Prepared for:

UNDP-GEF Danube Regional Project

Assessment of TNMN and identification of data gaps - DBAM Upgrade

Report

October, 2006

WL | delft hydraulics

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Jos van Gils

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Contents

1 Introduction 1

1.1 Background to the Danube Regional Project 1

1.2 Background to this Assignment 1

2 Upgrade of Danube Basin Alarm Model 3

2.1 Introduction 3

2.2 Modifications 3

2.3 Test programme 4

2.4 Test report 4

3 Assessment of TNMN and identification of data gaps 7

3.1 General 7

3.2 Objective of the assessment 7

3.3 Scope of the assessment 8

3.4 Evaluation of the TNMN 9

3.4.1 Selection of parameters 9

3.4.2 Selection of stations 9

3.4.3 Sampling frequency 10

3.4.4 QA/QC 11

3.5 Design of a tentative list of stations 12

3.6 Summary of recommendations 14

4 References 15

A Selection of MONERIS input data 16

1 Introduction

WL | Delft Hydraulics has been invited by the UNDP–GEF Danube Regional Project to provide an update of the Danube Basin Alarm Model (DBAM) and to utilise the outputs from the Danube Water Quality Model (DWQM) to identify any significant gaps in data that could assist the review of the TNMN that is currently being undertaken.

The present document provides the results of this assignment.

1.1 Background to the Danube Regional Project

The Danube Regional Project (DRP) has been established to contribute to the sustainable human development in the Danube River Basin (DRB) through reinforcing the capacities in the basin to develop effective co-operation to ensure the protection of the Danube River. The objective of the DRP is to complement the activities of the International Commission for the Protection of the Danube River (ICPDR) to provide a regional approach to the development of national policies and legislation and the definition of actions for nutrient reduction and pollution control in the DRB.

The tasks of the ICPDR are mandated by the "Convention on Cooperation for the Protection and Sustainable Use of the Danube River" (Danube River Protection Convention, DRPC). From this Convention also derive the responsibilities of the ICPDR directed to ensure its implementation and to enhance the cooperation of the Contracting Parties fulfilling their respective obligations.

The DRP's overall objectives, achievements and future programmes are given on its web site www.undp-drp.org.

1.2 Background to this Assignment

The Danube Water Quality Model has been designed and refined over many years and is an important tool for use in the Danube countries and to be available for the ICPDR. The outputs from the model have also been utilised in a number of research projects (e.g. *daNUbs*). The users of the model may also have identified deficiencies in the current Trans-National Monitoring Network (e.g. gaps in monitoring stations, data frequency etc.) which if addressed could provide improvements to the model output. This information will be of benefit to the ICPDR's review of the monitoring network to reflect the needs of the EU WFD. This review presents an opportunity to improve address any gaps in the TNMN data needed to improve the quality of the output from the DWQM. The DRP has a current project to assist the ICPDR undertake an assessment of the TNMN against the requirements of the EU Water Framework Directive and other drivers.

The DBAM has been used by the ICPDR for a number of years to assess the impact of any accidental pollution events in the basin and there is a wish to up-date the MS Windows compatibility of this software.

The two objectives of this assignment are:

- To upgrade the DBAM (to ensure compatibility with Windows XP operating system) and;
- To review the adequacy of the TNMN data sets with regards to the DWQM output and to make recommendations on improvements to data collection.

2 Upgrade of Danube Basin Alarm Model

2.1 Introduction

The Danube Basin Alarm Model (DBAM) is one of the tools under the Accident Emergency Warning System (AEWS). Its role is to compute the travel times and the concentration levels for a cloud of pollutants expected to cause trans-boundary effects on the water quality. The DBAM is supposed to do so quickly, based on simple and available input data. The DBAM was designed during a pre-study (WL | Delft Hydraulics, 1996), carried out during the system design phase of the AEWS. The DBAM concepts were based on the experience gained in the Rhine River Basin, where a similar model had been operational since 1988, following the Sandoz spill in 1986. The first version of the DBAM was developed in one of the Phare Applied Research Programme Projects (Vituki, 1996), and handed over in 1998. The Phare project “Strengthening Sustainability of Water Quality Management in the Danube Basin” provided the upgrade to version 2 of the DBAM in 2000 (HKV et al., 2000). The current project provides a minor upgrade to version 3 of the DBAM, with the aim to allow the installation and use of the DBAM on the Windows-XP operating system.

2.2 Modifications

The following modifications were implemented to the existing version:
- The calculation module was modified to run under Windows-XP.
- The set-up procedure was modified.

No functional modifications have been carried out.

The new installation consists of two install programs:

NetterSetup4.0.860.exe
Setup_DAM_v3.00.1.EXE

Both install programs need to be run. That can be done interactively, after starting both programs, e.g. with the “Run …” command on the Taskbar. The programs provide instructions. The order of installation of both programs is not relevant.

The programme is distributed with the documentation developed under version 2 and a short explanation regarding the installation.

The Danube Basin Alarm Model is started from the Taskbar, under the name that was provided during installation. A map of the catchment area appears. From that point onwards, user instructions are available under “Help” (F1). The program is intended to run under an MS Windows XP operating system. To ensure a sufficient performance, we advise the use of a PC with at least a Pentium 90 Mhz micro-processor.

2.3 Test programme

The new upgrade has undergone a test programme which was based on the previous, major upgrade. The tests documented in (HKV et al., 2000) were used as a starting point; where the limited scope of the current upgrade did not require an extended test programme, the test programme was shortened. The test plan is provided below.

Tests to be performed
Test C: • C1: Try installation on Windows XP *Installation prescription clear* *Installation successful* • C2: Try installation on non-default directory: *Installation successful* • C3: Try de-installation: *De-installation prescription clear* *De-installation successful*
Test A: • A1: Run a DBAM simulation based on one of the example hydrological data files (1c): *Help-facility should describe how to do this* (4c) *run should be made without problems* • A3: Modify the hydrological input table (1b): *Help should be available (4b)* • A5: No malfunctioning of the program may be encountered: *No problems found.*
Test B: • B1: Check if the Help file describes how a sub-region needs to be created *Description available (4d)* • B2: Load an example for a sub-region application *Example available,* *Help available (4c)* *Loading possible and clear* • B6: No malfunctioning of the program may be encountered: *No problems found.*
Test E: • E1: Run map presentation on test A1: *Inactive sections visible (5a)* *Performance improved (5d)* • E3: No malfunctioning of the program may be encountered: *No problems found (5b)*
Test G: • G1: Run graphs presentation on test A1: *Graphs presentation should work properly* • G3: No malfunctioning of the program may be encountered: *No problems found*

2.4 Test report

Test C

The installation was carried out on two different PC's satisfying the system requirements reported in the User Manual. The installation was tried in the default directory and in a non-default directory. The de-installation was carried out.

Criterion	Checked by	Date
Installation successful on Windows-XP	Jos van Gils	4-10-2006
Installation in non-default directory	Jos van Gils	4-10-2006
De-installation successful	Jos van Gils	4-10-2006

Test A:

A simulation was carried out by means of the "step-by-step description of a simulation" paragraph in the Help File, using an example hydrology file.

The hydrology input was modified and the activity of a range check verified. The presence of information about the entering of water levels and/or discharges was checked.

Criterion	Checked by	Date
Help File provides step-by-step description of a simulation.	Jos van Gils	4-10-2006
A simulation could be carried out according to this description (see also tests E and G!)	Jos van Gils	4-10-2006
Import of a hydrology file successful	Jos van Gils	4-10-2006
Help File provides a description of how to modify the hydrology input data	Jos van Gils	4-10-2006
Range checks active on hydrology input data	Jos van Gils	4-10-2006
Information about entering water levels and/or discharges available?	Jos van Gils	4-10-2006
No malfunctioning encountered during the complete test	Jos van Gils	4-10-2006

Test B

A sub-region (customisation) was created using the relevant description in the Help File. Afterwards it was loaded, and the proper functioning of the software was verified. Available example sub-regions were loaded as well.

Afterwards, test A was repeated.

Criterion	Checked by	Date
Help File provides a description of how to create a sub-region	Jos van Gils	4-10-2006
A sub-region could be created	Jos van Gils	4-10-2006
Example sub-regions are available	Jos van Gils	4-10-2006
A sub-region could be loaded	Jos van Gils	4-10-2006
A simulation could be carried out according to this description (see also tests E and G!)	Jos van Gils	4-10-2006
Import of a hydrology file successful	Jos van Gils	4-10-2006
No malfunctioning encountered during the complete test	Jos van Gils	4-10-2006

Test E

Test E implies a few extra checks in tests A and B.

Criterion	Checked by	Date
Map presentation working properly with improved performance in test A	Jos van Gils	4-10-2006
The network as a whole is visible, and it is clear which sections are active (carrying pollution) and inactive (not carrying pollution)	Jos van Gils	4-10-2006

Test G

Test G implies a few extra checks in tests A and B.

Criterion	Checked by	Date
Graphs and tables presentation working properly in test A	Jos van Gils	4-10-2006

3 Assessment of TNMN and identification of data gaps

3.1 General

The first version of the Danube Water Quality Model (DWQM) was created during the GEF Danube Pollution Reduction Programme Project, in order to quantitatively assess the fate of the nutrients N and P in the Danube River and its main tributaries (GEF, 1999). A special objective was to quantify the transboundary nutrient loads, and to assess the impact on these loads of the implementation of a Pollution Reduction Programme.

The Danube Water Quality Model was significantly modified during the research project *daNUbs* "Nutrient Management in the Danube Basin and its Impact on the Black Sea", which is a part of the EU's 5th framework programme (EVK1-CT-2000-00051). The more significant modifications were:

- The coupling of DWQM to MONERIS (for the calculation of point sources and diffuse sources).
- The assessment of additional field data from different sources (including the TNMN).

The results of the *daNUbs* project are compiled in two modelling reports (Constantinescu et al., 2001 and van Gils, 2004a). The analysis of the available data is compiled in a separate report (van Gils, 2004).

The *daNUbs* report concluded in relation to the TNMN: "The value of the TNMN data set as a basis to carry out research in support to the development of sustainable water quality management options can not be stressed enough". The modelling exercises carried out in *daNUbs* provided a good insight in the strengths and weaknesses of the TNMN. The current report builds on these findings to formulate recommendations for future optimisation of the TNMN.

3.2 Objective of the assessment

The current assessment has the following objective:

> *On the basis of existing information and results from the DWQM, to identify any gaps in data from the current TNMN and to make recommendations for addressing these gaps.*

The assessment will not be restricted to using the DWQM, but will be dedicated to a systems analysis in general. In this framework, a systems analysis is an analysis aiming at obtaining an insight in where pollutants are coming from, where they are going to, and what processes they are undergoing, on a basin-wide scale. Such an analysis includes an assessment of emissions, transport processes as well as transformation and degradation processes. In other words, such an analysis aims at compiling basin-wide mass balances. The most important instrument in this respect is data analysis, which is why we are discussing TNMN data, but modelling can also play a role (e.g. MONERIS and DWQM).

The ultimate goal of the systems analysis is to establish cause-effect relations, in order to carry out prognoses of effects (efficiency) of measures. This is highly relevant to the implementation of the Water Framework Directive (WFD), especially when measures will be developed to arrive at a Good Ecological Status. In other words, the WFD is the rationale behind the recommendations which will be formulated in the remainder of this report in relation to the TNMN, not so much to assess pressures or to evaluate the current status, but to create know-how on how the water system is functioning, in support to the development of measures to improve the status where necessary.

3.3 Scope of the assessment

The current assessment applies to pollutants which satisfy the following conditions:

- They are to a significant degree determined by diffuse emissions.
- They are persistent or slowly degrading.
- They are optionally transported in particulate form (attached to suspended matter).

The current assessment is less relevant for pollutants which can be described as follows:

- They are determined mainly by point sources.
- They are short living (e.g. BOD, coliform bacteria).

Obviously, the current analysis applies to nitrogen and phosphorus, but also heavy metals and a range of organic compounds are inside the scope. This means that most of the priority substances are addressed by this report, insofar as their dispersion into the aquatic environment is not the result of a limited number of point sources.

Note that the DWQM and MONERIS deal with N and P only. Their concepts however can be expanded to all pollutants satisfying the criteria listed above.

A final remark with respect to the scope of this report: our experience with the TNMN results is based on data from 1996-2001, and selected information from 2002-2003. We have not studied in detail the more recent data.

3.4 Evaluation of the TNMN

3.4.1 Selection of parameters

As discussed in Section 3.2, the compilation of mass balances is a key element of a systems analysis. Therefore, the river discharge is always the first parameter to be measured.

If we want to obtain a complete overview of the fate of a certain pollutant, it is important that all different forms ("species") of a pollutant are included in the sampling and analysis. This includes organic and inorganic fractions, and dissolved and particulate fractions. Specific examples of relevant species of nitrogen and phosphorus which are not commonly included in monitoring programmes are:

- The organic fractions of nitrogen (dissolved as well as particulate).
- The particulate fractions of phosphorus (organic and inorganic).

For nutrients sampling, also certain supportive parameters are relevant, such as dissolved oxygen (DO), pH, suspended solids (SS), dissolved silica (Si) and chlorophyll-α (Chlf-α). Phytoplankton is an important driver for transformation and retention processes in the aquatic environment, and dissolved silica is an important nutrient for phytoplankton. Therefore, also dissolved Si and chlorophyll-α (pigments in phytoplankton) need to be sampled and analysed. Similarly, DO and pH are indicators for transformation processes and need to be included. Finally, SS is a parameter which also determines the light availability for phytoplankton; however, it is also an important parameter in itself, because a significant number of pollutants is present in particulate or adsorbed form inside what we call suspended matter.

Although the TNMN formally includes organic N, particulate P, dissolved Si and chlorophyll-α, in practice only a small percentage of the samples taken is actually analysed for these parameters. During the *daNUbs* project, the completeness of the TNMN data set with respect to the abovementioned parameters turned out to be an important shortcoming of the TNMN.

3.4.2 Selection of stations

In view of compiling basin-wide mass balances, the monitoring stations should be selected in such a way that the gradual build-up of the river load of pollutants can be monitored. This can be guided by the distribution of the emissions over the basin. Because these are not always known, it is also possible to look at factors determining the emissions, such as population numbers, catchment size, run-off, land use (CORINE database), etc. For N and P, the estimated emissions by MONERIS could be used.

The stations are positioned to capture the basin-wide emissions (100%) in more or less equal parts of for example 5%. The choice for 5% leads to a number of stations around 20. This choice should be considered a minimum number of stations to more or less realistically represent the complex Danube River. A more ambitious approach is possible if the interval is chosen smaller (e.g. 2%) which leads of course to a higher number of stations and higher operational costs. From the basin wide perspective however, it is more important to have a complete and high quality data set, than to have high spatial resolution. Data gaps can create a high degree of uncertainty.

From the present perspective measuring exactly at state boundaries is not of particular interest. Furthermore, monitoring by different states at their mutual state boundaries, as it is done in the current TNMN, is not of particular interest either; in the best case it means a double effort for the same result.

The current practice of monitoring in three different locations over the cross-section (L, M and R) is in principle useful for river load assessments, in order to avoid artefacts due to lateral concentration gradients. Despite this practice, it is worthwhile to avoid stations immediately downstream of large tributaries. If this suggestion is implemented, it might be useful to check if monitoring in three locations per cross-section is still cost-effective; does the additional accuracy justify the additional costs?

In section 3.5 we present a tentative set of stations which could be used to set up a basin-wide systems analysis.

3.4.3 Sampling frequency

For carrying out accurate load calculations it is generally accepted (also by the TNMN, see ICPDR 2001) that the minimum required frequency of sampling is twice per month (24 to 26/year). This value is therefore recommended as a minimum frequency for basin-wide systems analysis purposes. It should be used for all measured parameters.

The TNMN has been operating stations where the discharge is measured daily. Theoretically, this increases the accuracy of the load calculations. The *daNUbs* project has demonstrated that the results from load calculations using daily discharges do not deviate significantly from those using only the discharges at the water quality sampling days only. Therefore, we consider daily discharge measurements not of key importance.

For pollutants (partly) attached to suspended sediments, such as phosphorus, it has been demonstrated that a more than proportional share of the annual river load is transported during flood periods when the river concentration of suspended solids is high. For example, the river phosphorus load at Vienna during the flood of 8-17 August 2002 equalled 4.7 kt, whereas the average annual load at the TNMN station in Vienna/Nussdorf over the years 1997-2001 equalled 8.5 kt. For such pollutants it is therefore interesting to work with a variable sampling frequency which is higher in wet periods and lower in dry periods. For example:

- The sampling is once per week in wet periods.
- The sampling is once per three weeks in dry periods.

In this respect “wet” and “dry” periods can be derived from long term hydrological data, so that the sampling can be planned in advance. It is probably not feasible to make the sampling frequency dependent on the actual river hydrology.

If such a variable sampling frequency is implemented to capture better the loads of particulate substances, it is anticipated that in larger river sections the overall frequency does not need to be more than 24/year. In larger rivers the flood waves last long and the wet period frequency does not need to be very high to capture them. In smaller sections however, the flood waves are shorter, the wet period sampling frequency needs to be higher and the overall frequency will probably end up to be higher than 24/year.

Prior to implementation, the practical feasibility of such a variable sampling frequency needs to be investigated.

3.4.4 QA/QC

It is evident that if a large amount of money is spent to carry out a sampling and analysis programme, it is necessary to have state-of-the-art QA/QC procedures in place in order to maximise the efficiency of the monitoring programme. In the case of a basin-wide systems analysis, QA/QC deficiencies might be more problematic than in the case when the monitoring is done to evaluate water quality objectives. In the latter case, only the samples/stations suffering inaccuracies are affected, while in the case of a basin-wide systems analysis one station with QA/QC problems can undermine a substantial part of the analysis. During the *daNUbs* project, the accuracy and reliability of the data turned out to be the most pressing shortcoming of the TNMN. In particular:

- In some cases, different stations within the TNMN proved to be internally inconsistent (e.g. with respect to the data for P).
- In some cases, the TNMN data turned out to be inconsistent with data from other sources (e.g. with respect to the data for N).

Examples are provided by van Gils (2004).

To our opinion the new TNMN urgently needs to address this problem. We see it as a potential pitfall to have a TNMN with sufficient coverage (stations, parameters, frequency) but with insufficient QA/QC. We would like to recommend integrating the QA/QC programme with the operational sampling and analysis, e.g. by including blind standards, blanks, duplicates and spikes in the operational sampling.

3.5 Design of a tentative list of stations

In this section we provider a tentative list of stations suited to capture the basin-wide emissions and load increase in more or less equal parts of about 5%. This effort is based on information regarding indicators for emissions and river loads of different pollutants, derived from the baseline MONERIS scenario as it was compiled in the *daNUbs* project (Schreiber et al., 2005). The following quantities have been taken into consideration:

- Population numbers;
- Catchment area;
- Run-off;
- River loads of N;
- River loads of P.

The criterion used to position one or more stations in the tributaries of the Danube River is that one of the 5 indicators mentioned above reach a value of more than 4 % of the total (see Annex A). This leads to the following selection of stations in tributaries:

- Inn: 2 stations.
- Drava: 1-2 stations.
- Tisa: 3-4 stations.
- Sava: 4 stations.
- Velika Morava: 1 station.
- Siret: 1 station.

Furthermore, stations need to be positioned along the main River Danube in such a way that the inflow from the tributaries which are not monitored is again captured in chunks of about 5%. The resulting list of stations could be as listed in Table 3-1.

Table 3-1 demonstrates that 20-25 stations are required if the target accuracy is about 5%. The list has been compiled using as much as possible existing TNMN stations (based on the 2001 TNMN Yearbook). It turns out that new TNMN stations are required in the Upper Danube (Germany, Austria) and in the Tisa sub-basin. The new stations are printed in *italics* and should be considered suggestions only. The proposed stations can be replaced by others as long as the distribution remains approximately even.

This tentative list only addresses the basin-wide scale. To obtain a more detailed picture about the fate of pollutants on the country or region scale the above list should be locally expanded. To this end, the same method can be used: distributing the stations in such a way that the emissions are traced in more or less equal parts.

The current assessment does not aim at redefining the TNMN stations list. It only points out which stations could be used for carrying out a basin-wide systems analysis. Other stations can of course still be part of the TNMN for other purposes.

Table 3-1: Tentative station list for basin-wide systems analysis approach.

Nr	River	Station	Distance (km)	Catchment (1000 km^2)
1	Danube	*Ingolstadt*	*2458*	*20*
2	Danube	*Passau (us Inn!)*	*2257*	*48*
3	/Inn	Kirchdorf	195	10
4	/Inn	*Passau*	*0*	*26*
5	Danube	*Stein-Krems*	*2003*	*96*
6	Danube	Bratislava	1869	131
7	Danube	Bezdan	1427	210
8	/Drava	Ormoz	300	15
9	/Drava	D.Miholjac/Dravaszabolcs	78	40
10	/Tisa	*Zahony*		
11	/Tisa	*Szolnok*		
12	/Tisa	Titel	9	157
13	/Sava	Jesenice	729	11
14	/Sava	Jasenovac	500	39
15	/Sava	Zupanja	254	63
16	/Sava	Ostruznica	17	96
17	/V.Morava	Ljubicevska	35	37
18	Danube	Pristol/NovoSelo	834	580
19	Danube	Svishtov	554	650
20	Danube	Silistra/Chiciu	432	690
21	/Siret	Sendreni	0	43
22	Danube	Reni	132	806

3.6 Summary of recommendations

This report presents recommendations for the future TNMN, derived from using the 1996-2001 TNMN data for a basin wide systems analysis and modelling exercise. The ultimate goal of such an analysis is to establish cause-effect relations, in order to carry out prognoses of effects (efficiency) of measures. This is highly relevant to the implementation of the Water Framework Directive (WFD), especially when measures will be developed to arrive at a Good Ecological Status.

To establish a sound basis for similar future exercises we recommend:

1. To monitor all species of the pollutants under investigation (see section 3.4.1). For nutrients sampling, parameters like organic N and particulate P need to be included on top of the more commonly monitored inorganic dissolved nutrient species, as well as supportive parameters (like DO, pH, SS, Si, Chlf-α). It should be noted that these parameters are already formally part of the TNMN, but for some of them the resulting data sets are far from complete.
2. The stations should be selected to monitor in more or less equal parts the emissions and thus the increasing river load (see section 3.4.2). When capturing the emissions by parts of e.g. 5%, a list of 20-25 stations remains, which mostly consists of already existing TNMN stations (see example in section 3.5).
3. The sampling frequency should be at least 24/year. Optionally, a varying sampling frequency could be considered for (partly) particulate pollutants like phosphorus and many heavy metals and hydrophobic organic compounds (see section 3.4.3).
4. The present QA/QC of the sampling and analysis process needs to be strengthened, in order to guarantee an accurate and consistent data set (see section 3.4.4).

On the basis of our experience in using the TNMN data during the *daNUbs* project, we would like to stress that recommendation 1) regarding the completeness of the TNMN data sets and recommendation 4) regarding the accuracy and reliability of the sampling and analysis should not be overlooked.

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A Selection of MONERIS input data

The table below provides the values for the indicators used in Section 3.5, derived from the baseline MONERIS scenario as it was compiled in the *daNUbs* project (Schreiber et al., 2005). It concerns:

- Population numbers;
- Catchment area;
- Run-off;
- River loads of N;
- River loads of P.

	Population	**Area**	**Discharge**	**N-load**	**P-load**	
	[inh]	**[km²]**	**[m3/s]**	**[t/y]**	**[t/y]**	
Inn	2344073	26074	712	28278	2033	
Drava	3236612	40315	469	22745	1867	
Tisza	13456974	151775	898	57099	3477	
Sava	8605227	95887	1218	65763	6361	
Velika Morava	3476979	33890	171	12676	1167	
Siret	3176485	36048	197	14886	916	
Basin totals	*82158006*	*802888*	*6185*	*423448*	*31001*	
	%	**%**	**%**	**%**	**%**	**Max%**
Inn	2.9%	3.2%	11.5%	6.7%	6.6%	11.5%
Drava	3.9%	5.0%	7.6%	5.4%	6.0%	7.6%
Tisza	16.4%	18.9%	14.5%	13.5%	11.2%	18.9%
Sava	10.5%	11.9%	19.7%	15.5%	20.5%	20.5%
Velika Morava	4.2%	4.2%	2.8%	3.0%	3.8%	4.2%
Siret	3.9%	4.5%	3.2%	3.5%	3.0%	4.5%