



# Investigating the influence of parameters on Pump Intake Design through the integration of CFD-GIS

Noha Kamal<sup>1</sup>, Ashraf Ghanem<sup>2</sup>, and Ahmed Abuzeid<sup>3</sup>

<sup>1</sup>Director of Mechanical and Electrical Institute, Egypt,  
noha\_kamal@nwrc.gov.eg

<sup>2</sup>General Manger, Planning Sector, Ministry of Water Resources and Irrigation, Egypt  
ashraf\_ghanem@outlook.com

<sup>3</sup>Institute of Applied Geosciences, Technische Universität Darmstadt, Darmstadt, Hesse, Germany  
ing.ahmedabuzeid@gmail.com

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## ABSTRACT

Pump intake design plays a crucial role in determining the efficiency and performance of pumping systems. The flow patterns and velocities at the pump inlet are significantly influenced by design parameters such as the orientation, size, shape, and location of the intake. This study aims to investigate the influence of these parameters on pump intake design by integrating Computational Fluid Dynamics (CFD) and Geographic Information System (GIS) techniques. The research focuses on a case study of pumping station number 7 in El-Hammam, New Delta, Egypt. ANSYS 2019 R3 (CFD) software is employed to simulate the flow in the intake and suction basin, analyzing the flow behavior around different intake designs under various operating conditions. The results demonstrate that modifying the intake design by incorporating a cone under the bell mouth and using Anti-Vortex Devices (AVDs) leads to increased velocity distribution and the elimination of dead zones. The proposed geometry for the intake and suction basin of the selected pumping station is deemed acceptable, as no dead zones or vortices are formed in front of the pumping units and the pumping house. Additionally, ArcGIS Pro software is utilized to analyze environmental factors such as topography, land use, and proximity to water sources, which may influence the intake design. By considering hydraulic performance concerns, this study aims to optimize pump intake designs through an integrated approach. Improved efficiency in pumping systems not only conserves water resources but also reduces operational costs and enhances agricultural productivity. The findings of this research contribute to the development of a well-designed water policy framework that promotes environmental sustainability and economic prosperity.

**Key words :** CFD, water pipelines, sump, GIS; Pump stations.

## 1. INTRODUCTION

The design of a pump intake is significantly influenced by various parameters, such as flow rate and inlet velocity profile. These

factors impact the efficiency and performance of the pump system. Proper consideration of these parameters is crucial to minimizing cavitation, ensuring uniform flow distribution, reducing energy losses, and preventing damage to pump components. By optimizing the intake design based on these parameters, engineers can enhance the overall reliability and effectiveness of the pumping system.

Egypt has over 600 large pumping stations for drainage and irrigation distributed throughout the country. These stations face numerous challenges, including hydraulic, dynamic, and electrical issues, which affect their efficiency, safety, and performance. The country invests millions of pounds in operating, establishing, maintaining, and purchasing replacement parts to keep Egypt's water distribution system functioning [1]. Continuous evaluation, observation, monitoring, and analysis of performance are necessary to prevent issues that could accelerate deterioration and damage components of these pumping stations. Defective pump sump or intake design has been identified as a leading cause of unsatisfactory pump operation in pumping stations [2]. One significant source of disturbance at intakes is the formation of free-surface vortices with an air core. The most common solution for avoiding air entrainment is the use of anti-vortex devices, particularly plates for large pipe or shaft intakes [3].

Computational Fluid Dynamics (CFD) has proven to be a valuable tool in pump intake design. Good agreement has been obtained between numerical and experimental results for flow characteristics in sump models with pump intakes [4]. Lee et al. [5] used CFD modeling to evaluate flow uniformity in a multi-intake pump sump model, predicting the location, number, and vorticity of vortices. Inadequate installation, inappropriate pump operation, and incorrect pump size selection contribute to excessive energy consumption. Poor pump performance can impact various aspects of plant operation, including increased maintenance expenses, downtime, production loss, and operational costs [6]. Model testing and CFD studies provide valuable design guidelines for pump sump shapes [7].

A specific case study at El-SHABAB Pumping Station investigated water level changes in the sump intake. ANSYS 2019 R3 flow simulation software was used to simulate flow conditions

and address declining water levels during low demand periods (winter closure). Seven scenarios were examined to determine the optimal solution [8].

Geographic Information Systems (GIS) and Remote Sensing (RS) offer benefits of rapid data access and broad-scale analysis in the evaluation process [9,10]. This study emphasizes the importance of a comprehensive approach to pump intake design that integrates CFD and GIS techniques. Pumping station number 7 at El-hammam, New Delta, has been chosen as a case study. By utilizing advanced computational tools and spatial analytical methodologies, we can enhance our understanding of how design parameters affect pumping system performance, ultimately leading to improved overall efficiency and sustainability in water management systems.

## 2. MATERIALS AND METHODS

### 2.1 Study Area

The pumping station number 7 in El-Hammam at new delta was chosen as a case study in which the water flow modeling in the intake and suction basin of the PS no.7 pumping station. PS no. 7 have 14 pumping units (12 pumps in operation and 2 standby) each is 8 m<sup>3</sup>/s (vertical pumping units).  $Q_{\text{Pump}} = 8 \text{ m}^3/\text{s}$ ,  $Q_{\text{total-max}} = 112 \text{ m}^3/\text{s}$ . The number of operating pumps depends on the level of the water in the canal.

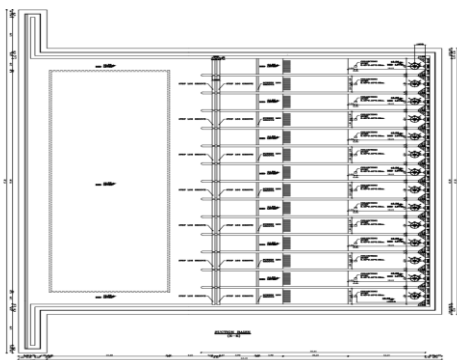
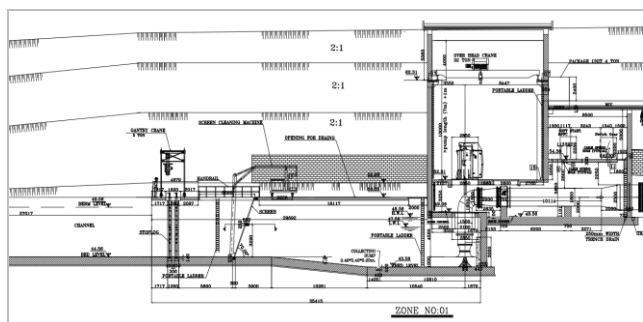


Figure 1: El-Hammam, New Delta, pumping station number 7

### 2.2 Methodology

In order to achieve the objective of this study, the following procedure should be applied as shown in figure (2):

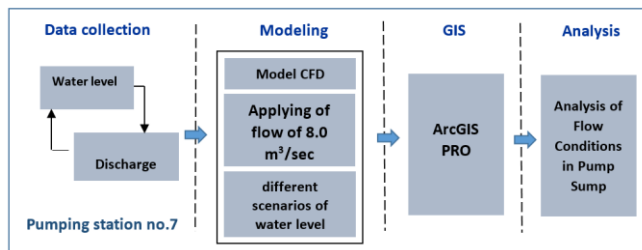


Figure 2: Methodology block diagram

## 3. NUMERICAL MODEL SIMULATION

### 3.1. Numerical Model

ANSYS 2019 R3 (CFD) software package was used to solve the flow equations using Navier-Stokes Equations within the suction and pump inlets using the standard k-epsilon turbulence model. Several scenarios for the operation of stopping units and operating other units were simulated to reach the best pump station design and to identify and analyze the problem to reach the optimum dimensions for the station. Figure (3) shows the boundary condition setup.

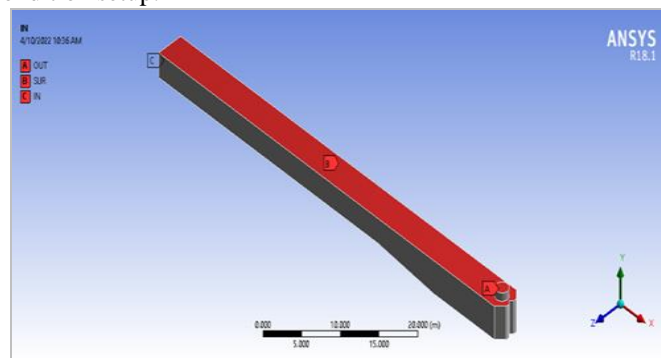


Figure 3: The boundary conditions setup

### 3.2. Mesh Generation

The meshing technique used is the tetrahedron method with inflation applied to all solid walls of the channel and suction pipe. Figure (4) shows a three-dimensional image of the suction sump. The three-dimensional unstructured mesh (tetrahedral) has been created by using the structured mesh (hexahedral). The number of mesh elements and computational nodes are within the range of 985,286 and 758,214, respectively.

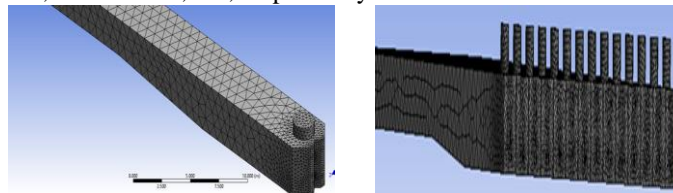


Figure 4: Mesh distributed across a 3D view

To confirm the flow field difference between the total intake sump model and one channel model, CFD simulations were performed for both the total intake sump model and one channel model of PS No. 7. After no obvious difference between the total intake sump model and one channel model was confirmed, as shown in Figures 5 & 6, the one channel model has been applied to verify the intake sump performance of pump stations.

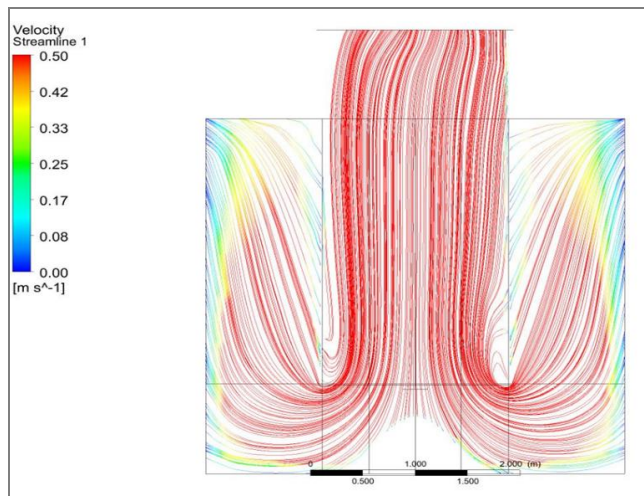
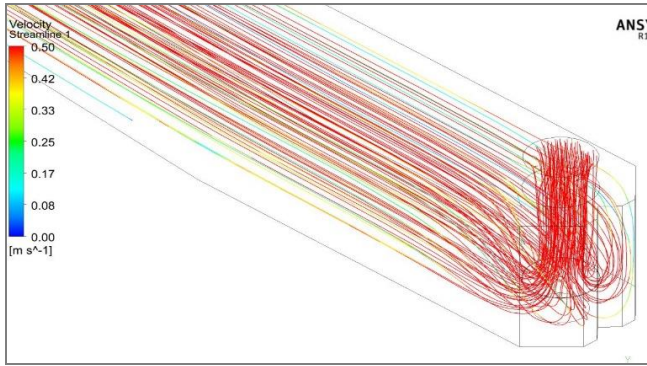


Figure 5: Streamlines in the flow computational domain

### 3.3. Results

After modifying the design of the intake and using a cone under the bellmouth and AVDs (Anti-Vortex Devices) according to Figure (6), the CFD results show:

- The streamlines show the direction of the flow of water in the computational flow domain and within the common bay intake and suction basin. No dead zone is formed at the inlet of the suction pipe.
- The velocity distribution increased, and the dead zone did not appear, as shown in Figure (7), which depicts the contour of velocity magnitude along the pump axis Figure (8) shows the velocity vectors along the pump axis, indicating that the flow is regular, and there is no separation zone.

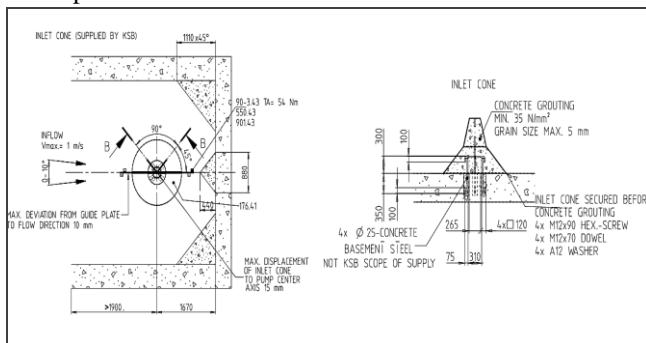


Figure 6: a cone under the bellmouth and AVDs (Anti-Vortex Devices)

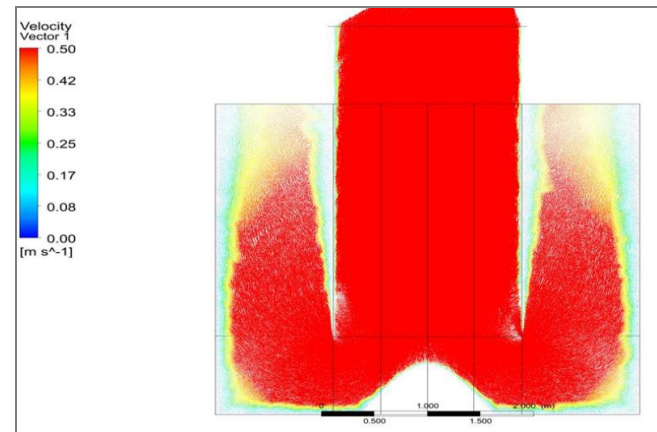
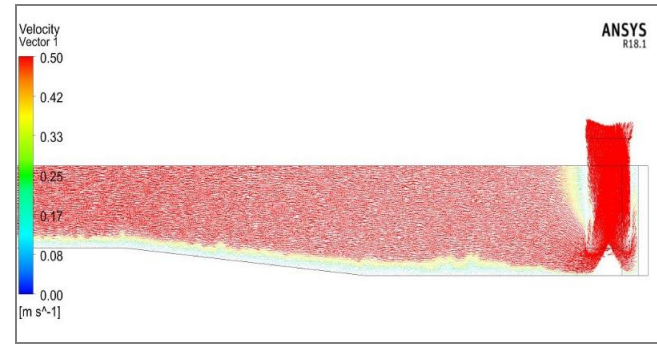


Figure 7: Velocity vectors in the flow computational domain

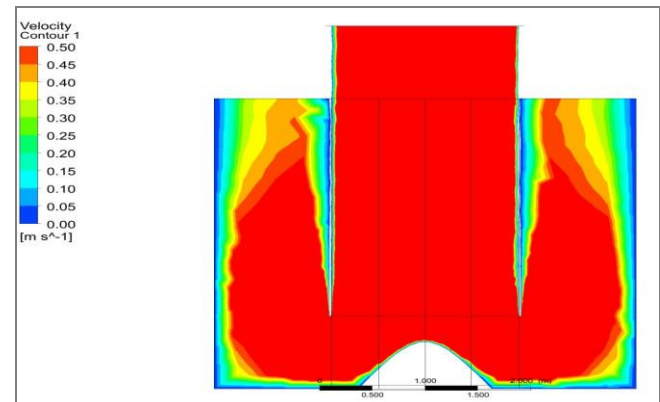


Figure 8: velocity contours in the flow computational domain

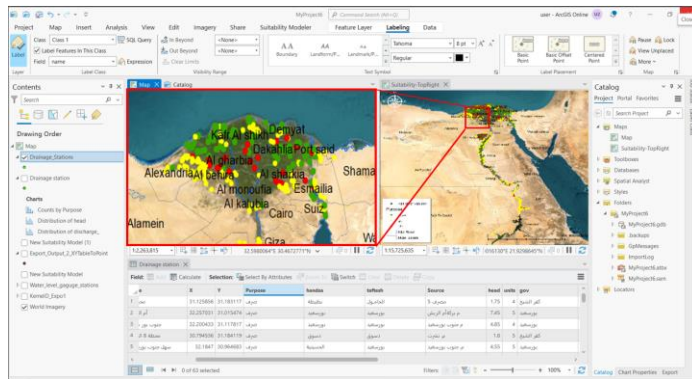
### 4. GEOGRAPHIC INFORMATION SYSTEM (GIS)

GIS provides advantages in data processing and spatial analysis. The data processing capability of GIS was utilized to process construction, landscape, and spatial data. GIS is used in pumping stations for various purposes, such as:

1. Asset Management: GIS can help in managing and maintaining information about pumps, pipelines, valves, and other infrastructure components within the pumping station by developing a geodatabase for all stations, as shown in Figure (9).
2. Spatial Analysis: GIS is used to analyze spatial data related to the pumping station's location, topography, proximity to water sources, and potential risks like flooding or environmental hazards.

3. Network Monitoring: GIS can aid in the real-time monitoring of the pumping station network, helping operators track water flow, pressure levels, and identify potential issues or leaks.
4. Emergency Response: GIS assists in emergency response by providing accurate location data for quick mobilization of resources during incidents like pump failures or system malfunctions.
5. Planning and Expansion: GIS supports decision-making processes by providing insights into optimal locations for new pumping stations, assessing capacity needs, and planning for future infrastructure upgrades.

By leveraging GIS technology in pumping stations, operators can enhance operational efficiency, improve maintenance practices, and ensure a reliable water supply to consumers.



**Figure 9:** Geo-database of pumping stations in Egypt

### 5. CONCLUSIONS AND RECOMMENDATIONS

The proposed geometry for the intake and suction basin of PS No. 7 Intake is considered acceptable since no dead zones or vortices are formed in front of the pumping units and the pumping house.

To maintain the flow velocity at the inlet suction of each tube of every pump unit at 0.50 m/s, it is recommended to adhere to the modified design and dimensions according to the drawings.

Ultimately, this study emphasizes the need for taking a comprehensive approach to pump intake design that integrates CFD and GIS techniques. Pumping station number 7 at El-Hammam, New Delta has been chosen as a case study. By utilizing new computational tools and spatial analytic methodologies, we can advance our understanding of how design parameters affect pumping system performance, resulting in increased overall efficiency and sustainability.

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