5.2 Detailed Geological Survey

5.2.1 Aerial Photograph Interpretation and Field Geological Reconnaissance

(1) Aerial photograph interpretation

Aerial photograph was used to interpret location and direction of the lineaments in the basement rock area focusing on the near-by areas of the candidate villages. The location map of the lineaments was utilized for arrangement of the geo-resistivity survey line (resistivity profiling across the lineament), because the promising area of groundwater exploitation is generally limited to a narrow zone along the faults or weaknesses.

The photo-lineaments have been observed everywhere in all of the districts in the basement rock area, although the distribution pattern (density and directions) of them is different by area. It was found that the most densely distributed area is the upper stream of Lukuledi River, where the lineament of northeast-southwest direction is predominant at the north and northwest-southeast direction is predominant at the southern part. The lineaments of various directions locally intersect, and this distribution pattern indicates occurrence of the complicated structural movements in the past geological age, suggesting the existence of porous zones, with high probability of groundwater development.

Fig. 5-2 represents the result of photo-lineament interpretation.

(2) Field geological reconnaissance

Emphasis was put on the following matters during the field geological reconnaissance;

i) Focusing on the near-by area of the candidate villages, considering that the supply facility is to be the community based independent one involving the supply source
ii) Reference to the well structure and production of the boreholes located in a similar geographic and/or geology circumstances to those of candidate villages
iii) Geological structure in relation with springing mechanism at the villages where spring source is not so far from the concerned villages
iv) Fixing of geophysical survey (resistivity sounding survey) points in the area of sedimentary formation for determination of the depths of the wells to be drilled
v) Confirmation of the location of interpreted photo-lineament on the site for fixing of the survey line for resistivity profiling survey
vi) Conduct of field geological reconnaissance at the areas that represent geological

characteristics for confirmation of interpreted hydrogeology on the concerned areas.

Groundwater in the basement rock area is fissure water, not the bedded aquifer. Therefore the promising area for groundwater exploitation is generally limited to the fissured zone, that is, along the faults or weak line designated by the photo lineaments. To determine the depth of the wells to be drilled is difficult only by the field geological reconnaissance and geophysical profiling survey. The depths of the wells in the basement rock area were determined based on elevation and topography of surrounding area and by referring to the structure/productivity of the existing wells.

The depth estimation of the wells to be drilled in each of the village is given in the column of “Drilling depth” in Table 5-2 (1)-(8) of the Main Report.

Major aquifer in the sedimentary rock area falls in sandstone and limestone layers, and in sand and gravel in the area of alluvium. Depth to the aquifer can be sounded by the electrical resistivity sounding survey by the difference of the apparent electrical resistivity by depth. But, the formations are cut by faults even in the sedimentary formations, especially in the formations of older age than Mesozoic Era, creating complicated hydrogeology; for example, two wells closely located each other can show quite different productivities.

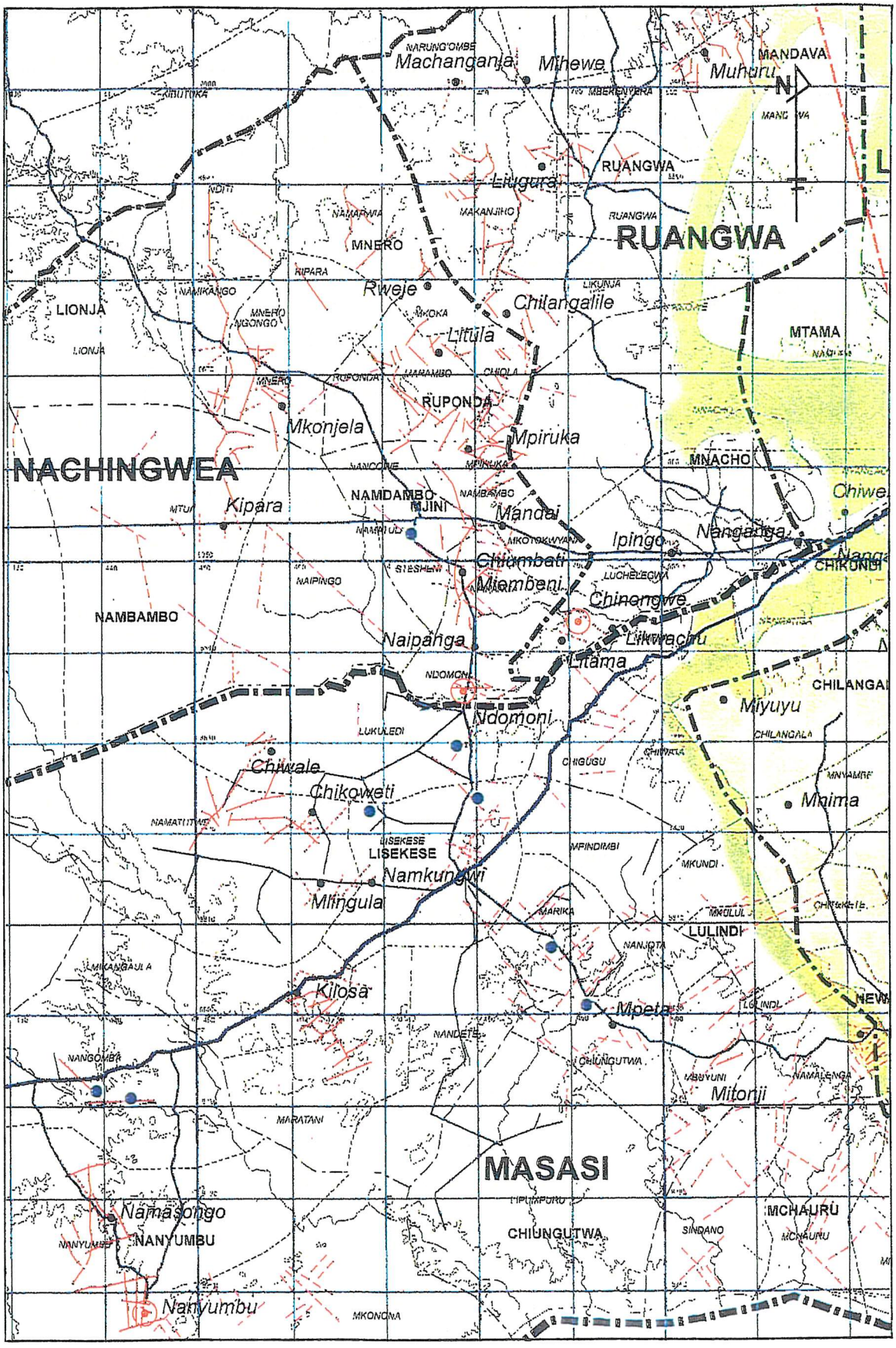

Figure 5-2 Lineaments of Basement Rock Area

5.2.2 Geophysical Survey

Electrical resistivity sounding by use of equally spaced 4-electrode method (vertical sounding method) was applied at the villages in the sedimentary rock areas, and the combination of resistivity sounding and profiling method (horizontal resistivity survey method) across the interpreted photo-lineament were used in the basement rock areas.

In vertical sounding method for differentiation of the formations by depth, attention was paid to comparatively higher resistivity layers, which designate higher porosity layers of probable aquifer like sandy or gravelly formation or sandstone and/or limestone beds. The layers of very low resistivity designate the low transmissivity beds like silt, clay, mudstone or shale, which cannot be the aquifer. The depths of the wells to be drilled were determined in accordance with the depths to the higher resistivity.

At the areas close to the coastal line, the curves showing the relation of resistivity-depth occasionally appear too steep an inclination, which does not allow analysis of resistivity value of the layers by depth. This is caused by extremely low resistivity value of seawater, which means that the area is contaminated by seawater intrusion. In this case, groundwater development by deep well construction is quite difficult. Depth of the wells in such area should be shallower than the level of seawater.

In the basement rock areas where the resistivity profiling method was applied, attention was paid at the anomaly of comparatively lower resistivity. Whereas the resistivity value are usually very high in the fresh and compact basement rocks, the points of lower resistivity anomaly suggests the higher porosity and/or higher transmissivity portion of the basement rocks, namely the fissured zones.

The most promising point and/or the best and 2nd best points for well drilling at each village are shown on the plain map of the individual village and its surroundings, that are attached in the Supporting Report.

5.2.3 Test Drilling and Pumping Tests

The sites for test-drilling were determined at the areas which represented the following geological formations in order to understand the condition of the aquifer distribution and the depth to the aquifer in the sedimentary formation, and to confirm whether the found fissure-zone has water or not; (JM1-5 and JL1-5 are the serial number of test borehole in Mtwara and Lindi regions, respectively)

JM-1 (Ziwani), JL-3 (Pande Plot): aquifer distribution in alluvium,

JM-2 (Mbawala), JM-3 (Arusha Chini), JM-4 (Litehu), JL-1 (Mnolela), JL-2 (Kilangala): aquifer condition in Tertiary and Mesozoic layer.

JM-5 (Nanyumbu): aquifer in fissure zone (with clear lineament of north-south)

JL-4 Ndomoni): aquifer in fissure zone (with clear lineament of east-west)

JL-5 (Chinongwe): aquifer in fissure zone (with weak lineament of southeast-northwest)

The result of these test drilling and pumping test is summarized in Table 5-3.

Table 5-2 Summary of Drilling and Pumping Test

Region	Well No.	Village Name (elevation) District	Drilled Depth (GL -m)	Screen Depth (GL -m)	Static Water Level (GL -m)	Dynamic Water Level (GL -m)	Drawdown (GL -m)	Discharge (m3/h)	Specific Capacity (m3/h/m)	Aquifer (Sequence GL-m)
MTWARA	JM-1	**Ziwani** (60m) Mtwara Rural	68.00	64.07	40.60	43.22	2.42	27.00	11.16	medium sand (20 - 24) fine - medium sand (44 - 56)
	JM-2	**Mbawala** (150m) Mtwara Rural	120.00	118.80	112.00	-	-	-		Discharge amout is very small
	JM-3	**Arusha Chini** (40m) Mtwara Rural	84.00	80.40	40.21	52.30	12.09	25.00	2.07	medium sand (24 - 42) fine - medium sand (52 - 76)
	JM-4	**Litehu** (350m) Tandahimba	142.50	142.00	-	-	-	-		Dry Hole
	JM-5	**Nanyumbu** (300m) Masasi	80.00	67.65	4.76	57.98	53.22	6.00	0.11	weathered gneiss (43.5 - 58.5)
LINDI	JL-1	**Mnolela** (160m) Lindi Rural	131.00	129.84	65.73	87.23	21.50	0.50	0.02	shale and sandsrone (118 - 131)
	JL-2	**Kilangala** (115m) Lindi Rural	132.00	94.50	+ 0.5 (Artesian)	58.50	58.00	3.90	0.07	limestone (120 - 132)
	JL-3	**Pande Plot** (30m) Kilwa	78.00	71.90	28.00	32.60	4.60	31.70	6.89	medium sand (48 - 62)
	JL-4	**Ndomoni** (310m) Nachingwea	76.50	-	-	-	-	-		abondoned due to high conductivity
	JL-5	**Chinongwe** (290m) Ruangwa	62.00		6.80	54.80	48.00	3.20	0.07	weathered gneiss (25.50 - 46.50)

5.3 Problem Villages for Groundwater Development

As one of the findings through above mentioned study and the water quality analysis, some problems have been pointed out. Special attention should be paid to the following villages at the further study or at the implementation of the full-scale project:

a. As previously anticipated, the groundwater development at the villages located in the basement rock area involves the risk regarding whether the drilling certainly hits water or not. Although the most promising site are pointed for each candidate village in this study program, trial-and-error in drilling must be inevitable. The ratio of successful well in terms of quantity will fall within a rage of 65-70% at 49 villages.

b. Development of good quality water is presumed difficult at the villages distributed in the Lukuledi River basin even though test drilling at Chinongwe luckily hit fresh water Those villages are 14; **Nanganga, Chikoweti** in Mtwara region, and **Somanga, Ndumbo, Lihimalyoao, Namakongoro, Nanganga, Chilangalile, Machanganja, Mihewe, Litama, Mkonjela, Rweje, Kipara Mtua** in Lindi region. Twice or thrice re-drilling will be common in many of above-mentioned villages, resulting to a very low successful rate of 30% in terms of both quantity and quality. Thus, this low rate may draw down the average success rate in the basement rock area to more or less 57%.

c. There are 14 villages where the water level in the well is presumed very low (lower than 150 m). Those are the villages of **Kitama, Mabeti, Nanjanga, Mkuti, Mnanje, Kilidu, Mnima, Namangudu, Likwaya, Mmulunga, Mdimba, Chiwonga,** and **Malatu** in Mtwara region all situated on Makonde plateau. The artesian (confined) aquifer may be hit by over 300m drilling at more or less half of the 14 villages. At the remaining half of the villages, however, the operation cost of pumping may be considerably high, so that the autonomous O/M seems difficult. The two alternative plans are suggested for those villages; one is connection of 2 or 3 villages from the available water source, but since the further studies are required for this plan, the implementation will be postponed to the 2nd phase of the project. Another is the replacement of the candidate village. In case that the drilling never hits the artesian aquifer, other villages of lower location shall replace this village.

5.4 Groundwater Development Potential by Area

The groundwater development potential is limited to the fractured zone and the deep weathered portion in the basement rocks and Karoo Formation (vicinity of the Makonde and Rondo Plateau). Some borehole data show existence of artesian wells and the wells with shallower static water level than 40 m below ground surface. However, productive wells are few in the area because most of the wells are not properly located. Since Masasi, Nachingwea and Liwale districts are situated in the difficult areas, a careful survey is required to distinguish the comparatively higher potential zones in these districts.

An aquifer of the porous sandstone beds occurs in the Coastal Sediment area, which extends across Newala, Tandahinba, Mtwara Rural district in Mtwara region and Lindi Rural, Kilwa and a part of Ruangwa district in Lindi region. Although aquifer expansion and depths are different by place-to-place, groundwater potential is generally quite high in these areas. Also, since artesian levels are usually shallow from the ground surface at the low-lying river valleys and coasts, the shallow borehole often hit confined aquifer resulting to the self-flowing wells. Therefore, these areas are not only high potential area but also the areas of economic exploitation of groundwater.

On the other hand, at the highly elevated areas of Makonde and Rondo Plateau has deeper static water level. Although groundwater development potential is not low at these areas, exploitation of groundwater is expensive, consequently, groundwater development potential apparently seems low in the southern area of Newala and Tandahimba districts, and at the boundary of Lindi and Ruangwa districts. These areas contain possible shallow aquifer in the weathered surface portion (shallower than 10-20m from ground surface). Dug wells are common on the Plateau. However, water level fluctuates, and the wells are often exposed to the contamination from intrusion of dirty surface water. Therefore, development of deep groundwater must be done in spite of “not economic exploitation” categorization.

In the basement rock areas, the high potential area is limited to the portion of the lineament structures that indicate fissuring. It must be mentioned, however, that the fissures that produce non-potable water are not the high potential zones.

The groundwater development potential in the study area is presented in Fig. 5-3.

This figure presents high potential area in terms of economic groundwater development in the sedimentary formations, and high potential zones in the basement rock areas without differentiation of good or bad quality of fissure water.

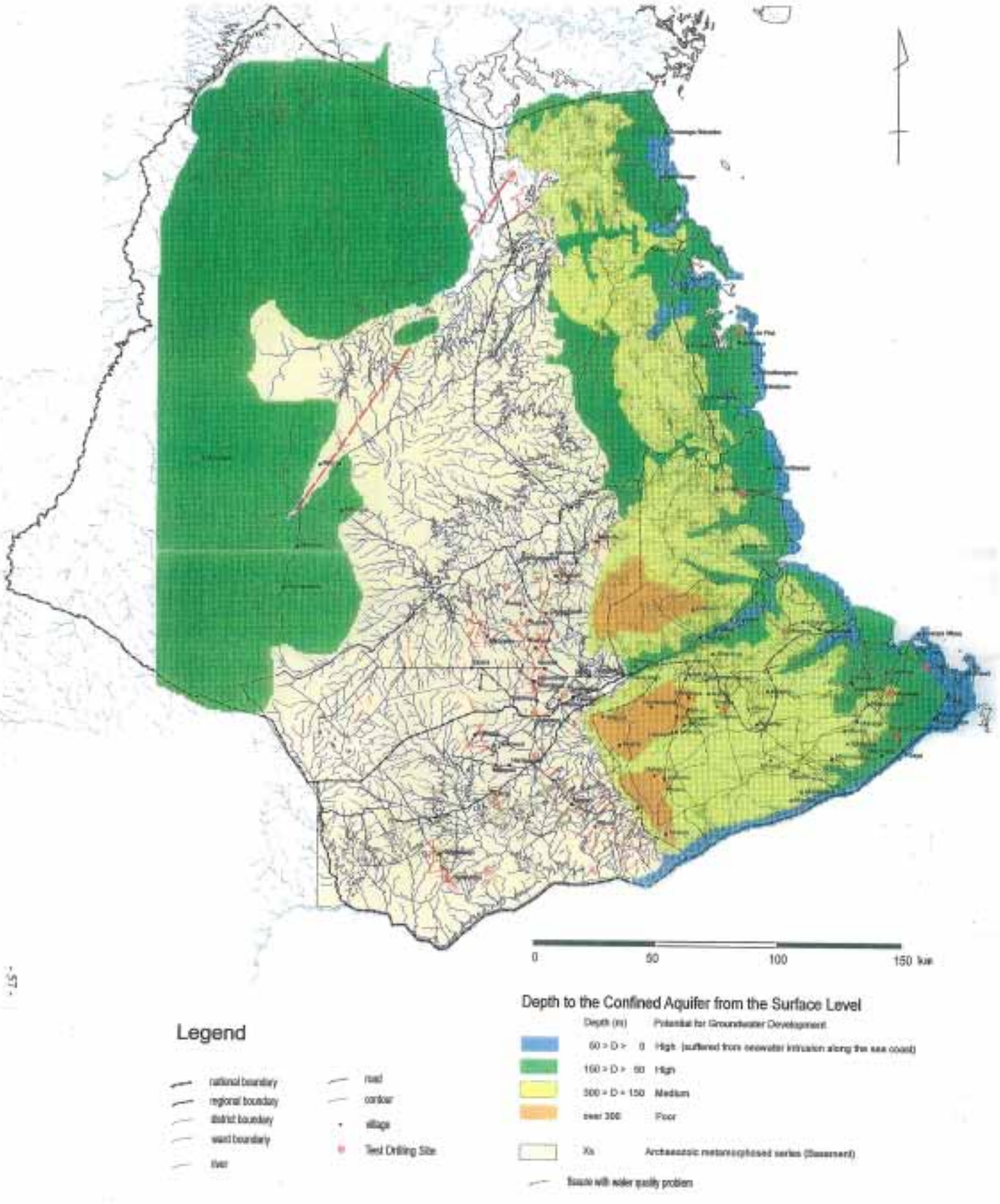

Figure 5-3 Depth of the Confined Aquifer and Potential Fissures