# Environmental Hydrodynamics Mitigation of Burullus Lake in Egypt

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*Abstract*- The objective of this study is to investigates issue related to hydrodynamics in Lake El-Burullus and flow patterns there by using tool for improving the environmental conditions in the surroundings which can assist the decision makers, it was utilized SMS, surface water simulation modeling to calibrated and validated hydrodynamic model. This chapter mainly discusses the data collecting stage and building the methodology followed in the whole study. The data discussed included the hydrodynamic water depth and velocity. The bathymetry of the Lake was preprocessed through SMS-GEFGEN, then the water levels and discharges of the drains were used in the model were preprocessed through TABS-RMA2. Climate of the Lake especially wind vectors and temperature are included as inputs in the TABS - RMA2 model. The next paper the coupled hydrodynamic water quality models procedure was discussed in details.

*Keywords- Lake Burullus, Numerical model, hydrodynamic modeling, Nile delta*

## I. INTRODUCTION

Wetlands consider one of the most important ecosystems in the world in which it provides services that are indispensable to human beings and biodiversity's survival, health and welfare. wetlands perform crucial basin-wide functions, like as providing food, water, livelihood sources, improving water quality, saving the ability to overcome draughts and flooding for the sake of the biological diversity protection. Many of these benefits – such as water quality and biodiversity – not only reach the populations living near them, but also produce positive effects for communities in the basin that live well outside the wetland area.

Wetlands and water bodies consider at least four percent of the total area. This relatively small portion of the territory provides a great range of basin-wide benefits. More than 70 major wetlands of relevance for the Nile system have been identified by the riparian countries, with concentrations in two areas: The Equatorial Lakes region and the area in South Sudan [1].

## II. STUDY AREA

Burullus Lake was considered the second largest of the Egyptian northern lakes along the Mediterranean coast as shown in Figure 1. It is located in the central part of the northern shoreline of the Nile Delta between longitudes $30^\circ30'$–$31^\circ10'$ E and latitudes $31^\circ35'$–$31^\circ21'$ N. The lake is shallow, water depths vary from 0.4m to 2.73m, maximum water depth is recorded near EL-Boughaz inlet, and the lake surface area is 410 km², of which 370 km$^2$ is open water [2].

## III. PROBLEM STATEMENT

Eight drains discharge into Burullus Lake with a total discharge of 3904 million m3/year including agricultural, industrial and domestic waste water. The Lake serves as reservoir for drainage waters, from agricultural areas through eight drains in addition to the fresh water from Brimbal Canal situated in the western part of the lake. Pollution inside the Lake is due to chemical pollution, which comes from the industry, and this indicates an industrial growth in the region. The lake's high nutrient environment allows floating plants to grow extensively. The subsequent sediment accumulating around the roots of the plants effectively sub-divides the lake and effects the water circulation. In addition, Total suspended solids TSS values are very high, which means that the high pollution of organic and non-organic material from industrial and agriculture waste. Declining of salinity levels inside the lake is considered a major problem. Total percentage by weight of marine fish species such as Liza Ramada decreased from 16% in 1973 to less than 1.8 % in 2003 and fresh water fish such as Tilapia increased from about 81% to 98.2 % [3].The brackish lake salinity levels range from 2.1‰ in the west to 17.2‰ in the north[4]. Figure 1 shows the drains discharge into the lake were obtained from NWRI 2016.
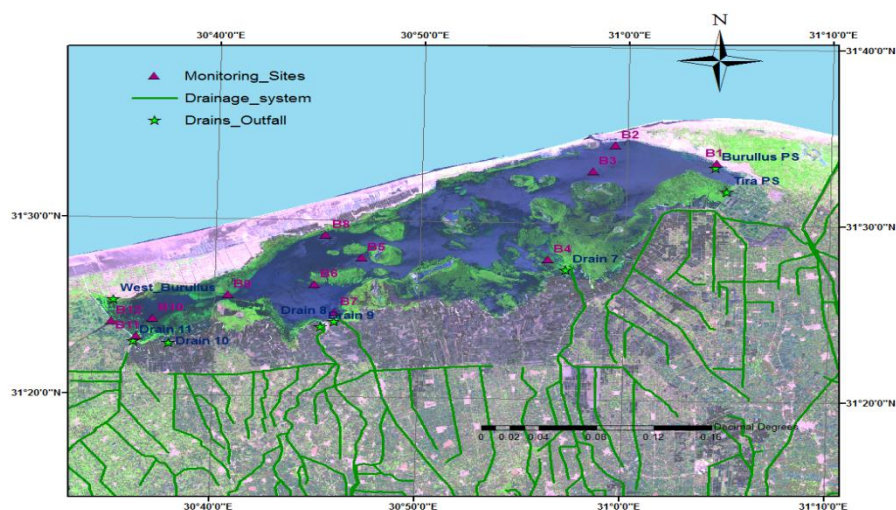
Figure 1.  Satellite Map of Lake Burullus

## IV.  OBJECTIVE OF THE STUDY

In this research work, an integrated approach was followed in order to help decision makers to take the necessary actions to control the pollution inside the lake and to improve the lake environment. The used integrated approach includes developing a calibrated/validated hydrodynamic A one-dimensional/two-dimensional numerical model for depth-averaged transport.

## V.  COLLECTION DATA

The available data of El-Burullus Lake which included hydrodynamic, meteorological and geometrical datasets was used in the calibration/validation process of hydrodynamic model. The model is used to simulate the hydrodynamics of the lake. Moreover, a calibrated and validated water quality model was developed based on the 2D depth averaged hydrodynamic model. Different datasets included water quality of the drains;

open boundaries at sea side and inside the lake were used in the model calibration/validation. The model also used to simulate the spatiotemporal distributions of the salinity, heavy metals, pH and ammonium (NH4). The developed coupled-hydrodynamic-water quality models were utilized in assessing potential mitigation scenarios aiming at enhancing the circulation patterns and controlling pollution inside the lake. These potential mitigation alternatives included decreasing the pollutant loads that enter the lake i.e. diversion of existing drains and/or enhancing the circulation patterns and exchange rates between the lake and Mediterranean Sea through artificial inlets, culverts or pump stations. Finally, the developed models of lake El-Burullus were used to assess the potential impacts of climate change on the spatial distribution of salinity.

Water levels for the period ranged from 6/8/2004 to 31/7/2005 were collected by Coastal Research Institute CoRI using stage boarder in stations shown in Figure (2), Data were collected two times a day. These water level data are presented in Figure (2).
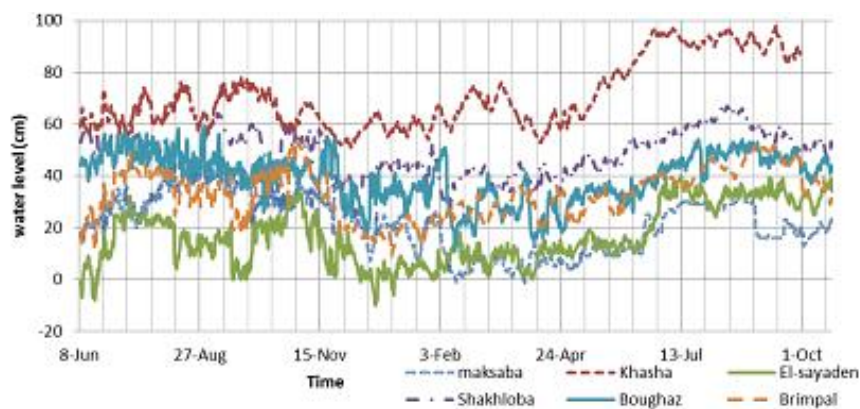


Figure 2.  Measured water levels in Lake Burullus

## VI. APPLICATION OF SMS

SMS (Surface-water Modeling System) is perfect software for establishing and simulating surface water models. It is a graphical user interface and analysis tool that allows researchers to visualize, analyze, and understand numerical data and associated measurements. Many of the tools in SMS are generic. They are designed to assist in establishing and operating the numerical models of bays, rivers, inlets and lakes it features 1D and 2D modeling and a unique conceptual model approach. Some of the currently supported models in SMS include, FESWMS, GenCade, PTM, STWAVE, TABS, ADCIRC, BOUSS-2D, CGWAVE, CMS-Flow, CMS-WAVE (WABED) and TUFLOW.

## VII. SMS MODEL

The TABS-MD (Multi-Dimensional) Numerical Modeling System was considered one of the most important software which was designed for studying multi-dimensional hydrodynamics in rivers, reservoirs, bays and estuaries. The hydrodynamic engine for the system is the RMA2 and RMA4 were written by Resource Management Associates, Lafayette, California, and modified by WES. SED2D was written jointly by Resource Management Associates and WES.

### A. RMA2

RMA2 is a hydrodynamic numerical model of finite element with two dimensional depth averaged. It computes water surface elevations and horizontal velocity components for subcritical, free-surface flow in two dimensional flows. It also computes a finite element solution of the Reynolds form of the Navier-Stokes equations for turbulent flows. Friction is calculated with the Chezy equation or, Manning's and eddy viscosity coefficients are used to define turbulence characteristics. Both steady and unsteady state (dynamic) problems can be analyzed.

### B. RMA4

Is part of the TABS-MD suite of programs and is used for tracking constituent flow in 2D models.

### C. Spread Simulation

#### 1) Shallow Water Equations and the Continuity Equation

In shallow sea, the density $\rho$ is assumed to be a constant number of two-dimensional fluids, and a horizontal component of velocity (u, v) is considered the vertical direction. Water is assumed to be incompressible fluid. Phenomena governing the movement equation and the continuity equations of shallow water equations are as follows:

$$\frac{\partial U}{\partial t} + \frac{\partial (uU)}{\partial x} + \frac{\partial (uV)}{\partial y} - fV = -gH\frac{\partial \eta}{\partial x} + \frac{\tau^{\alpha}}{\rho} - F^{\alpha} + T^{\alpha} \quad (1)$$

$$\frac{\partial V}{\partial t} + \frac{\partial (vU)}{\partial x} + \frac{\partial (vV)}{\partial y} - fU = -gH\frac{\partial \eta}{\partial y} + \frac{\tau^{\alpha}}{\rho} - F^{\alpha} + T^{\alpha} \quad (2)$$

The continuity equation is:

$$\frac{\partial \eta}{\partial t} + \frac{\partial U}{\partial x} + \frac{\partial V}{\partial y} = 0 \quad (3)$$

Where h is the depth to average submarine at sea level, H is water depth (H = η + h + hb), hb is the displacement of the seabed, g is the Gravitational acceleration. η is the displacement from standard sea level, τx, τy the wind stress x, y components, U, V are integrals of u, v from the seabed to the sea surface. Fx, Fy are x, y component of the seabed friction and, Tx, Ty viscous force of the horizontal x, y-direction component.

For most geometry settings, the automatic assignment of elemental turbulence coefficients (eddy viscosity) by Peclet number is a very powerful tool. The Peclet Method is based upon a Peclet numbers (P), where P is recommended to be between 15 and 40. Generally, larger elements, and elements with higher velocities will have larger eddy viscosity values. Smaller Peclet numbers win larger values of eddy viscosity.

$$E = TBFACT * A\left[\left(\frac{\partial u}{\partial x}\right)^2 + \left(\frac{\partial v}{\partial y}\right)^2 + 2\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right)\right] \quad (4)$$

Where A=the area of the element

$\partial u / \partial x$ and $\partial v / \partial y$ =velocity component gradients (evaluated over the element)

E=eddy viscosity

Recall that Eddy Viscosity (E) and Peclet number are inversely related. The formula for Peclet numbers (P), where P is recommended to range between 15 and 40.

PudxE=ρ

ρ= fluid density, u= velocity magnitude, dx=element length

$$P = \frac{\rho u dx}{E} \quad (5)$$

TABLE I. COEFFICIENT UNITS

| Coefficient | English Units | Metric Units |
|---|---|---|
| ρ= fluid density | 1.94 slugs/ft$^3$ | 998.46 kg/m$^3$ |
| u=average element velocity | fps | mps |
| dx=length of element in stream wise direction | ft | m |
| E=eddy viscosity | lb-sec/ft$^2$ | Pascal-sec |

### D. Simulation Plan

Surface bed elevations can read the data from Google earth, Lake Map and scatter point for water depths, also we will build bathymetry mesh map by using the same data with software SMS10.1, with applied GFGEN, RMA2 and RMA4.

Preprocessing software was used to combine and create bathymetries and assigning data of sample points to the cells.

The current study is considered the second study which deals with the water hydrodynamics of El-Burullus Lake. [7]

The developed field validated 2D and depth averaged model will enhance our understanding of the hydrodynamic behavior of Lake El Burullus. The next step is to construct a full water quality model through the hydrodynamic model. In this study, the applied forces in the model are wind speed and direction, water levels, temperature and salinity at the model marine boundary and freshwater inflow from the drains.

The objective of the study:

1. To represent the variability in hydrodynamic conditions inside the lake in case of Climate change.

2. To validate and calibrate the hydrodynamics model (water-level and velocity).

The second stage of an integrated management for El-Burullus Lake is aiming at assessing the current situation in the Lake and make scenario analysis to control pollution inside the Lake Finally; various mitigation scenarios were tested in order to find solution to control the pollution inside the Lake. Study the Climate change effect on the Lake based on the data of scenarios developed by Coastal Research Institute (CoRI) and the national water research institute (NWRI).

## VIII. MODEL INPUTS

In order to use the SMS, we need to apply some data, as:

### A. Eddy viscosity and Manning value,

As per we consider that the lake Burullus is shallow river.

TABLE II.    TIDAL WAVE (TIDAL CURVE)

| Region | Alexandria | Al-Burullus | Port Said |
|---|---|---|---|
| Tidal Trend (mm/y) | 1.6 | 2.3 | 5.3 |
| Subsidence (mm/y) | 0.4 | 1.1 | 3.35 |
| SLR (mm/y) | 1.2 | 1.2 | 1.95 |

### B. Roughness coefficients

A spatially varied bottom roughness was developed using manning roughness coefficients between 0.02 and 0.088 for floating leaved rooted plants as stated by environmental agency in 2008. The areas of floating vegetation were determined by a supervised classification using Land sat imagery of the same period [6].

### C. Drains Discharges

Drains discharge for the period ranged from 24/8/2009 to 24/7/2010 were collected by Coastal Research Institute CoRI as shown in Figure (3).
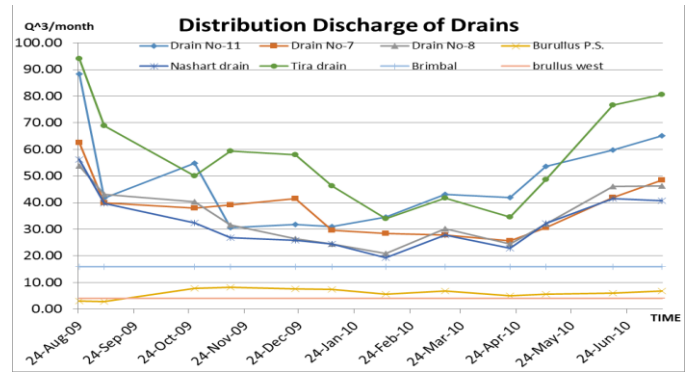


Figure 3.    Drains discharges into lake El-Burullus. Discharge: million m³/month.

## IX. CALIBRATION AND VALIDATION OF MODEL
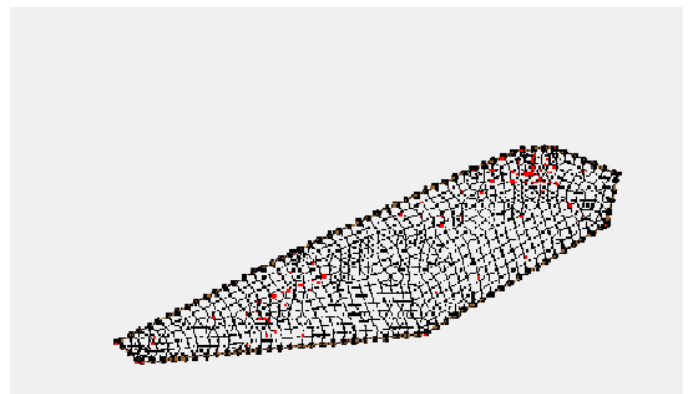
### A. Bed Elevations



Figure 4.    Water Depth Stations Monitoring.

The previous figure shows the water depth stations, this data are obtained from (salah, N. Ayyad1-2010), Distribution pattern and environmental controls on benthic foraminifera in el-burullus lake, north of the Nile delta, Egypt, journal of environmental sciences, 2010) then we use this data to build the bathymetry shape for the lake, by using SMS.GFGEN (Hydrodynamic Module).
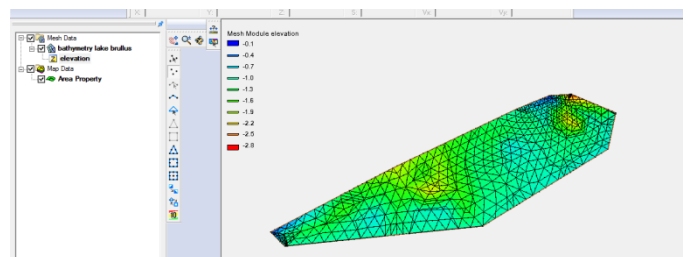


Figure 5.    Bathymetry Mesh for Bed Elevations of Lake El-Burullus.

The previous figure shows the elevation inside the lake and Boughaz outlet to the Mediterranean Sea, this output data are obtained from GEFGEN MODEL the preparation stage for TABS (Hydrodynamic Module) the contours color line indicate the point below surface sea level.

## X. HYDRAULIC RUN RESULT

### A. Output Results from GFGEN2D



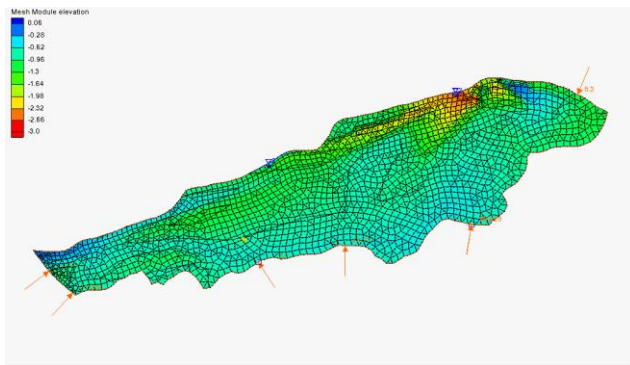Figure 6. The developed curvilinear grid to discredited Lake El-Burullus.



Figure 7. Bathymetric Map of Lake Burullus and Drains Locations.

Water depth for the period ranged from 24/8/2009 to 24/7/2010 were collected by Institutional Water Research for 64 station the deepest area is towards to Boughaz as shown in Figure 7.

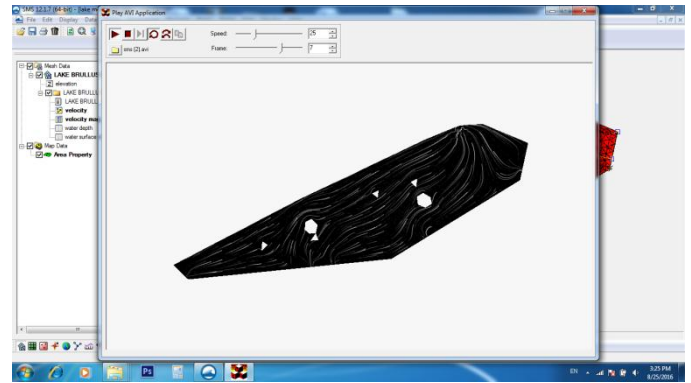### B. Output Results from RMA2 in Static State



Figure 8. Velocity Film Loop inside the Lake shows the Velocity Direction at Drains and inside the Lake with the absence of wind forces.

The above figure shows that the velocity direction pattern of flow form inlet drains to EL-Boughaz inside the sea in absence of wind force, it is noted that the velocity value around drains ranged between 0.03 m/s to 0.5 m/s and inside the lake where the velocity reach to 1.0 m/s and increase towards EL-Boughaz outlet until reach the maximum value 1.8 m/s in distance 5m, it is noted that the drains discharges effect on the velocity in the area near their inlets around drains.
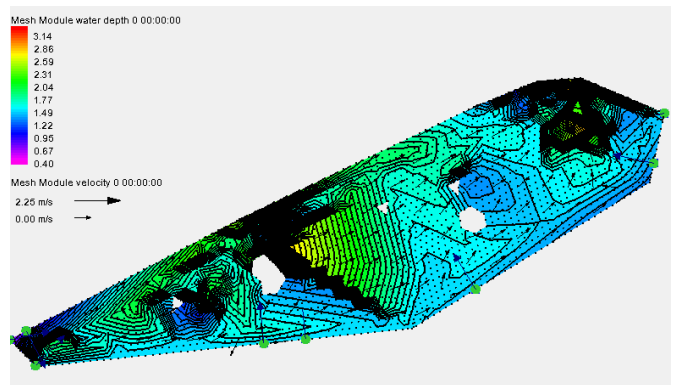


Figure 9. Simulation Water Depths inside the lake and at EL-Boughaz.

Water depths vary from 0.4m to 3.14m, in the middle and western area, the maximum water depth is recorded near EL-Boughaz inlet, it was indicated by dark area as shown in the figure.
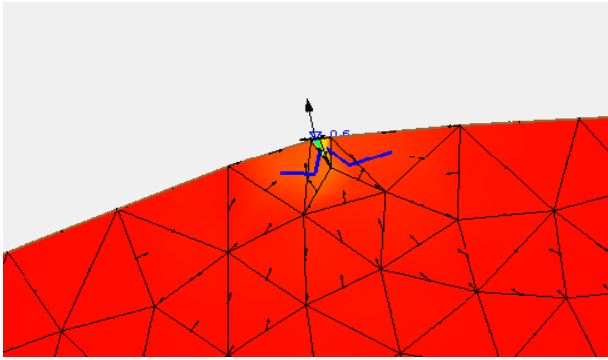
Figure 10. Velocity vectors and Direction at EL-Boughaz with the absence of wind forces
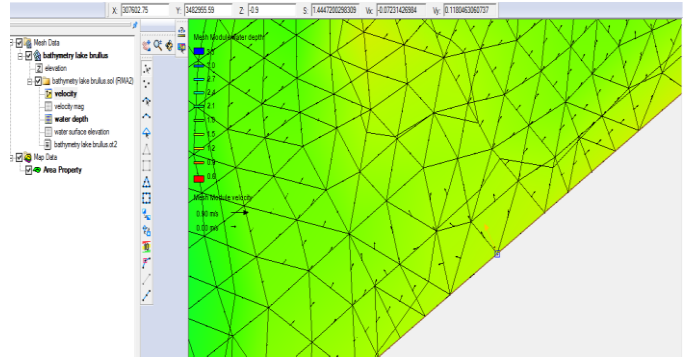


Figure 11. Velocity magnitude and Water Depth elevation at Drain-7.

The above figures show that the velocity magnitude and the direction pattern of flow around EL-Boughaz the velocity ranged almost 0.5m/sec and 1.2m/sec in the west side of Boughaz and reach 1.8 m/sec, in the center of outlet to the Mediterranean sea in the absent of tidal wave and wind force.

The above figures show that the velocity magnitude and the direction pattern of flow around Drain-7 velocity around the drain is about 0.5m/sec and decrease inside the lake which reach to 0.001m/sec.
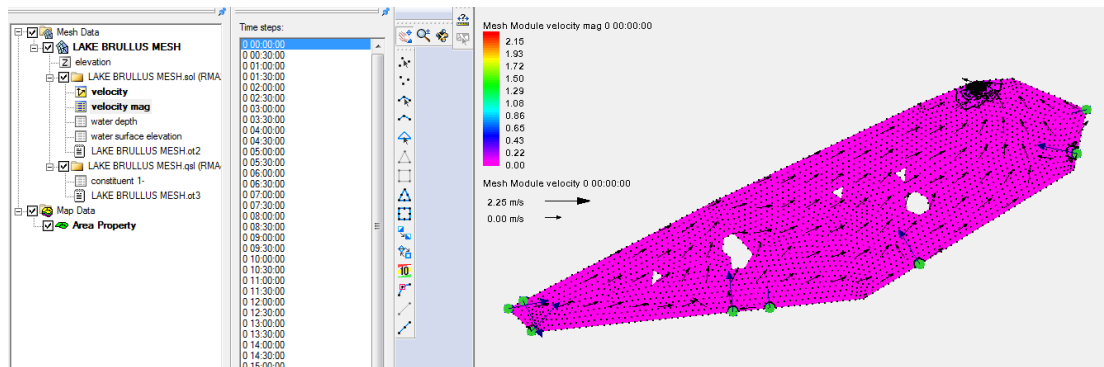
*C. Output Results from RMA2 in Dynamic State*



Figure 12. Velocity magnitude and Direction of flow in EL-Brullus Lake in case of wind force.

The above figures show that the velocity magnitude and the direction pattern of flow form inlet drains to EL- Boughaz inside lake in the dynamic state and take into consideration the wind force, which is west north direction as appear in figure it is noted that the effect of wind force on velocity is limited.
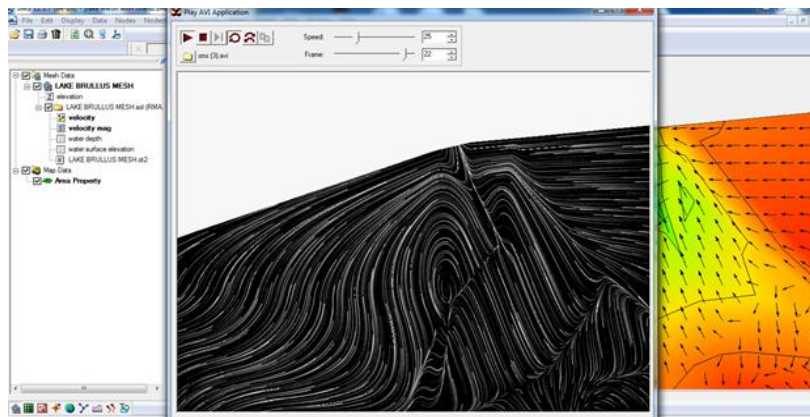


Figure 13. Velocity Film Loop inside the Lake shows the Velocity and flow Direction at EL-Boughaz in case of wind forces.
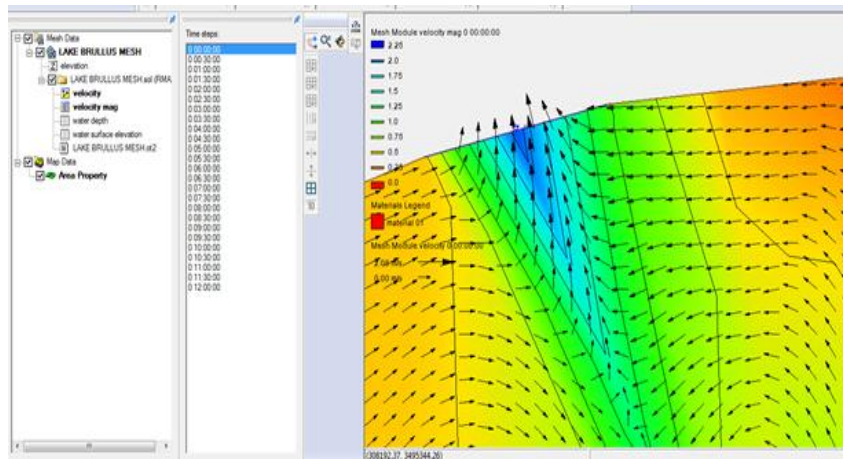
Figure 14. Velocity and Flow Direction at EL-Boughaz in Case of Wind Forces

The above figures (13) and (14), show the velocity direction and values near El-Boughaz and drains in dynamic state which ranged from 0.0623 to 0.2m/sec around drains and ranged from 1.0 m/sec at the east of El-boughaz and 0.56 at the west side of the outlet of EL-boughaz increase gradually to reach 2.08 m/sec in distance nearly 5m at the outlet of El-Boughz to the outlet to the Mediterranean sea in case of wind force which from west north direction.
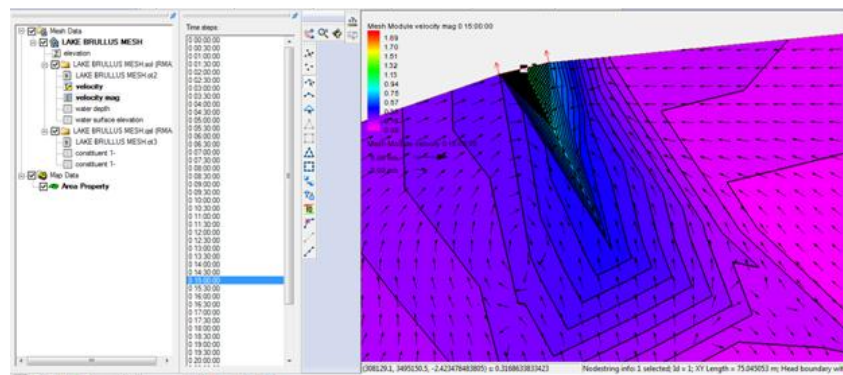


Figure 15. Velocity and Flow Direction at EL-Boughaz in Case of Tidal wave

The above figure shows the velocity direction and values near El-Boughaz in Case of Tidal wave which ranged from 0.6 to 1.2m/sec in distance nearly 5m at the outlet of El-Boughza to the outlet to the Mediterranean Sea.
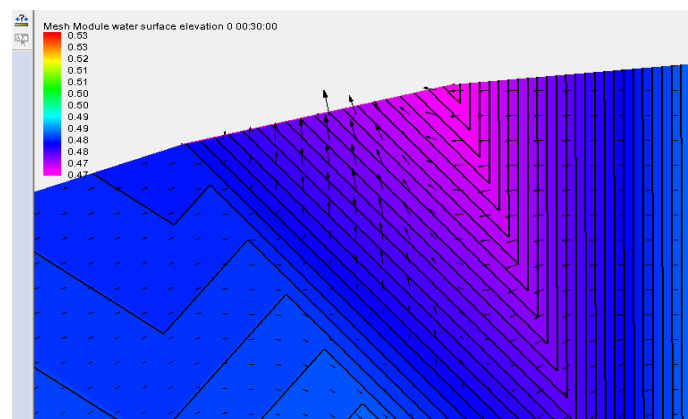


Figure 16. Water surface elevations at EL-Boughaz in Case of Wind Forces

The above figure shows the water surface elevations near El-Boughaz in Case of Tidal wave and wind force which have values ranged between 0.72m and .076 m, this values obtained from RMA2 Run inside the lake and at the outlet of El-Boughza.

## XI. CONCLUSION AND DISCUSSION

From the above curves and output from water surface simulation modeling system, SMS was utilized to develop the hydrodynamic model for lake EL-Burullus. The model was calibrated manually using data monthly average discharge daily water levels simulated exchange between lake and the Mediterranean sea at cross section in EL-Boughaz, simulated sea water levels at stations measured by Elshenawy as shown in figure 2 show the simulated water level in three stations inside the lake which are Boughaz, west and mid station and the simulated water levels as shown in figure 16, the results are well matched. And the wind force used in the simulation is from one station beside the lake, from this result its show that this simulation show how well the commuted and observed values match and applicable for the next simulation regarding to water quality parameters.

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