Supporting Information

Nitrate Source and Transformation in Groundwater under Urban and Agricultural Arid Environment in the Southeastern Nile Delta, Egypt

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Geology

The study area is predominantly characterized by the presence of Quaternary sediments underlain by Tertiary sediments (Figure S1). Stratigraphy and lithology were investigated using drilled boreholes and wells throughout the region[1,2]. The area is occupied by a substantial sedimentary column exceeding 1000 meters in thickness, extending from the Quaternary period to the Tertiary period. This sedimentary column comprises Nile silts, sand dunes, sands, and gravel. Towards the southern and southeastern part of the area, the surface reveals the exposure of the oldest Tertiary rocks, including basalt extrusions and sediments from the Pliocene, Miocene and Oligocene [2,3]. Also, some exposure of Pleistocene sand and gravel with clay intercalations appears at different places in the centre of the investigated area. The study area is covered by Holocene deposits, characterized by silt, sand, and sandy clay deposits with a thickness of 0 to 20 m [4]. In addition, this layer is underlain by the unconsolidated deposits of sand, gravel and clay lenses that comprise the main aquifer.

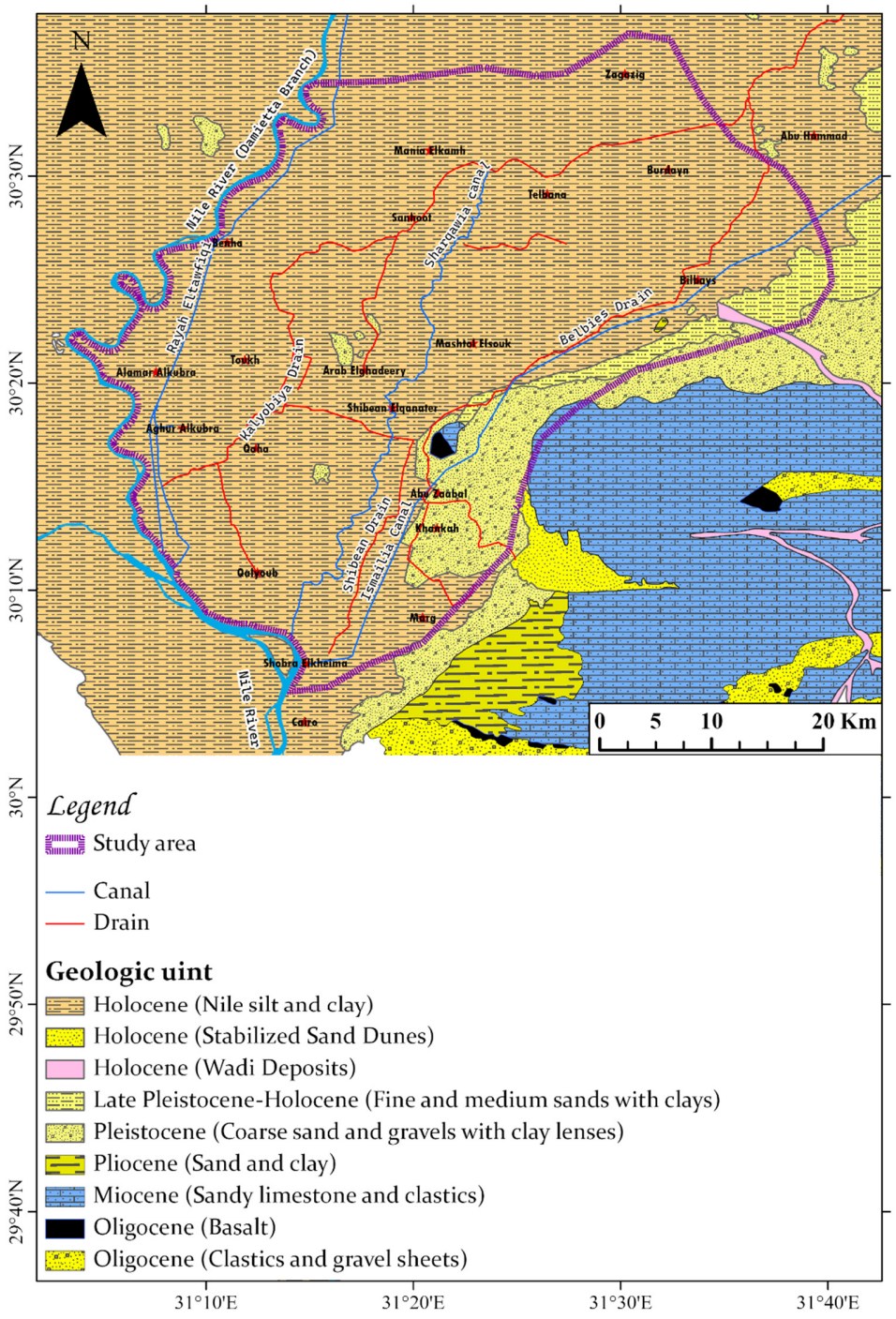

Figure S1. Geology of the southeastern region of the Nile Delta (modified from [2]).

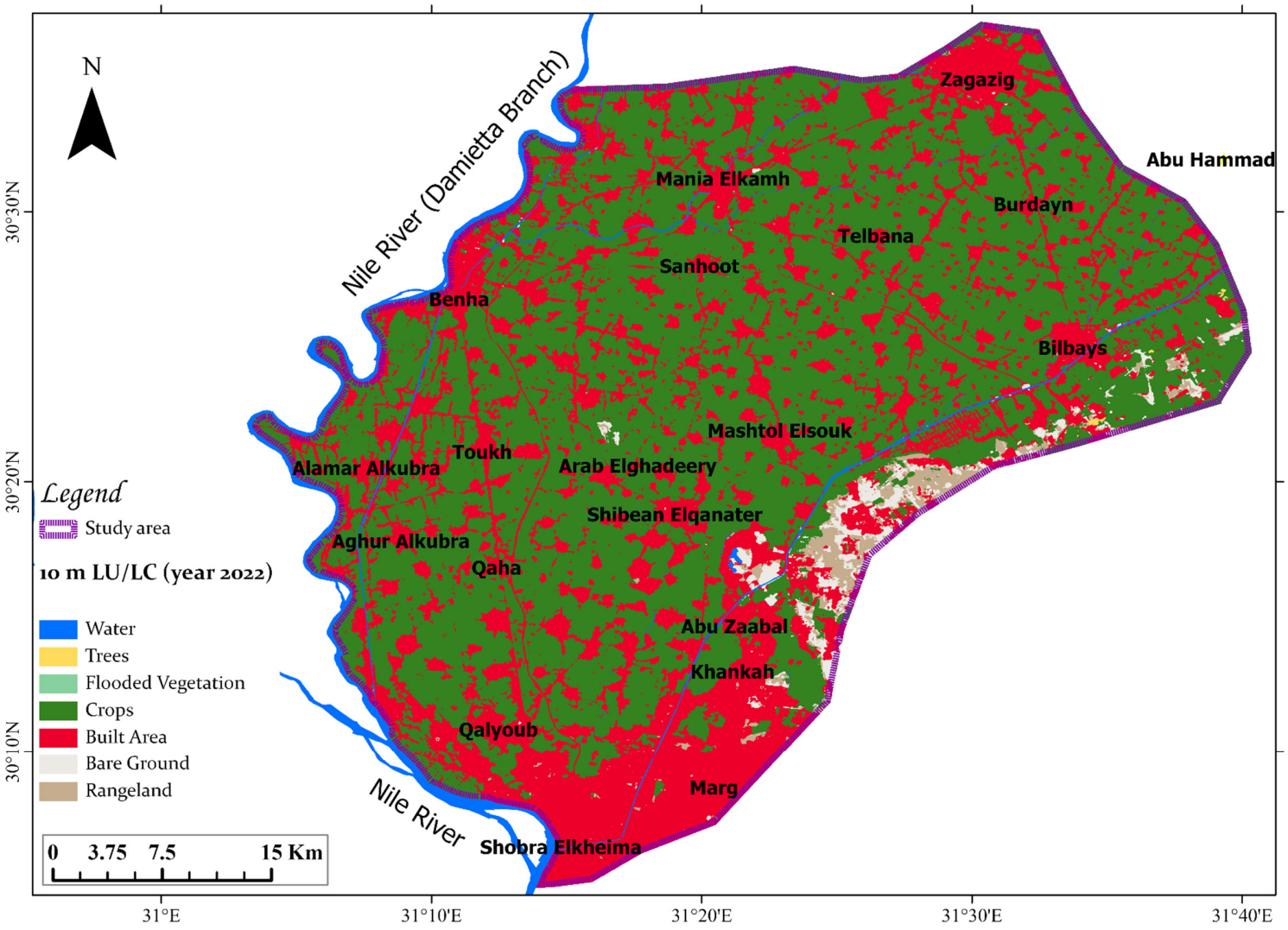

Figure S2. Land use/Land cover (LU/LC) 10 m resolution (year 2022) of the study area (modified from [5]).

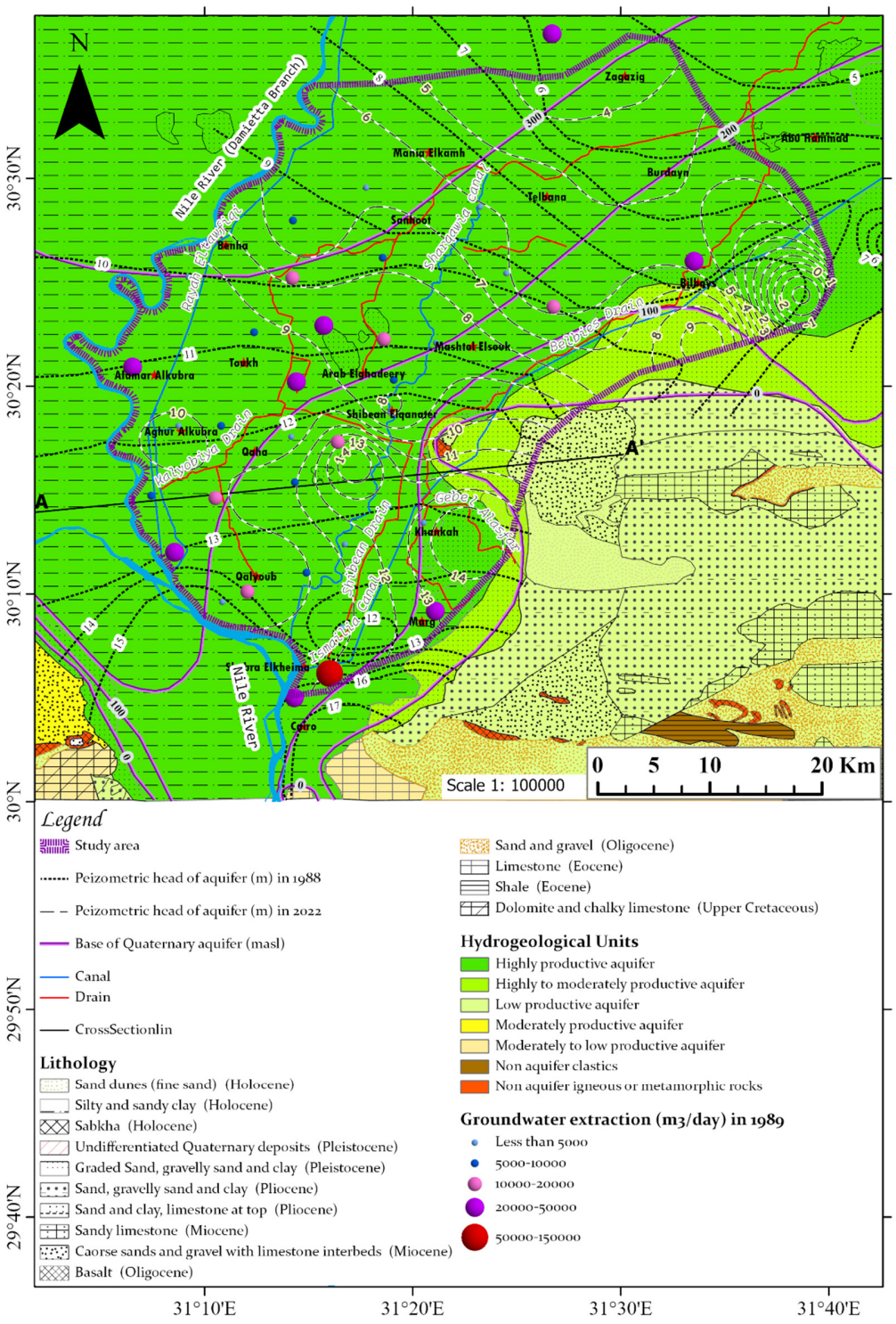

Figure S3. Hydrogeological map of the study area (modified from [4]).

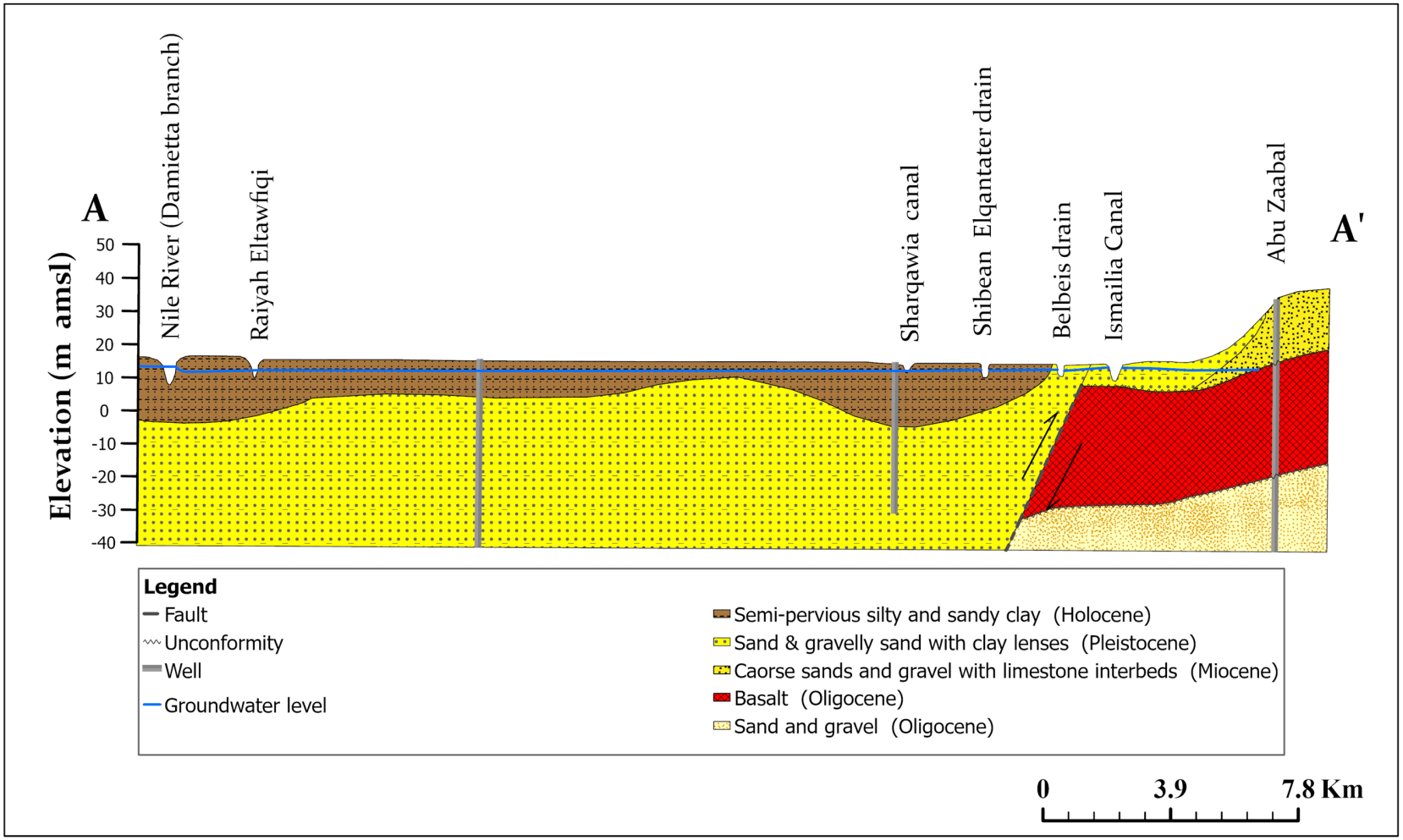

Figure S4. Hydrogeological cross-section A-A' [4].

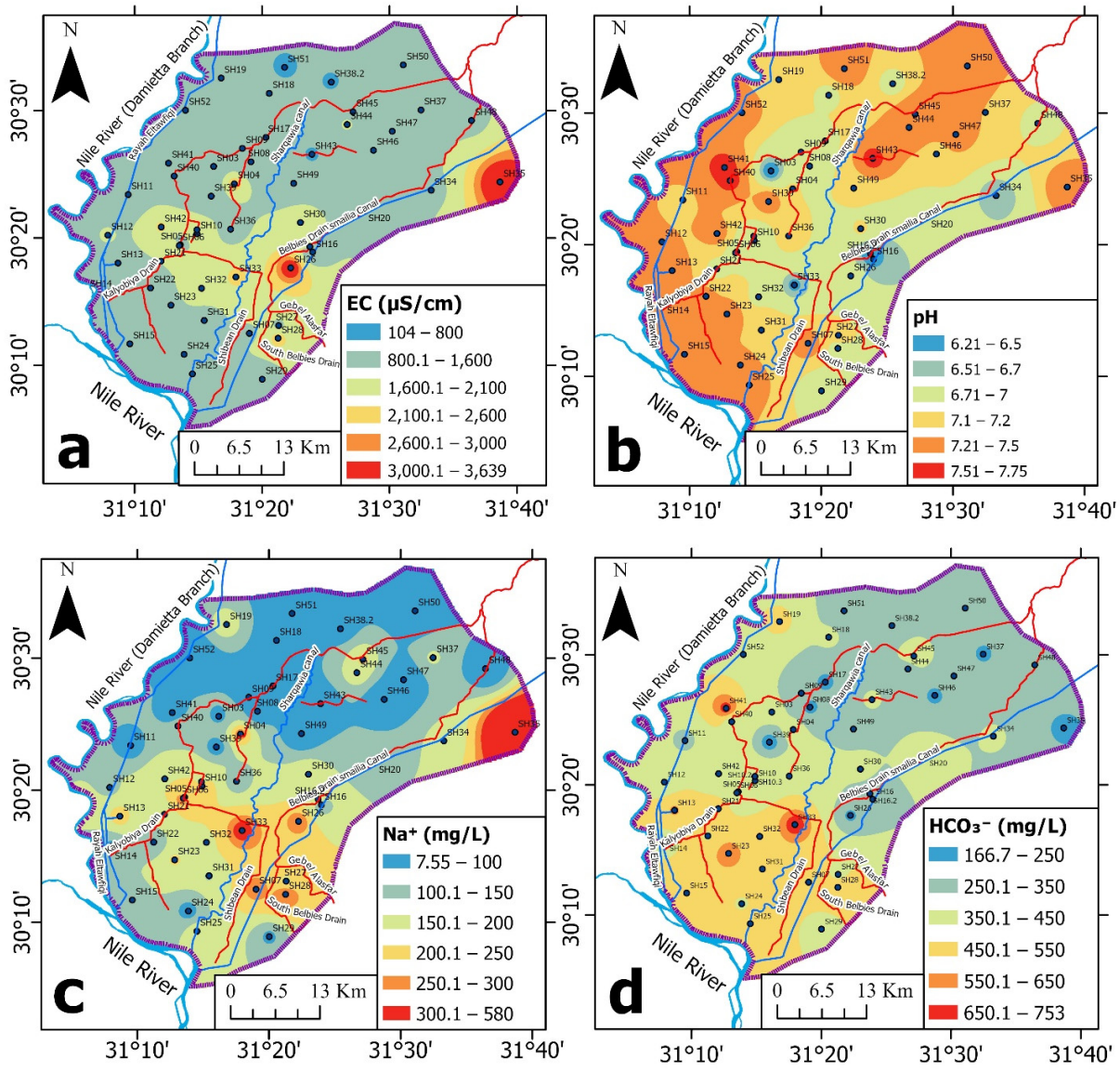

Figure S5. Spatial distribution maps of the groundwater in the study area: (a) EC; (b) pH; (c) Na^{+}; (d) HCO_3^{-}.

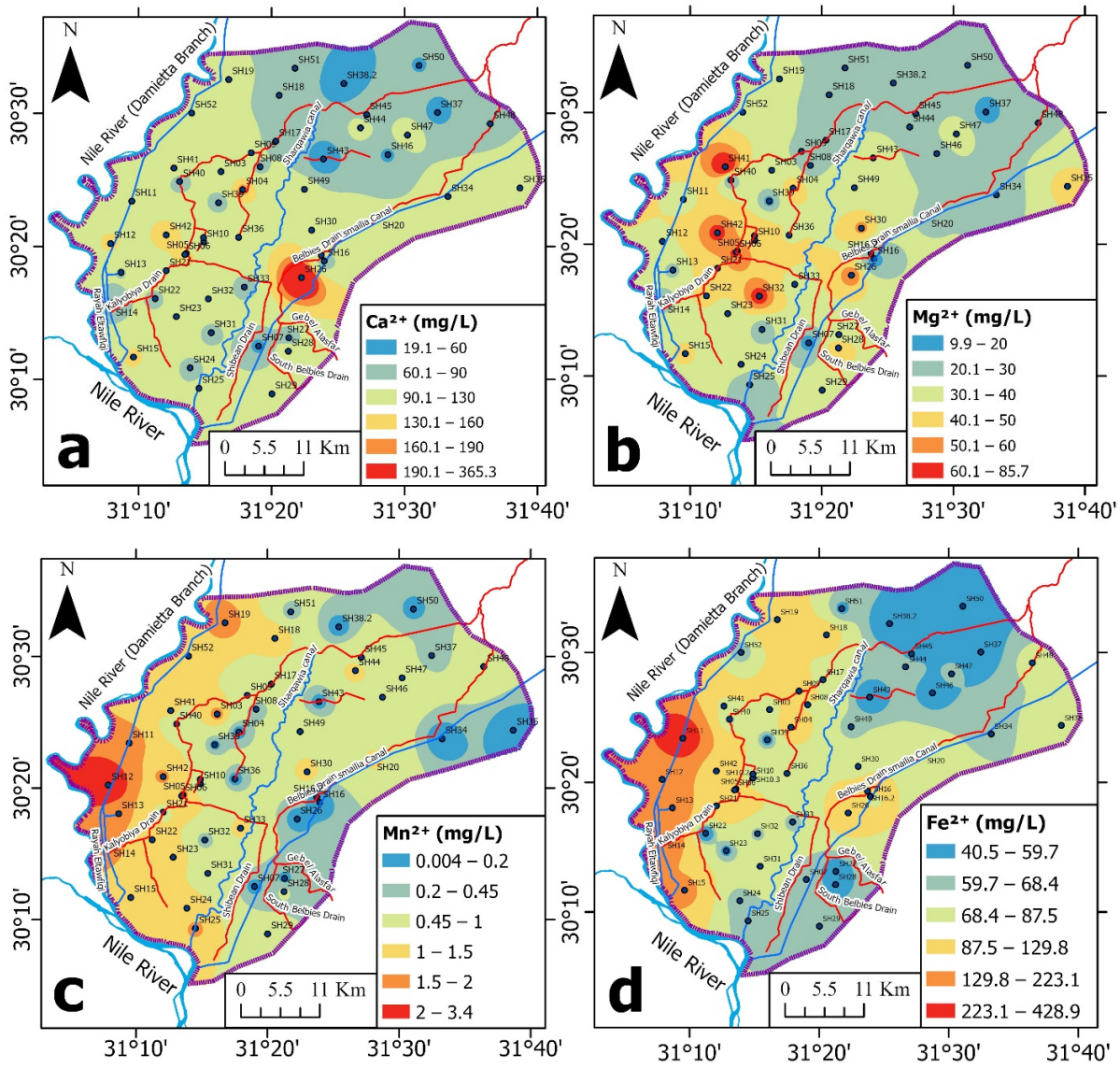

Figure S6. Spatial distribution maps of the groundwater in the study area: (a) Ca^{2+}; (b) Mg^{2+}; (c) Mn^{2+}; (d) Fe^{2+}.

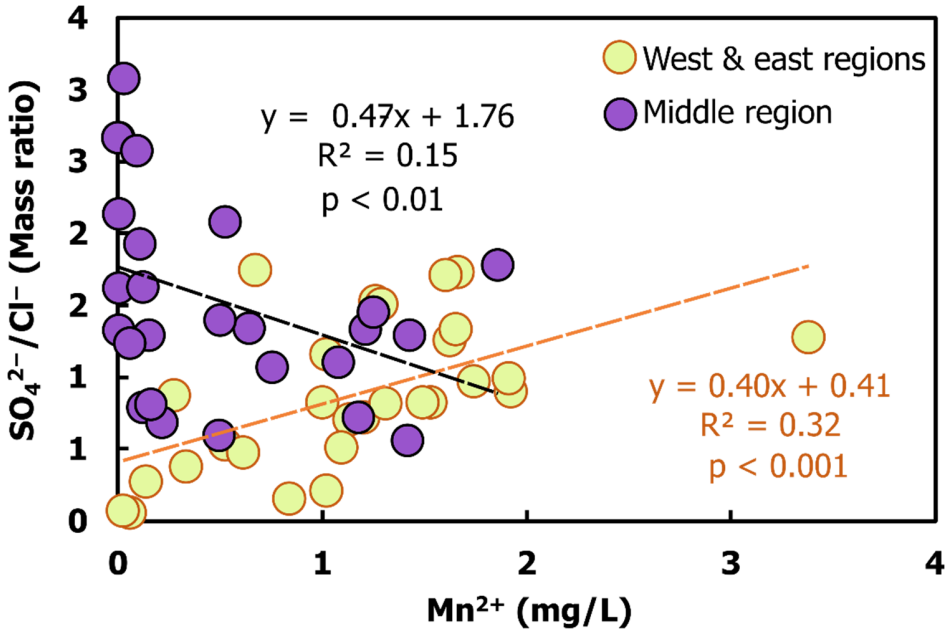

Figure S7. Scatterplot of Mn^{2+} versus SO_4^{2-}/Cl^- of the groundwater in the study area.

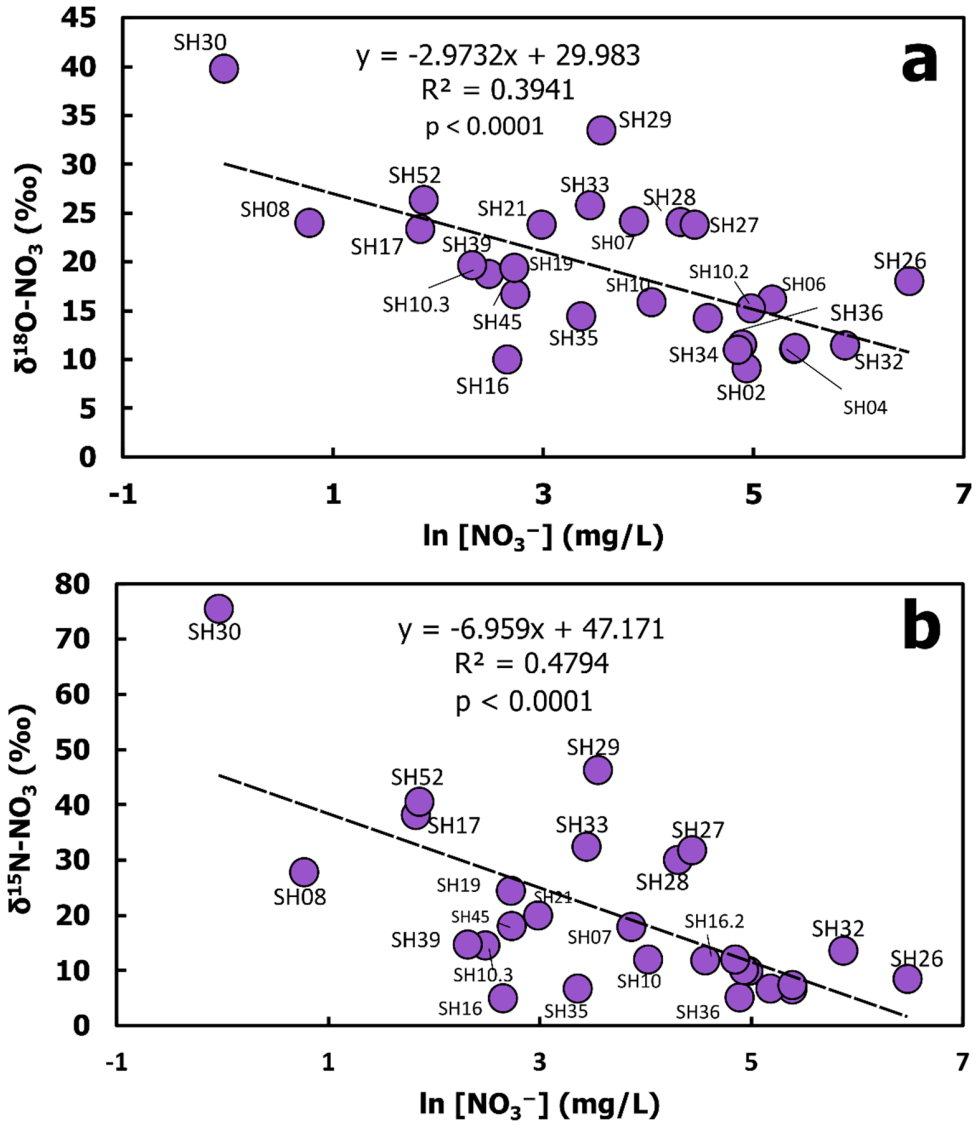

Figure S8. Scatterplot of (a) ln [NO_3^-] versus δ^{18}O-NO_3, (b) ln [NO_3^-] versus δ^{15}N-NO_3 of the groundwater in the middle region of the study area.

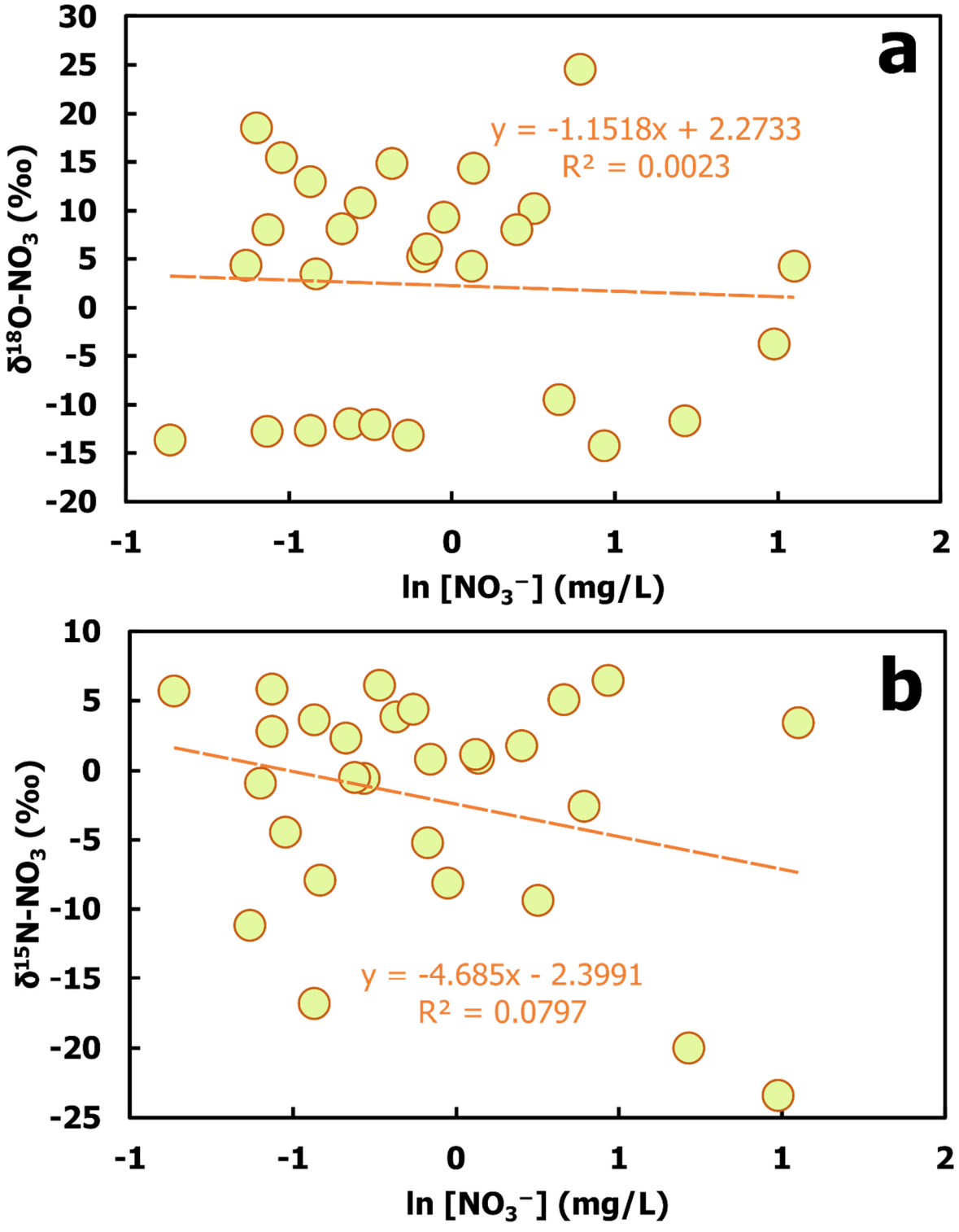

Figure S9. Scatterplot of (a) ln [NO_3^-] versus δ^{18}O-NO_3, (b) ln [NO_3^-] versus δ^{15}N-NO_3 of the groundwater in the west/east regions of the study area.

Table S1. Quality parameters of the groundwater samples in the study area.

Parameter	Unit	WHO Permissible Limit	Number of Samples Exceeding Limit	Groundwater Samples Exceeding Limit (%)
pH		**6.5 – 8.5**	4	7.3 % less than 6.5
TDS	mg/L	**1000**	19	34.5
NO_3^-	mg/L	**50**	13	23.6
SO_4^{2-}	mg/L	**250**	13	23.6
Mn	mg/L	**0.4**	35	63.6
Al	mg/L	**0.2**	3	5.5
Fe	mg/L	**0.3**	–	–

–: No samples exceeded the WHO [6] permesible limit.

Table S2. Limit of Detection of the Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES,IRIS Intrepid II XSP, USA) and ion chromatography (IC, Dionex 120, USA).

Element/Parameter	Limit of Detection (µg/L)	Instrument	Relative Standard Deviation (RSD)
F^-	20	Ion chromatography	< 5%
Cl^-	20		
NO_2^-	30		
NO_3^-	80		
SO_4^{2-}	90		
K^+	0.184	Inductively Coupled Plasma Optical Emission Spectrometer	
Na^+	0.079		
Ca^{2+}	0.006		
Mn	0.070		
Fe	0.105		
As	0.05		
B	5		
Li	0.005		
Sr	0.004		
Al)	0.070		
Cr	0.250		
Co	0.1		
Cu	0.600		
Zn	0.200		
Ba	0.030		
Ni	0.550		

References

1. Hefny, K.; Khalil, J.B. General Hydrogeological Condition of Greater Cairo Area. *Water Sci J, Oct* **1989**.
2. EEBS *Geological, Hydrological and Geomorphological Properties of Soil for Egyptian Governorates*; 2004;
3. Egyptian Geological Survey *Geologic Map of Egypt, Scale 1: 2 000 000*; Egyptian Geological Survey and Mining Authority: Cairo, 1981;
4. RIGW-IWACO Hydrogeological Map of Egypt, 1:2000,000. 1992.
5. Karra, K.; Kontgis, C.; Statman-Weil, Z.; Mazzariello, J.C.; Mathis, M.; Brumby, S.P. Global Land Use/Land Cover with Sentinel 2 and Deep Learning. In Proceedings of the 2021 IEEE international geoscience and remote sensing symposium IGARSS; IEEE, 2021; pp. 4704–4707.
6. WHO *Guidelines for Drinking Water Quality*; : Fourth edition incorporating the first addendum , World Health Organization, Geneva, 2017;