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Utilizing Hydrodynamic Modeling and GIS for Surface Water Intake Vulnerability Analysis

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Intake protection zones, Geographical Information System, Delft3D model, vulnerability score.

Abstract

Intakes for water plants are at risk of closing down because of sudden pollution accidents. The early warning system will enable authorities to take the necessary action to secure safe water for the water plant. This research will discuss the development approach to protecting the areas in the vicinity of the surface water intake which are known as Intake Protection Zones (IPZs) and determined IPZs according to the different vulnerability classes. The Delft3D model was used to define and delineate the (IPZs). It estimates the travel time for hypothetical contaminants by using particle tracing analyses for different scenarios of flow. The vulnerability score maps were established using the Geographical Information System (GIS) application for the delimitation of (IPZs). The combination of the field measurements, and the numerical model, to develop an early warning system by (GIS) is an effective tool for defining the protection zones scheme and becomes a vital tool for decision-makers to open or close the intake with spilled pollution or harmful water supply.

1. Introduction

Most water surface intakes suffer serious issues with pollution carried on by human activity. For sustainable use, it is crucial to safeguard surface water sources. For irrigation of land, the production of electricity, water treatment facilities, river navigation systems, and other applications, river intake structures are essential. By establishing intake facilities on the river, a defined amount of water will be changed from the river for different uses [1]. Numerical modeling has evolved into the go-to technique in the hydrology field for evaluating environmental threats to surface water, such as pollutant spills [2]. Modeling is done to determine if the pollution might spread to the intake and degrade the water's acceptability as a source of drinking water. [3].

River intake structures are inherently vulnerable to contamination from a variety of activities on or near surface water intakes. The water drawn from rivers can negatively affect the quality of municipal drinking water (accidental spills of hazardous materials). Consequently, this process causes many problems such as closing the water intake where potential contaminants could pose a significant risk or threat to river intake [4]. The Clean Water Act rule aids some ongoing and

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upcoming operations that pose serious drinking water dangers because they might pollute sources of drinking water, to protect and restore surface water [5].

The CWA is the fundamental federal legislation managing water contamination in the United States. A context for thinking about management techniques in these zones is provided by drinking-water source protection zones [6]. A surface water intake must be protected, as well as the water and land close surrounding it. An intake protection zone is an area of water and land (IPZs). The area immediately surrounding the intake is defined as the (IPZ-1). Due to its proximity to the intake, this zone is thought to be the most vulnerable area for surface water intake since contaminants of concern coming would be little to no diluted before reaching the intake. The IPZ-2, which often extends upstream of the IPZ-1, serves as a supplemental protection zone. The IPZ-2 is established based on the time needed to shut down the water treatment system in the case of a spill and the potential travel distance of contaminants during that period [3].

The IPZ-2 is determined by the region that may provide water to the intake when the travel time to the intake is equal to or less than the time needed for the system operator to react to a change in the surface water's quality. Based on a few variables that consider how readily pollution could reach the intake, the vulnerability of each zone for each intake protection zone was estimated. Some of the criteria used to determine the vulnerability of an intake protection zone included the depth of the intake pipe, its distance from the shoreline, and the ease with which contaminants could access the water body. Since there is less time for contaminants to degrade and for cleanup to take place before the water reaches the intake, the zones closest to the IPZ's intake are the most vulnerable [7].

For environmental evaluation and planning, notably for the protection of drinking water sources, numerical modeling is increasingly being used. [8].

The Geographical Information System (GIS) was used to identify vulnerability, and potential contaminant sources, monitor, and control big data sets map. The GIS was used to determine the risk associated with each probable source of contamination and to construct source water protection zones. This application allows one to connect to the data source locations. It is also used to involve spatial data management geo-referenced digital maps, data analysis using hydrologic and morphologic data, and the number of water intakes and the position of water [9]. Hydrodynamic simulation and particle-tracking analysis were used to determine the source areas of the St. Clair-Detroit River Waterway's public water intakes to protect the public's supplies from contamination spills [10]. The field velocity interpolation and the number of particles employed in the simulations, and the depiction of boundary conditions are considered [11].

The field velocity interpolation and the number of particles employed in the simulations Particle tracking techniques are known tools in limnology as well [12-14]. There are just a few applications for combining particle tracking models with remote sensing tools, and additional research is needed. [15]. Intake Protection Zones (IPZs) of the Abu Teg (Assuit) water intake station were defined under applying of different scenarios. An early warning system was studied and developed to predict the annual rate of sedimentation deposition and delineation of the river (IPZs) [16]. Sudden water contamination accidents have become more frequent, resulting in considerable effects on environmental safety. As a result, it is necessary to simulate and predict pollution accidents [17]. The Geographical Information System (GIS) application was developed for these intakes. The Delft3D can simulate river hydrodynamic processes. The flow module simulates the hydrodynamic flow in rivers [18]. Choi et al. combined between the geographic information systems (GIS) and a 1D water quality model to develop a system for spatiotemporal simulation and dynamic regulation [19].

Accidental pollution incidents have caused a major threat to water safety of drinking water sources, so Tian et al. studied the vulnerability of risk receptors such as drinking water intakes, and the environmental risk of different sub-regions were evaluated by model [20].Wang et al. developed a water source risk assessment method based on GIS in Shenzhen [21].The Municipal Artificial Lake is protected by three protection zones that have been constructed using Geographic Information Systems (GIS) techniques [22]. The objectives of this study are to develop a GIS application for the river surface municipal intakes data and apply the Delft3D model to simulate the river flow for different flow conditions. Utilizing a particle tracing module to calculate the time travel potential sources of contamination surrounding intakes and delineation of Intake Protection Zones (IPZs)., also, will contribute to the assessment vulnerability score of the existing and future river intakes.

2. Materials and methods

2.1. Study area

The Nile River is considered the main source of water in Egypt. The study region is situated in the fourth reach of the river, which is distinguished by the presence of several water station intakes. The four (4) water station intakes (Rod El Farag - Maadi – Badrashen - Korimat) were selected to estimate the Intake Protection Zones (IPZs) as shown in Table 1. According to Figure 1, the fourth reach has a total length of 408.22 km and runs from Assuit Barrage at km 544.78 of the High Aswan Dam (HAD) to Delta Barrage at km 953.000. North is the direction in which the river runs. River widths in the study region range from 400 to 600 meters.

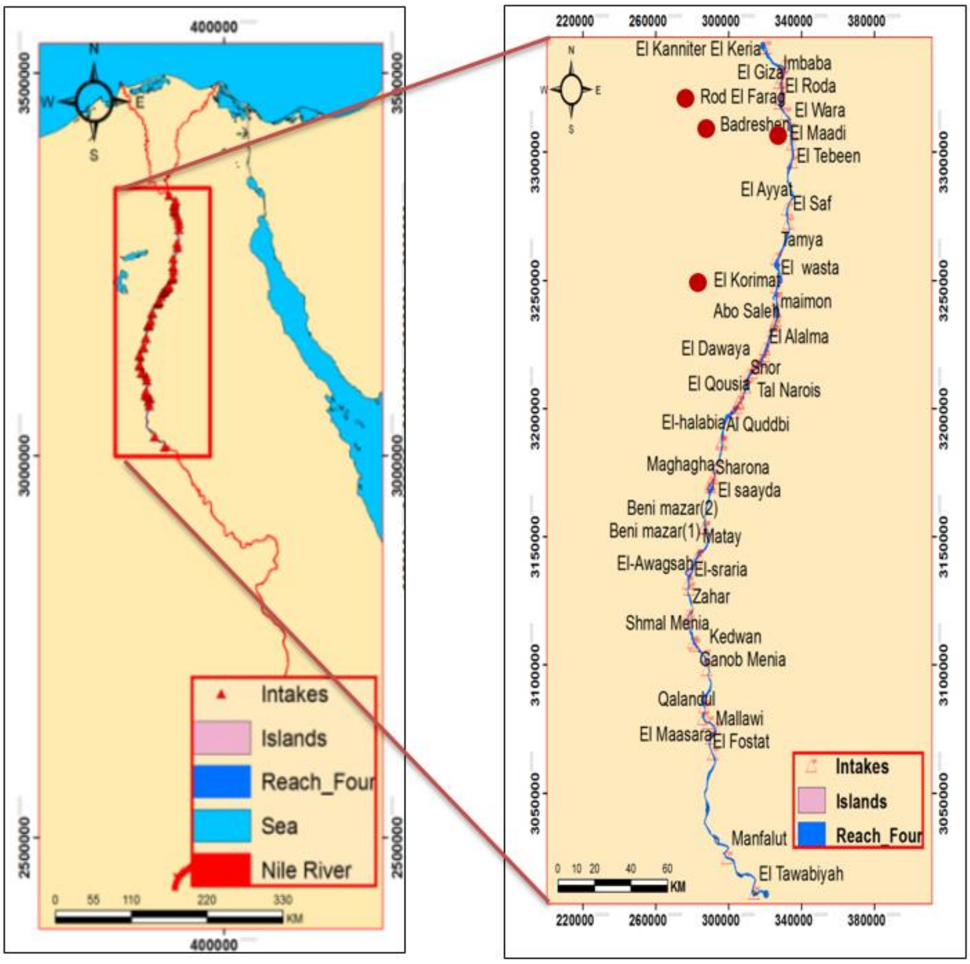


Figure 1. Study reaches and water intake location

Table (1): List of the selected water stations in the study reach

No.	Selected water stations intakes	Location		Riverbank	Distance Km from AHD	Capacity (m^3/day)
		E (m)	N (m)			
1	Korimat	326805	3242475	Right	839.150	112,320
2	Badrashen	334933	3303397	left	909.450	68,000
3	Maadi	331507	3314890	Right	919.750	400,000
4	Rod El Farag	329465	3329254	Right	935.650	870,000

2.2. Methodological approach

Figure 2 illustrates the flow chart for the research methods. The following are the key techniques used in this study: In this research, the main procedures are as followings:

- Develop the GIS database map for the water station intakes at the study reach.
- Obtain bathymetric and hydraulic data for the water station intakes that have been selected.
- Apply the Delft3D model to simulate a spill event releasing and tracking the movement of spill across the water cross section (Spill near the east bank, Spill the middle of the waterway, Spill near the west bank) for two cases of river flow for (maximum & minimum) scenarios.
- Determine the spill time of travel using the particle tracing module.
- Delineation of the (IPZ-1 & IPZ-2) considering the various conditions of river flow.
- Evaluate the vulnerability score for the selected water intakes.

2.3. Data collection and analysis

There are two different data sets. That were collected, the first data set is the digital data of topographic and hydrographic maps, and the data of the water intakes, which are located at both east and west riverbanks for creating the GIS application. The second data sets are the bathymetric and hydraulic data collected for applying the Delft3D model as shown in Table 1 and 2.

Table 2. Types of the data collection

Data	Location	Period	Source	Usage
Bathymetry Survey	River reach length of 117 Km	2016	NRI	Grid Development
U/S discharge	Downstream Assuit barrage	2010 to 2016	NRI	Boundary Condition (BC)
Water Level	El Roda Water Station	2010 to 2016	NRI	Boundary Condition (BC)
Velocity Measurements	Four Cross Sections at km 88.150, km 87.820, Km 4.250 km, and km 3.820	2016	NRI	Calibration & Verification

2.3.1. GIS data collection

Intakes on the river at the study area (58 water intakes) which were used to create ArcView point coverage) [23]. The data was inserted as an attribute table corresponding to intakes location (easting, northing, km from Aswan, riverbank), and intake pipe characteristics (depth, distance from shore, critical level, and water station capacity).

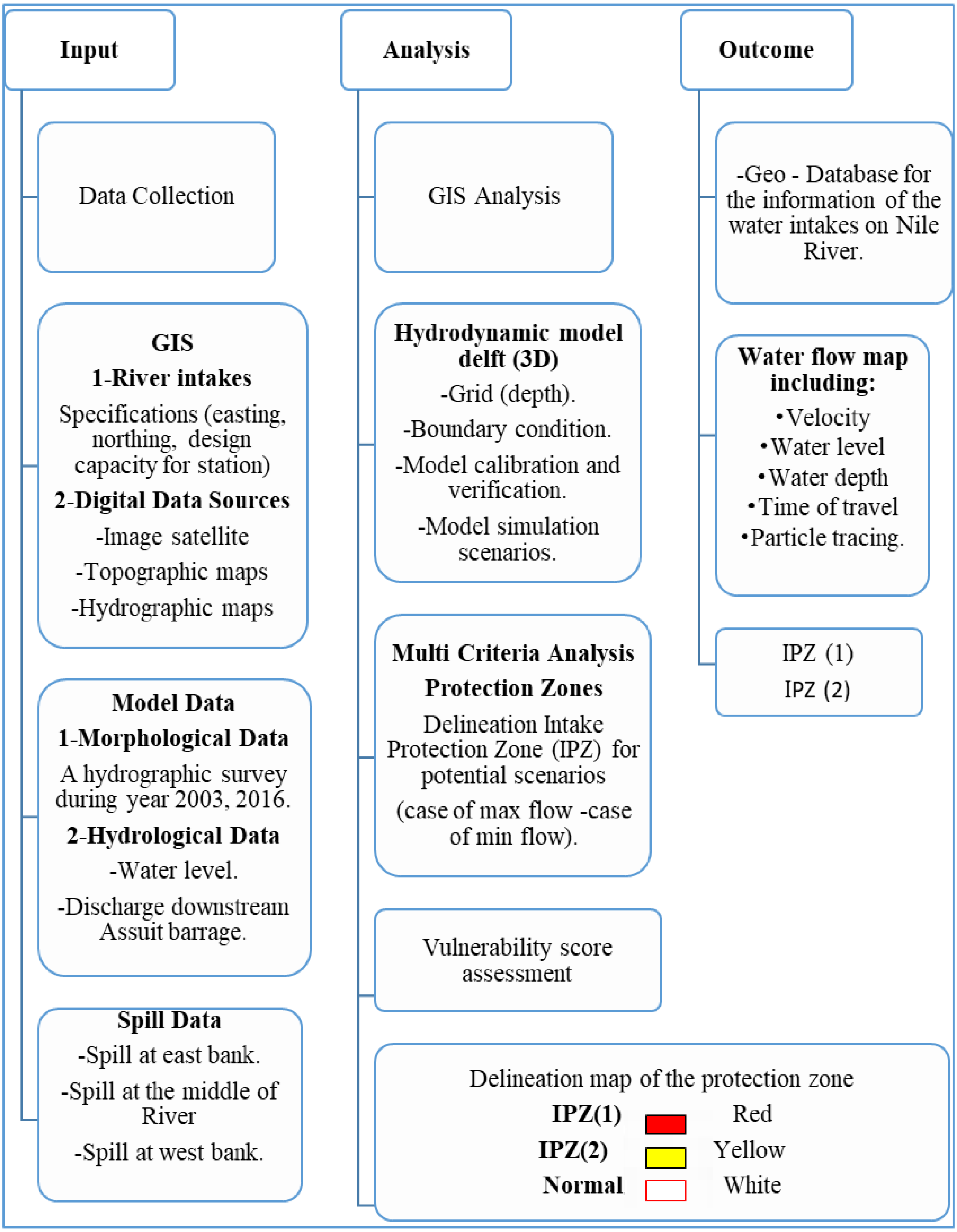


Figure 2. Flow diagram showing the methodology of the study.

2.3.2. Model data collection

Set up the Delft3D model, it is required water level, cross-section, and discharge data. It was collected the necessary data by the Nile River Institute (NRI) for different periods.

The values for both flow scenarios' discharges using the recorded D.S. Assuit barrage flow data for six years from 2010 are shown in Table (3) and Figure 3(a, b). The flow values were quantified by analyzing the maximum and minimum flow parameters, which were determined using the recorded D.S. Assuit barrage flow data for six years from 2010. Figure 3(c) illustrated the histogram for the discharge data, which was calculated.

Table3.Model scenarios and parameter values model

Calibration and Verification Processes			Parameter values adopted in the model	
Process	Discharge (M. m^3/s)	Water Levels(m)	Parameter	Value
Calibration	80	16.85	Gravity Water density	9.81 m/s^2 1000 kg/m^3
Verification	181.44	17.5	Roughness, n Horizontal eddy viscosity	0.025 1 m^2/s

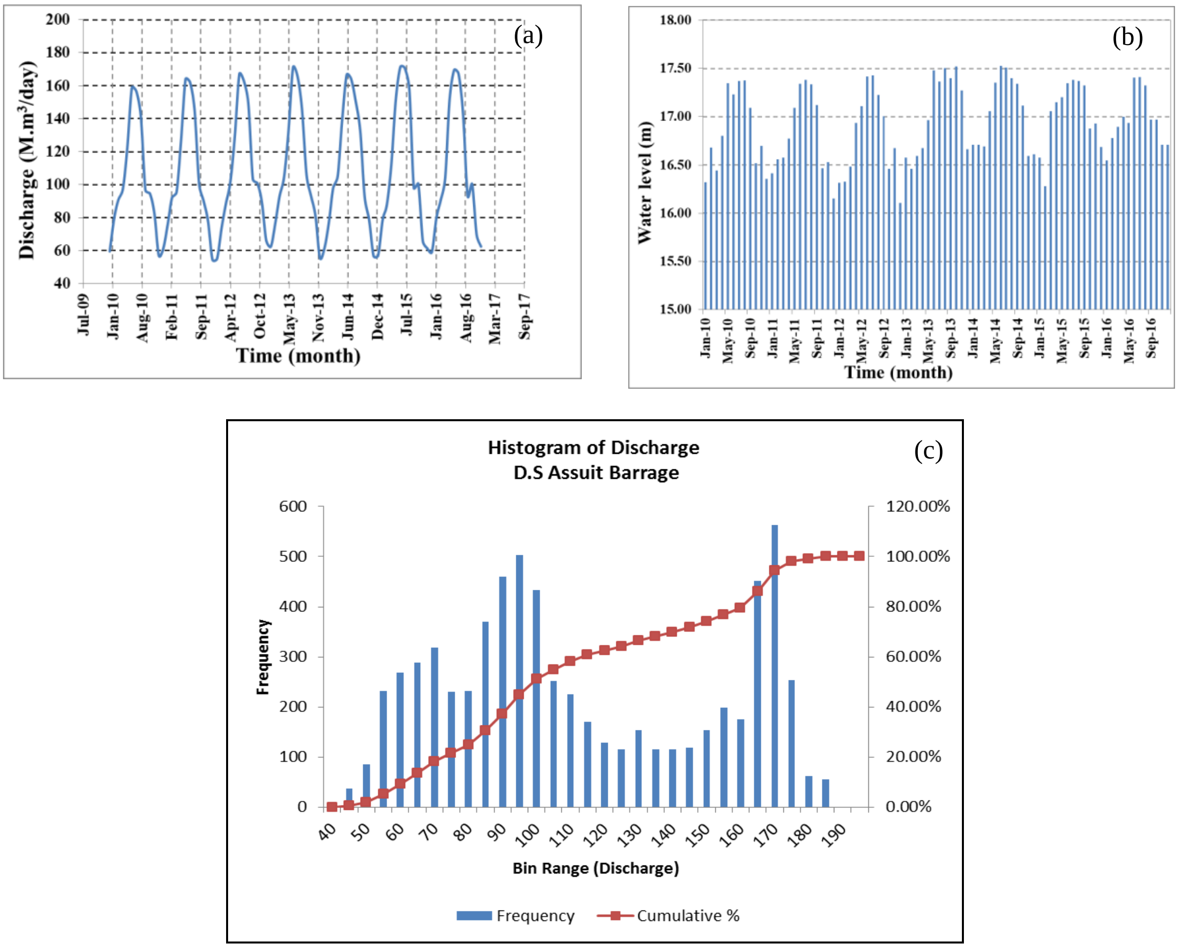


Figure 3. (a) River discharge DS. Assuit Barrage, (b) Water levels at the upstream of delta barrage for the study period year (2010-2016). (c) Discharge frequency histogram D.S. Assuit Barrage.

2.4. Hydrodynamic model simulation

2.4.1. Mathematical formation

The hydrodynamic component of Delft3D, a fully integrated software for simulating water flows, particle tracking, ecology, sediment, chemical transports, morphology, etc., is Delft3D-Flow. The model is based on some equations described below [18]: The Delft3D-Flow multi-dimensional (2D or 3D) hydrodynamic (and transport) simulation programmed calculates non-steady flow and transport phenomena brought on by tidal and meteorological stress using a rectilinear or a curved, boundary-fitted grid. In 3D simulations, the vertical grid is defined using a coordinated approach. The Delft3D was utilized to simulate the velocity flow, sediment transport, and bed level fluctuations in the river in the study area using various mathematical equations based on the conservation of mass, momentum, energy, etc.

$$\frac{\partial\xi}{\partial t}+\frac{1}{\sqrt{G\xi\xi}\sqrt{G\eta\eta}}\frac{\partial((d+\xi)U\sqrt{G\eta\eta})}{\partial\xi}+\frac{1}{\sqrt{G\xi\xi}\sqrt{G\eta\eta}}\frac{\partial((d+\xi)V\sqrt{G\xi\xi})}{\partial\eta}=(d+\xi)Q, \tag{1}$$

With *U* and *V* the depth-averaged velocities

$$U=\frac{1}{d+\xi}\int_{d}^{\xi}U\,dz=\int_{-1}^{0}U\,d\sigma \tag{2}$$

$$V=\frac{1}{d+\xi}\int_{d}^{\xi}v\,dz=\int_{-1}^{0}v\,d\sigma \tag{3}$$

The contributions made by evaporation, precipitation, and water withdrawal or discharge per unit area are represented by Q:

$$Q=\int_{-1}^{0}(q_{in}-q_{out})d\sigma+P-E, \tag{4}$$

$$\frac{\partial u}{\partial t}+\frac{U}{\sqrt{G\xi\xi}}\frac{\partial U}{\partial\xi}+\frac{v}{\sqrt{G\eta\eta}}\frac{\partial U}{\partial\eta}+\frac{\omega}{d+\xi}\frac{\partial U}{\partial\sigma}-\frac{v^2}{\sqrt{G\xi\xi}\sqrt{G\eta\eta}}\frac{\partial\sqrt{G\eta\eta}}{\partial\xi}+\frac{uv}{\sqrt{G\xi\xi}\sqrt{G\eta\eta}}\frac{\partial\sqrt{G\xi\xi}}{\partial\eta}-f\nu=-\frac{1}{\rho_o\sqrt{G\xi\xi}}p\xi+F\xi+\frac{1}{(d+\xi)^2}\frac{\partial}{\partial\sigma}\left(\nu_V\frac{\partial U}{\partial\sigma}\right)+M\xi \tag{5}$$

The term P indicates the non-local source due to precipitation and E is the non-local sink term due to evaporation.

2.4.2. Grid generation and boundary conditions

The computational domain of the Delft3D model covered of river study reached a 117-kilometer length as shown in Figure 4. The resolution of the grid was 20 m to achieve a reasonable resolution to predict the hydrodynamic conditions around the four intakes. The discharge downstream of Assuit Barrage is considered the inflow boundary condition for the study area. The water level at the upstream Delta Barrage was determined using the outflow boundary condition.

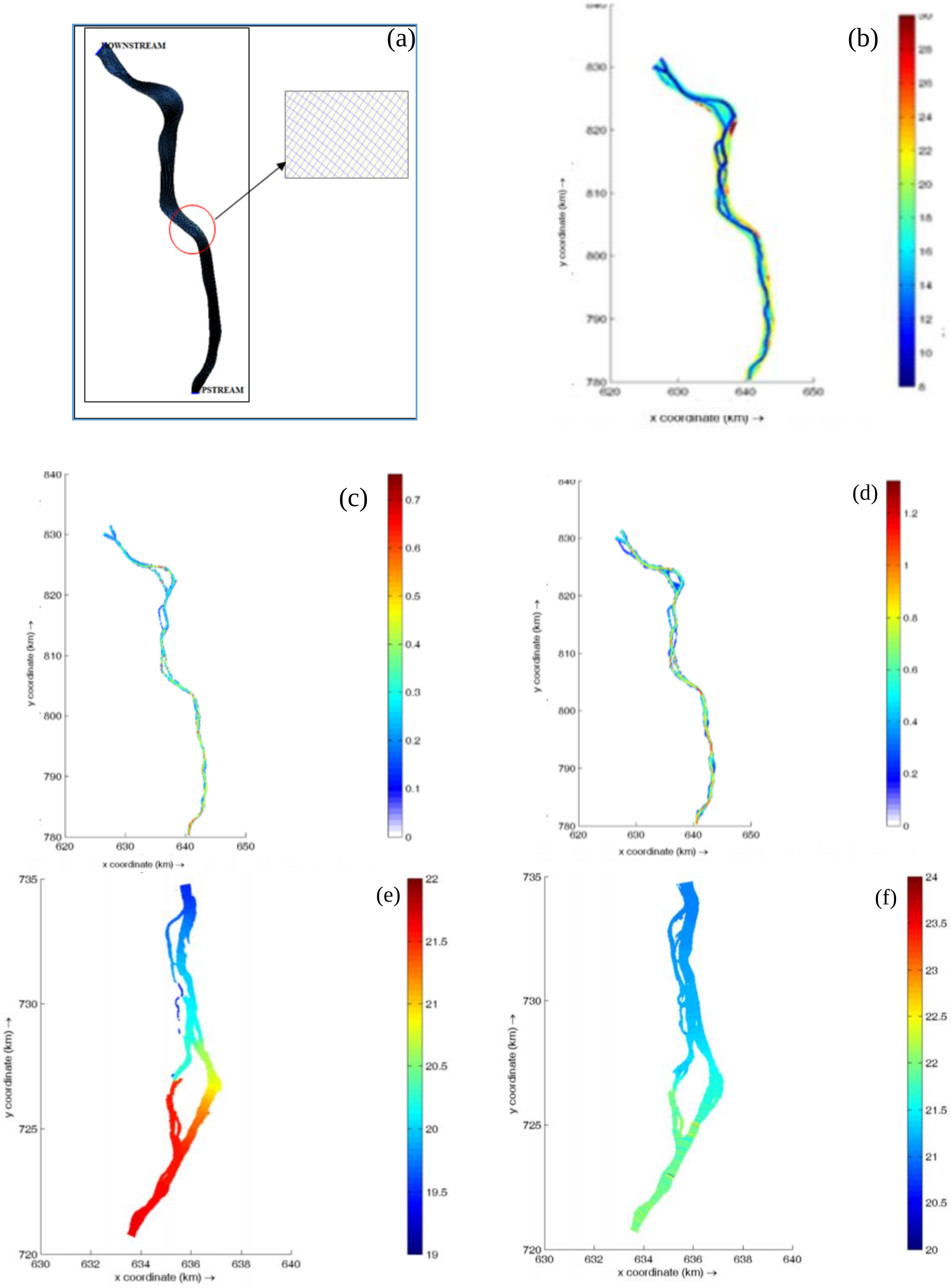


Figure 4. The output of the model for (a) Grid formation, (b) Bed elevation, (c) Velocity for a case of min. flow, (d) Velocity for a case of max. flow, (e) Water surface elevation for a case of min. flow, (f) Water surface elevation for a case of max. flow.

2.4.3. Calibration and verification processes

The model's calibration and verification depend on the number and quality of topographic and hydraulic data, such as velocity distributions, water-surface elevation, flow rates, and bed roughness, that are collected. For the calibration process, Manning's n was 0.025. The model was used to calculate the river discharge of 80 (million m3/day) at the downstream Assuit Barrage, which corresponds to a water level of 16.85 m at the upstream Delta Barrage, as shown in Table 3. To evaluate the accuracy of the model results, the velocities predicted by the Delft3D model were compared with measured current data as shown in Figure 5. The accuracy of the calibration and verification procedure was evaluated using two common statistical techniques, including the coefficient of determination (R^2) and the root mean square error (RMSE), as shown in Table 4. The comparison shows that there is a reasonable agreement between the measured and predicted velocities.

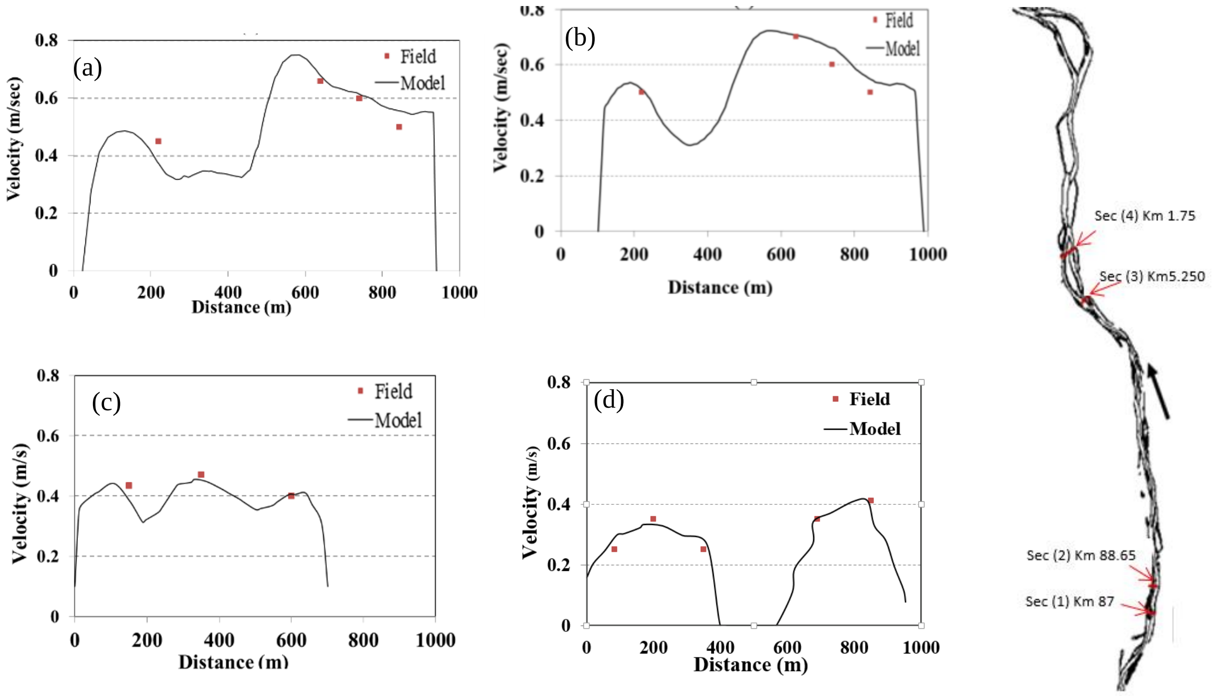


Figure 5. The comparison of observed and measured velocities for cross-section (a) 1, (b) 2, (c) 3, (d) 4.

Table 4. Error comparison methods the observed and measured flow velocities.

Parameter	Range	Optimal value	Expression	Calculated Value
R^2	0-1	1	$\left(\frac{\sum_{i=1}^{n}(X_{obs,i}-\bar{X}\,obs)(X_{model,i}-\bar{X}\,model)}{\sqrt{\sum_{i=1}^{n}(X_{obs,i}-\bar{X}\,obs)^2}\sqrt{\sum_{i=1}^{n}(X_{model,i}-\bar{X}\,model)^2}}\right)^2$	0.33
RMSE	0- ∞	0	$\sqrt{\frac{\sum_{i=1}^{n}(X_{obs,i}-X_{model,i})^2}{n}}$	0.04

3. Results and analysis

3.1. Transport pathways and travel time results

By short-circuiting the water flow, the transport channels are characteristics of the riverbed that give contaminants the chance to quickly reach an intake. An intake protection zone is more vulnerable to contamination the more transit paths there are inside the zone. The model has simulated a hypothetical spill, at the surface (positively buoyant) for two cases for potential river flow (maximum and minimum discharges) to compute the movement and spread of a spill across the study area for delineation Intake Protection Zone (IPZ). For the two river flow cases, the model has simulated a spill event by releasing and tracking the number of discrete particles at different three sites in the river cross-section (spill near the east bank, spill in the middle of the river, and spill near the west bank). In addition, the Delft3D model computed the travel time required for the surface water to travel a specified distance within a surface water body for potential scenarios (max and min river flow). The model was run in particle tracking mode with the paths by which the currents would have transported neutrally buoyant particles to the intake over a 2-hour travel time according to [6]. The green particles in Figure 6 on the east bank, mid-river, and near the west bank represent the pathways. The lines define the time that it would take a particle to reach the intake.

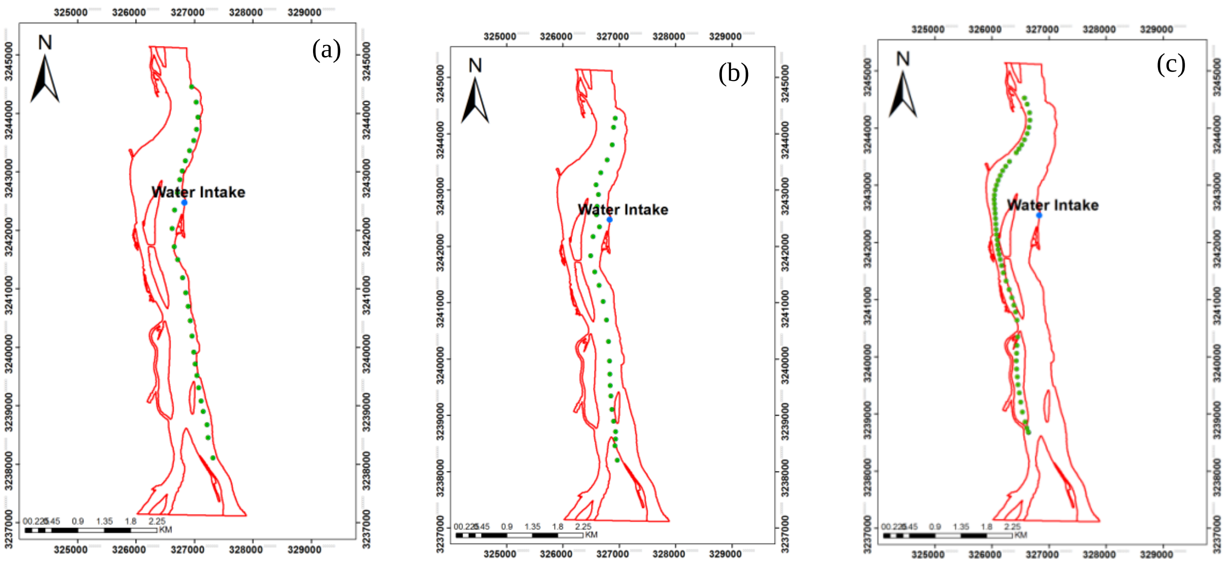


Figure 6. The particle tracing travel distances for maximum flow at Korimat water intake for Spill at (a) East bank, (b) Middle of the River, (c) West bank.

3.2. Delineation of the Intake Protection Zones (IPZs)

The Delineation of (IPZs) of the selected four water station intakes (Rode El Farag- Maadi-Korimat – Badrashen) areas was adopted. The size of (IPZs) areas varies based on factors including bathymetry, flow velocity, and the location of each intake. The Technical Rules identify the chosen water intakes as type (C), and the corresponding technical specifications are included [6]. The region directly adjacent to the intakes is known as the IPZ-1. This zone is considered the most vulnerable due to any contaminant of concern that may be released and will have the highest potential to impact water quality it is a semi-circle for a one km radius centered on the intakes. The IPZ-2 acts as a secondary protective zone around the IPZ-1. The IPZ-2 is defined based on the travel time of the contamination which is equal to or less than the time that is sufficient to allow the operator of the system to respond. The time of travel to the intake shall be estimated to be two hours [6]. as shown in Table 5.

Tables 5. The particle tracing travel distances for travel time 2 hours from intakes

Water Station Intake	Max 181.44 (M. m^3/day)		Min 51.84 (M. m^3/day)	
	Distance from intake (Km)	Average velocity (m/s)	Distance from intake (Km)	Average velocity (m/s)
Rode El Farag	2.60	1.04	1.26	0.30
Maadi	2.80	0.98	1.36	0.33
Badrashen	2.98	0.94	1.54	0.4
Korimat	3.39	0.95	1.98	0.45

The Delft3D model was applied using particle tracking to define the IPZ-2 area which includes transport pathways and river flow within the two-hour travel time. The outcomes of the numerical modeling were used to define the velocities that were used to define the IPZ-2. Using a GIS tool, it estimated the IPZ-1 and IPZ-2 zones for the maximum and minimum flow circumstances of the selected four water station intakes.

Delineation for Rode El Farag, Maadi, Badrashen, and Korimat Intakes Protection Zone (IPZ-1) is as a semi-circle for 400 m upstream, 10 m long, and 200 m upstream of intake. Delineation for Rode El Farag Intakes Protection Zone (IPZ-2) is calculated at about 2.60km from the intake at the case of max. flow and 1.26 km from the intake at the case of min. flow respectively. Delineation for Rode El Farag Intakes Protection Zone (IPZ-2) is calculated at about 2.60km from the intake at the case of max. flow and 1.26 km from the intake at the case of min. flow.

Delineation for Rode El Farag Intakes Protection Zone (IPZ-2) is calculated at about 2.60km from the intake at the case of max. flow and 1.26 km from the intake at the case of min. flow respectively. Delineation for Maadi Intakes Protection Zone (IPZ-2) is calculated at about 2.80km from the intake at the case of max. flow and 1.36 km from the intake at the case of min. flow. Delineation for Badrashen Intakes Protection Zone (IPZ-2) is calculated at about 2.98km from the intake at the case of max. flow and 1.54 km from the intake at the case of min. flow as shown in Figure 7 and Figure 8.

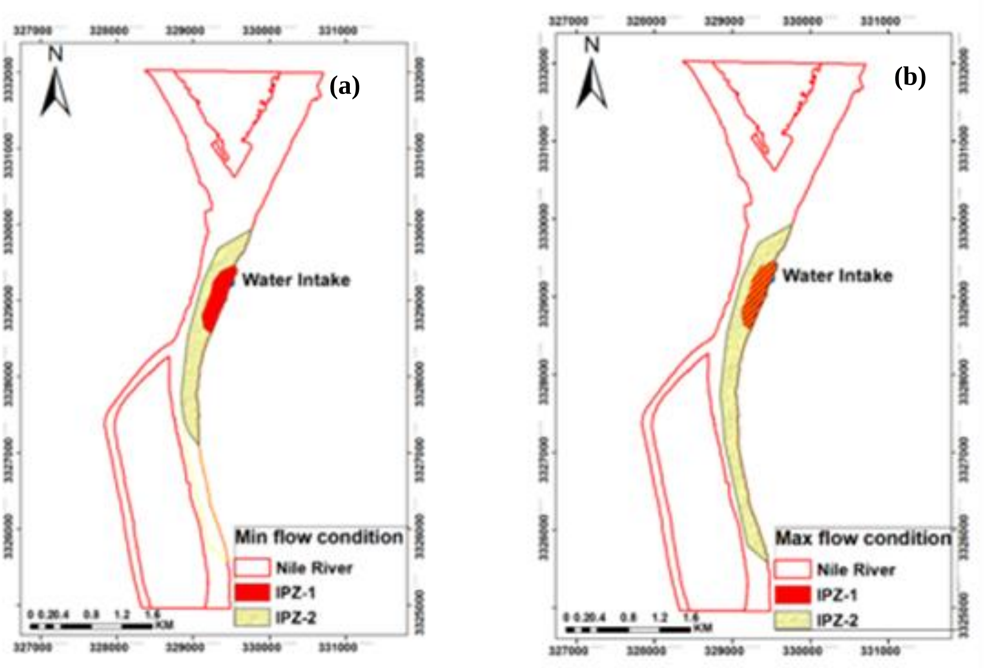
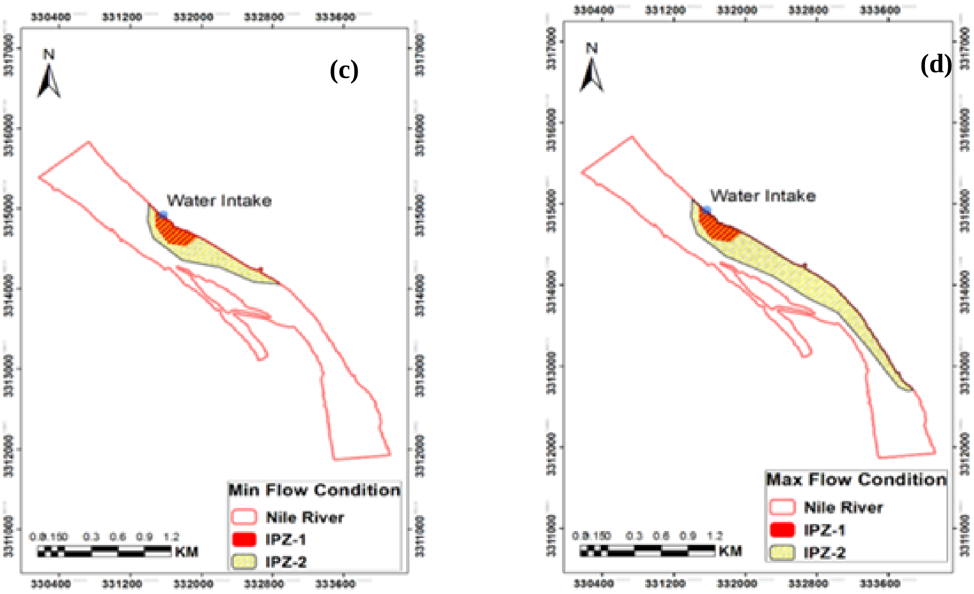


Figure 7. The water intake protection zones for (a) Min. flow for Rod El Farag station, (b) Max. flow for Rod El Farag station



Continue Figure 7. The water intake protection zones for (c) Min. flow for El Maadi station, (d) Max. flow for El Maadi station.

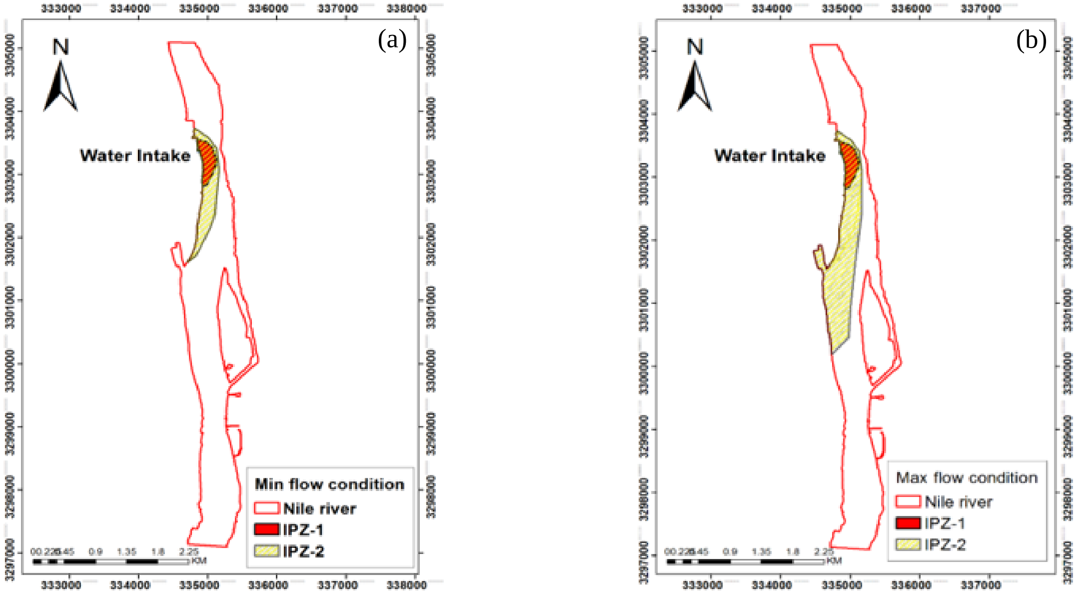
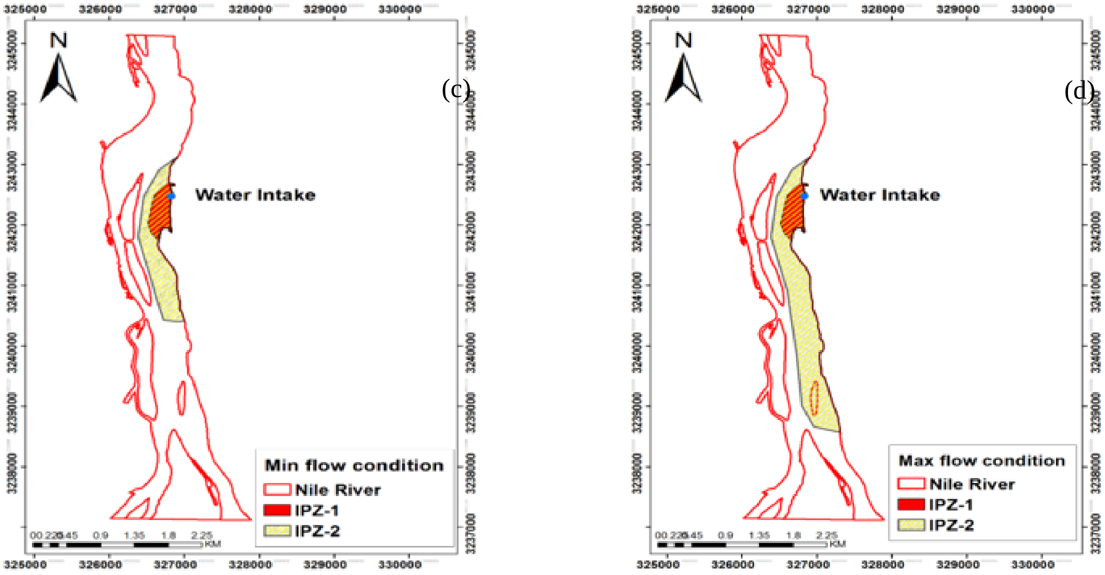


Figure 8. The water intake protection zones for (a) Min. flow for New Badrashen station, (b) Max. flow for New Badrashen station



Continue … Figure 8. The water intake protection zones for (c) Min. flow for Korimat station, (d) Max. flow for Korimat station.

3.3 Vulnerability assessment results

A source vulnerability factor and an area vulnerability factor are the two types of vulnerability. Area vulnerability factors were identified by an assessment of the hydrological and hydrogeological variables in the area that provides water to the area through transport pathways.

For determining area vulnerability scores (risk of contamination) for the intake protection zones IPZ-1 and IPZ-2, the Technical Rules give a thorough procedure. The degree of risk varies based on several variables, including the hydrologic and environmental features of the water body, the presence of pathways that allow these pollutants to get to the intake, and the vicinity of drinking water risks to the intake. The source vulnerability factor applies to where the intake is situated inside a certain body of water. The range of the source vulnerability factor for the chosen intakes is 0.9 to 1.0. As stated in Table 6, the vulnerability score for each intake protection zone is computed. A procedure for determining each intake protection zone's level of vulnerability is outlined in the Technical Rules [6]. Based on the following Eq. (6) the final vulnerability score is calculated.

$$V=B\times C \tag{6}$$

V is the vulnerability score; C is the source vulnerability factor and B is the area vulnerability factor the vulnerability score for the four water intakes was calculated with Eq. (6) as shown in Table 6. The higher vulnerability score indicates a higher vulnerability to contamination. The results showed that the vulnerability score for Rode El Farag, Maadi, Badrashen, and Korimat water Intakes for (IPZ-1 and IPZ-2) is high that indicated Rode El Farag, Maadi, Badrashen and Korimat water intakes have high capability of contaminants.

Table 6. The vulnerability scores for the selected intakes

Selected water stations intakes	Type Intake	Area vulnerability Factor (B)		Source Vulnerability factor (C)	Vulnerability score (V)	
		IPZ-1	IPZ-2		IPZ-1	IPZ-2
Korimat Badrashin Maadi Rod Elfarag	Type C Intake	10	8	1	10	8

4. Conclusions and recommendations

- The research proposed methodology describes the vulnerability of surface water drinking sources and proposes an approach to protect existing and future water intakes at the Nile River which identifies those with the greatest potential for reducing significant risks to drinking water supplies able to assist decision-makers in addressing the possibility that contaminants entering those areas may migrate towards a drinking water intake.
- The delineation Intakes Protection Zone (IPZ s) and the surface water vulnerability assessment are carried out for the four water river intakes (Rode El Farag, Maadi, Badrashen, and Korimat) at the Nile River that determine the areas that are the most sensitive to contamination using field data, numerical modeling, and GIS.
- The IPZs intakes were defined using particle tracking for the different flow periods of the river and the Delft 3D model was run by using the particle paths that the currents would have taken over a 2-hour trip time to carry neutrally buoyant particles to the intakes (defined by the operator as the required time to shut down the plant in the event of a spill or threat to the drinking water.
- The results showed that the vulnerability score for the four water Intakes is high, and it is indicated that the four water intakes have a high capability of contaminants.
- It is recommended that apply the proposed approach for the existing and future water intakes to maintain a long-term supply of clean water and develop an early warning system to predict contamination for river intakes.

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استخدام النمذجة الهيدروديناميكية ونظم المعلومات الجغرافية لتحليل درجة تعرض مأخذ المياه للتلوث

الملخص العربى:

تستخدم ماخذ المياه على نهر النيل لتحويل كمية معينة من مياه النيل للاستخدام فى اغراض مختلفة مثل ري الأراضي، توليد الطاقة الكهربائية، محطات المياه وغيرها من الاستخدامات وحيث ان مآخذ محطات المياه معرضة لخطر الإغلاق بسبب حوادث التلوث المفاجئة. سيمكن نظام الإنذار المبكر متخذي القرار من اتخاذ الإجراءات اللازمة لتأمين المياه الصالحة للشرب لمحطة المياه وتقليل المخاطر الكبيرة عليها. تهدف هذه الورقة إلى دراسة تتبع حركة الملوثات الافتراضية والوقت الذي يستغرقه الملوث للوصول الى مأخذ المياه وتحديد منطقة الحماية IPZو درجة تعرض المأخذ للتلوث.

سيناقش هذا البحث حماية المناطق المجاورة لماخذ المياه السطحية فقد تم اختيار منطقة الدراسة لعدد اربعة مآخذ مياه شرب سطحية (روض الفرج ، المعادي ، البدراشن ، والكريمات) بالحبس الرابع من نهر النيل و باستخدام البيانات الحقلية والجمع بين تطبيق نموذج رياضى ثنائى الأبعاد (Delft3D) لمحاكاة حركة سريان المياه و تتبع الجسيمات التي كان من الممكن أن تستغرقها التيارات على مدار ساعتين لحمل الجسيمات الطافية بشكل محايد إلى المآخذ (يحدده المشغل بأنه الوقت المطلوب لإغلاق المحطة في حالة حدوث انسكاب أو تهديد لمياه الشرب خلال منطقة الدراسة وتحديد المناطق الامنة لحماية الماخذ من الملوثات و استخدام تطبيق نظم المعلومات الجغرافية (GIS) كأداة فعالة لتطوير نظام إنذار مبكر من خلال تحديد مناطق الحماية ويصبح أداة حيوية لصناع القرار لفتح أو إغلاق المأخذ مع تسرب التلوث أو إمدادات المياه الضارةو قد أظهرت النتائج أن درجة التعرض عالية على الملوثات في مآخذ المياه الأربعة .

لذا يوصى بتطبيق المقترح لمآخذ المياه الحالية والمستقبلية للحفاظ على إمدادات طويلة الأجل من المياه النظيفة وتطوير نظام إنذار مبكر للتنبؤ بتلوث مآخذ الأنهار.