A RESEARCH PROJECT SUPPORTED BY THE EUROPEAN COMMISSION UNDER THE FIFTH FRAMEWORK PROGRAMME
AND CONTRIBUTING TO THE IMPLEMENT OF THE KEY ACTION "SUSTAINABLE MANAGEMENT AND QUALITY OF WATER"
WITHIN THE ENERGY, ENVIRONMENT AND SUSTAINABLE DEVELOPMENT

EVK1-CT-2002-00106

REPORT

D 9, June 2004

WP 3, Deliverable 9
Environmental impacts of rehabilitation

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CARE-S - Computer Aided REhabilitation of Sewer networks

COMPUTER AIDED REHABILITATION OF SEWER NETWORKS
RESEARCH AND TECHNOLOGICAL DEVELOPMENT PROJECT OF EUROPEAN COMMUNITY

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Report D 9

WP 3.3 – Environmental impacts of rehabilitation

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Dresden, June 2004

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1 INTRODUCTION

The aim of CARE-S is to develop a suite of tools, which provides the most cost-efficient system of maintenance, repair and rehabilitation of sewer networks, with the aim to guarantee security of sanitary sewage collection and storm water drainage in order to meet social, health, economic and environmental requirements. The tools will enable engineers to establish and maintain an effective management of their sewer network.

Environmental aspects are vitally important for many rehabilitation projects. The impact of a declined sewer network as well as the effect of rehabilitation actions on the environment are interesting factors in the rehabilitation planning and scenario analysis. The changing environmental legislation which is following the commencement of the European water framework directive requires instruments to assess urban drainage impacts with criteria that consider receiving water properties, usage and quality aims. The impacts and effects of the sewer system have to comply with the requirements of the responsible regulator. General requirements on sewer networks which are connected to environmental issues and therefore key parameters in the environmental assessment are contained in the EN 752-2 (DIN, 1996):

- Public health and life shall be safeguarded.
- The sewer surcharge frequencies shall be limited to prescribed values.
- Drains and sewers shall be watertight in accordance with testing requirements.
- Receiving waters shall be protected from pollution within prescribed limits.

Work package 3.3 provides criteria and methods to derive values for the inclusion of environmental aspects in the decision support system. The criteria can be used in the decision making process for assessing or ranking rehabilitation projects, or to design or assess long term rehabilitation strategies.

1.1 Task and aims

1.1.1 Task and working description

The project is organised in the following Working Packages (WP):

WP 1: Construction of a control panel of performance indicators (PI) for rehabilitation
WP 2: Description and validation of structural condition
WP 3: Description and validation of hydraulic performance
WP 4: Rehabilitation technology information system
WP 5: Socio-economic consequences
WP 6: Multi-criteria decision support
WP 7: Wastewater network rehabilitation manager
WP 8: Testing and validation
WP 9: Result presentation and dissemination
WP 10: Project management

TU Dresden is responsible for task 3.3 and within this task for the following subtasks:

3.3.1 Groundwater

Depending on the structural state of the sewer and the relative position of the groundwater level to the sewer, groundwater will either infiltrate into the sewer or sewage will exfiltrate to the ambient soil, i.e. the unsaturated zone. Both processes affect to a large extent the matter transport and balance within the sewer system and determine among other indicators the performance and rehabilitation needs from an ecological point of view. Infiltration and exfiltration must thus be quantified as a consequence of the catchment wide rehabilitation strategy. A correlation between the type of structural deterioration, the quality class of sewers and the exchange rate between groundwater and sewer will be developed. A strong interrelation with an ongoing European project on in- and exfiltration from sewers, where measuring methods for the exchange rates are developed, will be established.

3.3.2 Surface waters

The transport of matter in the sewer system is largely influenced by rehabilitation strategies. Sediments build-up is a function of the roughness and of local obstructions. Intense sediment build-up is the source for intensified erosion during wet-weather events. Further, through infiltration and ex-filtration processes between the sewer and groundwater the concentration of solubles in the sewage and the combined water is changed. These transport processes of particulates and solubles are the origin for the biochemical impact on the receiving waters due to combined sewer overflow events (CSO), which is a determining factor for river water quality in urban areas. Transport and CSO models will be extended to include the effects of rehabilitation on transport of matter and the prediction of receiving water impact.

3.3.3 Treatment plant (WWTP) operation

The change of wastewater composition due to the exchange with ambient soil and groundwater, and the affected transport processes will influence the WWTP operation. Therefore, these influences must be considered in both ecological and economic assessment of rehabilitation. In particular, transport processes in the sewer system are decisive for the loading of the WWTP during storm-water events. During these, the WWPT operation is affected by a pollutant overload; this, in turn, affects the receiving water body. All these interactions will be modelled to evaluate the overall environmental and economic impact of the proposed rehabilitation.

The task plan has been updated in autumn 2003 and further tasks have been included:

3.3.4 Rehabilitation strategies choice

Driving factors for the analysis of rehab impacts will be provided during task 3.3.1 to 3.3.3. Therefore emerging costs will be estimated and as far as possible quantified. For choosing a method to assess costs information is needed from WP5.

3.3.6 Progressive urbanization

The activity of TU Dresden will consist of the determination of guidelines for the evaluation of runoff coefficient as a function of nature and use of surface and of the evaluation of population increase in future years. The subtask activity will include literature survey on existing ongoing EU research projects.

1.1.2 Structure and contents of the report

For every task a literature review has been done and a methodology to assess the environmental aspects within CARE-S is presented. The results of the tasks are presented within this Deliverable D9.

The literature review in chapter 2 is focussed on describing the urban drainage influences on environmental components. Here, influences of urban drainage in general and the role of declined sewers are described. An integrated simulation example is added in chapter 2.6 to show and explain the role of sewer network deficiencies for the entire urban drainage system. In the methodology description in chapter 0 diverse methodologies applicable to the problem are described. The chosen methodology is described in detail with an example. In this context the criteria for the decision support system are presented. A table including all criteria with summarised information can be found in chapter 3.4.

In the final section the tools which can be used in the CARE-S rehabilitation manager are described shortly. The full detailed description of the tools is not part of this deliverable and will be presented in a later report.

1.2 Role in the rehabilitation planning process

Within work package 6 a questionnaire has been sent out which provided information on the relevance of environmental aspects as criteria for the choice of rehabilitation projects. In Figure 1 it can be seen that pollution of receiving water bodies and groundwater are important aspects in the rehabilitation planning although other aspects like collapse of the pipe or total cost of rehabilitation are more important in many rehabilitation projects.

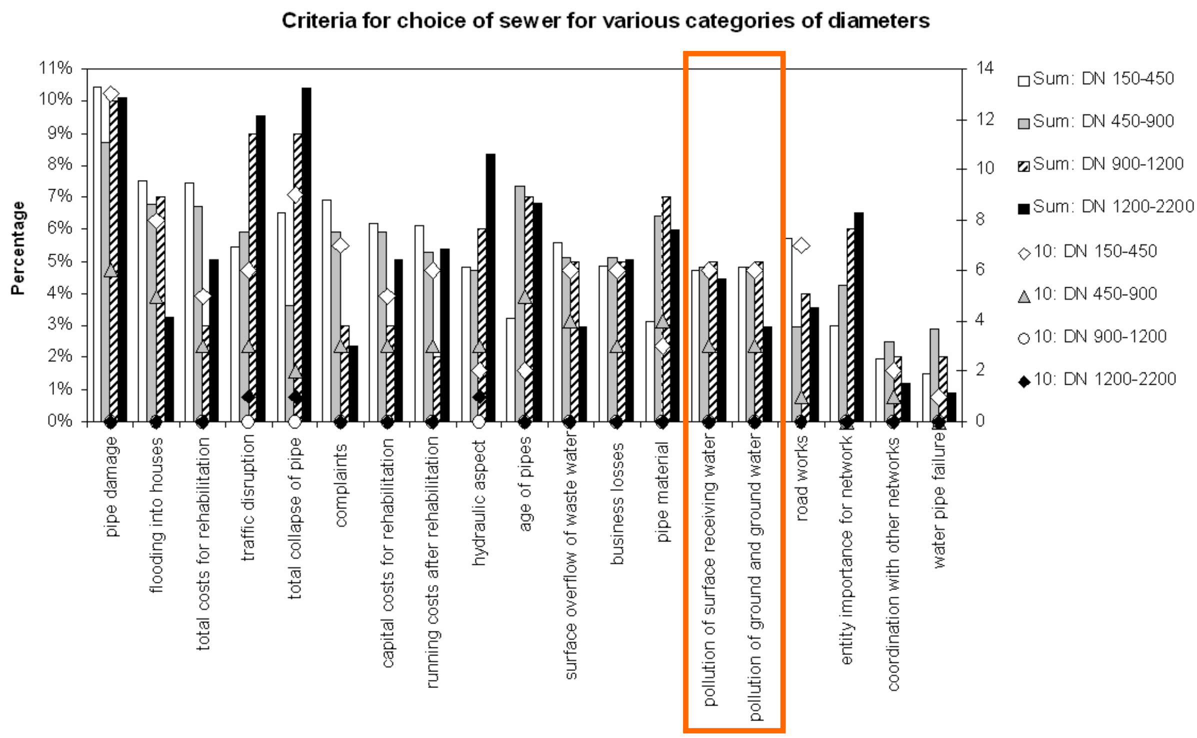

Figure 1: Decision criteria for sewer rehabilitation (CARE-S Deliverable D16)

To derive more detailed information on the question on the importance of environmental aspects questionnaires of work package 3.3 have been send out to the CARE-S partners. The aim of the survey was to collect information on end-users environmental problems connected with the sewer system and the inclusion of environmental aims and aspects in the rehabilitation planning. Details can be found in Annex I.
The evaluation is based on 10 returned questionnaires and gives a rough overview over environmental issues in rehabilitation planning. The assessment is not representative for whole Europe because the number of questionnaires is not sufficient for a general

evaluation. Nevertheless, the questionnaires give an insight in end-users problems and interests.

Problems with the performance of wastewater treatment plants and receiving water quality are the most often reported environmental problems connected to the sewer systems performance. (But not all problems that have been described for the wastewater treatment plant have their origin in the insufficient performance of the network.)
For rehabilitation planning these aspects and problems are considered at most sites by including information on infiltration, receiving water quality, combined sewer overflows and wastewater treatment plant performance into the rehabilitation planning process. Thus, the end-users are very interested in information about these aspects before and after rehabilitation. Although not many end-users have problems with groundwater quality or are not aware of them, nearly all of them focus on a reduction of exfiltration from their networks. However, the need for reduction of infiltration and exfiltration is not only due to the environmental impact of these processes but often due to the potential structural problems of sewers.
Besides that, users without environmental problems are also interested in information on environmental issues and prognosis. Nowadays, prognosis tools for environmental issues are seldom used for the rehabilitation planning.

The answers of the questionnaires showed that the use of hydraulic models is common in many cities. Even so it is not possible to use hydraulic models in every investigated site because not all users have established hydraulic models for their catchments. On the other hand some users are working with quality models and have therefore a very high level of understanding of their systems.

1.3 Position of environmental aspects in the rehabilitation planning process

The rehabilitation planning process is described in EN752-5 (DIN, 1996). Figure 2 summarises the steps of the rehabilitation progress. Details on the steps are described in CARE-S Deliverable D20.
The steps where environmental aspects are considered are marked in yellow. WP 3.3 can give assistance in the comparison of the systems performance to standards and performance criteria and in the analysis of scenarios. The analysis of the reasons and sources of current environmental problems needs to be carried out site specific outside the decision support procedure. The application of the CARE-S Decision support systme is limited to performance problems due to identified sewer deficiencies. The investigation and tracking of these sources cannot be done within the procedure. Table 1 describes the tasks of WP 3.3 in the decision support procedure. For explanation on the integration of subtasks into the EN 752-2 stages see Deliverable 20.

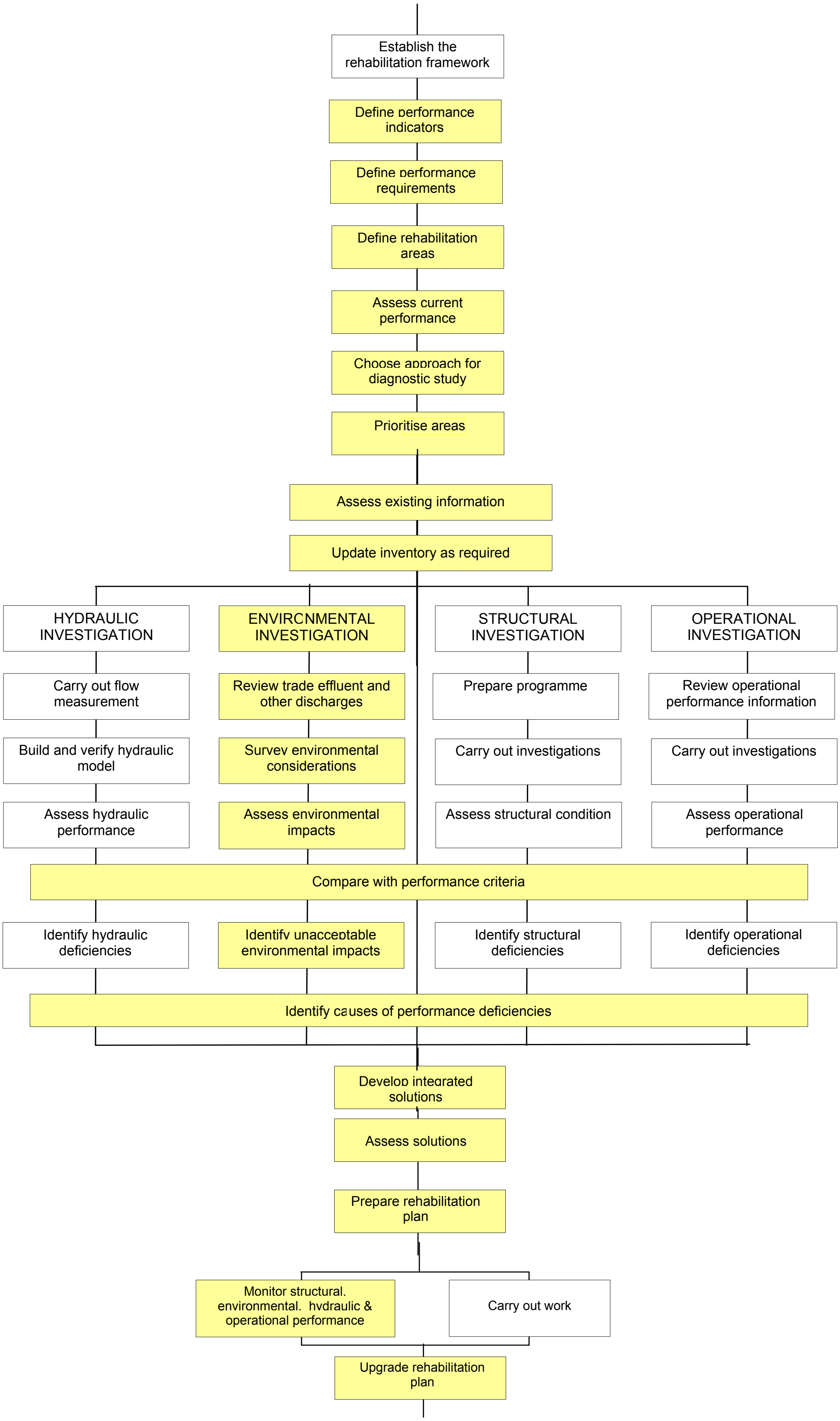

Figure 2: Rehabilitation planning process (modified from Deliverable D20)

Table 1: WP 3.3 in the rehabilitation planning process

Description of task and data flows	**CARE-S tasks (WP 3.3)**	**Comments**
Identify PIs which relate to these identified reasons for rehabilitation		TU Dresden will develop PI in the analysis which should be suggested for the evaluation of environmental problems together with their requirements for data collection.
Detailed investigation (Hydraulic)	if increased urbanisation should be considered: WP 3.3 proposes to include information from the cities master-plan in the data collection. Calculation of runoff coefficients.	(task 3.3.6)
Detailed investigation (Environmental)	user decides whether WP3.3 should be run or not (recommended if environmental problems have been observed or have been described by appropriate PI)	
	import PI and values from WP7 import asset data from WP 7(if not already done under 2.2) import hydraulic data import external environmental data (if available) import of data about operational problems (odour, CSO spills, visible water quality problems) calculate PI or criteria (store in WP7)	evaluation of data of current state (task 3.3.1-3.3.3)
Assess solutions	assessment with comparison to existing standards and to previous standard give information to WP 5, WP6, WP 7, WP 3.4	evaluation of data for diverse rehab scenarios comparison to standard requirements and to current state (task 3.3.1-3.3.4)

2 LITERATURE REVIEW

2.1 Performance deficiencies

According to work package 5 a failure was defined as the "termination of the ability of a pipe or of a network to perform a required function; a failure is a defect or a performance deficiency and is defined in reference to a required level of performance."
Performance deficiencies of the sewer or storm sewer network can be caused by defects or faults of the network. They can also have their origin in changing characteristics of the catchment, the input into the system or inadequate design.
Main network deficiencies are (LeGauffre et al., 2004) and EN 752-2 (DIN, 1996):

- infiltration
- exfiltration
- blockages
- reduced hydraulic capacity
- direct discharge from sewers into the receiving water
- emergency discharge of tanks or pumping stations
- excessive spillage
- sand silting

When a performance is to be defined as a failure can be described using the criteria listed in Table 2:

Table 2: Failures

	description of level of performance via	**criteria**	**value**
CSO*	PI target or trigger standard/regulation voluntary objective	volume spill frequency load design flow	depends on national or local regulation
WWTP*	standard/regulation for inflow voluntary objective initial design	ratio of extraneous water / dry weather flow	
exfiltration	any occurrence of exfiltration PI target or trigger	vulnerability of specific area; exfiltration volume	yes/no, low or high vulnerability
infiltration**	PI target or trigger Any regulation or voluntary objective	Infiltration volume	user defined values
receiving water*	standards and regulations voluntary values	discharged total load CSO criteria hydraulic load	

*Given the performance deficiency was caused by a network defect it has still to be investigated whether infiltration, blockages, root intrusion or other defects led to the increased overflow or other deficiency. Work package 3.4 is developing a procedure to identify the pipes probably responsible for a performance deficiency.

**The level of performance required for infiltration depends mainly on the consequences the extraneous water flow has for CSO, WWTP or other parts of the urban drainage system. The decision whether infiltration is a failure or not can only be made by simultaneously assessing the other compartments of the system.

CARE-S is mainly concerned with deficiencies caused by network defects. Solution proposals to resolve problems with other methods than pipe rehabilitation are shortly presented in Chapter 3.9 and in Annex III.

Criteria and performance indicators used within CARE-S and the decision support system are described in chapter 3.4.

2.2 Groundwater

2.2.1 Infiltration

Inflow is originally non-polluted so that it is not necessary to feed it to any treatment. (Weiß et al, 2002). Infiltration can cause additional costs in the sewer system and wastewater treatment plant and is an important aspect regarding the rehabilitation of sewer systems. Infiltration decreases the pollution concentration of the sewage. However, the reduction of effluent concentration from urban drainage should not be achieved by dilution of the effluent. Due to this fact it is the first aspect of consideration in WP 3.3. In this contexxt, an assessment of infiltration impacts can only be made qualitatively. Quantitative considerations require site specific measurements and investigations. A short overview on causes and impacts of infiltration is given in the following.

EU standards

Based on the EU legislation the member countries are committed to set up their own legislation. The following paragraph shows the actual state in laws regarding extraneous water. It has shown that there is a lack of a clear definition about the handling and the assessment of extraneous water.

EN 752-2: basic performance criteria:
- receiving water quality should be protected against sewered discharges
- the structural integrity of urban sewer systems including their water-tightness, should be guaranteed

EN 752-3:
- In case of the risk of an unwanted infiltration of groundwater into sewers the extension of the risk is to be determined.

EN 752-4:
- The design of sewers should take into account extraneous water until the limit that justifies rehabilitation. (Comment: The limit is not defined!)

EU Wastewater directive (91/271):
- large sewerage systems should comply with the requirements laid down in Annex 1(A) covering “leakage” by the end of 2000. (see below)

Annex 1 (A) of the EU Wastewater directive (91/271):
Collecting systems shall take into account waste water treatment requirements. The design, construction and maintenance of collecting systems shall be undertaken in accordance with the best technical knowledge not entailing excessive costs, notably regarding:
- volume and characteristics of urban waste water,
- prevention of leaks,
- limitation of pollution of receiving waters due to storm water overflows.

Sources of infiltration

It has to be distinguished between inflow and infiltration. Inflow is directly connected to a rain event. Furthermore, creeks flowing in the sewer system or misconnections lead to a high parasite water fraction.

Five types of infiltration can be defined (WP2, 2003):

groundwater infiltration
rainfall induced infiltration
fluvial induced infiltration (from river)
tidal induced infiltration (from sea)
infiltration due to nearby leaking water mains

Important sources of infiltration in seperate sewer systems are:

- street drains connected to the sewer system
- roof and yard pipes connected to the sewer system
- unsealed manhole covers
- sump pumps
- overflows from storm drains
- Misconnection of road/roof drainage.

Important sources of infiltration in combined sewer systems are:

- Cracks
- Leaking pipe joints (Weiß et al., 2002)
- Private house connection pipes (House lateral connections may contribute as much as 30-40 % to infiltration (WP 2.3. report) and are not recorded by CCTV)
- Drainage to combined sewers
- Trench backfill with a higher permeability than the surrounding soil leads the flow directly to the crack

More detailed information on infiltration path, detection of infiltration as well as measurements and models is given by the literature review of existing failure models of WP 2.2.3 (WP2, 2003)

The occurrence and amount of infiltration may depend on various factors:

- Size, diameter
- Age
- Material
- Way of construction
- “laying” conditions
- road traffic conditions
- insufficient maintenance
- Year of construction
- Groundwater level
- Soil type (Precipitation induced infiltration depends strongly on watercontent and water
- conductivity of the surrounding soil)
- “Freezing-depth”

These factors have to be considered regarding their significant influence on infiltration rates. Work package 2 will develop a model for the determination of infiltration rates per pipe.

Quantification

For quantification different units for rates of extraneous water are used :

l/(s*ha)
l/(s*km)
% of dry weather flow (extraneous water rate/ percentage/ fraction/ portion)
% of sanitary flow (extraneous water supplement/ surcharge)

Methods that have been applied to quantify infiltration rates showed a variation of the measured infiltration flow of 15 % around mean value. The results of chemical methods show to be below the statistical mean, statistical methods always show to deliver results above the statistical mean of measurements (Decker, 1998). The statement about the rate of infiltrated water is more exact the larger the investigated catchment is. Furthermore, infiltration is often underestimated because of the occurrence of exfiltration.

Examples for statements about infiltration quantity:

Table 3: examples for extraneous water flow (after (Decker, 1998) and (Ellis, 2001)

l/(s*ha)		l/(s*km)		% of Dry wheather flow		% of sanitary flow	
0.1 (D)	0.15 (D)	0.72 (USA)	1.4(USA)	26 (D)	77(D)	50 (D)	900 (D)

Ellis reported that the infiltration rate from 0.01 m^3/d/(mm pipe diameter)/(km length) to 1.0 m^3/d/(mm pipe diameter)/(km length) increases proportionally with the age of sewer.

Rain dependent infiltration

Inflow to WWTP caused by rain events may increase for several weeks due to groundwater. Inflow is expected to be lowest in filled pipes during rain and highest shortly after wet weather periods. During a rain event the largest contributor to inflow and infiltration is the base infiltration (through backfill trenches), followed by direct inflow from impermeable surfaces, which is followed by rain dependent groundwater infiltration (lasting for many days). Inflow/Infiltration varies seasonally, in winter/spring it is up to ten times higher than in summer/autumn (Ellis, 2001; Weiß et al., 2002). Values from 0%-900% (in Winter/Spring) for extraneous water supplement have been estimated. Ellis (2001) reports about extraneous water flow about 10%-20% of the total wet weather flow.

Weiß et al. (2002) give a fractionation of annual hydrographs:

35 % infiltration/ inflow
35 % stormwater
30 % sanitary water

Effects of infiltration on the groundwater level

The rehabilitation of pipes with a high infiltration rate can lead to an increased infiltration in other parts of the network due to the rising groundwater level or due to new pathways the infiltrating water established. Especially in wet land areas the raise of the groundwater level due to the prohibition of infiltration should be considered.

Effects of infiltration on the environment will be described in chapter 2.3, 2.4 and 2.5.

2.2.2 Exfiltration

EU standards

The main objective of the EU legislation is to prevent the pollution of groundwater by substances which could have a harmful effect on groundwater. The pollution by substances which percolate through the soil before they enter the groundwater layer are defined as indirect discharges. Since the substances that are listed in the List I and II of the groundwater directive have been found in sewage (Gulyas et al., 1993) a discharge via exfiltration which is an indirect discharge and needs to be prevented.

Concerning the Water Framework Directive, the no-deterioration clauses for groundwater (no-deterioration of groundwater body status, of unpolluted groundwater and of groundwater abstracted for drinking water) needs to be respected. Hence, since no quality check of groundwater and no detailed investigation of the actual groundwater pollution are feasible in the CARE-S procedure, all possible deteriorations due to exfiltration will be assigned and should be investigated in detail outside of the CARE-S decision support system.

A document accompanying the WFD (Article 4, Document 9085/99 DG11) requires the avoidance of sewer impacts to groundwater and the identification of point-sources and diffuse sources which contribute to groundwater pollution.

EU Standard EN 752-2 identifies basic performance criteria:
- receiving water quality should be protected against sewer discharges
- the structural integrity of urban sewer systems including their water tightness should be guaranteed

EN 752-3 recommends that Groundwater level and movement and saisonal fluctuations should if possible be monitored during the planning process. Geological maps should be a basis for the assessment.

EN 752-4 states that specific conditions can be set by the regulator in areas with a high groundwater level or in protection areas. In these areas measures for the protection of the groundwater are:

- installation of a additional watertight casing pipe
- installation of a warning system for leaky and broken sewers
- installation of house connections directly to a manhole
- higher requirements for the material and the construction method.

Exfiltration characteristics

The most common method for the detection of exfiltration is CCTV. However, in a number of cases large damages determined by CCTV did not contribute significantly to exfiltration while minor detected damages caused exfiltration (Vollertsen and Hvitved-Jacobsen, 2003).
Exfiltration is expected to depend on various factors like water level in the pipe, surrounding ground, status of sewer and material of the sewer. Although many investigations have been done on this topic, the causal relationship between these factors and the exfiltration rate is not clearly confirmed until now.

Experiments, where exfiltration from leaking sewers in different sand types were investigated, described in Vollertsen and Hvitved-Jacobsen (2003) and Dohmann et al., (1999) showed that the exfiltration rate becomes constant during experiments. At the beginning of the experiments high exfiltration rates occurred until a clogging zone with a high concentration of organic matter had built up. The exfiltration rate showed to be more dependent on this clogging zone than on the characteristics of the surrounding soil (soil type). Different sand types did not influence the exfiltration rate after some days. Dependency on the size of the leakage was proved as well as dependency on the water pressure inside the pipe and a dependence on the kind of the leakage (holes or joints). A list of priority of environmental risk for the damage descriptions can be found in Dohmann et al. (1999):

- change of position of the pipe
- sherds
- improper house connections
- longitudinal/ transverse cracks
- root intrusion

Furthermore Vollertsen and Hvitved-Jacobsen (2003) showed that exfiltration can be severe in zones where groundwater is fluctuating. The protective zone around the leak is removed when the sewer pipe becomes submerged below groundwater.
For a short time after flushing or after infiltration the exfiltration rate is increasing (some days) before returning to the constant level of exfiltration once the groundwater level has receded. Macke (1999) investigated not only a constant exfiltration flow in his experiment, he reported on a decrease of the exfiltration rate down to zero exfiltrating.

More information about case studies and models for the prediction of exfiltration can be found in the CARE-S WP2.2.3 literature review. There it is stated that significant uncertainty must be taken into account when predicting exfiltration rates using CCTV data.

Effects

The view on the effects of exfiltration is mainly a view on groundwater, rather than on other water bodies. No narrative information in the literature demonstrates or even suggests, that sewer exfiltration has directly contaminated surface waters. Sewers near surface water bodies generally are below the groundwater table, so that in these cases infiltration into the sewers occurs rather than exfiltration (Amick and Burgess, 2000).

Possible reasons for contaminated groundwater

The effects of exfiltration are not known in detail. Some studies suffer from difficulties in distinguishing pollution from sewers and pollution from other sources (Vollertsen and Hvitved-Jacobsen, 2003). The difficulties occur due to the high number of possible contaminants. Possible main sources for groundwater pollution in general are (Eiswirth and Hötzl, 1997):

- waste sites and solid waste disposals
- septic tanks and cesspools
- polluted precipitation of surface runoff
- road de-icing
- gasoline stations
- water treatment effluents
- mine tailings and brines
- runoff from tank pipelines and storage leakage
- industrial impacts (cooling water, process water)
- chemical dry cleaners
- agricultural impact. E.g. parks and gardens (fertilizers, soil amendments, pesticides, animal wastes, stockpiles, sheep dips)
- traffic accidents (dangerous goods)
- deep buildings (grout injections within the groundwater)
- leaky sewerage systems (industrial and urban waste water)

Impact of leaking sewers

Several studies have indicated widespread pollution of ground water in urban areas arising from the general leakiness of sewers (Amick and Burgess, 2000). Whether or not pollution is caused by leaking sewers can be investigated by the review of recorded incidents or by analysing the quality of the groundwater and investigating indicator substances that are sewage attributed.

Little published data is available on specific incidents on groundwater pollution and associated health/environmental impacts arising from leaking sewer, despite the widespread acknowledgment that these incidents occur (Amick and Burgess, 2000).
Reported incidents occurred in wells and are mainly bacteria caused illness or strangely tasting or looking water. The incidences occurred in chalk (which has inherent and significant secondary porosity in the form of fractures and fissures) so bacteria could brake through due to little retention time within the chalk system. The incidents gave evidence for leaking sewers as sources of contaminants (Misstear and Bishop, 1997).
For example incidents occurred in Yorkshire in 1980 where leakage from a surcharged sewer contaminated a borehole. 3000 cases of gastro enteritis occurred (also due to breakdown of chlorination). Consequently wells are endangered. More pollutions of wells that are associated with leaking sewers are reported (Misstear and Bishop, 1997).

As for groundwater quality, nitrate has been used as an indicator of sewage impact (ammonia is oxidised to nitrate in the groundwater) as well as sulphate, chloride, phosphate and boron (Misstear and Bishop, 1997). However these determinants are common pollutants from other sources too, nitrate and phosphate in particular are often derived from agricultural activities. In recent investigations (Kroiß et al., 2004) pharmacy residues are used as indicator substances.

Pollution characteristics

The CARE-S Report of Work Package 2 (WP2, 2003) on exfiltration states that there is generally not a well-defined correlation between exfiltration volume and the contaminative impact of exfiltration, the impact relating to the quality of sewage, the soil type, the depth to the groundwater table and the amelioration of pollutants such as pathogens. (i.e. natural degradation / biological breakdown of pollutants)
The question occurs what exfiltration volume or rate is a failure in terms of pollution?

Impacts on groundwater depend among other things on (Godbold, 2003; WP2, 2003):

- wastewater exfiltration rates
- type and concentration of wastewater pollutants (little polluted water exfiltrates more easily (Dohmann et al., 1999))
- adsorption, desorption, degradation and other reactions of the exfiltrated pollutants
- soil characteristics, e.g. soil type, redox potential, pH, and background concentrations
- depth to the groundwater table, and the degree of water table fluctuation
- groundwater formation rate and flow pattern
- geological formation (important as the soil layer can be very thin, especially in Chalk regions).
- topography
- groundwater recharge rate

Eiswirth and Hötzl (1997) described that the influence of the depth to the water table is important. The unsaturated zone between the sewer and the water table is mainly responsible for the degradation of biodegradable organic compounds which are the main compounds of sanitary wastewater. The degradation is less predominant for chemical compounds of industrial and urban discharge which, in their opinion, present greater risk for the groundwater than other pollutants. In Ellis (2001) and Ellis and Revitt (2002) it is stated that Groundwater deterioration is severest in a narrow zone at either side of the sewer trench line and relatively minor in occurrence. The general impact of exfiltration on groundwater seems not that severe in their opinion. Amick and Burgess (2000) conclude in their investigations that exfiltrated water does affect the groundwater quality.

Clodius et al. (1999) found in their investigation on the effects of exfiltration that a clear effect on groundwater is not provable. Most substances are reduced in a zone of 10 cm below the pipe. Exfiltration can be a danger in case of large or heavy damages, permeable soil and a groundwater table < 100 cm below the pipe. This applies mainly for heavy metals like lead, copper and zinc. For fine sand, clay and a groundwater table >100 cm pollution due to exfiltration is not expected.

Fenz (2003) states that the highest danger of groundwater contamination applies for groundwater tables directly below the pipe invert and by that also for the mobilisation of substances from the contaminated zone around the pipe (e.g. due to fluctuating groundwater level).

The literature survey showed that no general statements can be made about the risk of pollution by groundwater due to exfiltration. The coherences have not been clearly identified. Only detailed and site specific study of these characteristics or detailed search for pollutants in the urban groundwater allows a good assessment of pollution from exfiltration. Consequently a high level of uncertainty has to be taken into account by predicting pollution caused by exfiltrating wastewater. In order to assess potential impact it is important to concentrate on pollutants which indicate to originate exclusively (or predominantly) from sewers.

Effects

Biology

Of significance are the levels of faecal coliforms and faecal streptococci, coliphages or more general: bacteria. Faecel bacteria contamination is the most serious health risk associated with domestic sewage exfiltration. Presence of coliphages provides clear evidence for sewage impact to local groundwater. Contamination by viruses, protozoa and other microorganisms is also a concern (Amick and Burgess, 2000; Misstear and Bishop, 1997; Ellis, 2001).
Ecoli is reduced in the clogging zone around the pipe, so incidents resulting from bacteria are less likely if the soil is unsaturated until far below the pipe (>1m) (Vollertsen and Hvitved-Jacobsen, 2003; Vollertsen, 2003).

Inorganic pollutants

High concentrations of nitrogen compounds, sulphate and chloride in groundwater have been found to be sewage originated (Häring and Mull, 1992; Eiswirth and Hötzl, 1997; Amick and Burgess, 2000). As evidence of pollution from sewage, chloride and nitrate have comparable mobility within groundwater (Amick and Burgess, 2000). Phosphate and Boron together are good indicators of sewage pollution since they are not naturally occurring in ground water (Amick and Burgess, 2000; Barrett et al., 1997)
Nitrate is originated from leaking sewers in the same percentage as from agriculture (Häring and Mull, 1992). In rural and urban areas the Nitrate concentration in the groundwater can exceed the drinking water directive value of 50 mg/l (at this value the drinking water wells are closed or require blending with low nitrate sources (Godbold, 2003)). The reason is that the ammonium from the sewage degrades fast into nitrate. Nitrification takes place in the soil beneath the clogging zone (Vollertsen and Hvitved-Jacobsen, 2003). This process depends on the oxygen content of the soil. A Californian study indicated that ammonium disappears within 4 feet (around 1.2 m) probably by adsorption and bacteriological activity. Within this zone bicarbonate and nitrate increased several hundred percent and nitrite disappeared (Amick and Burgess, 2000).
However, in a case study it has been described, that sewage contributes less than 15% of total nitrogen load to the groundwater. More than 50 % of total nitrogen in the groundwater is entering with precipitation recharge which releases nitrogen from the soil. The study states that the nitrate concentration in groundwater is similar in urban and in rural areas (Barrett et al., 1997).

Organic pollutants

Various organic compounds have been found in the groundwater (Misstear and Bishop, 1997; Amick and Burgess, 2000; Vollertsen and Hvitved-Jacobsen, 2003). Around exfiltration pipes the COD is reduced due to biological activity in the soil and absorption. Macke (1999) observed a reduction of more than 90 percent for TOC and COD. In Dohmann et al. (1999) the decrease of pollutants in the surrounding soil was shown. COD decreased by 70 %. The pollutants have probably been decreased by adsorption on soil particles. This does not mean that they have been eliminated since they can be mobilised during changing conditions.
Oil, grease and toxic pollutants can also originate from exfiltration.
Chlorinated solvent pollution is widespread and BTEX have been found (source: fuel) (Barrett et al, 1997). “Hot spots” of BTEX contamination are being related to exfiltration. However, organic pollution is mainly originated from urban industrial areas. Examples are described in (Ellis, 2001).

Soil

A consequence of the pollution of the soil around the pipe is that the soil might have to be treated like waste if it is removed during a pipe rehabilitation project (Clodius et al., 1999).

2.3 Surface waters

This chapter will give an overview on receiving water bodies, their sensitivity to urban drainage impact, especially to sewer network deficiencies and environmental regulation and standards.

2.3.1 Kinds of receiving waters and properties

Receiving waters in Europe are rivers, estuaries, lakes and coastal waters. These waters have different sensitivities to the effect of urban drainage and different standards are applied to control urban drainage impact. Not only the sensitivity of the water bodies is a reason for developing different standards but also the use of the water bodies leads to different requirements. Uses of water bodies are for example, fisheries, recreation, potable water supply, industrial abstraction and agricultural abstraction.

2.3.2 Sensitivity

Different kinds of possible receiving waters are listed and qualitatively assessed regarding their sensitivity to impacts due to urban drainage in table 4 (House et al., 1993 in: (Butler and Davies, 2000)):

Table 4: Qualitative assessment of receiving water impacts of urban discharges

Receiving water	Water quality				Public health	Aesthetics	
	Dissolved oxygen	Nutrients	Sediments	Toxics	Microbials	Clarity	Sanitary debris
Streams							
- steep	-	-	-	x	xx	-	xx
- slack	x	-	x	x	xx	-	xx
Rivers							
- small	xx	-	x	x	xx	-	xx
- large	x	-	x	x	xx	x	xx
Estuaries							
- small	x	x	x	x	xx	x	xx
- large	-	-	x	-	xx	x	xx
Lakes							
- shallow	x	xx	x	x	xx	x	xx
- deep	x	x	x	x	xx	x	xx

xx Probable, x Possible, - Unlikely

The table shows that lakes are most sensitive to impacts caused by urban drainage. Small estuaries and small rivers are also very sensitive. Small rivers are particularly impacted by acute water pollution caused by combined sewer overflows, whereby accumulative pollution is a main problem for water bodies like lakes or estuaries. On these receiving waters the discharges from settlements have to be controlled most carefully and high standards have to be applied to protect aquatic life and to ensure the actual and further use of water.

The magnitude of the impact of urban drainage on receiving waters will vary depending on receiving water properties. These properties determine the water body class and influence the self-purification potential of the receiving water. For example in rivers the sensitivity is affected by:

- upstream quality and flow
- channel slope
- channel geometry and roughness
- in-river structures
- pH
- temperature
- ecology (macrophytes, algae, fish and invertebrates)

2.3.3 Standards

Within CARE-S standards are used to define criteria for the receiving water body impact assessment. According to the protection requirements and the use of water bodies various European guidelines exist and have to be applied. The urban wastewater treatment directive (EU, 1991) sets a framework for CSO and WWTP regulation for the protection of receiving waters which is (for population equivalents of more than 15000) or will be (for population equivalents of 2000 to 15000) put into national or local legislation by the EU member states.The water framework directive will overrule some important European guidelines within this and the next decade.
Thus parameters and methods of water body assessment will change. The methodology of CARE-S should therefore be flexible and able to include diverse thresholds and standards to provide a flexible basis for the assessment of impacts caused by network deficiencies.

Concerning the limitation of environmental impacts two main kinds of standards have been developed (EN 752 – 4):

- uniform emission standards, a general standard for all kinds of sewage
- site specific values (Environmental Quality Standards or EQS) dependent on the receiving water to comply with the requirements for the receiving water quality

Site specific values are applicable dependent on the use:

- drinking water withdrawal
- fishery
- bathing or other water sports
- special ecosystem

This approach considers the overall impact on the receiving water. Long-term as well as short-term impacts have to be considered. Often a combination of both standards is required.
Under standard conditions emission criteria for CSO and WWTP are sufficient. For sensible water bodies (waters in recreation areas, water withdrawal areas and lakes) additionally water quality based criteria must be kept. Emission standards are also used as surrogates for EQS (Environmental quality standards). For example, a maximum spill

frequency may be set which will ensure that EQS will be met safely or, an emission standard may be set to reduce the discharge of nutrients (FWR, 1998). A particular environmental regulator's policy may also have a requirement for a minimum level of wastewater system capacity or performance over and above that required to meet a specific EQS or emission standard. Expressions for minimum requirement criteria may, for example, take the form of: a minimum retained flow within the system (as a multiple of DWF, or some derivative) or a minimum storage capacity, related to catchment area or DWF (FWR, 1998).

Details about CSO and WWTP standards that are used to compare the compliance of the system to standards and to compare scenarios can be found in chapters 2.4 and 2.5.

For watercourses the methodology of CARE-S includes an assessment method developed in Germany which is used to determine the sensitivity of receiving waters to urban drainage discharges. The decision, when enhanced standards should be used and site specific values should be considered can be made using the following criteria described in Borchardt et al. (1993):

1. The self purification potential is too low for the pollutant potential of the catchment. As criteria, the assessment of CSO flow of the catchment to the low flow rate in the receiving water under consideration of the transport and transformation of matter is convenient.

2. Concentration and/or load of relevant parameters are not convenient for the water bodies use that is aimed at (e.g. bathing waters).

3. The maximum CSO flow leads to mobilisation of the riverbed. The criterion is the ratio of maximum flow from the urban catchment for a rain event with a return period of 1 year and the maximum flow in the receiving water with a return period of 1 year.

4. The section of the receiving water does not have enough recovery habitats for organisms. This is possible where high bottom velocities occur in the river and no interstitial exists or no zones with low velocities which guarantee the stay of water organisms.

5. Additionally to the lack of recovery habitats the possibility for drifted organisms to migrate upstream is not given. This can occur due to barriers or river sections with not typical conditions for the organisms (e.g. temperature).

2.3.4 Impacts on receiving waters due to urban drainage

Looking at rivers, Figure 3 shows the mechanisms of the ecosystem that are influenced by the impact caused by WWTP effluent and CSO discharges. Other water bodies are affected similarly.

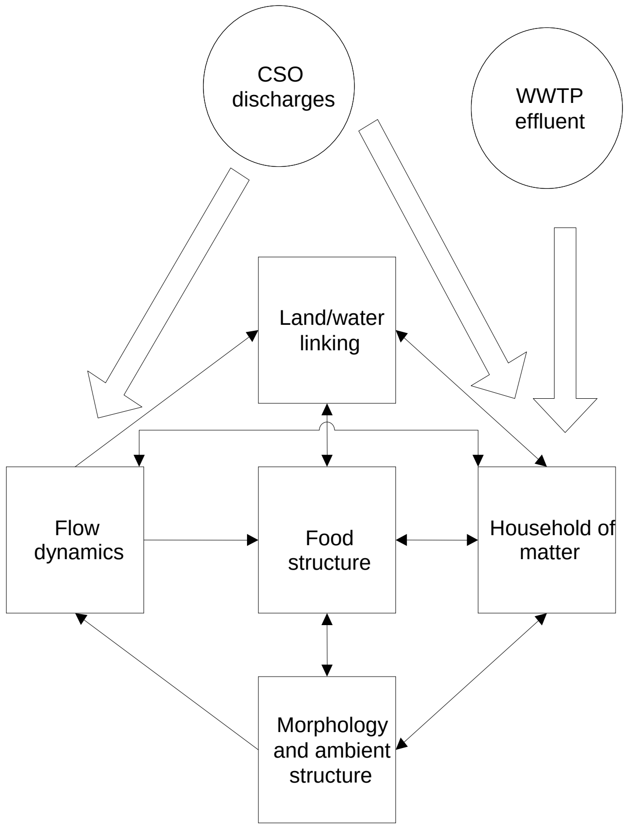

Figure 3: Flowchart of the most important compartments of a receiving water and the influence of sewage dicharge, after Decker (1998)

Borchardt (2000) summarizes the impacts of urban drainage on receiving waters and describes the effects in the water body, the river/sea ground and the biocoenosis.

Table 5: Impact of urban drainage on aquatic ecosystems after Borchardt (2000)

Impact	**Effect on the water body**
physical impacts	
Changes in Hydraulics	flow conditions, hydraulic stress
Temperature	complex
Solids	change of sediments – accumulation of mud
Chemical Impacts	
Nutrients (Phosphorus, Ammonia, Nitrate)	risk of eutrophication (photosynthesis/respiration > 1)
Organic matter (proteins, carbohydrates, fat)	Lack of oxygen (photosynthesis/respiration < 1)

Impact	Effect on the water body
Toxic substances	
NH_3-N, NO_2-N	acute or chronic toxicity, change of biocoenosis
slowly degradable organic matter (humic substances, tensides)	disturbance of interactions in the ecosystem; change of biocoenosis
organic matter (chloric solvences, mainly chloroform)	chronically toxic, change of biocoenosis
inorganic matter (e.g. Cu, Pb, Zn, Cd, Hg)	chronically toxic, change of biocoenosis
drugs (e.g. antibiotics, cytostatics)	acute and chronic toxic, endocrine effects, change of biocenosis
hormones, endocrine disruptors	endocrine effects, change of biocoenosis
bacteria	hygiene, health risk
solids	aesthetic problems, carrier for problematic matter

The changed hydraulic regime in urban drainage areas leads to a reduced natural inflow. Runoff reaches the receiving water concentrated via several point sources and within a shorter period of time. Looking at the load discharged by CSOs, in mountain-rivers the danger of an acute impact due to a lack of oxygen and peak loads of toxic substances is not very high. In flat-land rivers the possible accumulation of toxins and nutrients leads to a medium long-term risk. Shallow waters in warm areas are especially sensitive to toxics like ammonia. Due to the sunlight algae grow is increased which causes a depletion of CO_2 and thus an increase of the pH value. Since the balance between NH_4 and NH_3 depends on temperature and the pH value, the shift from NH_4 to NH_3 can cause toxic conditions for fish.
In urban areas especially the biochemical impact is a determining factor for receiving water quality.
The amount of sewage discharged by CSO has been quantified in an order of about 1/3 of the combined sewage. Table 6 shows the percentage of the urban drainage discharges in terms of pollutants load. In this context the discharges from CSOs and WWTP outlet have to be assessed differently due to their different composition

Table 6: Annual loads from urban drainage

COD		
	CSO	25 %
	WWTP (dry weather)	55 %
	WWTP (wet weather)	20 %
Total Nitrogen		
	CSO	2 %
	WWTP (dry weather)	78 %
	WWTP (wet weather)	20 %
Flow		
	CSO	10 %
	WWTP (dry weather)	60 %
	WWTP (wet weather)	30 %

The main part of the load is discharged from the WWTP effluent. For long term impacts and accumulative pollution this is still the main contributor. Long term problems caused by WWTP effluent but also by CSOs are

- heavy metals
- nutrients (N,P)
- organic compounds
- change of sediments (colmation)
- long term change of organisms community
- accumulating toxins

The load from CSOs is discharged in a very short time span with concentrations varying from low to high and is the most important factor for acute hydraulic and pollution impacts. Effects of CSOs can be (FWR, 1998):

- aesthetic problems
- deposits in receiving water (sludge from network)
- hygienic problems
- hydraulic impact (shear stress)
- eutrophication, organic load
- rapid increase in river concentrations of ammonia, bacteria, COD, and suspended sediments, as well as heavy metals and other toxic substances where industrial effluent discharges are present in sewage.
- depletion of dissolved oxygen as result of
    - degradation of dissolved BOD;
    - degradation of BOD attached to sediments;
    - resuspension of polluted bed sediments exerting an additional oxygen demand;

In mountain-rivers the impact of CSO can lead to hydraulic stress and an increasing oxygen demand. At the same time the physical re-aeration is increasing. The river bed can erode and the shear stress can cause substrates shift and organisms shift. However, in this kind of receiving waters the effects are unlikely to cause major problems.
In flat land rivers the physical aeration increases only little or not at all. Erosion of the riverbed, substrates shift and organisms drift is possiblen here and at the same time a remobilisation of settled oxygen demanding material.
Considering the use of receiving waters the UPM (FWR, 1998) describes three main uses and the disturbance due to acute impacts. Sustainable fishery can by hindered by the lack of oxygen and toxicity problems. The use of bathing waters can be disturbed by high concentrations of micro-organisms. Visual aspects are most important for an amenity use where gross solids from CSOs lead to problems.

Table 7 gives an overview on the time horizon of problems and which parameters can be used to check the magnitude of the impact in a watercourse.

Table 7: effects of sewer dicharge on rivers after Decker (1998)

time horizon	type of impact and parameter	reference value
acute (hours)	velocity close to riverbed shear stress on riverbed toxics (especially NH_3) sedimentation of solids pathogens in sediment	volume of water for single events
delayed (hours to days)	oxygen household solids household acute toxicity pathogens	concentration and load for single events
long-term (month to years)	organic persistent matter metals, inorganic and organic sediments nutrients causing eutrophication	load of substances for long-term considerations

2.3.5 Effect of sewer network deficiencies

The overall impact of urban drainage on receiving waters is a problem but cannot be solved alone with rehabilitation of the sewer network. Thus the specific influence of a declined sewer network has to be extracted from the variety of reasons for receiving water pollution.

Some impacts are described here using example investigations:
The influence of infiltration on the total load discharged into the receiving water was investigated by Decker (1998). He estimated in an example that an increase of the extraneous water from 0 to 0.6 l/(s*ha) increases the COD load in the receiving water due to CSOs by 80 %. On the other hand the dilution of sewage due to infiltration of groundwater in the network decreases the oxygen demand in the free water body. From diverse publications Decker reports that in Germany infiltration in the networks leads to an additional carbon-load of 2 to 3 Million person equivalents (p.e.) in the receiving water. One litre of extraneous water going through the WWTP causes the same Oxygen demand like the same amount untreated sewage (without nutrients) which is directly discharged. One litre per second of extraneous water causes an additional oxygen demand of 240 p.e. per day and is equivalent to 4.7 ha of totally sealed surface which is disconnected from the sewer. Details and references can be found in Decker (1998) and Weiß et al. (2002).

In this context the influence of infiltration on the first flush effect which has been reported and is discussed as a reason for high pollutant concentrations in the beginning of an overflow event should be mentioned. This effect is very difficult to determine for an unknown system. Many researchers believe that if there are no local data available, any strategy or remedial action based on the assumption of first flush could be misleading. Probably each sewer system reacts individually to each storm event (Sztruhar et al., 2002). A Spanish study shows that infiltration can lead to a less extreme first flush effect. The flow of infiltration water may lead to a continuous erosion of sewer bed load so that the potential for a first flush effect is reduced (Diaz-Fierros T. et al., 2002).

Chapter 2.4 and 2.5 describe more detailed the effects of the degraded network on CSOs and WWTPs. Details on the methodology used to evaluate the sensitivity of water courses are described in chapter 3.6.

2.4 CSO

Combined sewer overflows are together with diffuse pollution and WWTP effluents the main contributors to receiving water pollution. On a yearly basis, the emission of pollutants from combined sewer system into the receiving water represent only a fraction of the total pollutant load compared with the emissions from the WWTP. However, they must be considered due to their impact on receiving waters concerning peak concentrations and the accumulation of toxic substances. This impact will relatively increase with the improvements of the efficiency of WWTP (Bauwens et al., 1996). The aim of a good drainage design is to balance the effects of continuous and intermittent discharges against the assimilation capacity of the receiving water, in order to optimise the quality of the receiving water at minimal cost (Bauwens et al., 1996).
Within and prior to the use of CARE-S it has to be investigated whether the sewer has an important influence on the receiving water quality (EN 752-4) and in what way the CSO is contributing to receiving water pollution. Without the ability to identify and quantify the contributions CSOs make to the quality of receiving waters, identifying and upgrading unsatisfactory CSO will prove to be unrealistic (Blanksby, 2002).

2.4.1 CSO standards and requirements

The Urban wastewater Treatment Directive (UWWTD) is the main legislation for the control of urban pollution. It suggests that the regulations for CSOs which are left to the member states are based on dilution rates, treatment capacity in terms of dry weather flow or spill frequency. Additionally the requirements of European Directives like the bathing waters directive or fishery directive must be met. The EU Water Framework directive will increase the focus on the control of CSO.
The control of CSO is generally based on design criteria and/or operation conditions, which do not take into account the impact of the CSO on the receiving water. In Europe different approaches in design and licensing of CSO are used. Some countries do not license CSOs and do not check their design procedures. However, in most countries permits are related to spill frequency. Events with a low frequency and high magnitude with a significant impact on the receiving water are not considered in this approach.
Current practice designs of CSO of the member states vary throughout Europe and are listed in FWR (1998), Milne et al., (2000) and Zabel et al. (2001). Annex IV contains an overview on CSO design and licensing in the EU member countries. In most countries methods for assessing CSO are not that far developed (Zabel et al., 2001).

Only a low proportion of CSOs is monitored (Zabel, Milne et al., 2001). To assess the impact of CSOs in detail, the use of statistical analysis of Quantity-Duration-Frequency-relationships (QDF) or Concentration-Duration-Frequency-relationships (CDF) is recommended (Vaes et al., 2000).

According to the EN 752-4 following aspects of all discharges into the receiving water (including the WWTP) have to comply with the requirements of the responsible regulator:

- quality
- volume
- frequency

The design of the discharge structures should be in accordance with the self purification potential of the receiving water. In this context physical, chemical, microbiological and aesthetic aspects have to be considered.

The application of the standards depends on water usage. For wet weather discharges the UPM has categorized the standards in three classes. Standards for protecting river aquatic life, where intermittent standards or high percentile standards can be used, standards for protecting bathing waters where risk based EQS for bacteriological contaminants associated with sewage pollution or spill frequency emission standards are used and standards for protecting amenity use. Since these standards require the definition of return periods Monte Carlo simulations or long-term simulations need to be carried out.

2.4.2 Failure definition for CSOs

The requirements for CSOs are set by the responsible authority. The location of the CSO, pollutant load, duration and frequency of the discharges have to be considered. Whether a CSO performance is a failure or not can be decided following these criteria (FWR, 1998; Blanksby, 2002):

1) CSO causes significant visual or aesthetic impact due to solids (i.e. sewage-derived litter such as sanitary hygiene products, contraceptives and alike) or sewage fungus (cotton wool like growths of attached micro-organisms associated with heavy organic enrichment) and has a history of justified public complaint.

2) CSO causes or makes a significant contribution to a deterioration in river chemical or biological quality/class.

3) CSO causes or makes a significant contribution to a failure to comply with Bathing Water Quality Standards for identified bathing waters.

4) CSO operates in dry weather conditions.

5) CSO operates in breach of consent conditions provided that they are still appropriate.

6) CSO causes a breach of water quality standards and other EC Directives.

2.4.3 Defects affecting the CSO performance

A non-satisfactory working CSO might be related to various reasons. In an Slovakian publication (Sztruhar et al., 2002) several reasons for deficiencies on CSO performance are observed which are:

- oversized CSO (this could lead to a overloaded CSO downstream)
- overloaded CSO even during dry weather
- upstream pipes with steep slope leading to supercritical flows upstream the weir
- extreme sedimentation due to poor design (mainly on large CSO situated at large sewers)
- several inflow pipes into CSO causing high turbulences in the flow
- blockages of the outflow pipe
- tide affected sewer networks
- flooding of CSO during high water level of the receiving water.

Since CARE-S aims on pipe rehabilitation and not on the rehabilitation of CSO structures in the network the following chapter (2.4.4) aims at describing the influence on the network performance on the CSO. CSO with an insufficient performance due to other reasons as described in this chapter are outside the scope of CARE-S.

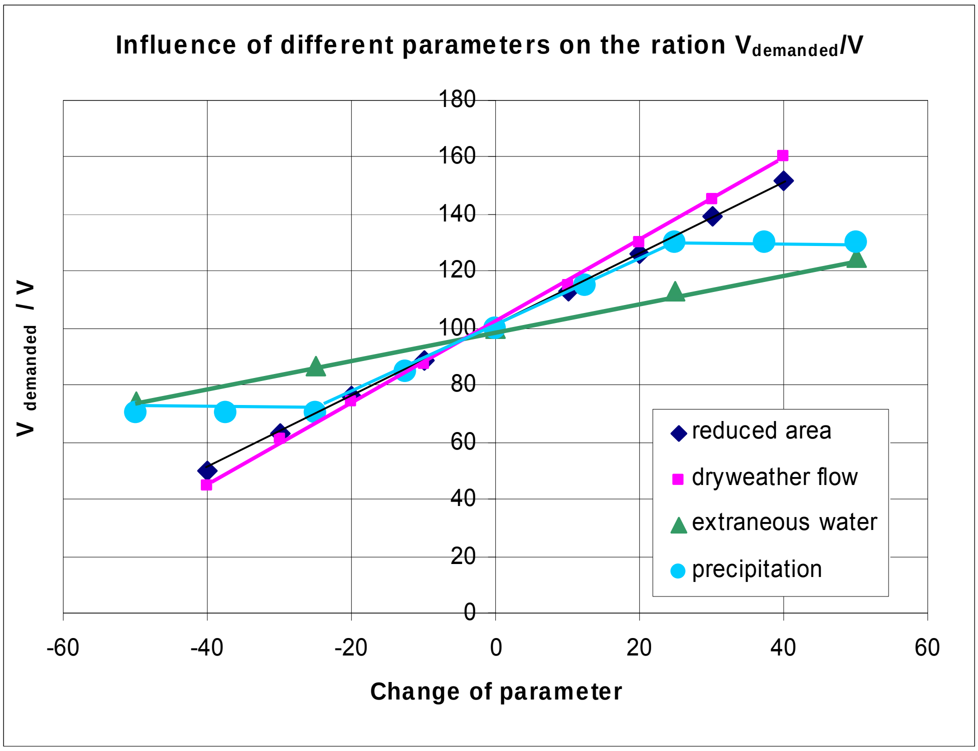

Figure 4: Influence of design parameters on the retention tank volume

Milojevic (1995) investigated the influence of the change of design parameters on the CSOs and the retention tank volume, respectively. Influencing parameters are:

- extraneous water
- population equivalents
- reduced area
- degree of pollution of wastewater
- combined water flow

Looking at the chosen parameters in Figure 4 (after (Milojevic, 1995) it can be seen that a change of the infiltrating volume does affect the calculated tank volume less than other parameters. It shows that sewer rehabilitation can, case dependent, only have a limited effect on the CSOs performance.

Whether the CSO performance failure can be traced back to a network defect or performance deficiency can be analysed by performing sensitivity checks on the virtual sewer network. Work package 3.4 will provide a procedure for this issue. By rehabilitating the sewer network the CSO performance should by changed. If no change can be registered, the problem is probably outside of the focus of CARE-S.

2.4.4 Influence on CSOs caused by the deteriorating network:

Blockages

Blockages can lead to overloading in CSOs upstream of the blockage or the reduced pipe diameter. Blockages or reduced hydraulic capacity can have diverse reasons. For example root intrusion or sedimentation (EPA, 1999). The effect can be modelled within the WP 3.2 modification of the hydraulic model.

Root Intrusion

Roots growing in sewers downstream a CSO or into orifices or other structures can lead to spills. The effect can also be modelled within the WP 3.2 modification of the hydraulic model.

Sedimentation

Sedimentation is induced by a flat gradient of the sewer and low velocities. It can also take place around obstacles in the system. Since no sedimentation is included in the hydraulic modelling this effect can not be assessed directly. Where sedimentation is causing blockages, the blockage model includes the probability of this effect.

Infiltration

Retention tanks in SEPERATE SYSTEMS

In separate systems the effect on retention tanks are low. In a case study of Decker (1998) infiltration increases the total volume of Overflows by 4 %, which has little effect on the receiving water. (The statement is based on design criteria comparison and does not include acute effects). Due to higher flows the emptying time of the retention tanks is longer.

Retention tanks in COMBINED SYSTEMS

The effect of extraneous water on retention tanks that are designed for 2 times DWF is high, while there is little effect for tanks that are designed for a critical rain event (Fenz, 2003). In an example calculated by Decker (1998) an increase of the extraneous water flow from 0.1 l/(s*ha) to 0.6 l/(s*ha) increases the necessary tank volume by 82 % under consideration of an increased inflow to the WWTP depending on the increased extraneous water flow. If the WWTP is designed for 0.1 l/(s*ha) an increase of the retention tank volume even by 350 % is necessary.

Partly filled retention tanks can cause a higher overflow volume and frequency occurring at new rain events. The worst case is to reach the maximum inflow to the WWTP under dry-weather conditions. Thus if there are high groundwater tables an increased frequency of CSO overflow operation even during dry weather conditions is possible (Decker, 1998; Michalska and Pecher, 2000; Ellis, 2001).

Infiltration increases the emptying time of retention tanks and increases the probability of a storm event meeting partially filled tanks. Thus the annually spilled pollutant load can be strongly increased by large extraneous water flow. In Germany tanks were observed that remained filled for several weeks after a wet weather period (Weiß et al., 2002).

CSO structures WITHOUT retention tanks

Extraneous water inflow leads to a diluted load being discharged from CSO structures. Design criteria show a low percentage of increased load discharged to the receiving water (4 %) when the specific infiltration rate is increased from 0.1 l/(s*ha) to 0.6 l/(s*ha). Reason for the low effect is the design criteria critical rain.)

The shear stress of the sewage flow is increase due to the higher flow in the system. This can lead to the positive effect of less solids being deposited during dry weather and so less solids being mobilised and discharged during rain events. Contradictive, according to Ellis (2001) infiltrating water can lead to an input of solids into the sewer and to a formation of a “soil filter” around the defect. An abrasion of sewer walls due to soil particles can also increase sediments and promote blockages. This can make flushing necessary more often. The mixing of organic compounds and minerals substances lead to a higher cohesive sediment that requires often high pressure cleaning which corrodes sewers and thus raises the risk of sediment wash-out at CSO events. Here it can not be finally stated which effect is more important in sewer systems with infiltration. It is assumed that the flush effect of the extraneous water is predominant and thus leads to less sedimentation in the network.

Costs

In retention tanks increased pumping costs occur (Ellis, 2001). Further costs occur due to possible higher cleaning costs. For Germany cost calculation on basis of LAWA guideline are possible for annual costs (LAWA-Arbeitskreis, 1994). The most important costs in this context are operational costs.

2.4.5 Measuring the performance of CSO (Example - The UK approach)

Aesthetic

A river reach is visually inspected and classified based on sewage based matter, litter, faeces, etc. This classification is highly sensitive to the presence of sewage.

Another method combines the visual data with data on sewers performance (history of complaints, dry weather discharge, performance measured against long term river quality objectives. The results are scored with A – E. The CSOs are classified in the three categories:

- satisfactory
- unsatisfactory
- very unsatisfactory

A similar method exists for beaches where different types of litter and the general impact of CSOs are assessed. Details can be found in FWR (1998) and Zabel et al. (2001)).

River class

High percentile standards (90/95 percentile) for a set of chemical determinants are used to assess the chemical impact. BOD, COD, total ammonia and unionizes ammonia are key indicators. The method is based on data obtained during dry weather flow.
99 percentile criteria are used for intermittent discharges in conjunction with long series of rainfall using verified sewer quality and river quality models.

A biological method assesses the tolerance of different species to pollution. This gives an impression of overall river quality in wet and dry weather.

UPM fundamental intermittent standards are expressed in terms of concentration-duration thresholds with an allowable return period or frequency for dissolved oxygen and ammonia. The duration threshold curves are based on knowledge from eco-toxicology and have a scientific background. They are criteria which directly assess the impact in the receiving water (compared to indirect criteria like CSO load etc.). The

standard is appropriate to protect all life-stages of fish in the receiving water. Since fish are the most sensitive species, the standard is suitable to protect other aquatic organisms as well (Bauwens et al., 1996).
The design method which is based on these standards is using verified sewer quality and river quality models (Zabel et al., 2001). The UK has derived intermittent standards for the receiving water which are applied to the design of CSO. The asessment method of the impact depends on the significance of the CSO (low - frmula A, medium – simple model, high – complex model) (Zabel et al., 2001).

Bathing water quality

It has been assessed that limiting the number of CSOs in bathing waters to three per season the required standard of the EC Bathing waters directive will be met, providing that the point of discharge is below the mean low water level for spring tides (Blanksby, 2002).

Operation in dry weather

The assessment is based on complaints and operational records.

Breach of consent

Typical performance measures to check the compliance with consent conditions are:

- the flow to the treatment at the first spill (Depth/discharge relationship for control)
- storage volume
- spill frequency
- spill duration
- peak spill rate
- solids retention

Breach of water quality standards or other directives

These standards are aimed at identifying the quality of the receiving water and are not specifically aimed at the performance of individual CSOs.

EU Shellfish directive (coastal and estuarine waters)
EU Dangerous Substances Devices (inland waters)

The range of measures is unlikely to change dramatically in the future (Blanksby, 2002). It remains difficult to accurately quantify performance. No method describes the overall performance of single CSOs. Currently ther are no methods available to directly assess the impacts of individual CSOs on river quality. It is perhaps more realistic to regard performance measures as performance indicators and to adopt suitably risk averse design strategies that will allow CSOs to be further improved where necessary.

To check the compliance to standards modelling is often essential. As an example, for the assessment of spill frequency long term data as input for a simulation is required. The use of simplified rain data can lead to an underestimation of 50 % for the frequency of the of the overflow emissions. The high variability of the overflow events makes the statistical evaluation absolutely necessary (Vaes, Berlamont et al., 2000).

2.5 WWTP

The urban wastewater treatment directive sets a framework for the national legislation concerning WWTP effluents. In most cases minimum requirements have been formulated where the effluent flow and the effluent concentrations are limited. These cirteria are based on technology limits or environmental quality standards in the receiving water below the discharge (Milne et al., 2000). The regulation of dry weather discharges is well developed compared to rain weather discharges. Effluent standards can be locally adapted to specific receiving water needs.

The performance of the treatment plant is influenced by the design of the plant and thus by the assumptions and measurements that where made during the planning process. Various publications focussed on the influence of the sewer system performance and environmental condition on wastewater treatment plant performance. Examples are the performance of the plant under rain conditions or the pre-decay of organic matter in the sewer system. In the following chapters the influence of failures of the sewer system are discussed regarding their possible effects on the performance of the wastewater treatment plant.
The description of infiltration impacts are the main part of this chapter. Other network deficiencies are of minor importance for the WWTP.

2.5.1 Failures and effects

Especially in separated sewer systems with high infiltration rate problems with the WWTP performance can occur. Here the discharge of the sewage via overflow structures is not allowed if the capacity of the WWTP is exceeded as it is common for combined sewer systems.

Wastewater composition

The inflow of groundwater or surface water leads to a change of the wastewater composition. Dependent on the geological and soil conditions, on the land use, on the infiltration volume following the seasons, changes are possible.

- increased content of NO_3^- possible due to agriculture
- increased oxygen concentration
- dilution
- decrease in temperature
- change of acid capacity

With the extraneous water the danger of high concentrations of inhibitory substances decreases (Kroiss and Prendl, 1996).

Wastewater treatment plant performance

The effects of infiltration are the best described effects concerning the treatment plant performance. Descriptions can be found in (Kroiss and Prendl, 1996; Decker, 1998; Ellis, 2001). They focus is on plants with nitrogen removal, some statements have been made for other systems like trickling filters.

a) Hydraulics

The increase of wastewater volume leads to a higher hydraulic load and possible degradation for all parts of the system that are designed using hydraulic criteria. The additional amount of water requires a higher pumping effort. Kroiss and Prendl (1996) describe that there is no adverse effect on grit chambers. During the night hours the increased inflow might prevent the deposit of organic matter in the grit chamber.
This is beneficial in case of screening. The residence time of pollutants in the plant is shortened which has a negative effect on all settling tanks like the grit chamber, primary and secondary clarifier. Overloading of the grit chamber can lead to sand discharge into the subsequent measures and to corrosion, overloading of the primary clarifier can effect the activated sludge system (Michalska and Pecher, 2000). In the secondary clarifier adverse effects similar to those during rain events can occur which might lead to a rising sludge level due to higher loads and in the worst case to sludge surcharge into the receiving water. While problems can occur due to the increased amount of wastewater, the decreased amplitude of the flow pattern can prevent shock loadings and first flush effects on the plant (Kroiss and Prendl, 1996; Diaz-Fierros et al., 2002). However, there are converse opinions on this point (Krebs, 2004). The effects depend very much on the amount of infiltrating water and might be low depending on the design of the wastewater treatment plant (Kroiss and Prendl, 1996). The decrease of WWTP performance due to extraneous water refers to loads not concentrations! The WWTP effluent concentrations might even decrease due to extraneous water inflow (Michalska and Pecher, 2000).

b) Dilution/ Temperature

In many European countries where infiltration takes place the spring is the season with the lowest sewage temperatures (snow melting) and highest rate of extraneous water flow.

The growth rate of microorganisms decreases (depending on substrate), speed of enzymatical reaction decreases (depending on temperature), therefore the degradation rate decreases. Figure 5 shows the influence of temperature on the enzymatical reaction. Interactions between dilution and temperature may increase the adverse effect. In trickling filters these effects were observed with a low value. Diffusion problems are more important here than limiting substrate concentrations.

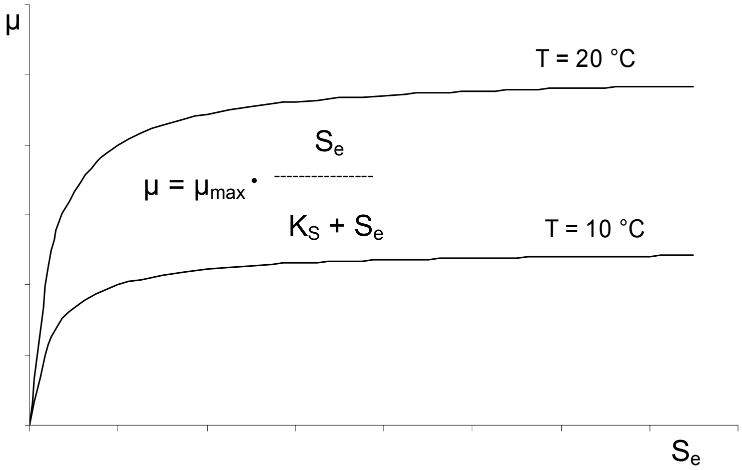

Figure 5: Influence of temperature on Monod relation (after Kroiss and Prendl, 1996)

c) Alkalinity

The infiltrated water with low carbonate concentration in most cases reduces the alkalinity of the sewage. At a K_s value < 1.5 mmol/l nitrification may be inhibited.

d) Oxygen

The degradation of easily biodegradable matter in sewers and oxygen in sewer inflow (due to infiltration) is a disadvantage for biological phosphorous elimination and denitrification (Kroiss and Prendl, 1996). This effect is important for networks with low slopes since in steep networks oxygen is mixed into the wastewater predominantly due to turbulences while infiltrating water is only of minor significance.

e) Nitrate

NO_3^- from agricultural sources influences the denitrification process, causes denitrification in the sewers and additional degradation of easily biodegradable organic matter in the sewer. This decreases the denitrification potential for the wastewater in the WWTP. Biological phosphorous elimination can also be affected. Anaerobic processes in the WWTP can be disturbed. Denitrification occurs which causes a lack of organic acids needed for the biological phosphorous elimination (Kroiss and Prendl, 1996).

The process water load from an affected sludge treatment can lead to a further load for the already affected nitrification in the activated sludge process

The effluent nitrate concentration decreases due to an increase of extraneous water flow underproportionally due to a decrease of denitrification.

f) Ammonia

The nitrogen elimination depends on the COD/N ratio which does not depend on the rate of extraneous water (Kroiss and Prendl, 1996).

Higher concentration of NH_4^+ due to decreasing nitrification and decrease of degradation of organic matter leads to a decrease of nitrification since nitrifiers are most sensitive to lack of substrate and low temperature. However, nitrification process is not that hard affected that it would break down.

g) Phosphorous

The efficiency of phosphorous removal decreases with lower organic compounds concentrations in the wastewater. The increase of extraneous water from 0 to 200 % in an example of Kroiss and Prendl (1996) leads to an increase of the effluent phosphorous load of 100 %. If the phosphorous is removed using chalk, the chalk amount needed increases with the extraneous water inflow.

h) Organic matter

Infiltration has a low influence on the removal efficiency for organic matter. An increase in the effluent will be mainly due to sludge discharge from overloaded secondary clarifiers.

Costs

Increased costs due to extraneous water are mainly operational costs:

- pumping costs (lifetime of pumps are decreased)
- aeration for activated sludge tanks
- chemicals for phosphorous removal

2.6 Integrated simulation example

To assess the performance of the WWTP and CSO under consideration of network failures, simulations have been carried out for different rates of extraneous water in the network. Extraneous water as consequence of network performance deficiencies was chosen as an example due to its relevance in many networks and particularly due to its impact on the WWTP. The infiltration rate was chosen according to literature values. The results of the simulations should be understood as a demonstration example of the consequences of infiltration into the network.
The simulations were computed in the SIMBA® simulation environment. This program enables the user to consider all urban drainage components as an entity and thus to reflect the interactions in the system.

System description:

A hypothetical system has been used for the simulation. The catchment is described in Table 8. The processes in the catchment were modelled using MOSI, a module for runoff modelling implemented in the SIMBA® simulation environment. The model considers the runoff losses and transport processes on the catchment surface.

Table 8: catchment description

Catchment	400 ha
surface sealing	99 %
inhabitants	60000
NH4 in sewage	55 g/m^3 = 655.8 kg/d
COD in sewage	600 g/m^3 = 7153,9 kg/d
industry flow	0 m^3/d
surface runoff losses	approx. 5 mm
mean flow	0.0023 l/(s*EW) = 11923.2 m^3/d

The wastewater treatment plant model was taken from the benchmark simulation study of the COST group (Copp (ed.), 2002). For building the model and make it possible to verify the results with acknowledged values the model ASM1 (Henze et al., 2000) for the activated sludge tanks and the Takács model (Takács et al., 1991) for the secondary clarifier have been implemented. The plant is operated as a pre-denitrification plant. Two tanks are not aerated and three tanks are aerated (Figure 6).

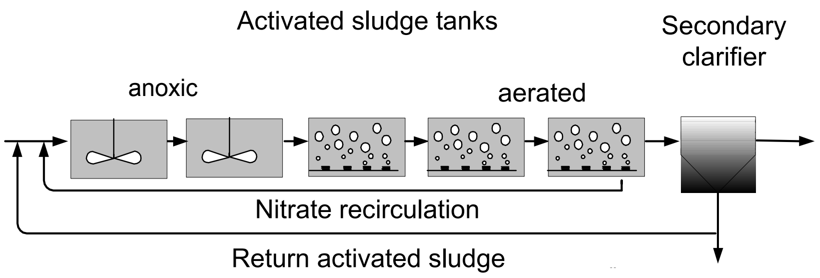

Figure 6: scheme of the WWTP

The tanks that are not aerated have a volume of 1000 m^3 each. The aerated tanks have a volume of 1333 m^3 each. The secondary clarifier is 4 m deep with a surface of 1500 m^2 (volume: 6000 m^3). The maximum design inflow is 2*dry weather flow + extraneous water flow = 54000 m^3/h.

The sewer system has a length of 19.5 km. Each of 65 assets is 300 m long. The slope is homogeneous in the system with 0.001 m/m.

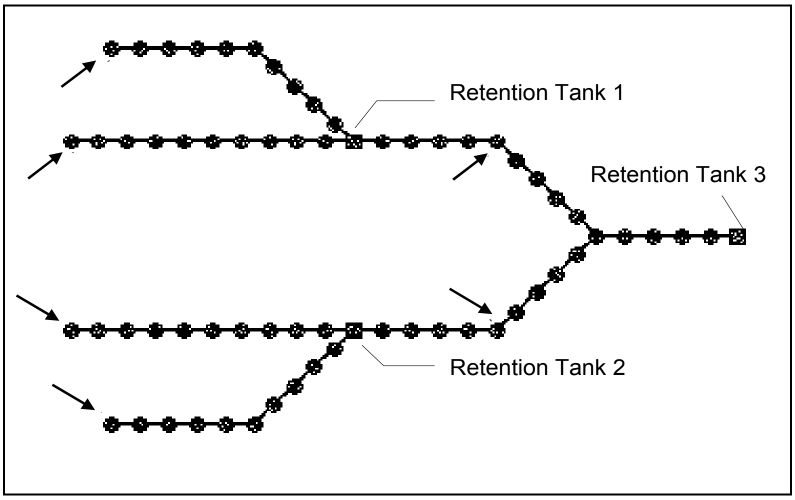

Figure 7: sewer system

Figure 7 shows the structure of the sewer system. Arrows mark inputs into the system. The system consists of pipes with diameters from 1000 mm to 2500 mm. Retention Tank 1 and 2 have a volume of 4000 m^3 each. Tank 3 has a volume of 6000 m^3. The total volume of all tanks is equivalent to a specific tank volume of 35 m^3/ha. For the water level modelling in the pipes the diffusive wave approximation was applied. The sewer model can be used with a model for sedimentation and remobilisation of matter in the sewer system or alternatively with transport of matter in the flow assumed to be transported similar to dissolved components.

In dry-weather simulations the ratio of infiltration has been varied from 0 to 120 % in steps of 20 percent for the assessment of emissions. Further, simulations have been carried out varying the infiltration rate between steps of 0%, 40% and 80% for simulations of the integrated system including the receiving water.

Two boundary conditions of the extraneous water were varied: temperature and NO_3-N concentration in the infiltrated water. With these two parameters four infiltration configurations have been simulated:

T = 10°C, NO3-N = 20 mg/l
T = 10°C, NO3-N = 0 mg/l
T = 15°C, NO3-N = 20 mg/l
T = 15°C, NO3-N = 0 mg/l

In Figure 8 two results of the simulations are shown exemplary for the ammonium load in the effluent and in Figure 9 for the COD load in the effluent of the WWTP.

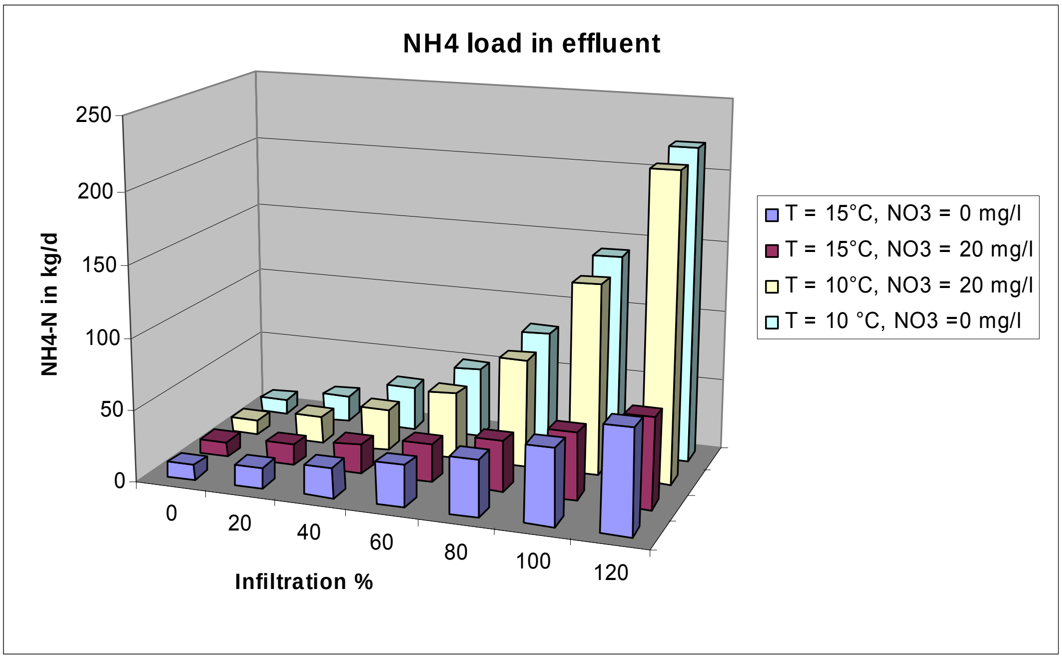

Figure 8: Ammonium load in the WWTP effluent

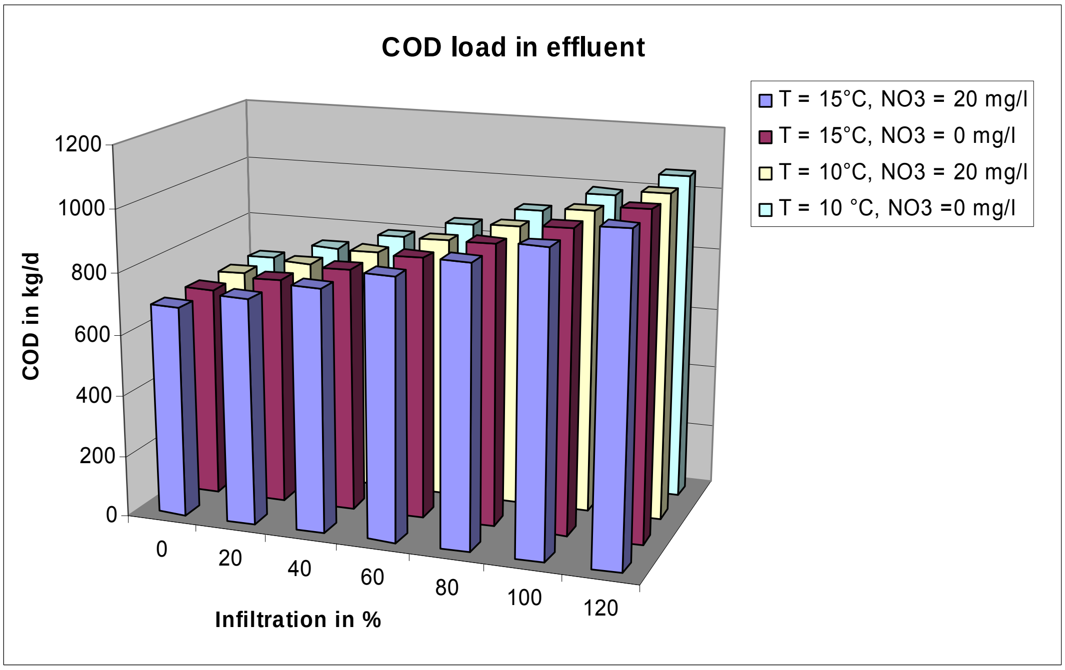

Figure 9: COD load in the WWTP effluent

The effects of increased infiltration on the pollutant load are described in the following tables.

Effect of the increased hydraulic load:

Parameter	Effect
COD	The effluent concentration decreases while the effluent load increases. Reason for this is mainly the washout of biomass from the secondary clarifier and the simultaneous dilution of the effluent.
TKN	The concentration of effluent TKN increases slightly. The TKN load in the effluent increases strongly since the lower concentration of TKN in the reactors is responsible for a slower degradation rate. The main components of the TKN found in the effluent originate from ammonium and biomass.
NO_3-N	The Nitrate concentration in the effluent decreases while the hydraulic load increases. This is due to the degradation in the nitrification process.
TSS	The TSS concentration as well as the TSS load increase in the effluent.

Effect of the decreased temperature:

Parameter	Effect
COD	COD load in the effluent increases slightly due to slowered degradation velocity by microorganisms.
TKN	TKN load in the effluent increases strongly. The main contributor to this increase is ammonium due to the effected temperature dependent nitrification.
NO_3-N	Nitrate load increases for infiltration levels until 60 % and decreases for higher infiltration levels. This is due to the reduction of the denitrification in the first place and to the decrease of nitrification in the second place, respectively.
TSS	TSS load increases slightly
Alkalinity	Alkalinity increases because Ammonium is increasing in the effluent.

Influence of the increased Nitrate load:

Parameter	Effect
COD	The increase of the Nitrate load leads to a very slight decrease of the COD load in the effluent probably due to an increased denitrification.
TKN	The TKN load in the effluent decreases slightly.
NO_3-N	Very high values for Nitrate effluent load.
Alkalinity	The alkalinity in the effluent increases

The effect of infiltration has been shown to be linear concerning water volumes and some pollutant loads e.g. described as COD. Especially for pollution loads like Nitrogen the relation can be also non linear because the biological processes in the WWTP are affected not only hydraulically but also by properties of the extraneous water like temperature or concentrations of compounds.

Considering the whole urban drainage system, the additional input of 40% extraneous water and 80 % extraneous water, respectively, leads to a slight change in the pollutant load and concentrations.

Table 9: Increase of the total load from the system

	40 % Infiltration	80 % Infiltration
COD load	**1.0 %**	**2.0 %**
N load	**2.0 %**	**8.0 %**

The COD dryweather load increases in all compartments of the system. Due to the additional input of low polluted water the COD concentration decreases in the whole system. The effect on loads and concentration in the effluent of the single compartments are shown in Table 10 to Table 13. The load and concentration values in % reflect the comparison with a leak-proof system assumed to have 0 % infiltration.

Table 10: COD dryweather load

	40 % infiltration	80 % infiltration
catchment	0.2 %	0.3 %
sewer	0.3 %	0.5 %
WWTP	16.5 %	35.8 %

Table 11: COD dryweather concentration

	40 % infiltration	80 % infiltration
catchment	- 31.6 %	- 47.0 %
sewer	- 28.9 %	- 44.6 %
WWTP	- 16.8 %	- 24.6 %

Here the degradation of the performance regarding ammonium in the WWTP is very obvious. So the concentration of NH4 in the WWTP effluent increases significantly although the concentration of NH4 in the sewer system with extraneous water is lower than in a leak-proof sewer system.

Table 12: NH4 dryweather load

	40 % infiltration	80 % infiltration
catchment	0.0 %	0.0 %
sewer	0.2 %	0.3 %
WWTP	193.6 %	803.1 %

Table 13: NH4 dryweather concentration

	40 % infiltration	80 % infiltration
catchment	- 31.7 %	- 47.1 %
sewer	- 29.0 %	- 44.7 %
WWTP	107.9 %	393.9 %

2.6.1 Dry weather impact on the receiving water

The increase of the impact due to extraneous water on the receiving water due to the WWTP effluent is low for the load and concentration of BOD. The BOD load increases up to 2.6 % directly after the location of the WWTP effluent. The concentration of BOD decreases with increasing infiltration in the system.

Table 14: BOD load in different river sections

	Section2	Section5	Section6	Section39
40% infiltration	-0.0 %	-0.0 %	1.2 %	1.0 %
80% infiltration	-0.0 %	-0.1 %	2.6 %	2.1 %

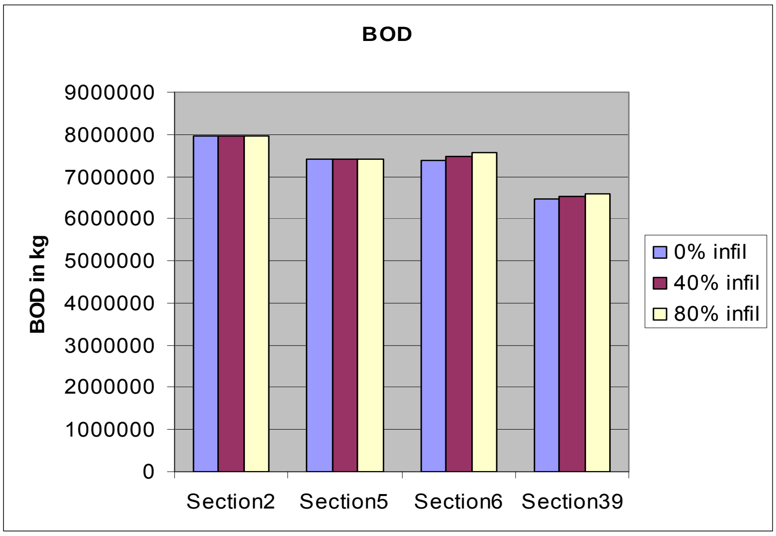

Figure 10: BOD load in different river sections

Table 15: BOD concentration in different river sections

	Section2	Section5	Section6	Section39
40% infiltration	0.0 %	-0.1 %	-2.0 %	-2.0 %
80% infiltration	0.0 %	-0.1 %	-3.6 %	-3.9 %

Contrary to the BOD the load and the concentration of ammonium increase significantly due to the declined performance of the WWTP.

Table 16: NH4 load in different river sections

	Section2	Section5	Section6	Section39
40% infiltration	-0.0 %	-0.0 %	21.4 %	16.9 %
80% infiltration	-0.0 %	-0.1 %	77.7 %	61.5 %

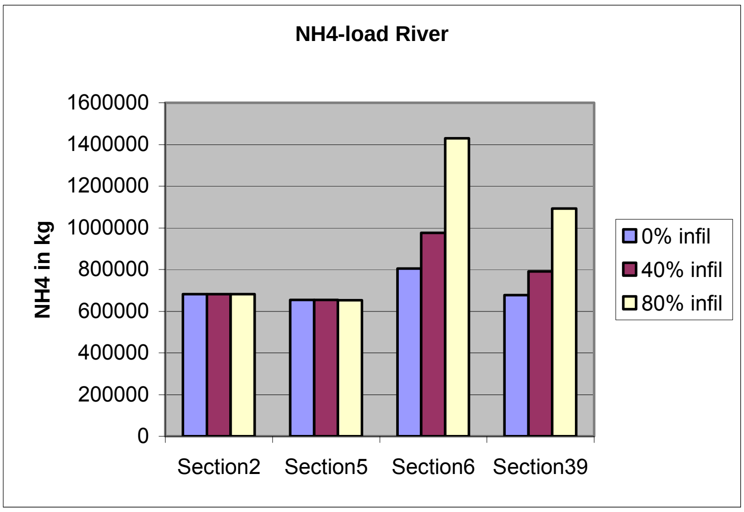

Figure 11: NH4 load in different river sections

Table 17: NH4 concentration in different river sections

	Section2	Section5	Section6	Section39
40% infiltration	0.0 %	0.0 %	17.0 %	13.5 %
80% infiltration	0.0 %	0.0 %	67.0 %	51.7 %

The concentration of dissolved oxygen decreases due to the input of BOD and especially ammonium. The delayed degradation of organic material leads to a low oxygen concentration in river sections downstream the discharge point (section 6).

Table 18: Dissolved oxygen concentration in different river sections

	Section2	Section5	Section6	Section39
40% infiltration	0.0 %	- 0.1 %	- 0.6 %	- 2.3 %
80% infiltration	- 0.1 %	- 0.2 %	- 1.6 %	- 7.5 %

Rain-weather simulations have been carried out for the evaluation of infiltration during storm events which cause combined sewer overflows. As an example a rain from Dresden (October 2001) was chosen to demonstrate the effect of infiltration on the combined sewer overflow performance.

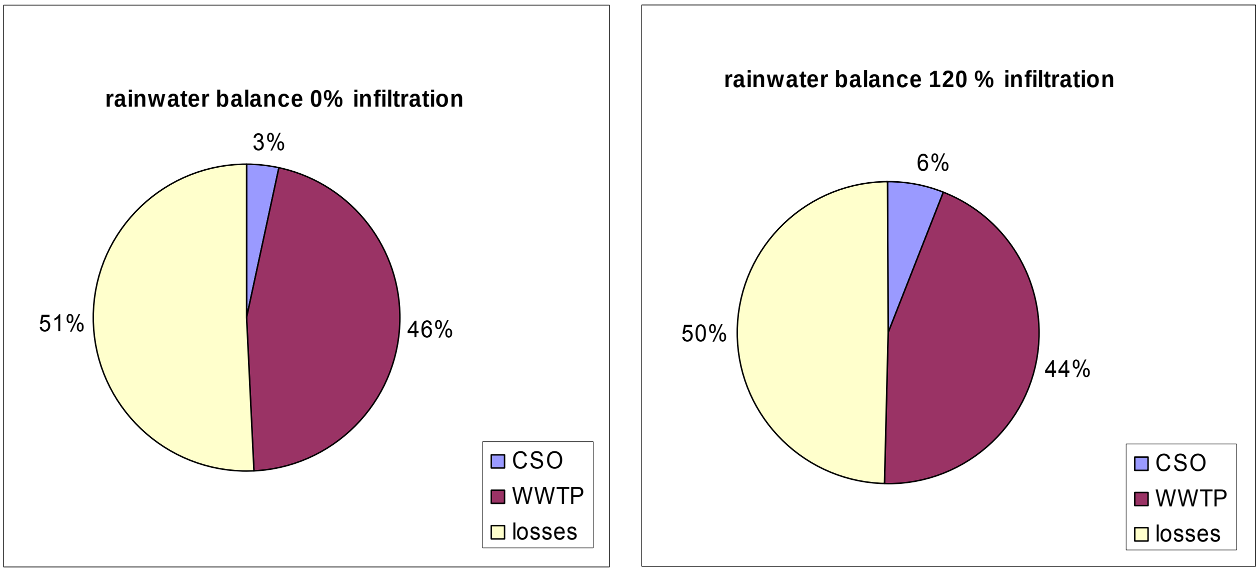

Figure 12: rainwater balance

The rainwater balance (Figure 12) shows that the water discharged via the CSO is increased from 3 % to 6 % of the rainwater by infiltration. It can be also seen that the main part of the rainwater flows via the WWTP into the receiving water and is reduced by runoff losses.
The rain event investigated had a duration of 385 minutes and an height of 9.2 mm. It led to an overflow at two of the three retention tanks of the system. The hydrograph of the event is shown at the upper axes of Figure 13.
The rain event has a return interval of approximately 0.22 a.

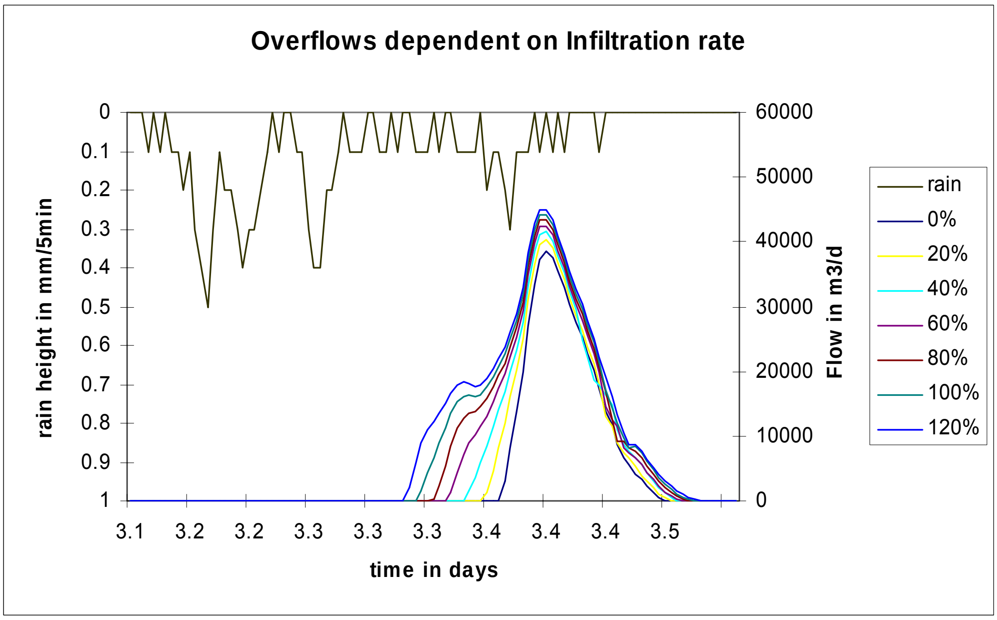

Figure 13: rain event and overflow

For higher infiltration rates the overflow for higher infiltration rates starts earlier and ends later compared to lower infiltration rates. Additionally to the increase of the peak flow and the possible increased impact on the receiving water, the overflow in an early phase of the event can influence the receiving water at a time where it is still in dry weather status (low base flow). Thus, the consideration of the overflow dynamics is of special interest for small rivers.

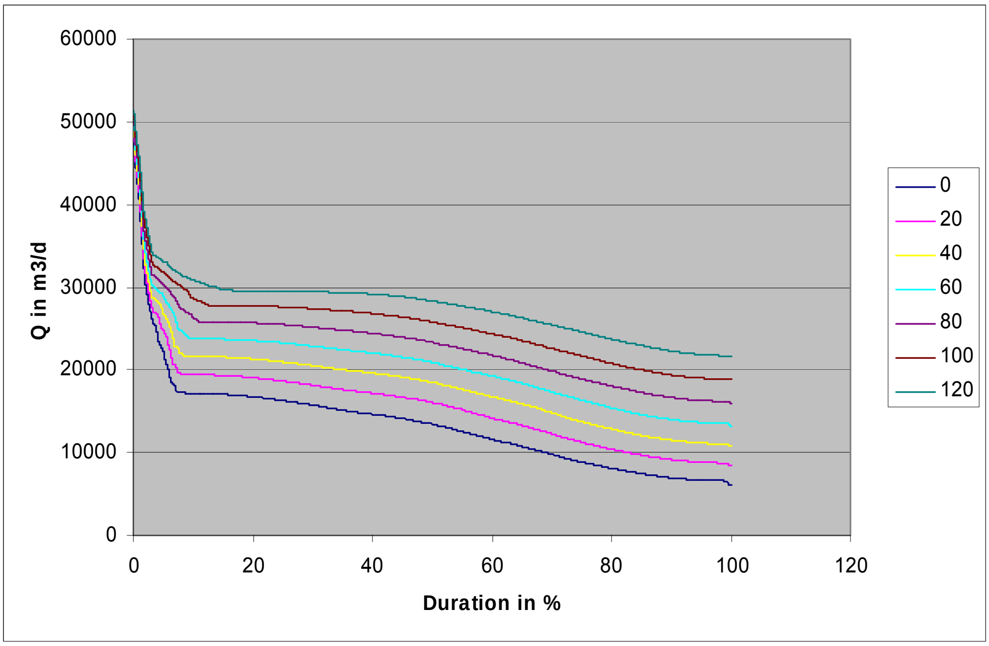

Figure 14: Flow-Duration curve for the WWTP inflow

An effect of infiltration during rain events on the WWTP is the change of the flow rate. In Figure 14 the inflow into the WWTP has been arranged according to its size. Extreme flows during rain events and the emptying time of retention tanks reach approximately the same peak for all simulations referring to the WWTP capacity. The progress of the curve shows that the difference between dry-weather flow and rain-weather flow increases with a lower percentage of infiltration. The extraneous water has an alleviating effect on the dynamics. This can be important for the secondary clarifier because the dynamics of the inflow have a disturbing effect on the flow in the secondary clarifier, the sludge inventory between activated sludge tank and secondary clarifier and on the potential of sludge wash-out into the receiving water.

Further simulations have been carried out assessing 265 days of the year 2001 in Dresden for one rain station.

The sum of total load in the receiving water shows that rain events contribute only slightly to the total load assessed for longer periods. The values in Table 19 are similar to the values for the dry weather assessment in Table 9.

Table 19: Increase of the total load from the system

	40 % Infiltration	80 % Infiltration
COD load	**0.8 %**	**1.8 %**
N load	**2.0 %**	**8.0 %**

The acute impact of combined sewer overflows and declined performance of the WWTP can be assessed looking at indicator substances concentrations and their duration and evaluating the performance of the combined sewer overflows.

In this simulation the overflow volume corresponds directly with the load discharged since no explicit pollution transport model has been included.

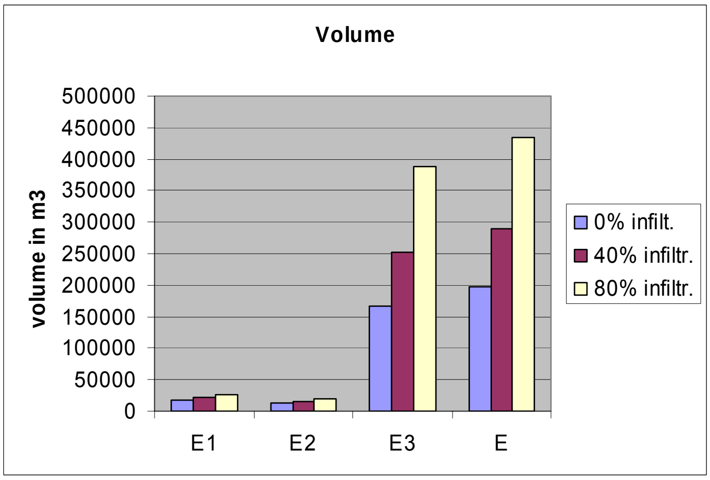

Figure 15: Discharged volume of 3 CSO structures and total volume

Further criteria to assess the performance of overflows are Number of overflows and duration of overflows. These criteria do not always show similarity in expressing the performance on the overflow and are affected differently by the increased input of extraneous water.

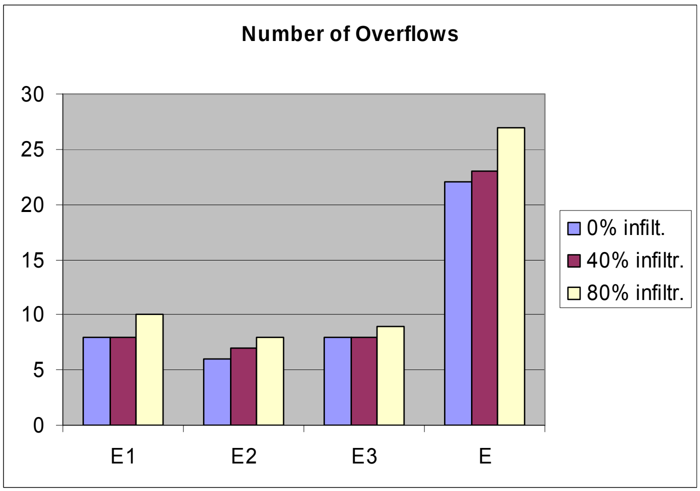

Figure 16: Number of overflows of 3 CSO structures and sum of overflows

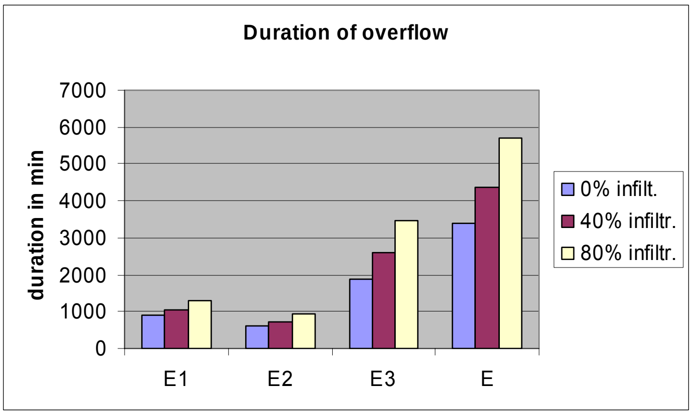

Figure 17: Duration of overflows of 3 CSO structures and total duration

The acute impact of combined sewer overflows can be expressed by analysing the minimum oxygen concentration and the maximum ammonium concentration and the duration of the exceedance of the threshold value. In this analysis thresholds have been set to minimum oxygen concentration = 5 mg/l and maximal ammonium = 4 mg/l.

The maximum concentration of ammonium is very high. This is acceptable since the hypothetical model without adaptation of parameters should provide a relative comparison. The influence of the infiltration on the maximum NH4 is not very high compared to the magnitude of the value. The same can be said for the dissolved oxygen threshold.

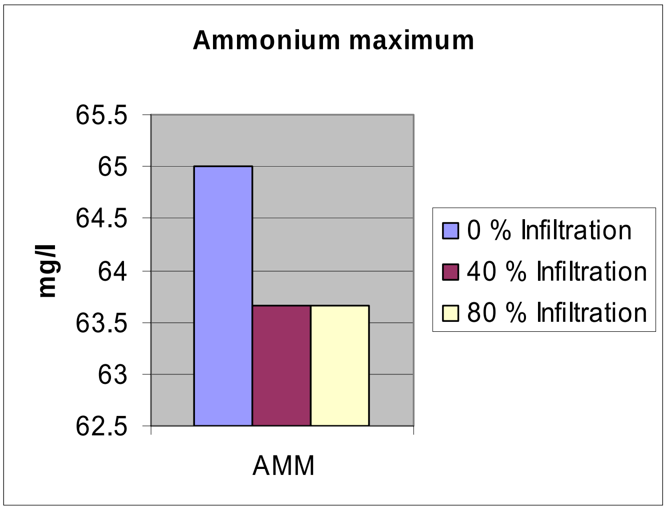

Figure 18: Maximum of ammonium concentration

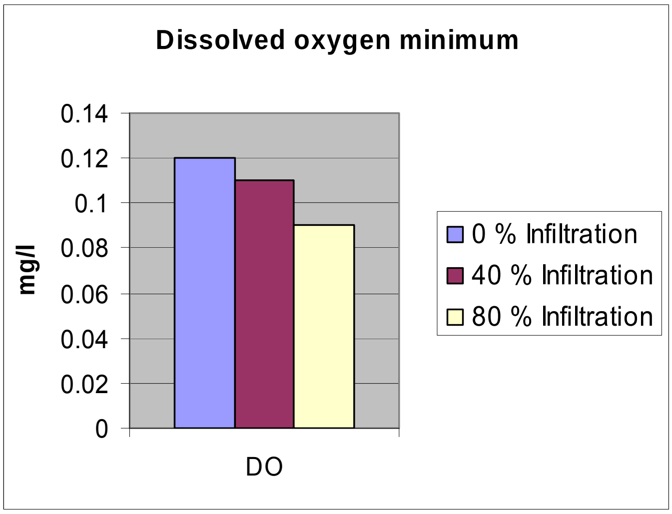

Figure 19: Minimum of dissolved oxygen concentration

The duration of a critical concentration (Figure 20) is heavily affected. Since the intensity of an event is described by the threshold concentration and the tolerated duration, this is an important factor for the assessment of acute impacts.

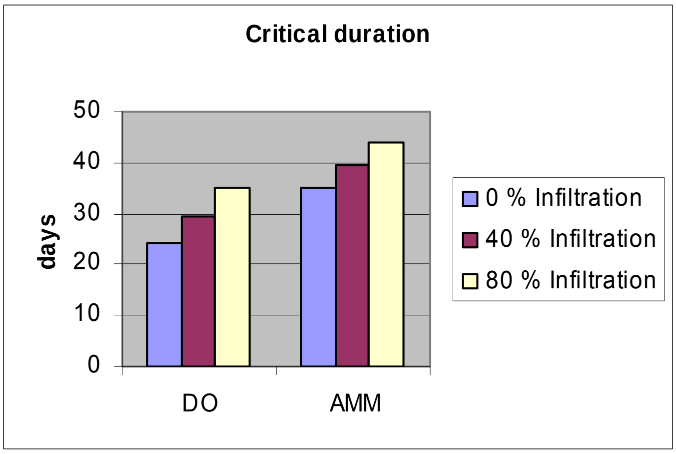

Figure 20: Duration of exceeding dissolved oxygen threshold and ammonium threshold, respectively

In the example several simplifications and limits have to be considered which are:

- only one kind of WWTP has been investigated
- the process rates in the WWTP depend on the parameters which were calibrated using literature values
- infiltration enters the flow already in the catchment together with the sanitary flow
- no long term simulation has been carried out to evaluate the return period of overflow events
- the dependence of the environmental impact on CSO structure design, distribution of rain, status of the system prior to rain has not been investigated
- no case study was available to verify the results. They were qualitatively checked using literature experiences.

It could not be evaluated in what extend a rehabilitation measure will influence the systems performance. Data to analyse this point will be derived from the application of CARE-S infiltration models and the analysis of determination of rehabilitation scenarios. However, the simulations showed that network deficiencies can have a significant impact especially on the WWTP performance. Performance indicators can be used to describe the effects that were shown in the simulations. To describe the dynamics of the inflow the ratio of the maximum inflow into the WWTP and the average dry-weather flow can be used. Further the extraneous water flow divided by the sewage flow should be considered. CSOs should be investigated considering return period, duration, volume and pollution load if possible. Reference values are partially provided by national or local standards. For a comparison to standards the application of long term simulations for the assessment of CSO compliance is inevitable. Performance indicators and criteria are described in chapter 3.4.

3 ASSESSMENT METHODOLOGIES

3.1 Flowchart and Integration of WP 3.3

The main task of work package 3.3 is the assessment whether the systems performance complies with environmental standards and the evaluation of the impacts of the declined network on environmental compartments or the improvement potential. Figure 21 shows the position of WP 3.3 within the CARE-S procedure. Connections between the other work packages outside of the application of WP 3.3 are not included here in more detail (e.g. the connection between WP 3.4 and WP 6).

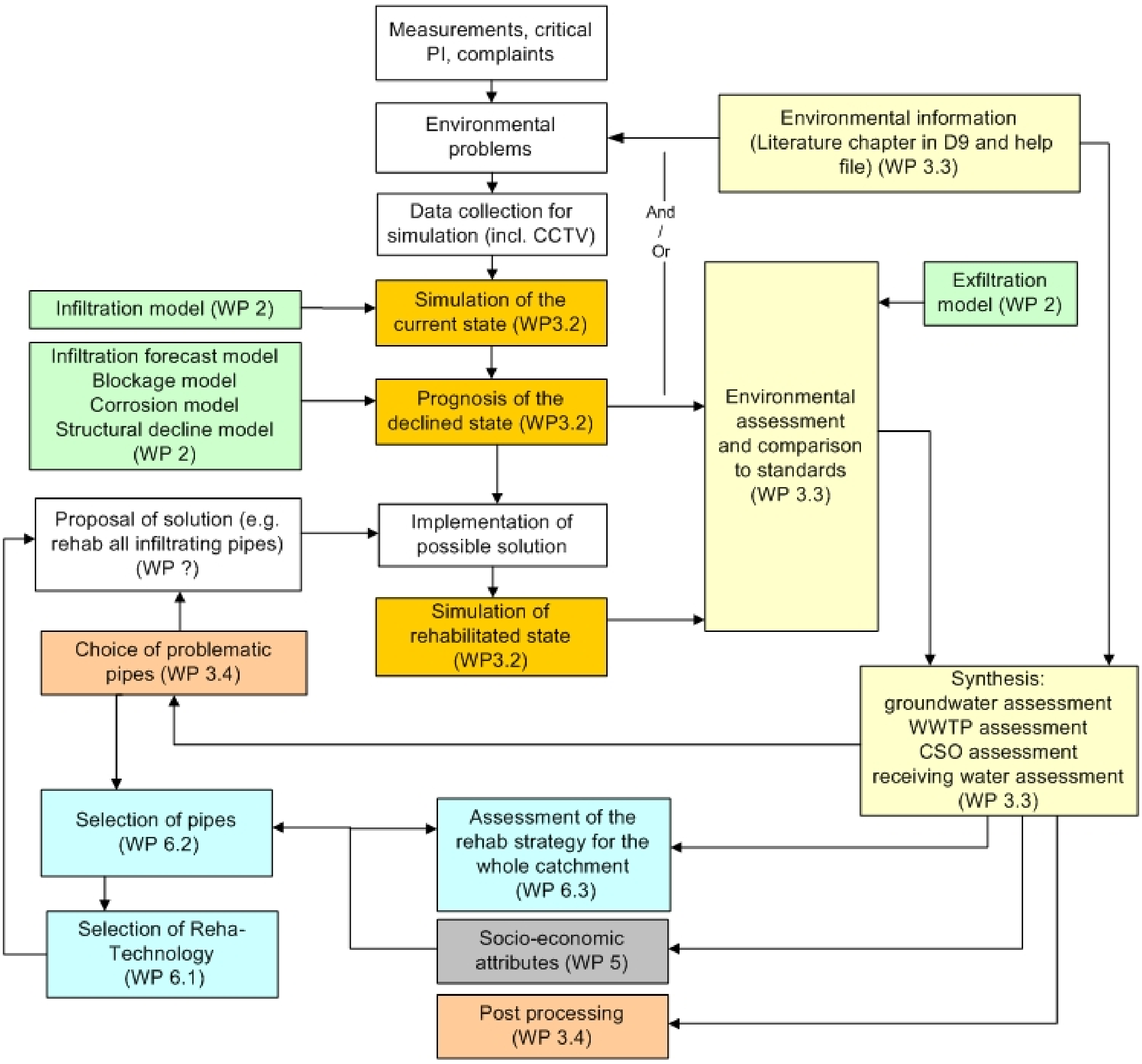

Figure 21: WP 3.3 Data flow

The flowchart shows that the evaluation of environmental impacts is only possible when a hydraulic simulation will be carried out. Network failures will be considered in the assessment directly (e.g. exfiltration rates) or indirectly by assessing the results of the hydraulic model which considered the effect of network failures on the hydraulic conditions. Data which will be processed by WP 3.4 can be additional information to the user in form of diagrams or tables. These data will not be an input to the decision support software.

3.2 Presumes, boundaries and further investigations

To check the compliance with environmental standards simple methods are required. The application of CARE-S should be possible even with a low density of data. However, several aspects and questions cannot be answered with simple methods. For example, for a pollution assessment for estuaries, pollutants concentration and conversion models are necessary because of the influence of saline water and complex currents. Marine pollution can be assessed using spill frequency of CSO, for assessing dilution and transport under the consideration of currents, detailed modelling is required. For a more detailed assessment of problematic combined sewer overflows guidelines to derive solutions are described in the UPM (Urban pollution manual). The product of such a UPM study is a detailed emission specification for all significant discharges in the urban wastewater system, together with an outline form of engineering solution (FWR, 1998).

The assessment of CSOs within the CARE-S procedure as described below depends mainly on the results of the hydraulic model provided by work package 3.2. Therefore it is necessary that retention tanks as well as CSO structures are modelled within the hydraulic model. The model building will be done outside of the CARE-S decision support procedure. In this context the user has to be pointed to the fact that CARE-S has no mechanisms to verify the results regarding CSO modelling or flow modelling. The verification has to be done carefully previous to the use of the CARE-S tools.

Processes that influence the dry-weather flow or the storm-weather flow have to be included into the model. It is important that the calculated infiltration rates and other network performance or structural failures, described with the models developed in WP2, are implemented in the hydraulic modelling. Otherwise the effects of infiltration into the pipes on flooding, WWTP performance and CSOs cannot be evaluated. The performance indicators sOp10 (exfiltration volume), sOp9 (Infiltration Volume), sOp8 (Inflow volume) and sOp7 (Inflow + Infiltration - Exfiltration volume) should be used to compare observed values to the results from the WP 2 models and the output of the hydraulic model for the current status.

For the evaluation of return frequencies of CSOs long term simulation are recommended. For the simulations a set of historical rain data for at least 20 years should be used. For detailed modelling the use of rain data with a resolution of not more than 5 minutes is recommended (FWR, 1998).

3.3 Prediciton of runoff and population change

The runoff coefficient as a function of nature and use of surface and the development of the population in future years should be evaluated in task 3.3.6. Basis of the assessment of these factors for a prediction should be the masterplan of the city concerned. The masterplan gives detailed information on the change of surface characteristics and includes information on the possible development of the population.

How runoff coefficients or runoff characteristics are considered in the models SWMM, Infoworks and Mouse is reported in D7 (State of the art in urban drainage modelling).

3.4 Criteria and performance indicators

Within Work package 3.3 a list of criteria that can be used within the decision support system was developed. Further Indicators that can provide additional information or that can be processed by work package 3.4 are explained.

Indicators that characterise catchment wide properties are not appropriate to WP 6.2 needs. They are used as Input to WP 3.4 which will analyse the contribution of single pipes to a performance deficiency that was observed in the catchment or in parts of the catchment.

Background information about the methods and the calculation of the criteria and indicators can be found in chapter 3.5 to 3.9.

WP 6.1: Choosing the rehabilitation technique
no criteria will be delivered from WP 3.3

WP 6.2: Choosing the rehabilitation project							
Number	**Name**	**Criteria**	**Description**	**Unit**	**Range**	**Scale**	**Comment**
C8	CGWvul	Vulnerability of groundwater	Vulnerability is estimated from exfiltration rate, permeability of soil and groundwater level	-	High, Moderate, Low	pipe / catchment	There are 4 Versions of producing the final weighting. Dependend on data availablility and users choice. the vulnerability will be evaluated further on by WP 5 (use of groundwater etc)

WP 6.3: Choosing the rehabilitation strategy							
Number	**Name**	**Criterion**	**Description**	**Unit**	**Range**	**Scale**	**Comment**
C8	CGWvul	Vulnerability of groundwater	Vulnerability is estimated from exfiltration rate of current and future status, permeability of soil and groundwater level	-	High ,Moderate, Low	pipe / catchment	the vulnerability will be evaluated further on by WP 5 (use of groundwater etc)
C9	COVload	CSO compliance to standard	Overflow total load	yes/no, absolute value %		catchment	to be programmed
	COVfreq		Overflow frequency/number of spills	yes/no, absolute value %		catchment	to be programmed
	COVvol		Overflow volume	yes/no, absolute value %		catchment	to be programmed
	COVdur		Overflow duration	yes/no, absolute value %		catchment	to be programmed
C10	CWPdry	WWTP inflow infiltration rate	dry weather flow divided by sewage or extraneous water flow divided by sewage or extraneous water flow divided by dry weather flow	m^3/m^3, %	…	catchment	the criterion implemented depends on data from WP 3.2
C11	CWPrain	WWTP inflow rain / dry weather dynamics	description of the change of the amplitude between dry-weather flow and rain-weather flow	…	…	catchment	

Further information and indicators					
Name	**Description**	**Unit**	**Range**	**Scale**	**Comments**
A - value	Estimation of pollution impact of urban drainage on rivers				
B - value	Estimation of the hydraulic impact of urban drainage on rivers				
Duration curve of CSO	Characterisation of CSO effluent of single CSOs (Flow)				
Duration curve of WWTP	Characterisation of WWTP inflow				
List of alternative measures	List of measures, besides pipe rehabilitation, for the reduction of environmental problems.				

The inputs and outputs for the calculation of the criteria is attached in Annex V. This list will be concluded by the release of the WP 3.3 tools.

3.5 Groundwater and soil

3.5.1 Methodology of Vulnerability assessment

The existing recommendations for sewer rehabilitation advocate a risk approach to exfiltration. There are considered: effluent type, risk of leakage from the sewer, transmission through the ground, level of water use (WP2, 2003). A standard method for the assessment does not exist in Europe.

There are several methodologies to assess groundwater vulnerability. A definition of vulnerability can be found in Focazio et al. (2003): “Groundwater vulnerability to contamination was defined by the National Research Council as the tendency or likelihood for contaminations to reach a specified position in the ground water system after introduction at some location above the uppermost aquifer. “

Vulnerability can be divided in intrinsic vulnerability which only depends on soil and groundwater itself and specific vulnerability which includes use and potential pollutant input and its properties (Heinkele et al., 2001). Since in CARE-S the focus is on exfiltration-caused pollution, specific vulnerability will be assessed.

This chapter contains a short overview on the methodology of groundwater assessment. More information can be found in Focazio et al., (2003).

The methods can be divided into two major groups:
- subjective rating methods
- statistical and process-based methods.

While subjective rating methods assign qualitative descriptors (e.g. high moderate, low) to physical attributes, process based methods give a more objective picture without subjective interpretation of observed data. Subjective rating methods are often used to focus on policy or management objectives. They are often more easily to apply to a case study than process-based methods although they are more difficult to defend scientifically.

In the USA the most widely used method is named DRASTIC (see ANNEX I), named for the seven factors considered in the method: depth to water, net recharge, aquifer media, soil media, topography, impact of vadose zone media, and hydraulic conductivity of the aquifer.
With the scoring used in DRASTIC a simple map for the vulnerability can be produced.

In hybrid methods statistical evaluation of the factors used in the index methods is applied. That gives the scientist more confidence in the significance of the factors used.

Statistical methods use historical data and methods like simple descriptive statistics or regression analysis to assign empirical weights to factors and to eliminate insignificant variables. Therefore, historical data must be available for a reasonable time horizon.

Process-based methods are based on deterministic models or physical and chemical laws. They include statistical methods e.g. for the simulation of complex hydrological processes. These approaches, although scientifically most reasonable are very complex and time consuming.

Conclusion and CARE-S Application

From the literature review about effects of exfiltration it can be seen that information about the effect on groundwater are rare, site specific and very uncertain concerning the dependencies of the clear evidence of pollution due to sewers.

It can be stated that the water abstraction sites can be polluted by sewage and should be included in the risk assessment; that pollution due to Nitrate is severe and bacteria are important since they can cause diseases. It is also important whether the ground is homogeneous or not and whether the sewer is close to the groundwater table or whether exfiltration and infiltration occur in a sewer (e.g. due to seasonal groundwater fluctuations). For assessing the vulnerability of groundwater several methods are possible. They are limited by the availability of data. If the end user has already maps or data about the state of groundwater or an applied methodology for groundwater assessment they should be used in this study or substitute the method that will be proposed within CARE-S if it is more detailed. It should be used to validate the method and to support an improvement of the method.

The assessment of groundwater vulnerability is done independently of the groundwater typology. A further step in the assessment can be the inclusion of the groundwater use. This assessment might be done within WP 5.

Since data availability is limited very simple approaches are proposed in this section to be applied in CARE-S. The method includes only groundwater level and exfiltration rates and soil permeability (or soil type) as the three most important factors in the assessment.

Method 1 - derived from DRASTIC method:

Similar to the DRASTIC approach vulnerability is defined as $V = 5*G + 4*E + 2*S$. Further factors as applied in the DRASTC approach are not included into the assessment here to provide a simple procedure and to cope with the limited data availability.

G... Rating for the Groundwater level beyond sewer level
E... Rating for Exfiltration rate
S…Rating for Soil type

Ratings have been assigned to the values see Table 20 , Table 21 and Table 22.

Table 20: Distance from Sewer to Groundwater level in m

	G
0 - 1.5	10
1.5 - 4.5	9
4.5 - 10	7
10 - 15	3
15 - 22.5	2
22.5 - 30	1

Table 21: Exfiltration Rate in m^3/h

	E
> 0.4	10
0.1 – 0.4	5
< 0.1	1

Table 22: Soil type

	S
Thin or Absent	10
coarse gravel	10
coarse sand	9
medium sand	8
fine sand	6
Silt	4
Clay	1

For assigning permeability to soil types Table 23 has been proposed and agreed by the CARE-S partners.

Table 23: soil types and permeability

kf m/s	soiltype	grain diameter mm	Permeability
1.00E+01			
1.00E+00	coarse gravel	6…20	very high
1.00E-01	gravel	2…6	
1.00E-02	coarse sand	0.6…2	
1.00E-03	medium sand	0.2…0.6	high
1.00E-04	Finesand	0.06…0.2	moderate
1.00E-05			
1.00E-06	silt	0.0006…0.06	low
1.00E-07			
1.00E-08			
1.00E-09	clay	<0.0006	very low
1.00E-10			
1.00E-11			

Additionally to the rating the values have been associated with weightings. Weights have been associated following the DRASTIC method. The influence of the distance to the groundwater (Weight: 5) and the exfiltration rate (weight: 4) which substitutes the recharge rate are more decisive for the vulnerability compared to the soil type (weight: 2). According to an investigation by Vollertsen (2003) the soil type has not a significant influence on the exfiltration so the weighting is reasonably set.

Because the DRASTIC method provides numerical values which have to be classified and do not give a demonstrative result on high or low groundwater vulnerability, a method is provided within CARE-S which classifies groundwater vulnerability directly in "high", "moderate" and "low". This method is based on the rating system of Eaton and Zaporozec (1997). In the original method the recharge rate to estimate travel time of pollutants is considered. The recharge rate has been replaced by the exfiltration rate to tailor the method to the needs of exfiltration assessment. Soil type, exfiltration rate and depth to the groundwater table will be classified by the user prior to the application of the procedure. The values will then be evaluated in a matrix and the groundwater vulnerability will be assessed using a classification matrix.

The distance from groundwater can be provided from maps. The soil type and/or permeability can also be provided from maps or can be estimated. For the classification Table 23 can be used. The exfiltration rate can be derived from calculations of WP2 models.

The classification of the three parameters is done by the user. This can be done by taking default values or by insert own classification limits. Table 24: Classification of permeability to Table 27 show the steps in the vulnerability assessment with example values.

Table 24: Classification of permeability

Class	material	estimated permeability
high	sand and gravel	>= 1E-0,3 cm s^{-1}
moderate	sandy silt till	>= 1E-0,5cm s^{-1} < 1E-0,3 cm s^{-1}
low	silt and clayey silt till	< 1E-0,5cm s^{-1}

Table 25: Potential vulnerability

Distance to aquifer --> **permeability**	<7,5 m	7,5-15 m	>15 m
high	H	H	M
moderate	H	M	L
low	M	L	L

Table 26: Potential contamination

Exfiltration rate --> **potential vulnerability**	Low	Moderate	High
H	M	H	H
M	L	M	H
L	L	L	M

Table 27: Combinations of parameters by boolean logic

Depth to aquifer	Estimated permeability	estimated soil percolation	final ranking
> 15m	Low	Low	L9: Low
> 15m	Low	Moderate	L8: Low
> 15m	Moderate	Low	L7: Low
> 15m	Moderate	Moderate	L6: Low
> 15m	High	Low	L5: Low
> 15m	Low	Low	L4: Low
7.5-15 m	Low	Moderate	L3: Low
7.5-15m	Moderate	Low	L2: Low
7.5-15m	Low	Low	L1: Low
> 15m	Low	High	M9: Moderate
> 15m	Moderate	High	M8: Moderate
> 15m	High	Moderate	M7: Moderate
7.5-15 m	Low	High	M6: Moderate
7.5-15 m	Moderate	Moderate	M5: Moderate
7.5-15 m	High	Low	M4: Moderate
< 7.5 m	Low	Moderate	M3: Moderate
< 7.5 m	Moderate	Low	M2: Moderate
< 7.5 m	High	low	M1: Moderate
> 15m	High	High	H9: High
7.5-15 m	Moderate	High	H8: High
7.5-15 m	High	Moderate	H7: High
7.5-15 m	High	High	H6: High
< 7.5 m	Low	High	H5: High
< 7.5 m	Moderate	Moderate	H4: High
< 7.5 m	Moderate	High	H3: High
< 7.5 m	High	Moderate	H2: High
< 7.5 m	High	High	H1: High

The classification used here enables the user to derive a more detailed view how the results were derived. The path the result was derived is characterised by the numbers assigned to the values “low”, ”moderate” and “high”.

If data for the three parameters are not available groundwater vulnerability assessment is also possible using classification methods. The combination of exfiltration rate and groundwater level and the combination of groundwater level and permeability will provide “high”, ”moderate” and “low” values for a simplified assessment. Details about the applications will be delivered in a separate report on the WP 3.3 tools.

Where a significant vulnerability has been observed detailed investigations at the identified sites are recommended. Investigations should especially be done in groundwater protection zones.

Further investigations can include:

- visual inspections of the sewer by CCTV
- tightness tests of pipes and joints
- analysis of groundwater samples to identify whether pollution has taken place and where necessary matching with trade effluent and other information to identify the possible sources

3.5.2 Example Dresden

The City of Dresden catchment served as an example for application of the DRASTIC rating system. The assessment is based on exfiltration rates calculated with the leakage approach based on infiltration and exfiltration studies (Karpf and Krebs, 2004a; Karpf and Krebs., 2004b). The maps show the central part of the sewer network of Dresden. The grey lines show assets where no data for the groundwater vulnerability assessment was available.

Assumptions for the assessment:

- the travel time of pollutants in the sewage is the same for all assets
- the pollutant concentration in the exfiltrating sewage is the same for all sites
- the exfiltration rate is dependent on the groundwater table when it is not below the pipes invert, the wastewater level in the pipe and the size of the pipe
- the maximum exfiltration rate is assessed
- the mean value for groundwater table fluctuations has been taken from assets where the groundwater table was below sewer level.

Figure 22 shows the Exfiltration rate as it was calculated with the leakage approach. The values allow the relative comparison for different sites.

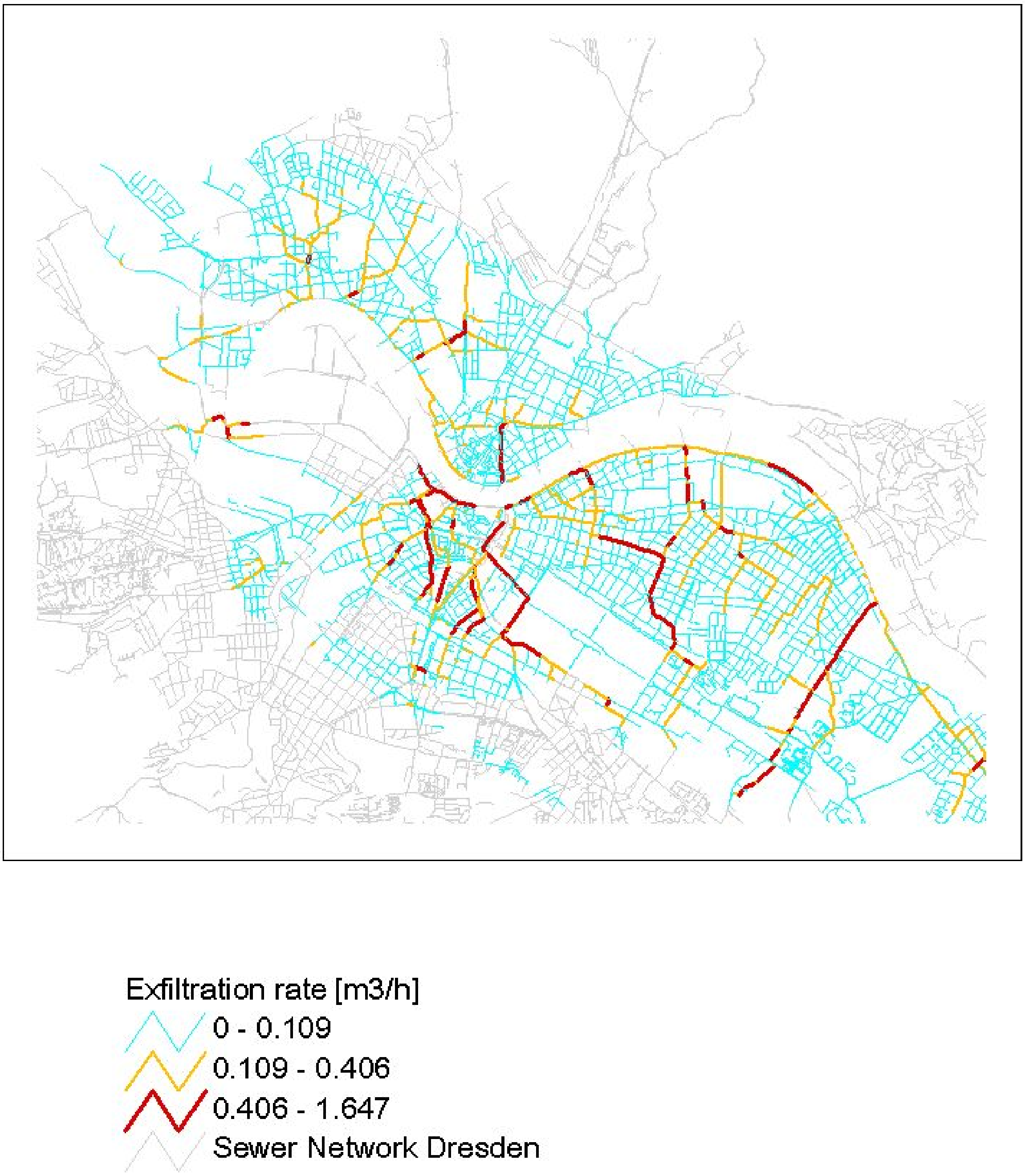

Figure 22: Exfiltration rate

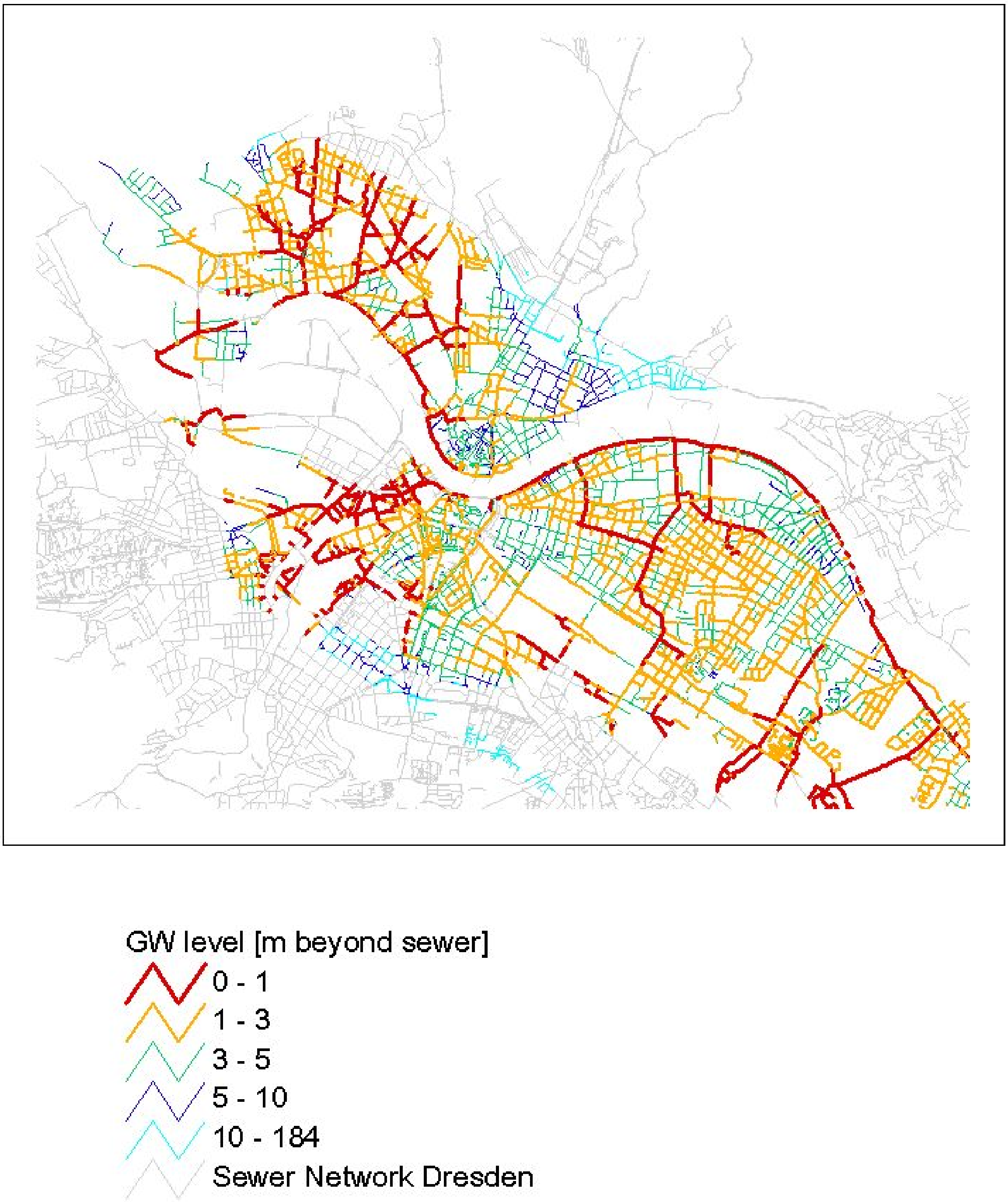

Figure 23: Groundwater level beyond sewer

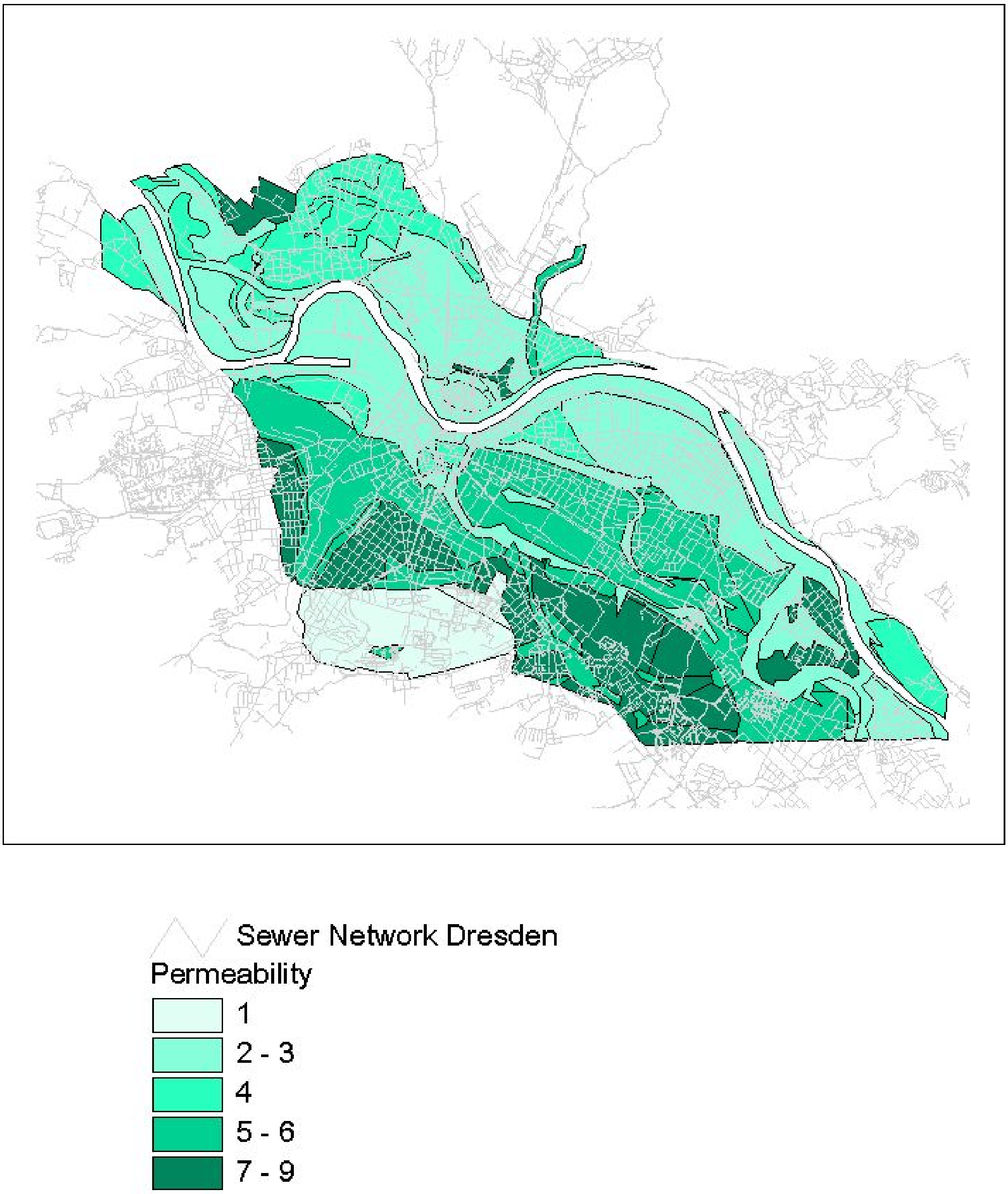

Figure 24: Permeability classes

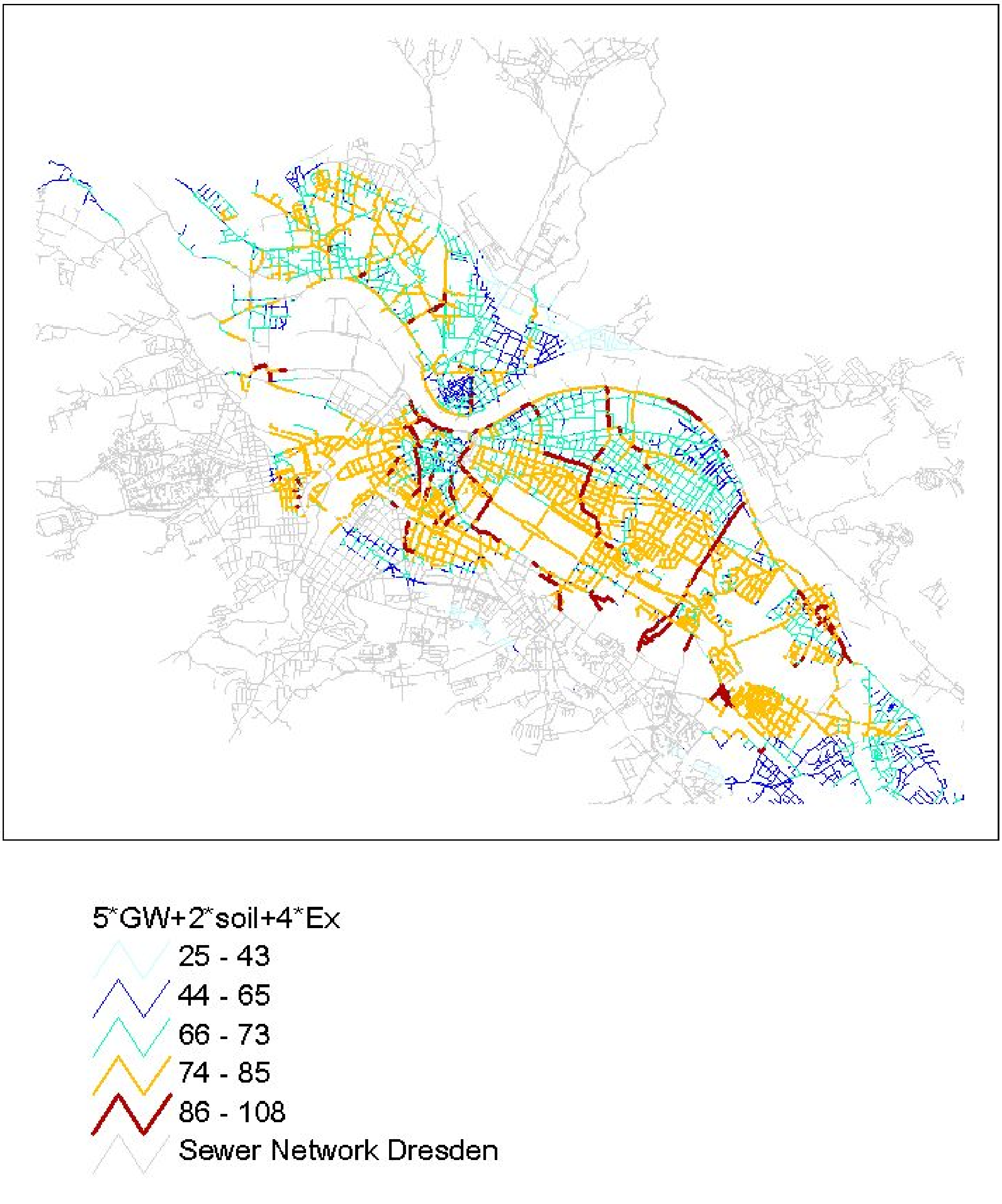

Figure 25: Groundwater vulnerability

Vulnerability values reach from 25 to 108 in the example. The default classification method of ArcView has been used to assign 5 classes to the groundwater vulnerability values. The method is named „Natural Breaks" and uses the Jenk's optimisation for identifying breakpoints between classes. The method minimises the sum of variance within each of the classes.

3.6 Surface waters

3.6.1 Rivers - enhanced requirements regarding combined sewer overflows

Previous to the assessment of the CSOs a general study on the sensitivity of the receiving water can be carried out, where it is assessed whether the receiving water is sensitive to urban discharges. In two reports the ATV-workgroup 2.1.1 (Borchardtet al., 1993; Sperling et al., 1997) developed indicators for assessing the potential of a severe impact to rivers. Therefore, they developed "values" (a-value and b-value) to assess whether a river potentially may be chemically or hydraulically adversely affected by CSO discharge. If the requirements for receiving waters are not guaranteed by following emission standards, enhanced requirements have to be developed. Those have to be adapted to the individual receiving water quality and properties. The values developed in the ATV reports give a help to identify critical cases with a high potential of receiving water damage due to discontinuous discharges with a method which can be applied with low effort in data collection. The method will give recommendations whether a receiving water and its urban impacts have to be investigated in detail or whether emission based standards are sufficient to protect the water body. The method has been developed for "typical" (mainly sanitary) sewage.

Most important indicators for the assessment of the rivers are ammonium/ammonia, lack of oxygen, solids and hydraulic impacts. In cases where these parameters are important for receiving water assessment, this method can be used.

Table 28: Qualitative assessment of impacts from (Borchardt et al., 1993)

Type of water body	O_2	NH_4^+ at pH > 8	NH_4^+ at pH < 8	solids
mountain river	-	+	-	-
flat land river	+	+	-	+
reservoir	++	++	-	+

(- no relevance, + relevant, ++ very relevant)

Table 28 shows the sensitivity of water bodies on relevant indicators. Especially endangered are water bodies with a low friction force, a low physical gas exchange and high depth of water. Solids have to be considered because they can be carrier of problematic substances.

Very important for the ecological impact of CSO on the receiving water is the ratio of CSO flow to receiving water flow, frequency and duration of the CSO. It is assumed that most of the CSO meet low flow conditions or conditions lower than mean water flow in the receiving water. Thus the impact is assessed for low flow conditions. Important for the assessment is the impulse-like character of the impact as well as the interaction of compounds and hydraulic effects. Investigations have shown that the compounds impact on the receiving water correlates roughly with the number of inhabitants. The values of the ATV group consider that water bodies with a low shear force and a low gas exchange are most affected by CSOs.

The **a-value** is calculated from: a = number of population / MNQ (l/s)

MNQ:

from continuous measurements:

NNQ lowest day mean of all years
NQ lowest day mean of one year
MNQ mean of NQ (NQ from all years)

Thresholds within this assessment method for the receiving water quality under rain weather conditions are:

Solids: 50 mg/l
Oxygen: 4 mg/l
Ammoniak (NH3-N): 0,1 mg/l

These limits will probably be exceeded if the calculated a-values exceeds the critical a-value (a_G or a_F) under circumstances defined in Table 29 :

Table 29: a-value

	property in the receiving water	**critical a value (inhabitants/low water (l/s))**
dissolved matter (O_2 and NH_3)	MNQ velocity v (m/s) water depth h (m) pH	a_G
	pH > 8,5	10
	v < 0,1 and h > 0,1 v 0,1 – 0,5 und h > 0,5 oder pH > 8	15
	v < 0,1 and h < 0,1 v 0,1 – 0,5 and h < 0,5 v 0,5 – 1 and h > 1	20
	v 0,5 – 1 and h < 1 v > 1	25
	high self purification potential (low depth and high velocities)	40
solids	flushing of sewer deposits or biofilm	a_F
	strong	15
	low	25

a_G: critical a-value regarding dissolved matter
a_F: critical a-value regarding solids

For more than one CSO, the results have to be summed up and considered as one CSO. The a-value depends on pH, velocity and water depth. Exceeding the a-value requires the initialisation of a detailed investigation of the adversely effected indicators.

The assessment of the hydraulic impact is based on the ratio of the maximum sum of CSO flow and the natural runoff in the receiving water (without surface sealing). For the assessments of more than one CSO in the system a critical distance has been estimated. If the distance is below the critical limit CSOs can be summed up to one theoretical CSO. Table 30 the critical distance is determined regarding acute ammonium and oxygen impact for 20 (EW/l*s) at MNQ for width/depth ratio = 20:1 (Sperling et al., 1997).

Table 30: Distance of interferences of discharges in km

mean depth	mean flow (m/s) ≤ 0,1	≤ 0,5	> 0,5
≤ 0,1	< 4 km	4 km	-
≤ 0,5	5 km	7 km	10 km
> 0,5	10 km	12 km	-

These values can differ very much by the factor 2 to 5 in dependence of the self purification potential.

The **b-value** is based on the impact of CSOs on the biocoenosis and on the critical shear stress. The frequency of critical shear stress depends roughly on the ratio of the size of the urban catchment compared to the natural catchment.

$b = (A_i/A_H) * 100$ [%]

A_i = impervious area of the catchment (A_{red} can be used also: $A_i \sim 0,85 * A_{red}$)
A_{red} = area drained by sewers
A_H = hydrologic catchment of the river upstream the urban catchment

According to 30 case studies in Germany and Switzerland significant impacts were shown for a b-value of above 5 %. Is the critical b-value exceeded a decrease of number of individuals and species will occur in the river. For supporting and proving the estimation of the impact, investigations of the biocoenosis in different time periods will have to be undertaken.

3.7 CSO

A method is provided here to check compliance with CSO standards. The method should be applied to assess the effect of the declined network on CSOs and to evaluate different rehabilitation scenarios.

The application of a CSO permit or standard depends on country and on region as well as on measurement possibilities and on environmental politics. It is not part of CARE-S do decide which standard is to be used. Within the environmental assessment the possible impact on the system will be described using various specifications and standards. The user can then compare the result with the respective standards.
Threshold values that are used for legislation and control can be used in the CARE-S procedure as well but must be looked at with caution. Since there is no pollutants transport simulation model included in the assessment of CSO, the simulation results do reflect reality only up to a certain degree.
In the first step CSO data is analysed for the whole catchment and compared to the standards. Thereafter the contribution of single CSOs is analysed as far as possible. Pollutants considered in the load estimations are COD, BOD, NH_4-N and DO.
The actual performance of single CSO structures has to be investigated site specific and can not be predicted by CARE-S.

3.7.1 Use of standards

The criteria and performance indicators are formulated in parameters used in typical national standards to receive a comparable result of the assessment. National standards are included in the assessment method as far as information was available. They are described in Annex IV. Further criteria can be used in the assessment e.g. PI targets. The PI sEn1 (Overflow discharge frequency), sEn2 (Overflow discharge volume), sEn3 (Duration of overflow discharge), sEN4 (Overflow discharge related to rainfall) and sQs7 (pollution incidents complaints) will be used for this issue. Additionally the user can include further thresholds if required.

3.7.2 Proposed methods

A methodology for the assessment of CSO was proposed in the work package 3 meeting in Trondheim (December 2003).
For every CSO and for the WWTP inlet a quantity-duration curve for the simulation period can be calculated which represents the flow in m^3/d for the given time in % (see Figure 26). The whole assessment period is included in the calculation and generation of the diagram.

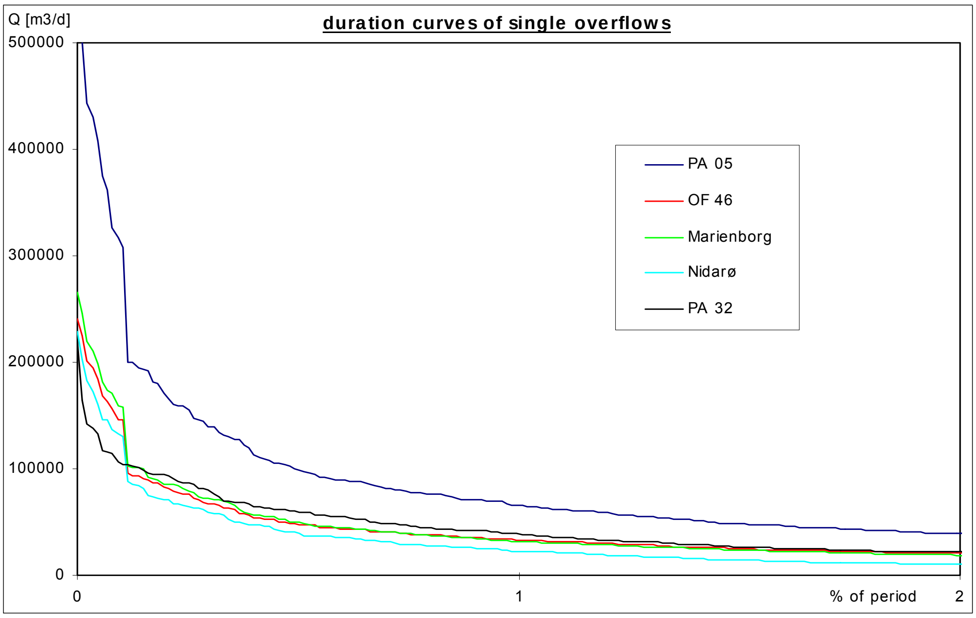

Figure 26: Duration curve used in a case study in Trondheim (Schilling et al., 1998)

For CSOs this diagram visualizes the time the CSO discharge lasted and the peaks that were reached. Different CSO structures can be compared and different scenarios are comparable. For flow and pollutant concentrations of loads the curves might have different shapes. Figure 27 shows the effect of extraneous water on the quantity–duration-curve in a simulated example.

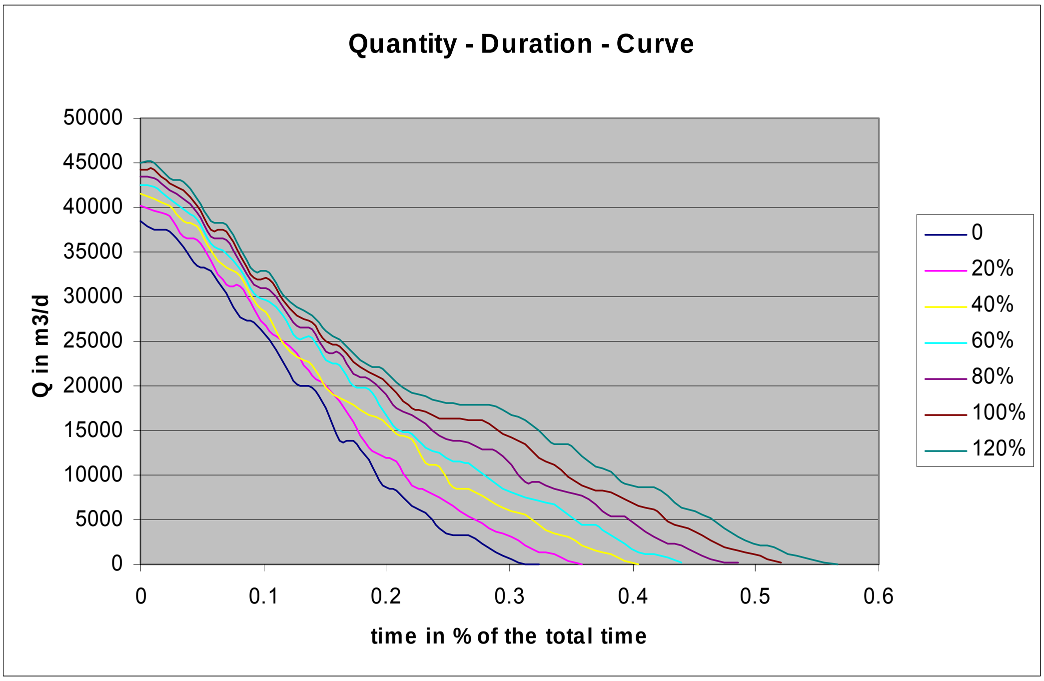

Figure 27: Infiltration effect on Quantity-Duration-Curve

The curve can also be drawn for receiving water impacts and behaviour. Here we can compare the curves regarding two aims:

1. decreasing the duration of impacts
2. decreasing the peaks of impacts

Figure 28 represents another way of analysing pollution events that was discussed in the Trondheim meeting. The total mass of pollutants is set to 100 % and their sources/pathways are visualised in the diagram. The pollution can be calculated from population estimations and from hydrographs. A pollution transport model is ideal for the calculation. Using this method requires detailed information about sources and pathways of pollutants. The diagram can be drawn for the flow as well as for pollutants like nitrogen, COD or phosphorus.

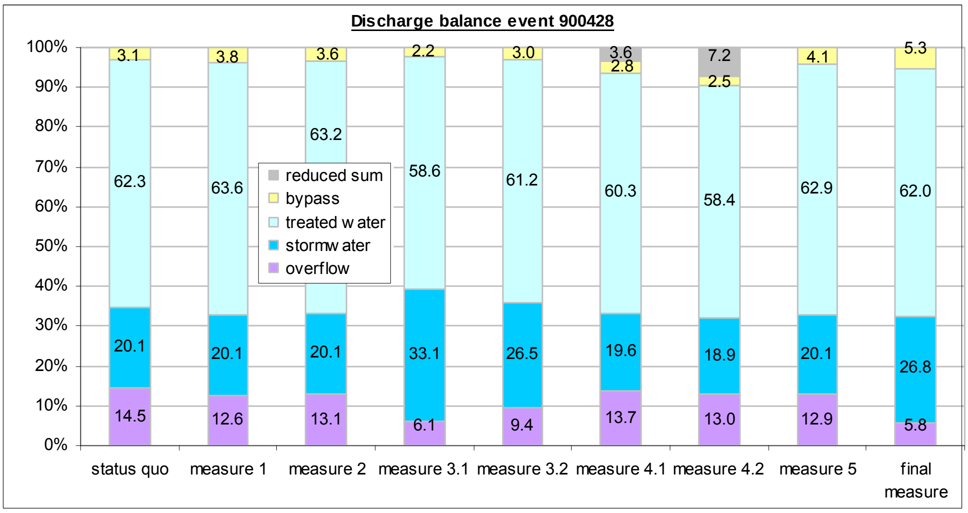

Figure 28: Example of a mass balance (Schilling, Lei et al., 1998)

3.7.3 Methodology

By choosing a standard and therefore performance criteria for the CSO the method of assessing the CSO is also decided on. Standards are described in detail in Annex IV. In this chapter the criteria for the assessment are listed:

Design standards:

n times dry weather flow

Emission based standard (no river modelling included):

Spill frequency
Spill duration
Volume
Total load from (WWTP and) CSOs
Quantity–Duration–Frequency relations (QDF)
Concentration–Duration–Frequency relations (CDF)

Immission (requires river modelling):

DO and NH4 in the receiving water (intermittent standard)
Percentile based standards

Table 31 gives an overview over the used standards, their data requirements and some details.

Table 31: CSO standards, data and calculation needs

	derived from WP 3.2 simulations				calculated within WP 3.3			
	n times dry weather flow (design)	Spill frequency	Spill duration	Volume	estimated total load from (WWTP and) CSOs	QDF and CDF for Volume and Concentration of CSO	DO and NH4 concentration in the receiving water (intermittent standard)	Percentile based standards
Threshold	in n times dry weather flow	number of spills/year	time/year	volume/year	load/year	QDF, CDF	CDF	concentration n-percentile
data needed to check compliance (finest solution – single CSO structures)	start time of the first overflow of every overflow-structure	number of spills for every CSO structure	duration of single spills of every CSO structure	overflow volume of single structures and events	sanitary water load industrial and other load wash load (surface+sewer)	Volume and Duration of every CSO	sanitary water load industrial and other load wash load (surface+sewer)	CSO load
	volume in upstream pipe at this time				overflow volume	CSO pollutant concentration	river flow concentration data	flow and pollution concentration in the river
	actual (not design) dry weather flow						overflow volumes	
Data processing and calculation requirements	analysis of water flow in network upstream of every CSO structure	long term simulation	long term simulation	long term simulation	calculation of WWTP load and CSO load in a simple estimation (or pollutant transport modelling)	long term simulation and visualisation	river modelling and pollutant transport modelling or load and low water estimations	long term simulation river modelling or minimum flow information
Comments	the actual dryweather flow has to be taken to calculate the compliance with the design criteria				the estimation cannot be correct within the simple estimation. For more intensive investigation a pollution model is recommended.	this criterion is only useful in scenario analysis studies	an estimation of the criteria should only be done in simple case studies or as an pre-study	

Estimation of the CSO impact:

Hydraulic assessment:

The values for assessing spill frequencies and volumes will be derived from WP 3.2 simulations. Frequency or return periods of CSOs have to be derived from long term simulations. If it is assumed that the CSOs have the same return period as the rain events leading to the overflows, the return periods of the rain events can be used to assign frequencies to CSOs. This method to be applied for flooding events was proposed within work package 3.2.

Duration-frequency curves can be derived for all CSO time series or single event data.
The events will be sorted by the maximum flow. Then the events will be printed as frequency-duration curve. Volume and duration of all events will be compared for different scenarios (current status, rehabilitated status scenarios).

Loads

The modelling of water quality requires a high amount of input data which is often of stochastic nature. The pollutants load is often highly fluctuating and is compared to water quantity inputs very difficult to measure (Vaes et al., 2000).
With a simplified method total loads and event loads from CSOs should be estimated and frequency duration curves for load estimations should be produced. The methodology is similar to the duration curve used for the description of overflow volumes. However it has to be considered that according to Sztruhar et al. (2002) event mean concentrations are weakly correlated to runoff volumes. The UPM also points to the site specificity of event mean concentrations (EMC). The UPM proposes a method to estimate EMC from dry-weather loads if event mean concentrations are not available. If dry-weather loads are also not available standard EMC are suggested. It is also mentioned that the uncertainty of an estimation carried out with these standard values is significant.

Dry weather loads of CSOs can be estimated from:

a) daily pattern derived from measurements or simulations by the user
b) estimations by using standard values, number of inhabitants and amount as well as composition of industrial sewage

Flow values can be chosen from Table 32. The user also has the possibility to add own values or use dry weather flow values from hydraulic simulations.

Table 32: Values for sanitary water flow in different countries (EN 752-4)

Country	**l/(EW * d)**
Austria	200 – 400
Denmark	150 – 250
France	150 – 200
Germany	150 – 350
Portugal	120 – 350
Switzerland	170 – 200
UK	150 – 300

Dry-weather load values can be taken from Table 33 if no information or measurements of dry weather load is available.

Table 33: average gross loads per capita in municipal wastewater (Borchardt, 2000)

Substance	Unit	Average gross load
COD	g/E*d	120-150
TOC	g/E*d	40-50
DOC	g/E*d	15-20
BOD5	g/E*d	45-60
Total N	g/E*d	11-14
NH4-N	g/E*d	7-10
Total P	g/E*d	2-2.5
Cu	mg/E*d	5-50
Pb	mg/E*d	10-50
Zn	mg/E*d	20-150
Cr	mg/E*d	5-50
Cd	mg/E*d	5-50
Ni	mg/E*d	0.5-3

Dry weather concentration can then be calculated from the derived values.
Another possibility is to use classified values as proposed by Henze (Henze et al., 2002) as can be seen in Table 34 (Henze, Harremoes et al., 2002). These values can be assigned variable to diefferent parts of the catchment. The values from the table will be used to calculate the dryweather load by subtracting extraneous water flow provided by WP 2 or Wp 3.2. So the concentration of the sanitary flow can be obtained.

Table 34: Typical average contents of organic matter and nutrients in domestic wastewater

		Wastewater type			
Analysis parameters	**Unit**	**concentrated**	**moderate**	**diluted**	**very diluted**
BOD_5	g O_2/m^3	350	250	150	100
COD_{total}	g O_2/m^3	740	530	320	210
N_{total}	g N/m^3	80	50	30	20
NH_4-N	g N/m^3	50	30	18	12
NO_3-N	g N/m^3	0.5	0.5	0.5	0.5
NO_2-N	g N/m^3	0.1	0.1	0.1	0.1
Kjeldahl-N	g N/m^3	80	50	30	20
P_{total}	g P/m^3	23 (14)*	16 (10)	10 (6)	6 (4)

*figures in parenthesis for catchment areas where detergent without phosphate is used

Storm loads can be derived from

a) estimations from standard values as provided in the UPM
b) modelling
c) measurements

The UPM (FWR, 1998) proposes an easy method where factors are used to calculate the concentration of the pollutants by using dry weather loads. These factors can be used in CARE-S.

Table 35: Factors to relate determinant concentrations in base flows to storm flows in combined sewer systems

Determinand	Multiplying Factor (F)	
	Flat/average catchment	Steep catchment
BOD	0.5	0.3
COD	1.0	1.0
Ammonia	0.3	0.3
Suspended solids	2.0	2.0
Total dissolved solids	0.4	0.5
Volatile suspended solids	1.2	1.1

Notes:

1. Multiply sampled base flow concentrations by the factors given to compute average storm sewage concentrations.

2. Use "steep catchment" factors only where the average gradient of the modelled sewers upstream of the CSO is in excess of 1 in 50.

3. The above factors relate to areas drained on a completely combined basis. Where a significant proportion of the drainage area is separately sewered, with stormwater flows discharging direct to stream, the factors should be modified in accordance with the formula:

$F' = 1 - P + PF$

Where F´= modified multiplying factor
P = proportion of drainage area contributing stormwater to the combined system
F = multiplying factor from above table

4. For systems suffering exceptional infiltration, base flow concentrations for undiluted base flows should be computed before application of the factors from the table.

Table 36: Average determinant concentrations for combined water in combined sewer systems

Determinand	Concentration (mg/l)	
	Flat/average catchment	Steep catchment
BOD	125	75
COD	390	330
Ammonia	8	4
Suspended solids	420	340
Total dissolved solids	400	250
Volatile suspended solids	190	160
Total Heavy Metals:		
- Copper	0.15	0.15
- Lead	0.25	0.25
- Zinc	0.90	0.90

Note: Steep catchments are those where the average gradient of the upstream sewers is in excess of 1 in 50.

For estimating the load of the discharged water, factors from Table 35 (FWR, 1998) are used and rain weather concentrations are calculated. If no dry-weather flow information is available, take average rain weather concentrations from Table 36 (FWR, 1998). With this information an estimation of the load from CSOs is possible.

A mass balance and a plausibility calculation for the flow in the system have to be done. Therefore, the flow from industry or other contributors must be included in the considerations.
Loads derived by these methods do not include catchment characteristics which influence the load of the sewage during storm events. An assessment of dynamic behaviour of the sewage composition and the composition of water from combined sewer overflows can not be done with this simple method.
For large catchments (> 20000) which are flat (and average gradient of the sewers of lessthan 1 in 50) and/or show to have significant interaction with the WWTP the analysis of the system should be done using a detailed model (FWR, 1998).

To assess different time interval impacts and evaluate long-term or short-term effects, mean overflow emissions over different durations can be used. Proposed are here:

- yearly
- daily
- hourly
- single events

For the prioritisation of possibly problematic pipes connected to a non complying CSO the criteria which are assed in WP3.3 will be provided to work-package 3.4, 5 and 6. If the thresholds are not met in a catchment, the most problematic CSO has to be identified. This will be done by evaluating the contribution to pollution and include further criteria like complaints or known CSO performance problems.
If there is no compliance of the observation and the simulation, the simulation does potentially not express the reasons for the unsatisfactory CSO performance completely. Thus, the reason might be an issue outside of the CARE-S decision support procedure (outside the sewerage network) or the simulation must be improved.

For every simulation run for every CSO a set of attributes will be produced (example):

Table 37: CSO attributes

CSO ID				
measured/observed	Criteria 1	o	value	%
	Criteria 2	x	value	%
simulated	Criteria 3	x	value	%
	…	x	value	%
	Criteria n	o	value	%

For known problem CSOs a flag will be set and the contributing catchment will be assigned by WP 3.4.

3.8 WWTP

Influences on wastewater treatment plant performance as they are described in chapter 2.5 can be quantified if modelling of the WWTP is applied. Within CARE-S no WWTP model is used, thus inflow characteristics are used to describe possible impacts on the wastewater treatment plant.

The criteria are:

Q_d / Q_s (dry weather flow divided by sanitary flow)
Quantity-duration-curves to assess the effect of the declined network on the dynamic in flow magnitude.

These criteria characterise the dynamics in the WWTP inflow and especially the influence of extraneous water.

3.9 List of alternative measures

The table (Annex III contains the full tables of alternative measures) should give an overview on methods for solving environmental problems that cannot be sufficiently solved by network rehabilitation. The methods in the table are partially taken from (Sperling et al., 1997) and (DIN, 1997) as well as from contributions from Carlos Montero (CLABSA), Gabriele Freni (TU Palermo) and partners from the CD4WC project.

The idea to produce the table was developed in the meeting in Swindon in 2003. It is a border area for CARE-S. In case a solution is not to be found in an iterative way, that solves a problem using pipe rehabilitation methods, the list gives ideas or hints that further measures should be applied in the Network. CARE-S will not analyse these solution proposals further on.

The table is divided into two parts. (Annex III contains the full tables.)The first part is a list of possible problems, reasons and methods that can help to solve these problems. The second part is an alphabetical list of the measures with the location where the measure will be applied and more detailed information. The table is available as an excel sheet and can be accessed within the WP 3.3 tool.

SUMMARY

This report is part of the subtask 3.3 ”Environmental impacts of rehabilitation”. In the first part of the report the role of environmental aspects in the rehabilitation planning is described. A literature review summarises the research on impacts of a declined sewer network on environmental compartments (groundwater, surface water, combined sewer overflows and wastewater treatment plant). European and national legislation dealing with discharges from urban drainage are described.

Simple methods for the assessment of environmental impacts in scenario analysis are provided. Basis of the work package 3.3 investigations are the results of the hydraulic model reflecting declined sewer network properties which are derived in work package 3.2 by including results from work package 2 (especially information on infiltration) and CCTV data.
The sensitivity of rivers, the vulnerability of groundwater and the compliance of combined sewer overflow to standards can be evaluated. From the evaluation results a list of performance indicators and criteria can be produced that will be used within the decision procedure developed in work package 6. The criteria will be further assessed in work package 3.4 and 5.
The methods proposed in this report are instruments for preliminary planning and cannot substitute site specific investigations and analysis.

The programming of the tools including the evaluation methods is still in progress. The developed tools will be presented at a later date.

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ANNEX I – Questionnaire

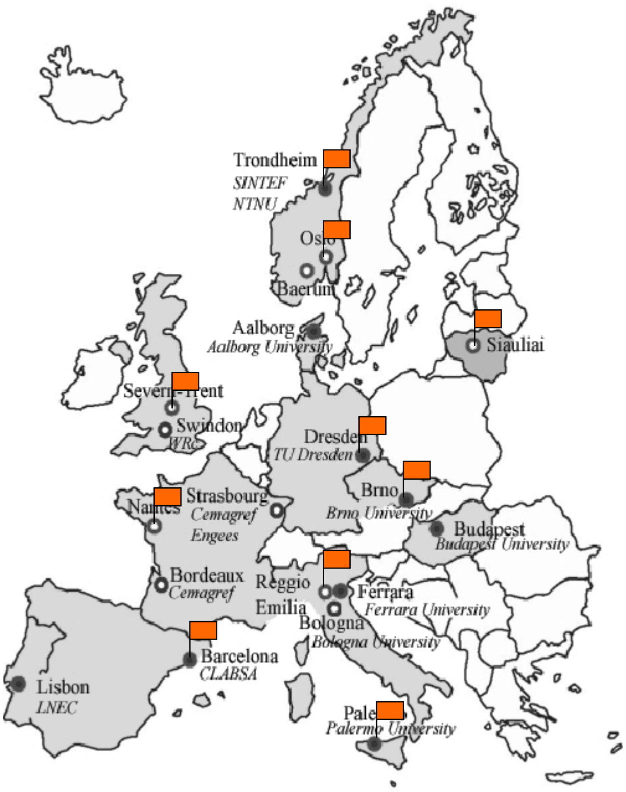
Aim

The WP 3.3 questionnaire has been prepared by TU Dresden and has been sent together with and accompanying letter to the project partners asking them to answer the questions in close cooperation with their end users.

Aim of the questionnaire was

- to explore which environmental problems do the end-users have in their catchments that are related to the sewer systems performance
- which of these aspects are included in the rehabilitation planning
- which of these aspects could be of interest in further rehabilitation planning

Participation



The following co-operating end-users from have returned the filled questionnaires.

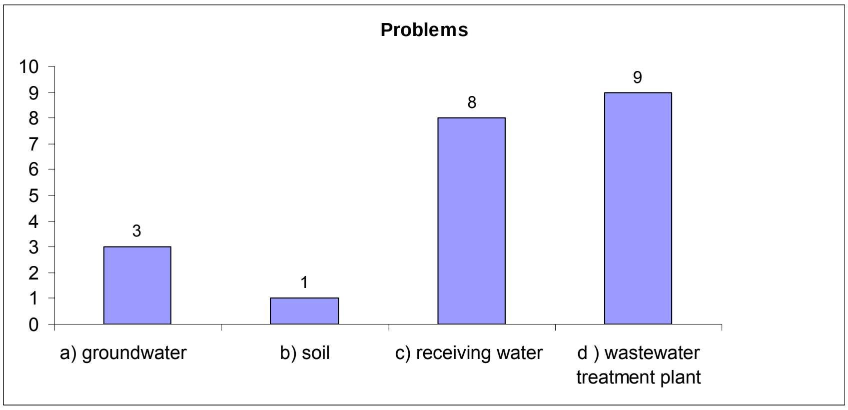
Oslo water and sewage works (VAV),	Oslo, Norway
Trondheim municipality,	Trondheim, Norway
CLABSA,	Barcelona, Spain
AMAP SpA,	Palermo, Italy
JSC "Siauliu vandeys",	Siauliu, Lithuania
Dresdner Stadtentwässerung,	Dresden, Germany
Severn Trent Water,	Great Britain
Brno Water and Sewer Works,	Brno, Czech Republic
Nantes Metropole,	Nantes, France
AGAC SpA,	Reggio Emilia, Italy

Contents

The structure of the questionnaire is:

a) Environmental problems that are connected to the sewer system
b) Consideration of environmental aspects in rehabilitation planning
c) Usage of hydraulic models or quality models
d) Usage of prognosis tools for environmental aspects in the rehabilitation planning
e) Interest in environmental information for the rehabilitation planning

Environmental problems connected to the performance of the sewer system:



The answers of 10 end-users have been evaluated. Most end-users (9) reported problems in the wastewater treatment plants. Receiving water problems have been reported by 8 end-users. A less common problem is groundwater (3 end-users). Problems concerning soil has been reported by one end-user.

Comments of the end-users:

Groundwater problems:

End-users reported groundwater problems mainly resulting from exfiltration or infiltration caused by pipe joint leakage or more general by poor condition of the wastewater network.

Soil:

Pollution of soil was caused by exfiltration from a poor conditioned sewer network.

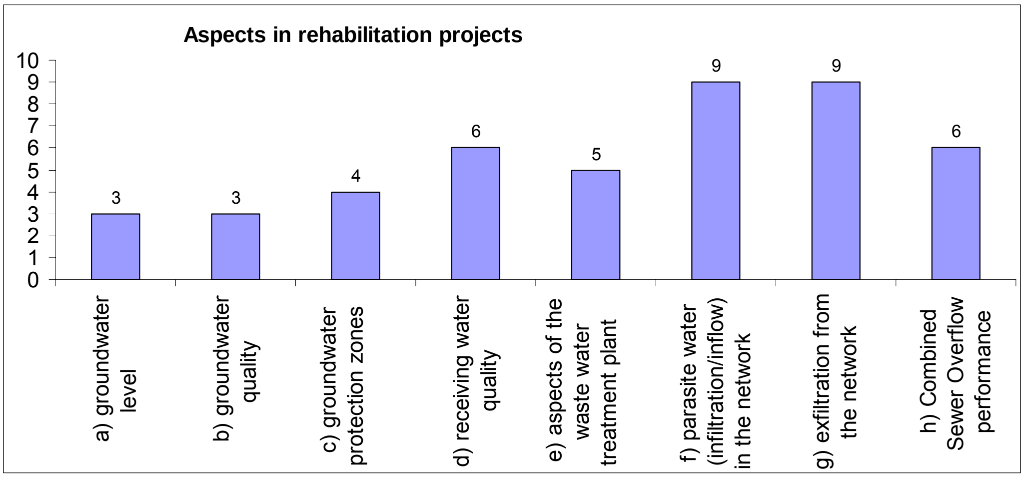
Receiving water:

The reason for receiving water problems are mainly: not complying CSO and overloaded wastewater treatment plants. In Barcelona discharging CSO during even small storms lead to problems in coastal areas with beaches. Odours, suspended solids and hydraulic problems occur and often the water quality is not compatible with the receiving water usage. Further more, non compliant house installations with a direct outlet to receiving waters cause problems as well as discharging pumping stations (Nantes). In Trondheim 10 % of phosphorous is lost to the receiving water during the transport of the sewage to the WWTP.

Wastewater treatment plant:

Infiltration as a problem for the WWTP is reported from many end-users. In Dresden problems are resulting from hydraulic overload during rain weather with high rainwater inflow from sanitary sewers in separated systems. Excess of matter flowing into the plant has been reported from Barcelona. Further problems are heavy metals in the WWTP sludge (that prevent using the sludge in agriculture), aerosol and odours.

Environmental Criteria that are considered by choosing a sewer for rehabilitation:



The end-users have been asked which criteria are decisive for the rehabilitation if environmental constraints are considered. The questionnaire of WP 6 has already shown that environmental criteria can play an important role in sewer rehabilitation planning (CARE-S Deliverable D 16). Infiltration and Exfiltration are the criteria relevant in most sites. Problems concerning the receiving water and associated to this to the CSO performance are relevant for more than 50 % of the end-users. Problems concerning the WWTP are mainly of interest in rehabilitation planning because they are connected to the infiltration problems. Groundwater issues play a role in some cases, but are not decisive for most of the users.

Comments of the end-users:

groundwater level:

Construction issues are in most cases the reason for considering the groundwater level (bearing capacity for inliners, open trench construction). The critical groundwater level has been defined in general as the level above the pipe (Barcelona).
Problems resulting from the groundwater during operating time are considered in some cases.

groundwater quality:

Groundwater quality is mainly of concern when the groundwater is taken for special uses underlying special regulation. In Dresden the quality is interesting for choosing the right material for the pipe.

groundwater protection zones:

Groundwater protection zones are taken into account but in most cases they do not play a big role since sewers are rarely located in groundwater protection areas.

receiving water quality

Aesthetic aspects and the water bathing directive are drivers for the interest in the receiving water quality. Therefore in UK the UPM (Urban Pollution Manual) is used for detailed analysis. In Palermo the regulations are fixed on receiving water characteristics and city extension in term of inhabitants. In all cases local authority regulations are decisive.

aspects of the wastewater treatment plant:

The wastewater treatment plant is evaluated in term of treatment efficiency reduction caused by parasite flow in the network. As already mentioned in point d) the effluent concentrations are fixed on receiving water characteristics and city extension in term of inhabitants (Palermo). Maximum flow and flow regulative devices are being investigated in Reggio Emilia. In England the WWTP is only considered where significant effects occur.

parasite water:

Parasite water is often considered because of the structural problems it can cause. Besides that in some cases the infiltrating water itself is reason for rehabilitation, especially in sewers close to rivers (Dresden).

exfiltration from the network

From Barcelona is reported that exfiltration takes place when the invert of the sewer is too wasted. It is repaired when it presents deterioration marks, even if the outflow is not yet produced. (groundwater protection)

CSO performance:

Parasite water increased CSO running times (In Trondheim, 100 CSOs with 1000 – 1500 hours per year. 5-6% of the pollutants are lost through CSO). Bacteria problems should be decreased by including CSO performance evaluation in rehabilitation planning.
Italy uses a design flow of $5*Q_{24}$ (mean daily flow during dry period). In order to mitigate hydraulic or quality problems other facilities can be imposed by the regulation authority.

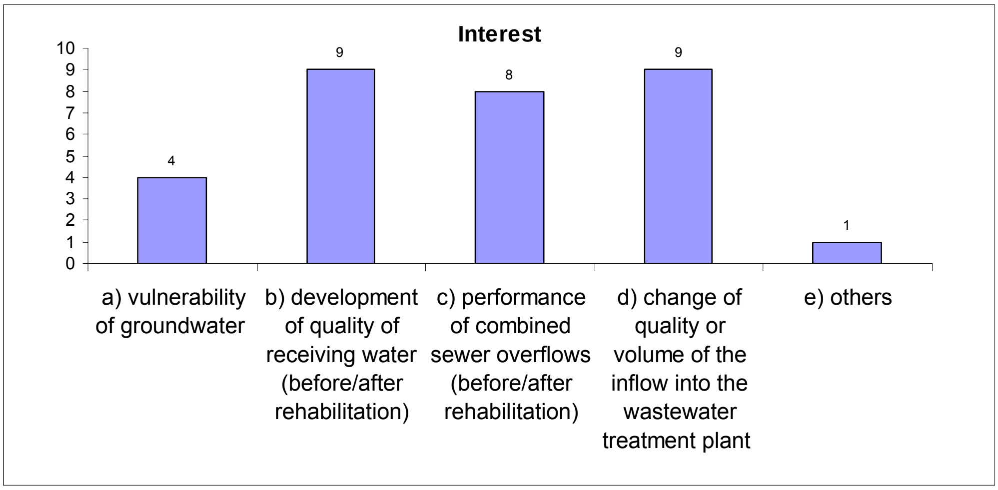
Modelling issues:

Eight of ten users use hydraulic models. Only 4 of ten users are modelling additionally quality issues.
Quality issues are in most cases only modelled for problem areas and for important catchments.

Prognosis tools:

Two of ten users are using environmental prognosis tools for the rehabilitation planning. In the UK these are models for modelling the effects on receiving water quality using the UPM procedure. In Lithuania water monitoring is used (probably without prognosis tools).

Interest in environmental information:



Wastewater treatment plant inflow, CSO performance and the receiving water quality are the most interesting fields for the end-users. Vulnerability of groundwater is interesting for 4 of 10 end-users. In most rehabilitation cases this topic is of minor interest.

Questionnaire

Information on End-user:

Organisation

Name	
City	
Country	
Type of company	

Contact person

Name	
E-mail	
Telephone	
Fax	

QUESTIONS

Do you have environmental problems that are connected to the performance of your sewer system in the following compartments?

a) groundwater	[ ] yes [ ] no
b) soil	[ ] yes [ ] no
c) receiving water	[ ] yes [ ] no
d) wastewater treatment plant	[ ] yes [ ] no

If yes: could you please describe the problems and their possible causes more detailed?

3. By choosing a sewer for <u>a rehabilitation project</u> do you consider one or more of the following issues?:

groundwater level	[ ] yes [ ] no
groundwater quality	[ ] yes [ ] no
groundwater protection zones	[ ] yes [ ] no
receiving water quality	[ ] yes [ ] no
aspects of the waste water treatment plant	[ ] yes [ ] no
parasite water (infiltration/inflow) in the network	[ ] yes [ ] no
exfiltration from the network	[ ] yes [ ] no
Combined Sewer Overflow performance	[ ] yes [ ] no

If you chose a criterion of question 3 could you please give more detail. (which groundwater level is critical, what are interesting criteria in receiving water quality for you, what problems are caused by parasite water, etc.)?

5. Are you using a hydraulic model of your sewer network? [ ] yes [ ] no

6. If yes, are you modelling pollutant transport or other quality issues? [ ] yes [ ] no

7. Do you use prognosis of environmental aspects in the rehabilitation decision process (prognosis of groundwater level, water quality etc)? [ ] yes [ ] no

8. If yes, which tools and which parts of the environment (groundwater, receiving water) do you consider?

9. Which of the following environmental information could be interesting to you in the rehabilitation decision process?

vulnerability of groundwater	[ ] yes [ ] no
development of quality of receiving water (before/after rehabilitation)	[ ] yes [ ] no
performance of combined sewer overflows (before/after rehabilitation)	[ ] yes [ ] no
change of quality or volume of the inflow into the wastewater treatment plant	[ ] yes [ ] no
e) others	[ ] yes [ ] no

10. If you chose e) , could you please give more detail.

Thank you very much!

ANNEX II – DRASTIC - Groundwater Assessment method

DRASTIC method (Cooper et al., 1998)

DRASTIC has been developed by the EPA in 1980. It is a groundwater quality model for evaluating the potential of large area pollution using hydro-geological settings. The model uses a ranking system that assigns relative weights to various parameters. The parameters are

[D] Depth to water table: Shallow water tables pose a greater chance for the contaminant to reach the groundwater surface as opposed to deep water tables.

[R] Recharge (Net): Net recharge is the amount of water per unit area of the soil that percolates to the aquifer. This is the principal vehicle that transports the contaminant to the groundwater. The more the recharge, the greater the chances of the contaminant to be transported to the groundwater table.

[A] Aquifer Media: The material of the aquifer determines the mobility of the contaminant through it. An increase in the time of travel of the pollutant through the aquifer results in more attenuation of the contaminant.

[S] Soil Media: Soil media is the uppermost portion of the unsaturated / vadose zone characterized by significant biological activity. This along with the aquifer media will determine the amount of percolating water that reaches the groundwater surface. Soils with clays and silts have larger water holding capacity and thus increase the travel time of the contaminant through the root zone.

[T] Topography (Slope): The higher the slope, the lower the pollution potential due to higher runoff and erosion rates. These include the pollutants that infiltrate into the soil.

[I] Impact of Vadose Zone: The unsaturated zone above the water table is referred to as the vadose zone. The texture of the Vadose zone determines how long the contaminant will travel through it. The layer that most restricts the flow of water will be used.

[C] Conductivity (Hydraulic): Hydraulic conductivity of the soil media determines the amount of water percolating to the groundwater through the aquifer. For highly permeable soils, the pollutant travel time is decreased within the aquifer.

DRASTIC evaluates pollution potential based on the above seven hydro-geologic settings. Each factor is assigned a weight based on its relative significance in affecting the pollution potential. Each factor is further assigned a rating for different ranges of the values. The typical ratings range from 1-10 and the weights are from 1-5. The DRASTIC Index, a measure of the pollution potential, is computed by summation of the products of rating and weights for each factor as follows:

DRASTIC Index = Dr Dw + Rr Rw + Ar Aw + Sr Sw + Tr Tw + Ir Iw + Cr Cw

Where

Dr = Ratings to the depth to water table
Dw = Weights assigned to the depth to water table.
Rr = Ratings for ranges of aquifer recharge
Rw = Weights for the aquifer recharge
Ar = Ratings assigned to aquifer media
Aw = Weights assigned to aquifer media

Sr = Ratings for the soil media
Sw = Weights for soil media
Tr = Ratings for topography (slope)
Tw = Weights assigned to topography
Ir = Ratings assigned to vadose zone
Iw = Weights assigned to vadose zone
Cr = Ratings for rates of hydraulic conductivity
Cw = Weights given to hydraulic conductivity

The higher the DRASTIC index, the greater the relative pollution potential. The weights assigned are relative, therefore a site with a low pollution potential may still be susceptible to groundwater contamination but it is less susceptible to contamination compared to the sites with high DRASTIC ratings.

Table 38: DRASTIC Ranges and Ratings

Depth to Water (Feet)

Weight: 5
Pesticide Weight: 5

Range	Rating
0 - 5	10
5 - 15	9
15 - 30	7
30 - 50	5
50 - 75	3
75 - 100	2
100+	1

Soil Media

Weight: 2
Pesticide Weight: 5

Range	Rating
Thin or Absent	10
Gravel	10
Sand	9
Peat	8
Shrinking and/or Aggregated Clay	7
Sandy Loam	6
Loam	5
Silty Loam	4
Clay Loam	3
Muck	2
Nonshrinking and Nonaggregated Clay	1

Hydraulic Conductivity (GPD/FT^2)

Weight: 3
Pesticide Weight: 2

Range	Rating
1 - 100	1
100 - 300	2
300 - 700	4
700 - 1000	6
1000 - 2000	8
2000+	10

Net Recharge (Inches)

Weight: 4
Pesticide Weight: 4

Range	Rating
0 - 2	1
2 - 4	3
4 - 7	6
7 - 10	8
10 +	9

Topography (Percent Slope)

Weight: 1
Pesticide Weight: 3

Range	Rating
0 - 2	10
2 - 6	9
6 - 12	5
12 - 18	3
18+	1

Aquifer Media

Weight: 3
Pesticide Weight: 3

Range	Rating	Typical
Massive Shale	1	2
Metamorphic/Igneous	2 - 5	3
Weathered Metamorphic/Igneous	3 - 5	4
Glacial Till	4 - 6	5
Bedded Sandstone, Limestone and Shale Sequesnces	5 - 9	6
Massive Sandstone	4 - 9	6
Massive Limestone	4 - 9	8
Sand and Gravel	4 - 9	8
Basalt	2 – 10	9
Karst Limestone	9 – 10	10

Vadose Zone Material

Weight: 5
Pesticide weight: 4

	Rating	Typical Rating
Confining Layer	1	1
Silt/Clay	2 - 6	3
Shale	2 - 6	3
Limestone	2 - 5	3
Sandstone	2 - 7	6
Bedded Limestone, Sandstone, Shale	4 - 8	6
Sand and Gravel with significant Silt and Clay	4 - 8	6
Sand and Gravel	4 - 8	8
Basalt	2 - 10	9
Karst Limestone	8 - 10	10

ANNEX III – List of alternative measures

Table 39: List of alternative measures sorted by problems (Part I)

PROBLEMS (EXAMPLES)	POSSIBLE REASON	POSSIBLE KINDS OF ACTION (for details see table "Action detail")										
Disturbed Biocoenosis	Lack of refugies	Implementation of protected areas for fishes										
	Typical fish population not abundant	Fishing restock										
	Q, pH, Temperature in the water body are not in the state aimed at	Structural measures										
Various pollution of the receiving water, disturbance of the biocoenosis	Aeration in the receiving water is not sufficient to cope with the oxygen demanding substances from urban drainage	bed cleaning of receiving waters, downstream of CSO structures	artificial increasing of low flows	aeration	oxygen oversaturated water injection							
	Critical dilution rate during/after rain events	Base flow variation in rivers										
	CSO into sensitive part of the receiving water	relocation of CSO structure										
	CSO overflow due to unused or insufficient capacity in the sewer network	regulation of flow	stormwater detention tank	Activation of unused capacity in the network	separation of storm water runoff from downstream combined sewers	construction of additional storm water sewers	Transfering flow in other systems	Avoidance of creeks drained in the system	disconnection of drain pipes from the network	Advancement of the retention of solids and the hydraulic performance of the CSO structure	Items in the Network	Integrated Real Time Control
	CSO overflow due to unused capacity in the catchment	Compensatory techniques of infiltration-detention	Establishment of retention volumes in selected sub-catchments, preferably in sub-catchments upstream, with large degree of imperviousness, and with low infiltration/inflow.	use of existing retention volume on the surface								
	CSO overflow due to unused capacity in the WWTP	Increasing the input into the wastewater treatment plant										
	Specific pollutants from CSO and/or WWTP	decentral treatment of pollutants(waste stream management)	Material/substance substitution	Point sources allocation	Soil filter	Disengage of industrial flow,	Avoid metall emissions from roofsand gutters					
	Pollution due to WWTP effluent, e.g nutrients causing eutrophication, other pollutants	Management and technology improvment										
	Pollution regulations are not adequat to the receiving water needs	Change Regulations: types and concentrations of pollutants that single users can send to the sewer system										
	Hydrocarbons from CSO floating on receiving water surface or sunken to the ground	Hydrocarbon dividers	Point sources allocation									
	Eutrophications due to nutrients from agriculture mobilised by runoff	Nutrient management in the catchment	Avoid over fertilisation									
	pollution input from single users, yearly load of pollutants exceed standard	Tax Lever: if single user send less pollution (or less water) to the sewer than property taxes are reduced										

Table 40: List of alternative measures sorted by problems (Part II)

PROBLEMS (EXAMPLES)	POSSIBLE REASON	POSSIBLE KINDS OF ACTION (for details see table "Action detail")										
Acute pollution problems without hydraulic problems	CSO pollutants	Discharge low polluted rainwater directly into the receiving water	Change to a separate/pressurised system									
Toxicity problems, Problems with solids	Pollution from single pollutants from e.g. industry	Pre Treatment	Point sources allocation									
	Solids from CSOs	Compact clarifiers on-line	Sewer network cleaning	sediment management (sand trap)	Sieve	grid	Filter	Removal of floating matter form the receiving water				
	Toxic substances from households	Education of population										
	waste from households	Education of population										
	solids and mud from diverse sources in the river bed	Dredging (polluted sediments)										
Local flooding	insufficient connection to the sewer network	Gutters with direct fall										
Local flooding and odors	insufficient connection to the sewer network	Gutters with Syphon										
Local flooding and sand detention	insufficient connection to the sewer network	Gutters with sand trap										
Hygienic Problems	microorganisms from WWTP effluent	Desinfection of WWTP effluent										
	Microorganisms from CSO	Activation of unused capacity in the network	Stormwater detention tank	Establishment of retention volumes in selected sub-catchments, preferably in sub-catchments upstream, with large degree of imperviousness, and with low infiltration/inflow.								

Table 41: Details on alternative measured sorted alphabetically (Part I)

KIND OF ACTION (in alphabetical order)	AIM	ACTION PLACE	DETAIL					
Activation of unused capacity in the network	Reduction of flooding/Overflows	Network	Change pumping strategy	Movable weir	Modification of orifice capacities/overflow settings	Sewer system management (real time control)		
Advancement of the retention of solids and the hydraulic performance of the CSO structure	Prevent pollution from entering the receiving water	Network						
Aeration	Increasing O2 dissolved in receiving waters	Receving water	water shaking	Waterfall in weirs (navigable rivers)				
Artificial increasing of low flows	Increasing O2 dissolved in receiving waters	Receving water						
Avoid metall emissions from roofsand gutters	Prevent pollutants from entering the sewer system	Catchment						
Avoid over fertilisation	Prevent pollutants from entering the sewer system	Catchment						
Avoidance of creeks drained in the system	Reducing extraneous water	Network						
Base flow variation in rivers	Prevent critical pollutant concentrations	Receiving waters						
Bed cleaning of receiving waters, downstream of CSO structures	Increasing O2 dissolved in receiving waters	Receving water						
Change Regulations: types and concentrations of pollutants that single users can send to the sewer system	Reduce and control pollutant input	Integrated System and other instuments						
Change to a separate/pressurised system	Reduction of pollution of the receiving water caused by overflows	Network						
Cleaning public places (streets, markets,etc.)	Visual pollution and coarse matter reduction	Catchment						
Compact clarifiers on-line	Solids suspended elimination	Network						
Compensatory techniques of infiltration-detention	Reduction of runoff volumes and peak flow, detention of diverse pollutants (solids suspended, heavy metal, etc.)	Catchment	Terrace roof	Drainage or infiltration trench	Ditch/Gutter in parks	Infiltration manhole	Flooding infiltration area	Infiltration pavements
Construction of additional storm water sewers	Reduction of flooding/Overflows	Network						
Desinfection of WWTP effluent	Reduction of Microorganisms	WWTP	UV Desinfection	Chlorination	Combined UV and Ultrasonic			
Decentral treatment of pollutants(waste stream management)	Prevent pollutants from entering the sewer system	Catchment						
Discharge low polluted rainwater directly into the receiving water	Reduction of runoff volumes and peak flow, detention of diverse pollutants (solids suspended, heavy metal, etc.)	Catchment						
Disconnection of drain pipes from the network	Reducing extraneous water	Network						
Disengage of industrial flow,	Prevent pollutants from entering the sewer system	Catchment						
Dredging (polluted sediments)	Remove pollutants	Receiving waters						
Education of population	Reduction of avoidable pollution	Integrated System and other instuments	Recycling programs	Prevention of toilet use as waste bin				
Establishment of retention volumes in selected sub-catchments, preferably in sub-catchments upstream, with large degree of imperviousness, and with low infiltration/inflow.	Reduction of runoff volumes and peak flow, detention of diverse pollutants (solids suspended, heavy metal, etc.)	Catchment						
Filter	Reduction of suspendedSolids	Network						
Fishing restock	Restore fishing population	Receiving waters						
Grid	Reduction of suspendedSolids	Network						
Gutters with direct fall	Avoid local flooding	Inlet						

Table 42:Details on alternative measured sorted alphabetically (Part II)

KIND OF ACTION (in alphabetical order)	AIM	ACTION PLACE	DETAIL					
Gutters with Syphon	Avoid local flooding and odors	Inlet						
Gutters with sand trap	Avoid local flooding and sand detention	Inlet						
Hydrocarbon dividers	Separate hydrocarbons (based in coalescence principle) but limited to peak flow of 0.3 m3/s	Network						
Implementation of protected areas for fishes	Fishes refuge for high pollution events	Receiving waters						
Increasing the input into the wastewater treatment plant	reducing overflow by using capacity of the WWTP	WWTP						
Integrated Real Time Control	Optimal use of the systems capacity	Integrated System and other instuments	movable weirs	pumps	use of simulation			
Items in the Network	Reduction of flooding and/or SS elimination	Network	Deviation or contention floodgates	Pumping				
Management and technology improvment	Optimize pollutants reduction in outgoing flow	WWTP	Control of the processes	Use of new technologies and chemicals(by-pass, sludge circuit modification, stormwater disinfection, etc.)	Optimisation of denitrification process, digestion process, mixing, aeration			
Material/substance substitution	Prevent pollutants from entering the sewer system	Catchment	washing agent	fertilizer				
Nutrient management in the catchment	Prevent pollutants from entering the sewer system	Catchment						
Oxygen oversaturated water injection	Increasing O2 dissolved in receiving waters	Receving water						
Point sources allocation	Prevent pollutants from entering the sewer system	Catchment						
Pre Treatment	Prevent pollutants from entering the sewer system	Catchment						
Regulation of flow	Activate capacity of the network	Network						
Relocation of CSO structure	Reduce pollution or hydraulic problems on a specific site in the receiving water	Network						
Removal of floating matter form the receiving water	Retention of floating matter	Receiving waters	"Pelican" ship	Floating barrier	Intercepting vertical net			
Sand trap	Sand and coarse matter reduction in the catchment	Catchment						
Sediment management (sand trap)	Reduction of suspendedSolids	Network						
Separation of storm water runoff from downstream combined sewers	Reduction of flooding/Overflows	Network						
Sewer network cleaning	Detachment of settled deposits, that cause receiving waters pollution	Network						
Sieve	Reduction of suspendedSolids	Network						
Soil filter	Prevent pollutants from entering the sewer system	Catchment						
Stormwater detention tank	Flooding and solids suspended elimination	Network	Underground	Surface				
Structural measures	Prevent erosion and improve the biodiversity and life conditions for the biocoenosis	Receiving waters	Eenhancement of water body properties(e.g. velocity, provide shadow)	Water plants, plants and trees on banks for natural bank reinforcement				
Tax Lever: if single user send less pollution (or less water) to the sewer than property taxes are reduced	Reduce and control pollutant input	Integrated System and other instuments						
Transfering flow in other systems	Reduction of flooding/Overflows	Network						
Use of existing retention volume on the surface	Reduction of runoff volumes and peak flow, detention of diverse pollutants (solids suspended, heavy metal, etc.)	Catchment						

ANNEX IV – Design and licensing of CSO

Country	Design setting [x] times DWF	Design settings [x] times DWF (new systems)	Design settings [x] times peak DWF	Duration of CSO per year	number of spills (per year)	Consideration of quality aspects	Licensing of CSO and comments
Belgium	2 to 5	5 to10			7		Discharge permit may specify overflow frequency, emission standards, little monitoring
Denmark	8 to 10		5			yearly BOD rates compared to those from WWTP, EQO/EQS* approach and modelling	All CSO require discharge licences. The discharge permit specifies overflow frequency related to the nature of the receiving water (is rarely checked). Some municipalities monitor problem CSOs. Intermittent and annual loads are considered for rivers, lakes and fjords (Modelling is used). Best practice is accepted by courts.
France	4 to 6 at WWTP 2-3		3			EQO/EQS approach introduced together with modelling	Permits are required if pollution load exceeds 500 person equivalents, 1-2% of CSOs are monitored, mainly near bathing waters and shellfish waters, modelling takes place in large cities or at sensitive waters, emission standards are locally agreed depending on receiving water (pollution concentration, spill frequency, duration). New framework : monitoring of CSO performance is required for CSOs with > 600 kg BOD per day. Emission standards are set by "water police service" in a case by case procedure.
Germany	7 where no storage is provided					90 % of load to treatment. Storage up to 40 m^3/ impervious area, typically 20 - 30 m^3	A 128: Permits is required for all wastewater discharges, including CSOs. Minimum requirements are set for CSO and WWTP. Some water management plans require more stringent criteria dependent on the receiving waters sensitivity. Monitoring, regulation and sampling procedures vary between individual states. Some states require new CSO structures to be equipped with monitoring/telemetry facility for operational and regulatory reasons. Monitoring allows compliance with A128 guidelines to be checked.

Country	Design setting [x] times DWF	Design settings [x] times DWF (new systems)	Design settings [x] times peak DWF	Duration of CSO per year	number of spills (per year)	Consideration of quality aspects	Licensing of CSO and comments
Greece	3 to 6					sometimes considered	no discharge licences required, no monitoring of CSOs
Ireland	6					sometimes EQO/EQS introduced with modelling	Legislation is proposed which will require discharge licences. Recently Formula A* is considered, modelling is introduced.
Italy	3 to 5				locally intro-duced		Spill frequency criteria are introduced locally Italien law 152/99
Luxembourg	4 to 6		3			ATV 128 see Germany	New CSOs require authorisation (approval permits). Existing CSOs require to be registered. The german ATV 128 is the main standard.
Netherlands					3 to 10 per year depen-ding on rec. water sensi-tivity	storage 7 mm of runoff over impervious area, EQO/EQS introduced with modelling	Discharge permit sets limit on overflow frequency and storage requirements. This is rarely checked except for problem CSOs causing public complaint (< 5%). Monitoring facilities are being added to many systems. Modelling is introduced, some continuous monitored CSO exist. Real time control exists.
Norway	4						Some cities practice a pollution budget approach for rehabilitation planning. Monitoring and computer model calculations to analyse overflow frequency and receiving water vulnerability is done in some cities.

Country	Design setting [x] times DWF	Design settings [x] times DWF (new systems)	Design settings [x] times peak DWF	Duration of CSO per year	number of spills (per year)	Consideration of quality aspects	Licensing of CSO and comments
Portugal	6						No licensing is required, no monitoring is performed
Spain	3 to 5 (5 most frequent in smaller towns)			is considered ,please see comment	goal of Barcelona master-plan: 20 overflows a year (now 63)		All CSOs require to be registered, formal permits (with conditions) are not issued at present. The total spill duration to sea water is limited to < 450 h per year and 3% bathing hours, aim: 1.5% overflow time during bathing season.
Sweden							Emission standard is formulated but not implemented, recommendations on spill frequency and total volume to WWTP (e.g. <2 % of total volume can be spilled), considering the total load is under discussion, some monitoring of CSO frequency and duration is undertaken
UK and Scotland	traditionally: 6 to treatment (3 to WWTP 3 to storm tanks) Formula A**				bathing waters: 3 per season; shell fisheries: 10 per year	traditional regulation increasingly replaced by EQO/EQS and modelling	Discharge consents are required for CSOs (normally based on emission standards). Consents include: overflow location, overflow type, weir setting, storage requirements, aesthetic performance standards. (not necessarily numeric, chemical and bacterial conditions). Choice of method depends on impact and environmental performance criteria. (Low significant CSO: flow based discharge control (Formula A), medium significant CSO: simple impact assessment, high significant CSO: complex modelling.) Important criteria: population size and designated status of the receiving water. Monitoring of problem CSOs is undertaken at present only by Environmental agency. Spill frequency is assessed by short or long term monitoring plus modelling studies by water companies. Major new CSO structures may include a permanent monitoring facility. Modelling is introduced.

* EQO/EQS = Environmental quality objectives / Environmental quality standards

**Formula A = DWF + 1360 * population + 2 * industrial effluent (litres /day).
Typically: 6.5-9 times mean DWF; may be higher

European countries not mentioned in this table have either no regulations for CSOs or did not participate in the questionnaires where the information was collected.
The information collection is based on investigations done in 2000 and 2003. Further developments that took place in the member countries are possible.

References

Workpackage 5: survey on national legislation, 2003

Milne, I., et al. (2000). Integrated planning and management of urban drainage, wastewater treatment and receiving water systems, WRc.

ANNEX V – Input Output

Groundwater

Field	Unit	Data type	Range	Scale	Comment
INPUT					
pipe ID of exfiltrating pipes		Text or integer			identification of the pipe (ideal: consistent use in the different tools)
groundwater depth	m	number			difference between groundwater table and surface
average invert depth	m	number			
exfiltration flow per pipe	litre/day	number			
soil type		Text or integer			soil type definition according to the hydraulic model requirements (if available)
permeability (k_f)	m/s	number			permeability of soil beneath the pipe
OUTPUT					
pipe ID for all exfiltrating pipes		text			pipe with exfiltration rate which is environmental relevant
classified exfiltration		text	High, moderate, low	pipe	
classified groundwater level		text	High, moderate, low	pipe	
classified permeability		text	High, moderate, low	pipe	
vulnerability (1)		text	High, moderate, low	pipe	vulnerability according to the method of Eaton and Zaporozec
vulnerability (2)		text	1 - 1000	pipe	vulnerability simplified after simplified DRASTIC method
vulnerability (3)		text	High, moderate, low	pipe	simplified (with exfiltration and groundwater level)
vulnerability (4)		text	High, moderate, low	pipe	simplified (with groundwater level and permeability)

CSO Compliance to standards

Field	Unit	Data type	Range	Scale	Comment
INPUT					
name of the catchment		text			
choice of standards		text, number		catchment / part of catchment	The standards are based on Water Framework directive requirements and on national legislation and can be corrected or changed by the user.
ID of overflow structures		number/text		CSO structure	ID of all overflow structures in the system
frequency of spills	spills per assessed period	number		CSO structure	
duration of spills	h	number			duration of every spill of every structure in the assessment period
overflow volume	m3	number			overflow volume per overflow structure per spill
assessment time		number			
flow in pipe before first spill	m3/h	number		CSO structure	the flow in the pipe located upstream the CSO structure
average dry weather flow	m3/h				
person equivalents		number			person equivalents including industry etc.
average dry weather loads	g/(E*d)	number			values will be chosen and added within WP 3.3 tool
factor for rain weather loads		number			factor will be chosen within WP 3.3 tool
OUTPUT					
ID of overflow structures		number/text			
actual value for [x] times dry weather flow (DWF)	-		yes/no		compliance with standard or reference value chosen by the user
	times DWF		actual value		see above
	times DWF		deviation from standard absolute		see above
	%		deviation from standard relative		see above
load estimated from volume	kg		see above		see above
duration of CSO per year	h		see above		see above
number of spills (per year)	-		see above		see above

overflow volume	m^3		see above		see above
duration curve for single CSO		diagram			additional information to be used within WP 3.4

Receiving water

Field	Unit	Data type	Range	Scale	Comment
INPUT					
mean Flow	l/s	number			
low water	l/s	number			
depth at mean low flow		m			
pH					
velocity at mean low flow		m/s			
mobilisation of deposits in the sewer system		text			high/low
number of inhabitants		number			
impervious urban area	ha, m^2	number			
hydrological catchment area	ha, m^2	number			
OUTPUT					
a-value comparison		yes/no			estimation whether urban drainage has impact on river due to pollutant load
b-value comparison		yes/no			estimation whether urban drainage has hydraulic impact on river

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