

Research Paper

GEOPHYSICAL MONITORING **OF** ALONG THANDAVA
RIVER BASIN FOR THE PROSPECTS OF
GROUNDWATER IN THE HARD ROCK TERRAIN
REGIONS OF EAST GODAVARI DISTRICT

Abstract:

The occurrence, movement and control of groundwater, particularly in hard-rock areas, are governed by different factors such as topography, lithology, and structures like fractures, faults and nature of weathering. An attempt is made in the present study to investigate the extent of the influence of structures such as fractures and thereby delineate the nature of subsurface lithology with the help of **an** electrical resistivity method.

Vertical Electrical Soundings by Schlumberger array configuration were recorded in fifty stations of the study area. The choice of the sampling stations **in, around and along the basin made the research the first of its kind in the area.** The huge sample number made ease of the interpretations with reliability in establishing the geomorphology of the area around the river basin. Groundwater potential zones were delineated with the present status of the reserves. The lithological segregation of the hard rock terrain stands reference for future studies besides suitability of the area made the study in announcing the challenges to be faced for sustainability.

Keywords: Vertical Electrical Sounding, Groundwater, Potential Zones

Introduction:

According to Lewis (2003), it is possible to image the subsurface quickly and inexpensively through the application of various non-intrusive surface geophysical methods. Electrical resistivity studies have been extensively used in groundwater geophysical investigations because of the correlation that often exist between electrical properties, geologic formations and their fluid content (Zohdy and Jackson, 1969; Fitterman and Stewart, 1986). Schwartz and McClymont (1977) and Stollar and Roux (1975) reiterate that the variations in apparent resistivity in the area can often be related qualitatively to geological features. Delineation of aquifers is the pre-requisite for assessment of regional/local groundwater potential. In view of present studies which include the river basin study, earlier integrated studies were reviewed in an attempt to draw significant anomalies and approaches to be followed. Delineation of aquifers and subsequently their groundwater potential assessment were carried out in different part of the country by using different geophysical, geological, geochemical, remote sensing and GIS methods depending on the local hydro geological conditions (Rai, 2009), (Elias and Ierotheos, 2006), (Saxena et al., 2005), (Chandra et al., 2006). and isotope and GIS integration study was reported by

51. A new hydro chemical technique based on EC logs was
52 developed for the delineation of water bearing fractures in hard rock areas and tested in
53 the Maheshwaram watershed An integrated study was carried out in
54 Bairasagara watershed in Karnataka to investigate the subsurface conditions in hard rock
55 environment with the aim of identifying zones with groundwater potential
Geochemical studies on the Dankar, Thinam and Gete lakes in the Spiti valley

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57 of Higher Himalaya was carried out to understand the nature of lithology and the type of
58 weathering at the source (Das and Dhiman, 2003), geochemistry and quality assessment
59 was reported by Singh et al. (2007) and hydrogeological and hydro chemical study on
60 Kali-Ganga was also reported by Asad et al. (2001). An integrated approach of
61 weathering, chemisorptions and trace metals was reported by Crolyn et al. (2003) along
62 Bengal basin groundwaters and quality assessment and determination of pollution sources
63 interactive study was reported on Axios-Varda river by Milovanovic (2007), integration
64 of thematic maps and GIS was reported by Murthy et al. (2003).
65 Groundwater studies involving integrated approach reported mainly basing on the
66 geophysical dominance assessments relating to areas in and around the present study area
67 include, mathematical modeling basing on resistivities by Vinod Rao and Gurunadha Rao
68 (2006), integration of geoelectrical and pumping data by Subba Rao (2003), electrical
69 resistivity surveys Sagar and Naga Malleswara Rao (1989) have applied in Varaha River
70 basin and by Sarma and Swamy (1981) on Visakhapatnam basin. In fact, studies like
71 these carried in assessment of groundwater potential or for that matter of any other had
72 obviously used one interpretation, courtesy of various factors. But from comprehensive
73 and thus by making use of water supply to meet the ever-increasing demands for
74 domestic, agricultural and industrial uses makes more benefits. Review of these, revealed
75 the respective interpretations being dominant rather than a comprehensive study and
76 which might not be needed, if focused on for a particular characteristic study. But, at the
77 same time, multiple parameter analysis with integrated interpretation would always
78 reveal an overall scenario of better understanding and thus lead to confirmation rather

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79 than speculation. The resistivity survey was carried in 50 locations along the Thandava
80 reservoir during June 2011 along with soil sample collection.

81 Study Area:

82 The Thandava river basin extends over an area of 909.48 Km². The basin has a
83 maximum length from North to South of 49.88 Km between latitude 17° 50' and 17° 15'
84 North and maximum width from East to West of 21° 5' between longitude 82° 17' and 82°
85 45' East. This basin covers water of Visakhapatnam and East Godavari districts of
86 Andhra Pradesh state. The basin is surrounded by Sabari sub-basin of Godavari in north
87 and Varaha river basin in the east, Bay of Bengal in the south and Pampa and Yeleru in
88 the west. The upper reaches and most of the eastern portion lie in Visakhapatnam district
89 and the lower portion and western side lies in East Godavari district. About 2/3rd of the
90 catchment lies in the former district and the balance lies in the later district.

91 Thandava River originates at an altitude of 4250' and flows over the Chintapalli,
92 Narsipatnam, Tuni and Yelamanchili taluks for a length of 99.7 KM. The Thandava River
93 rapidly falls to +1000 in its first 9.5 KM reach. After travelling about 14.4 KM, it
94 receives a tributary Sapegedda kalva, Lower down Peddagadda lanka, another tributary
95 flowing in West ward direction falls in to Thandava, after the later traversing a distance
96 of 19.3 KM from its origin. The level at this confluence is +650'. After travelling another
97 10.4 KM, a small tributary from West comes and joins the river, the bed fall in this reach
98 works out to about 1 in 264. At about 40.2 KM of its traverse, a minor tributary formed
99 by the small streams viz; Dhara gedda and Chittampadu gedda and Gorri gedda, joins the
100 Thandava flowing in South ward direction. After 4.8 KM confluence, another tributary
101 Addakala gedda joins the main river from the West. Lower down after 11.2 KM another

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102 tributary from West Sarugudu gedda taking its origin in Sarugudu forests falls in
103 Thandava River. After this there are no streams worth monitoring that join the Thandava
104 River. This reach is flat, and the average bed slope is mild until the river enters into Bay
105 of Bengal at Pentakota in Visakhapatnam district.

106 Topographically Thandava River rises in Eastern ghat hill ranges and enters Bay
107 of Bengal. The basin is surrounded by hills almost all around except in the southern part
108 which is plain. The entire catchment's consists of undulating country, a series of ridges
109 and villages interspersed with low hill ranges. Large flat areas are not available in this
110 basin. The Northern and Western sides of the basin are hilly with dense forests.
111 Particularly the Northern hilly range is the area of heavy rainfall. The slopes of these hills
112 are covered with thick jungles and in some places mixed with bamboo. The Eastern
113 portion of the Thandava basin is generally flat and of low elevation. The coastal belt is
114 sandy. The resistivity stations stations were shown in fig.1.

115

116 **METHODOLOGY**

117 The ease and accuracy of any study or work for instance depend largely upon the
118 planning made prior to collection of the samples. The plan includes the location of
119 sampling sites and parameters to be analyzed, methods of data collection and also the
120 handling procedures. Sampling points should be such that, they represent the existing
121 environment (APHA, 1995). The discussions with the Groundwater Board prior and
122 before the finalizing of the number, parameters to be analyzed, mandals to be covered,
123 district topographical marking of the stations, etc., had made meaningful effects at
124 various stages of the work in the study area. A trail run before the execution made the

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125 things to be sorted out and means in collection at the ground level, where there were
126 significant deviations in the reality and the hypothetical assessments made were quite
127 evident and thus made the work to be carried in smooth manner.

128 The station's latitude and longitude were obtained by using GPS at the site. The
129 values of coordinates were cross checked using topo sheets of the respective districts
130 (District Ground Water Board). After the finalizing the number of sample sites, the total
131 distance of the two districts were broken into parts of possibility for collection based on
132 the time of journey, travel route, feasibility for collection etc. along with the onsite
133 changes from time to time in accordance with the ground realities. The rainfall data of the
134 area for five years had been collected from the groundwater department assessments at
135 two rain gauge stations for relative understanding along with the present results.

136 **Results and Discussion:**

137 According to Scheidegger (1973), water is an important agent in the formation of
138 landforms and thus geophysical assessment of an area invariably signifies the potentiality
139 of groundwater. The electrical resistivity of rock is a property which depends on lithology
140 and fluid content and depends on many factors like, chief among these are the mineral
141 content, texture, moisture content, salinity, fissures and fractures of geological
142 formations. The resistivity values of rocks vary depending upon the presence of
143 secondary porosity such as weathered, fractured and joints. The resistivity of coarse
144 grained, well-consolidated sandstone saturated with fresh water is higher than that of
145 unconsolidated silt of the same porosity, saturated with the same water. The ultimate
146 objective of Vertical Electrical Soundings (VES) study at any locality is to obtain a true

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147 resistivity log similar to, for example, the induction log of a well at the locality, without
148 actually drilling the well (Sabet 1975).

149 In general, traditional methods for characterizing protective layers include test
150 hole drilling and analyses of log, with the objective being to characterize thickness and/or
151 lateral extent of the protective layer. Disadvantage of such investigations are that can be
152 labor intensive and expensive. The Electrical Resistivity Meter (ERM) method has
153 proved very popular with groundwater studies due to simplicity of the technique
154 (Muhammed et al., 2007) and is being used in the present study. This is a method
155 whereby consecutive readings are taken automatically and the results are averaged
156 continuously. The ERM can operate in different modes (resistivity, self potential &
157 induced polarization). A useful facility of this is its ability to measure in multiple
158 channels simultaneously. This implies that as well resistivity and induced potential
159 measurements as voltage measurements can be performed in quick times. The electrically
160 isolated transmitter sends out well defined and regulated signal currents, with strength up
161 to 1000 mA and a voltage up to 400 V. The receiver discriminates noise and measures
162 voltages correlated with transmitted signal current and also measures un-correlated DC
163 potentials with the same discrimination and noise rejection. This makes it suitable for all
164 sorts of resistivity surveys. These results are more reliable in resistivity surveying mode,
165 as it comprises a battery powered, deep penetration resistivity meter with an output
166 sufficient for a current electrode separation of 200 m under good survey conditions. The
167 micro processor, monitors, controls operations and calculates results. The ratio between
168 voltage and current V/I is calculated automatically and displayed in digital form in ohms
169 or millions.

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170 The “Schlumberger” and “Wenner” array configurations are two electrode layouts
171 which are widely employed in the resistivity surveys. The different arrays (Wenner,
172 Schlumberger & double-dipole) were compared using the absolute value of the sensitivity
173 and its spatial distribution. On a per measurement basis, there was almost no difference
174 between the Wenner and the Schlumberger surveys. However in this study, Schlumberger
175 array layout was used. By putting two electrodes into the ground and inducing an electric
176 current through the ground, a potential field is created. Two additional electrodes are
177 used to measure the potential at some location. Increasingly deeper measurements are
178 achieved by using a bigger separation between the current electrodes. Moving the current
179 electrode and having the potential electrode fixed is named the “Schlumberger” method
180 (Emenike, 2001, Frohlich & Urish, 2002).

181 At each of the station a direct current was introduced into the ground through two
182 current electrodes A and B. The potential electrodes M and N were inserted in the ground
183 between the outer current electrodes A and B, where the potential difference was
184 measured across these two potential electrodes. By measuring the current (I) between the
185 two current electrodes A and B and the associated potential difference (V) between the
186 potential electrodes M and N, the apparent resistivity (ρ_a) was computed. This was
187 repeated and the Schlumberger measurements with the entire setup moved one step to the
188 side, vertical electrical soundings (VES) were performed continuously and the
189 resistivities along a profile were measured. Since the values measured in the field
190 correspond to resistances or potentials the first step when processing the data was to
191 calculate the apparent resistivities. These were computed using the formula relevant to
192 the electrode configuration. The resistivity survey was carried for 50 locations along the

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193 Thandava River Basin during June 2011. The Schlumberger soundings were carried with
194 maximum current electrode spacing (AB) 400 m ($AB/2 = 200$ m). The field data
195 acquisition was generally carried out by moving two or four of the electrodes used,
196 between each measurement. The resistivity values at various thicknesses are given in
197 Table 1.

198 It was expected that based on the resistivity values the lithology, weathered,
199 fractured pattern, depth to basement and resistivity variations would be evaluated. As
200 different values of the resistivities at various depths indicate the different formations
201 based on the local geomorphology and geology. The soil and alluvium layer is underlain
202 by weathered shale and the weathered shale is underlain by fractured shale. It was
203 observed that resistivity soundings falling under high-density lineament zones provide
204 favorable results when compared to soundings that fall under other zones. Moderate-to
good yields are tapping from weathered zones, where no fracture zones are present. In
206 these areas the thickness of alluvium followed by weathered shale's is greater, and the
207 percolation of the groundwater in the unconsolidated material led to the formation of the
208 moderate to good yields without presence of fractured zones.

209 In some cases though the fracture zone is not present, yields are high, maybe due
210 to the presence of high alluvium thickness and the weathered zone, and also recharge
211 from the adjacent canal sources of the river. Some areas are devoid of fractures and
212 alluvium zones with low yields during rainy season and dry up during summer season.
213 Whereas areas covered with high alluvium and more fractured zones are abundant with
214 rich resources groundwater. These areas show much lower resistivity values compared
215 with rocky regions. It was apparent that the primary porosity is clear within the geology

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216 but, groundwater occurrence is mainly due to the secondary porosity, i.e. weathering,
217 joints, fissures and fracture/lineaments. Most of the wells located in this zone yield a
218 good quantity of water. The high resistivities are located over topographic high at the
219 southern and northeastern portions of the study area. The wells located in high resistivity
220 zones give relatively poor yields. The major part of the basin constitutes the values
221 relating to piedplain with moderate and plain weathering. The thickness of piedmont
222 zones increases from northern area to southern areas of the present river basin, where the
223 apparent resistivity values are found to decrease in the same direction. The alluvium
224 consists of pebbles, gravel, sand, silt and clay, ranging in thickness from 2 to 26 m
225 occurring from a northern direction of the study area and presence of coastal plain to
226 deep.

227 The average soundings curve does confirm that the curve begins to descend, after
228 the last measured data point. Shows the presence of fractured bedrock at a depth of about
229 4 m and subsequent depths showed that the bedrock is in fact fractured sandstone. This
230 may not be a good aquifer. The plots flat shape for the minimum which apparently
231 narrows down the possible range for the value of the true resistivity of the conductive
232 layer, above bedrock, to about 35 m. These preferred orientations of deep-seated fractures
233 are responsible for the groundwater potential zones in the study area and this is ably
234 assisted from the torrential rainfall in these parts in comparison with the limited in others.
235 But in areas where such information is not available or is rather scanty it is difficult to
236 infer either the thickness of the alluvial column or the presence of granular zones in the
237 subsurface formations, particularly in the marginal areas where marked irregularity of the

238 basement topography and a wide variation in the nature of the sediments are usually
239 observed.

240 Based on these it is a segregation of three zones in the study area as a Pleistocene
241 coastal belt, the central zone and Northern part of the basin formed by Archean type rock
242 and khondalites and the remaining portion is unclassified crystalline which also belongs
243 to Archean group. The northern part of the area is topographically a narrow longitudinal
244 valleys, formed by the discontinuous recent hill ranges of Archean complex as basement
245 for the younger formations which are occupying the Southern part of the area. The
246 younger sediments are fringing at North, with the hard, compact crystalline rocks
247 whereas, towards South these are concealed mostly by thick veneer of alluvial and
248 Gondwana sedimentary formations. The high resistivities are located over topographic
249 high at the southern and northeastern portions of the study area. The wells located in high
250 resistivity zones give relatively poor yields. The geomorphology of basin is shown in fig.
251 2 and groundwater potential zones are shown in fig. 3.

252 **Geological Assessment:**

253 The soil/aquifer samples (28) collected at some of the points were thoroughly
254 analyzed for the differentiation and origin basis in and around the river basin. Table 2 is
255 the summarized results of the analysis and its outcome in assessing the local geology and
256 the possible sources and their types in the study area. Soils differ in their capacity for
257 crop production and suitability for irrigated agriculture. Their physical and chemical
258 properties which determine this capacity and suitability are governed by several factors
259 operating singly and collectively geological, topographically, climate, agronomies and
260 biologically. The behavior of sub soil-waters also plays an important part in the final

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261 outcome. Under natural conditions, there is a soil-water crop relationship peculiar to each
262 area.

263 There are mainly three types of soils in this river basin. They are i) Red Loamy
264 soils in the upper reaches of the basin ii) Red Sandy soils in the interior and iii) Coastal
265 sands and alluvial soils in the coastal belts. The extent of these soils in the basin with
266 respect to the total area is 63.80% (582.00 Sq. KM) of Red Sandy, 29.2% (265.89 Sq.
267 KM) of Coastal Sands & Alluvial and 7% (63.89 Sq. KM) of Red Loamy. Red sandy
268 soils cover the largest area (interior) in the basin. The regions occupied by acid granite,
269 genesis, quartzite and felpathic, with only subordinate rock types rich in iron and
270 magnesium bearing minerals, gives particularly to red soil, but at places yellow to grey or
271 even black colored soils. Some red colored soils are of different constitution having been
272 derived from the surface – cropping of laterized rocks or from lime stone formations.
273 This type of soil, though frequently red in color not always necessarily so, and the color
274 is not due to a high percentage of the iron content. Texturally, red soils comprise course
275 sandy loams, medium fine sandy loams, fine sandy loams and loams. The deep red soils
276 exhibit a sandy loamy texture at the surface, loamy composition in the deeper layers. The
277 soils usually are friable and light textured, sufficiently permeable to be well drained, have
278 water retainability, negligible, salt content seldom, exceeding 0.2%, a low base status and
279 are almost free from lime concentration and carbonates etc,. Generally these soils are
280 deficient in exchangeable bases. They are different in nitrogen and organic matters but,
281 have sufficient potash and lime. The extent of available phosphate is generally low to
282 sufficient. Because of they are being friable, well drained and easily manageable and are
283 capable of withstanding heavy moisture saturation without detriment to crop growth.

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284 The sand stones present in the study area belong to the Upper Jurassic age and
285 that of the Tirupati sand stone (Gondwana group). The general character and
286 distribution of these would be the intercalation of clay and sandstones, brown in color.
287 These are generally suitable for light tube wells with a discharge of about 30,000 liters
288 per hour and these groundwaters are in general good. Coastal sands and alluvial soils
289 occur in the coastal belt of Thandava basin. Alluvial soils are as a rule, of sedimentary
290 type and are found in the deltaic areas and on the coastal belt belong to the Recent type.
291 They are formed by annual depositions of rich silts brought down by rivers. On the basis
292 of textural characteristics these soils can be silty loams, clay and rarely sandy loams.
293 They are generally well drained and being inherently fertile. They respond well to
294 irrigation and generally give high crop yields, but at some cases there have been reports
295 of saline patches at various depths along the coast.

296

297 **Conclusions**

298 Interpretation of the VES results indicates the presence of an alluvial aquifer that
299 mainly consists of sand and clay. The resistivity of the aquifer between 30 to 140 ohm-m
300 showed the increasing value, which indicated the existence of fresh groundwater. The
301 geological structure can be summed up as, the coastal belt as Pleistocene, the central zone
302 and Northern parts with Archean type rock and khondalites, with the remaining as
303 unclassified crystalline correlates with the other results. These are correlated to the
304 presence of the Red and mixed soils, which predominantly exist in this basin. Their
305 permeability and low water holding capacity react favorably to the application of
306 irrigation water, as they are friable, well drained and easily managed.

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443 Table 1: Vertical Electrical Soundings Along Thandava River Basin

444

S.No. Sampling Stations

Resistivity (μm) Thickness (m)

μ_1 μ_2 μ_3 m1 m2 m3

1 THANDAVA RESERVOIR 25.61 29.54 141.2 1.42 17.9 55.26

2 THANDAVA COLONY 142 4029.7 407.7 1.35 7.99 -

3 NATHAVARAM RIGHT CANAL – 1 37.02 13.16 19.02 1.12 1.91 9.42

4 NATHAVARAM RIGHT CANAL – 2 39.59 7.28 599.8 1.58 10.9 10.83

G.GUDEM 23.61 176.2 62.5 4.84 12.5 41.82

6 CHAMMACHINTTA 177 25.81 81.61 2.84 14.9 36.4

7 THANDAVA RIGHT CANAL 10.69 183.4 45.15 0.96 2.18 15.47

8 VENNELAPALEM 38.63 137.5 514.4 9.04 12.2 52.89

9 RANGULAKOTTURU 203.8 150.2 161.9 2.33 3.72 42.1

VALASAMPETA 137.7 25.85 192 1.36 12.3 5.74

11 MALLAMPETA 59.12 92.63 20.85 1.09 6.88 45.62

12 AGRAHARAM – 1 331.8 6332.6 1252.5 0.69 8.24 -

13 NATHAVARAM 14.28 22.9 2267.8 1.41 48.8 -

14 RAJANAGARAM 33.52 5.27 522.2 3.47 16.8 -

GANDHINAGARAM 45.95 66.17 508.4 2.22 7.73 19.89

16 EDURUPALLI RIGHT CANAL 19.42 6.08 602.5 4.64 11.9 6.09

17 NATHAVARAM LEFT CANAL – 1 154.4 17.61 48.35 3.64 41.6 -

18 NATHAVARAM LEFT CANAL – 2 125.1 236.6 534.2 1.52 7.39 -

19 VENKAYYAPALEM 287 61.17 2892 3.73 39 -

GANDHI NAGAR 51.01 24.87 50.44 1.94 16.6 42.6

21 THANDAVA LEFT CANAL – 1 126.8 186.9 42.32 0.71 2.12 7.62

22 THANDAVA LEFT CANAL – 2 15.37 9.53 79.31 1.71 18.1 29.49

23 SRUNGAVARAM 30.75 37.3 3693.4 1.3 60.9 -

24 VEDURUPALLI – 1 50.91 179.1 338.3 1.57 6.15 61.81

VEDURUPALLI – 2 72.87 7214.5 72.87 0.65 0.15 7.95
 26 GOLUGONDA PETA 130.7 54.57 59.25 2.4 1.46 71.5
 27 PEDA GOLUGONDA – 1 99.53 237.8 21.29 1.37 3.65 26.39
 28 PEDA GOLUGONDA – 2 161.8 79.59 702.9 5.12 25.4 46.93
 29 GUNUPUDI NATHAVARAM 180.3 603.2 22.25 1.08 3.41 8.7
 GUNUPUDI PORU 103.1 438.8 304.1 1.41 2.21 16.62
 31 GUNUPUDI TOWN 27.96 10.26 22.77 1.78 9.11 13.3
 32 GUNUPUDI MINOR 12.49 10.73 166.47 1.08 11.6 26.25
 33 S.B.PATANAM 109.3 66.5 55.27 1.55 16.5 50.31
 34 ALLIPUDI MAJOR CANAL 10.52 3.44 260.9 1.28 7.3 -
 ALLIPUDI 29.77 25.96 56.36 0.66 258 4.75
 36 KOTNANDURU – 1 40.81 13.08 83.34 1 14.7 32.04
 37 KOTNANDURU – 2 55.51 10.35 875.8 2.2 12 -
 38 AGRAHARAM – 2 26 120.7 11953 2.59 43.8 -
 39 D.POLAVARAM 8.2 50.22 30.22 1.99 9.94 53.46
 KOLIMERU 28.46 4.68 199.1 1.08 20.3 12.27
 41 MARUVADA 19.54 245 2.47 0.9 1.68 3.27
 42 KUMMARILOVA 160.1 41.27 4086.1 4.66 50.3 -
 43 TUNI 10.01 25.58 35.52 1.49 10.9 5.1
 44 PAYAKARAO PETA – 1 349.7 46.27 3.96 1.33 6.23 43.08
 PAYAKARAO PETA – 2 14.31 4.58 217.7 1.55 9.59 -
 46 SATYAVARAM 5.34 2.3 13.11 1.47 6.27 21.63
 47 M.S.PETA – 1 47.29 168.1 5.43 1.75 9.82 36.38
 48 M.S.PETA – 2 13.67 6.82 10.48 2.28 4.61 29.26
 49 M.S.PETA – 3 69.1 124 6.48 1.34 6.84 31.14
 PENTAKOTA 0.0126 0.0118 -1.35 --

17 Kollimeraka River Bed -0.300

2.152 14.706 59.914 99.034 99.138 STC

18 Atikivanipalem Field 7.525 17.198 25.424 44.384 72.912 99.591 99.293 MS

19 T.Jagannadhapuram Field 9.903 31.159 39.216 53.075 69.200 97.853 99.974 MCS

20 Surapurajupeta River Bed -5.251

24.123 54.299 85.153 99.012 99.449 MCS

21 Agraharam River Bank 1.356 15.610 23.265 74.923 89.680 99.951 110.000 MCS

22 Kakarpalli River Bed 2.520 9.926 23.184 67.036 93.489 99.289 99.289 MCS

23 Kakarpalli River Bank 12.353 23.925 29.182 54.037 63.738 95.797 100.047 MCS

24 Kotanaduru-1 River Bed 1.432 9.908 20.881 55.058 88.516 99.49 99.803 M S

25 Kotnanduru-2 River Bed 26.254 61.175 76.934 88.637 94.795 99.452 99.954 VCS

26 K.Mallavaram Aquifer -1.658

2.983 23.790 81.348 99.740 99.852 FMS

27 K.Agraharam River Bed 1.927 14.679 42.952 80.208 95.465 99.116 99.488 M S

28 K.Agraharam River Bank -3.896

6.994 14.222 38.518 94.572 99.225 FS

*FMS = Fine to Medium Sands; FS = Fine Sands; MS = Medium Sands; MCS = Medium to Coarse Sands;

CS = Coarse Sands; VCS = Very Coarse Sands; FS = Fine Sands; SC = Sandy Clay; STC = Silty Clay; STS = Silty Sands

UNDER PEER REVIEW

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UNDER PEER REVIEW

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UNDER PEER REVIEW

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