0 EXECUTIVE SUMMARY

Background

The Danubian Lowland between Bratislava and Komarno is an inland delta formed in the past by river sediments from the Danube. The entire area forms an alluvial aquifer, which throughout the year receives infiltration water from the Danube in the upper parts of the area and returns it into the Danube via a network of drainage canals in the downstream part. The aquifer is an important water resource for municipal and agricultural water supply.

Various human activities have gradually changed the hydrological regime in the area. In particular a lowering of the water levels in the Danube has been observed between 1960 and 1990. In most of the area the Danube controls the ground water flow regime and hence a lowering of the general ground water level in the area has also been observed.

The Gabçikovo hydropower scheme was put into operation in October 1992. The upstream reservoir and various hydraulic structures related to Gabçikovo have major impacts on the hydrological regime and the ecosystem of the region. The Gabçikovo hydropower scheme is the most important of the man induced impacts of the area and therefore it plays a key role in the project.

Project Objective

The immediate project objective is to develop, test and transfer an integrated mathematical modelling system including the most important aspects for water resources management in the Danubian Lowland. The ultimate project objective is that the transferred modelling system be used as the technical/scientific basis for future management decisions.

Project Framework

The project "Danubian Lowland - Ground Water Model" was defined in 1991 within the PHARE programme agreed upon between the Commission of the European Communities and the Government of the Czech and Slovak Federal Republic. The project was initiated in February 1992. During 1992 the project was executed by the Federal Committee for Environment, Government of the Czech and Slovak Federal Republic. From the beginning of 1993 the project was transferred to the Ministry of the Environment, Slovak Republic.

The Project Manager is appointed by PRIF UK. Professor Igor Mucha was the Project Manager until the end of 1994. Andrej Cibulka was appointed as new Project Manager in the beginning of 1995.

A Danish-Dutch consortium of six organisations was selected as Consultant for the project. The Consultant is headed by the Danish Hydraulic Institute (DHI) and comprises the following associated partners: DHV Consultants BV, The Netherlands; TNO-Applied Institute of Geoscience, The Netherlands; Water Quality Institute (VKI), Denmark; I Kruger Consult AS, Denmark; and the Royal Veterinary and Agricultural University, Denmark.

Staff members from the following Slovakian organisations have participated actively in the project implementation:

- Comenius University (PRIF UK)
- The Ground Water Consulting, Ltd. (GWC)
- The Water Research Institute (VUVH)
- The Irrigation Research Institute (VUZH)

The work of in total 11 persons from these organisations have been funded by various Slovakian organisations and by the Ministry of the Environment. In addition various field- and monitoring programmes have been funded by Slovakian organisations.

Originally, GWC was a part of the Faculty of Natural Science, Comenius University (PRIF UK), but from the beginning of 1994 they established a private firm.

Due to a delayed delivery of about 20 months of the major computer equipment, the project period has been extended with 6 months. The project termination is December 31, 1995.

Equipment

Equipment for almost ECU 600.000 has been procured during the project. This includes various field and laboratory equipment, office equipment and computer hardware and software. The backbone of the computer system is 2 Hewlett Packard Apollo 9000/735 UNIX workstations. The procured equipment has been extensively used during the project and it has fully accommodated the needs of the project. Although, the progress in developing faster computers, more advanced software etc. is tremendous, the procured equipment will be the front end of technology for many years yet to come.

Establishment of the Integrated Modelling System

In order to address the problems within the project area an integrated modelling system has been established based on the consultants mathematical modelling systems. These are:

- MIKE 11 which is a one dimensional river modelling system for hydraulics, sediment transport and morphology and water quality.

- MIKE 21 which is a two dimensional modelling system used for reservoir modelling, including hydrodynamics, sediment transport and water quality.

- MIKE SHE which simulates the major flow and transport processes within the hydrological cycle. MIKE SHE comprises modules for flow and transport on the ground surface, in rivers, in the unsaturated zone and in the ground water zone

- DAISY which is a one-dimensional root zone model for simulation of soil water dynamics and nitrogen transport and transformation.

Although these modelling systems are generalized tools with comprehensive applicability ranges, a few model modifications have taken place within the project, in order to accommodate the very special conditions in the area.

The integrated modelling system is formed by the exchange of data and the feedbacks between the individual modelling system. The structure of the integrated modelling system is illustrated in the figure below.

The Danubian Lowland Information System (DLIS) is a combined data base and geographical information system that has been developed under this project. The DLIS is based on Informix (database) and Arc/Info (GIS) and provides a framework for data storage, maintenance, processing and presentation. In addition, an interface between DLIS and MIKE SHE allowing import and export of maps and time series files in MIKE SHE file formats has been made. Furthermore, an interface that allows loading and storage of river cross-sections in a MIKE 11 file format has been developed. A direct interface to the remaining models has not been developed, but files can easily be transferred from MIKE SHE file format to any other of the applied modelling systems.

Model Setup, Calibration and Validation

The various mathematical models have been established using the three step approach below.

step 1) Model setup
step 2) Model calibration
step 3) Model validation.

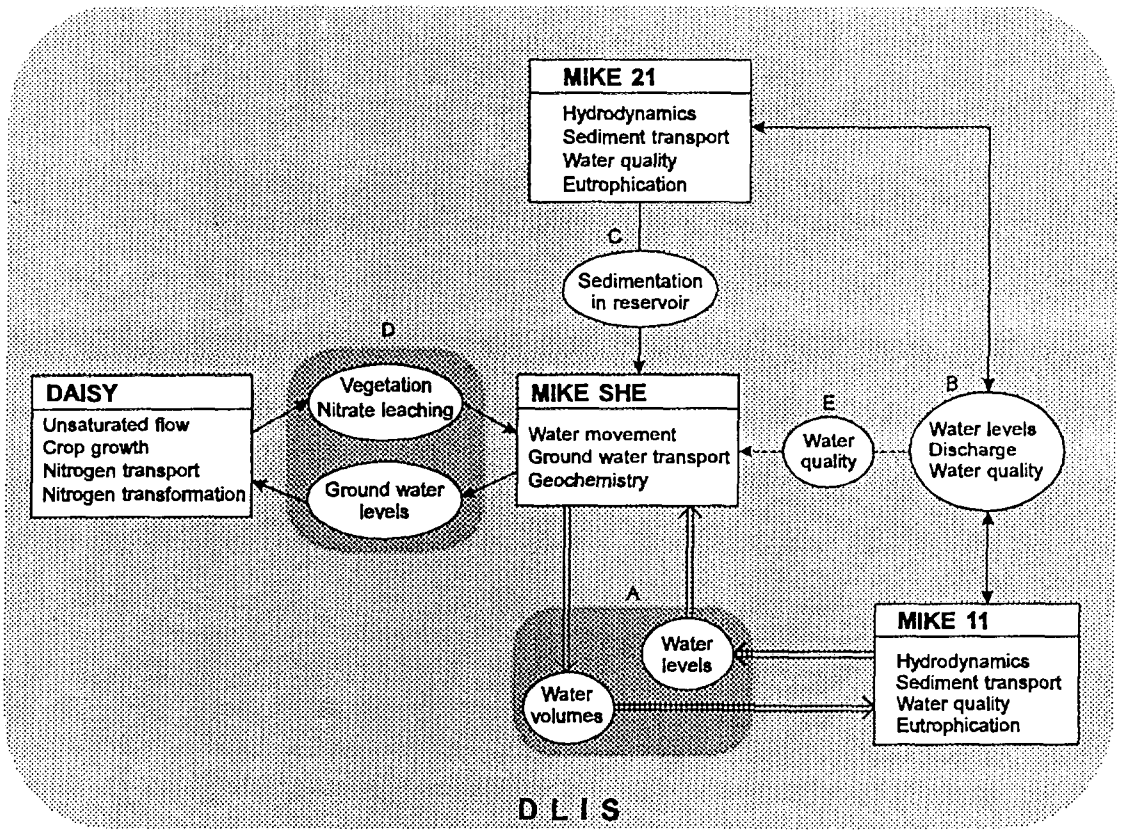

Fig. 0.1 Structure of the integrated modelling system.

The following models have been established:

- a MIKE 11 hydrodynamic model for the Danube
- a MIKE 11 water quality model for the Danube
- a MIKE 11 sediment transport and morphological model for the Danube.
- a MIKE 11 hydrodynamic model for the river branch system on the Slovak floodplain.
- a MIKE 11 eutrophication model for the river branch system.
- a MIKE 11 sediment transport model for the river branch system.

All the MIKE 11 models have been established in two versions reflecting the situation before and after the damming of the Danube.

- a MIKE 21 hydrodynamic model for the reservoir.
- a MIKE 21 eutrophication model for the reservoir.
- a MIKE 21 sediment transport model for the reservoir.

- a MIKE SHE regional ground water model for the entire project area (3500 km^2 (pre- and post-conditions).
- a MIKE SHE detailed model for the reservoir area (180 km^2).
- a MIKE SHE detailed model for the river branch system (60 km^2)
- a MIKE SHE geochemical transect model for a geochemical field site.
- a MIKE SHE geochemical model for the reservoir area (under preparation)
  - a number of DAISY models (profiles) reflecting the different agricultural and hydrological conditions within the area.

Definitions of Scenarios for Model Applications

Phase II has mainly been dedicated to model application. The specific scenarios for which model simulations have been decided jointly by the Slovak Ministry of the Environment and the Consultant.

A framework comprising four Water Management Regimes was chosen. The Water Management Regimes are based on a measured discharge time series at Bratislava for the period 1986 to 1991. This period has an average discharge (2027 m^3/s) which is close to the long term average and furthermore contains high flow as well as low flow situations.

- Water Management Regime I is a reference situation reflecting the pre-dam situation.
- Water Management Regime II reflects a post-dam situation where, in average, 400 m^3/s are diverted from the reservoir to the Old Danube.
- Water Management Regime III reflects a post-dam situation where, in average, 800 m^3/s are diverted from the reservoir to the Old Danube.
- Water Management Regime IV reflects a post-dam situation where, in average, 200 m^3/s are diverted from the reservoir to the Old Danube.

Results of Model Applications

The main objectives of the model applications were to illustrate the applicability of the established integrated modelling system and to provide modelling results that can support technical decisions and water management policies in the project area.

For the selected water management regimes and scenarios model predictions have been made on the following issues:

- Ground water levels, ground water table fluctuations (Pegelweg) and amount of recharge from the river/reservoir to the aquifer.

- Ground water quality especially with focus on nitrate, nitrite and redox conditions.

- Crop growth potential, irrigation requirements and nitrate leaching from agricultural areas including their dependence on the location of the ground water table.

- Water levels, flow velocities, sedimentation/erosion and oxygen concentrations for the Old Danube. These calculations have been carried out for scenarios with and without underwater weirs.

- Flow velocities, sedimentation and eutrophication in the reservoir.

- Water levels, flow velocities, sedimentation/erosion and water quality in the river branch system. Furthermore depths, areal extent and duration of surface water inundations as well as ground water depths and fluctuations have been calculated.

- On the basis of model predictions of the above hydrological conditions qualitative inferences have been made on possible changes in ecological developments for the reservoir, the Old Danube and the river branch system.

Assessments of Uncertainties of Model Predictions

Assessments have been made of uncertainties related to the specific model predictions. In general, it can be stated that the highest uncertainties exist for predictions of changes in ecology, geochemistry and to some extent sedimentation, while predictions of water levels, ground water levels, flow velocities and surface water quality are less uncertain.

Future Model Applications

The model applications carried out during the last phase of the project serve as illustrations of the type of modelling studies which can be made by using the established integrated modelling system. A large range of further modelling studies may be carried out, and the modelling system is a very suitable tool to support decisions on optimal water resources management in the Danubian Lowland region.

Need for combined Monitoring and Modelling

Due to the large uncertainties related to predictions of geochemical changes, development of ecological systems and sediment transport and morphological developments it is recommended to combine future modelling applications with field monitoring programmes.