1 Lake Victoria Framework Model Application

1.1 Introduction

1.1.1 Model Development

The World Bank funded a project in June 1999 for the development and implementation of a framework model for the simulation of the physical processes and water quality in Lake Victoria. The model was developed and installed in the three riparian countries by a consortium consisting of Delft Hydraulics, HydroQual and IHE.

The framework model is a preliminary, or pilot model since it was based on existing data that is insufficient to support a full calibration or verification of the models. The model was intended to serve as a working example of how data from LVEMP can be used to predict responses to possible management actions for the remediation of water quality problems in view of sustainable economic development.

It was the intention that the framework model should subsequently be calibrated and verified on data collected by the WQ Components and extended with pre- and post-processing facilities to form a fully operational and flexible model for the study of lake water quality management practices. The objective of the final model was to help managers identify:

- How nutrients entering at various points in the lake affect phytoplankton growth, in relation to development of thermoclines and subsequent mixing, and how the rate of eutrophication is likely to change over time.

- How seasonal inflow of sediments from rivers move and deposit within the lake.

- How lake horizontal and vertical circulation patterns may affect the movement of water hyacinth, and the transport and dispersal of nutrients and organic matter on a seasonal basis.

The model is thus an essential tool in the water quality and ecosystem management of Lake Victoria.

1.1.2 Planned modelling activities

Accordingly, the Consultant planned to make extensive use of the model during the present assignment.

The value of the model lies in determining the effectiveness of the remedial measures. The range of possible remedial measures can be determined from knowledge of the magnitudes of the various sources of pollution and the present state of the lake. The remedial measures will naturally consist of reduction of the loadings from one or more sources. The magnitude of the reduction will be a compromise between that necessary to achieve an acceptable water quality in the lake, and the cost of implementing and operating the reduction. Optimising the magnitude of the reduction can only be done with the model. Application of the model in the form of a large range of sensitivity tests will determine the reduction of pollution loadings that is necessary to achieve acceptable water quality conditions. It will also identify which combination of feasible reductions of the various pollution sources is most effective in improving the lake at a minimum cost.

The model is a very comprehensive tool that cannot be applied without adequate training, and the Consultant recommended an extensive training programme for the WQ Component staff who had been introduced to the model during its installation in the riparian countries. The training programme consisted of 6 weeks in Delft, Netherlands, for 4 staff from each country. It is noted that the training given to the WQ Component staff during the installation of the model by the developers was not sufficient for the staff to be able to calibrate and apply the model. A much more extensive and thorough training is necessary, and such training was not included in the developer's contract.

It was then planned to calibrate and verify the model at the Hydraulic Conditions and Eutrophication Working Sessions. The model would then be applied to optimise the choice of remedial measures as described above.

1.1.3 Constraints to the application

The planned application of the model was not possible due to a number of constraints.

1. The training was postponed to the next phase of LVEMP.

2. Data on the currents in Lake Victoria was only available from a few cruises in Ugandan water and nothing was available from the other countries due to lack of equipment.

3. Similarly, there was no data available on the exchange of nutrients between the lake bed sediments and the water column due to the lack of sediment coring equipment in all three countries.

During the final Eutrophication Working Session, considerable efforts were made by the Consultant and the WQ staff to apply the model, and two additional constraints were revealed. The staff from Kenya and Uganda who had been introduced to the model by the developers had either left the project or were not working on the modelling anymore, and the new staff had never seen the model running. Finally, it was found that the model had been delivered without the input data pre-processor because it was never intended that the framework model should be used for full application. This made the preparation of new input data very difficult and time consuming, and effectively prevents application of the model in its present form.

1.1.4 Modelling activities

In view of the above constraints, the modelling activities were reduced to:

- Preparation of input data in a format which can be used in the final model.
- A few sensitivity tests on the influence of wind speed on the horizontal and vertical circulations.
- Preparation of a users guide for the formating some of input data, importing the data into the model and running the model. This guide will not be necessary when the full version of the model is implemented and the staff trained thoroughly.

1.2 Application to Hydraulic Conditions

1.2.1 Input data

The hydraulic input to the model consists of the time series of river discharges, rainfall, evaporation and outflow from the lake. All the data had been prepared in the hydrology/meteorology working sessions and it was formatted and imported into the model.

1.2.2 Comparison of measured and modelled currents

The currents measured in Ugandan waters are presented and discussed in a previous chapter. The currents were highly irregular in speed and direction, and were poorly correlated to the wind.

The modelled currents are totally dependent on the wind speeds and directions applied as the main driving force. The only wind data which could be used in the model was the global winds for 1998 which were delivered together with the framework model. A comparison of the measured surface currents (February 2001) and the modelled surface currents (February 1998) is shown in Figure 1.1. It is seen that there is no agreement between the two sets of currents.

Of course it is not correct to compare measured and modelled currents from two separate instants in time when the wind can be completely different.

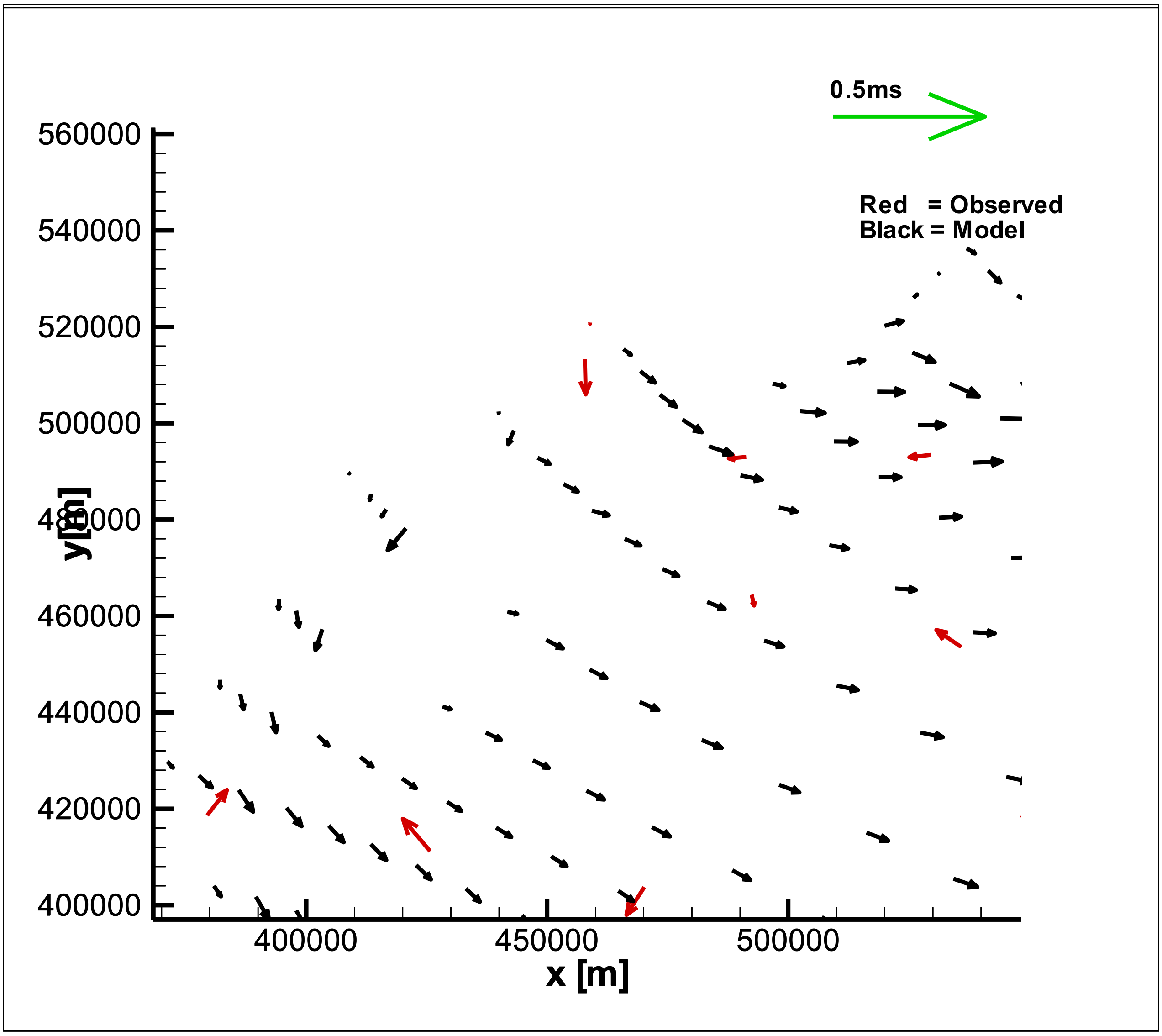

Figure 1.1 *Measured and modelled surface current vectors in the month of February in Ugandan waters.*

On the other hand the model simulations always show a very even current pattern at all depths due to the correspondingly even wind pattern over the lake. There are a sufficient number of measured currents to prove that the modelled currents are unrealistic, which is equivalent to saying that the use of global winds in not correct.

The global winds are those at a high altitude above the lake, and it is now clear that they differ greatly from those at the lake surface. At the lake surface the winds are generally light and irregular and greatly affected by the diurnal onshore-offshore cycle all around the lake perimeter.

It is likely that the strong global winds in July and August penetrate downwards to the lake and cause the total vertical mixing, but this has yet to be proved by measurements.

Although not seen in Figure 1.1, it was generally observed that the modelled current speeds were several times larger than the measured, which is more evidence that the global winds are stronger that those at the lake surface.

However, it is now clear that a successful application of the model will require an intensive effort to measure winds at the lake surface and around the lake shores. The measurements should be made at 1 hour intervals to resolve the diurnal cycle. Further, another specific task will be to generate the spatial and temporal wind over the entire lake surface on the basis of the measurements and the global winds for the period of calibration and application of the model.

1.2.3 Sensitivity to wind speed

Two tests of the sensitivity of the model to wind speed were made. It was not possible to alter the actual wind speeds, so the wind friction coefficient was altered to give the same effect as halving and doubling the wind speed.

The lake water levels and current speeds reacted as expected and proved that the wind is indeed the most important driving force for the lake hydraulics.

1.2.4 Comparison with measured temperatures

A comparison between the measured and modelled temperature profiles in the month of October along transect 4 (across the northern part of the lake from Uganda to Kenya) is shown in Figure 1.2. The patterns are remarkably similar and show that, with further refinement the model will be able to reproduce the actual conditions in the lake.

1.3 Application to Eutrophication

Attempts were made to make a series of tests of the sensitivity of the eutrophication module to changes in the pollution loadings. Data on all the revised loadings produced during the present study were formatted and imported to the model. However the model failed to run, probably because of a formatting error which could not be found. This emphasises the need for supplementing the framework model with the input data pre-processor.

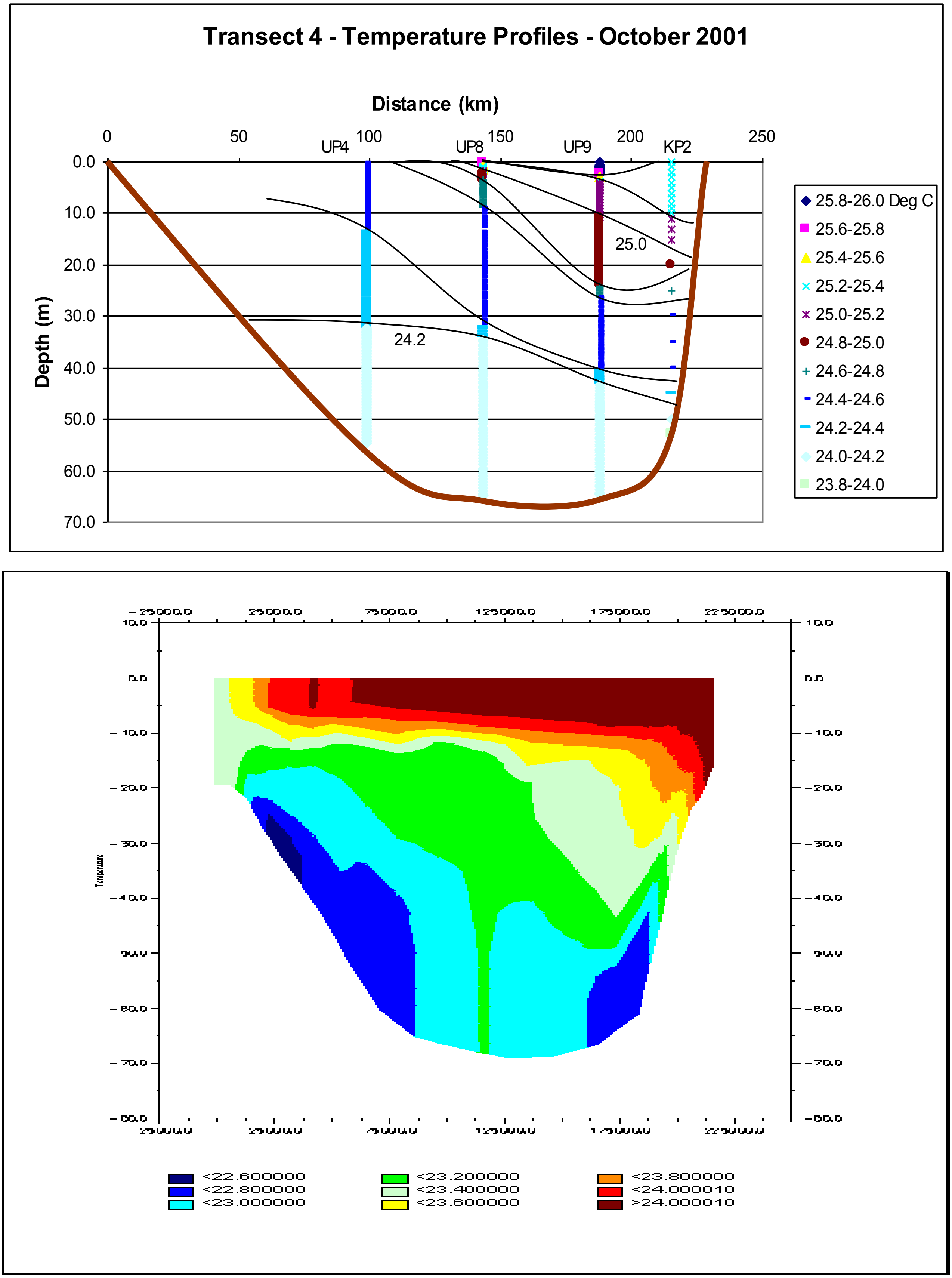

Figure 1.2 Measured and modelled temperature profiles along transect 4 for October.

1.4 Conclusions and Recommendations

The Consultant's study of the model has confirmed that it is well-suited to the purpose of analysing management practices and remedial measures for Lake Victoria. However, for it to be a useful tool, it is recommended that:

- The model should be extended with the full facilities for analysing and pre-processing of input data, and for analysing and post-processing of model results.

- The global winds that are used in the model do not represent the winds at the lake surface. A new sub-task is required to measure winds on the lake and around the shores and to develop a proper wind model which can generate realistic wind patterns for use in the Lake Victoria hydraulics and water quality model.

- The WQ Component staff should receive extensive and comprehensive training in the use of the model and the scientific background.

- The model be extended with detailed local models of focus areas in the three countries, eg. Winam Gulf, Mwanza Gulf and Murchison Bay.