Full title: Integrated Geographic Information System and Remote Sensing approach to Groundwater Potential modelling in Trans Mara West and Narok West, Narok County, Kenya

Short title: Integrated GIS and RS approach to Groundwater Potential modelling in Narok County, Kenya

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Abstract

Narok County is one of the arid and semi-arid counties in Kenya characterized by variable rainfall patterns and limited surface water resource. Therefore, groundwater is a critical source of water for the sustenance of lives and livelihoods in Narok. This study aimed to model groundwater potential in Narok West and Trans Mara West sub-counties using an integrated approach that combined Geographic Information Systems (GIS), Remote Sensing (RS) and multi-criteria decision analysis. The key inputs into this process include the rainfall, slope, soil type, geology, land use/land cover, drainage density and lineament density. The overarching objective was to identify areas with high groundwater potential. The Analytic Hierarchy Process was employed to assign weights to each input factor based on its relative importance and a weighted overlay analysis that was conducted to generate a groundwater potential map. The results revealed that approximately 43.3% of the study area falls under high to very high groundwater potential zones, primarily in gentle slopes and permeable soil areas, while approximately 56% was classified as low to very low potential, mainly in steep slopes and impermeable regions. These findings provide valuable insights for sustainable groundwater management, enabling policymakers and stakeholders to prioritize areas for groundwater development and conservation. The study also validates the efficacy of GIS and RS technologies in groundwater potential modelling thus offering a replicable framework. It also highlights the potential of using spatial analysis tools to optimize water resource utilization and management.

Key Words: Groundwater potential modelling, GIS and Remote Sensing, Multi-Criteria Decision Analysis (MCDA), Analytical Hierarchy Process (AHP), Water Resource Management.

Introduction

Water is a vital resource for the sustenance of lives and livelihoods, particularly in arid and semi-arid regions like Narok County in Kenya. However, with the increase in human population, climate variability and agricultural expansion, the demand for water has surged even more, necessitating efficient and sustainable management strategies of this precious resource. Moreover, due to the variability and limitations of surface water sources in these regions, groundwater often becomes the primary source of water for domestic, agricultural and even industrial use [1] [2] [3]. In Kenya, where Arid and Semi-Arid Lands (ASALs) cover about 80% of the country's total land area, the management and assessment of groundwater resources is crucial in ensuring water security [4]. Drilling and geophysical surveys are among the traditional groundwater exploration techniques that are often costly, time-consuming and even have restricted geographic reach.

On the other hand, Remote sensing (RS) and Geographic Information Systems (GIS) have in recent emerged as powerful tools for modeling groundwater potential, offering a cost-effective and spatially comprehensive approach to assessing and managing groundwater resources [5] [6]. These technologies enable the integration of multiple spatial datasets, such as topography, soil type, land use, rainfall, and vegetation cover, to delineate zones of high groundwater potential. They also facilitate the analysis of complex interactions between various hydrogeological factors, providing a holistic understanding of groundwater dynamics. For instance, satellite imagery from platforms like Landsat and Sentinel can be used to derive critical parameters such as Normalized Difference Vegetation Index (NDVI), which indicates vegetation health and indirectly reflects groundwater availability [7]. Similarly, Digital Elevation Models (DEMs) derived from remote sensing data are essential for analyzing slope, drainage patterns and flow accumulation, which are key factors influencing groundwater recharge [8].

Narok County's diverse topography and semi-arid climate contribute to its highly variable surface water availability [9]. The county's groundwater availability and distribution across remain largely unassessed due to limited hydrogeological data and insufficient spatial analyses [10], [1]. This hinders the county's ability to make informed decisions regarding water resource allocation, especially in light of increasing population, agricultural expansion and climate variability. This can further complicate sustainable resource management, often leading to unregulated extraction practices that can exacerbate aquifer depletion, water quality degradation and environmental degradation [10]. The use of GIS and RS technologies for groundwater potential modeling is particularly relevant in such environments because of the county's varied terrain, which includes the high-altitude Mau Escarpment and the low-lying Rift Valley lowlands. Useful assessments require an understanding of recharge rates, aquifer storage capacity and the factors influencing water quality. However, traditional hydrogeological surveys can be costly and time-consuming, limiting their applicability in large or resource-constrained areas.

On the other hand, GIS and remote sensing technologies have significantly advanced in groundwater exploration by enabling large scale groundwater spatial data integration and analysis for cost-effective and accurate resource mapping and modelling [12]. While GIS and RS technologies offer advanced tools for mapping and modelling groundwater potential, these technologies have not yet been fully utilized in areas like Narok County. Applying these tools can provide essential insights by integrating key environmental factors like topography, soil type, land use and rainfall to accurately identify and assess groundwater-rich zones.

Recent studies have shown that GIS and RS are useful tools for modeling groundwater potential in a variety of geographical areas. For instance, [7], mapped groundwater potential zones in a semi-arid region of India using RS-derived NDVI and GIS-based multi-criteria decision analysis (MCDA), attaining excellent accuracy in identifying recharge locations. Similarly, [5], evaluated groundwater potential in a region that is prone to drought by combining RS data with hydrogeological factors, highlighting the significance of rainfall, soil type, and slope in recharge processes. Also [11] used GIS and RS techniques to assess groundwater resources in the Upper Ewaso Ng'iro Basin in Kenya, emphasizing how climate variability and changes in land use contribute to groundwater depletion.

This study therefore seeks to address the existing gaps in groundwater potential modelling in Narok County by using GIS and RS to develop a comprehensive groundwater potential map. This spatial model will therefore guide policy and management practices, promote sustainable groundwater use and enhance water security for the region's residents and agricultural systems.

Materials and Methods

Study design

This study adopted an integrated research design combining RS, GIS-based spatial analysis and field validation techniques. This approach ensured a comprehensive and data-driven evaluation by leveraging multiple sources of information and analytical methods. GIS-based spatial analysis played a crucial role in integrating, processing and analyzing various thematic layers related to groundwater potential. The key thematic layers included geological formations, soil types, land use/land cover, topography, rainfall distribution, and drainage networks [13] [14]. These spatial datasets were collected from remote sensing imagery, government agencies, and previous studies.

Desktop study was also conducted to review existing studies, reports and databases relevant to groundwater occurrence in Narok County. The secondary data reviewed included; the hydrogeological reports; climatic and meteorological data; topographic and geological maps; and satellite imagery and remote sensing datasets. These secondary data sources were analyzed and incorporated into GIS models to improve the accuracy of groundwater potential assessment.

Lastly, field validation techniques and hydrogeological surveys were conducted within the study area in order to validate the GIS-based analysis and ensure reliability. These included; ground-truthing surveys in selected sites to verify the accuracy of RS and GIS-derived data through observations on geological formations, surface water interaction and land use conditions [17]. They also included: geophysical surveys, that is electrical resistivity tomography (ERT) and vertical electrical sounding (VES), to assess subsurface hydrogeological conditions and identify potential aquifers; borehole and well inventory [18]; and water quality assessments from existing boreholes and wells.

By integrating GIS-based spatial analysis, desktop study, secondary data and field validation techniques, the study provided a robust and scientifically grounded assessment of groundwater potential.

Study Area setting

This comprehensive study focused on Narok West and Trans Mara West sub-counties within Narok County, Kenya - a region of remarkable geological complexity, diverse ecosystems, and significant hydrological importance. Situated in southwestern Kenya between latitudes 0.96°S to 1.15°S and longitudes 34.84°E to 35.59°E, the study area encompasses approximately 7,948 km^2 of varied terrain that forms a critical transition zone between Kenya's highland water towers and the semi-arid plains of the Great Rift Valley.

The Narok West sub-county (5,421 km^2) occupies the eastern part of the study area, characterized by dramatic elevation changes from 1,800 meters in its Rift Valley floor sections to 2,700 meters in its western highland areas. This sub-county presents a fascinating geological profile where precambrian basement rocks - including quartzites, gneisses, and pelitic schists of the Mozambique belt - interface with younger tertiary and quaternary volcanic deposits associated with the tectonic activity of the East African Rift system. The weathering of these ancient metamorphic formations has created complex regolith aquifers where groundwater occurrence is primarily controlled by secondary porosity along fault zones and fractures [19].

Transmara West sub-county (2,527 km²) displays an equally compelling but distinct geological character. Its geological landscape is dominated by precambrian basement rocks, primarily composed of gneisses, schists, and granites [19]. Its stratigraphic sequence includes Archaean Nyanzian system rocks (conglomerates, banded iron formations, and pillow basalts), proterozoic kavirondian sediments, and more recent miocene phonolites and pleistocene gravel deposits. The volcanic units, particularly the phonolites and basalts, exhibit well-developed fracture networks that serve as preferential pathways for groundwater movement and storage. These geological differences between the two sub-counties create fundamentally different hydrogeological regimes that this study seeks to characterize.

The Mara River system, originating in the Mau highlands, forms the hydrological backbone of the region, supported by numerous tributaries and seasonal streams. This surface water network interacts with groundwater systems, maintaining baseflows during dry periods.

Land use varies markedly between the sub-counties. Trans Mara West maintains significant forest cover interspersed with tea plantations and smallholder farms, while Narok West is characterized by expansive rangelands for pastoralism and growing areas of maize and wheat cultivation. The climate follows a bimodal rainfall pattern, with significant spatial variability. The highland areas of Trans Mara West receive 1,200-1,800 mm annually, supporting the Mau Forest Complex - a critical water tower feeding the Mara River Basin. In contrast, Narok West's lowlands experience more erratic precipitation (800-1,200 mm/year), with frequent dry spells exacerbating water scarcity.

Groundwater occurrence across the study area reflects this complex interplay of geology, climate, and land use. Preliminary data indicate borehole yields ranging dramatically from 0.6

m^3/hr in low-permeability basement areas to 40 m^3/hr in favorable volcanic zones, with transmissivity values typically between 3-6 m^2/day (see table 4). The highest yields are generally associated with fractured volcanic aquifers in Trans Mara West, while the lowest yields occur in Narok West's metamorphic terrain where groundwater is restricted to shallow weathered zones and fault-controlled systems.

Figure 1: **The location map of the study Area**

Data collection methods

Data Preparation

Desktop Studies

Detailed borehole data was collected from twenty-three (23) and nine (9) existing boreholes in Narok West and Transmara West sub-counties respectively. The sources of the data included Amref projects, Water Resources Authority and Narok County Water Offices (Figure 2).

Figure 2: A map of the existing boreholes in the study area of Narok West and Trans Mara West

Geological/Lithological maps for the study area was obtained from Geology and Mines Department in Kenya. Additional secondary data utilized for this study included the geological maps, soil maps, 20-year period rainfall map and hydrological records obtained from government agencies such as the Kenya Meteorological Department, Food and Agriculture Organization (FAO) and the Water Resources Authority. The DEM dataset was used to prepare a lineament density map using the line density tool in ArcGIS 10.5, the slope map of the study area, and the IDW interpolation technique used in the development of study area rainfall map. All prepared maps were transformed into raster format with 30 M of spatial resolution.

Remote Sensing Data

Multispectral and radar image datasets were used for this study. The Shuttle Radar Topography Mission (SRTM), 1 arc second 30m resolution was acquired from the United States Geological Survey (USGS) earth explorer and Sentinel 2 10m resolution was obtained from Copernicus. The datasets were used to develop lineament and lineament density, Land Use/Land Cover, Normalized Difference Vegetation Index (NDVI) and slope layers. Data acquisition was influenced by cloud cover and time of collection where data with minimal to no cloud cover (0-3%) were obtained between the period running from January 2023 to January 2024.

Satellite imagery is the primary source for spatial datasets, providing information on land use/land cover (LULC), vegetation indices and soil moisture. The following datasets were used: Landsat 9 OLI/TIRS for land use and vegetation mapping; Sentinel-2 MSI for high-resolution vegetation and soil analysis; and SRTM Digital Elevation Model (DEM) for slope, elevation, and drainage analysis [16]

Field data Collection

Field surveys were conducted to validate the geospatial analysis. The field surveys included investigating groundwater levels, aquifer parameters (from pumping test data) and water quality from existing boreholes at representative sites. In addition, geophysical investigations were carried out in 10 locations (5 in each sub county) for the purpose of exploratory borehole drilling in order to validate the groundwater potential model.

Data Analysis and Management

The investigation commenced with detailed water quality analysis, where samples from existing boreholes underwent thorough physical and chemical testing. Parameters including pH, electrical conductivity, total dissolved solids, and major ion concentrations were tested to establish baseline water quality characteristics. These findings were subsequently translated into spatial suitability maps, highlighting zones with optimal water quality.

Building upon this foundation, advanced remote sensing techniques were employed to analyse surface indicators of groundwater potential. Satellite imagery from Landsat and Sentinel-2 platforms was processed to derive multiple thematic layers. NDVI helped identify areas with persistent vegetation moisture; land use/land cover classification revealed anthropogenic impacts on recharge zones; structural lineament mapping detected fracture systems; while drainage pattern analysis provided insights into surface water infiltration potential. These remotely sensed datasets offered a synoptic view of groundwater controlling factors across the entire study area.

The data analysis then progressed to the GIS integration phase, where all collected data layers were systematically combined using Multi-Criteria Decision Analysis (MCDA). A weighted overlay approach incorporated key factors including soil permeability, slope gradient, geology, land use/land cover, rainfall distribution, and lineament density, with each parameter's relative importance to groundwater recharge determined through the Analytic Hierarchy Process (AHP) [13] [15]. It involved breaking down the problem into a hierarchy of criteria and sub-criteria, followed by pairwise comparisons to determine the relative importance of each factor. A scale of 1 to 9 was used, where 1 indicated equal importance and 9 signified extreme importance of one factor over another. The resulting priorities were quantified, aiding in selecting the best alternative or identifying priority areas.

A weighted overlay analysis was then performed in QGIS 3.34 to integrate the selected parameters. Each factor was assigned a normalized parameter value on a scale of 1–5. Weights were then assigned to these factors based on their relative importance, determined through the AHP. The AHP scores were derived from pairwise comparisons of factors. The weighted factors were then overlaid in a GIS environment using the formula:

Composite Groundwater Potential Index (GWPI) = Σ (Weight of Factor × Normalized Parameter Value)

This analytical framework generated a comprehensive Groundwater Potential Index map, classifying the study area into distinct potential zones ranging from very high to very low.

The final and most critical stage involved rigorous ground truthing to validate the model's accuracy. Field teams conducted extensive surveys to measure actual well yields (from pumping test data), water table depths, and infiltration rates at strategic locations across all potential zones. Additional 45 electrical soundings (VES) were carried out to determine the lateral and vertical extent of the water body, the texture of the aquifer deposits (grain-size distribution) and the depth and nature of the layers underlying the groundwater store. Finally, geophysical investigations through drilling of exploratory boreholes at representative points were carried out in 10 locations (5 in each sub county) in relation to geomorphological observations to validate the groundwater potential model.

This sequential, multi-method approach provided a robust assessment of groundwater resources while establishing clear relationships between surface indicators, subsurface characteristics, and actual groundwater occurrence. The integration of water quality data ensured that potential mapping considered not just water quantity but also usability, while the RS and GIS components enabled cost-effective, large-area assessment. The ground truthing phase served as the essential reality check, confirming the model's practical utility for water resource planning and management in the region. The methodology's success in this semi-arid environment suggests its potential applicability to similar hydrogeological settings across the region.

Results

Water Quality

A total of 26 water samples were collected from existing boreholes across the study area. The analysis evaluated physical and chemical parameters to determine compliance with the World Health Organization (WHO) drinking water quality standards.

Physical Parameters Analysis

The results indicated that turbidity levels vary significantly between from one source to another, with most of the water samples exhibiting clear and acceptable clarity, while few exhibited elevated turbidity (Naarolong and Olontare boreholes in Transmara West and Ositeti borehole in Narok West). High turbidity is often attributed to soil erosion, surface runoff and disturbance of sediments.

Chemical Composition Analysis

This assessment focused on parameters such as pH, iron, manganese, fluoride, chloride and nitrates. The pH of most of the water samples fell within the recommended range, with certain sources exhibiting deviations that may require corrective measures such as pH adjustment or buffering (table 2). Iron and manganese levels exceeding acceptable limits were detected in several locations, 3 of these samples (Embiti, Ololchura and Ositeti) were in Narok West while 1 of the sample (Naarolong) was in Tansmara West (table 1).

The fluoride levels were of concern in 15 out of the 26 water samples, with 2 of them (Nkairuwani and Oldonyo Rasha) being ten times over the limits (table 1). Chloride analysis indicate that all the water samples, except one (Olkiloriti), was within the allowable limits (table 1). Nitrate analysis revealed that all the water sources were within allowable levels while high EC values were detected in 2 water samples (Ilmonchin and Olomanira) (table 1).

Thematic Remotely Sensed Data

Geology

Geology/lithology of the project area is composed of igneous, sedimentary and metamorphic rocks. Each of this rock formations were classified very low, low, medium high to very high dependent on the hydrogeological characteristics of the rocks based on the previous studies carried out in the project area. Generally, metamorphic rocks are likely to have very low potential, while sedimentary and igneous (volcanic) rocks may have medium to high potential (figure 3 and figure 4).

Figure 3: **Geological map of Narok West sub-counties**

Figure 4: **Geological map of Transmara West sub-counties**

Lineament density

Lineament density, underlying geological structures such as faults, fractures and joints, act as conduits or barriers to groundwater movement and may significantly influence water availability. The areas with high lineament density typically indicate extensive fracturing, which enhances groundwater infiltration and storage due to increased secondary porosity and permeability. Conversely, areas with low lineament density suggest compact rock formations with limited groundwater flow, making them less favorable for drilling (figure 5).

Figure 5: Lineaments map of Narok West and Transmara West sub-counties

Land Use Land Cover

Land use and land cover (LULC) significantly influences groundwater potential by affecting infiltration rates, surface runoff and recharge processes. The study indicates that areas with dense vegetation had better recharge potential due to their ability to intercept rainfall and allow infiltration. Conversely, built-up areas or regions with sparse vegetation showed lower potential for groundwater recharge (Figure 6). Additionally, the study indicated that wetlands and riparian zones had high groundwater potential. The possibility of groundwater in water bodies, sand, vegetation, agricultural land was also found to be highest due to their capacity to recharge.

Figure 6: Land Use Land Cover map of Narok West and Transmara West sub-Counties

Slope

The slope of the terrain plays a critical role in groundwater recharge and permeability. Steep slopes are associated with faster runoff and reduced infiltration, leading to lower groundwater recharge rates and minimal percolation into underlying aquifers.

The study findings indicate that Narok West sub-county generally has a varied topography, with slopes influenced by the Great Rift Valley escarpments, highlands and river basins. The findings of the slope can be classified as follows: 0 – 5% (flat to gently sloping) covers approximately 35% of the sub-county, mostly in low-lying plains and river basins; 6 – 15% (moderately sloping) covers about 30% of the sub-county, mostly in transitional zones between the plains and highlands; 16 – 30% (steep Slopes) covers around 20%, mainly in escarpment areas and foothills; and above 30% (very steep slopes) covers about 15% of the land, located in the high-altitude sections and hilly terrain.

The study findings of the topography of Transmara West sub-county indicates rolling hills, escarpments and valleys. The slope distribution can be classified as follows: 0 – 5% (flat to gently sloping) covers approximately 25% of the area, primarily in river valleys and lower elevation zones; 6 – 15% (moderately sloping) covers around 40% of the area, making it the most dominant terrain; 16 – 30% (steep slopes) covers approximately 25% of the area, found in hilly and escarpment areas; and above 30% (very steep slopes) covers around 10% of the sub-county, mostly in highland regions with rugged terrain.

The moderate slopes (6-15%) in Transmara West sub-county provide a balance between drainage and soil stability. The slope analysis for both sub-counties shows that Narok West has a higher proportion of steep and very steep slopes compared to Transmara West (figure 7).

Figure 7: Slope map of Narok West and Transmara West sub-Counties

Rainfall

Rainfall stands as the primary natural source replenishing groundwater resources as it directly influences how much water infiltrates the ground to recharge the aquifers. Higher rainfall generally translates to greater potential for groundwater recharge, assuming other factors like slope, soil type, and land cover are conducive to infiltration. This study generally classified the study areas into three zones. The high rainfall zones (shown in Fig. 8) are primarily found in the elevated parts of Transmara West, particularly near the Mau forest and the hilly regions bordering Nyakweri forest. These areas receive an annual rainfall of between 1,200 mm and 1,800 mm. The medium rainfall zones are found in parts of Narok West and the mid-altitude areas of Transmara West. These areas receive between 800 mm and 1,200 mm of rainfall annually. The rainfall distribution is reliable during the long rains (March to May) and less consistent during the short rains (October to December). Finally, the low rainfall zones are predominantly in the lower-lying areas of Narok West, particularly towards the Rift Valley floor. These areas receive less than 800 mm of rainfall annually, with the short rains being particularly unreliable. The dry spells are more prolonged, and the region is prone to drought (figure 8).

Figure 8: Rainfall map of the study area – Narok West and Transmara West sub-counties

Soil Type

Soil type significantly influences groundwater potential due to its impact on water infiltration and storage. Highly porous and permeable soils allow water to readily infiltrate the ground, contributing to groundwater recharge.

The study findings (figure 9) indicate the volcanic-derived soils, particularly Andosols and Nitisols to be prevalent in the highland areas of Transmara West. These soils possess a loose, porous structure with high infiltration capacities, allowing precipitation to percolate rapidly through the soil profile. Their granular composition and well-developed structure facilitate vertical water movement, minimizing surface runoff and maximizing recharge to underlying aquifers. The presence of these permeable soils in the Mau escarpment zone creates natural recharge areas that feed groundwater systems extending into lower elevations.

In contrast, the clay-rich Vertisols dominates the plains of Narok West (figure 9) presenting a more complex hydrological scenario. While these soils demonstrate substantial water storage capacity, their shrink-swell behavior and low permeability significantly restrict infiltration rates. Their ability to retain moisture over extended periods supports gradual seepage during drier intervals, albeit at much slower rates than their volcanic counterparts.

The low-lying plains and river basins in Narok West predominantly feature sandy and loamy soils (figure 9), which promote groundwater infiltration and recharge. Conversely, the highland and escarpment areas, particularly in parts of Trans Mara West and the eastern sections of Narok West, are characterized by clay-rich and rocky soils (figure 9) with poor infiltration capacity.

Figure 9: Soil map of the study area – Narok West and Transmara West sub-counties

The study findings of the soil types and their proportional distribution in Narok West and Trans Mara West sub-counties is summarized and presented in table 3. Planosols (PLe) covers approximately 42% of the area, mainly in the low-lying areas of Narok West; Cambisols (CMu) and Vertisols (VRe) covers about 13% of the area, primarily in the low-lying plains of Narok West. The rest of the soil types in the study area each occupies less than 10% of the area (table 3).

Table 1: Proportion covered by each soil type

Soil Type	Description	% Coverage
ACh	Acrisols	0.05
ACu	Acrisols/Alisols	0.07
ANm	Andosols	0.26
CMe	Cambisols	0.35
CMu	Cambisols	0.99
GRh	Gleysols	1.19
LPu	Leptosols	1.27
LVv	Luvisols	2.79
NTu	Nitisols	5.74
PHh	Phaeozems	5.8
PHl	Phaeozems	5.86
PLe	Planosols	6.61
PLu	Plinthosols	13.27
RGe	Regosols	13.69
VRe	Vertisols	42.06

NDVI (Normalized Difference Vegetation Index)

High NDVI values were established in Transmara West compared to Narok West (Figure 9). Narok West sub County exhibited relatively lower NDVI value in August and December 2023 (see Figure 9), while Transmara West had the highest NDVI value during the Months of January and April 2023. High NDVI values (close to +1) indicate dense, healthy vegetation, while low values (closer to 0 or negative) suggests sparse vegetation or barren land. In the context of groundwater potential modeling, NDVI serves as a proxy for vegetation cover, which indirectly relates to soil moisture and groundwater availability. Areas with higher vegetation cover often correlate with higher groundwater recharge, as these regions typically experience more significant rainfall interception and infiltration.

Figure 10: NDVI map of the study area – Narok West and Transmara West sub-counties

Drainage density

The study findings in Narok West and Transmara West sub-counties, indicate that the drainage density varies across different regions due to topography, soil types and geological formations. The classification of drainage density in the study area ranges from very low (1) to very high (5), each with distinct implications for water movement and groundwater potential (figure 11).

Very Low Drainage Density (Category 1) was found in areas with permeable soils and gentle slopes, particularly in regions with Cambisols and sandy soils that allow for higher infiltration rates. These areas have fewer surface water channels, as most of the rainfall infiltrates the ground rather than forming surface runoff. Groundwater recharge is high, making these zones important for aquifer replenishment.

Low Drainage Density (Category 2) was common in regions with moderate slopes (6–15%), where some runoff occurs but infiltration remains relatively high. Found in parts of Narok West, where vertisols and moderate permeability soils dominate. Moderate groundwater recharge potential, with water slowly percolating into the ground.

Moderate Drainage Density (Category 3) was found in areas with a balanced mix of infiltration and runoff, often located in transitional zones between highlands and lowlands. These areas have a moderate number of streams, meaning that while surface runoff is evident, some groundwater recharge still occurs where the subsurface is permeable. Found in parts of Trans Mara West, where moderate clay soils and loamy textures contribute to variable recharge potential.

High Drainage Density (Category 4) was found in areas with steep slopes (16–30%), such as near the Great Rift Valley escarpments and foothills. Surface runoff is high, reducing the chances of groundwater recharge due to rapid water movement and limited infiltration. These areas contribute more to river flow than to groundwater storage, making them critical for surface water resource management.

Very High Drainage Density (Category 5) was found in hilly and mountainous areas with steep terrain (>30%), where streams are densely packed due to high runoff. Groundwater recharge is minimal as water quickly drains away before infiltration can occur. These regions primarily serve as watershed areas, supplying water to lowland zones but with limited direct recharge potential.

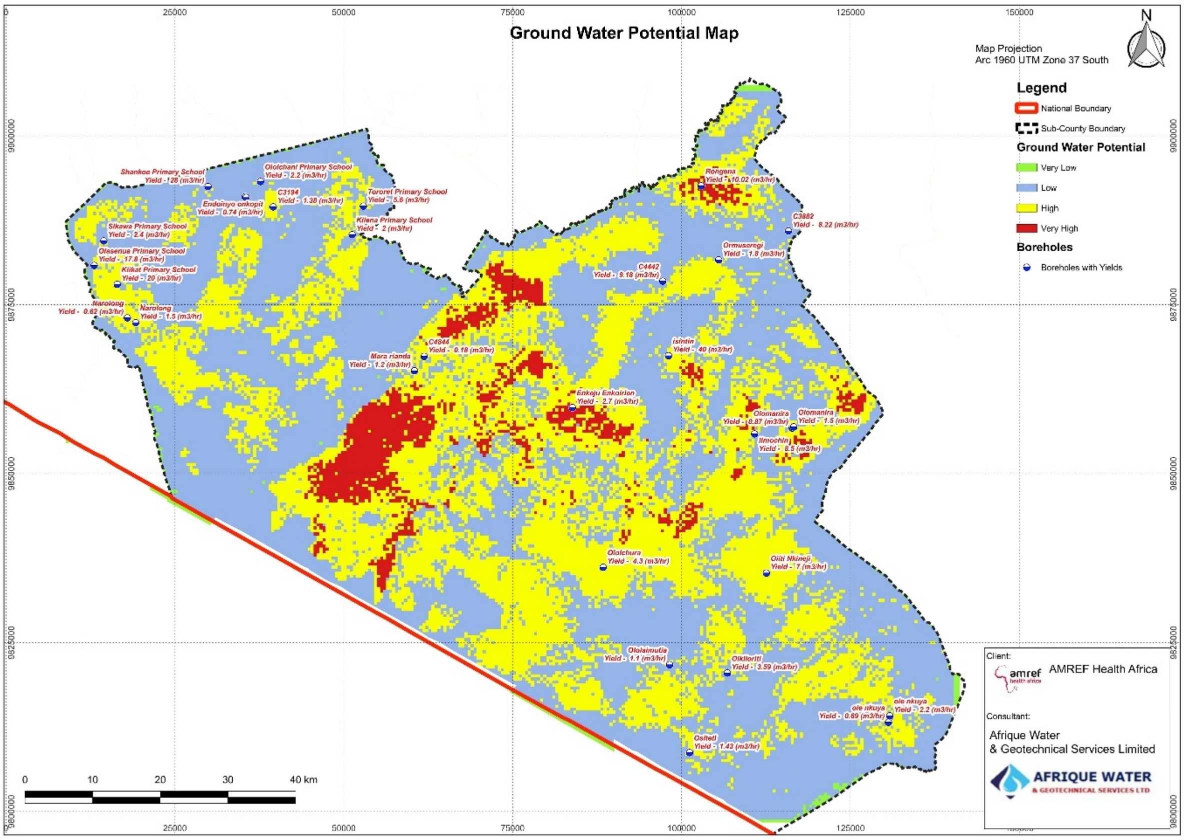
Figure 11: Drainage density map of the study area – Narok West and Transmara West sub-counties

Composite Groundwater Potential Model and Its Achievement

Groundwater Potential Modelling

This study employed a GIS-based MCDA approach, specifically the AHP, to delineate groundwater potential zones in Narok West and Transmara West sub-counties. The study output was a groundwater potential model that was derived from integrating thematic layers such as slope, soil permeability, drainage density, land use, and rainfall distribution.

Figure 12: Groundwater potential map of the study area – Narok West and Transmara West sub-counties



The final groundwater potential map classified the study area into four classes namely very high, high, low, and very low groundwater potential zones (Figure 12). The output map illustrates the spatial distribution of groundwater potential across the study area, where the red zones present high groundwater potential, the yellow colour depicts medium to high potential while the sky-blue colour show low to very low groundwater potential. (figure 12). Distribution of each groundwater potential zones (in m2 and % area coverage in the study area) is illustrated in Table 4.

Table 4: Groundwater Potential Distribution in Trans Mara West and Narok West Sub Counties

S/N	Groundwater Potential Zone	Area Coverage (m2)	% Area coverage
1	Very Low	14,185,544	0.2
2	Low	4,475,439,159	56.5
3	High	3,029,912,270	38.2
4	Very High	403,189,117	5.1
Total		**7,922,726,091**	**100**

Very high groundwater potential zones cover 403.19km^2 (5.1%), high groundwater potential zones cover 3,029.91Km^2 (38.2%), low groundwater potential zone covers 4,475.44Km^2 (56.5%), and very low groundwater potential zone occurs an area of 14.19Km^2 (0.2%). Very high groundwater potential was found in volcanic formations which have fissures in form of jointing or fault movement cracks; porous old land surfaces composed of more coarsely divided sandy material. As well as within locations with gentle to moderate slopes (0–15%) with permeable soils and low drainage density, identified in both the desktop study and spatial analysis. Similarly, from the findings of the geological surveys, these regions had Cambisols and sandy soils thereby supporting higher recharge.

High potential areas were located in transitional zones with mixed hydrogeological conditions, while low and very low potential areas corresponded to steep terrains, poorly drained soils, and high runoff regions (Figure 11 and Figure 12 illustrates this). The influence of drainage density, another factor identified in the desktop study, was also analyzed, revealing that low to moderate drainage density areas were more favorable for recharge compared to high drainage density zones where rapid runoff occurred.

Low and very low groundwater potential zones (56.7%) of the project area are found mostly in locations characterized with high slope, less rainfall, built-up land, less lineament density and high drainage density areas. Majority of the project area consists of low groundwater potential that is covered mostly by metamorphic rocks whose potential is greatly dependent on occurrence of groundwater along the faults and general lines of weakness. In such cases, weathering has not only resulted in secondary porosity, but has also created a storage media in the regolith, saprolite and saprock. Similarly, from the findings of the geological surveys, these regions had Planosols and Vertisols soils that restricts infiltration due to their low permeability. Groundwater recharge along the streams is provided by the infiltration of surface discharge, and underflow through the alluvium, faults and the weathered zones.

Comprehending these relationships is fundamental for successful groundwater exploration and the sustainable management of water resources within the diverse landscapes of these sub-counties.

Validation of the Groundwater Potential Map

To validate the groundwater potential model developed for Narok West and Trans Mara West sub-counties, a comprehensive ground-truthing exercise was conducted. This involved both a comparative analysis of existing borehole yield data and the implementation of geophysical investigations and exploratory drilling across different hydrogeological zones. The primary aim was to assess the reliability of the model in accurately identifying groundwater prospective zones [20]. Validation began by analyzing borehole yield data from 22 boreholes previously drilled by AMREF (as presented in the attached Table) as illustrated in Table 5 below.

Table 5: Existing Boreholes in the Study Area

S/N	Borehole name	Sub-County	Total depth (m)	Yield (M^3/hr)
1	Oldonyo Rasha	Narok West	195	1.5
2	Nkairuwani	Narok West	184	10
3	Ilmochin	Narok West	250	8.5
5	Olomanira	Narok West	230	1.5
6	Endoinyo Narasha	Narok West	200	1.5
7	Enkeju Enkoirien	Narok West	152	2.7
8	Ololchura	Narok West	166	4.3
9	Empoo	Narok West	154	2.0
10	Embiti	Narok West	150	4.4
11	Olkiloriti	Narok West	132	3.59
12	Parmolile	Narok West	193	10.3
13	Ositeti	Narok West	75	2.5
14	Ololaimutia	Narok West	110	1.1
15	Isintin	Narok West	198	40
16	Ole nkuya	Narok West	230	2.7
17	Oloontare	Transmara west	180	0.75
18	Endoinyo onkopit	Transmara west	175	1.2
19	Naarolong	Transmara west	180	2.5

Further field validation involved exploratory drilling of the additional 9 boreholes at selected sites across varying hydrogeological settings. Results consistently indicated that areas with gentle slopes recorded higher borehole yields, thereby confirming the model's assertion that such topographies offer favorable conditions for groundwater accumulation and storage. In contrast, areas with moderate slopes, while not yielding as much water directly, were observed to possess high recharge potential, suggesting their critical role in the long-term sustainability of groundwater resources. This observation aligns with the understanding that such terrain is more conducive to the accumulation and subsequent infiltration of rainwater. This empirical evidence from exploratory drilling in Narok West and Trans Mara West reinforces the critical role of slope in predicting groundwater potential and highlights the advantage of targeting areas with gentle slopes for successful borehole development. Specifically, the findings reinforce the significance of slope and permeability as key variables influencing groundwater occurrence.

The model thus proves to be a valuable tool in guiding site selection for borehole development, identifying zones for targeted water conservation, and planning artificial recharge interventions to support sustainable groundwater management in Narok West and Trans Mara West.

Table 6: Exploratory Boreholes in the Study Area

S/N	Borehole Name	Location	Depth	WRL	Yield
1	Sosio Primary School	Transmara west	270	33.13	5.5
2	Sikawa Primary School	Transmara west	205	8.62	2.4
3	Olasenua Primary School	Transmara west	150	18.57	17.8
4	Shankoe Primary School	Transmara west	160	28.34	28
5	Tororet Primary School	Transmara west	180	2.99	5.6
6	Ildungisho Primary School	Narok west	170	10.22	1.8
7	Ilpoori Primary School	Narok West	150	18.96	4.8
8	Kilena Primary School	Transmara west	160	10.82	2
9	Ololchani Primary School	Transmara west	160	19.00	2.2

Note: Very high groundwater potential has yield above 10m^3/hr while high groundwater potential zones have yields between 5-10m^3/hr. Yields between 4-2m3/hr were considered to be low whole yields below 2m3/hr were considered to be very low.

Existing and exploratory boreholes located in very high and high groundwater potential zones include Kiket (20m^3/hr, Shankoe (28m^3/hr), Toreret (5.6m^3/hr), Insitin (40m^3/hr). Boreholes located in low and very low groundwater potential zones include El Donyo (-.74m3/hr), Ositeti (1.43m3/hr), Ole Nkuya (0.06m3/hr), Olalamutia (1.1m3/hr, Olamanira (0.87m3/hr) (table 6). Majority of the very high groundwater potential zone is located within the Game Reserve which is a restricted conservation area.

Discussion

The groundwater potential assessment for Narok West and Trans Mara West sub-counties employed a comprehensive, multi-stage methodology that systematically integrated water quality analysis, remote sensing, GIS techniques, and field validation. This progressive approach ensured a scientifically rigorous evaluation of groundwater resources across the study area. These results are consistent with similar studies conducted in various regions. For instance, a study in Baringo County, Kenya, utilized an integrated approach combining remote sensing, GIS, and AHP techniques to identify groundwater potential zones. The research incorporated thematic layers of rainfall, slope, lithology, soil type, land use, drainage density, and lineament density. The study's validation using borehole yield and fluoride data underscored the efficacy of integrating these parameters in groundwater potential assessments [20].

Similarly, research in central Antalya province, Turkey, applied AHP and frequency ratio (FR) models to delineate groundwater potential zones. This study considered factors such as lithology, slope, drainage density, land cover/land use, lineament density, rainfall, and soil depth. The integration of these parameters within a GIS framework facilitated the identification of areas with varying groundwater potential, highlighting the robustness of combining AHP with geospatial techniques [21].

Furthermore, a study in Embu County, Kenya, utilized remote sensing and GIS approaches to identify groundwater potential zones. The research emphasized the significance of integrating geospatial data to enhance the accuracy of groundwater assessments, aligning with our study's methodology and findings [22].

Collectively, these studies reinforced the effectiveness of integrating GIS-based MCDA approaches, particularly AHP, with geospatial data to assess groundwater potential. The consistent identification of key influencing factors, such as slope, soil permeability, and drainage density, across diverse geographical contexts underscores the reliability of this methodology in groundwater resource management.

Conclusions

This study conclusively demonstrated the power of integrating Geographic Information Systems (GIS) and remote sensing technologies in groundwater potential modelling. Through systematic analysis of multiple input parameters including geology, soil characteristics, land use patterns, slope dynamics and rainfall distribution, the research successfully mapped groundwater potential zones with remarkable accuracy. The study revealed distinct spatial variations in groundwater potential across the study area. Volcanic formations demonstrated very high groundwater potential, covering 403.18 km^2 and accounting for 5.1% of the total study area. In contrast, areas dominated by metamorphic rocks showed significantly lower yields, covering 4,475.44 km^2 which represents 56.5% of the study area. The analysis also identified a limited very low potential zone spanning just 14.18 km^2. This clear differentiation in groundwater potential highlights the strong geological control on aquifer productivity within the study area. These geological distinctions proved critical in understanding groundwater occurrence patterns, with volcanic zones benefiting from fissures and porous structures, and metamorphic areas dependent on fault lines and weathering features for water storage.

Field validation played a pivotal role in confirming the model's reliability, with comparative analysis of borehole yields providing compelling evidence. High-yield sites like Isintin (40 m^3/hr) and Shankoe (28 m^3/hr) aligned perfectly with predicted high-potential zones, while low-output locations such as Ole Nkuya (0.06 m^3/hr) matched areas identified as having limited groundwater resources. Particularly noteworthy was the concentration of high-potential zones within the protected Game Reserve, highlighting both the value of conservation areas for water resource protection and the challenges this presents for practical utilization.

The study's methodological approach, incorporating Multi-Criteria Decision Analysis (MCDA) and Analytical Hierarchy Process (AHP), proved particularly effective in reducing the search area for groundwater exploration. This represents a significant advancement over traditional methods, offering a cost-effective preliminary assessment tool that can dramatically improve the efficiency of subsequent field investigations. The success of this approach in Narok County's semi-arid environment suggests strong potential for application in similar regions across East Africa.

Building on these robust findings, several strategic actions emerge as critical for sustainable groundwater management. First, the clear delineation of high-potential zones calls for implementation of monitored extraction protocols to prevent over-exploitation of these valuable resources. Second, regularly monitoring of groundwater levels, recharge rates and quality to ensure long-term resource sustainability. For policymakers though, these results provide a scientific foundation for developing robust water governance frameworks. Furthermore, the demonstrated success of geospatial techniques argues strongly for their institutionalization within water resource management agencies, potentially through capacity-building initiatives and technology transfer programs.

This study represents a significant step forward in sustainable water resource management for arid and semi-arid regions. The methodologies developed and insights gained offer not just immediate benefits for Narok County, but also a replicable model for groundwater assessment that integrates scientific rigor with practical applicability. By implementing the findings and pursuing the recommended follow-up studies, stakeholders can ensure that groundwater resources continue to support both human needs and ecological functions for generations to come. The success of this integrated approach underscores the value of combining modern geospatial technologies with field validation to address complex water resource challenges in developing regions.

Acknowledgments

We are profoundly grateful to the well:fair Foundation for their generous sponsorship and unwavering support of this critical groundwater assessment study in Narok County. We are also grateful to the team of engineers at Amref Kenya and Afrique Water and Geotechnical Services Ltd for their exceptional technical expertise. Their specialized knowledge in hydrogeological assessments, GIS modeling and precise data interpretation was indispensable in ensuring the scientific rigor and reliability of our findings.

This study stands as a testament to the power of collaboration, and we recognize that its success would not have been possible without the dedication and shared vision of these esteemed partners. Their commitment to advancing sustainable water resource management has left a lasting impact on both this research and the communities it serves.

Author Contributions

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Data analysis and Modelling: Dr. Justus Korir

Data curation: Dr. Justus Korir, Vincent Okello

Writing – review & editing: Dr. Justus Korir, Vincent Okello, Dennis Munai, Dr. Martin Muchangi, James Ayacko, Kenneth Ochieng, Mary Watuka, Edward Mukanda, Judy Muriithi

Data Validation: Dennis Munai, Dr. Martin Muchangi

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Supporting Information

S1 Fig: The location map of the study area

S2 Fig: A map of the existing boreholes in the study area of Narok West and Trans Mara West

S3 Fig: Geological map of Narok West sub-counties

S4 Fig: Geological map of Transmara West sub-counties

S5 Fig: Lineaments map of Narok West and Transmara West sub-counties

S6 Fig: Land Use Land Cover map of Narok West and Transmara West sub-Counties

S7 Fig: Slope map of Narok West and Transmara West sub-Counties

S8 Fig: Rainfall map of the study area – Narok West and Transmara West sub-counties

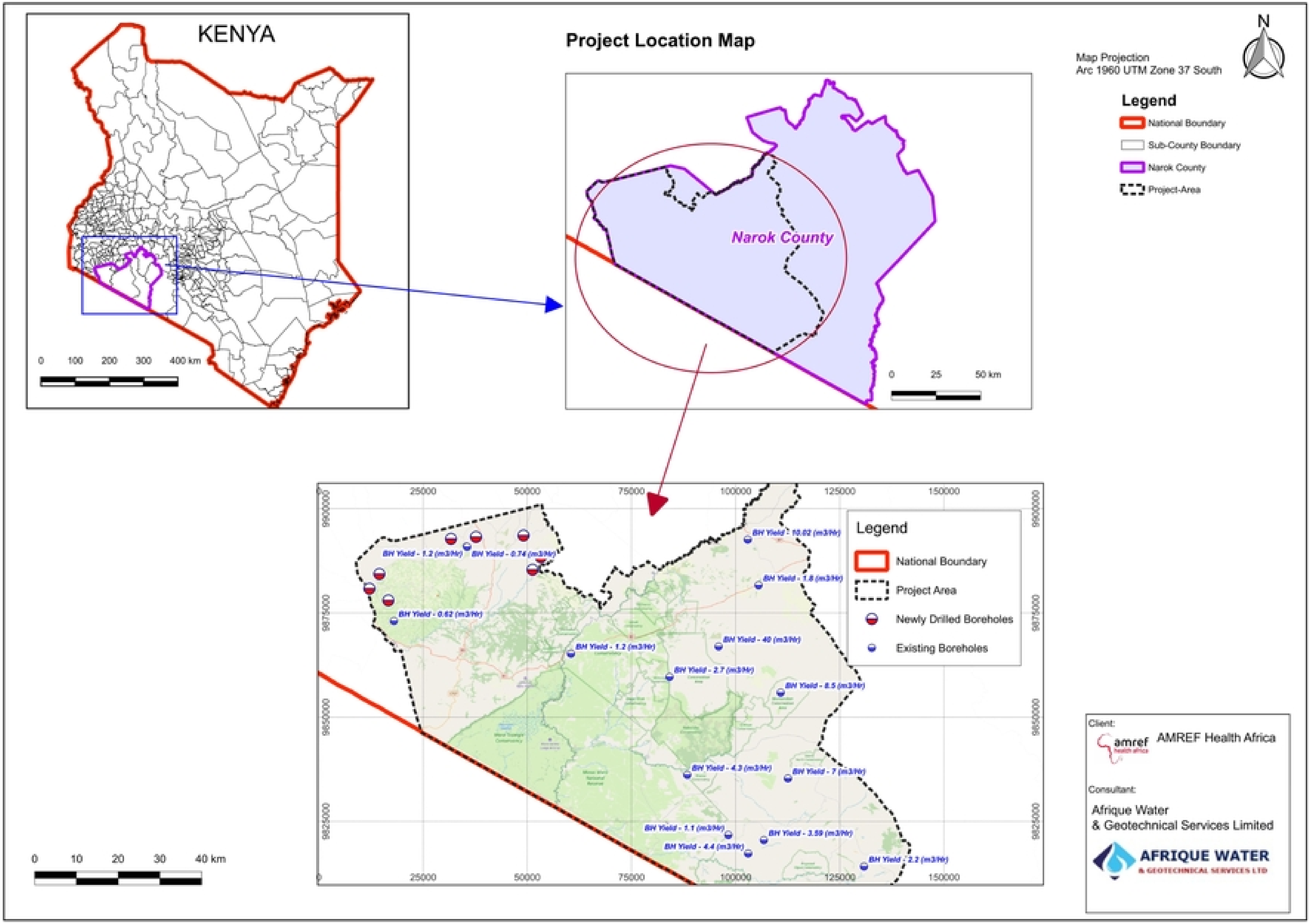
S9 Fig: Soil map of the study area – Narok West and Transmara West sub-counties

S10 Fig: NDVI map of the study area – Narok West and Transmara West sub-counties

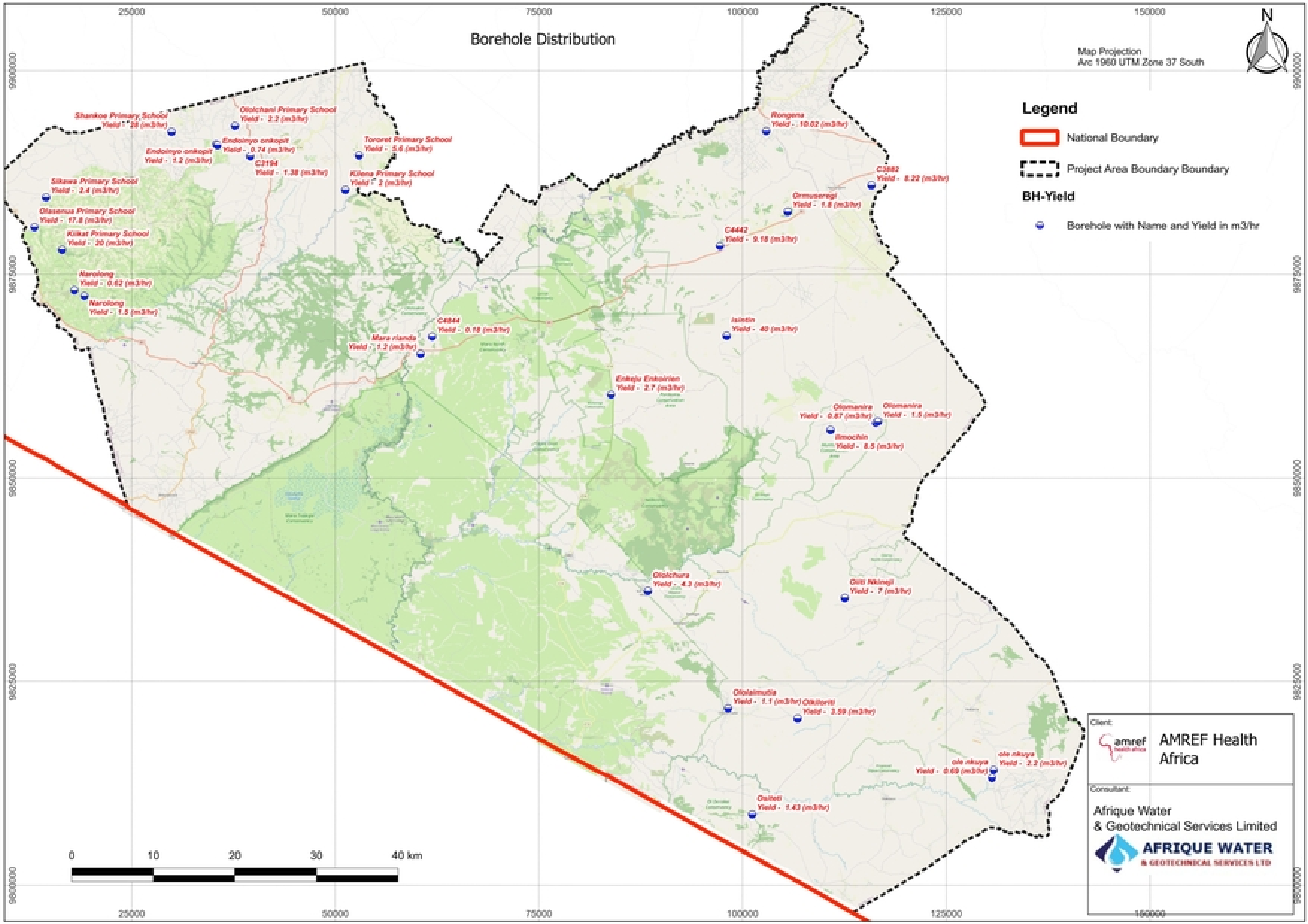
S11 Fig: Drainage density map of the study area – Narok West and Transmara West sub-counties

S12 Fig: Groundwater potential map of the study area – Narok West and Transmara West sub-counties

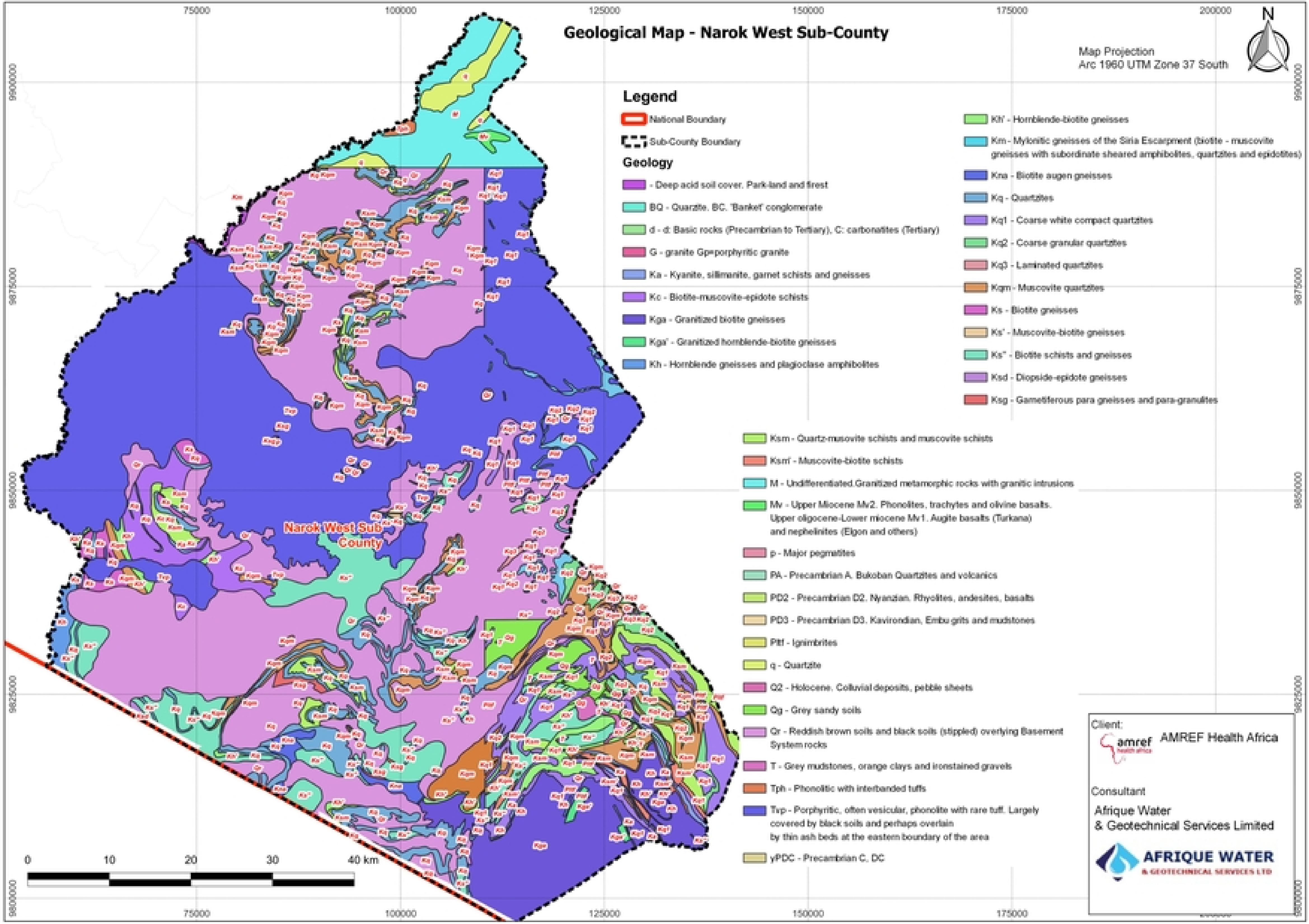
S1 Table: the results from the water quality analysis in sampled boreholes


KENYA
0 100 200 300 400 km
Project Location Map
Narok County
0 25 50 km
Map Projection
Arc 1960 UTM Zone 37 South
N
Legend
National Boundary
Sub-County Boundary
Narok County
Project-Area
Legend
National Boundary
Project Area
Newly Drilled Boreholes
Existing Boreholes
BH Yield - 10.02 (m3/Hr)
BH Yield - 1.2 (m3/Hr)
BH Yield - 0.74 (m3/Hr)
BH Yield - 1.8 (m3/Hr)
BH Yield - 0.62 (m3/Hr)
BH Yield - 40 (m3/Hr)
BH Yield - 1.2 (m3/Hr)
BH Yield - 2.7 (m3/Hr)
BH Yield - 8.5 (m3/Hr)
BH Yield - 4.3 (m3/Hr)
BH Yield - 7 (m3/Hr)
BH Yield - 1.1 (m3/Hr)
BH Yield - 3.59 (m3/Hr)
BH Yield - 4.4 (m3/Hr)
BH Yield - 2.2 (m3/Hr)
0 10 20 30 40 km
Client:
AMREF Health Africa
Consultant:
Afrique Water
& Geotechnical Services Limited
AFRIQUE WATER

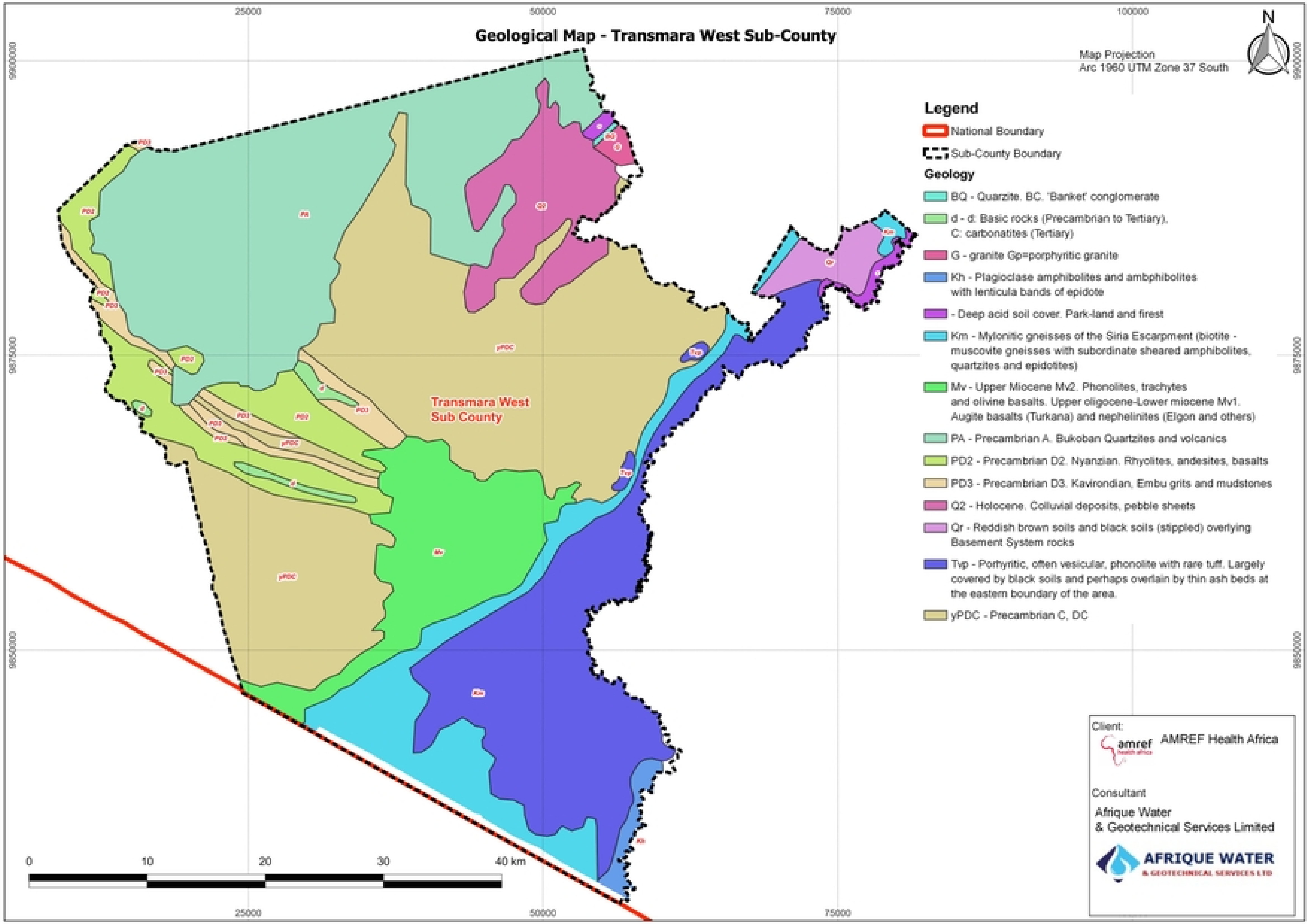
S1_Figure


Borehole Distribution
N
Map Projection
Arc 1960 UTM Zone 37 South
Legend
National Boundary
Project Area Boundary Boundary
BH-Yield
Borehole with Name and Yield in m3/hr
Shankoe Primary School
Yield - 20 (m3/hr)
Ololchani Primary School
Yield - 2.2 (m3/hr)
Endoinyo onkopit
Yield - 0.74 (m3/hr)
Endoinyo onkopit
Yield - 1.2 (m3/hr)
C3194
Yield - 1.38 (m3/hr)
Tororet Primary School
Yield - 5.6 (m3/hr)
Kilena Primary School
Yield - 2 (m3/hr)
Sikawa Primary School
Yield - 2.4 (m3/hr)
Olasenua Primary School
Yield - 17.8 (m3/hr)
Kilkat Primary School
Yield - 20 (m3/hr)
Narolong
Yield - 0.62 (m3/hr)
Narolong
Yield - 1.5 (m3/hr)
C4844
Yield - 0.18 (m3/hr)
Mara rianda
Yield - 1.2 (m3/hr)
Rongena
Yield - 10.02 (m3/hr)
C3882
Yield - 8.22 (m3/hr)
Ormuseregi
Yield - 1.8 (m3/hr)
C4442
Yield - 9.18 (m3/hr)
Isinin
Yield - 40 (m3/hr)
Enkeju Enkoirien
Yield - 2.7 (m3/hr)
Olomanira
Yield - 0.87 (m3/hr)
Olomanira
Yield - 1.5 (m3/hr)
Ilmochin
Yield - 8.5 (m3/hr)
Ololchura
Yield - 4.3 (m3/hr)
Oiti Nkineji
Yield - 7 (m3/hr)
Ololaimutia
Yield - 1.1 (m3/hr)
Olkiloriti
Yield - 3.59 (m3/hr)
ole nkuya
Yield - 0.69 (m3/hr)
ole nkuya
Yield - 2.2 (m3/hr)
Osilteti
Yield - 1.43 (m3/hr)
0 10 20 30 40 km
25000 50000 75000 100000 125000 150000
9900000 9875000 9850000 9825000 9800000
Client:
AMREF Health Africa
Consultant:
Afrique Water
& Geotechnical Services Limited
AFRIQUE WATER
& GEOTECHNICAL SERVICES LTD

S2_Figure

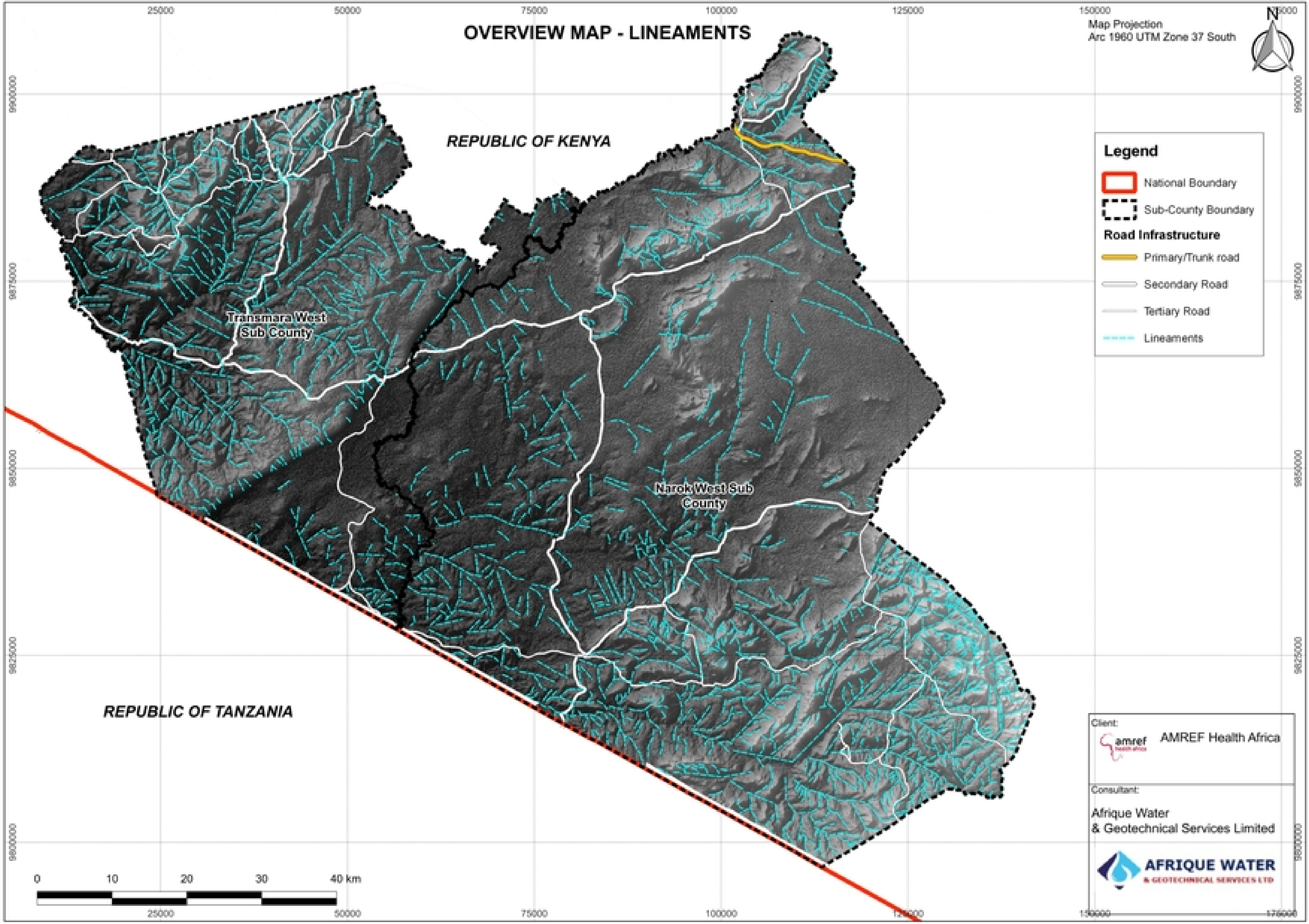

Geological Map - Narok West Sub-County
Map Projection
Arc 1960 UTM Zone 37 South
N
Legend
National Boundary
Sub-County Boundary
Geology
- Deep acid soil cover. Park-land and forest
BQ - Quartzite. BC. 'Banket' conglomerate
d - d: Basic rocks (Precambrian to Tertiary), C: carbonatites (Tertiary)
G - granite Gp=porphyritic granite
Ka - Kyanite, sillimanite, garnet schists and gneisses
Kc - Biotite-muscovite-epidote schists
Kga - Granitized biotite gneisses
Kga' - Granitized hornblende-biotite gneisses
Kh - Hornblende gneisses and plagioclase amphibolites
Kh' - Hornblende-biotite gneisses
Km - Mylonitic gneisses of the Siria Escarpment (biotite - muscovite gneisses with subordinate sheared amphibolites, quartzites and epidotites)
Kna - Biotite augen gneisses
Kq - Quartzites
Kq1 - Coarse white compact quartzites
Kq2 - Coarse granular quartzites
Kq3 - Laminated quartzites
Kqm - Muscovite quartzites
Ks - Biotite gneisses
Ks' - Muscovite-biotite gneisses
Ks'' - Biotite schists and gneisses
Ksd - Diopside-epidote gneisses
Ksg - Garnetiferous para gneisses and para-granulites
Ksm - Quartz-muscovite schists and muscovite schists
Ksm' - Muscovite-biotite schists
M - Undifferentiated.Granitized metamorphic rocks with granitic intrusions
Mv - Upper Miocene Mv2. Phonolites, trachytes and olivine basalts. Upper oligocene-Lower miocene Mv1. Augite basalts (Turkana) and nephelinites (Elgon and others)
p - Major pegmatites
PA - Precambrian A. Bukoban Quartzites and volcanics
PD2 - Precambrian D2. Nyanzian. Rhyolites, andesites, basalts
PD3 - Precambrian D3. Kavirondian, Embu grits and mudstones
Pltf - Ignimbrites
q - Quartzite
Q2 - Holocene. Colluvial deposits, pebble sheets
Qg - Grey sandy soils
Qr - Reddish brown soils and black soils (stippled) overlying Basement System rocks
T - Grey mudstones, orange clays and ironstained gravels
Tph - Phonolitic with interbanded tuffs
Tvp - Porphyritic, often vesicular, phonolite with rare tuff. Largely covered by black soils and perhaps overlain by thin ash beds at the eastern boundary of the area
yPDC - Precambrian C. DC
Narok West Sub-County
0
10
20
30
40 km
75000
100000
125000
150000
175000
200000
9900000
9875000
9850000
9825000
9800000
Client:
AMREF Health Africa
Consultant
Afrique Water
& Geotechnical Services Limited

S3_Figure



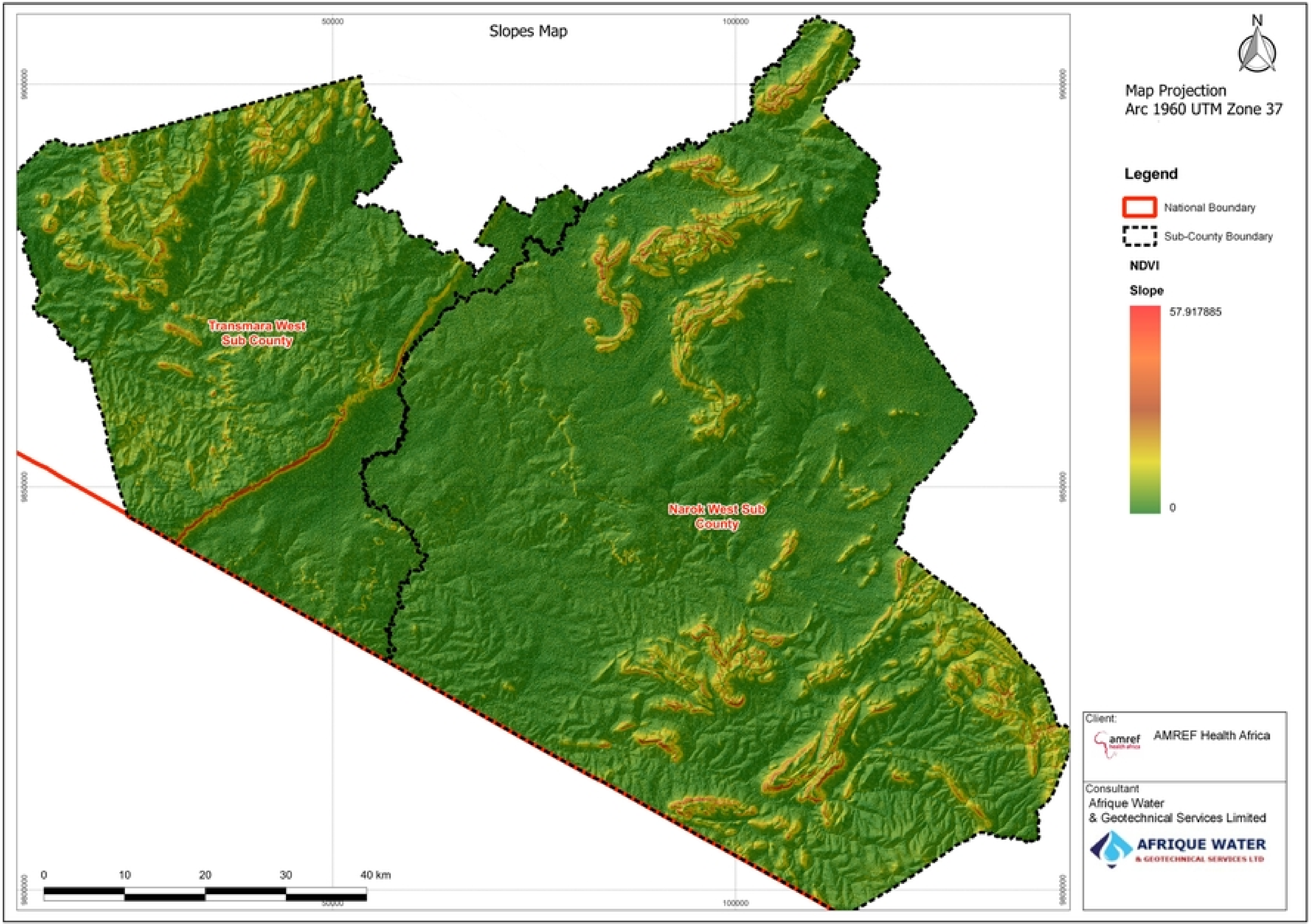
Geological Map - Transmara West Sub-County
Map Projection
Arc 1960 UTM Zone 37 South
N
Legend
National Boundary
Sub-County Boundary
Geology
BQ - Quarzite. BC. 'Banket' conglomerate
d - d: Basic rocks (Precambrian to Tertiary), C: carbonatites (Tertiary)
G - granite Gp=porphyritic granite
Kh - Plagioclase amphibolites and ambphibolites with lenticula bands of epidote
- Deep acid soil cover. Park-land and firest
Km - Mylonitic gneisses of the Siria Escarpment (biotite - muscovite gneisses with subordinate sheared amphibolites, quartzites and epidotites)
Mv - Upper Miocene Mv2. Phonolites, trachytes and olivine basalts. Upper oligocene-Lower miocene Mv1. Augite basalts (Turkana) and nephelinites (Elgon and others)
PA - Precambrian A. Bukoban Quartzites and volcanics
PD2 - Precambrian D2. Nyanzian. Rhyolites, andesites, basalts
PD3 - Precambrian D3. Kavirondian, Embu grits and mudstones
Q2 - Holocene. Colluvial deposits, pebble sheets
Qr - Reddish brown soils and black soils (stippled) overlying Basement System rocks
Tvp - Porhyritic, often vesicular, phonolite with rare tuff. Largely covered by black soils and perhaps overlain by thin ash beds at the eastern boundary of the area.
yPDC - Precambrian C, DC
Transmara West Sub County
25000
50000
75000
100000
9900000
9875000
9850000
0
10
20
30
40 km
Client:
amref health africa
AMREF Health Africa
Consultant
Afrique Water & Geotechnical Services Limited
AFRIQUE WATER & GEOTECHNICAL SERVICES LTD

S4_Figure

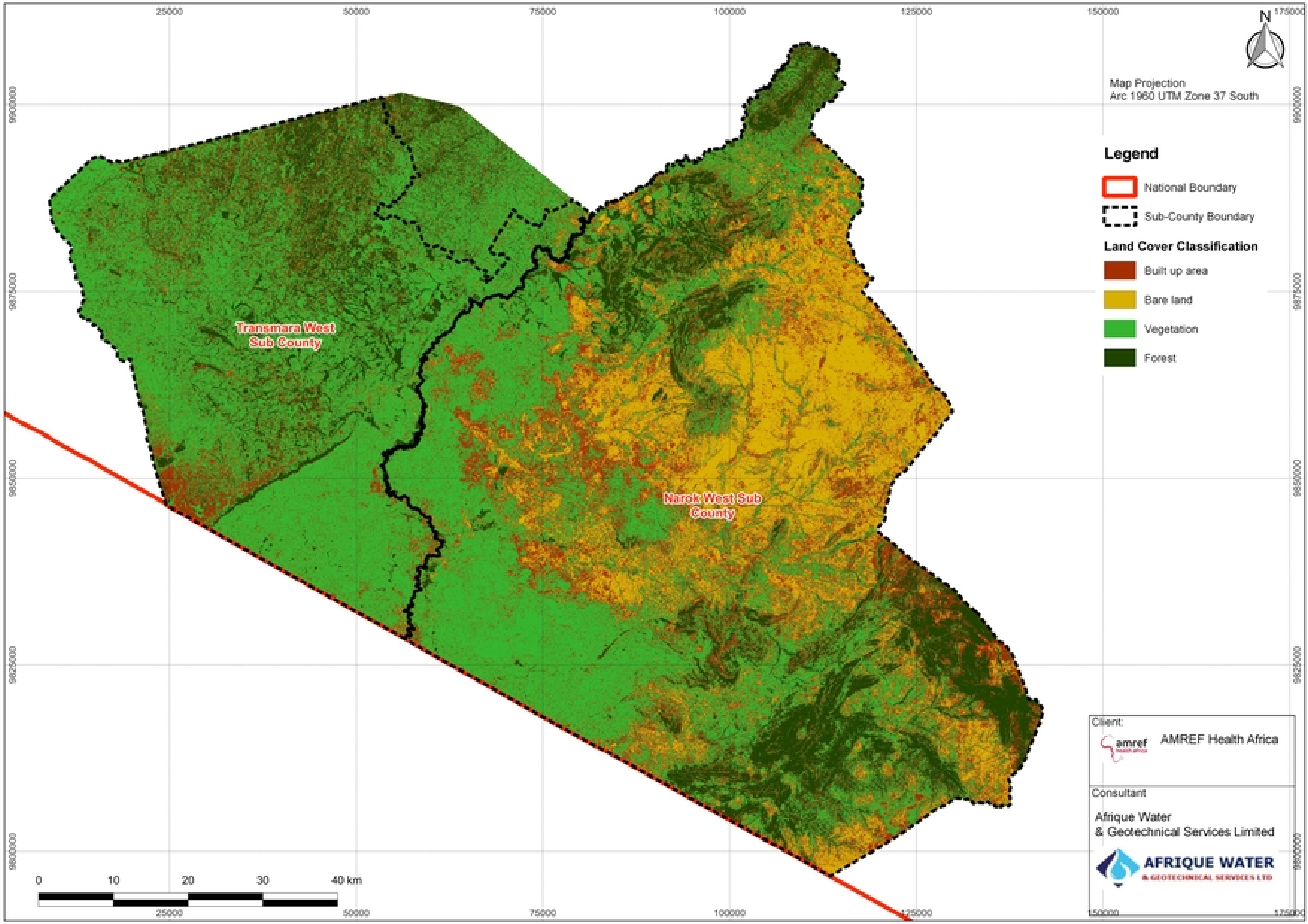


OVERVIEW MAP - LINEAMENTS
Map Projection
Arc 1960 UTM Zone 37 South
N
REPUBLIC OF KENYA
REPUBLIC OF TANZANIA
Transmara West Sub County
Narok West Sub County
Legend
National Boundary
Sub-County Boundary
Road Infrastructure
Primary/Trunk road
Secondary Road
Tertiary Road
Lineaments
Client:
AMREF Health Africa
Consultant:
Afrique Water
& Geotechnical Services Limited
AFRIQUE WATER
& GEOTECHNICAL SERVICES LTD
0
10
20
30
40 km
25000
50000
75000
100000
125000
150000
175000
9900000
9875000
9850000
9825000
9800000

S5_Figure

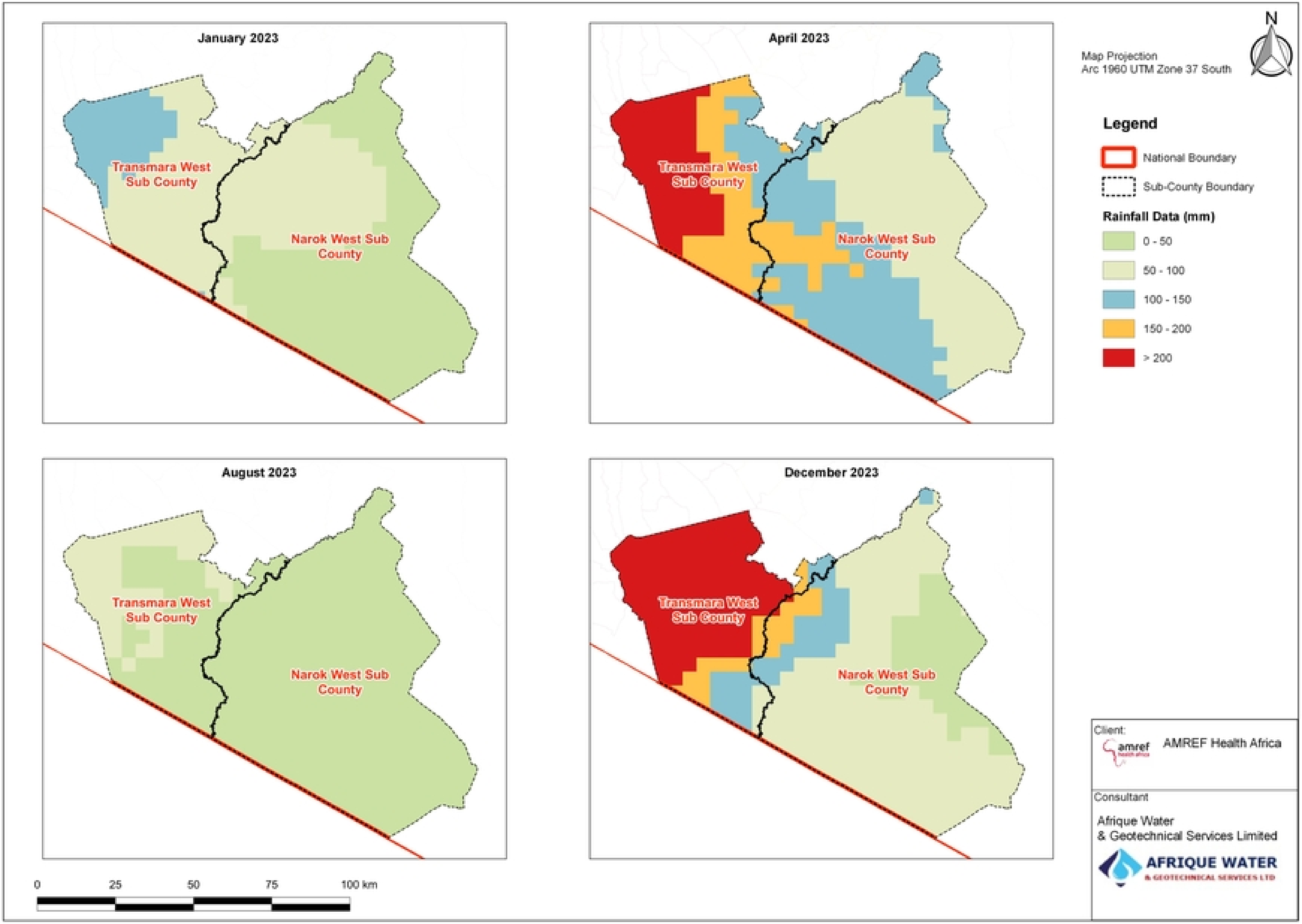

Slopes Map
Transmara West Sub County
Narok West Sub County
N
Map Projection
Arc 1960 UTM Zone 37
Legend
National Boundary
Sub-County Boundary
NDVI
Slope
57.917885
0
Client:
AMREF Health Africa
Consultant
Afrique Water
& Geotechnical Services Limited
AFRIQUE WATER
0
10
20
30
40 km

S7_Figure

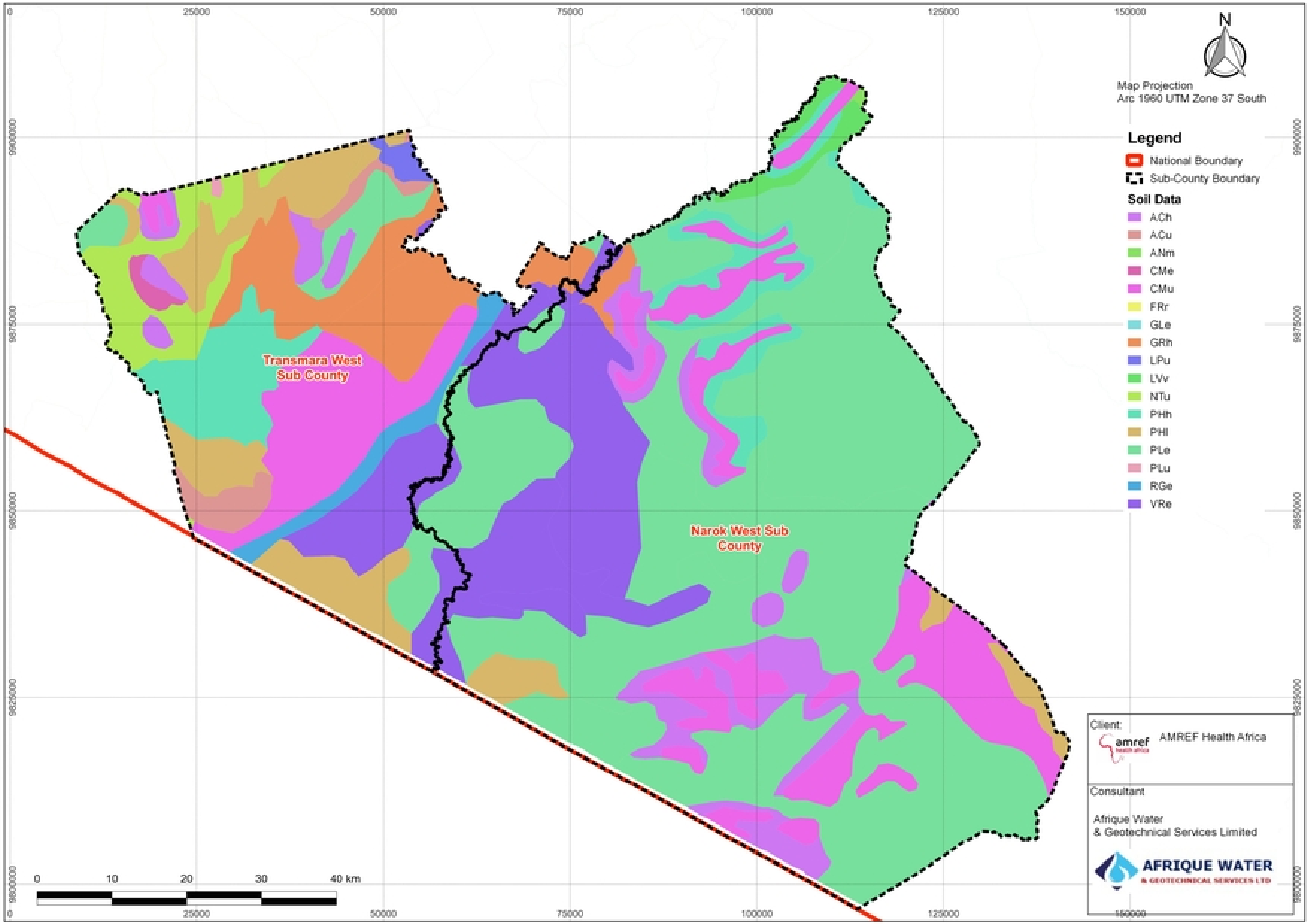


N
Map Projection
Arc 1960 UTM Zone 37 South
Legend
National Boundary
Sub-County Boundary
Land Cover Classification
Built up area
Bare land
Vegetation
Forest
Transmara West
Sub County
Narok West Sub
County
Client:
AMREF Health Africa
Consultant
Afrique Water
& Geotechnical Services Limited
AFRIQUE WATER
0
10
20
30
40 km
25000
50000
75000
100000
125000
150000
175000
9900000
9875000
9850000
9825000
9800000

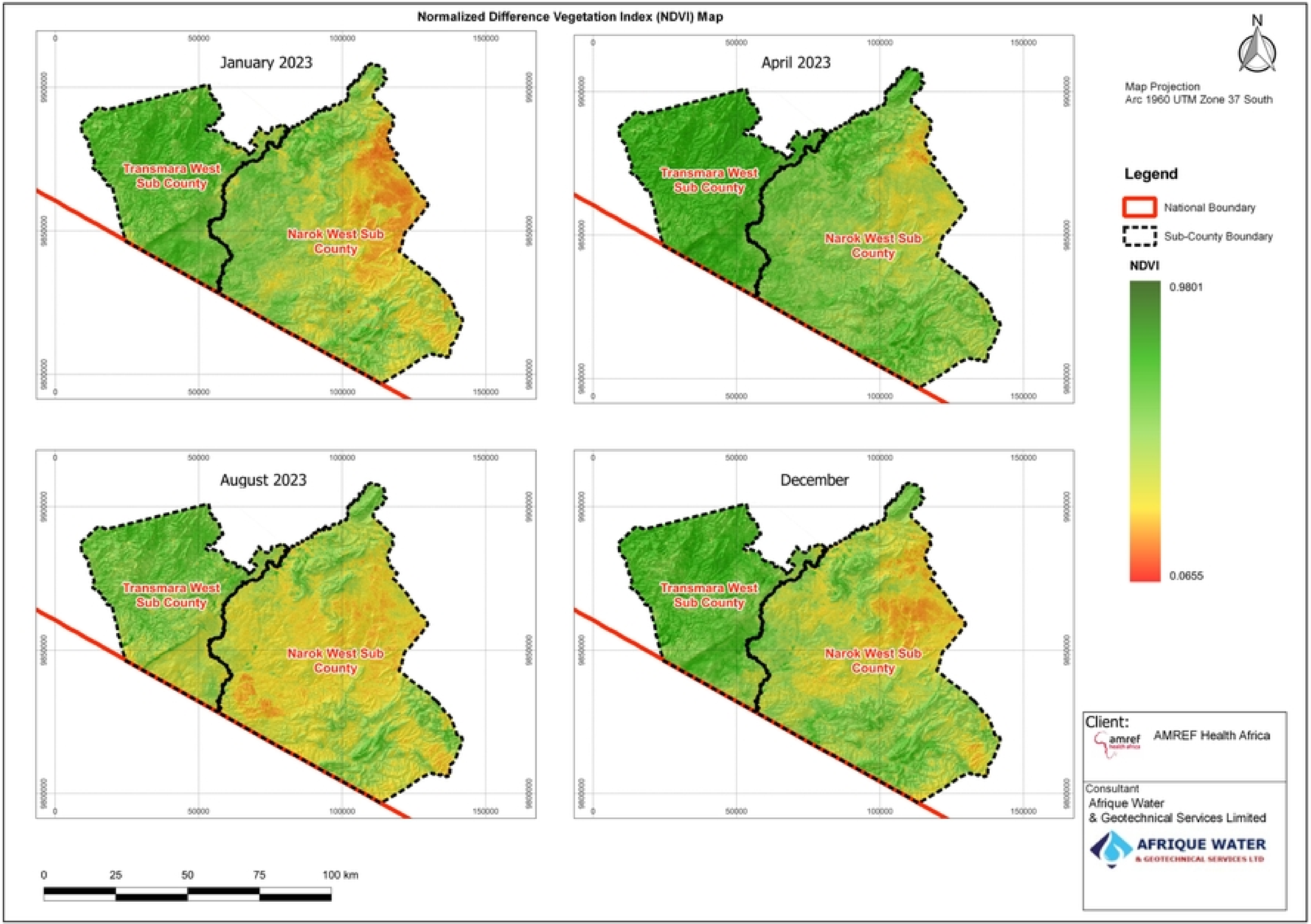
S6_Figure


January 2023
April 2023
August 2023
December 2023
Transmara West Sub County
Narok West Sub County
N
Map Projection
Arc 1960 UTM Zone 37 South
Legend
National Boundary
Sub-County Boundary
Rainfall Data (mm)
0 - 50
50 - 100
100 - 150
150 - 200
> 200
0
25
50
75
100 km
Client:
AMREF Health Africa
Consultant
Afrique Water
& Geotechnical Services Limited
AFRIQUE WATER

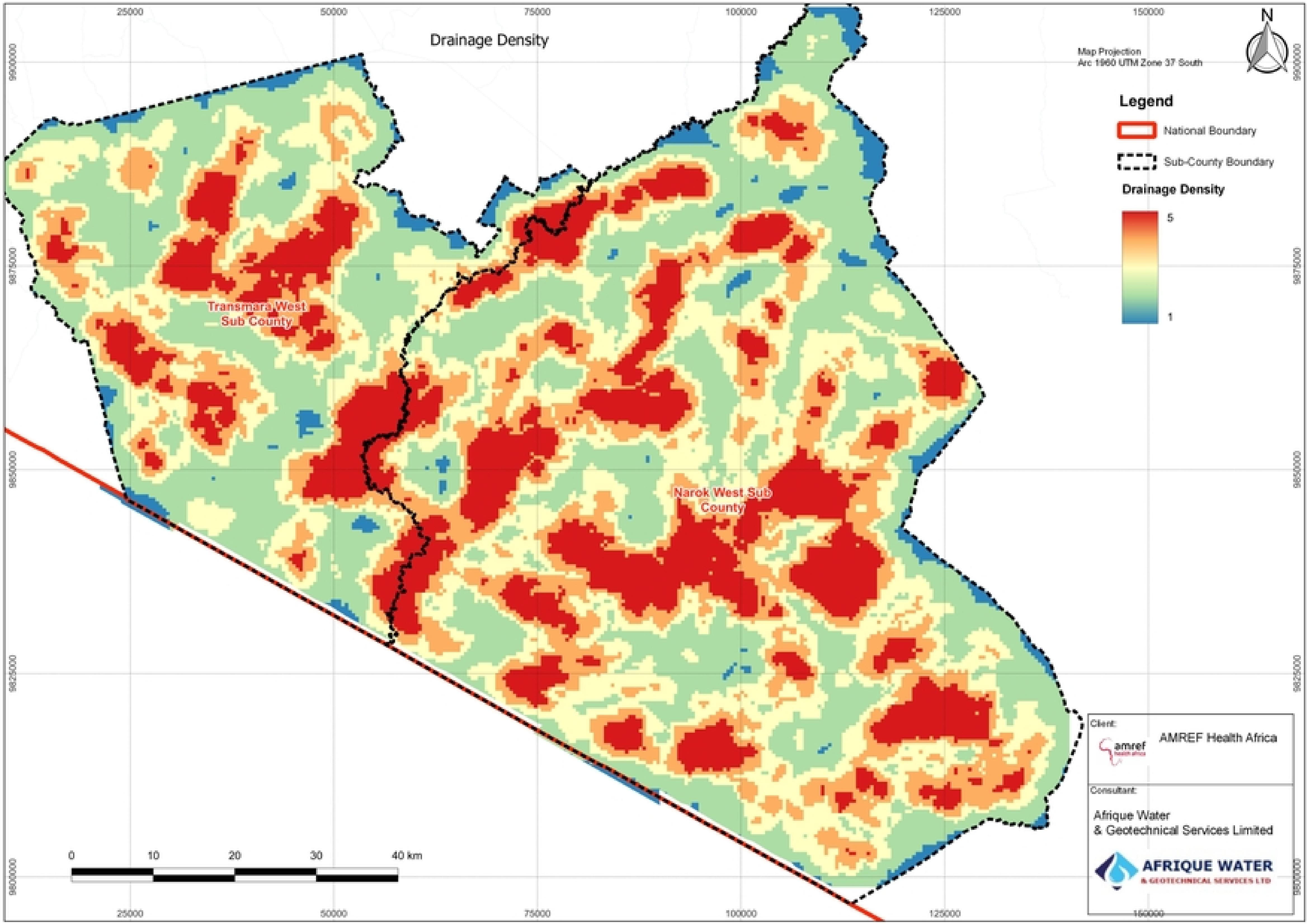
S8_Figure


0
25000
50000
75000
100000
125000
150000
9900000
9875000
9850000
9825000
9800000
N
Map Projection
Arc 1960 UTM Zone 37 South
Legend
National Boundary
Sub-County Boundary
Soil Data
ACh
ACu
ANm
CMe
CMu
FRr
GLe
GRh
LPu
LVv
NTu
PHh
PHl
PLe
PLu
RGe
VRe
Transmara West Sub County
Narok West Sub County
0
10
20
30
40 km
Client:
AMREF Health Africa
Consultant
Afrique Water
& Geotechnical Services Limited
AFRIQUE WATER

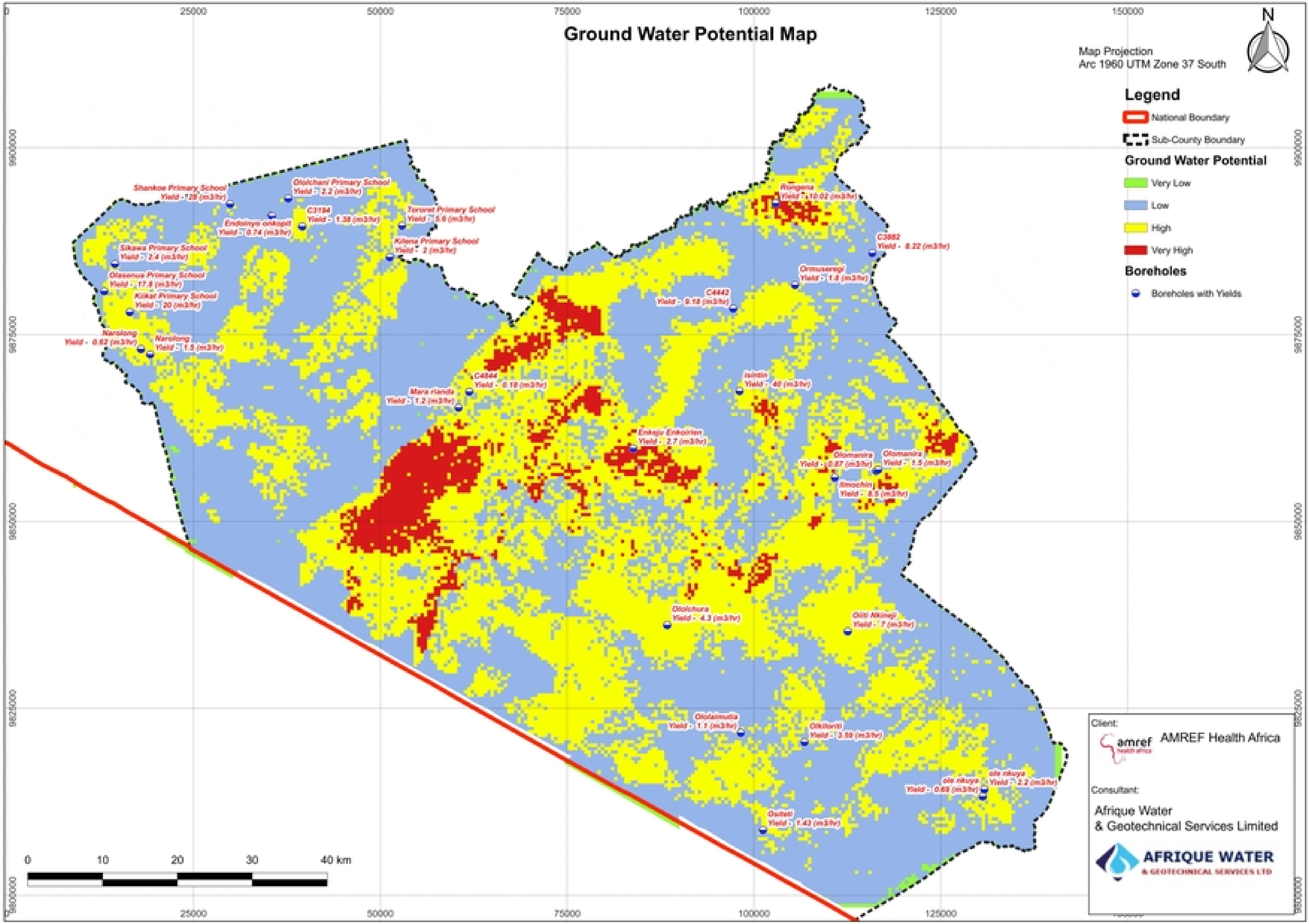
S9_Figure


Normalized Difference Vegetation Index (NDVI) Map
January 2023
April 2023
August 2023
December
Transmara West Sub County
Narok West Sub County
Map Projection
Arc 1960 UTM Zone 37 South
Legend
National Boundary
Sub-County Boundary
NDVI
0.9801
0.0655
0 25 50 75 100 km
Client:
AMREF Health Africa
Consultant
Afrique Water & Geotechnical Services Limited

S10_Figure


Drainage Density
Map Projection
Arc 1960 UTM Zone 37 South
N
Legend
National Boundary
Sub-County Boundary
Drainage Density
5
1
Transmara West Sub County
Narok West Sub County
Client:
AMREF Health Africa
Consultant:
Afrique Water
& Geotechnical Services Limited
AFRIQUE WATER
0
10
20
30
40 km
25000
50000
75000
100000
125000
150000
9900000
9875000
9850000
9825000
9800000

S11_Figure



Ground Water Potential Map
N
Map Projection
Arc 1960 UTM Zone 37 South
Legend
National Boundary
Sub-County Boundary
Ground Water Potential
Very Low
Low
High
Very High
Boreholes
Boreholes with Yields
Shankoe Primary School Yield - 28 (m3/hr)
Ololchani Primary School Yield - 2.2 (m3/hr)
Endoinyo onkopit Yield - 0.74 (m3/hr)
C3194 Yield - 1.38 (m3/hr)
Tororet Primary School Yield - 5.6 (m3/hr)
Kilena Primary School Yield - 2 (m3/hr)
Sikawa Primary School Yield - 2.4 (m3/hr)
Olasenua Primary School Yield - 17.8 (m3/hr)
Kilkat Primary School Yield - 20 (m3/hr)
Narolong Yield - 0.62 (m3/hr)
Narolong Yield - 1.5 (m3/hr)
C4844 Yield - 0.18 (m3/hr)
Mara rianda Yield - 1.2 (m3/hr)
Rongena Yield - 10.02 (m3/hr)
C3882 Yield - 8.22 (m3/hr)
Ormuseregi Yield - 1.8 (m3/hr)
C4442 Yield - 9.18 (m3/hr)
Isintin Yield - 40 (m3/hr)
Enkeju Enkoirien Yield - 2.7 (m3/hr)
Olomanira Yield - 0.87 (m3/hr)
Olomanira Yield - 1.5 (m3/hr)
Ilmochin Yield - 8.5 (m3/hr)
Ololchura Yield - 4.3 (m3/hr)
Oiiti Nkinej Yield - 7 (m3/hr)
Ololaimutia Yield - 1.1 (m3/hr)
Olkiloriti Yield - 3.59 (m3/hr)
ole nkuya Yield - 0.69 (m3/hr)
ole nkuya Yield - 2.2 (m3/hr)
Osilteti Yield - 1.43 (m3/hr)
0 10 20 30 40 km
Client:
AMREF Health Africa
Consultant:
Afrique Water
& Geotechnical Services Limited
AFRIQUE WATER

S12_Figure