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WATERSHED MANAGEMENT FAST TRACK PROJECT EGYPT-SUDAN

Monitoring System Design

Draft
Stockholm 17 August 2007

Project No. 1989152

ra02e 2005-01-17

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1 Introduction

Increasingly extensive efforts have been laid down in annual surveys and measurements in the Lake Nasser/Nubia. Also various modelling exercises have been carried out to understand and investigate the deposition pattern for the sediment carried into the reservoir by the Nile. The large amounts of data that have been accumulated have been kept in an organized manner, although no proper database has yet been established.

Annual investments in these activities are large and there is a need to review and optimise the activities in order to achieve the desired results at a minimum cost.

It has been suggested in the ToR to see all of these activities/items (surveys and measurements/modelling/database) as part of an integrated Monitoring System.

In the following, the present situation is analysed briefly and the results of the presently ongoing activities are compared with the desired results. The existing gaps are identified and a draft proposal for activities to complement/revise the existing set-up to create an integrated Monitoring System that will provide the desired results.

2 Present Situation

Extensive annual surveys are carried out in Lake Nasser/Nubia. The surveys are presently being carried out at the same period every year, the main result being the level of the sediment along a number of cross sections in the lake. Also grain size distribution of deposited sediment, concentrations of suspended sediment, water quality parameters and flow velocities are being measured during these annual surveys.

The extent of the surveys as well as the methodologies applied are in continuous development, and presently the annual surveys cover the entire sedimentation area. Also the mathematical modelling efforts have the character of research and development, continuously striving to improve the results of the modelling. With the rapid growth of the data volume, the establishment of a robust and flexible database becomes increasingly necessary. Some modest attempts have been made, but there is a long way to go before such database system is operational.

3 Objectives

- Analyze the status and evolution trends of available data on sedimentation processes in Lake Nasser/Nubia, both in terms of flood-carried sediments and wind blown sand; status of knowledge on corresponding effects on water quality and water resource availability

- Design a monitoring system to assess direct and indirect impacts of future upstream watershed management projects as well as sand blown effect on sedimentation in Lake Nasser/Nubia

Specific objectives with respect to different components are:

Surveys, measurements and investigations

1) Complete hydrographical survey to be executed for the whole Lake area to create a complete bathymetric map with suitable contour intervals, for better estimates of sediment deposition volumes and distributions
2) Lake water levels versus Lake surface area and Lake Volume curves require updating
3) Proposed design for Lake Nasser/Nubia Sediment Monitoring System shall allow for upgrades and adjustments. Focus of the system on sedimentation (flood-carried sediments and wind blown sand)
4) Consider in design of Monitoring System to use efficient low cost modern technologies such as bathymetric survey using sonar and satellite imagery

Mathematical modelling

5) The design of the sediment monitoring system and sampling strategy will require preliminary modelling based on readily available information to determine specifications. It is expected that the national consultant will use one of the well-established one-dimensional models to input the Lake Nasser specific data

6) An approach to be designed to analyze main properties of delta formation/progress in Lake Nasser/Nubia, and to estimate the time for filling the dead buffer zone of the Lake, which defines the lifetime of the reservoir. *This may result in a one- or two- dimensional model approach or a combination of the two. Two-dimensional modelling could be applied for more detailed assessment of delta deposition in a second phase of the project.*

Dune migration, encroachment and windblown sand

7) Propose a monitoring system for dune migration, encroachment and wind erosion

Environmental aspects

8) Sediment quality and deposition monitoring programme to obtain lake bed materials and deep borings. Physico- and biochemical analyses to be applied on lakebed materials and sediment deposition borings to study organic contents and contaminants in deposited sediments, particularly clay soils

4 Desired results

At present, the requirements that the results of monitoring activities in the Lake Nasser/Nubia must fulfil are of a qualitative nature. This is closely linked to the present application of the results, rather for information than for concrete planning purposes. The transition to an improved Monitoring System may be seen in conjunction with the transition to the use of the Monitoring System for planning of future activities within the Lake Nasser/Nubia area, with more rigorous and quantitative requirements to the results from the Monitoring System in the future.

At present the monitoring of sediment deposition in the Lake serves the following purposes:

- Provide information on the present situation with respect to sedimentation in the Lake, including the distribution of the sedimentation
- Provide timely information on any sudden increase in sedimentation, such that remedial actions can be planned as early as possible
- Improve the understanding of the sedimentation process
- Provide information on sediment and water quality

It is the intention that information shall be used in the planning of possible future dredging of the sediment and utilisation of it for agricultural and industrial purposes. Such plans are, however, still at a very early stage.

While present requirements to performance and results of ongoing surveys, measurements and mathematical modelling are somewhat diffuse, it is anticipated that requirements will be formulated in the future in connection with more specific applications. The recommendations of a future Monitoring System of improved quality and accuracy takes into account such future requirements.

5 Concept of Monitoring System

While the present 'system' has all the basic elements of a future Monitoring System, the three elements:

- surveys and measurements
- mathematical modelling
- database

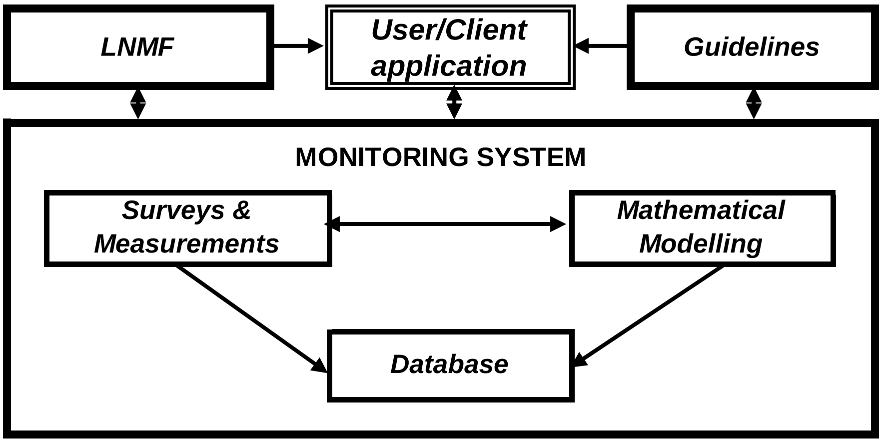
are not presently integrated into a coherent system. At present, data from surveys and measurements are applied in the modelling and entered into the 'database'. It is the integration of the three components that makes a Monitoring System. Possible interactions between the three components are:

- The mathematical models and the modelling scenarios are selected, so that they can provide the results requested

- Surveys and measurements are planned to provide the data required by the model, so that the model can provide the results required by the user. This means data for model calibration and validation shall be provided by the surveys and measurements activities

- Choice of modelling system and model setup is chosen to suit the data that can be made available within the various areas, given the limitations in survey and measurements efforts

- The database system is designed to contain the data types and volumes that will come out of the surveys and measurements in the past and in the future



By considering each of the three components as part of a coherent Monitoring System, the design of each component will be optimised to provide the facilities required.

The Monitoring System for wind-blown sand and sand dune encroachment is presently kept separate, although there is a clear connection:

- The volume of wind-blown sand into the Lake Nasser/Nubia contributes to the sedimentation of the reservoir
- The volume of wind-blown sand into the river cross section upstream of Lake Nasser/Nubia contributes to the sediment balance for the river reach between Merowe Dam and the Lake
- Satellite images is a very useful tool to monitor bank erosion as well as sand dune migration. At the same time it is very useful for mathematical modelling

The reasons for presently keeping a Monitoring System for wind-blown sand and sand dune encroachment separate are:

- although quantification is limited, it seems the total volume of wind blown sand entering the Lake Nasser/Nubia annually is only of the order of 10% of the volume entering with the Nile flow
- the general difficulty in reducing this figure by any measures and the very large reaches along which such measures should be implemented makes it cost ineffective to spend efforts on reducing the volume of wind blown sand into the Lake

There are, however, very good reasons to locally limit the sand dune encroachment close to villages, valuable agricultural land. Likewise, it may be worthwhile limiting the encroachment on the Nile river cross sections in certain places, if quantifications and modelling of the effect of the encroachment shows that it has a considerable and unfavourable effect on the river morphology and river regime.

Bank erosion is an essential river morphological process, which is dealt with in the monitoring system through the use of satellite images to follow the development in bank erosion and if required detailed 2D modelling to predict this process in critical areas.

6 Surveys and measurements

It is anticipated that the following will need to be surveyed/measured in the future:

1. Lake bed bathymetry (including dry shore)
2. Grain size distribution and sediment quality of bed sediment
3. Suspended sediment concentration
4. Grain size distribution of suspended sediment
5. Flow velocities (profiles) and discharge
6. Waves
7. Temperature profiles
8. Water quality parameters

The frequency and density of measurement will vary considerably from item to item and depending on the use it may be decided to change the measuring frequency and density with time.

In the following each of these items are discussed in more detail.

6.1 Lake bed bathymetry (including dry shore)

The surveys of the lake bed levels are used to update the estimate of the amount of sediment that has entered into the lake and to obtain information about where in the lake the sediment has deposited.

Presently, lake bed levels are measured annually, while dry shore levels have been measured once. It is not clear to the Consultant why bed level surveys as frequently as every year is required. During one year the storage volume of the Lake will reduce by a fraction of a percent, and doing the surveys at the same time every year limits the possibility of gaining the experience that would follow from measurements done at different seasons with a very different flow conditions. Nile flood flows are indeed very different from year to year, something that will affect the sedimentation pattern.

It is proposed to introduce intensified surveys over a number of years (2-3). During those years, lake bed bathymetry will be surveyed 2 times while all other parameters are measured 4 times. The aim of the intensified surveys is to learn from the frequent measurements at very different flow conditions, and based on a careful analysis, in the future be able to predict with sufficient accuracy the development, say 4 years ahead, based only on rated inflow of water and sediment at the upstream end of the Lake. Once the method has proved adequate, the present annual survey can be reduced to a survey campaign every 5 years.

At the same time it is proposed to improve the bathymetric survey techniques to make the surveys more cost effective in the long run and delivering results to satisfy any future requirements. The project will upgrade the survey techniques to state-of-the-art methods that are the most suited for Lake Nasser/Nubia. This will be done through some pilot tests to determine the best combination of techniques.

The techniques to be tested are:

- multibeam echo sounder for bathymetric surveys
- LIDAR green and red light bathymetry/topography methods for bathymetry (in areas of clear water, eg at low inflow/shallow water)
- bed penetrating sonar, to test the possibility of detecting annual layering

Based on the findings from the pilot tests, the best suited instruments and auxiliary equipment and software will be acquired and tested on-board survey vessels. Staff will be trained in the use of the equipment, as well as in the handling and analysis of data using the analysis software.

The advantage of using LIDAR green light for bathymetry of shallow areas compared with multibeam surveys over water is illustrated in Figure 6.1.1 below.

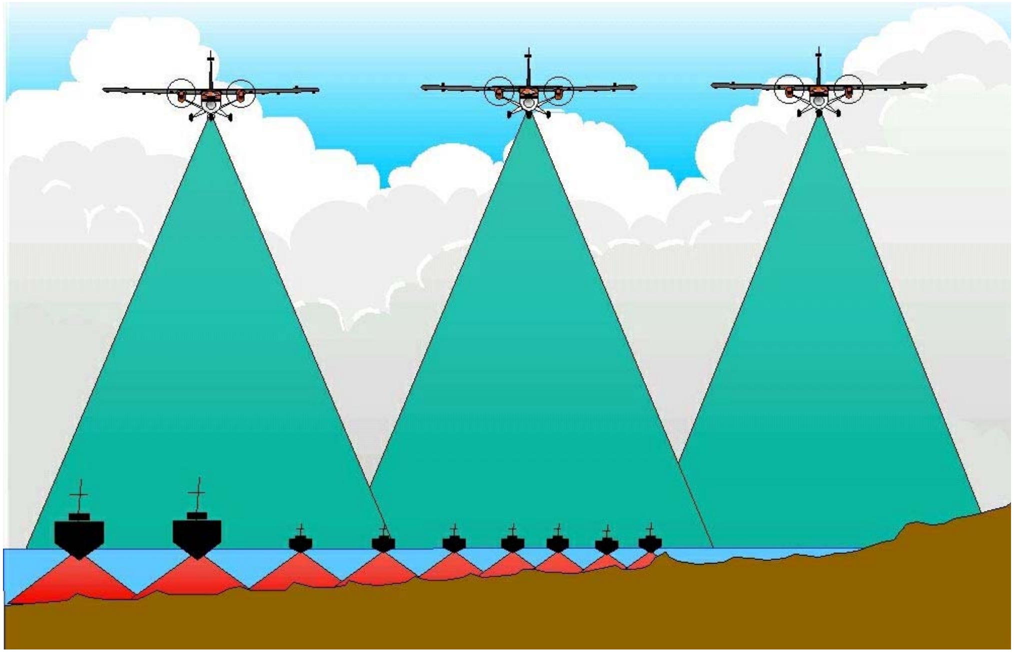


Figure 6.1.1 Principles of LIDAR survey and multibeam echosounder survey in shallow areas.

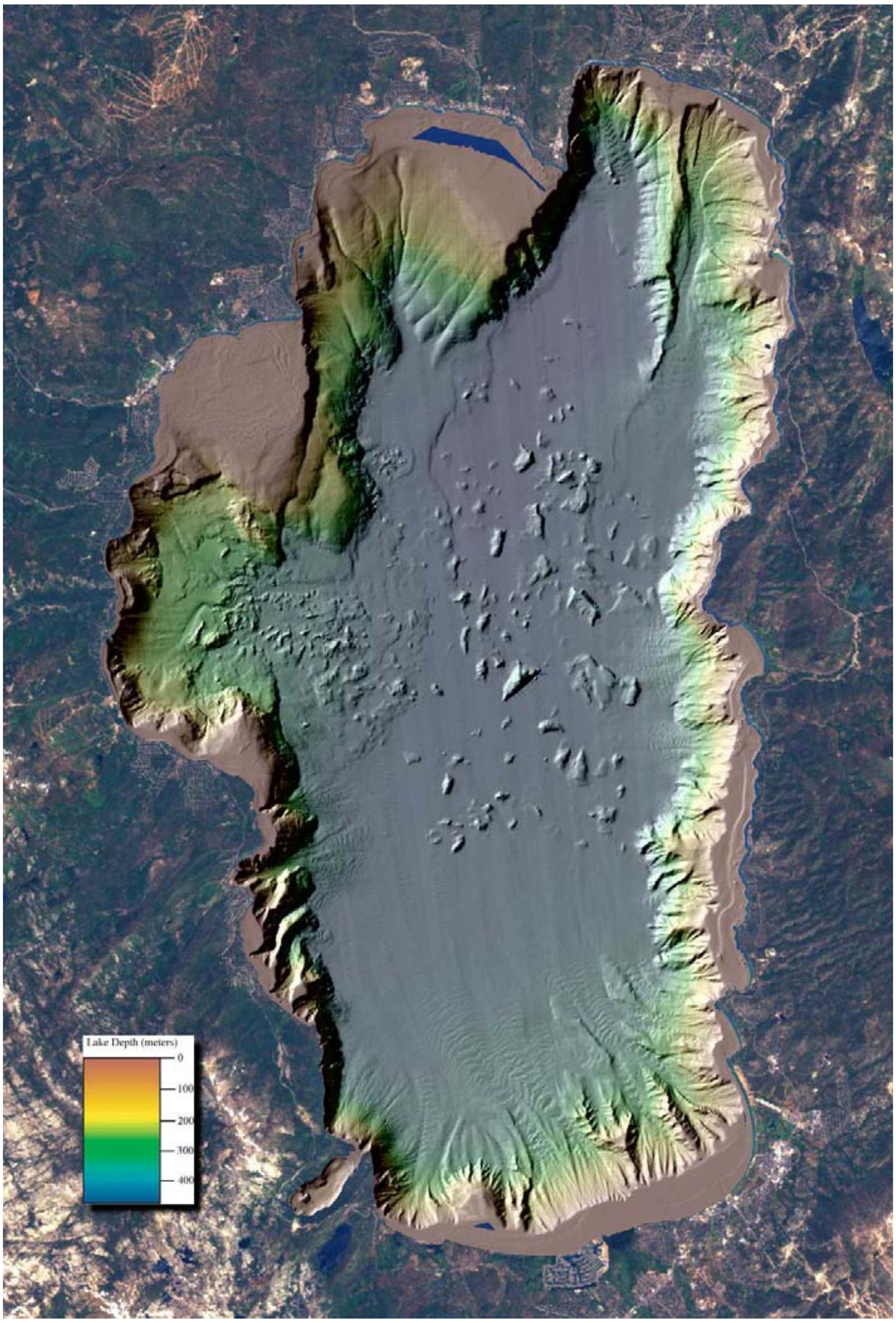


Figure 6.1.2 Combined LIDAR (to 15m depth) and multi-beam echosounder (from 10m depth and to bottom) survey of Lake Tahoe http://walrus.wr.usgs.gov/pacmaps/lt-shoal.html

6.2 Grain size distribution and sediment quality of bed sediment

The grain size distribution of bed sediments is related to the prevailing flow conditions at the time of settlement. Coarser fractions will settle during relatively high turbulence and thereby high flow velocities, while the finer fractions will settle only in relatively calm water.

Grain size distribution can be determined from samples taken of the top layer (by for instance van Veen grab sample method) or from deeper layer by drilling and core sampling.

While the sampling of bed sediment is simple and inexpensive, the core sampling requires more effort to ensure samples represent the depth where they are taken, in order to establish the stratigraphic series of layers, for instance with an annual sequence.

Setting up a drilling rig on the soft unconsolidated bed may cause problems due to penetration of the legs into the bed. Other methods involve lowering an underwater facility for bed penetration and sampling. While penetrometer testing may be sufficient to register a layering with say an annual sequence, sampling would be required to determine sediment quality data.

The determination of sediment quality properties may be useful, mainly in deciding on the potential use of the sediment, but also to investigate the possible content of pollutants.

Possible improved techniques to be tested will include:

- acoustic sub-bottom profiler (single or multi beam)
- submerged penetrometer
- sub-surface sampling techniques

In addition to these may come laboratory techniques tailored to determining the characteristics of the sediment as required.

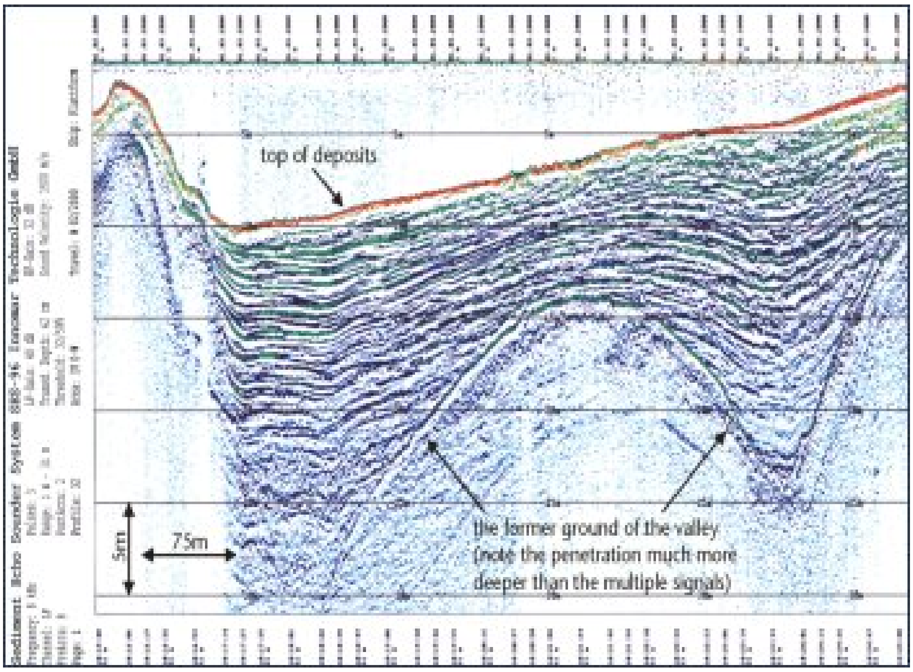


Figure 6.2.1 Echo print example from a German lake filled with deposits (INNOMAR SES 2000 Light from RESON)

6.3 Wave recorder

It is presently considered unnecessary to register actual wave characteristics. Instead, the wind speed and direction should be measured and applied to calculate the corresponding wave climate and wind generated currents (as part of the model setup). Continuous wind measurements would be required to be able to determine the wave climate.

6.4 Wind measurements

It is important to have continuous and representative records of wind speed and direction. At least one wind measurement station should therefore be set up and maintained at a location with winds that well represent the winds over the area of the lake where sedimentation is mainly taking place. The wind data are useful for calculation of:

- wave climate
- wind generated currents
- wind blown sand transport (if a model has been set up)

Wind gauging station(s) should be set up to provide this data.

For the wind blown sand transport, it may be necessary to set up more than one wind measurement station at appropriate locations. Existing wind measuring stations at airports may be applied as a supplement.

6.5 Flow/discharge and water levels

Flow measurements should be carried out, not only in the lake, but also in the Nile, upstream of the lake. As conditions vary with time due to the continuous morphological changes, the measurements should be repeated year after year. It is, however, important that the measurements are done at a variety of flow conditions so that all possible inflow rates are covered in the data. This is not possible if measurements are done at the same time every year, as per the present procedure. It is necessary that the measurements programme is designed to represent the prevailing flow conditions in the Nile as well as in Lake Nasser/Nubia. The aim of the measurements in the Nile at a station upstream of the lake (with no backwater effect from the lake) is to develop and continuously check/update a rating curve for the Nile inflow. It is essential that water levels are measured at the same time as flow velocities.

The upgrading of the present measuring equipment should consist of:

- Acoustic Doppler Current Profiler (ADCP) (minimum 2 for vessel mounting and minimum 1 for placing on lake bed)
- Water level recorders

The backscatter signal from the ADCP may (after calibration) be applied to record sediment concentration profiles as well.

A variety of water level recorder types exist. It is important to establish a robust and reliable system, which means the recorders should be reliable under the prevailing conditions and damage and theft should be unlikely.

6.6 Temperature

Temperature profiles are presently being measured in Lake Nasser/Nubia during the annual surveys. The measurements indicate the presence of layers with different temperature/density.

The primary purpose of temperature measurements in future will be the detection of density stratification, because this may affect the flow patterns and thereby the deposition/erosion of sediment and also water quality.

Point measurements are reliable, but only provide momentary stratification at single points.

Future developments should concentrate on surveys that can detect the stratified flow boundary along a sailed line. This will provide a an improved understanding of the character of the stratification. This may be possible with echo-sounders and/or ADCP.

Density differences may also be due to the high concentrations of sediment in the water entering the Lake from the Nile. This is described further in the next section.

6.7 Sediment concentrations

Sediment concentrations are presently measured at a number of locations using depth-integrating sampler and also point samples (by pumping). The depth-integrating sampler measures the average sediment concentration in a vertical, whereas the pump point samples measure the concentrations at a specific point in the water column. Both methods are reliable, but the disadvantage is that they are time consuming to do over a larger area and therefore are unsuitable for providing an overview of the concentrations in a larger area.

A method with the potential of providing an excellent overview of sediment concentrations, laterally as well as vertically is the use of the ADCP backscatter signal. With the ADCP placed on a moving boat, this method has the potential of providing a fast mapping of the sediment plume including the variation of sediment concentrations with depth. This method is therefore even applicable in recording a submerged sediment plume. The method is relatively new and a good quantitative result relies on a good calibration of the method. The calibration depends on several characteristics of the sediment, which even may vary with the flow conditions. A thorough calibration, therefore, requires a large number of manual concentration measurements simultaneously with the ADCP backscatter measurements, at a variety of flow conditions. It may, however, be possible to obtain a good qualitative ADCP backscatter measurement of the sediment plume with a less detailed calibration. Even such measurement will be useful for the decision on whether a submerged sediment plume exists or not. Thereby, this measurement becomes important in the decision on which type of Lake model to use (2D or 3D).

7 Modelling

Mathematical modelling, calibrated and validated with comprehensive and well selected data sets integrates the theoretical knowledge about the physical processes that is laid down in the mathematical equations, with the empirical information collected through surveys and measurements. The main purpose of the modelling is to enable predictions of what will happen under conditions that are different from the conditions at the time of measuring. The models are primarily expected to provide results on sediment deposition and erosion. But as these depend on flow conditions, it is essential that flow conditions are well described in the models.

A mathematical model has in general the advantage that it interpolates in time and space. Thus a model which has been calibrated on basis of point measurements is able to provide information on the sedimentation conditions at locations which do not have data available. Therefore, another result of the modelling effort is the enhanced understanding with the modelling team, of how the sedimentation/erosion system works in the entire lake area. Further, the models make it possible to perform relatively easily experiments with the system response to any imagined change. The detailed answers provided make the model a very good learning tool.

The continuous changes in bed level that take place due to sedimentation/erosion affects the flow pattern and in turn the sedimentation/erosion pattern. It is therefore important that the models applied are so-called morphological models (at least in areas where bed level changes are considerable) that take into account the ongoing changes in bed level during the simulation.

Density layering in the water column, due to temperature differences and/or differences in sediment concentration may under some circumstances determine the deposition/erosion characteristics. It is therefore also important that the mathematical model is able to describe such effects.

The models will need input/calibration/validation data of a certain quality and degree of detail in order to provide accurate and reliable results. The planning of surveys and measurement campaigns should therefore be done in parallel with the planning of the modelling.

The model area will comprise the Lake Nasser/Nubia and a reach of the Nile upstream of the lake. The upstream boundary is of the model area is very well placed at Merowe Dam. It is not necessary to look further upstream than Merowe Dam, since this dam is very newly established and the release of water and sediment from the dam is well known many years ahead. This means that changes further upstream are not going to have any impact downstream Merowe Dam for many years ahead. The reason it is not recommended to place the upstream boundary of the model further downstream, close to the lake, is the fact that presence of Merowe Dam is going to continuously change the morphology of the Nile for many years ahead. From now on, the morphology of the Nile between Merowe Dam and the Lake will start changing, modifying to the changed flow and sediment input conditions, with some similarity to the downstream effects of the Aswan High Dam: Due to less sediment entering upstream, the river flow will pick up sediment from river bed and banks, ie increased bed and bank erosion. Also the changes in flow regime may cause some changes to the plan form of the river reach. The adaptation to the Merowe Dam may well take several decades. During this period, the annual volume of sediment entering Lake Nasser/Nubia is likely to be less than what it was before Merowe Dam, but more than the sediment volume flowing out of Merowe reservoir. Only the model, verified by measurements can tell us how much more.

The model types recommended are:

- 1D morphological model from Merowe Dam to Lake Nasser/Nubia
- 2 D vertical morphological model for Lake Nasser/Nubia, or
- 3D morphological model for Lake Nasser/Nubia

It may be argued that a 2D horizontal morphological model is sufficient, but at present it cannot be excluded that under certain flow conditions, the sediment plume entering the lake will dive and act as a turbidity flow. If that is indeed the case under important flow events it will be necessary to apply a 2D vertical or a 3D model to describe this process, which will be important in describing erosion/deposition patterns. Only measurements of concentration profiles carried out at the time of high sediment concentrations in the Nile water can provide the evidence of whether or not relatively high density of the Nile inflow will cause a submerged sediment plume and spread as a turbidity flow. If this is not the case, a 2D horizontal morphological model may be applied instead of a 3D model. In the following it is assumed that a 2D vertical or a 3D model will be required. A 3D model may not be practical to set up for the entire lake, hence it is proposed to utilise a 2D vertical model in conjunction with a 3D model The 2D vertical model can provide information of the advance of the delta for the entire delta, and also provide initial bathymetry conditions for the 3D model at different times. The 3D model can then be run for a shorter period, and possibly only for selected areas in the lake.

The 1D model will take its upstream boundary conditions from Merowe Dam including the release of flow and sediment, whereas the 2D vertical/ 3D model will take its upstream boundary condition from the 1D model.

Rock outcrops in the river bed and lake bed will be incorporated in the models as non-erodible areas. This is going to be important in the 1D/2D vertical model, but less important in the 3D model.

Even the effect of wind blown sand will be included in the modelling. In this respect it is primarily the sand that is blown into and deposited within the river cross section at various locations that is of interest. Sand deposited within the ‘wetted’ section of the Nile contributes to the sediment balance in the river and will be available for erosion and downstream transport by the river flow. It is assumed that the wind blown sand will deposit in discrete events. Magnitudes and probable locations will be determined through studies of wind blown sand and dune migration, with specific event related to recorded high wind speeds. The 1D model will be able to quantify the effect of wind blown sand deposited in the river cross section (encroachment) on the morphology of the river and on the sediment entry to the Lake Nasser/Nubia.

The 2D vertical/3D model will model the flow in the Lake and the erosion/deposition of sediments, which during the simulation will influence the flow pattern. With a combination of the 2D vertical model and the 3D model it will be possible to test various scenarios, for instance:

- increased or decreased sediment inflow
- increased or reduced regulation of the inflow
- changes to water levels in the Lake
- dredging in the river or the Lake
- changes in the wind (and thereby wind driven flows and wave action)

All models can further be used to simulate the transport and dispersion of pollutants that arrive to Lake Nasser/Nubia with the Nile flow. Also in this case, reliable results from the model depend on good data obtained through measurements.

8 Database

There are presently no proper databases set up to organise the extensive sets of data concerning the Lake Nasser/Nubia. Databases serve the purpose of providing easy access to the data, and will further facilitate data sharing amongst various stakeholders and between countries. According to NRI, work has been initiated to set up a database system.

In the following, the present status is stated in general and in detail, and specific suggestions (recommendations) are put forward in connection with each statement of present status.

8.1 General situation

Status: inventory of all surveying dates available

Suggestion: some data need re-entering from hard copies

Status: inventory of all surveying types available for recent data

Suggestion: some data need checking re-entering from hard copies

File types

Autocad files for contour maps

Status: many files available
Suggestion: Select one typical contour map file and store as template

Autocad files for cross section data

Status: many files available (one for each cross section area)
Suggestion: Select one typical section and store as template

Excel files for cross section data

Status: inventory of files available. Point for the recent systems are defined by x,y,z global system. There is a use of graphic excel sheets and graphic links to autocad
Suggestion: Document these routines and atomize as much as possible

Excel files for velocity data

Status: no complete inventory available. Not consistent specification of the x,y,z coordinates.
Suggestion: Complete the inventory and add routines for proper definition of x,y,z

Excel files for bed sample data

Status: no complete inventory available. Not consistent specification of the x,y,z coordinates.
Suggestion: Complete the inventory and add routines for proper definition of x,y,z

Excel files for suspended sample data

Status: no complete inventory available. Not consistent specification of the x,y,z coordinates.
Suggestion: Complete the inventory and add routines for proper definition of x,y,z

Excel files for Water quality data

Status: inventory of files available. Not consistent specification of the x,y,z coordinates.
Suggestion: Add routines for proper definition of x,y,z

Excel files for sediment quality data

Status: inventory of files available. Not consistent specification of the x,y,z coordinates.
Suggestion: Add routines for proper definition of x,y,z

Word files for reports, analysis, and studies

Status: no proper inventory of files and reports available.
Suggestion: Inventory and reference of all relevant reports. Add key-words.

8.2 Database design

Database under development

Status: A system exists but is not complete. The system is not tested yet. The system builds on existing data. Data entry is not complete.
Suggestion: Complete the functionality and testing of the system on high priority using typical data of all types and from many (all) sources/file-types. Adding all data has lower priority since this can be time-consuming. The future monitoring needs may be discussed in a technical seminar.

Data quality assurance and quality control
Status: Quality control and assurance procedures are followed by the multiple check of the available data and different data relationship as well as graphical representation.
Suggestion: Future development may require more quality assurance and control specification. This should be discussed

Data dissemination
Status: The database design should enable and enhance information sharing among the ENSAP countries and therefore, should be compatible with relevant databases and models under development. It seems that NRI still has a “head start” on other organisations.
Suggestion: Use open software for the development (e.g. Access). Invite relevant stakeholders from the ENSAP countries to a technical seminar where issues can be discussed and decided. Such a seminar should be regularly re-occurring to accommodate feedback and development.

User interface
Status: Data storing and extraction have been specified. The system is still under development.
Suggestion: Keep specifications well documented as a living document. Publish regular progress reports that should be reviewed and commented by the users

(researchers and technicians) in NRI as a feedback to the database developers.

Queries and output routines

Status: The queries are being built to include certain data values, temporal and spatial data queries.

Suggestion: Keep progress well documented. Prepare for a possibility to be flexible and add other data values to the queries.

Specific temporal and geographical concerns

Status: Temporal and geographical distribution and varied sampling depths implies a need to decide how to present the data in thematic maps and graphs.

Suggestion: These issues should be discussed in a professional seminar with concerned researchers and stakeholders. Decisions are needed on routines and processing techniques for generating maps and graphs for different purposes. Data can for example be sorted for:

- Selected time and/or depth
- Average, Max or Min values
- Over selected time span
- Over selected depth intervals

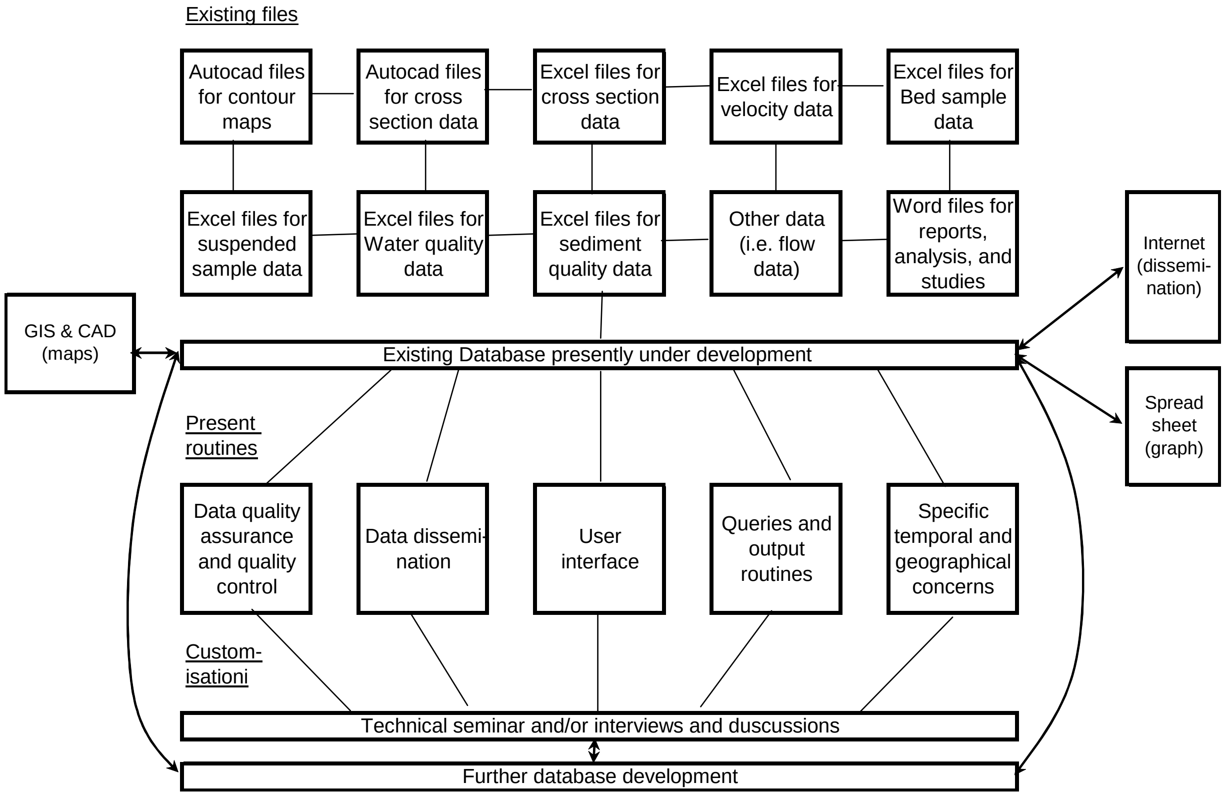


Figure 8.2.1 Example of the database development process

9 Monitoring System Design

The Monitoring System shall be designed, making use of the extensive experience with NRI and AHDA in surveys and measurements in the Lake Nasser/Nubia and even mathematical modelling. The present programming study has applied this experience in putting forward specific recommendations for a Monitoring System Design project that develops and implements Monitoring System, continuing to make use of experience with NRI and AHDA.

The Monitoring System will comprise a number of components that are more ore less interrelated. This means that the degree of development of one component must be adapted to the development that is preferred for other components. As an example, if it is required that a full 3D model is acquired and set up, then such model needs quality input from a 1D model for the upstream reach of the Nile and it needs adequate input and boundary data collected from surveys and measurements. Likewise, the database system and the entries in the database must match the data collected and facilities of easy correspondence with the modelling system should be included.

Keeping this in mind, the Monitoring System may be developed to a selected level and the system should be sufficiently flexible to allow future expansions or extensions.

The optimal composition of the Monitoring System is uncertain from the outset: In particular the success of the various methods/equipment proposed, is uncertain. As part of the Monitoring System Design, therefore, the survey/measuring devices will be tested and the results critically reviewed before it is decided to purchase the equipment and the necessary auxiliary equipment, such as computers, software and the necessary training of staff in the use of the equipment and associated software. It is recommended that one Monitoring System Design is implemented over a period of time, which allows adequate testing of survey methods, model setups and database, say a 2-3 year period. During that time selected options and combinations of components are tested, equipment, software and hardware purchased and implemented. The various components of the project are executed in parallel and the final design of the Monitoring System evolves during execution rather than being set from the beginning.

The Monitoring System Design project shall:

- Design a system comprising upgrades/extensions of surveys and measurements, mathematical modelling and databases, with focus on the interaction between the components and with each component optimised to satisfy the requirements to the entire Monitoring System

- Determine in consultation with stakeholders a suitable development level for the Monitoring System taking into account requirements, performance and costs

- Optimise the development of each component and subcomponent based on performance analyses from field tests, trial runs and well documented performance from literature

- Based on the experience from field tests, prepare specifications, obtain and evaluate bids from manufacturers, including installation and all necessary training

The scope of work shall include testing, evaluation, selection and implementation of the following potential new developments:

Surveys and measurements

Lake bed bathymetry (including dry shore)
- multibeam echo sounder for bathymetric surveys
- LIDAR green and red light bathymetry/topography methods for bathymetry (in areas of clear water, eg at low inflow/shallow water)
- bed penetrating sonar, to test the possibility of detecting annual layering

Grain size distribution and sediment quality of bed sediment
- acoustic sub-bottom profiler (single or multi beam)
- submerged penetrometer
- sub-surface sampling techniques

Wind measurements
- wind gauging station(s) (continuous)

Flow/discharge and water levels
- Acoustic Doppler Current Profiler (ADCP) (minimum 2 for vessel mounting and minimum 1 for placing on lake bed)
- Water level recorders

Temperature
- survey of density stratification (echo-sounder or ADCP)

Sediment concentrations
- ADCP (backscatter signal calibrated against measurements)

Modelling

1D hydrodynamic/morphological model for the Nile upstream of Lake Nasser/Nubia

3D (or 2D) hydrodynamic/morphological/water quality model for Lake Nasser/Nubia

Database

(to be filled in)

10 Wind Blown Sand Transport and Sand Dune Encroachment

Problems that may arise from wind blown sand transport and sand dune encroachment are:

a) Sand blown into Lake Nasser/Nubia contributes to the sedimentation of the Lake.

b) Dunes migrating into villages or agricultural areas cause destruction and misery for the local people.

c) Wind blown sand that deposit within the river Nile cross section contributes to the sediment balance of the river and may cause changes to river regime and morphological development.

Re a): It is hard to obtain any quantification of the sand volume involved. Studies of dune migration in Sudan have figures for the migration rate, but there is not sufficient information about dune dimensions to convert this into sand volumes. Only one quantitative estimate has been found. El-Moattassem (Ref. /1/) quotes Dr Daheb for a total volume of 12.5 mill tons per year blown into the Lake Nasser/Nubia or the rive Nile downstream of Dongola. This is of the order of magnitude of 10 % of the volume that enter the Lake from the Nile, indicating that wind blown sand is a minor source of sedimentation in the Lake Nasser/Nubia, compared to sediment transported with the Nile. In addition, any effort to try and reduce the volume of wind blown sand into the Lake will have very limited success simply due to the large length to protect. For many areas it may be impossible to reduce the problem more than temporarily. Thus, the efforts required to obtain a relatively small reduction of the volume of wind blown sand into the Lake Nasser/Nubia would be extensive, and benefits very limited. If the figure given in Ref. /1/ is of the right order of magnitude, then the efforts to limit sedimentation are better spent on the river Nile. But there is a need to obtain good estimates, so research and investigations to determine the volumes of sand involved are well justified.

Re b): In case of sand dunes migrating into villages or valuable agricultural land, there is a lot at stake for the local community that is hit. Reduction of dune migration rate can be of high value for these communities. There seem to be limited knowledge about the scale of this problem in Egypt. In the North State of Sudan the problem of sand dune encroachment is well known and the there are ongoing efforts to establish shelterbelts, as well as research in suitable plant species for such shelter belts.

Re. c): Sand deposition and sand dune encroachment on in the Nile River cross section takes place in the North State of Sudan. Principally, the sand volume deposited enters the sediment balance for the river Nile and thereby will affect the river regime and morphology. There is, however, no information on any dramatic effects that are believed to be caused by this phenomenon. The mathematical model is well suited to study this effect in a schematized way. Based on assessments using the mathematical river model it will be possible to quantify the effect of sand blown sand entering the river cross section.

On the basis of the above it is recommended to:

- continue research and investigations to determine the volume rate of wind blown sand
- continue and intensify the ongoing work with establishing well functioning shelterbelts
- apply estimated deposition volumes and mathematical morphological river model to determine the effect of sand dune encroachment on the river Nile upstream of Lake Nasser/Nubia
- continue and further develop the use of satellite images for dune tracking, to include volume estimates as well

11 References

/1/ El-Moattassem, Md. : Sediment Control in Aswan High Dam Reservoir. Eastern Nile Technical Regional Office (ENTRO). Watershed Management Projects. Nile Basin Initiative. EN/WS/No 006.

/2/ El-Moattassem, Md., Abdel-Aziz, T. M. and El-Sersawy, H. E-D.: Modelling of Sedimentation Process in Aswan High Dam Reservoir. FRIEND/UNESCO.