EXPERT SYSTEM FOR THE DESIGN OF STORMWATER MANAGEMENT SYSTEMS FOR URBAN RUNOFF QUALITY

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EXECUTIVE SUMMARY

This report is one in a series of reports on urban stormwater drainage and its management. The expert system described in this report draws from the information presented in the other project reports. The computer-based expert system has been developed to assist urban planners in assessing the impacts of urban stormwater runoff on receiving water bodies and to undertake the preliminary design of stormwater management systems to mitigate against the impacts. The expert system has been structured in a "User-Friendly" computer program which enables practitioners who are not necessarily computer experts to operate it. The pollutant types that have been included are suspended solids, ammonia, orthophosphate, chemical oxygen demand, TKN, dissolved oxygen, and faecal coliforms.

The expert system deals with a single catchment discharging stormwater at a point source into a stream. The system consists of the following three sections:

- A catchment categorization system
- Receiving water impact
- Management

The catchment categorisation system is used to categorise the catchment based on land-use, development type, development densities and costs, and the state of the catchment services and service maintenance. The broad development type is categorised into residential and industrial/commercial land uses. This categorisation system was developed from a review of the monitoring programs undertaken on South African catchments. The user is presented with a set of tables on the computer screen which are filled in to categorise the catchment. The category is used to determine typical pollutant concentration ranges and default values for the catchment runoff.

In the receiving water impact section, information on the receiving river is input. The information required is the distance to the downstream point of interest, the stream cross section shape, stream slope, Mannings roughness, the pollutant concentrations in the receiving water upstream of the discharge point and the decay parameters used in the modelling. Default values are provided for the decay parameters. The runoff from the urban area is mixed with the stream water and routed downstream using the plug flow equation to predict pollutant concentrations at the downstream point of interest. The predicted downstream pollutant concentrations can be compared to the drinking water standards and the instream water quality guidelines.

In the management section, grass buffer strips, wet and dry detention ponds and vegetation lined channels can be used in series (up to 3) to intercept and treat the urban runoff before discharging to the stream. The detention ponds are modelled as completely mixed reactors while the plug flow equation is used for the grass buffer strips and vegetated channels. Default values for pollutant loss parameters are given for each of the management options. Once the expert system is run with the management options in place, the concentration of the different pollutants in the outflow from each of the management options used can be viewed as well as the downstream concentrations in the receiving stream.

The main conclusions that were made as a result of the study can be summarised as follows:

- a methodical approach from the assessment of receiving water impacts, township planning and stormwater management is provided by the expert system

- the framework can be extended to include additional management options, costs, receiving water body types, and a more comprehensive catchment categorisation system

- the preliminary sizes of the management options that are provided by the expert system gives planners an idea of the extent and feasibility of implementation

- a case study should be used to test the expert system

- the system should be expanded to include additional catchments and point sources.

CONTENTS

List of Figures

List of Tables

CHAPTER 1 INTRODUCTION

1.1 INTRODUCTION

An expert system has been developed to assist urban planners in assessing the impacts of urban stormwater runoff on receiving water bodies and to undertake preliminary design of stormwater management systems to mitigate against the impacts. The expert system was originally going to be developed as a spread sheet application. However, due to the incompatibility of spread-sheet packages and the possibility of running into computational shortcomings during development, a stand-alone system has been developed using Visual Basic version 3 for Windows 3.1

The expert system allows for an assessment of the concentrations in a river, a specified distance downstream from the discharge point of the urban runoff into the river. At this stage only the effect of urban runoff on rivers as the receiving water body can be investigated. Other water bodies such as lakes, dams, estuaries and the sea have not been included. The system allows for the examination of the effect of the reduction of pollutants at source, the planning of townships, and the preliminary sizing of management methods.

The system will allow an urban planner to categorise the catchment of interest. Based on the catchment category, typical pollutant concentrations are provided by the expert system. The catchment characteristics such as area, percentage impervious area, slope and length of the longest water course are also input by the user. These catchment parameters are used to generate a typical storm runoff for the area. The concentrations together with a flow estimate are used as input into the management and receiving water modelling sections. The pollutant concentrations output from the receiving water model can be compared to water quality objectives set for the stream. This will allow an assessment of the impacts and the abilities of the management systems tested in improving the water quality of the runoff.

The report describes the structure of the expert system, the decision support or decision making methodology, the algorithms used to determine the pollutant removal abilities of the management methods and the receiving water system, and the operation of the program. The report is divided into 4 sections, viz. an introduction, the decision making system, the algorithms used to model the treatment methods, and the program operation.

This report forms part of a series of reports dealing with urban runoff and its management. The catchment categorisation and the methodologies used in the expert system are only summarised in this report. Default values for the modelling parameters are provided in the report where available and are built into the expert system.

1.2 GENERAL DESCRIPTION OF SYSTEM

The expert system consists of 2 databases, and a set of algorithms describing the pollutant treatment processes which can be used to determine the pollutant removal abilities of the stormwater management structures. Database 1 contains the categorisation of the different types of urban developments and the pollutant concentrations that can be expected in the stormwater runoff. Database 2 contains the water quality standards to which the impacts of the stormwater runoff on the receiving water can be compared. The pollutant types that are included in the model are suspended solids (SS), ammonia (NH_4), ortho-phosphate (PO_4), chemical oxygen demand (COD), total Kjeldahl nitrogen (TKN), dissolved oxygen (D)) and faecal coliforms (FC).

The treatment options that are included in the management part of the expert system are:

- Wet and dry pond systems
- River systems
- Grass swales
- Grass buffer strips

A management system consisting of up to 3 of the individual management elements can be used in series to treat the urban runoff. The treated runoff can be compared to the water quality standards set for the receiving waters. An iterative procedure can then be followed whereby the sizes of the individual elements can be changed or more elements added until the required water quality criteria are reached at the point of interest in the receiving water system.

The modelling of water quality is difficult and essentially empirical. Many of the available water quality models of the different components that make up the management system require measured data for calibration. The same applies to the modelling approaches used in the expert system. Although default parameters are given, they will only serve as a guide to the performance of any of the elements in the management system and the impacts on the receiving water.

CHAPTER 2 DECISION-SUPPORT SYSTEM

2.1 INTRODUCTION

The decision-support system consists of the decision-making procedure that is followed during a consultation, the catchment categorisation system, the water quality guidelines, and the algorithms used to model the pollutant removal mechanisms in the management methods. The details of the decision-making procedures, catchment categorisation and water quality guidelines are discussed in the following sections. The algorithms used to determine the pollutant removal efficiencies of the management methods are discussed in Section 3.

2.2 DECISION SUPPORT SYSTEM

The user is guided through a consultation by means of a series of screens. The expert system checks the input after the completion of each screen by the user and displays an error message if information has been omitted. A warning is also given if an input parameter appears to be out of the expected range.

A complete consultation consists of 3 phases viz:

- A data input phase
- An initial assessment of the impact of the runoff on the receiving water
- The application of stormwater management techniques to improve runoff quality

The consultation procedure is detailed in Figure 2.1. During the data input phase, the catchment information and the details of the receiving water body are entered. The catchment information is used to compute a typical flow rate and the catchment category for the determination of typical pollutant concentrations that can be expected from the catchment.

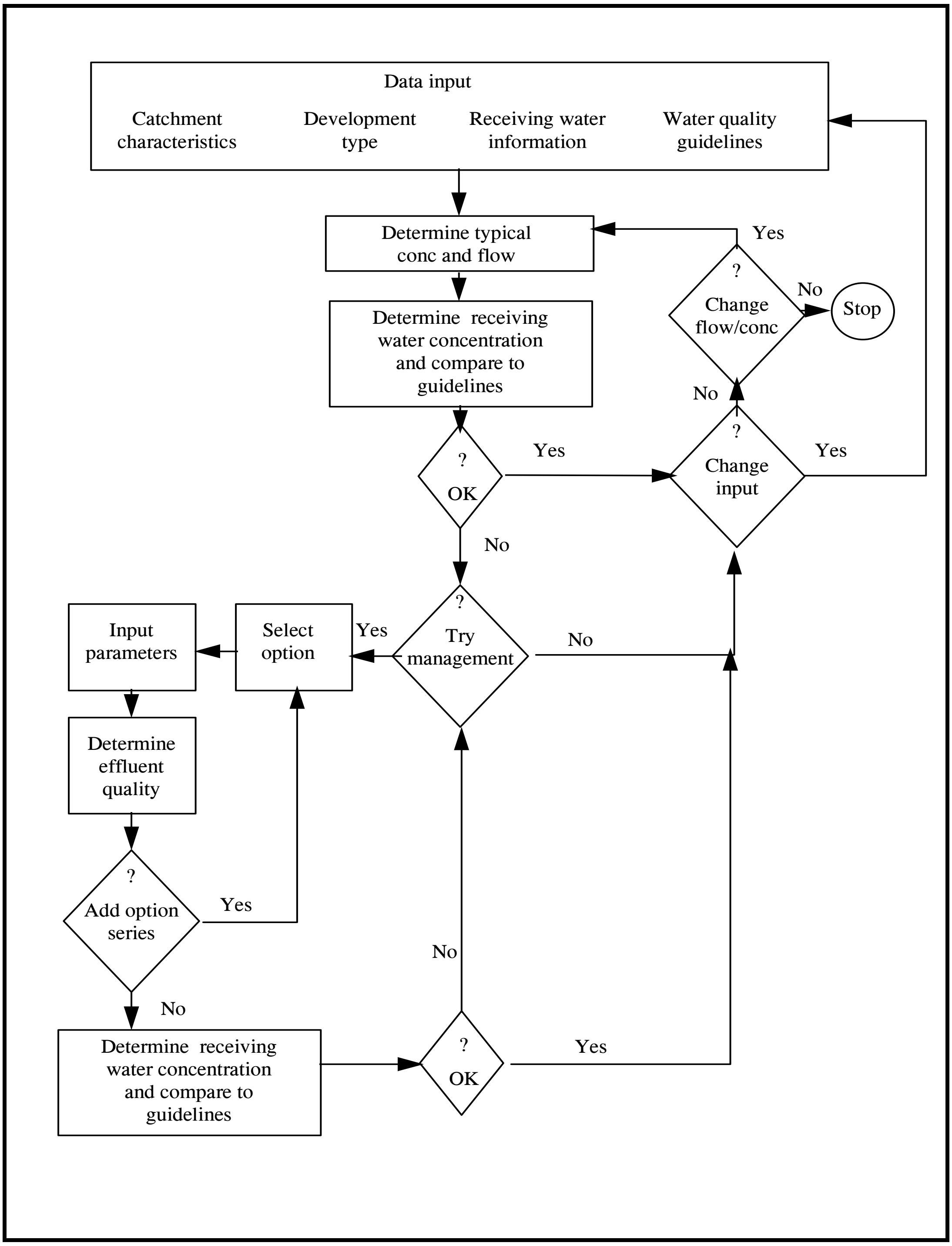


FIGURE 2.1 Decision-support system followed by the expert system

During the initial assessment stage, the data on the receiving water body is used to carry out an assessment of the impacts of the urban runoff on the receiving water body. The possible impacts and the concentrations of the pollutants in the outflow are listed for comparison to the water quality criteria set for the receiving water body. The user then has the option of ending the consultation, proceeding to the management section of the expert system, or changing the catchment characteristics and repeating the analysis.

In the management phase, a series of up to three management methods can be used to improve the quality of the runoff. The outflow from the management system is then routed through the receiving water body to assess the impacts and the quality of the outflow from the receiving water body. During this procedure, the sizes of the components and values for the modelling parameters used in the algorithms for the management system have to be entered. Once completed the sizes of and the management methods used can be changed or the user can return to the data input stage and change the catchment categorisation.

2.3 CATEGORISATION OF RUNOFF POLLUTION

The expert system requires information on the catchment so that typical pollutant concentrations can be determined. The categorisation system used in the expert system resulted from the review of the literature on the monitoring of urban runoff carried out on South African and overseas catchments. The details and results of this review are given in the report entitled "Integrated report on urban runoff study" which formed part of this study.

The information collected by the monitoring programs that were reviewed was insufficient to be able to assess the relative effects of all the parameters that could affect the pollution levels in the runoff. However, by comparing the pollutant concentrations and the pertinent catchment characteristics highlighted in the literature that affect the runoff quality, a categorisation system was formulated which allows the expert system to present the user with typical pollutant concentrations based on the catchment characteristics. The review highlighted the following characteristics of the catchment land use that could be related to the differences in the levels of pollution observed in the runoff:

- Land-use
- Development type
- Development densities
- Standard or cost of development
- State of catchment and levels of services and services maintenance

The predominant land use of a catchment forms the first category. The last uses catered for in the expert system are residential or commercial/industrial. In the case of mixed land use catchments, the land use required by the expert system is the predominant land use in the catchment. If the predominant land-use type is not apparent, the expert system should be run for each of the land uses.

2.3.1 Industrial/commercial land-use

The types of pollutants found in the runoff from these catchments depends on the types of industry and the management and pollution control measures employed by the industries in the catchment. The monitoring information available did not allow for a further categorisation of the commercial and industrial catchments into sub-categories which would allow for a more accurate estimation of pollutant concentrations based on the land use and catchment characteristics. The concentrations used in the expert system for this type of catchment are listed in Table 2.1.

TABLE 2.1 Pollutant concentration ranges for an industrial catchment

Pollutant	Concentration/conductivity rate
NH_3 (mg/ℓ as N)	1 - 8,2
TKN	1 - 74
EC (ms/m)	9 - 80
SS (mg/ℓ)	40 - 2000
PO_4 (mg/ℓ as P)	1 - 6
COD (mg/ℓ)	80 - 250
DO (mg/ℓ)	3 - 6
Faecal Coliforms (/100 mℓ)	5 000 - 750 000

2.3.2 Residential land-use

As most of the catchments monitored in South Africa tend to be residential catchments, the expert system is primarily aimed at assessing the impacts of the runoff from residential areas, particularly the informal settlements. The residential land-uses are further subdivided based on development type and density, cost of housing and standard of services.

Development type

The two types identified in the literature review are the formal and informal developments. A formal development is one which has been planned with laid out stands and a road network. A wastewater disposal system has been installed which can be waterborne, septic tanks and soak-a-ways or pit latrines. A development has a piped water reticulation system into the houses or at least a standpipe per stand. An informal settlement has no planning and has taken place in an ad-hoc fashion. These development types are characterised by minimal services. If a sewage disposal system is present, it will probably be a bucket or pit latrine system. The water supply is by stand pipe, borehole, tanker or nearby stream.

Development density

There are two categories that were identified, viz. high and low density developments. Although a medium density category could possibly be added, the extent of the data reviewed does not allow for the addition of such a category. The plot sizes, population density, and the percentage impervious area are the criteria used to determine the development density. The criteria are given in Table 2.2 below.

Table 2.2 Definition of development density used in expert system

Development density	Plot size	Population density	% Impervious area
High density	< 500 m^2	> 80 p/ha	> 50%
Low density	> 500 m^2	< 80 p/ha	< 50%

The development density used is chosen on the basis of any two of the three criteria in Table 2.2 being true.

Development cost

The development cost refers to the standard of the home or structure erected on the plots. The analysis of the data reviewed in the literature showed that a distinction could be made between the level of pollution from low cost and high cost developments. The cost of the development reflects the socio-economic standing of the community that resides in the catchment. A high- and a low-cost category have been included in the expert system. A guideline cost figure of R30 000/unit is suggested as a cut off between low and high cost developments.

Pollution potential

The state of the catchment of pollution potential was found to be an important consideration for inclusion in the expert system. One of the common causes of the high concentrations found in the runoff is the standard and level of maintenance of the wastewater disposal systems. The poor quality of the runoff can, in part, be attributed to the misuse of the sewerage system. This can be due to overflowing sewage from a waterborne system, the infrequent emptying of buckets, or the total lack or abuse of a sewerage system. The presence of garbage on the catchment and the lack of vegetation are also factors contributing to the pollution potential of a catchment. A catchment can be categorised as having a low or high pollution potential. A high pollution potential implies that the catchment has a poor standard of services and service maintenance. The high pollution potential catchments also generally have a poor vegetation cover. A catchment having a low pollution potential implies a well-maintained and high standard of services, and a good vegetation cover.

2.3.3 Pollutant concentrations used in the expert system

The catchment categorisation system and the range of pollutant concentrations (mg/ℓ) that are stored in the expert system database are presented in Table 2.3. To access the database, the user chooses from a series of options presented on the screen. These are used to search the database and access the typical and range of pollutant concentrations that can be expected from the catchment.

TABLE 2.3: Pollutant concentration ranges for categories of residential catchments

Development type	Development density	Development cost	Pollution potential	NH_3 (mg/l as N)	TKN (mg/l as N)	EC (ms/m)	SS (mg/l)	PO_4 (mg/l as P)	COD (mg/l)	DO (mg/l)	Faecal coliforms (/100 ml)
Formal	High density	High cost	High	3-7	4-14	13-100	20-1000	0,2-6,0	60-500	3-6	10000-100000
			Low	1-3	2-8	12-50	40-150	0,2-3,0	40-300	3-6	1000-10000
		Low cost	High	1-30	10-40	70-2500	40-1850	0,4-14,0	150-400	1-6	10000-1000000
			Low	1-5	2-8	15-200	21-400	0,2-3,0	15-70	3-6	10000-1000000
	Low density	High cost	High	1-21	1-16	30-200	1-2500	0,1-6,0	5-800	3-6	1000-10000
			Low	0-3	1-5	10-50	21-350	0,0-3,0	20-80	1-6	0-1000
		Low cost	High	-	-	-	-	-	-	-	-
			Low	-	-	-	-	-	-	-	-
Informal	High density	Low cost	High	5-24	7-103	25-700	800-8000	1,0-8,0	70-3000	1-3	10000-10000000
			Low	1-5	4-18	8-180	180-3500	0,2-5,0	40-400	3-6	10000-1000000
	Low density	Low cost	High	-	-	-	-	-	-	-	-
			Low	-	-	-	-	-	-	-	-

2.4 RECEIVING WATER QUALITY STANDARDS

To be able to assess the impacts of the urban runoff on the receiving water body, the concentrations in the outflow from the receiving water body can be compared to those given in the water quality guidelines. The concentrations as given in the Instream, Domestic, Recreation/Contact and Agricultural Guidelines for the pollutant types considered in the expert system, are listed in Table 2.4.

TABLE 2.4 Guideline pollutant concentrations

	Guidelines				
Pollutant	**Domestic**	**Recreation**	**Irrigation Class 1**	**Livestock**	**Instream Target Water Quality Criteria**
NH_3 (mg/ℓ as N)	1	-	-	-	< 7 µg/ℓ
TKN (mg/ℓ as N)	-	-	-	-	
EC (ms/m)	70	-	40	154	Not changes by >15% from normal cycles or background concs.
SS (mg/ℓ)	0	-	-	-	Background <100 mg/ℓ increase limited to <10% of background
PO_4 (mg/ℓ as P)	-	0.05	-	-	Conc. not changes by >15% and trophic status not increased above present levels
COD (mg/ℓ)	-	-	-	-	
DO (mg/ℓ)	5	-	-	-	80% to 120% of saturation
Faecal Coli-forms (/100 mℓ)	0	<1 000	-	1 000	

The domestic and instream water quality guidelines have been included in the expert system.

2.5 MANAGEMENT METHODS

The impacts of urban runoff can be reduced by applying appropriate management methods. The management methods than can be used can be categorised into natural, engineered or induced systems. Natural systems include naturally occurring wetland, lake and river systems. Engineered systems are defined as those that, although using natural processes, are completely controlled. Such systems are activated sludge, anaerobic treatment plants, biofiltration, or the chemical treatment of urban runoff. Induced systems are man-made, but not completely controlled by man. Such systems are retention/detention dams, man constructed wetland systems, vegetation-lined channels, grass buffer strips, oxidation pond and lagoon systems. The inclusion of all of these management systems in the expert system is beyond the scope of this project. Some of the natural and induced systems have been included in the expert system.

The treatment processes active in these systems are discussed in the report entitled "Engineering treatment options". The treatment methods used in the expert system are pond systems, grass swales, grass buffer strips, and river systems. The pond systems include wet and dry pond systems. The grass swales are taken as wide channels having a vegetation lining. The flow depth in these channels is generally greater than the vegetation height. Grass buffer strips are strips of zones of vegetation which behave as overland flow planes where the depth of flow is generally less than the height of the vegetation. A river system in the expert system is assumed to have an alluvial bed of cohesionless material.

CHAPTER 3 METHODOLOGY USED IN EXPERT SYSTEM

3.1 INTRODUCTION

The following aspects of the expert system are addressed in this section:

- The method used to estimate a typical flow rate from an urban catchment
- The removal processes included in the expert system for the different pollutant types
- The method used to represent the flow and pollutant transport through the treatment options included in the expert system
- Typical values for the parameters required by the algorithms used in the expert system

Each of the above will be discussed in a separate section. Many of the details of the methods that can be used to model the pollutant removal mechanisms in the various treatment options are discussed in the treatment options report. Only the essential elements that are pertinent to the expert system are presented in this report.

3.2 CALCULATION OF STORMWATER RUNOFF RATE

The application of the expert system requires the estimation of a typical flow rate from the catchment. The rational method is simple to apply and gives a reasonable estimate of the flow rate that can be expected from a small (< 12 km^2) catchment. The 1-year recurrence interval rainfall event is used as input to the rational method to determine a typical runoff peak. This flow rate only serves as a guide to the magnitude of the storm peak that can be expected from the catchment. The rational formula is:

$$Q_p = \frac{CIA}{3.6}$$

where Q_p (m^3/s) is the peak flow rate
I (mm/hr) is the average rainfall intensity
A (km^2) is the catchment area
C is the runoff coefficient

The rainfall intensity is determined using one of the following equations (Op ten Noort and Stephenson, 1982).

Inland region:

$$I = \frac{7.5 + 0.034.MAP)R^{0.3}}{(0.24 + t_d)^{0.89}}$$

Coastal region:

$$I = \frac{(3.4 + 0.023MAP)R^{0.3}}{(0.2 + t_d)^{0.75}}$$

where MAP (mm) is the mean annual precipitation, R (yrs) is the recurrence interval, and t_d (hours) is the storm duration.

The storm duration t_d is determined using the formula for the time of concentration t_c (hours) given by (Alexander, 1990):

$$t_c = \left[\frac{0.87L^2}{1000S}\right]^{0.36}$$

where L (km is the length of the longest water course and S (m/m) is the average catchment slope. The MAP, S, A and L are entered as part of the input to the expert system. The value used for R is set in the program as 1 year.

The runoff coefficient C is determined by computing coefficient values for the impervious and pervious catchment surfaces. The percentage impervious area is then used to compute a weighted runoff coefficient for the catchment. The runoff coefficient for the pervious catchment areas is determined using the values given in Table 3.1 (Alexander, 1990). A value of 1 is used for the runoff coefficient for the impervious areas.

A weighted value of C is then given by

$$C = P_{IMP} . 1 + (1 - P_{IMP})\, C_{per}$$

where P_{IMP} is the percentage impervious area and C_{per} is the computed runoff coefficient for the pervious areas. The percentage impervious area is part of the data input to the program.

TABLE 3.1 Runoff coefficients for pervious areas

		MAP (mm)		
Component	**Category**	**< 600**	**600 - 900**	**> 900**
Steepness	< 3%	0.01	0.03	0.05
	3% to 10%	0.06	0.08	0.11
	10% to 30%	0.12	0.16	0.20
	30% to 50%	0.22	0.26	0.30
Soil permeability	Very permeable	0.03	0.04	0.05
	Permeable	0.06	0.08	0.10
	Semipermeable	0.12	0.15	0.20
	Impermeable	0.21	0.26	0.30
Vegetal cover	Dense bush	0.04	0.04	0.05
	Cultivated land	0.07	0.11	0.15
	Grassland/lawn	0.17	0.21	0.25
	Bare surface	0.26	0.28	0.30

The rational formula gives the peak flow rate. By assuming a triangular shaped hydrograph with a recession limb of length $2t_d$, the volume can be determined as:

$$V = \frac{3t_d.Q_p}{2}$$

which gives an average flow rate of $Q_{ave} = \frac{Q_p}{2}$ which is suggested as atypical storm flow for the catchment. The storm duration will then be $3t_d$. Allowance, however, is made in the expert system for the flow rate to be changed during program operation. This allows for the investigation of the low flows during dry periods as well as the stormwater runoff.

3.3 POLLUTANT PATHWAYS

There are a number of processes that the pollutants included in the expert system could undergo while passing through the treatment options and in the receiving water body. The pollutant pathways that could be followed by a particular pollutant type in the different treatment options are similar. An example of the pathways for the more common pollutant types found in urban runoff are shown in Fig. 3.1.

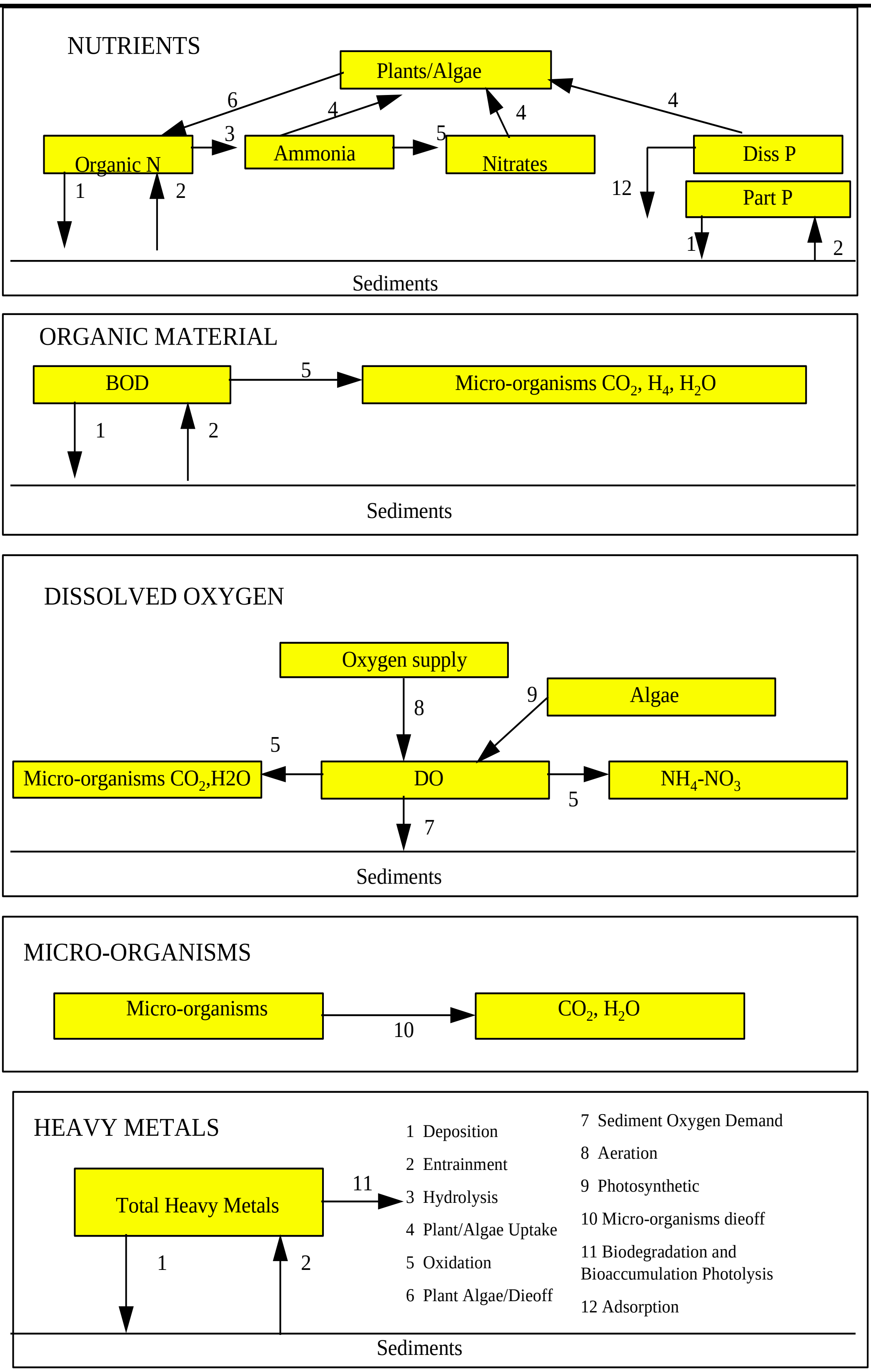


FIGURE 3.1 PROCESS POLLUTANT PATHWAYS IN POND SYSTEM

FIGURE 3.1 Process pollutant pathways in pond system

In some modelling systems, all the pathways and transformation processes shown in Fig.e 3.1 are included. A large number of input parameters are required to be able to model at this level of detail. The values of these input parameters are not always known and data has to be collected for calibration or values based on previous experience have to be used. The planning level at which the expert system is aimed does not warrant this level of detail and the pathways have been substantially simplified. The simplified approach adopted in the expert system is similar to the approaches advocated and applied by Thomann and Mueller (1987) and Wanielista and Yousef (1993). Campbell (1996) applied many of the equations adopted in the expert system with some success to the data collected on the Jukskei River.

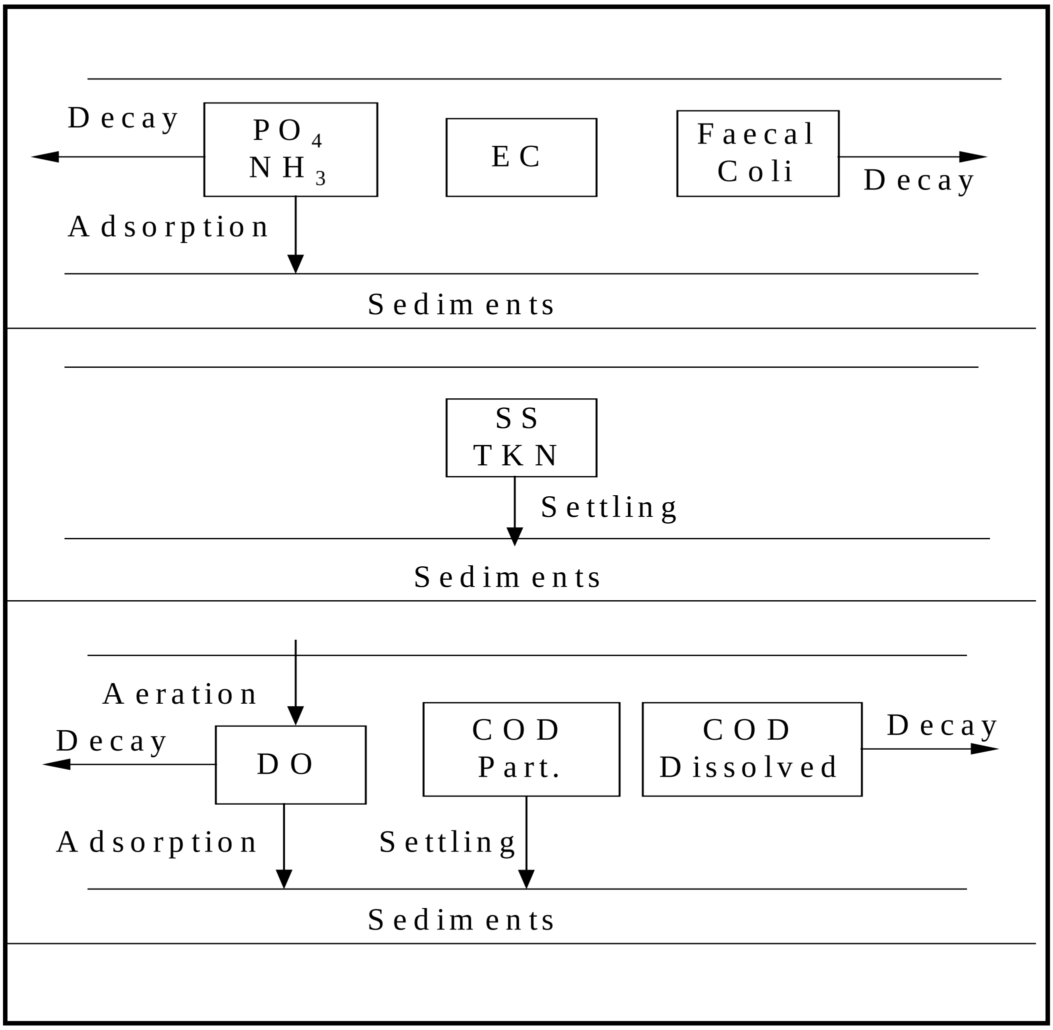


FIGURE 3.2 Simplified pollutant pathways used in expert system

Four processes have been included in the expert system which can be used to model the transformation of pollutants in the treatment options and to assess the effect of the urban runoff on the receiving water body. These are settling, decay, re-aeration and an adsorption process between the bed sediments and the pollutant dissolved in the water column. Not all the processes are necessarily applicable to all the pollutant types and treatment options included in the expert system. The simplified representation of the pathways for the different pollutant types are shown in Fig. 3.2

The SS mass in suspension in the runoff water is assumed to be inert and can only be removed from the water column by settling. TKN, because of its strong association with SS, is also assumed to be removed by settling only. The TDS, as represented by the EC, PO_4 and NH_4 are considered to be in dissolved form only. The removal of NH_4 and PO_4 is by a decay process, or, in the case of vegetated channels, the adsorption to the bed sediments. The decay represents the uptake by algae and plants and the oxidation of NH_4 to NO_3. The TDS is assumed to be conservative and passes straight through the management systems without any removal or additions. Only the mixing of the urban runoff with the receiving water stream can change the concentration of the TDS. The organic material, as represented by the COD, is assumed to be in particulate and dissolved form. The removal of the particulate form is by settling and the dissolved form by a decay process representing the oxidation of the organic material by micro-organisms. The sinks for DO are the adsorption of the DO to the bed sediments and, in an aerobic environment, the use of DO in the oxidation of organic material. The source of DO considered is the re-aeration due to the transfer of oxygen from the atmosphere to the water body. The production of oxygen by photosynthesis is not considered in the model.

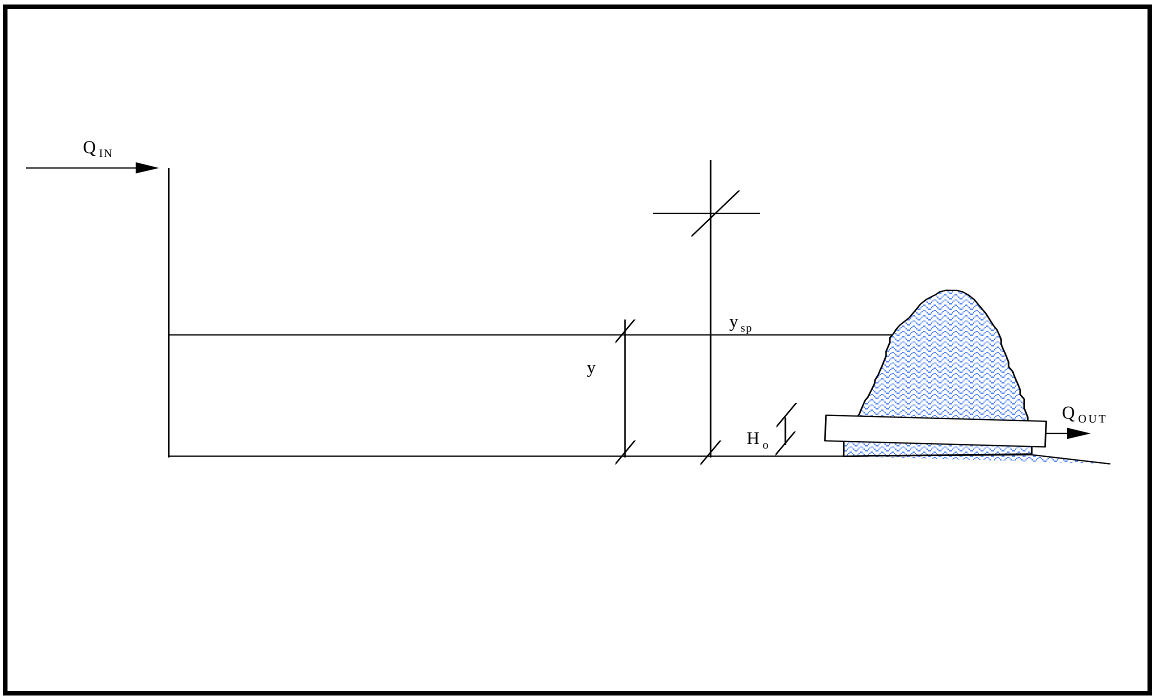


FIGURE 3.3 Components of a typical pond system

3.4 WET POND SYSTEMS

3.4.1 Flow routing

Detention times in excess of 3 days are generally required to treat urban runoff. These long detention times are necessary if nutrients and organics are to be treated in the pond system. The required detention time is attained in a pond by a combination of storage and flow characteristics of the outlet structure. The outlet structure can consist of a spillway and a bottom outlet through the dam wall (see Fig. 3.3). The bottom outlet can be made up of pipes and/or box culverts.

The pond is assumed to be full at the start of a storm event with the flow through a wet pond system assumed to be steady or having reached equilibrium flow conditions immediately. This assumption implies that the inflow and outflow are equal and of the same duration. In the expert system, the pond is assumed to be a tank with a rectangular surface area A_s (m^2) and a depth of y (m). The volume V (m^3) of the tank is therefore given by:

$$V = A_s \cdot y$$

The values for A_s and y are entered as part of the input.

3.4.2 Pollutant pathway and mass balance equations

The wet ponds are modelled as a completely mixed system where the concentration of pollutant in the effluent is the same as that in the pond. By carrying out a mass balance around a pond, the following equation can be derived which includes removal by settling, decay and adsorption to the bed sediments:

$$\frac{dC}{dt} = -\frac{Adsorp}{y} - \frac{Dep}{y} - Decayrate + \frac{Q}{V}\left[C_{in} - C\right]$$

where C (g/m^3) is the pollutant concentration in the pond, Dep ($g/m^2.s$) is the deposition rate, Decayrate ($g/m^3.s$) is the rate at which pollutant disappears per unit volume of pond water, C_{in} (g/m^3) is the pollutant concentration in the inflow, and t (s) is time. The methods used in modelling the individual processes will be discussed in the following sections.

Dep

This is the deposition rate ($g/m^2 \cdot s$) of particulates per unit pond bed area. The particulates are represented by a single particle size having a specific gravity SG. A typical size of 64 μm with an SG of 2.65 are used as default values. The particle size and SG can be changed during run time by the user. The particulates are assumed to be uniformly distributed over the depth of the water column in the pond. The assumption is made that quiescent conditions are present in the pond so the deposition rate at the bed is given by W_sC, where W_s (m/s) is the settling velocity of the particles. The pond is assumed to have a fixed bed and the entrainment of bed sediments or the re-entrainment of settled particles is not considered in the model.

The removal of TKN by deposition is determined as a fraction of the SS mass deposited as follows:

$$\text{Dep TKN} = \text{Dep SS} \cdot \frac{C_{TKN}}{C_{SS}}$$

Decayrate

This is the rate ($g/m^3.s$) at which the pollutant mass in the pond is reduced per unit volume of pond water. The rate is given by the first order reaction

$$\text{Decayrate} = K_{decay}D$$

where K_{decay} (/s) is the decay constant.

Adsorp

This is the rate ($g/m^2.s$) at which the pollutant are adsorbed to the bed sediments per unit area of the bed. The adsorption rate Adsorp used in the expert system is taken as a constant.

A further criterion which is checked in the expert system is the possibility that the pond could become anaerobic if overloaded with organic material. A criterion given by Marais and Shaw (1964) for stabilization ponds for the treatment of sewage effluent is used. The relationship states that the maximum BOD concentration in the pond must not exceed $\frac{600}{1.97y + 8}$. If the BOD level in the pond exceeds this limit, a warning is given that anaerobic conditions may occur in the pond.

3.4.3 Solution to a completely mixed tank

The completely mixed equation as used in the expert system is given by:

$$\frac{dC}{dt} = \frac{Q}{V}\left[C_{IN} - C\right] - KC - \frac{W_s C}{y} - \frac{\text{Adsorb}}{y}$$

which can be integrated to give:

$$C(t) = \frac{B}{D}\left[(1 - \exp(-Dt))\right] + C_0\left[\exp(-Dt)\right]$$

where $B = \frac{QC_{IN}}{V} - \frac{\text{Adsorp}}{y}$

$D = \frac{Q}{V} + K + \frac{W_s}{y}$, and

C_0 is the concentration in the pond at t = 0 which is taken as equal to C_{in}.

The outflow pollutograph is determined by calculating the concentration at time intervals $\Delta t = td/10$. C_{IN} is constant from time t = 0 to td. An average outflow concentration is computed by determining the total load in the outflow and dividing by the outflow volume.

3.5 DRY POND SYSTEMS

A dry pond, as used in the expert system, has a storage volume and a bottom outlet from which the water exits the pond. The water may only exit by means of the bottom outlet as a spillway is not included in the modelling system. To keep the algorithms simple and to limit the number of input parameters, the outflow from the pond Q_{out} (m^3/s) is assumed to be constant with time. Like the wet detention pond, the storage volume is represented as a rectangular tank having a Volume V. Dry pond systems are assumed to be empty at the start of a storm event.

This pond system can be used to attenuate inflows and the necessary retention time required for treatment is achieved by controlling the outflow from the pond and providing sufficient storage volume. The flow rate through any subsequent treatment options and into the receiving water will then be Q_{out}.

3.5.1 Pollutant pathway and mass balance equations

As in the wet pond systems, the dry ponds are modelled as a completely mixed tank system. The same pollutant removal mechanisms are considered. However, the mass balance equation differs in that the volume V is not constant with time. The equation describing the removal of pollutants in a dry pond system is given by:

$$\frac{d(VC)}{dt} = Q_{in}C_{in} - Q_{out}C - KCV - \frac{W_s CV}{y} - \frac{AdsorpV}{y}$$

The above equation is solved numerically in the expert system using a finite difference scheme.

3.6 VEGETATED CHANNELS (GRASS SWALES)

The parameters used to define a vegetated channel are the length L(m), average longitudinal slope S_o, a trapezoidal cross section shape, and a Manning roughness coefficient n. The parameters describing the trapezoidal cross section shape are shown in Fig. 3.4 and are the left and right side slopes SSL (m/m) and SSR (m/m) respectively and the bottom width b (m). The depth of the channel is assumed to be large enough to cater for the flow rate Q (m^3/s). The depth of water in the channel is y (m).

The Manning equation is used to computer the flow depth reached in the channel for the flow rate Q. The Manning equation is given by:

$$Q = \frac{\sqrt{S_0}}{n} AR^{2/3}$$

where A = Area = $by + \frac{y^2[SSL + SSR]}{2}$

R = Hydraulic Radius = $\frac{A}{P}$

P = Wetted Perimeter = $b \text{ x } y \left[(SSL^2 + 1)^{.5} + (SSR^2 + 1)^{.5}\right]$

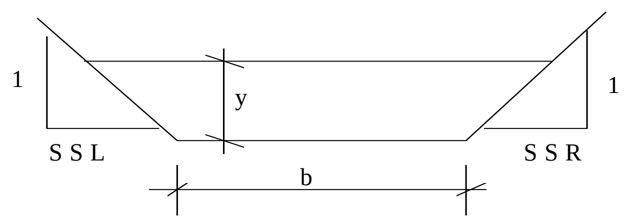


FIGURE 3.4 Definition sketch of trapezoidal cross section

A Newton-Raphson iterative technique is used to solve the Manning equation to give the depth in the channel for the flow rate Q. The average flow velocity V (m/s) is given by Q/A. The flow rate Q is assumed to be steady through the vegetated channels. The assumption is made therefore that the inflow and outflow are equal in magnitude and in duration, i.e. no flood wave routing is undertaken down the channels.

3.6.1 Mass balance equations and pollutant removal pathways

The plug flow equation is used in routing the pollutants down the channel and is given by:

$$\frac{\partial C}{\partial t} + V\frac{\partial C}{\partial x} = \frac{NetDep}{y} - K_{decay}C - \frac{Adsorp}{y}$$

where x (m) is the distance downstream and NetDep ($g/m^2/s$) is the net deposition rate of SS and TKN per unit bed area. The decay and adsorption processes are as described in the section covering the ponds. The assumption of quiescent conditions made for the pond systems will not apply in the channels. Therefore, a different approach accounting for flow turbulence has to be adopted for the modelling of vegetated channels.

NetDep

The removal of particulates from the surface water column is due to the trapping of the particles in suspension that reach the bed by the vegetation lining. The particles that reach the bed are considered to be no longer available for entrainment back into the flow. The approach of using a zero entrainment flux at the bed used by van Rijn (1986) in modelling the results of Wang and Ribberink's (1986) experiment in a flume with a slotted bottom is used in the expert system. The deposition flux is then given by W_sC as for a pond under quiescent conditions. The turbulence is accounted for by using a probability Pr that a certain size particle under the flow conditions found in the channel will reach the bed, i.e. NetDep = W_sCPr. The approach used by Holly and Rahuel (1990) has been adapted to get an estimate of the probability Pr. The relationship used can be expressed as follows:

$$\frac{V_*}{W_s} \geq 10 \quad Pr = 0$$

$$\frac{V_*}{W_s} \leq 1 \quad Pr = 1$$

where V_* (m/s) is the shear velocity. A linear relationship is used to interpolate Pr values for ratios of V_*/W_s between 1 and 10.

The decay and adsorption processes are dealt with in the same manner as the pond systems. The modelling of DO and the solution to the plug flow equation adopted in the expert system is discussed in section 3.7 on river systems.

3.7 RIVER SYSTEMS

The river system is taken as the receiving water body for which the instream pollutant concentrations have to be determined at some distance L downstream of the discharge point. The runoff Q_{urb} (m^3/s) from the urban area is added to the river flow Q_{riv} (m^3/s) which is assumed to be known as is the concentration of the pollutant in the river C_{riv} (g/m^3). The urban runoff is assumed to mix completely and instantaneously with the river flow. The resulting concentration C_{in} in the river is given by:

$$C_{in} = \frac{Q_{riv}C_{riv} + Q_{urb}C_{urb}}{Q_{tot}}$$

where $Q_{tot} = Q_{urb} + Q_{riv}$

The river system as used in the expert system is considered to have an alluvial bed of cohesionless material. The same steady flow conditions are assumed for the river system as the vegetated channels. The inflow concentration is assumed to be constant with time over the duration of the inflow. The interaction between the pollutants stored in the bed sediments and the water column are not considered in the model.

As in the case of the vegetated channel, the river is described by a length L(m), average longitudinal slope S_o, a trapezoidal cross section shape and a Manning roughness coefficient n. The parameters describing the trapezoidal cross-section shape are shown on the left and right side slopes SSL (m/m) and SSR (m/m) respectively, and the bottom width b (m) (see Fig. 3.4). The depth of the channel is assumed to be large enough to cater for the flow Q_{tot}. The depth of water in the channel is y (m). The Manning equation is used to compute the flow depth reached in the channel for the flow rate Q_{tot}.

3.7.1 Pollutant removal algorithms

The same pollutant pathways as are shown in Fig. 3.2 are active during the passage of a pollutant along the length of the river. The same approach as was used for pond systems is used in the river systems. The removal of SS, TKN and the particulate COD fraction is by settling. A first order decay reaction is used to model the disappearance of PO_4, NH_4, dissolved COD and faecal coliforms. The adsorption to the bed sediments is used in the form of a sediment oxygen demand in the modelling of DO.

The plug flow equation is used in routing the pollutants down the river and is given in section 3.6 on vegetated channels. The algorithm used to compute NetDep differs from that used for vegetated channels and is explained below.

NetDep

A typical particle size and SG for the bed material of the river has to be input to the expert system. The issues that have to be addressed by the expert system are:

- The extent to which the particulates will be deposited
- Whether the flow introduced into the river could cause erosion of the bed sediments

The approach adopted is based on that of Cheng (1984) and Celik and Rodi (1988) for a fixed bed. The interaction of the transported sediment can be represented by a net deposition rate which is the difference between an entrainment and a deposition rate at the bed. The particulates are assumed to be uniformly distributed over the depth of the water in the pond. The deposition rate at the bed is given by W_sC, where W_s is the settling velocity of the particules. The entrainment rate ($g/m^2/s$) of particulates at the bed is given by the minimum of the deposition rate at equilibrium suspended solid transport conditions and the deposition rate W_sC. The deposition rate at equilibrium is W_sC_{ae}, where C_{ae} is the depth averaged particulate concentration under equilibrium transport conditions. The net deposition rate is therefore given by :

$$NetDep = W_s(C_{ae} - C) \quad C_{ae} < C$$

$$NetDep = 0 \quad C_{ae} \geq C$$

C_{ae} is determined using the stream power formulation of Yang (1973).

$$\log C_{ae} = 5.435 - 0.286 \log \frac{W_k d}{v} - 0.457 \log \frac{V_*}{W_k} +$$

$$(1.799 - 0.409 \log \frac{W_s d}{v} - 0.314 \log \frac{V_*}{W_s}). \log(\frac{VS}{W_s} - \frac{V_{CR}S}{W_s})$$

where V (m/s) is the average flow velocity

S is the energy slope

$V_* \text{ (m/s)} = \sqrt{gRS}$ is the shear velocity

v (m^2/s) is the kinematic viscosity

d (m) is the representative particle size for the size group k

V_{CR} (m/s) is the critical average velocity at which particles first move

V_{CR} is given by:

$$\frac{V_{CR}}{W_s} = \frac{2.5}{\log\left[\frac{V_* d}{v}\right] - 0.06} + 0.66 \qquad 0 < \frac{V_* d}{W_s} < 70$$

$$\frac{V_{CR}}{W_s} = 2.05 \qquad 70 \leq \frac{V_* d}{v}$$

The removal of TKN by deposition is determined as a fraction of the SS mass deposited as follows:

$$NetDepTKN = NetDepSS.\frac{C_{TKN}}{C_{ss}}$$

The same parameters as are given in Table 3.2 are suggested for use in the river. The downstream pollutant concentrations can be compared to the guidelines for an assessment of the impacts of the urban runoff on the receiving river system.

The effect on the DO concentration in the river also has to be assessed by the expert system. Re-aeration, sediment oxygen demand (SOD) ($g/m^2 \cdot s$), and the removal of DO due to the oxidation of organic material are the sources and sinks of DO considered in the expert system. The conservation of mass equation based on the plus flow approach yields the following equation:

$$\frac{\partial C_{DO}}{\partial t} + V\frac{\partial C_{DO}}{\partial t} = \text{Re aerationrate} - \text{DecayrateCOD} - \frac{\text{SODrate}}{y}$$

The re-aeration rate is given by $K_a(C_s - C)$ where K_a (/s) is the re-aeration coefficient and $C_s$is the saturated DO concentration. A value of 9.5 mg/ℓ at a temperature of 18°C is used in the expert system. The value of K_a is computed using the following equation:

$$K_a = \frac{21.6V^{0.67}}{y^{1.85}}$$

where V is in ft/s, the depth y is in ft, and K_a is in units of per day. The mass of oxygen used in the oxidation of organic material is given by the COD decay computations discussed earlier. The SOD is entered as part of the data input and is assumed to be constant with distance and time.

3.7.2 Solution to plug flow equation

The general form of the plug flow equation which includes all the pollutant pathways considered can be written as follows:

$$\frac{\partial C}{\partial t} + V\frac{\partial C}{\partial x} = \frac{W_s(C_{ae} - C)}{y} - K_{decay}C - \frac{Adsorp}{y}$$

By moving with a plug of pollutant, the equation can be reduced to an ordinary differential equation of the form:

$$\frac{dC}{dt} = \frac{W_s(C_{ae} - C)}{y} - K_{decay}C - \frac{Adsorp}{y}$$

For constant coefficients, the equation can be integrated to give

$$C(t) = \frac{D_1}{D_2}\left(1 - \exp(-D_2 t)\right) + C_0\left(\exp(-D_2 t)\right)$$

where $D_1 = \frac{W_s C_{ae}}{y}$

$$D_2 = \frac{W_s}{y} + K_{decay} + \frac{Adsorp}{y}$$

and C(t) is the concentration at time t in the river section. The concentration at the outlet of the river will be given by the concentration at t = L/V.

3.8 GRASS BUFFER STRIPS

The grass buffer strips are defined by a width b(m), a length l(m) and a Mannings roughness coefficient n. The inflow to the buffer strip is spread over the full width b of the buffer strip and the water level is assumed to be less than the height of the vegetation. The approach used is similar to river and vegetated channel systems in that the plug flow approach is used in the model with the same pollutant removal pathways. The net deposition methodology used for the river systems are used for the grass buffer strips.

3.9 PARAMETER VALUES USED IN EXPERT SYSTEM

The problem associated with the application of the expert system in modelling the management systems is the choice of values for the model parameters. Ranges of parameter values are available for certain applications such as stabilization ponds for sewage treatment (Marais and Shaw, 1964) and river modelling (Brown and Barnswell, 1987). K_{decay} as used in the expert system describes the overall effect of a number of processes. In representing the removal of NH_4, the decay constant represents the uptake by algae, the net effect of adsorption and release from the bed sediments of the pond, and the conversion of NH_4 to NO_3. Values of the decay coefficient are listed in Table 3.2 for oxidation of organic material, faecal coliform die-off and the decay of NH_4 and PO_4. The uncertainty in the parameter values is shown in most cases by the wide range given for the values. Some of the decay and growth rates are temperature dependent. The values given in Table 3.2 are for a temperature of 20^oC.

TABLE 3.2 Model parameter values found in literature

Pollutant	**K_{decay} (/d)**	**Reference**	**Comments**
Organic material	0.17	Marais and Shaw (1964)	BOD, Sewage, Stabilization ponds, Settling and oxidation
	0.02 - 3.4	Brown and Barnswell (1987)	BOD, River modelling, QUAL2-E, Oxidation only
	0.01 - 0.4	Thomann and Mueller (1987)	BOD Municipal waste
	0.35	Sherwood et al. (1988)	BOD Municipal waste
	$0.3\ (H/2.44)^{-0.434}$ for $(0<H<2.44$ m) 0.3 for H>2,44 m	Thomann and Mueller (1987)	BOD River system for treated effluent
Coliforms	0.05 - 4.0	Brown and Barnswell (1987)	River systems Coliforms
	36	Campbell (1996)	Faecal Coliforms River system
PO_4	0.02 - 0.15	Wanieliesta and Yousef (1994)	Uptake of PO_4 into bed sediments in a pond
NH_4	1.04	Sherwood et al (1988)	Removal in sewage stabilization ponds

CHAPTER 4 PROGRAM OPERATION

4.1 INTRODUCTION

In this chapter, the steps and procedures are described for the operation of the program. This includes installation of the program and an explanation of the various input and output screens that are displayed during the operation of the expert system.

The program is written in Visual Basic ver. 3.0 for Windows 3.1. Your computer must therefore have loaded the Windows 3.1 or later operating system. The program can run on a 386 or 486 or Pentium computer with 8Mb of RAM, a hard disk and a VGA level graphics system. A mouse is essential for the operation of the system as this is used to select items and initiate commands displayed on the screens. It is assumed that the user is familiar with the Windows operating system and the operation of a mouse.

4.2 INSTALLATION PROCEDURE

Down-load the file **Expert System from the website http:\\www.wrc.org.za\software** and save into a new folder called say **c:\Expsys**. Get into the directory and double click on the new file **Expert System** to unzip it. The unzipped file will by default be stored in the folder called **c:\Expsys**. In the unzipping process a file **SETUP1.EXE** will be created in the WINDOWS directory as c:\windows\setup1.exe. (If there happens to be another file called **SETUP1.exe** in the Windows directory, rename it temporarily.) Go into the folder c:\expsys and click on **SETUP,** and then double click on **Expsys** to run program or press **Start - Programs - Expsys - Expsys.exe**. Click on **File** then **New** to run a new problem. The menus will appear on the screen.

4.3 PROGRAM OPERATION

The program consists of a series of 4 screens which is used to input data and display the results of a consultation. The first screen allows for the input of data describing the catchment. This is used to categorise the catchment according to the category system explained in section 2 and to provide the necessary input information to determine a flow rate from the catchment. The third screen displays the results of the analysis. Concentrations in the outflow from the elements making up the management system and at a specified distance downstream from the discharge point in the receiving water body are displayed on this screen. The downstream concentrations can be compared to the guidelines for instream water quality and domestic water use. Plots of the concentration profile along the length of the receiving water body can also be displayed for the different pollutant types. The fourth screen allows for the building of the management system and the input of the data required for the elements used in the management system. A button system is used to move between the screens. The **(NEXT>>)** button moves the user to the next screen and the **(BACK<<)** button allows the user to move back to the previous screen. The movements between the screens follows the procedure discussed in the decision-support system presented in section 2.

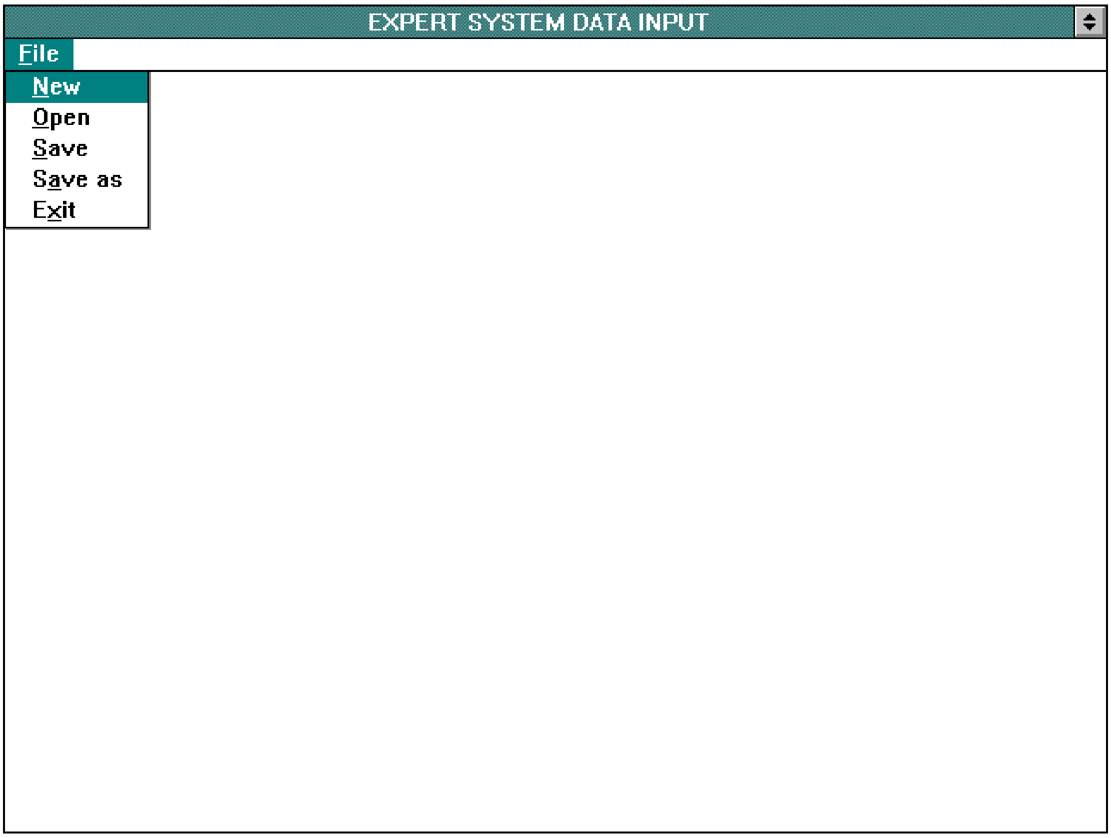


FIGURE 4.1 Start-up screen

4.3.1 Catchment data input screen

The screen displayed on start up is blank, except for the **File** command in the upper left hand corner of the screen. Use the mouse to put the cursor on the **File** command and click the left mouse button. The menu will be displayed as shown in Fig. 4.1. By moving the cursor and clicking the left mouse button on an item in the list, the user can create a **New** consultation, **Open** an existing consultation, **Save** the consultation currently being undertaken, **Save** the current consultation under a new name, or **Exit** the program.

New : This selection of this item in the list will start a new consultation. If executed during a consultation, the data currently in use will be unloaded from the computer memory. A message will be displayed enquiring if the user would like to save the existing consultation before starting a new one. The selection of **New** will display the catchment data input screen shown in Fig. 4.3.

Open : The selection of this item from the menu will display a box which allows for the selection of a file of a previously saved consultation which will be loaded into the program for further work. The file selection box is shown in Fig. 4.2.

The data files containing the input are in ASCII format and have the .DAT extension. Once the file is selected, use the **OK** button to proceed to the catchment data input screen.

Save : The selection of **Save** will save the current consultation input data. If the consultation is a new one, the user will be prompted to enter a filename for the data. If an existing consultation has been used then the old data in the file will be overwritten with the new data.

Save as : The selection of **Save as** allows for the existing consultation to be saved under a new file name.

Exit : By selecting this item, the program is exited. A warning is given reminding the user to save the consultation.

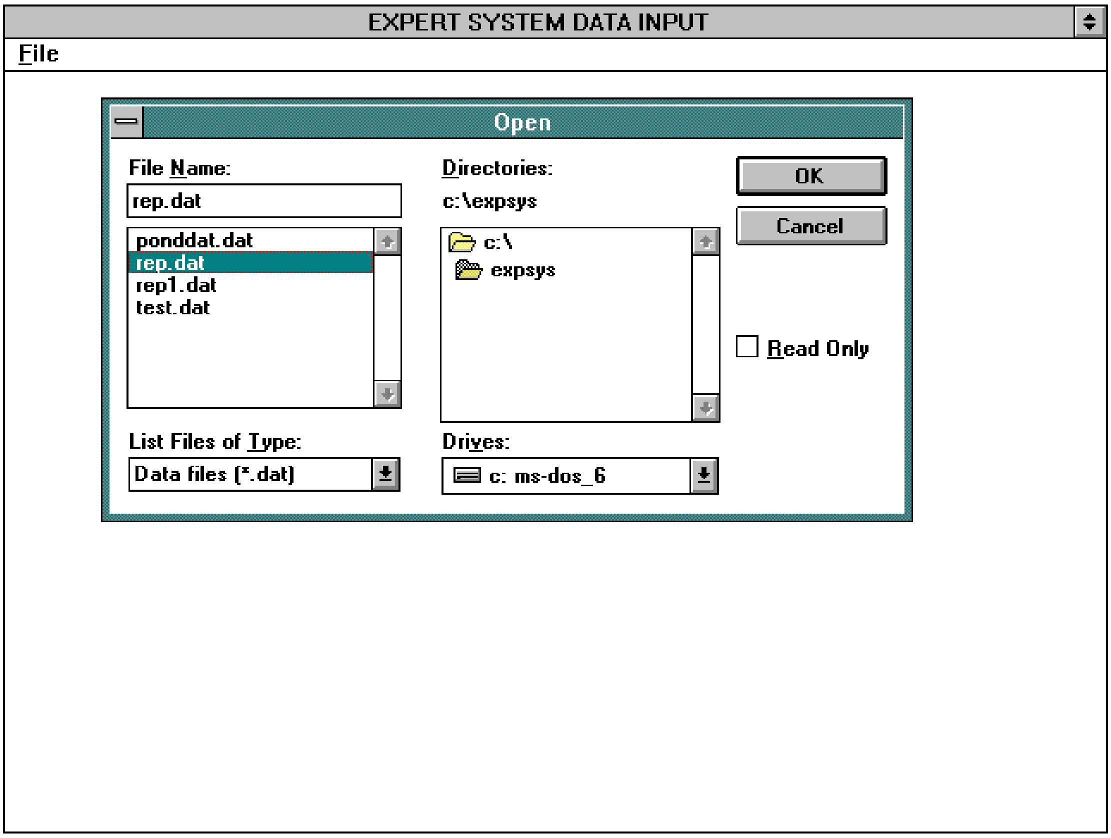


FIGURE 4.2 Menu to open a previously saved consultation

Input of catchment data

The data input screen shown in Figure 4.3 consists of a series of options which the user can select using the mouse. The series of options displayed in the upper half of the screen are used to categorise the catchment in terms of the criteria set out in section 2. If the industrial option is selected under land use, the development type, development density, development cost and pollution potential option boxes disappear. Similarly, the selection of the informal development type will result in the high cost (> = R30 000/unit) option disappearing as high cost informal settlement has not been catered for in the database.

The lower half of the screen is used to input data for the determination of a flow rate and storm duration for the catchment. The catchment area, catchment slope, % impervious, catchment length, and the mean annual precipitation (MAP) have to be determined outside of the expert system. The data must be input in the units shown on the screen. The data can be assembled from maps and plans of the catchment and development. The MAP can be obtained from the publications on the Surface Water Resources of SA (WRC, 1996).

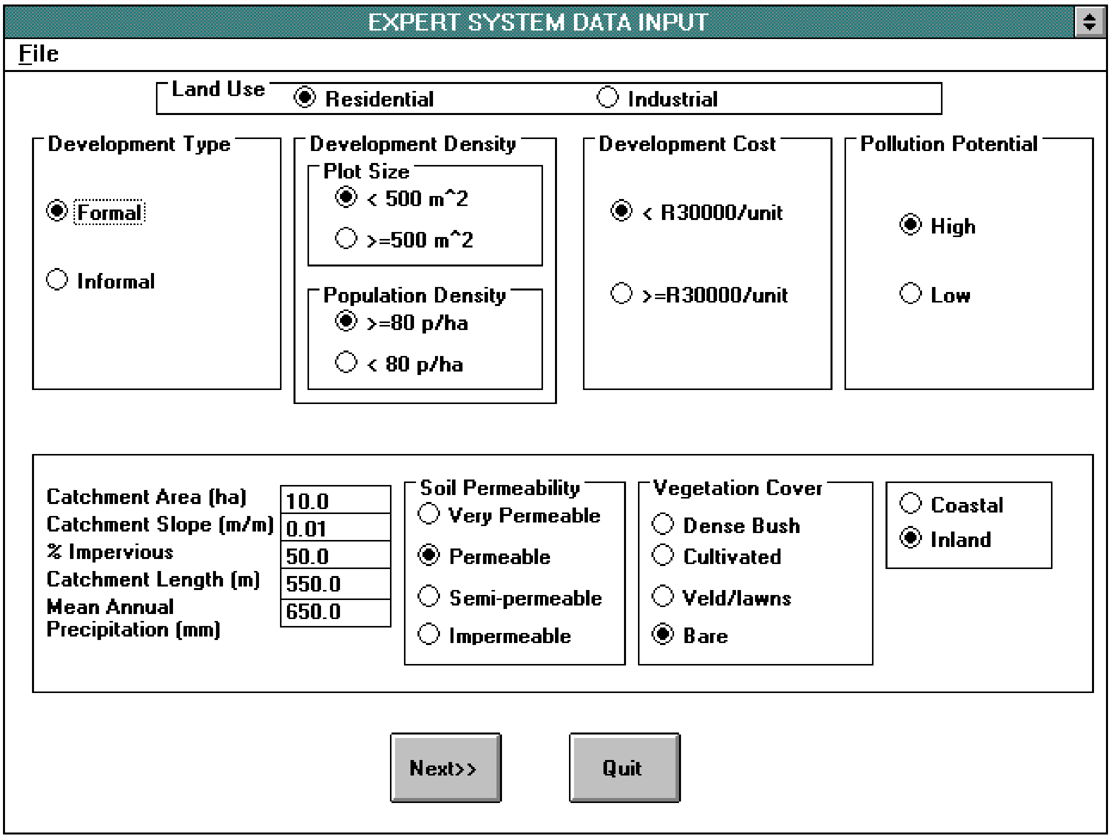
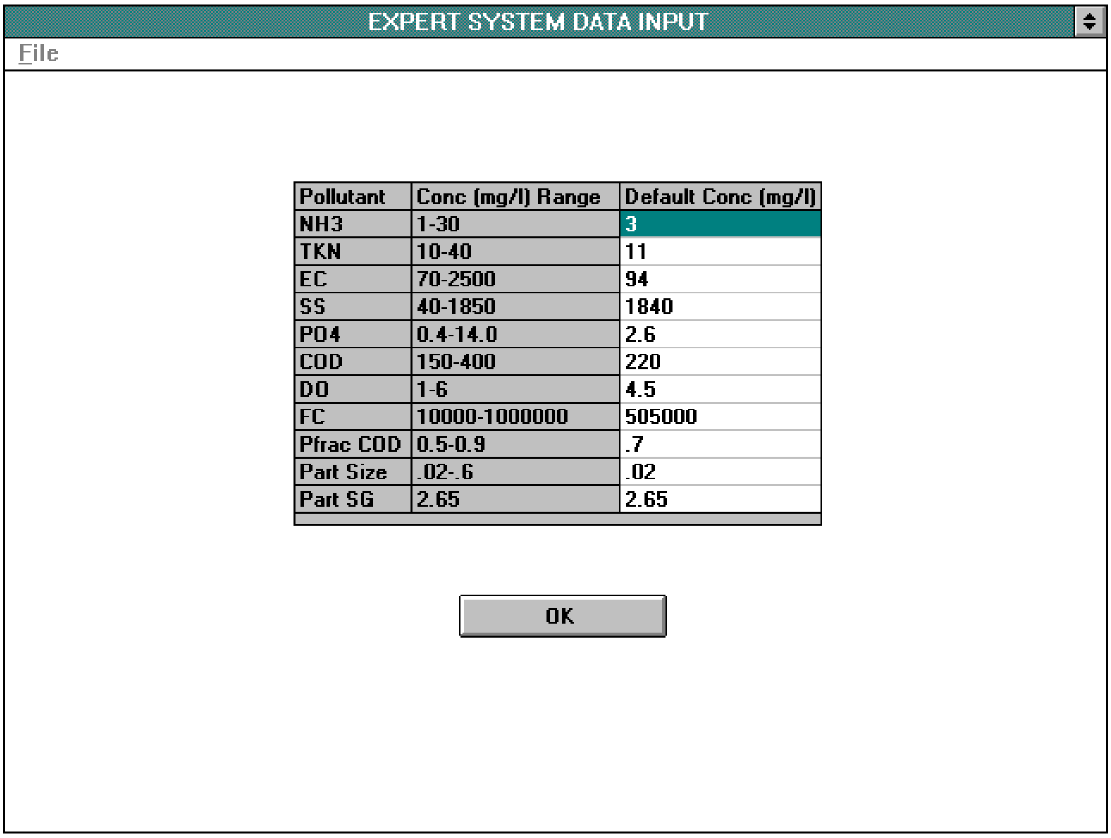


FIGURE 4.3 Catchment data input screen

Once all the information has been entered, the user can proceed to the receiving water data input screen by using the **NEXT>>** button or he can quit from the consultation using the **Quit** button. The use of the **Quit** button returns the user to the start of the application, as shown in Fig. 4.1. The data input thus far is lost. The **Quit** button should be used with caution.

Before leaving the catchment data input screen, the pollutant concentrations and the default particle size and specific gravity (SG) are displayed in a table on the screen (see Fig. 4.4). The data displayed on the screen is abstracted from the database of values given in Section 2. If the user has input a category which does not have any pollutant concentrations in the database, a warning message is displayed and a different categorisation is suggested. A default range of possible pollutant concentrations and a default value are displayed in the table. The default values shown in the table may be edited by selecting the value of interest by clicking the left button on the mouse. The new value can then be typed in and, once completed, the **ENTER** or **UP** and **DOWN** arrows can be used to enter the new value.



Pollutant	Conc (mg/l) Range	Default Conc (mg/l)
NH3	1-30	3
TKN	10-40	11
EC	70-2500	94
SS	40-1850	1840
PO4	0.4-14.0	2.6
COD	150-400	220
DO	1-6	4.5
FC	10000-1000000	505000
Pfrac COD	0.5-0.9	.7
Part Size	.02-.6	.02
Part SG	2.65	2.65

FIGURE 4.4 Table of runoff pollutant concentrations and particle sizes

Once the values have been entered to the satisfaction of the user, the **OK** button can be used to exit to the next screen. The values of the pollutant concentrations shown on the screen will remain for the duration of the consultation, unless it is edited. A change of catchment characteristics will change the default concentration range but will not change the actual concentration values.

Before proceeding to the receiving water body data input screen, limited checking of the input data is undertaken. If an error is found, a warning message is displayed on the screen.

4.3.2 Receiving water body data input screen

The receiving water data screen consists of data input boxes, a table of model parameters and a series of command buttons (see Fig. 4.5). The data input boxers are used to input the parameters defining the receiving water body system. These include the physical characteristics defining the shape and roughness of the channel.

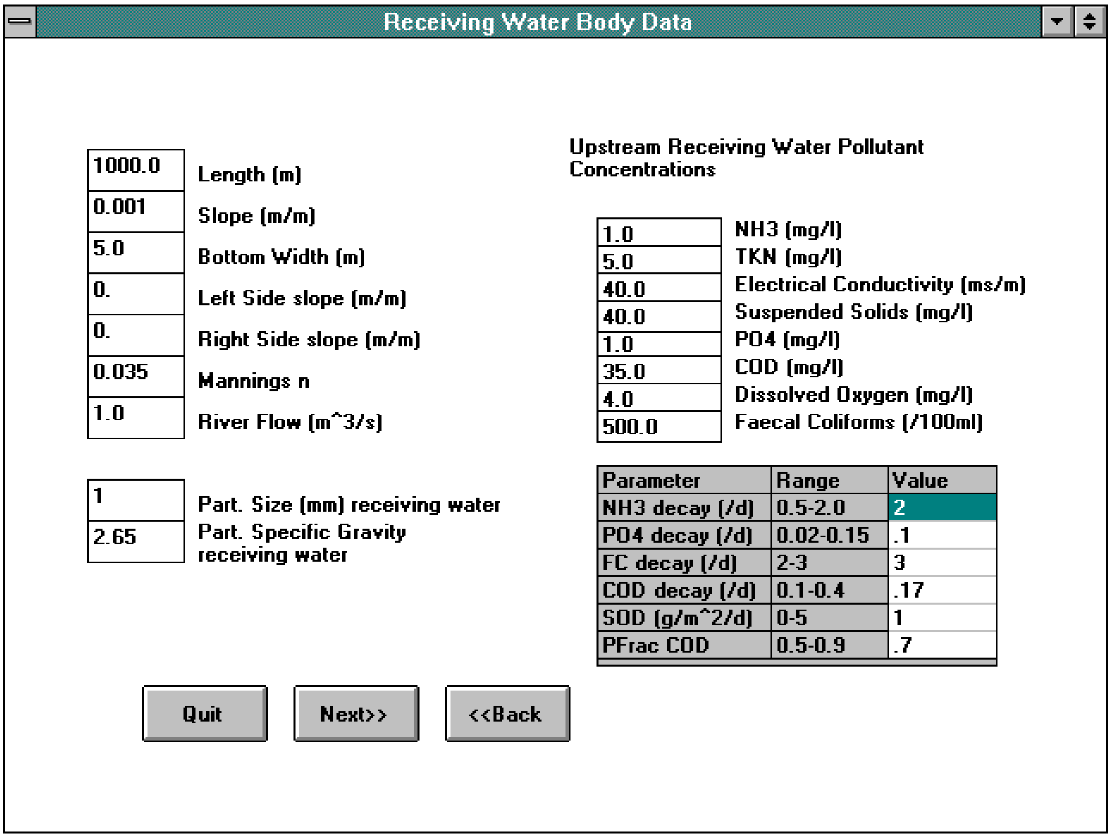


FIGURE 4.5 Receiving water body data input screen

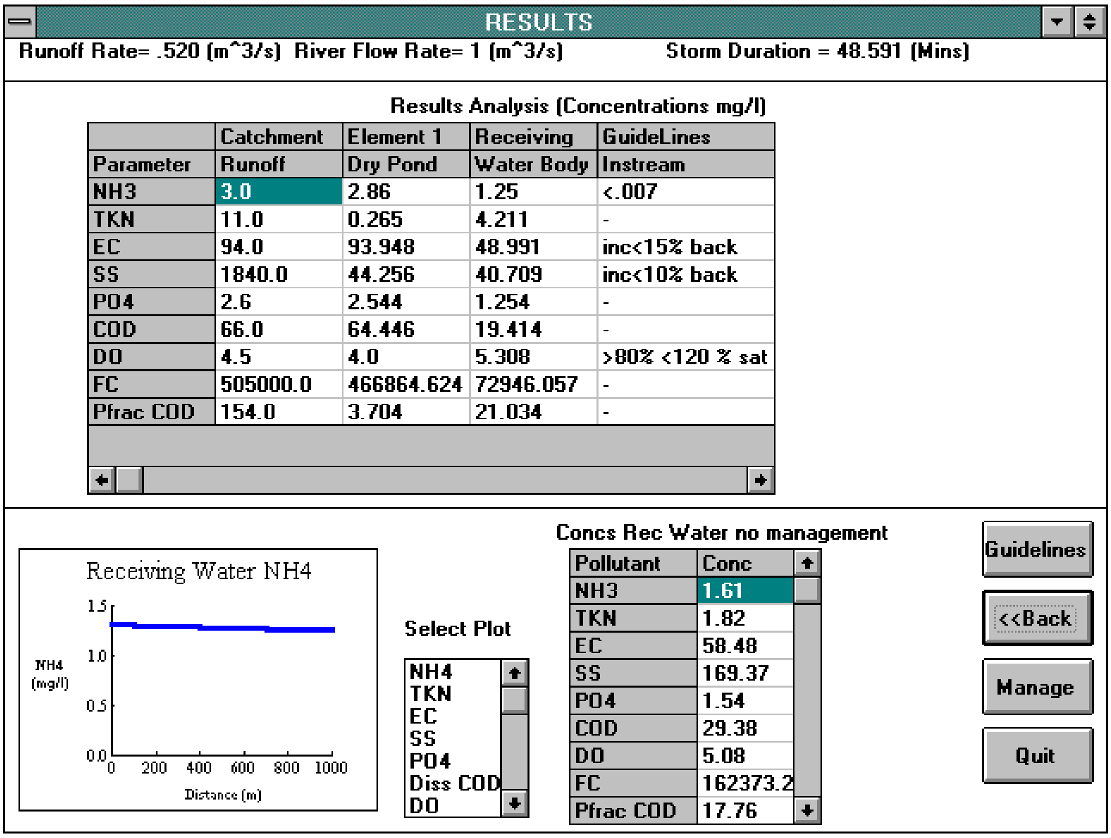
The length is the distance downstream of the discharge point where the pollutant concentrations in the river are required to be known for comparison to the guideline values. The default particle size and the specific gravity are displayed on the screen and can be edited if required. The pollutant concentrations that have to be entered are those in the receiving water body upstream of the discharge point. Similarly, the flow rate is that in the river upstream of the discharge point.

A range and a default value of the model parameter values are displayed in the table. The default values can be edited in the same fashion as the concentrations displayed in the table shown in Fig. 4.4. The model parameters are discussed in section 3 of the report. The Pfrac COD is the fraction of the COD in the receiving water body upstream of the discharge point that is in particulate form.

The **BACK<<** button can be used to return to the catchment data entry screen. The **Quit** button returns the user to the startup screen. As in the case with the catchment data screen, the current data is lost and a new consultation will have to be started or an existing consultation opened. The **NEXT>>** button is used to exit the receiving water body data input screen. Upon exiting this screen, the input data is checked and a message displayed if an error is found. The next screen displayed is the results screen. The receiving water body model is run to determine the downstream concentrations for comparison to the water quality guidelines. If management structures have been input using the management screen described later, these models are also run and the results displayed.

4.3.3 Results screen

The information displayed on the results screen cannot be edited in any way. The screen consists of 2 tables, a graph and a series of command buttons (see Fig. 4.6).



Parameter	Catchment Runoff	Element 1 Dry Pond	Receiving Water Body	GuideLines Instream
NH3	3.0	2.86	1.25	<.007
TKN	11.0	0.265	4.211	-
EC	94.0	93.948	48.991	inc<15% back
SS	1840.0	44.256	40.709	inc<10% back
PO4	2.6	2.544	1.254	-
COD	66.0	64.446	19.414	-
DO	4.5	4.0	5.308	>80% <120 % sat
FC	505000.0	466864.624	72946.057	-
Pfrac COD	154.0	3.704	21.034	-

Pollutant	Conc
NH3	1.61
TKN	1.82
EC	58.48
SS	169.37
PO4	1.54
COD	29.38
DO	5.08
FC	162373.2
Pfrac COD	17.76

FIGURE 4.6 Results screen

The table in the upper portion of the screen, displays the concentration values resulting from the analysis and the guideline values. The concentrations presented in the table are those in the outflow from the elements in the management system and the receiving water body. The element number and type are displayed in the top row of the table. The second table displays the receiving water body concentrations at the downstream point of the river had there been no management options in place. This has been included for comparison purposes. If no management has been used, then the values in this table will match those in the upper table.

The graph in the lower part of the screen shows the variation in pollutant concentration along the length of the receiving stream. The list to the right of the graph can be used to change the plots between the various pollutants. At the very top of the screen, the runoff rate from the catchment, the river flow rate and the storm duration are presented. The **BACK<<** button returns the user to the receiving water body input screen. The **Manage** button transfers the user to the management option screen, while the **Quit** button returns the user to the startup screen while losing all current data values.

4.3.4 Management system screen

The management screen allows the user to build a management system to intercept the runoff before reaching the receiving water body. A management system consisting of three elements in series is allowed for in the expert system. The outflow from one becomes the input to the next management option. The outflow from the last management option in the series is then input to the receiving water body.

The screen consists of a group of titled pictures of the management options from which the three elements making up the management system can be selected. The management options available are dry and wet ponds, vegetated channels and grass buffer strips. The management system section adjacent to the management option consists of three boxes which represent the three elements that make up the management system (see Fig. 4.7). To build the management system, a management option is dragged from the management option section to the desired box in the management system section. This is achieved by clicking and holding down the left mouse button on the required management option and dragging the mouse cursor and the outline of the picture frame until the cursor is over the required box. Once over the box, the left mouse button can be released and the picture of the management option will fill the box.

To delete an element in the management system, the **Delete** button is clicked using the left button on the mouse. The cursor is then placed over the picture of the element to be deleted and the left mouse button clicked. The picture in the box will then disappear.

In the bottom left-hand corner of the management screen is a series of boxes which allows for the editing of the flow rate and flow duration of the runoff from the urban area, the particle size and SG in the runoff and the receiving water body. This allows for sensitivity analyses to be conducted to assess how the system reacts under different conditions.

The model parameters for each of the elements are entered by means of tables in a similar fashion to the method used for the receiving body. To display the input table, the mouse is used to place the cursor over the element of interest and the left mouse button clicked on the element. A table will pop up in the section of the screen to the right of the management system (see Fig. 4.7). The table gives a range of parameter values and a default value. The value can be edited by selecting the value using the mouse. The new value is typed in and the **ENTER**, **UP** or **DOWN** arrows can be used to enter the value into the table. Once the table has been edited to the satisfaction of the user, the **OK** button is selected using the mouse and the table disappears.

The **Back<<** button returns the user to the receiving water body data input screen. The **Run** command button runs the various models of the elements making up the management system and the results are presented on the results screen. By using the **Back<<** and **Run** buttons on the management screen, the **Manage** and **Back<<** buttons on the results screen with the **Next>>** button on the receiving water screen, a flexible system has been created by which the user can change the characteristics of the receiving water body, change the management system and view the results.

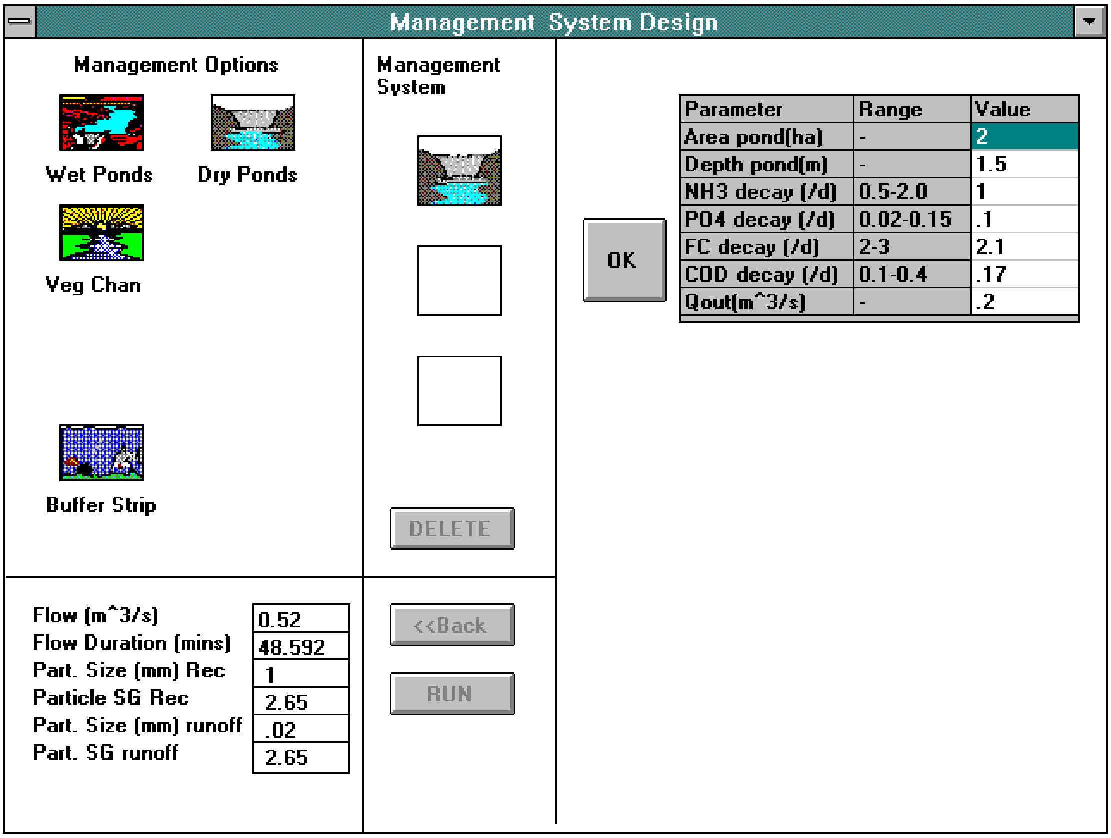


FIGURE 4.7 Management screen

CHAPTER 5 CONCLUSIONS

The following conclusions can be made as a result of this study:

- The expert system provides a methodical approach to the assessment of receiving water impacts, the planning of townships, and the preliminary design and assessment of the effectiveness of various management methods. The “User Friendliness” of the program and the fact that it has been written for the Windows environment makes the system usable by practitioners who are not necessarily experts in computers. The inclusion of default parameters gives the user, who may not necessarily be an expert in water quality modelling, the ability to carry out a preliminary impact assessment and design of mitigation measures;

- The expert system developed thus far provides a framework from which the system can be further developed by including more management options, different receiving water bodies, and updating the default parameter values for the pollutant removal algorithms. The catchment categorisation system can also be adapted to include new information or categories to describe the catchment types;

- The preliminary sizes provided by the expert system will give planners an idea of the extent of the management required and the feasibility of implementation in terms of the physical size of the management elements. An assessment on the basis of cost has not been included at this stage;

- The use of the expert system will also highlight the shortcomings in the available data which will be necessary to carry out a more complete assessment of the impacts on the receiving streams.

CHAPTER 6 RECOMMENDATIONS

The following recommendations can be made as a result of this study:

- The expert system should be expanded to include preliminary costings of the management options. This would provide a better basis for the assessment of the viability of a management system for urban runoff.

- The usefulness of the expert system should be tested on a case study involving an urban planner. The necessary classification of the catchment should be made by the planner, the data collected, and the expert system tested to determine the accuracy of its predictions.

- If found to be useful and used in the field, the structure of the expert system should be expanded to enable the user to change the catchment categorisation system by being able to add or delete categories, edit runoff concentrations, and update parameter values as new information comes to hand.

- The expert system at present only deals with a single point-source discharge to the receiving stream from a single urban catchment. The impact on the stream may be affected by the runoff from other catchments and additional point sources such as sewage treatment plant discharges. Consideration should be given to the expansion of the system to account for additional catchment and point sources.

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