OUTLIER**	**POWER**	**MEAN**	**1_SECTOR**	**4_SECT**	**4(45*)SECT**	**8_SECT**
PRE_02	SWL	9-19-46	3	1	0.8118		7.624		
	EC		0	1	-329.4	2905			
	CL	6-24-40	3	1	-52.72	723			
POST_02	SWL		0	1.8472	0.4248			6.343	
	EC	6-21-22-	4	1.1879	-60.23	1382			

		40							
	CL	6-22-40	3	1.1282	-18.34		498.5		
PRE_03	SWL	14-33-43	3	3.777	0.3784				7.607
	EC	5/3/1935	3	2.4337	-80.36				1076
	CL	6-13-35	3	1	-51.92		799.1		
POST_03	SWL	6-007	2	1.5497	-0.1743		3.061		
	EC	8-16-22-38	4	1.9116	-151.7		1307		
	CL	8-16-38	3	1.7502	-40.19			435.6	
PRE_07	SWL	-	-	2	0.574	5.797			
	EC	-	-	1.9503	-14		2455		
	CL	3-0038	2	1.5565	-10.94		556.7		
POST_07	SWL	-	-	1.3596	-0.0264				2.304
	EC	03-0039	2	2.0728	-92.23		941.6		
	CL	3-39-40	3	1	-55.58		383.5		
PRE_08	SWL	-	-	2.9608	0.3121		5.465		
	EC	24-42-42	3	1	-198.6	1895			
	CL	42	1	1.4551	-45.09		666.5		
POST_08	SWL	-	-	1.2428	0.02043	2.627			
	EC	6-22-43	3	1.9363	-129.8		860.8		
	CL	-	-	1.7764	-38.7				787.1
PRE_12	SWL	-	-	4.5746	0.2597		6.027		
	EC	20-41	2	1.7623	-96.13		1284		
	CL	-	-	2.15	-10.48		454.3		
POST_12	SWL	-	-	1	1.834	19.55			
	EC	-	-	2.0964	-57.98	1204			
	CL	-	-	1.9844	-10.99				439
PRE_13	SWL	-	-	1	0.2995				10.04
	EC	-	-	1.6199	-43.24		1624		
	CL	-	-	1.6223	-8.271		561.1		
POST_13	SWL	-	-	1.0209	0.000967		3.234		
	EC	-	-	2.1654	-40.94		1137		
	CL	-	-	2.1043	-9.23	402.4			
PRE_14	SWL	-	-	1	0.5152		7.848		
	EC	-	-	2.0531	-1.383		1519		
	CL	43-46	2	1.82	-10.09		495.9		

Table – 2: IDW Modeling and Fit Parameters

Thematic maps generated for the various ground water quality parameters like SWL, EC and CL for the Pre and Post monsoon period of last fifteen years shown below.



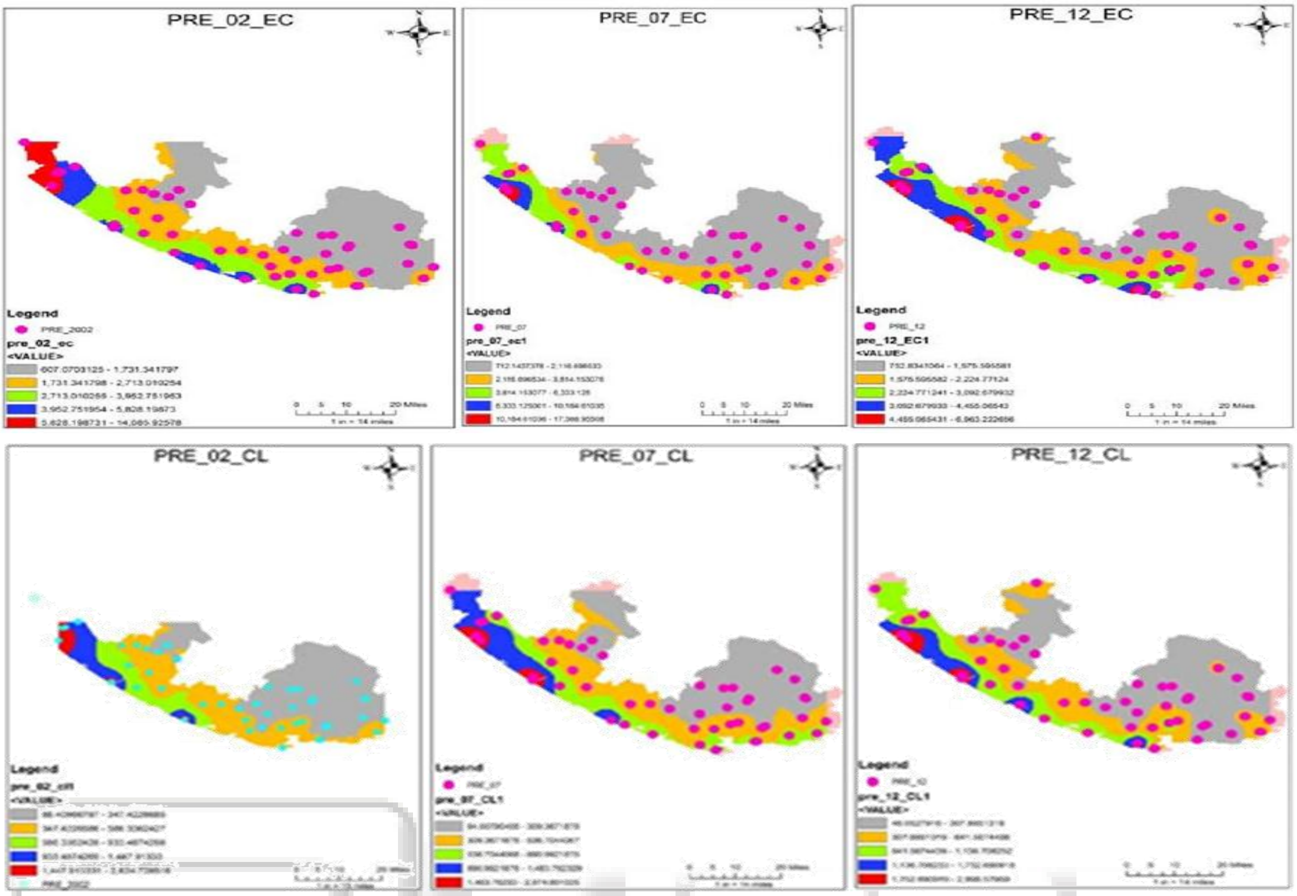


Fig. 4: Thematic Maps of Water Quality

IV. Conclusion

The maps of IDW modeling above i.e. fig. 4 shows the variability of SWL, EC and CL of pre-monsoon period of the years 2002, 2007 and 2012 respectively. The optimization for power and Root Mean Square Error (RMSE) has been carried out for each year's data sets for SWL, EC and CL which is shown in Table No: 2. from the study it is concluded that the some of talukas of Junagadh district have been badly affected by salinity namely Malia, Una and Kodinar. It can be noticed that the salinity is getting intruded in the northward direction over the years. The EC and CL are almost behaving well in tandem with each other. The groundwater has become more saline over the years. The SWL has been increased over the years in some of the regions which are directly affecting the groundwater quality in the region validating Ghyben Herzberg principle.

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