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Integrated techniques for groundwater prospecting in Arochukwu, Abia state Nigeria

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Abstract
The study integrated Remote Sensing and Vertical electrical sounding techniques in the delineation of groundwater potential zone in the study area. It employed Landsat 7 ETM^+ imagery of 30m resolution, topographic and geologic maps of the area. These were analyzed in a GIS environment to obtain the thematic maps of groundwater indicating factors. furthermore, Ffifteen VES data were acquired from various points within the study area using the Schlumberger electrode array, at a maximum spread of AB/2 = 400 and MN/2 = 50 and Ohmega Resistivity meter. The correlations between the results from the two techniques were used to establish areas of good or otherwise low – moderate groundwater potentials. The result indicated a resistive region at the uplands and conductive region at the lowlands. Aquifer resistivity, aquifer thickness and transverse resistivity were high at Ihechiowa, Umuzumgbo, Ugwuakuma, Eziama, Ututu, Ameke Abam, while they recorded poor - moderate values at the low lands of Ndi Okorie, Ndi Okereke, Amuvi and Amanagwu. High storability for aquifers at the uplands suggesting sustainable aquifer yield to boreholes and good aquifer potentials in the region were inferred. This study establishes that fact that the two techniques can be effectively used for groundwater assessment.

Keywords: Remote sensing, Ihechiowa, Abam, Groundwater potentials, Aquifer

Introduction

The demand for groundwater resource is continuously increasing with the advancement of industrialization and population growth. Hence, assessment, planning and management of groundwater resources become a crucial and essential issue. Moreover, the need for the adoption and implementation of effective methodological tools that will aid in identifying, observing, measuring and delineating all possible features connected with localization of groundwater has become vital if we must overcome the challenge of water scarcity in remote areas (Raju *et al.*, 2017) [16].

Remote sensing has been an effective tool that play vital role in exploration and assessment of groundwater. Remote sensing and GIS techniques have wide applications in detecting, monitoring, assessing, conservation and in other fields of groundwater related studies. They facilitate time and have the advantage of being cost effective. They are able to rapidly assess groundwater resource, which otherwise through traditional method becomes very costly, laborious and time consuming (Jha *et al.*, 2010 [11]; Arkoprovo *et al.*, 2012 [3]; Davoodi *et al.*, 2015) [5]. The necessity of remote sensing based groundwater exploration is to demarcate and delineate all possible features connected with localization of groundwater. These features are extracted from the appropriate satellite data products and integrated with the thematic details obtained from topographic sheets of a desired scale and used for groundwater assessment. This study is aimed at identifying the potential areas where groundwater can be explored in Arochukwu area using integrated techniques of remote sensing and geo-electrical method.

Remote sensing provides multi-spectral, multi-temporal and multi-sensor data of the earth's surface (Rashid *et al.*, 2011) [17]. One of the advantages of using remote sensing and GIS for hydrological investigations and monitoring is its ability to generate information in spatial and temporal domain, which is very crucial for successful predication and validation. Remote sensing is providing useful base-line information in conjunction with ground water truths on soils, land use, vegetation, surface and ground water, geology, landforms, topography and settlements in the regional prospective (Senthil and Shankar, 2014 [18]; Ibrahim-Bathis and Ahmed, 2016) [10]. It involves the integration of spatially referenced data in a problem solving environment. Unlike conventional methods, its methods for demarcation of suitable areas for groundwater replenishment takes into account the diversity of factors that control groundwater recharge and occurrence.

Although the advantages of managing groundwater resources through geospatial technology cannot be overemphasized, the use of conventional methods is still relevant. However, its use becomes an uneasy task when applied in the study of surface parameters of large areas in an attempt to identify suitable sites for groundwater resource development. More so, since many controlling parameters must be independently derived and integrated, it may involve additional cost, time and manpower. Modern remote sensing technologies have many advantages over older, conventional methods due to their synoptic coverage, improved spatial resolution, and their capabilities for multi-spectral and multi-temporal analysis (Prabhu and Venkateswaranb, 2015).

Classical geophysical methods of exploration such as seismic refraction, electromagnetic methods, and electrical resistivity have become the widely used techniques for groundwater exploration. They have been implored by (Awosika *et al.*, 2020 [4]; Fajana, 2020 [8]; Joel *et al.*, 2020 [12]; Raji and Abdulkadir, 2020) [15]. These methods can determine aquifer characteristics, storage, and transmission. The resistivity geophysical approach is used as the key to exploration because it can give detailed information about the subsurface layer by passing electrical current down the subsurface. It also reduces the possibility of financial losses through the drilling of abortive wells. Recently, it stands out as the most commonly used technique of groundwater exploration since it gives valuable information about the aquifer characteristics. (Sunkari *et al*., 2021) [19].

The study area is found within latitudes 5º 22' 48" N - 5º 39'.52"N and longitudes 7º 30' 19" E - 7º 54' 17"E. It is underlain by three major geological formations; the false bedded Ajali sandstones, the Imo shale and the Nsukka Formation (Fig. 5). It falls within the south-eastern part of the Anambra basin, within the Deltaic marine sediment of Cretaceous to recent age. The three major geological formations in the area are; the false bedded Ajali sandstones which stands out to be the most promising formation for groundwater recharge, the Imo shale and the Nsukka Formation (Adindu and Akoma, 2023) [2]. The challenge to groundwater resource development in this area due to its characteristic Shale Formations has necessitated this study. Therefore this study seeks to use integrated techniques of remote sensing and geo-electrical method for groundwater prospecting in Arochukwu watershed.

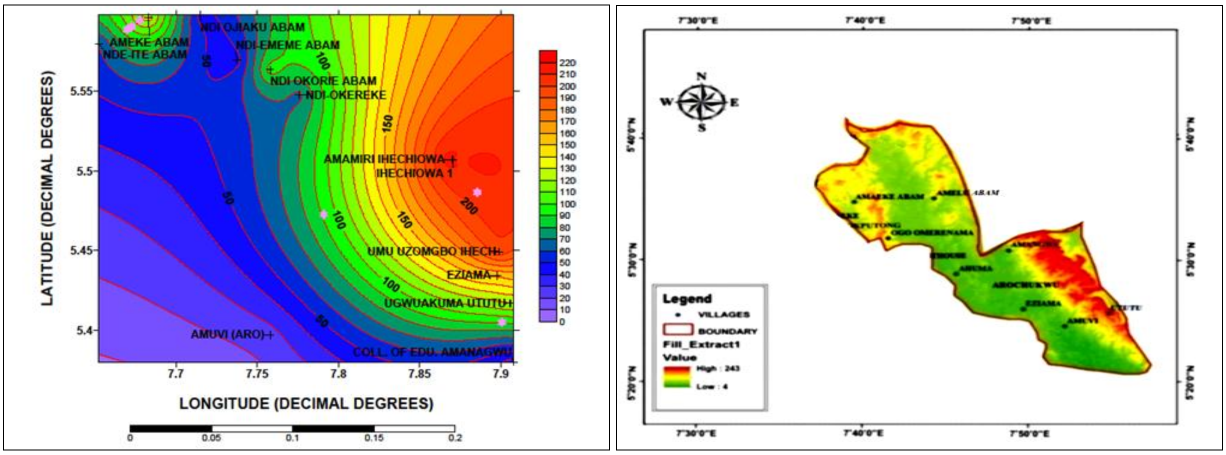
Materials and method

The study integrated Remote Sensing and Vertical electrical sounding techniques in the delineation of groundwater potential zone in the study area. It employed Landsat 7 ETM^+ imagery of 30m resolution, topographic and geologic maps of the area. Edge enhancement, stretching, high pass filter and directional filtering were applied to data using ERDAS IMAGINE software. This was done to enhance the image quality and resolution. Maximum likelihood classification scheme (MLCS) was employed and the Resulting imagery was then exported to ArcGIS software where it was integrated with the Shuttle Radar Topographic Mission (SRTM) data and ancillary data to generate thematic maps of drainage, geomorphology, geology, lineament, slope maps of the study area.

Then fifteen VES data were acquired from various points within the study area using the Schlumberger electrode array, at a maximum spread of AB/2 = 400 and MN/2 = 50 and Ohmega Resistivity meter. Current was sent into the subsurface through the current electrodes and the resulting potential difference at each of the locations was measured. From the field data, the apparent resistivity (ρ_a) of the soil materials was calculated. The ρ_a values were processed using the RESIST software, to obtain geo-electric layer parameters. The layer parameters were further used to map aquifer units. Contour maps of the geo-electric parameters were generated using Surfer 11 software. The result was then integrated with that obtained from Remote sensing technique to delineate the groundwater potential zones and distribution in the area.

Results

Figures (1- 10) presents the results from both techniques in a pictorial form. Each map describes the extent of the contribution of a parameter to groundwater occurrence in the area using color gradations. The maps were visually inspected and evaluated for groundwater potential distributions in the area.



(a) (b)

Fig 1: Elevation map of the area from (a) VES (b) Remote Sensing technique

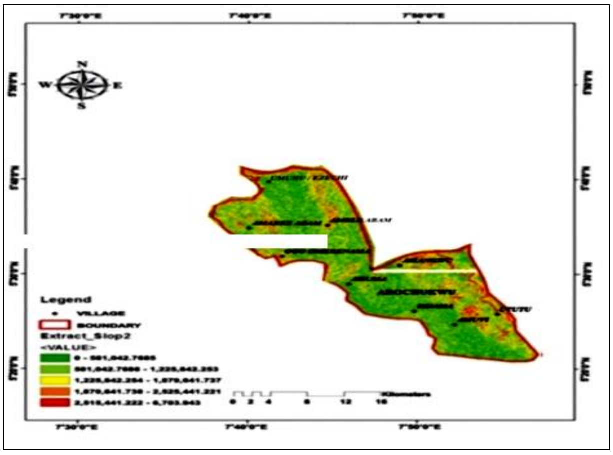


Fig 2: Slope map of the area

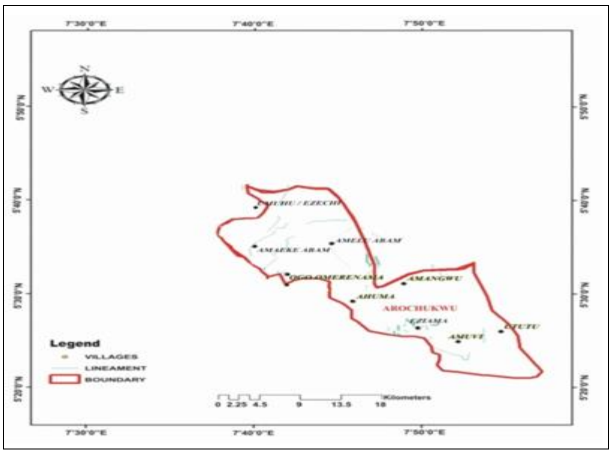


Fig 3: Lineament map of the area

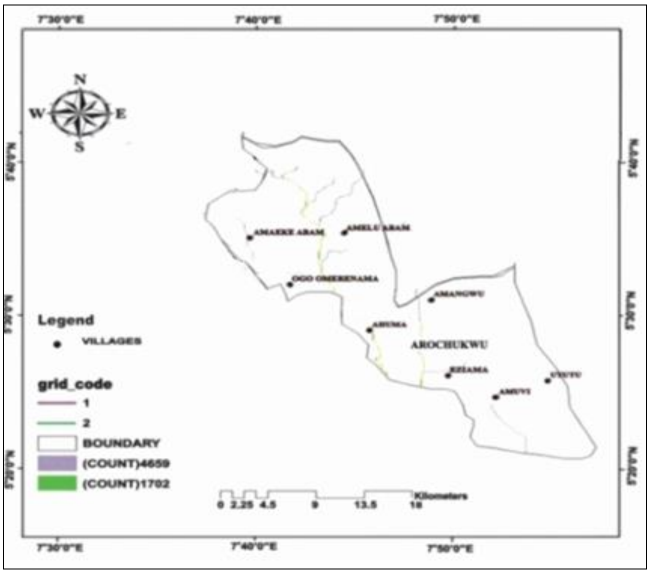


Fig 4: Drainage map of the area

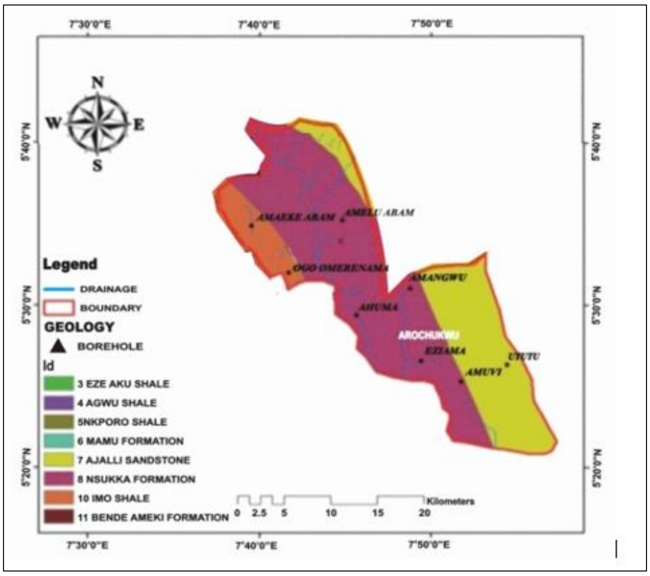


Fig 5: Geology map of the area

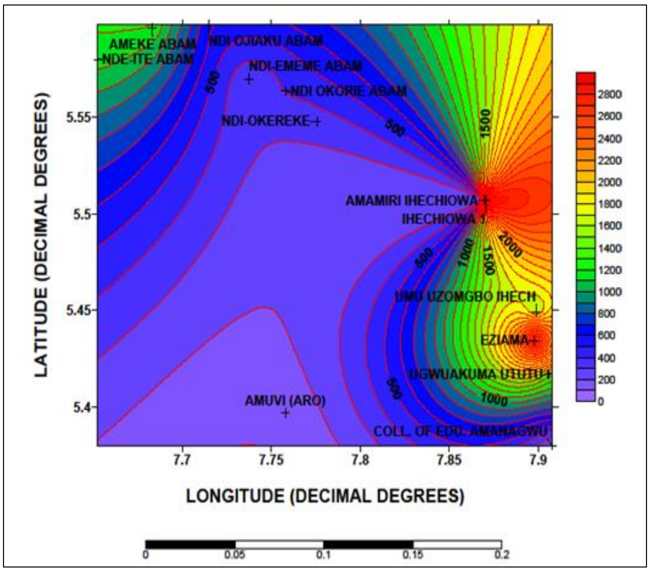


Fig 6: Aquifer resistivity map of the area

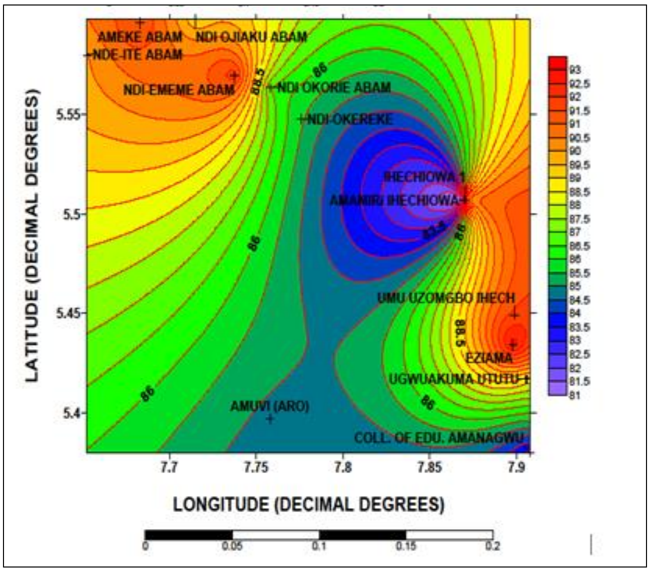


Fig 7: Aquifer thickness map of the area

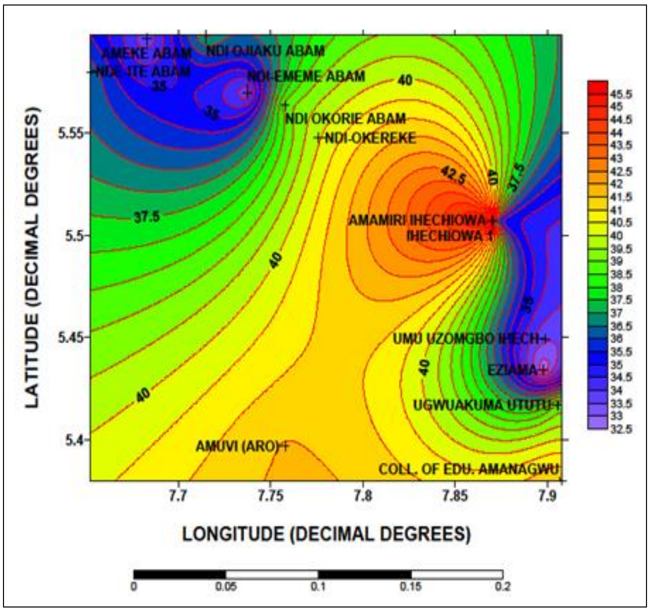


Fig 8: Aquifer depth map of the area

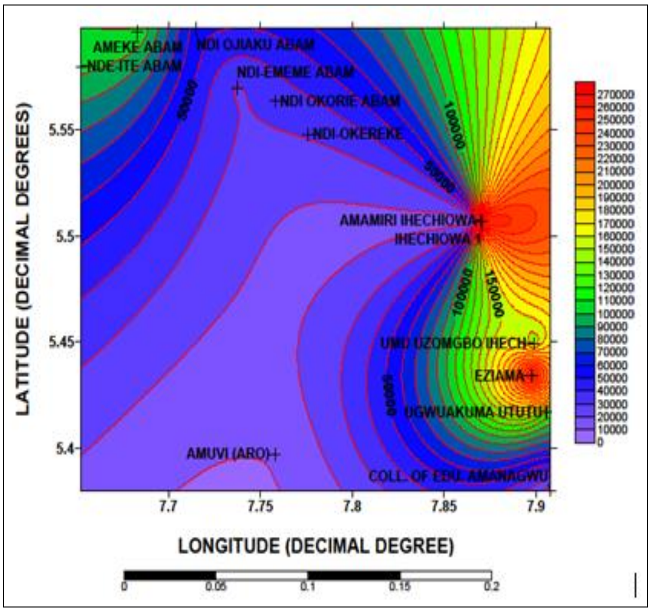
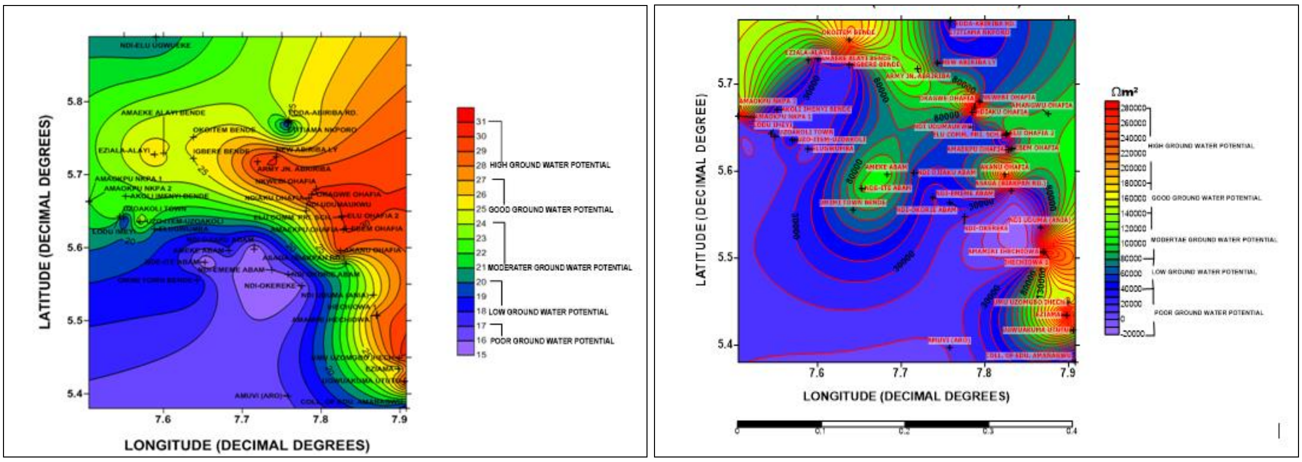


Fig 9: Aquifer transverse resistance map



(a) (b)

Fig 10: Groundwater potential map (a): from Remote Sensing technique (b): from resistivity survey

Discussion

Geomorphology

The study area has generally an undulating topography. The geomorphological features identified in the area are a flat ridge and pediments underlain by the Ajali sandstones, stretching from areas beyond Ihechiowa to Ututu. Their alititudes range from values greater than 100m to 220m in the Northeast – Southeast region (Fig. 1). The valleys and flat plains observed in the Western region are below 100 m above sea level and form floodplains in the area (a portion of land adjacent to a stream or river that stretches from the banks of its channel to the base of the enclosing valley walls and experiences flooding during periods of high discharge (Goudie, 2004) [9]. Within this flood plains, precipitated water is expected to percolate into the ground to recharge groundwater, However, this region is underlain mostly by shale formations and are thereby characterized by poor infiltration and consequently poor recharge thereby having less groundwater potential. Whereas the hilly region underlain by sandstones is a region of good infiltration, recharge and has good groundwater potential.

The drainage pattern of an area is a reflection of the rate at which precipitation infiltrates into the subsurface compared with surface runoff. The infiltration–runoff relationship is controlled largely by permeability, which in turn is a function of the underlying rock type. (Adeniyi and Anifowose (2017) [1]; Edet *et al*., 1998) [7]. The drainage pattern in the study area is both parallel and dendritic in nature and seems to be geomorphologically controlled. Dendritic drainage pattern is found concentrating within the low lying plains of the Abam communities in the northwestern region of the area. This implies a measure of impermeability of the underlying rock material and unfavourable condition for groundwater recharge. The hilly region that are underlain by the Ajali sandstones show low drainage density, indicating favorable condition for groundwater recharge. Kumar (2017) and Obimba *et al*., (2017) [13] noted that areas with higher drainage densities tend to have lower groundwater potential since such areas are usually less porous and less permeable making the loss of groundwater to the surface more prominent.

The resulting output maps of ground water parameters and the potentiality from the Remote sensing approach was further validated by the analyzed VES data. Contour maps of the aquifer parameters from the VES relating to groundwater potentialities of the area are presented in Figures 6 – 10. The resistivity, thickness and transverse resistance are interpreted with respect to aquifer potentials of the areas. Pictorial representation of the final groundwater potential zone maps from the two techniques are presented in Figs. 10 a and 10b. The two data show good correlation with each other in most locations. Elevation of the area in each case indicated an upland region characterized by a ridge-like structure that stretches in a Northwest – Southeast direction, stretching from beyond Ihechiowa to Ututu.

The aquifer resistivity map (Fig. 6) indicated a resistive region that constituted aquifer units in the uplands (northeast - southeast) and conductive region in the North-central – Southern region that are indicative of impermeable beds of shale in the lowlands. This result is attributed to the geology of the area as shown in Fig. 5, thereby correlating the results from the two techniques.

Aquifer thicknesses are high at the uplands (Ihechiowa, Umuzumgbo, Ugwuakuma, Eziama, Ututu, Ameke Abam, Abam), while it is moderate at the low lands of Ndi Okorie, Ndi Okereke, Amuvi and Amanagwu. This implies thick and sustainable aquifer yield to boreholes, high storability for aquifers and good aquifer potentials at the uplands than it is at the low lands. This is attributed also to the underlying lithologic units in these areas.

Again, high transverse resistivity values were delineated at the uplands whereas low values were recorded more in the shale dominated lowlands. From the two techniques, there is a correlation between the results from the two techniques with respect to delineated areas of poor – low ground water potentials (Figs. 10a & 10b). Delineated areas of high ground water potentials from the two techniques include Ihechiowa, Eziama and Ututu and part of the Abam localities (Ndi-Ememe, Ndi Ojiaku) in the northeast – southeast region of the area. Whereas, poor groundwater potentials are delineated around the southern region of the area.

Conclusion

Groundwater potentials of the study area have been evaluated using Remote Sensing and VES techniques. The result of the VES technique was used to validate that of the Remote Sensing. It was observed that there is a correlation between the two techniques. This correlation establishes areas of good or otherwise low – moderate groundwater potentials.

The underlying geology was observed to have played major role in the distribution of groundwater potentials of the area.

Secondly, the lowlands/valleys underlain by shale materials portrayed poor - moderate groundwater potentials. Whereas the highlands typifies good groundwater potentials zones where borehole resource development can be sustained.

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