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NATURAL INDICATORS OF SHALLOW GROUND WATER IN KIBWEZI DIVISION, KENYA

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ABSTRACT

Human ability to locate sources of ground water using natural indicators is a skill developed from experience which improves with use. This ability, essential in many environments for survival, has to be nurtured. This paper describes the use of natural indicators to detect ground water in Kibwezi Division, Kenya. These skills have been developed and adapted during the period of recent settlement of the area in the early 1970s. The local people have become self-reliant in siting wells with a success rate of 70% in part of the area. The purpose of this paper is to record these methods before they become redundant, replaced or forgotten. Already the reduction of natural tree cover in Kibwezi has reduced the variety of signs available.

INTRODUCTION

Kibwezi Division, situated some 200 km south east of Nairobi (Fig. 1) has erratic rainfall averaging 644 mm per year. The Division covers an area of 8000 km^2 and experiences droughts during both rainy seasons in 60% of years (Fenner, 1982a). In the past, the area was covered with tangled scrub such as *Acacia mellifera* (Vahl) Benth. and was home for a wide variety of game. Maasai passed through the area and the Akamba people hunted there, although few made permanent settlements in the area in the last century.

In 1891 the Lovedale Mission was established in Kibwezi near to the present site of the railway station. Due to an earth tremor in 1896 (Younge, 1977) the Kibwezi river, then the main source of water, increased its flow. The Mtito Andei river and the Masongaleni river were also important sources of water in the area and consequently were stop-over points for Arab and Akamba traders. Mackinnon's road reached Kibwezi in 1895, from where Sclater's road began as the continuation towards Uganda.

With the establishment of a road through the area, enterprising persons ventured into the inhospitable environment and attempted to grow rubber, to harvest *Sansevieria* and, more successfully, to grow sisal. This all required permanent sources of water, both for agriculture and human consumption. The most reliable and readily available sources were the rivers. Undoubtedly wells were dug at prime sites not far from the visible surface water sources.

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The railway line was built soon after the road and water sources for the steam engines, initially railed to the stations, were secured. A number of stations to the east of Kibwezi were supplied via a pipeline from Umani spring in the nearby Chyulu Hills. The water from this pipeline still supports a considerable number of inhabitants. In 1918 a second major earth tremor reduced the flow of the Masongaleni river considerably, but it was partially restored in the 1930s. It became obvious that without adequate ground water any development in the area would have to depend totally on the rains or the rivers, of which only the Kibwezi appeared reliable, and of good quality. There was therefore considerable incentive to investigate ground water resources.

The geological knowledge of the area was based on an early speculative, but perceptive, report (Brantwood Muff, 1908). It was not until 1954 that a more thorough investigation was carried out in a study which established the basis for the present-day understanding of the hydrogeology of the area (Temperley, 1955). The colonial administration was active during the 1930s drilling boreholes, as was the Kenya Sisal Company at Dwa farm. A more recent study has served to quantify the system suggested by Temperley (British Geological Survey *et al.*, 1988).

The Chyulu Hills, which form the southern boundary of the Division, rise 900 metres above the surrounding country. Benefiting from an average annual rainfall above 1200 mm, they form the focal point of hydrogeological studies. The Chyulu Hills are of recent volcanic origin and as a result of their high porosity there is no rainwater run off. The rainwater percolates down into the lava and meets an Archaean basement of the Kasigau and Kurase series. Water flows east on top of the basement to emerge at Mzima Springs, the source of Mombasa's water supply. Temperley (1955) estimated that 80% of the rainfall on the Chyulus reappears at Mzima Springs and that the remaining 20% feeds the springs of the local rivers, showing that very little Chyulu water is recharging local aquifers.

The basement system emerges from under the Chyulu lava and gives rise to the flat, red landscape characteristic of the area. Along the edge of the lava there exists a mosaic of gneisses which are poor but useable aquifers. It is these aquifers which are now being tapped by local people. Significant numbers of people began to settle in Kibwezi with the immigration of Akamba in the late 1960s, the previous restrictions on settlement now only applying to the Chyulu Hills. The availability of drinking water became a priority and the Government and non governmental organisations began to develop water resources in the area. With a present population of about 180,000 people a great demand for water exists. In a 1985 survey, the average distance people travelled to a water source was 4.4 km, the average amount of water obtained was eight litres per head per day, and a single journey took an average round-trip time of 90 minutes returning with 20 litres of water of dubious quality (Ferguson *et al.*, 1988).

Efforts are continuing in the Division to improve the water-supply situation via pipeline schemes, rainwater harvesting, boreholes and shallow wells. In the case of shallow wells, this is largely a community-based activity. The local people organize themselves into well groups, select a suitable site to dig and seek assistance with construction from agencies active in the area.

Well-site selection using geophysical equipment has not been particularly successful in the past (Temperley, 1965) largely because no alternatives to resistivity techniques were available in Kenya. Well groups usually have only their own resources to call upon when siting a new well and consequently do not have the option of an elaborate geophysical survey. As a result, they have used natural indicators to help them. As the population of the Division increases and more land is cleared for farming, indicator trees, in particular, are becoming scarce. At the same time, advances have been made in geophysical techniques which are enabling cheaper and more accurate well siting to be done. The use of natural indicators may well become redundant.

METHODS

Over a six-year period the author became familiar with the current state of scientific knowledge of water resources in the Kibwezi area. Local knowledge was gathered informally through discussions with local Well group members and leaders. The African Medical and Research Foundation (AMREF) has held annual training workshops for groups constructing wells. There are now over 80 such groups. The workshops were a valuable forum for the exchange of local knowledge and served to consolidate the information gained through discussion. In particular, the close association between AMREF field staff and the Well groups they have assisted has led to a deeper insight into local methods for well siting.

RESULTS

There is increasing reliance upon machines to assist in locating ground water. In Zimbabwe in 1987, when using integrated geophysical techniques, a success rate of 90% was obtained for boreholes. When sites were allocated "logistically" the success rate was 50% (White, 1987). These interpretations still require human judgement to be made, whether computer assisted or not.

In cases where people do not have access to modern technologies, they can only hope to use their own judgement to interpret their senses to find ground water. In Kibwezi a success rate of 70% has been obtained for siting wells in areas where natural indicators exist. The community is not reliant upon outside technical expertise and is in a position to continue unaided to find well sites.

Where no alternatives exist there is little need to argue the merits of such an approach and the methods should only be judged by their success. Since the exploitation of ground water is essential to sustain human life, it would be expected that our senses do give indications of the location of ground water.

Natural indicators of ground water in Kibwezi

The indicators identified in Kibwezi may not be suitable for use in other areas. In fact in Kibwezi itself the indicators are not ubiquitous. The people of Kibwezi are currently making accurate identifications of the indicators discussed below, and this is reflected in the fact that many of the indicators have specific local names. Good knowledge of the environment has always been important for survival in Kibwezi, a fact still evident as well groups continue to develop their skills in locating ground water. For reasons of clarity the indicators are here put into six groups.

Topography

The flat topography of Kibwezi is punctuated only by resistant inliers and seasonal river channels. The more resistant basement geology has formed the watersheds of the area. The land drains north into the Athi river. As there is no run off from the Chyulu Hills, seasonal rivers rise where the lava ends, which having eroded lines of least resistance have preferentially cut into the softer gneisses, thus indicating their location. The gneisses to the east of the main road are less permeable and therefore poorer aquifers.

The lack of definitive indicators of ground water on the Chyulu lava meant that Well groups applied their efforts away from the lava belt and initially concentrated on the larger seasonal river beds. The edges of lava flows are easily recognizable as they are several metres thick, end abruptly and have very little soil cover. The lava is black, often set against a red soil, and supports green vegetation for much of the year. The most productive wells are located in river basins generally not more than 2 km from the edge of the lava flow. Typical yieids from these wells of depths between 6.5 and 7.5 metres are above 3^3 m per day.

Without exception, the Well groups chose to dig in low-lying places, locating their wells in areas of softer gneiss rock and away from the basement watersheds. As more wells were dug, the people quickly realized that the closer they were to the watersheds the deeper they would have to dig, and there was the increased likelihood of a low yield. As experience grew, initial siting of wells began with a general survey to recognize the location of watersheds. Generally, the drainage channels are well defined and there was little difficulty in excluding potential basement sites and the watersheds as they bear different soils and vegetation.

Some confusion occurs where seasonal water sources exist at the edge of basement outcrops. These sites have, without exception, failed to provide permanent water. Such sources are probably fed from local rainfall recharge on the outcrops, the water being stored in cracks. The storage volume is low and likely to be subject to evaporation losses.

There are a number of old earth dams in the area which were explored as potential well sites. The dams generally only store water until September and are thus useful but inadequate during the dry season. As the dams dry out people make shallow excavations in the dam floors and along the walls thus gaining accurate information about the location of water. Frequently, groups went on to dig wells downstream of the dam walls. Presumably, the dams leak from the floor thus recharging a small area of local aquifer. Digging at the sides and upstream of the dams has so far proved unsuccessful.

As most of the wells are dug along river channels, flood damage is a risk. Initially this risk was not a consideration in siting a well and certainly previous experience with shallow holes in river beds had resigned their users to the inevitable annual chore of re-excavation. With the location of good wells outside the channels, better practice quickly caught on. Sites could still be improved by a more thorough consideration of flood levels, easily done by checking for past flood debris caught up in riverine trees. Similarly, wells could also be better sited after consideration of the erosion patterns of the river — wells dug on the inside of meanders are less likely to be damaged in the future.

Changing patterns of land use are also increasing the run off carried by seasonal rivers. Land clearance for farming, resulting in less retention of rain water, is extending the drainage systems. It is now quite common to see drainage channels which have encroached upon sites of previously stable vegetation. Well groups should be particularly wary when they choose to dig a well near a river where there are mature trees being undercut in the middle of the channel; this is clear sign of rapidly increasing erosion.

Geology

The Kibwezi area can be divided into two distinct geological regions, the area underlain by basement system gneisses, and the volcanic region to the south of the railway (Saggerson, 1963). (Fig. 2)

There are three main classes of rock of interest to potential well groups: lava, gneiss and undifferentiated basement rocks. These rocks have specific names in the Kamba language of Kibwezi; they are, respectively; *kivuthi*, *ingee* and *nganza*.

Being agriculturalists, the Akamba who moved into Kibwezi were well aware of the potential of the various soil types encountered and had a good knowledge of the rock types in the area. Although this knowledge is more general than specific, it was quickly applied in the search for ground water. Experience gained from successful wells has enhanced common knowledge and soils and geology are now included amongst the natural indicators of ground water in common use.

The siting of wells on lava is a very difficult task for which there is little local expertise. Suitable geophysical techniques have yet to be found, although some very productive wells have been dug in lava flows. Being a haphazard process, few groups are willing to risk wasting their energies and resources digging in lava. It is important, however, to establish where a lava-flow ends when siting a new well. In following the courses of old rivers, which cut preferentially into the softer gneisses, lava flow boundaries point towards the location of suitable digging sites. The soils found near the edge of a lava flow are a hybrid between black cotton soil and red laterite soil. These soils are rarely deeper than five metres and the gneiss aquifers are found beneath them .

At the edge of the lava flow, where water may seep into gneisses from local recharge, many of the tree species which are indicators of water may be seen.

When river channels arise at the end of a lava flow, exposures of limestone may be seen. These were laid down in places where water collected over a long period of time, presumably showing historic drainage systems which cut into softer rock. They indicate suitable sites for well digging. Goats are quick to identify these outcrops and use them as salt licks.

River channels which expose geology are surveyed by local Well groups. They look for the darker biotite-rich gneisses which are more productive aquifers. It is rare to find a homogeneous gneiss more than four metres thick. The gneiss hardens off and becomes less productive at depth until it is impossible to dig by hand. When banded with schists it can still be productive at depths of up to 26 metres. Due to the very mixed nature of these metamorphic rocks, local knowledge has not yet developed to the point at which accurate determination of possible well depth can be made from surface geological information alone. Once digging has begun, and the gneiss reached, its colour and hardness are interpreted to give a reasonably accurate prediction of the depth at which water may be found.

In some cases, bars of gneiss can be seen cutting across river channels where they form good sites for sand dams. As these bars may have cut through productive gneiss, they help retain water in the buried gneiss. Wells have been successful downstream of these bars where presumably leakage is occurring and the bars are acting as sub-surface dams. Such areas are frequently explored as seasonal water holes by the local people.

Undifferentiated basement outcrops forming inliers are not good sites for well construction. The soils in the vicinity of the outcrops are sandy, reddish and often contain large quartz fragments. Such soils are good negative indicators of water presence even when rock does not outcrop.

On the eastern side of the main Mombasa road, the river channels are considerably larger; some have almost permanent baseflows which are held in the sandy river beds. The sands found in these locations are good for construction work and can be over 12 metres deep. Some productive wells have been sunk into these sands using concrete rings. Caution is needed in such places since not only are flash floods a major hazard but also the performance of the proposed well in the dry season must first be established.

There are good murrams beneath the topsoil on the eastern side of the road. When people have dug pits for latrines here they have found that water has entered. These stony murram layers are usually not thicker than one metre, thus their storage capacity is small. So far a permanent dry-season source of water has not been found from these murrams.

There are some clays and soils in the area which act as impermeable layers preventing rainwater from percolating downwards. Water is often taken from these clay pan areas, but the pans are heavily influenced by evapotranspiration and rarely remain wet throughout the dry season.

As more experience is gained from wells that have been dug, the richer the understanding of the relationship between geology and ground water becomes. Obviously local knowledge of geology will not develop to a specialist level, nonetheless the present basic understanding is a significant contribution to well siting.

Trees

Table 1 gives the English, Kamba, Swahili and scientific names of trees found in the area.

Longland (1952) refers to "*Mkuju*", (*Ficus sur* Forsk.) together with *Acacia tortilis* (Forsk.) as indicators of ground water in Tanzania. The use of trees as indicators of ground water is a very old practice, however, the usefulness of some species is probably only applicable to certain areas. For example, Longland's (1952) observation that ground water is found at a depth of three times the height of the crown of *A. tortilis* has not been shown to be the case in Kibwezi. It is important to realize that trees may be associated with a certain soil type and environment and not directly with the ground water table itself.

A good general description of the woodland of Kibwezi is given in Fenner (1982a).

The Kamba people were new to this area in the 1970s but knew most of the trees they came across. The names used locally for trees are not all of Kamba origin; many are similar to Taita names. Presumably these names were imported by the Akamba settlers. They had never needed to look at these trees in relation to ground water in this area before; rather they had to learn from experience.

As the number of successful wells has increased, it has been possible to compare local tree cover with the degree of success. As a consequence, confidence and reliability have increased and now, once a general site has been selected, the tree species present are used as the principal indicator of the exact site to dig.

The most successful tree indicator of good-quality ground water at shallow depth so far identified is *Acacia robusta*. (Taub.) Brenn (Figs. 3, 4) Where this tree is found and supported by topographical indicators, ground water of salinity below 1500 µS[1] can be obtained at depths of less than ten metres. The appearance of *A. robusta* can differ greatly depending upon its environment, and the anatomy of its non-reproductive parts is diverse.

Acacia gerrardii (Benth.), *Acacia xanthophloea* (Benth.), and *F. sur* are all useful indicators of ground water at shallow depth and their presence in conjunction with *A. robusta* confirms a good site.

Hyphaene compressa Gaeren is a very good ground water indicator but it is only found in Mangalete Sub-location of Kibwezi. Where present, water can be obtained at depths of less than seven metres.

Grewia bicolor (Juss.) is frequently used as a forked stick by dowsers[3]. Even though found near river valleys, its presence has not been associated with ground water.

Table 1. Botanical names

Generic/specific names	English	Kikamba	Kiswahili
Acacia gerrardii (Benth.)	Gerrards acacia	*Muthithiu*	-
Acacia mellifera (Vahl) Benth	Hook-thorn	*Muthia*	*Kikwata*
Acacia robusta (Taub.) Brenan		*Munina*	-
Acacia tortilis (Forsk.) Hayne	Umbrella thorn	*Mulaa, Kilaa*	*Mgunga*
Acacia xanthophloea (Benth.)	Fever tree	*Mulela*	*Mukonge*
Cyperus papyrus L.	Papyrus	*Ndoi*	*Ndago mwitu*
Ficus sur (Forsk.)	Cape fig	*Mukuyu*	*Mkuyu*
Grewia bicolor (Juss.)		*Mulawa*	*Mkone*
Hyphaene compressa (Gaeren)	Doum palm	*Malala*	*Mkoma*
Newtonia hildebrandtii. (Vatke) Torre		*Mukami*	
Sansevieria. spp.	Bowstring hemp		*Mkonge*
Sphaeranthus cyathuloides. O. Hoffm.		*Musonzouwa*	
Sterculia rhynchocarpa (K. Sch.)		*Kyusia*	

[1]µS or microsiemen is a unit of the electrical conductivity of water and is proportional to its salinity.
[3]water diviner

Some tree species have also been found to be useful negative indicators of ground water thus enabling an area to be excluded from a survey. *Acacia mellifera* (Vahl) Benth. and *Sterculia rhynchocarpa* (K. Sch.) generally exist where there is very little chance of finding shallow water. Thus, by elimination, the margins of aquifers can be inferred. Even so, *S. rhynchocarpa* can be seen growing close to seasonal river beds. The change in tree cover above different geological systems is readily observable. *Newtonia hildebrandtii* (Vatke) is a very useful indicator of water, but due to the high value of its timber for carving and charcoal it is now rarely found in the settled areas. Mature specimens of *N. hildebrandtii* can be seen near to the springs and dams protected on Dwa sisal estate.

A rough estimate of the number of wells in Kibwezi with tree indicators in their immediate vicinity is 30%. As more land is cleared for agriculture it can be expected that in the not too distant future the natural tree cover of the area will have been removed.

Herbaceous plants

No herbaceous plants have been recognized in Kibwezi as reliable ground water indicators. Those which were considered were mainly wet-area plants and included marsh grasses, rushes and *Cyperus papyrus* L. and *Sphaeranthus cyathuloides* (O. Hoffm.) which can be found near most of the wells in the rainy season. The latter species appears to enjoy the moist freshwater environment resulting from retained run-off. Presumably it is for the same reasons that it is found growing near to granite inliers. Even so, *S. cyathuloides* does not thrive in areas of stagnant water and thus may indicate good quality local recharge, although this has not been confirmed by the author.

Areas which retain some green cover during the dry season are likely well sites. The obvious exception is on lava flows where moisture can be retained in pockets of black soil and support some green cover for most of the year.

Fauna

In the past, the area supported abundant wildlife and many of the earlier settlers remember places where animals could be seen drinking water. Some people insist that Elephant (*Loxodonta africana*) (Blumenbach), Warthog (*Phacochoerus aethiopicus*) (Pallas) and Zebra (*Equus* (*Hippotigris*) *burchelli*) Gray, are all able to detect shallow ground water and dig for it. Even though some people say that their wells were sited where these animals used to drink, there is little consensus of opinion as to whether this is a true relationship or not.

Bees (Hymenoptera: Apidae) are undoubtedly fond of wet areas and are very common around wells. Local bee-keepers say that bees will not occupy a hive if the nearest source of open water is more than 1.5 km away. However, bees are not regarded as a definitive indicator of ground water. It is also well known that termites do not build mounds in places which are wet. This can be seen particularly when trying to determine where spring lines exist when springs are non-emergent. The termite mound margin on the uphill side of a swampy area would normally mark the limit for attempted excavations.

Perception by the local people

There are numerous dowsers in the area and some have a good reputation having sited good wells. Many of them utilize natural indicators together with a forked stick (Fig. 5). Sticks of *G. bicolor* are commonly used. The dowsers use a simple technique. They have not been seen to make multiple passes over a specific site, but sometimes do give clients an indication of depth and yield but not of quality.

There are also a number of very poor dowsers in the area. As considerable amounts of money can be made from dowsing, this is not surprising. At some particularly poor sites a dowser may specify a considerable depth to water, through a rock which cannot be dug by hand, thus maintaining his reputation, since the depth specified can never be reached. The dowsers encountered by the author have all been men. It would be useful to study the abilities of the local dowsers in detail and to introduce them to the approaches and experiences of established dowsing societies.

At a few wells people have said that a further reason for choosing the site was a sensation of warmth or cold when walking past the site at night. This may be linked to a microclimatic effect resulting from ground water or from the fact that the site was in a low-lying enclosed area. It is not disputed that such sensations exist..

Table 2. Summary of natural indicators for detecting shallow ground water in Kibwezi

Highly likely	Near seasonal/permanent river beds. Within 2 km of the edge of the lava belt. Presence of *A. robusta, A. gerrardii, A. xanthophloea* Absence of termite mounds, *S. rhynchocarpa* and *A. mellifera*
Likely	Absence of basement outcrops. Near to a dam. Green cover in the dry season. In a low-lying area. Surface outcrops of mafic schist. Approved by a reputable dowser. Humid / cool sensation in still weather.
Poor	Presence of murram. On high ground. Near granite outcrops. Sandy/quartz soils.

Water quality

It is important, when promoting the methods mentioned, that as far as possible good-quality water is identified. This is due to the need for drinking water and because digging a well by hand is a major undertaking.

The average salinity of the wells dug so far is 1900 µS. This is high because 17% of the wells had a salinity above 3000 µS. Water is often potable up to 2500 µS, whilst international standards may be set as low as 400 µS. At present an investigation is being carried out to relate salinity to soil type and vegetation and it is apparent that the high-salinity wells are restricted to a small geographical area. It is hoped that, should a relationship be identified, then the vegetation of the "salt aquifer" areas could be used as a negative indicator to prevent people from digging where such an aquifer exists.

It is a major concern that the change in land use, which is resulting in the removal of natural bush cover, will increase evapotranspiration losses from the soil. This in turn may increase the salinity of the well water. The resultant increase in run off also represents the loss of a valuable resource as well as a threat to the stability of river morphology.

There is a considerable wealth of local knowledge and awareness of the environment in Kibwezi. This may change as land pressure increases and new technologies are introduced. In such a fragile ecosystem the inhabitants represent the most powerful force to conserve or destroy the environment. Fortunately, the people of Kibwezi have an intimate awareness of their environment and it is encouraging to see the present trend of community-based conservation strategies emerge. The harnessing of the knowledge and attitudes of people in Kibwezi could tip the balance in favour of successful conservation of the area.

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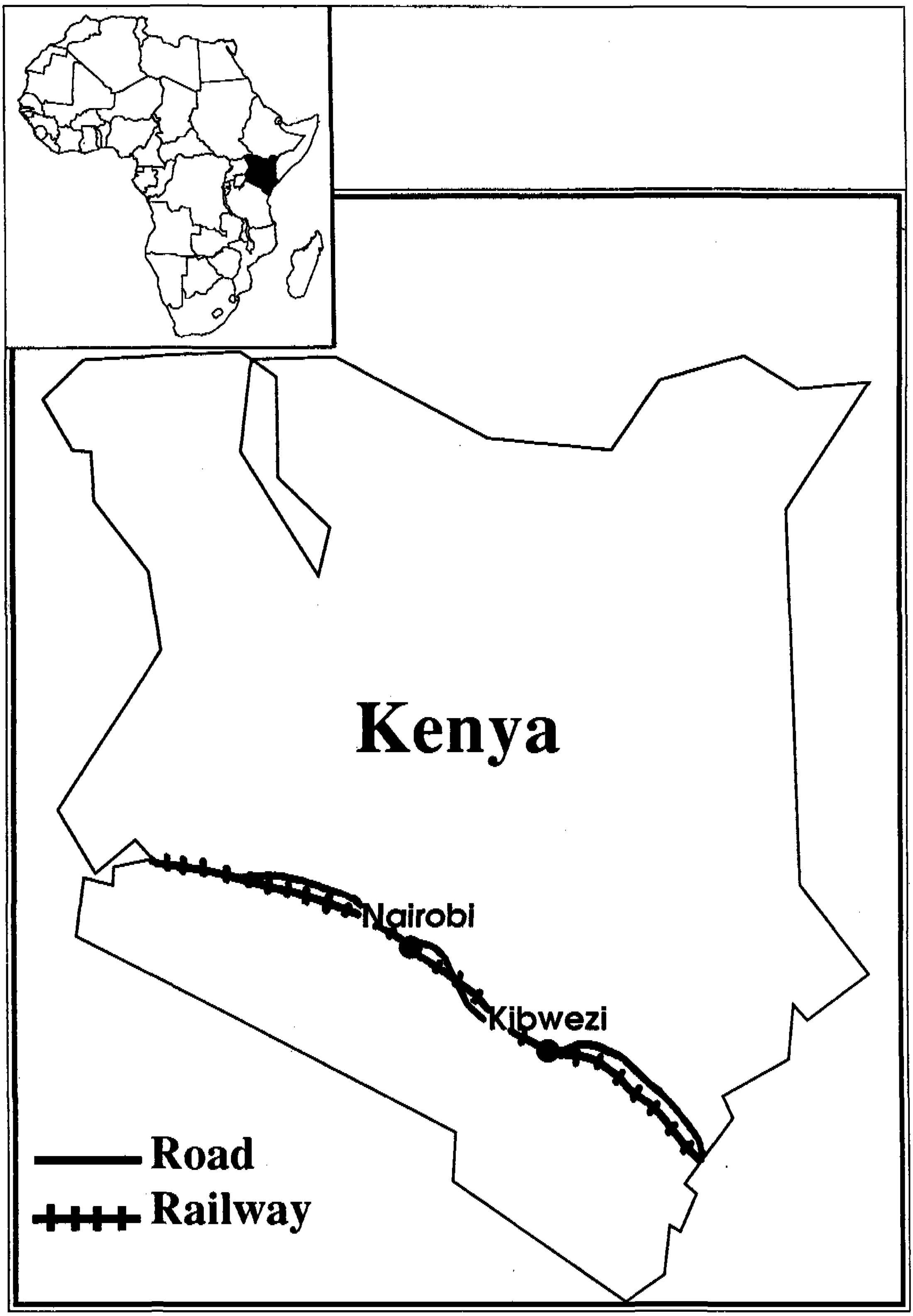

Figure 1. Map of Kenya showing location of Kibwezi

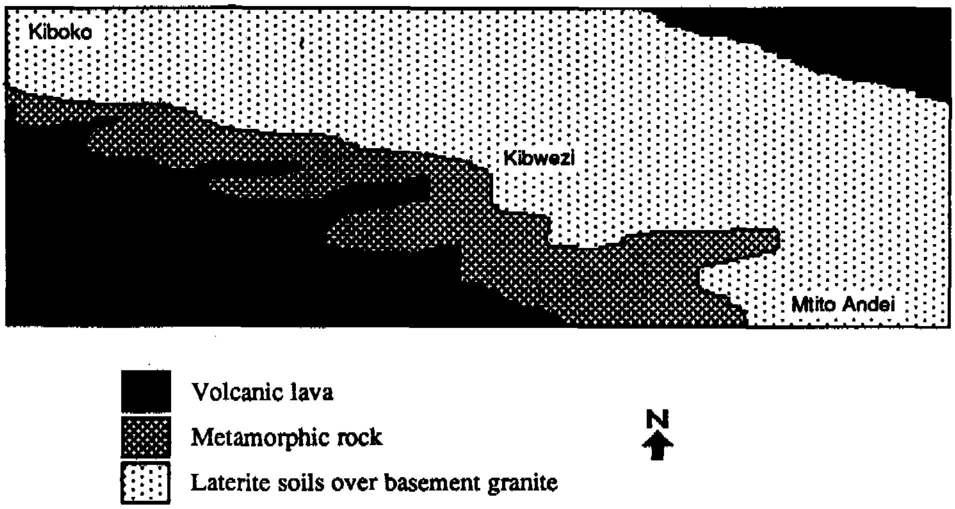

Figure 2. Geology of Kibwezi Division

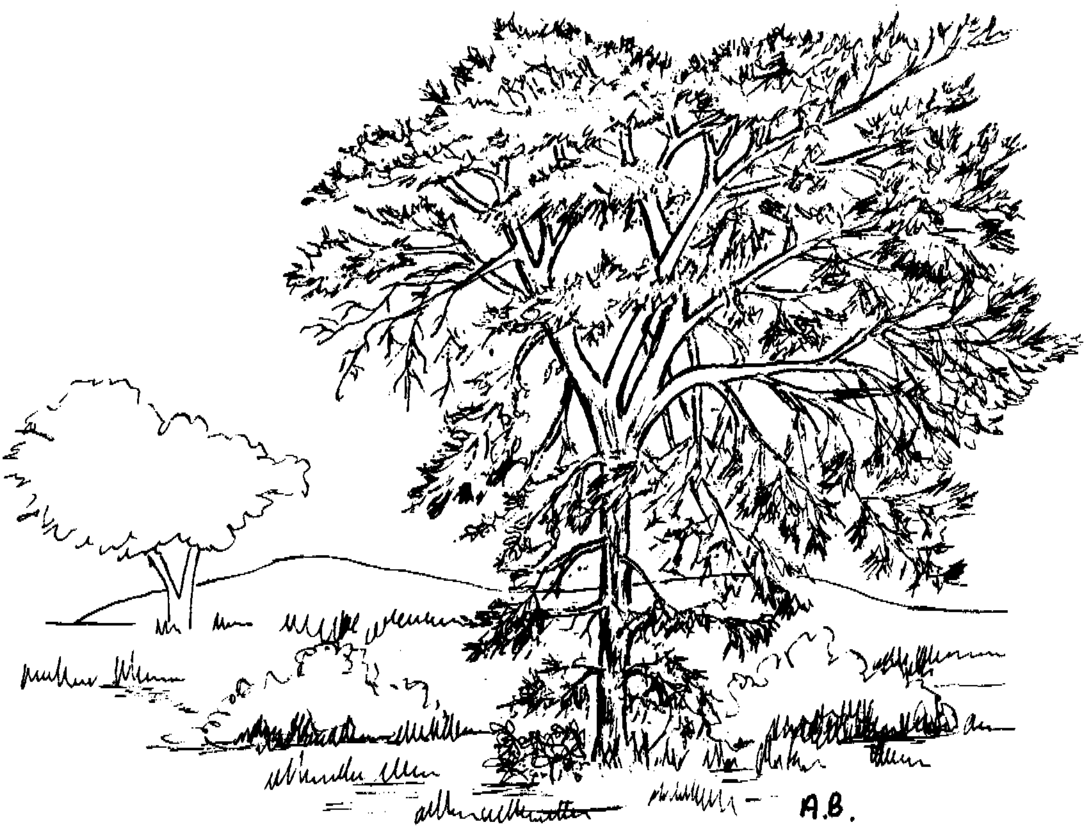

Figure 3. *Acacia robusta* mature tree

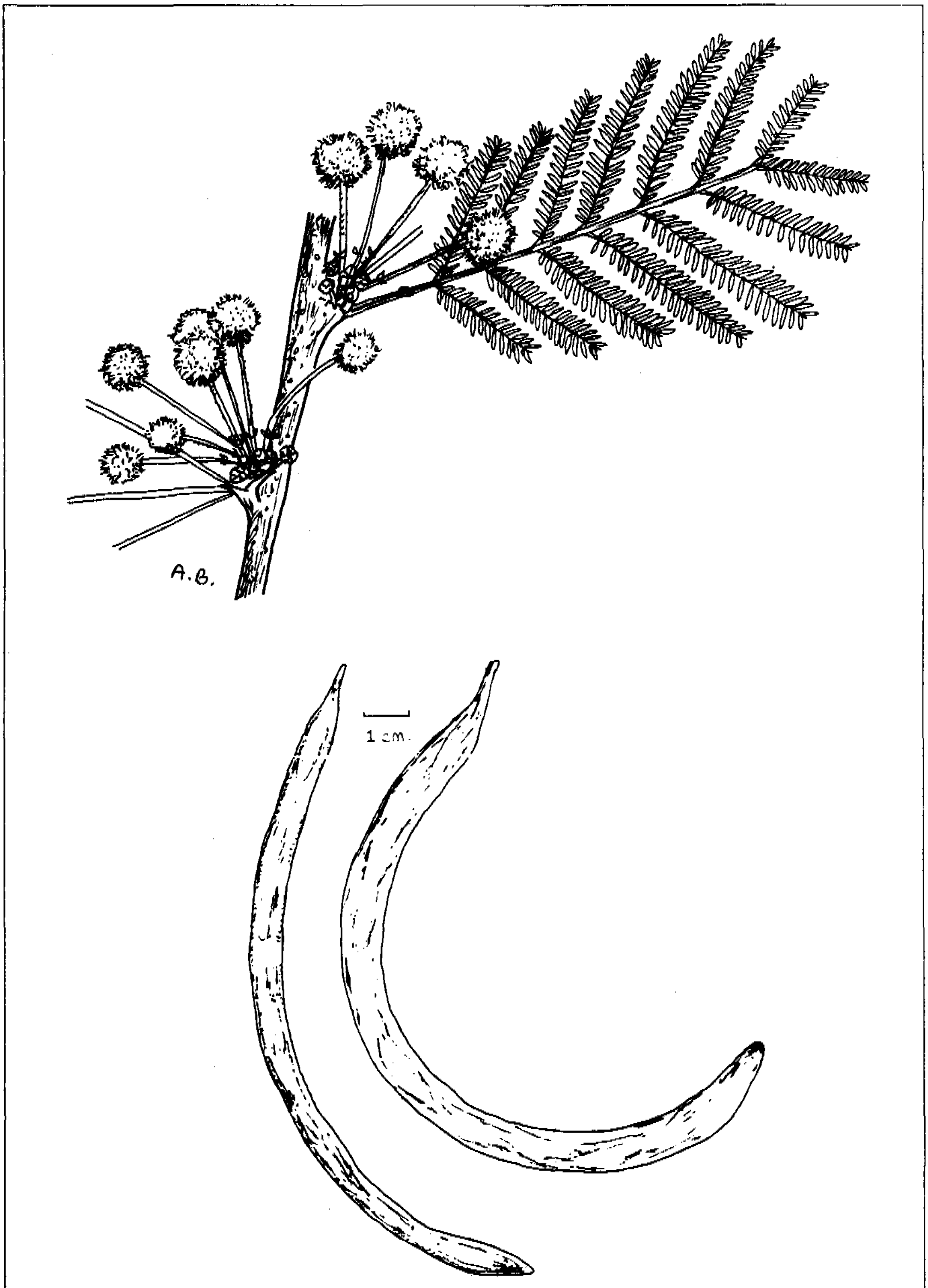

Figure 4. *Acacia robusta*: flower cluster, leaf and pod

Positive signs

Presence of *A. robusta*
A. gerrardii
A. xanthophloea
Near to a river bed
Within 2 km of lava belt

Likely signs

Near to a dam
Green cover in dry season

Negative signs

Basement outcrops
On high ground
Sandy/Quartz rich soils
Presence of *A. mellifera*

Chyulu Hills
Lava flow
Seasonal river bed
Laterite soils
Basement outcrop

Figure 5. Summary of natural indicators for detecting shallow ground water in Kibwezi

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The authority should not be given if scientific names are used to describe an "association" or species complex, e.g. *Acacia drepanolobium – Themeda triandra,* wooded grassland. Type in capitals the first letter of the English names of species (e.g. Crowned Eagle, Grey-capped Warbler) but not of the higher taxa (e.g. eagles, warblers).

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