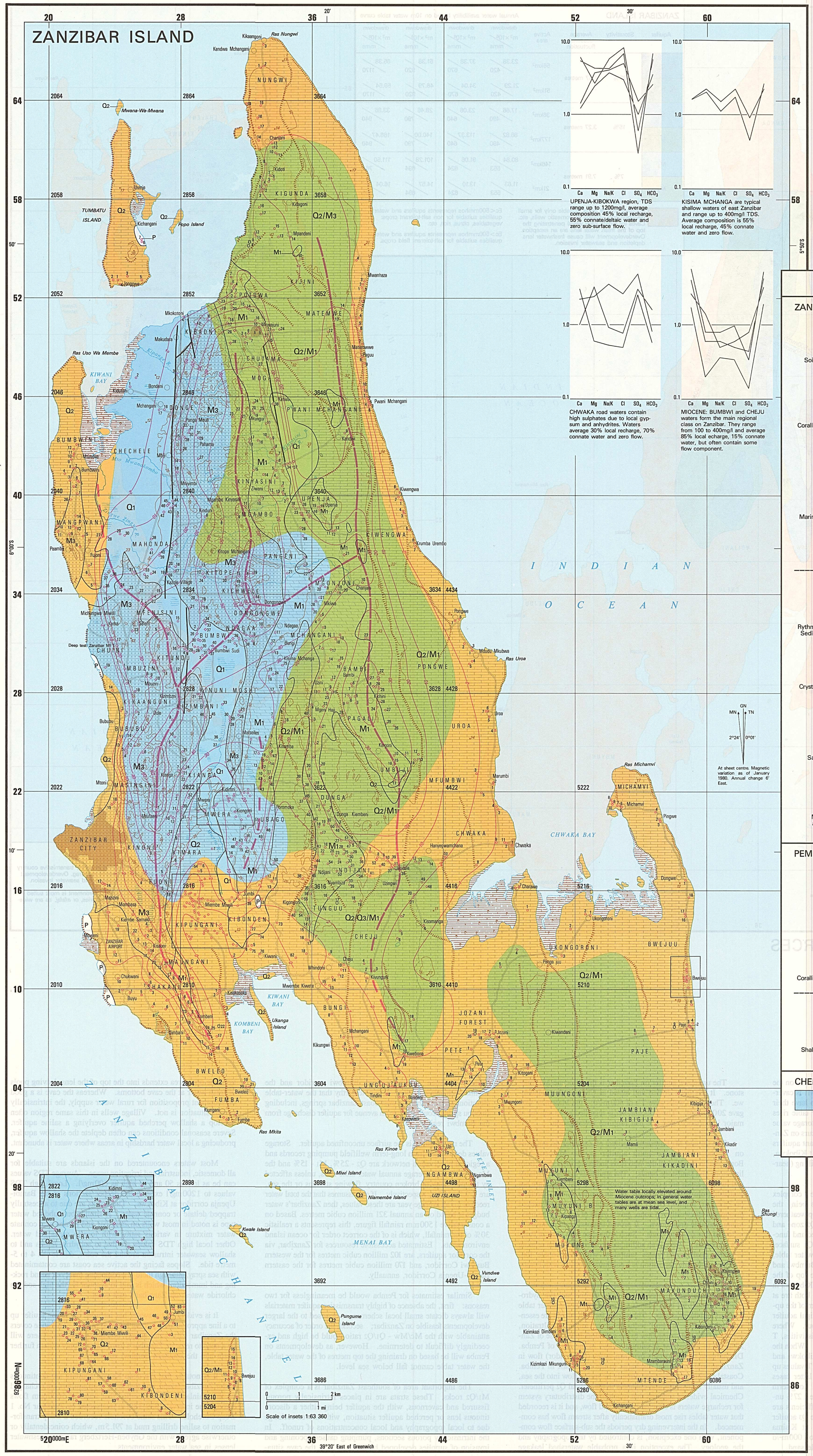
HYDROGEOLOGICAL MAP OF
ZANZIBAR

INCLUDING THE ISLANDS OF ZANZIBAR AND PEMBA
THE UNITED REPUBLIC OF TANZANIA

Scale 1:125 000

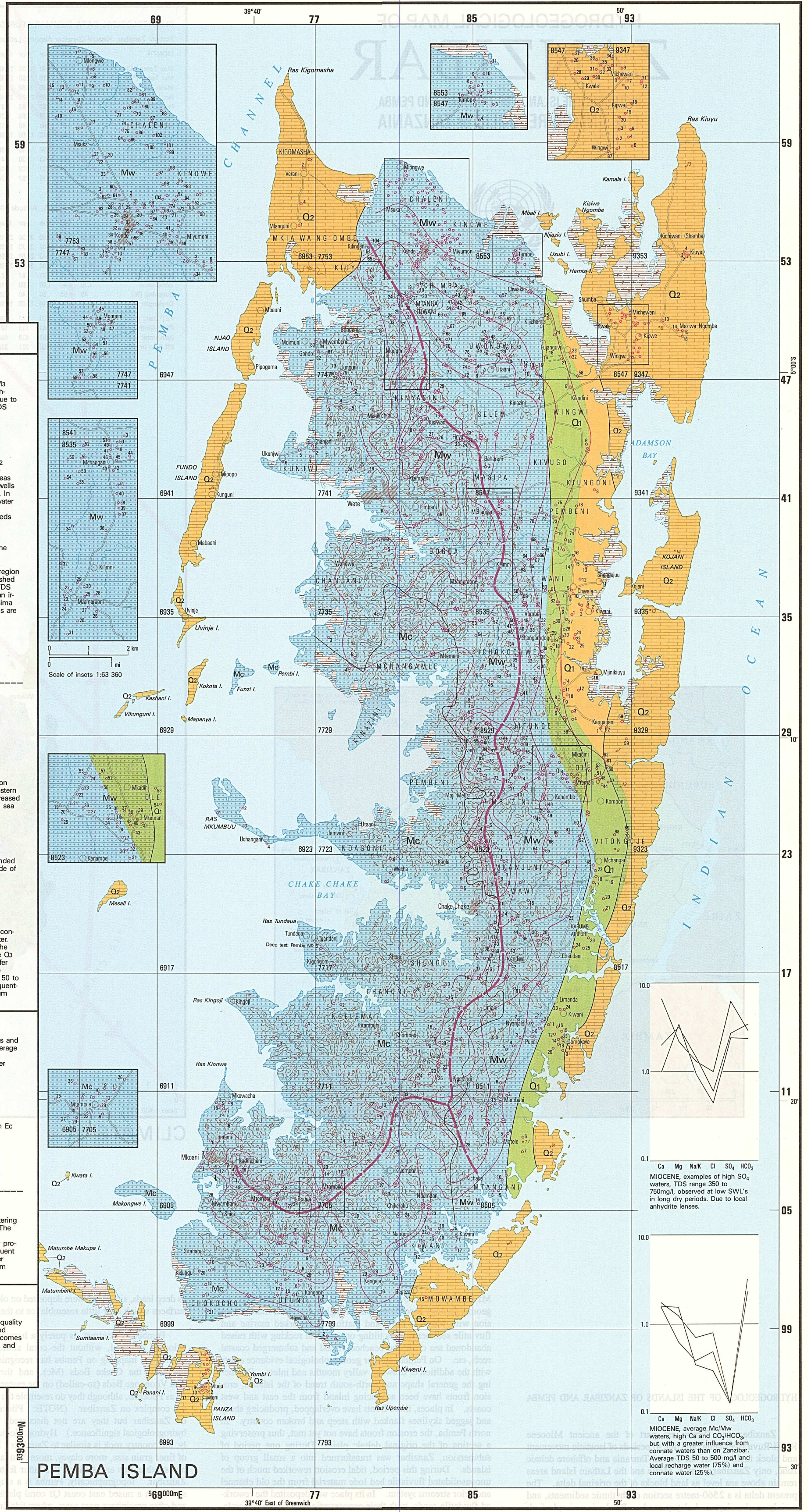
PUBLISHED BY THE UNITED NATIONS



LEGEND	GEOLOGY and LITHOLOGY	HYDROGEOLOGY	GEOHYDROLOGY	WATER QUALITY
ZANZIBAR				
QUATERNARY Q_1 Soils, Laterites, Alluvials, Colluvials.	Complex of red, chocolate, brown and black soils, thin tropical laterites, reworked Miocene sands, gravels, unsorted colluvial sands and clays, laterite and limestone fragments. Maximum thickness 25m.	The soil cover maintains a water table, but acts mainly as the confining layer to the Q_2/Q_3 aquifer complex in the corridor zones. Laterites form local aquifers and form the source for the hillside springs.	Laterites possess hydraulic continuity with the M_3 and provide a main discharge avenue for the M_3. Spring flow is related to water table elevations in the M_3.	Generally a mixture of local and M_3 connate water. Eastern facing catchments show increased chlorides due to wind blown sea spray. Average TDS ranges from 100 to 300mg/l.
QUATERNARY Q_2 Coralline and Reef Limestone	White, cream and cherty limestone, often porcellaneous; grey, rocky and jagged in outcrop. Notably free of lateritisation and iron staining. Forms as a thin veneer over the coastal platform where it is frequently cavernous and with many solution channels. Forms part of Zanzibar's corridor aquifer complex. Maximum thickness 30 to 35m.	The top 10 metres of the Q_2 limestone are weathered and coarsley honeycombed. Below the water table in the corridor zones it constitutes the island's main aquifer complex with the Q_3. In many places the Q_2 is above the water table and is not an aquifer. It is cavernous in many places in conjunction with the M_1, forming Zanzibar's many cave wells.	Above the 2 to 3m water table contour the active Q_2 water table zone covers an area of 465km². It produces well T's from 500 to 10 000m²/d in weathered fresh limestones. Unconfined S values are about 25%. Average water table gradients are .004. Annual water table recovery due to two wet seasons is 1.67m. Aquifer discharge is north and south via the corridor zones. in the southeast the Q_2/M_1 complex hosts local freshwater lenses.	Acting mainly as a conduit, the Q_2 limestones impose little quality influence of their own. In coastal areas the Q_2 is open to the sea, many wells are tidal and TDS values are high. In the corridor zones the TDS and water type is similar to the M_3 waters. Groundwater qualitiy seldom exceeds 200mg/l in the west corridor, and 450mg/l in the eastern corridor. Seawater intrusion exists in the southwest in the Q_2/M_1 up to a line from Fuoni to Mtoni.
QUATERNARY Q_3 Marine and Fluviatile Sands, Sandstone.	Sands, lightly cemented sandstone, grey, coarse and opaline, sub-angular to rounded, shells, shell fragments, fish bones, sharks' teeth, with garnets, kyanites and rare tourmalines. Non-conformable with the Miocene. Maximum thickness 25m.	Significant but untested aquifers which by definition occur in the corridor zones. The sand is well graded and not difficult to screen, but is frequently unstable.	The Q_3 does not outcrop. At Kisima Mchanga and Cheju the aquifer sands produce well T's of 500m²/d. Cheju's water table is about 2m above mean sea level. Pumping drawdowns are several meters below mean sea level.	In the northeast Upenja-Kibokwa region the Q_3 waters are trapped non-flushed chloride rich deltaic waters with TDS values up to 1200mg/l;they have an irrigation rating of C3:S1. In the Kisima Mchanga and Cheju areas qualities are from 100 to 200mg/l.
PLIOCENE P	Limestones and soft sandstones.	Of no hydrogeological significance		
---U/C---				---U/C---
MIOCENE M Rythmic Fluviatile and Deltaic Sediments and Limestones.	Rythmic fluviatile sediments of the dissected Rufiji river delta. Includes limestones, sandstones, marls, sandy clays and clayey sands in 5 metre bands. Lenses of crystalline limestone and anhydrite frequent, with local ferruginous and siliceous cementing. Maximum thickness 2560m.			
MIOCENE M_1 Crystalline, Reef and Detrital Limestone.	Contemporaneous hard, dense, pearly white crystalline limestone in strata and lenses, detrital limestone of colluvial origin and recemented, consists of broken limestone, crushed corals, shell fragments and chert bands. Non-contemporaneous reef limestone, sandy and gritty, formed as discontinuous fringing reefs, cavernous in places.	The M_1 limestones are significant but untested aquifers. The reef limestones of eastern Zanzibar supply water to many wells and springs, and support the water table lakes at Bambi. The reef limestones are cavernous, often forming cave wells in conjunction with the Q_2 limestone.	The area of the M_1 outcrop is 135km², but much of its area is masked by thin Q_2. At Cheju the M_1 produces well T's of 500m²/d. Flownet observations show a uniform regional value for permiability. Estimated unconfined S values are 15%. Average water table gradient is .004. Average annual water table rise is 3.27m.	Similar in every way to the Q_2 limestone, with the notable exeption that the M_1 outcrops mainly in eastern Zanzibar and tends to contain increased chloride water due to wind blown sea spray.
MIOCENE M_2 Sands and Sandstone	Grey, white, opaline, coarse, clean, angular siliceous sands, often sugary in texture and lightly cemented, hard siliceous bands.	Not a significant aquifer. But due to the 3 degree easterly dip, outcropping sand lenses and strata cause many swampy and treeless depressions. Water logging in the Zanzibar town area is an example.	Forms areas of closed surface drainage.	Similar to the M_3. Closed and ponded drainage show the interesting mode of formation of local and isolated limestone lenses.
MIOCENE M_3 Marls, Sandy Clays and Clayey Sands.	Bluish grey to bluish green, dense, roughly sorted chalky rocks, frequent gravel stringers, which weather to a red, yellow, or brown colour. The M_3, together with the Mc/Mw of Pemba constitute the main base rock of both islands.	Not a significant aquifer at depth, but the weathered zone can produce useful small supplies. Drilling to 200m produces small seepages from thin limestones. To 2560m there are only few loss circulation zones.	The M_3 outcrops over an area of 110km² and maintains steep local water table gradients. It posesses an estimated 7% unconfined storage value and registers an average 7.91m per year water table rise. It discharges to springs via the M_1 laterites.	M_3 waters are simple mixtures of connate water plus local recharge water. The connate waters are typically the chloride rich waters trapped in the Q_3 sands at Upenja by ancestral aquifer closure in Miocene times. Average quality for M_3 well waters is from 50 to 250mg/l, but high sulfates are frequently recorded due to anhydrite/gypsum lenses.
PEMBA				
QUATERNARY Q_1 Soils, Colluvials and Fan Deposits.	Complex of coloured clayey and sandy soils, overlying various sands and gravels. The deeper material is believed to have a geomorphologic relationship with the corridor zones in Zanzibar, in that it is the remnant of a past deltaic channel. Includes also the alluvial and colluvial tracts on Pemba's eastern watershed.	This coastal strip and associated valleys maintain a shallow water table, swampy areas and ponds. Proximity to the coast and tidal inlets precludes deep drilling and development, but shallow drains and excavations can provide major potential.	Average surface elevations range from 5 to 25m amsl. Water levels vary from 0.5 to 2m below ground level and possess a 0.5 to 2m seasonal variation. Many coastal wells in the northeast are tidal.	Water in the narrow valley alluvials and in the elevated areas of the Q_1 average from 50 to 400mg/l TDS. Deep development would cause seawater invasion.
QUATERNARY Q_2 Coralline and Reef Limestone.	The Q_2 of Pemba is lithologically similar to the Q_2 of Zanzibar, with the difference that it is a raised coral reef and is unweathered to the extent of the Zanzibar rock. It is an equally hard cherty limestone, buff to grey in colour.	Pemba's Q_2 limestone is a coastal deposit occuring entirely within the tidal area of the east coast. It has no hydrogeological significance.	Forms discontinuous perched aquifers which fail seasonally.	Qualities are characterised by high Ec values and seawater invasion.
---U/C---				---U/C---
MIOCENE Mc/Mw Shales, Marls, Sandy Clays.	Chake/Wete Beds resemble the M_3 of Zanzibar, but with the exeption that the Mc/Mw is finer in grainsize and more shaley, with dips and strikes being more apparent. Cliffs and broken country are a feature of the Pemba Miocene area.	Generally poor aquifers with low porosity and permiability. Many aquifers are perched and discontinuous. The formation is more fractured than the Zanzibar M_3, and aquifer flow is more likely to be of the fissure type. In basins of weathering the saturated aquifer is more continuous and productive, but is friable and hard to screen.	Average water table depth is 8 to 12m in the broken country and 2 to 4m in the flatter rolling country. Seasonal variation is 3 to 5m; the dry season water levels are at least 10m above sea level. Borehole yields of 10 l/s can be developed in various zones of weathering. Discharge is via spring flow to the re-entrant valleys and Q_1 alluvials.	Mc/Mw waters are mainly local recharge water from simple dewatering of the well's cone of depression. The water is highly saturated with CO_3/HCO_3, and crusts are a major problem. High sulfate waters are frequent occurence at low dry season water levels due to anhydrite and gypsum lenses.

CHEMICAL QUALITY

- (blue) Miocene type waters, typically of a low TDS/$CaCO_3$ type, and simple two-component mixtures of local recharge (90%) and connate (10%) waters. Flow component is in most cases zero, which suggests that the steep Miocene water table gradients are the result of a steps-and-stairs type aquifer. Sulphate is a principal contaminant at low season water levels when connate water percentages rise.
- (green) Chloride type waters due either to past ages of higher sea level, island movement or more simply wind blown sea spray from an active coast. Island tilting, as evidenced by raised abandoned sea cliffs, is considered the main cause in Zanzibar.
- (orange) Areas where seawater invasion is a natural phenomenon at depth, and where the good quality waters are due to the development of perched aquifers. In dry times the perched aquifer becomes depleted and severs its contact with the well and the deeper contaminated aquifer takes over.



- General low season water table contours—approximate in steep broken country
- Water table divide, definite
- Water table divide, indefinite
- Geological boundary
- Fault
- Sea cliff, ancient and present shorelines
- Hand-dug well
- Borehole
- Spring
- Cave, pond, disappearing stream
- Drainage, definite
- Drainage, indefinite
- Fresh water marsh
- Mangrove
- Terrain contours, 25m vertical interval
- Spot elevations in metres
- 6092 Grid square number
- Well identification number (full identification number would be: 12/6092)
- Road
- Motorable track
- Footpath
- CHEJU Area name
- Village
- Area of congested buildings

Scale 1:125 000

KILOMETRES 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

MILES 0 1 2 3 4 5 6 7 8 9 10

Topography based on preliminary plots, scale 1:10 000, of the islands of Zanzibar and Pemba, and the One Inch to a Mile Series, Y744 Edition 3 GSGS, by the Directorate of Overseas Surveys.

Field data collected 1981-84 by the Hydrogeological Unit, Ministry of Water, Power and Minerals, Zanzibar. J. H. Johnson Consultant Hydrogeologist.

Geology by Tanzania Petroleum with modifications by the Ministry and UNDTCD

Compiled as part of United Nations Department of Technical Co-operation for Development Executed Project URT/80/001.

Map produced by George Colbert and Bernhard H. Wagner of the Cartographic Unit, Miklos Pinther Chief Cartographer, Department of Conference Services, United Nations, New York, 1987.

HYDROGEOLOGICAL MAP OF ZANZIBAR
MAP NO. 3344 UNITED NATIONS
JULY 1987